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Harran University, Türkiye

*CORRESPONDENCE
Ying Wang,
wangying@ustl.edu.cn

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Research on cultural diversity and sustainable land-use management assessment model

Ying Wang[1]* and Junqiao Zhang[2]

[1]School of International Education, University of Science and Technology Liaoning, Anshan, Liaoning, China, [2]School of Electronics and Information Engineering University of Science and Technology Liaoning, Anshan, Liaoning, China

This study quantitatively evaluated the role of cultural diversity and psychological awareness in sustainable land-use management (SLUM). Firstly, an assessment model based on fuzzy analytic hierarchy process is established by combining fuzzy logic, expert knowledge and analytic hier-archy process. The model addresses the uncertainty of qualitative assessment and adapts to dy-namic environments and complex human behavior. The research process included a literature review and expert consultation to identify key factors influencing land use and assign weights to these factors through FAHP. Subsequently, FAHP determined that cultural diversity had the highest weight among all considerations, indicating the urgent need to respect and integrate local cultural diversity in land management. Psychological awareness follows closely, suggesting that land-use decisions are profoundly influenced not only by tangible economic and environmental conditions, but also by the psychological states, knowledge levels, value systems, and social perceptions of groups and individuals. These findings highlight the need to consider and integrate these intangible factors when developing land management strategies. This approach fosters broad social acceptance and participation, ultimately moving towards the long-term goal of sustainable land use. Finally, the study provides decision-makers with a tool for identifying subtle differences at the cultural and psychological levels that can help develop more nuanced and personalized management options for different land use strategies.

KEYWORDS

sustainable land-use management (SLUM), cultural diversity, psychological awareness, fuzzy analytic hierarchy process (FAHP), land management strategies

1 Introduction

With the continuous growth of global population and rapid economic development, land resources are facing unprecedented pressure. China is one of the most populous countries in the world, its land-use management is particularly complex and urgent. Sustainable land-use management plays an important role in ensuring agricultural safety, protecting the ecological environment and socio-economic development (Cervero, 2013; Ragheb et al., 2016). Therefore, a thorough understanding and integration of these elements is essential to propose and im-plement effective land management strategies.

Land-use management is an integrated decision-making process that guides the development and management of land to meet human needs and provide ecological services while ensuring long-term sustainability (Hurni, 2000). Sustainable land-use management extends the basic concept of land-use management to emphasize the need to maintain long-

term environmental, social and economic health during land development and use. The con-cept of sustainable land management emphasizes that land resources are limited and must be used without compromising the ability of future generations to use them. The idea is to promote economic development, social welfare and environmental sustainabil-ity through the rational use of land. This requires a comprehensive consideration of var-ious land uses—such as farming, forestry, urban development—and the impact of human activities on the ecological environment (Aznar-Sánchez et al., 2019). This process involves planning, operating, maintaining and monitoring land-use with the aim of striking a balance between various land-uses, such as residential, agricultural, industrial and recreational, while protecting the environment and natural resources. In addition, sustainable land-use management often requires a systematic approach that goes beyond mere geography or environmental planning, but requires interdisciplinary collaboration that includes knowledge and skills in environmental science, urban planning, public policy, economics, law, and more (Bouma, 2002). Sustainable land-use management involves the development of policies, including laws, regulations, incentives and education, to ensure that all stakeholders are able to take social, economic and environmental impacts into account when utilizing land over time (Mensah, 2019).

In exploring the complexity of land-use decisions, Meyfroidt (Meyfroidt, 2013) emphasizes the in-fluence of social norms, emotions, beliefs, and values, and proposes a cognitively realistic approach to understanding how environmental changes feed back into land-use practices through human cognition. Subsequently, Salvati et al. (Salvati et al., 2017) by analyzing land cover changes in rural cultural landscapes in central Italy, revealed major changes driven by human ac-tivities such as urbanization, land abandonment, and deforestation, highlighting the im-portance of understanding local population dynamics for the development of effective landscape conservation policies. Four key concepts for achieving land degradation neutrality are presented (Keesstra et al., 2018): regenerative economics, nature-based solu-tions, connectivity and systems thinking highlight not only the global importance of sus-tainable land management (SLM), but also the sociocultural, institutional, economic, and policy challenges to achieving these goals. More recently, Sullivan-Wiley proposes an integrated social perception approach that combines qualitative and quantitative methods to reveal how rural landowners' ecological thinking maps and future imaginings influ-ence land-use practices, finding that landowners' narratives about the future are related to their current woodland use (Sullivan-Wiley and Teller, 2020). Nightingale and Richmond (Nightingale and Richmond, 2022) further explore the ways in which indigenous peoples strengthen cultural identity and self-determination by re-claiming and reconnecting traditional lands, an approach that not only strengthens community ties and preserves indigenous knowledge, but also improves mental health. However, Batterham et al. (Batterham et al., 2022) note that despite the clear negative effects of extreme cli-mate events and environmental degradation on psychological health in rural zones, there is a significant research gap at the individual level, particularly on farms, as well as the impacts of biodiversity and natural resource management on psychological health. This suggests the need for an interdisciplinary research approach to understand these rela-tionships more fully. Finally, Van Noordwijk et al. (Van Noordwijk et al., 2023) argue that instrumental and rela-tional values of nature are critical in natural resource decision-making, and that effective science-policy interfaces need to address both by providing prominent, credible, and le-gitimate synthesis of knowledge, acknowledging diversity of value perspectives and dif-ferences in decision-making patterns, with a view to changing the trajectory of develop-ment. Ma et al. (Ma et al., 2023) showed that neighborhood characteristics such as walking ability, vegetation cover, and social cohesion enhance mental resilience during crises, with sub-urban and medium-density areas showing greater mental health resilience, suggesting that urban planning that promotes these elements can improve overall urban resilience. Together, these studies build a multidimensional framework for understanding and re-sponding to the complexities in land-use decisions and how these decisions affect the fu-ture of the environment and society on a global scale (McDermott et al., 2023).

However, in China's numerous agendas to promote sustainable land-use manage-ment (SLUM), the issues and challenges of cultural diversity and psychological awareness have become increasingly acute. These challenges are not only demonstrated in the utili-zation and allocation of land resources, but also touch on the collaborative process of so-cial and economic development and environmental protection (Sun et al., 2022). As the country at-taches great importance to the building of ecological civilization, SLUM has become a key way to realize regional development and ecological balance. However, SLUM practice and evaluation in China still face the challenge of cultural diversity and the influence of psy-chological factors, which are often ignored in the decision-making process. China's cul-tural diversity and deep cultural heritage have influenced its land-use patterns. Social and cultural backgrounds and values in different regions have a profound impact on land-use decision-making, which reflects people's cognition and attitude towards land resources to different degrees. In exploring cultural differences in ecosystem services and attitudes to-wards forest biodiversity, Lindemann-Matthies et al. (Lindemann-Matthies et al., 2014) found that Swiss participants tended to prefer species-rich forests, while Chinese participants had more mixed prefer-ences. Unless they are educated about biodiversity, they generally do not show a prefer-ence for species-rich forests. This finding highlights the importance of cultural context in the perception of ecological service value. Subsequently, Yu et al. (Yu et al., 2016) highlighted that China's cultural heritage landscapes, especially those in central and southern regions, are at high risk from large-scale urbanization and diverse land-use changes. They raise the need to implement targeted conservation measures through spatial analysis and risk as-sessment to protect these areas of great value. This study provides a new perspective and methodology for the protection of cultural heritage landscape. Entering the 2020s, Gu et al. (Gu et al., 2022) further explored urban residents' perception of suburban multifunctional land-use. They found that residents placed particular emphasis on meeting the need for respect and self-actualization when considering suburban land-use. This finding suggests that land-use policies and planning should take these needs fully into account, and that effec-tive communication between residents, farmers, and decision makers is critical. Next, Dai et al. (Dai et al., 2023) put forward a new view that government-led

tourism development initiatives in rural China are transforming traditional rural communities into commercial tourism communities with economic benefits at their core. This shift has not only changed the basic social structure and values, but also had a profound impact on the sustainable de-velopment and policy making of rural tourism. Together, these studies paint a picture of how China, in the face of rapid development and change, is finding a balance between protecting cultural heritage, meeting the needs of residents and promoting rural develop-ment. In the context of SLUM, ignoring the difference of cultural values often leads to the disconnect between management strategies and local realities, which in turn affects the effective implementation of land management policies (Chen et al., 2019). For example, some national cultures attach importance to the spiritual connection with land and emphasize the im-material value of land, which conflicts with the economic value-oriented land-use deci-sions. Therefore, how to implement efficient SLUM strategy while respecting and protect-ing local culture is a problem that needs further study.

The transformation of psychological consciousness is also an important factor in SLUM. Psychological factors, including the psychological belonging, risk perception and behavioral motivation of land owners and users, are also of important implications to the sustainability of land management. With the rapid change of social and economic structure, people's cognition and values of land are also changing, which is reflected in the land-use pattern and management (Naz et al., 2023). In particular, the large-scale migration of the rural population to the city has caused the change of the rural land-use population struc-ture, which poses new challenges to SLUM. Qian et al. (Qian et al., 2022) delve into the complexity of rice farmers' perceptions of land tenure in eastern China, revealing that such perceptions involve not only cognitive assessments of the possibility of land redistribution, but also emotional responses. They found that psychological factors such as personality charac-teristics have a significant impact on farmers' perception of land tenure, which indicates that probability estimation alone cannot fully reflect farmers' overall feeling of land tenure. Subsequently, Nie et al. (Nie et al., 2023) pay attention to the land-use behavior of coastal farmers, in particular how they decide whether to abandon arable land based on their psychological construction of environmental risks. By combining the effects of four psychological dis-tances—social, temporal, hypothetical, and spatial—their research reveals the complex in-terplay of factors such as social trust, probability of extreme weather events, spatial prox-imity of residence to coastlines, and population mobility in the behavior of farmers who abandon arable land. These findings provide new perspectives for understanding and predicting land-use patterns in coastal areas. For such psychological and behavioral changes, how to promote people to form awareness and behavior to support SLUM through effective policy guidance and education mechanism becomes the vital to realize the goal of sustainable land management (Langemeyer et al., 2021). The balance between preserving cultural traditions and modernization is also an important issue in Chinese SLUM. In the process of modernization, it is a complex and urgent task to protect and inherit the traditional land-use methods that are beneficial to ecology, promote the efficient use of land resources, and avoid cultural homogenization and the loss of biodiversity (Ghermandi et al., 2020).

In summary, there are some significant research gaps in the field of SLUM in China. First, although land-use patterns are strongly influenced by cultural values and practices, cross-cultural comparative studies on the influence of land-use patterns on sustainable land management in different cultural contexts are insufficient (Hofstede, 1984). This type of compara-tive research is critical to understanding how cultural factors shape land-use decisions and how to integrate these factors in management strategies (Kaushal and Kwantes, 2006). Second, existing studies have rarely touched on the influence of psychological consciousness on land-use deci-sion-making, especially the psychological motivations and cognitive biases among key groups such as farmers, policymakers, and land developers. In-depth analysis of these psychological factors is the key to understanding and guiding land-use decisions. Third, studies assessing the long-term impact of cultural diversity and psychological factors on land-use patterns and sustainability are also relatively scarce. Long-term follow-up stud-ies are essential to assess the ongoing impact and changing trends of these non-material factors. In addition, the research mainly focuses on macro-level analysis, and the specific analysis of how to implement policies at the local level, especially at the individual and community level, is insufficient. This limits our understanding of the effects of policies and their implementation. In terms of research methods, the current methodological de-velopment has not fully integrated the methods and theories of psychology, cultural stud-ies and land management. Developing new interdisciplinary research methods will pro-vide a broader perspective for future research. In addition, the current research may focus on qualitative description in the method, and there are still deficiencies in providing quantitative analysis to support the qualitative conclusion. The strengthening of quantita-tive research will provide necessary objective data support for research.

Therefore, in order to quantitatively assess the role of immaterial factors such as cul-tural diversity and psychological awareness in SLUM, and to identify the major issues and challenges faced, an intelligent decision support system is constructed based on fuzzy Analytic Hierarchy Process (FAHP). This system combines fuzzy logic, expert knowledge and hierarchical analysis to form a compound decision-making tool, which can not only deal with ambiguity in qualitative evaluation, but also adapt to changing en-vironment and complex human factors (Kubler et al., 2016). In the process of introducing intelligent deci-sion-making systems, we will first identify the key factors affecting land-use, including ecological, economic, psychological, social and cultural factors, through an extensive lit-erature review and expert consultation (Mardani et al., 2015). Then, these factors are weighted using FAHP, and these data are further integrated by intelligent systems to simulate and forecast to evaluate the feasibility and potential effects of different management decision schemes (Liu et al., 2020). In addition, the results of FAHP will help us identify key intervention points and man-agement strategies in the impact of cultural diversity and psychological awareness on SLUM (Amiri and Mohajeri, 2017). For example, it may be discovered that in a specific cultural context, preserv-ing traditional land-use knowledge holds more importance than promoting modern ag-ricultural techniques. Additionally, under the influence of certain psychological expecta-tions, enhancing public participation could be more effective for implementing land pro-tection policies than solely offering

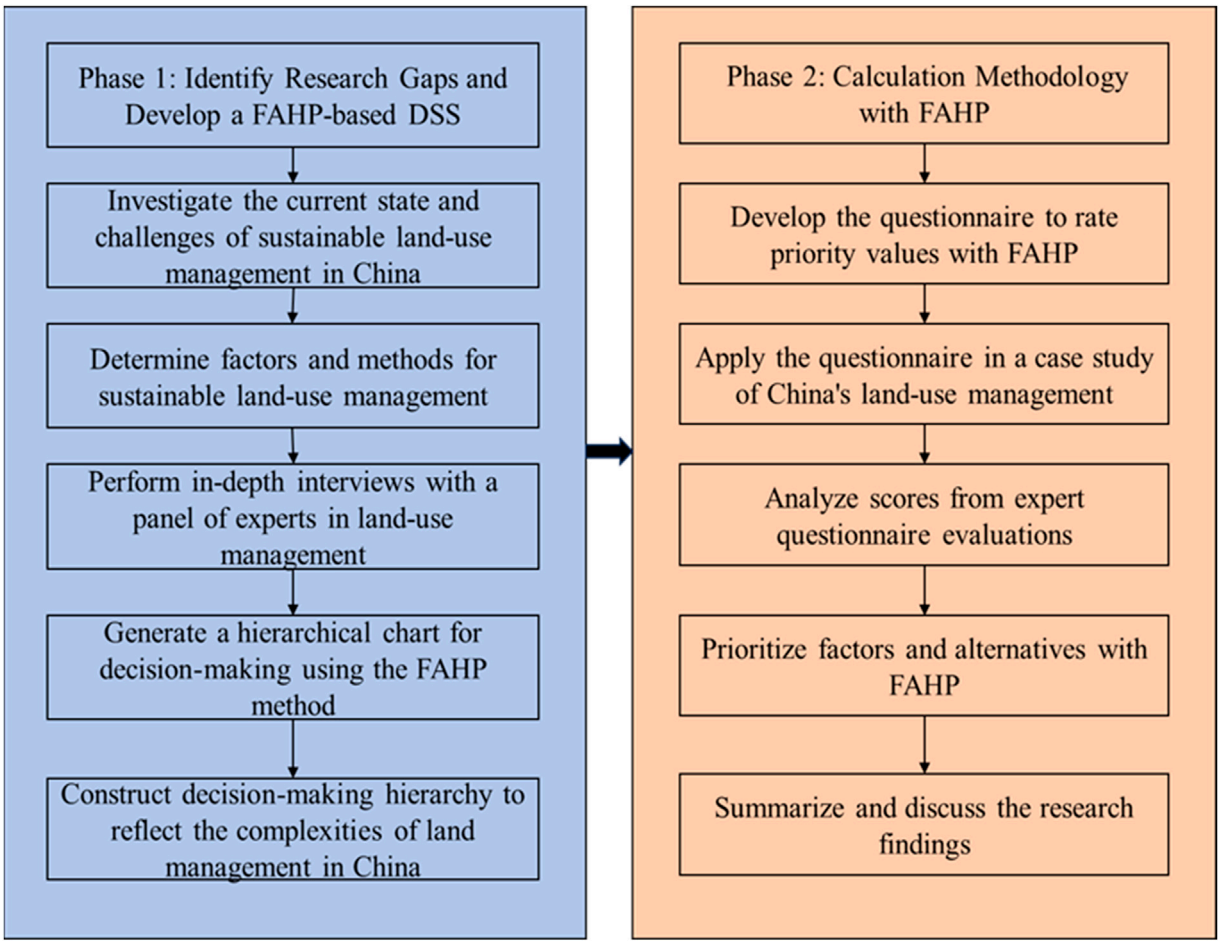

FIGURE 1
Flow chart of research methods.

economic compensation. The introduction of this in-telligent decision-making system is expected to enable decision makers to identify subtle differences in cultural diversity and psychological awareness that may have an important influence on the successful implementation of land-use management strategies. The sys-tem analyzes the psychological attitudes and cultural tendencies of the public, evaluates their acceptance of different land-use management strategies, and proposes more refined and personalized management plans accordingly (Skogen, 2003; Mosadeghi et al., 2015; Turner et al., 2020). By combining FAHP, this paper will provide a structured and scientific framework for in-depth analysis of the complex issues of SLUM in China, and propose more forward-looking and operational policy recommendations accordingly, contributing new perspectives and methodologies to the research and practice in related fields.

The rest of this paper is organized as follows. In Section 2, materials and methods are described, including research design and Fuzzy analytic hierarchy process (FAHP). In Section 3, a case study is presented, focusing on a specific region in Eastern China to demonstrate the practical application of the FAHP evaluation method. In Section 4, in a thorough discussion and analysis of the results. Finally, The conclusions of the study are given in Section 5.

2 Materials and methods

2.1 Research design

The method adopted in this study is divided into two stages. Firstly, a hierarchical decision support system is established by identifying research gaps and clarifying re-search objectives. Secondly, based on fuzzy analytic hierarchy process (FAHP), the priority of various alternatives is evaluated using computational techniques. Figure 1 shows the methodology of the whole research process.

Phase 1: Identify research gaps and develop FAHP-based DSS.

In the first phase, the goal is to identify gaps in the study of SLUM in China and a decision support system (DSS) based on Fuzzy Analytic Hierarchy Process (FAHP) is developed. This stage is achieved through the following steps:

1. Research on the *status quo* and management of sustainable land-use in China. Theoretical research and literature review to investigate the present situation and existing challenges of SLUM in China. Identify gaps in current research and areas where decision support systems can provide significant benefits.

2. Identify factors and methods for sustainable land management. List potential factors that affect sustainable land-use, such as economic, environmental, social and policy-related aspects. Choose appropriate methods and tools to manage the land sustainably and incorporate FAHP to deal with ambiguities and uncertainties in expert judgment.
3. In-depth interviews of the expert group. Conduct interviews with a diverse panel of experts, from experts in psychology, sociology, urban planners, cultural researchers, etc., to gather comprehensive insights. According to the feedback of several rounds of expert consultation, the Delphi method is used to improve the list of factors, and the FAHP method is applied to transform the qualitative opinions into quantifiable data.
4. Construct the decision-making hierarchy to accurately reflect the priority of factors pointed out by experts. Use FAHP to address the ambiguities of human judgment and create a more robust decision-making framework.

The second stage: FAHP calculation method. In this stage, FAHP approach was applied to analyze and identify the weight of SLUM factors and program priorities in China.

1. Develop a questionnaire based on FAHP. Based on the principle of comparing the two, to assess the relative importance of various factors. The factors and methods identified were translated into fahp compliant questionnaire items. The questionnaire was designed in an accurate pairwise comparison and factor rating manner.
2. Apply the questionnaire in the context of a case study. Focus on specific areas or aspects of land-use in China. Ensure that the case study is representative of the broader trends and issues in SLUM across the country.
3. Distribute questionnaires to a panel of experts and conduct follow-up interviews. MATLAB and other software were used to analyze the scores of expert questionnaires. Compile questionnaire results and perform fuzzy analysis using software tools to handle large data sets and complex calculations.
4. Rank factors and alternatives according to the comprehensive judgment of experts. Identify land-use management practices that best align with the principles of sustainable development in China.
5. Summarize and discuss the findings. Highlight how FAHP-based decision support systems can contribute to more sustainable land management in China. Discuss the implications of this research and the potential for developing strategic support to influence policy and practice.

2.2 Fuzzy analytic hierarchy process

In the context of SLUM in China, incorporating cultural diversity and psychological awareness into the decision-making framework is a complex task. Fuzzy Analytic Hierarchy Process (FAHP) provides a powerful tool that can help decision makers quantify the impact of these often elusive non-material factors (Chen, 2020). By building a hierarchical model that includes a layer of objectives, a criterion level, and sub-criterion level, FAHP enables experts to assess the relative importance of different factors through fuzzy paired comparisons (Chang, 1992). Such pair comparisons can generate a fuzzy judgment matrix and ultimately extract the weight of each factor reflecting its role in sustainable land-use. Combining these weights not only reveals the key cultural and psychological drivers that influence land-use decisions, but also guides policy formulation to ensure that management strategies are developed and implemented taking full account of cultural richness and individual psychological differences in order to promote more effective and durable land-use patterns.

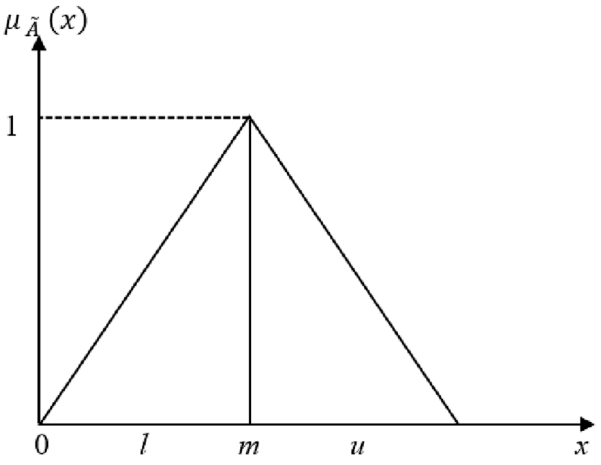

FIGURE 2
A triangular fuzzy number, $\tilde{A} = (l, m, u)$.

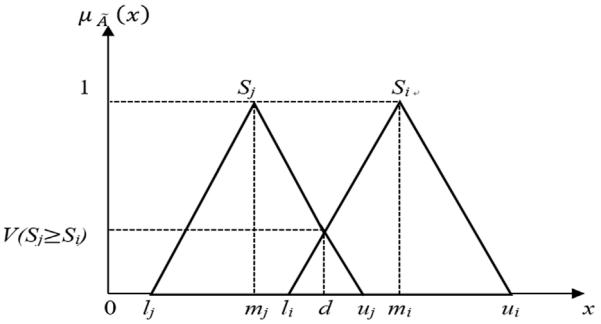

FIGURE 3
The intersection between S_j and S_i.

2.2.1 Triangular fuzzy numbers

A fuzzy number A on R is defined as a triangular fuzzy number (TFN) if its membership function $\mu_{\tilde{A}}(x)$: $R \rightarrow [0,1]$ conforms to the equation mentioned Eq. 1 (Chang, 1996)

$$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{x-l}{m-l} & for\, l \leq x \leq m \\ \dfrac{u-x}{u-m} & for\, m \leq x \leq u \\ 0 & otherwise \end{cases} \quad (1)$$

here l ≤ m ≤ u, the values of l and u represent the lower and upper bounds of the support for the fuzzy number $\tilde{A}$, respectively, with m

denoting the modal value (as illustrated in Figures 2, 3). If the condition $l = m = u$ is met, then the TFN is transformed into a non-fuzzy, or crisp, number (Anile et al., 1995).

2.2.2 Distance of TFN

Let $\tilde{A} = (l_1, m_1, u_1)$, $\tilde{B} = (l_2, m_2, u_2)$, the distance between $\tilde{A}$ and $\tilde{B}$ is express as (Van and Pedrycz, 1983):

$$d\left(\tilde{A}, \tilde{B}\right) = \frac{(l_1 - l_2) + (m_1 - m_2) + (u_1 - u_2)}{3} \tag{2}$$

2.2.3 The extent analysis FAHP method

Chang's Fuzzy Analytic Hierarchy Process (FAHP) involves the creation of a fuzzy pairwise comparison matrix $\tilde{A} = (\tilde{a}_{ij})_{n\times n}$, which is a key step in the process. Thus, based on The process of Chang's FAHP, the fuzzy pairwise comparison matrix denoted as $\tilde{A} = (\tilde{a}_{ij})_{n\times n}$, is mathematically defined in the following manner:

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & 1 & \cdots & \tilde{a}_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{2n} & \cdots & 1 \end{bmatrix} \tag{3}$$

where

$$\tilde{A} = \tilde{a}_{ij} = \begin{cases} 1 & i = j \\ 1, 3, 5, 7, 9 \; or \; \ldots 1^{-1}, 3^{-1}, 5^{-1}, 7^{-1}, 9^{-1} & i \neq j \end{cases} \tag{4}$$

The fuzzy synthetic extent value, denoted as S_i, with respect to the i-th object is expressed as follows:

$$S_i = \sum_{j=1}^{m} M_{ij} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij}\right]^{-1} \tag{5}$$

With

$$\sum_{j=1}^{m} M_{ij} = \left(\sum_{j=1}^{m} l_{ij}, \sum_{j=1}^{m} m_{ij}, \sum_{j=1}^{m} u_{ij}\right), i = 1, 2, \ldots, n \tag{6}$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij} = \left(\sum_{i=1}^{n}\sum_{j=1}^{m} l_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} m_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} u_{ij}\right) \tag{7}$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} u_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} m_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} l_{ij}}\right) \tag{8}$$

The degree of possibility of $S_j = (l_j, u_j, m_j) \geqslant S_i = (l_i, u_i, m_i)$ is denoted as:

$$V\left(S_j \geq S_i\right) = height\left(S_i \cap S_j\right) = \begin{cases} 1 & if \; m_j \geq m_i \\ 0 & if \; l_i \geq u_j \\ \dfrac{l_i - u_j}{\left(m_j - u_j\right) - \left(m_i - l_i\right)} & otherwise \end{cases} \tag{9}$$

To compare two elements S_j and S_i in Chang's FAHP, it's essential to compute both $V\ (S_i \geq S_j)$ and $V\ (S_j \geq S_i))$. The minimum degree of possibility $d(i)$ for $V(S_j \geq S_i)$, where $i, j = 1, 2, \ldots, k$, is determined as follows:

$$\begin{aligned} &V\left(S \geq S_1, S_2, S_3, \cdots, S_k\right) \\ &= V\left[\left(S \geq S_1\right) \text{and} \left(S \geq S_2\right) and \cdots \left(S \geq S_k\right)\right] \\ &= minV\left(S \geq S_i\right), i = 1, 2, 3, \cdots, k \end{aligned} \tag{10}$$

If assumed $d\left(A_i\right) = \min V\left(S \geq S_i\right), for i = 1, 2, , \cdots, k$. Then, the weight vector can be obtain as follows:

$$W = \left(d\left(A_1\right), d\left(A_2\right), \cdots, d\left(A_n\right)\right)^T \tag{11}$$

Here $A_i\ (i = 1, 2, \ldots, n)$ are n elements.

The weight vectors are gained by normalizing:

$$W = \left(W_1, W_2, \cdots, W_n\right)^T \tag{12}$$

Where W is a real number.

2.2.4 Questionnaire design and linguistic scales

In this study, TFNs are employed to quantify the subjective pairwise comparisons made by decision-makers. A graphical representation of the language terms and triangular language labels is shown in Table 1 and shown in Figure 4 (Kahraman et al., 2006).

2.2.5 The consistency tests

In the Analytic Hierarchy Process (AHP), it is crucial to maintain consistency in the comparison matrix. This consistency ensures the logic and rationality of paired comparison evaluation. To assess the reliability of the comparison matrix in the Analytic Hierarchy Process (AHP), two key measures are used: the Consistency Index (CI) and the Consistency Ratio (CR). These are defined as follows (Saaty, 1994):

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{13}$$

$$CR = \frac{CI}{RI} \tag{14}$$

Here RI is the random index and λ_{max} denote the maximum eigenvalue. To ensure the reliability of the decision, the value of CR should not exceed 10%, as shown in Table 2. This threshold reflects the accuracy of the assessment and whether pairwise comparisons need to be modified to enhance consistency.

3 A case study

In eastern China, the widespread influence of Confucian culture is deeply rooted in the hearts of the people, and it has a significant guiding effect on land management attitudes and practices. Family ties, social harmony, and respect for the collective good are key principles in Confucian culture that occupy a central position in land-use and management. To gain a deeper understanding of how these cultural values influence land management decisions, this study applied Fuzzy Analytic Hierarchy Process (FAHP), a highly flexible multi-criteria decision-making tool capable of dealing with ambiguity. This approach identifies the interplay between cultural values and sustainable land-use and provides strategic recommendations on how to promote sustainable management of land resources while maintaining regional cultural identity. The results of this study offer a new perspective for understanding land management in eastern China where Confucian culture is prevalent,

TABLE 1 Linguistic scales and fuzzy scales for importance.

Linguistic scale for importance	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Absolutely more important (AMI)	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)
Very strongly more important (VSMI)	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Strongly more important (SMI)	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Weakly more important (WMI)	(1, 3/2, 2)	(1/2, 2/3, 1)
Equally important (EI)	(1/2, 1, 3/2)	(2/3, 1, 2)
Just equal	(1, 1, 1)	(1, 1, 1)

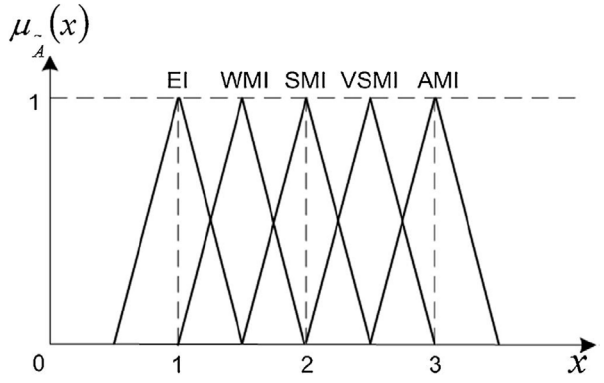

FIGURE 4
Linguistic scale for relative importance.

TABLE 2 The random consistency index.

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.09	1.12	1.24	1.32	1.41	1.45

and provide a scientific basis for local policymakers to formulate land-use planning that is consistent with cultural and sustainability principles. The specific operation process is as follows.

3.1 Expert discussion

The study of the role of immaterial factors such as cultural diversity and psychological awareness in SLUM in China is an interdisciplinary research topic involving the fields of geography, psychology, sociology, environmental science and cultural studies. The joint efforts of psychologists, sociologists, experts in cultural studies and experts in the field of sustainable development are crucial in constructing an assessment model for SLUM in China. These experts can identify and distill the key factors for evaluating sustainability from different perspectives, ensuring that the assessment model is comprehensive and in-depth. The role of the cultural studies specialist is to identify and integrate cultural elements of land-use, which may include links between land and specific cultural identities, traditional knowledge and practices, and the relationship between land-use and cultural heritage conservation. They will also be able to assess how cultural diversity affects the acceptance and implementation of sustainable land management strategies. Psychologists can contribute to a deeper understanding of the psychological motivations and cognitive biases behind land-use decisions, including decision-makers' attitudes toward risk, expectations for the future, and how their values and beliefs affect land management. Sociologists can analyze how land-use decisions are influenced by social networks, social capital, and local governance structures from the perspective of social structure and community interaction. These contributions by environmental researchers are essential to ensure that the indicator system is scientific and practical in the environmental dimension, ensuring that SLUM strategies are able to address current and future environmental challenges. By combining these interdisciplinary expertise, the system will be able to provide policymakers with a comprehensive, balanced and actionable framework for evaluating and guiding the sustainable use and management of land resources in China.

3.2 Building an assessment model for SLUM in China

To ensure the comprehensiveness and scientific nature of the assessment factors, 35 professionals, including academics, researchers and engineers, were organized into five groups grouped according to their fields of expertise. These groups cover a wide range of disciplines, from ecology, sociology, and environmental science to psychology and cultural studies, and each group examines and discusses factors in the assessment model that are relevant to its area of expertise. These groups usually work by conducting a thorough review of the existing literature, followed by in-depth discussions based on the field experience of the members. Through this process, they are able to identify and determine the evaluation factors that are critical to SLUM, taking into account China's unique socio-economic conditions, cultural context and ecological environment. In the selection and adjustment of evaluation factors, panellists strive to reach a consensus to ensure that each factor objectively reflects the sustainability of land-use and helps guide practical land management decisions. After several rounds of discussion and repeated verification, the assessment model finally formed has not only been recognized by the peers academically, but also accepted by the actual management department. The successful

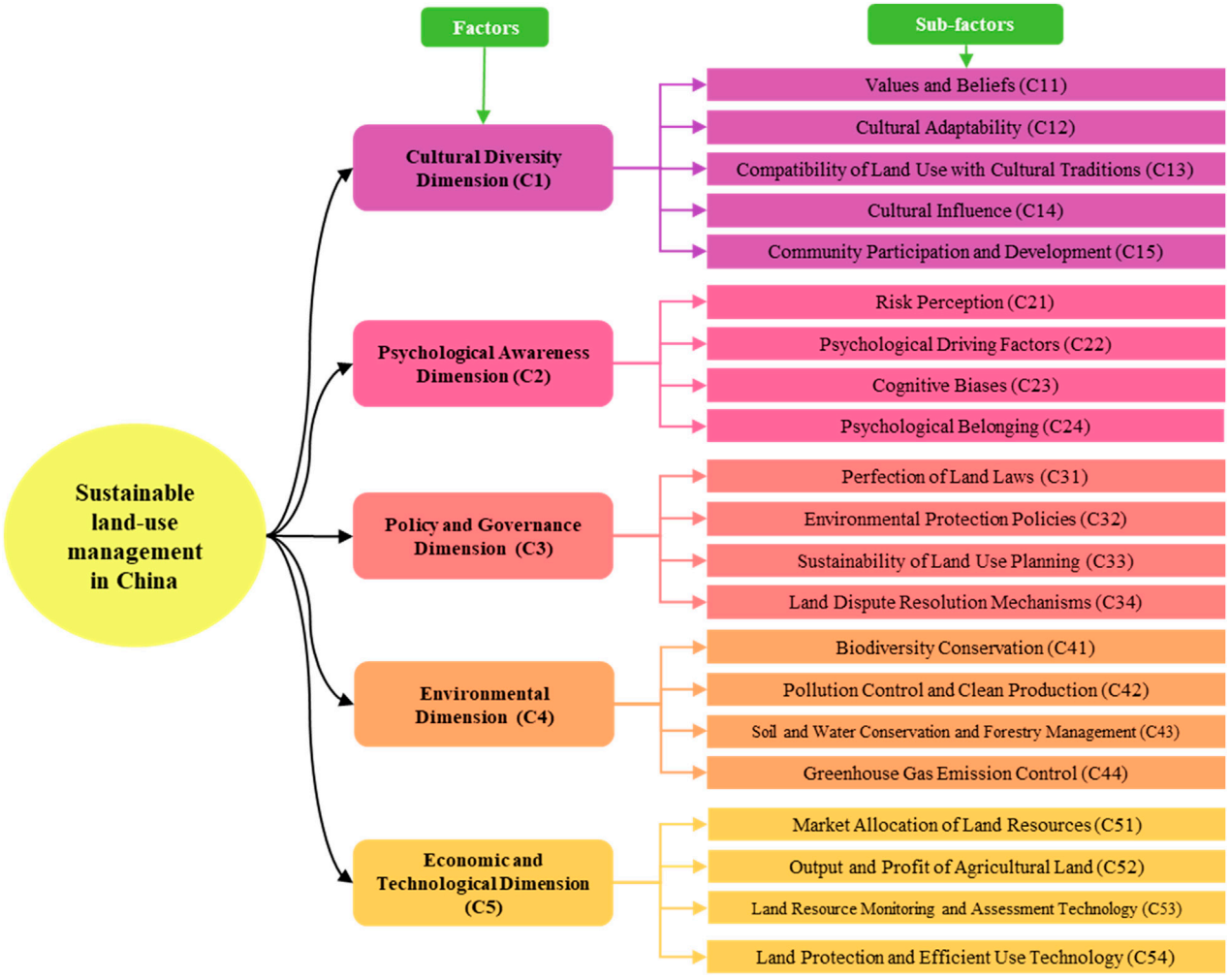

FIGURE 5
The assessment model for SLUM in China.

construction of this system, thanks to the power of interdisciplinary cooperation, will guide the sustainable use of China's land resources, promote the construction of ecological civilization, and ensure the rational use and long-term protection of land resources.

As shown in Figure 5, the assessment model divides the decision problem into three levels, including the target level, the criterion level and the sub-criterion level. In this study, China's SLUM assessment model through in-depth research and comprehensive review, established five key factors and 21 related sub-factors, involving cultural, psychological, policy, environmental, economic and technological dimensions. These factors and sub-factors together constitute a comprehensive evaluation model aimed at comprehensively assessing and guiding the sustainable use and management of land resources. The cultural diversity dimension includes how land-use activities are adapted to local culture and maintain harmony between cultural traditions and modern land-use. Values and beliefs influence land-use decisions; cultural adaptation emphasizes the coordination of land-use and local culture; compatibility of land-use and cultural traditions considers whether land activities respect traditional values; cultural impact evaluates the strength of cultural factors' influence on land management; and community participation and development emphasizes the importance of public participation in the decision-making process. The dimension of psychological consciousness involves people's cognition and psychological factors of land management risk. Risk cognition analyzes the degree of public perception of land-use risk, psychological drivers focus on people's attitudes and motivations towards land-use, cognitive bias explores possible psychological errors in decision-making, and psychological belonging reflects people's emotional connection with land.The policy and governance dimension emphasizes the role of laws, regulations and planning. The perfection of land laws and regulations assesses the support degree of the current legal system for sustainable land-use, the sustainability of land-use planning considers whether the planning can meet the needs of long-term development, and the effectiveness of land dispute resolution mechanism focuses on the justice and efficiency of conflict resolution.

TABLE 3 Comparison matrix of the factors.

	C1	C2	C3	C4	C5
C1	1,1,1	1.4571,1.3124,2.0891	1.5116,1.3312,1.4282	1.8517,1.4413,1.8741	1.0931,1.789,1.195
C2	0.7984,0.925,0.991	1,1,1	1.5431,1.1121,1.3310	1.2211,1.6512,1.2214	1.3319,1.3354,1.22
C3	0.331,0.2206,0.4651	0.8222,0.5354,0.6299	1,1,1	1.2508,1.3314,1.3827	1.2232,0.9774,0.867
C4	0.745,0.9870,0.6340	0.3249,0.3067,0.5038	0.7892,0.4326,0.5549	1,1,1	1.1595,1.9541,1.3961
C5	1.1045,0.8664,0.761	0.5692,0.7859,0.9441	0.7674,0.8674,0.9664	1.4323,0.7745,0.8777	1,1,1

TABLE 4 Comparison matrix of the "Cultural Diversity Dimension."

	C11	C12	C13	C14	C15
C11	1,1,1	1.4256,1.9341,1.7526	1.8837,1.1414,0.2176	0.4444,0.9811,0.8172	0.4664,1.5285,1.7992
C12	0.7984, 0.925,0.991	1,1,1	1.6702,1.8574,1.2784	1.4779,1.5798,1.2252	1.9151,1.6506,0.2308
C13	0.7002,0.9668,1.9322	1.3218,1.9703,1.1335	1,1,1	0.7243,0.9563,0.8987	0.3007,0.2646,0.1401
C14	0.3982,0.4853,0.8236	0.5254,0.6550,0.5740	0.2763,0.5637,0.8210	1,1,1	1.7134,1.0320,1.6226
C15	0.7359,0.7838,0.4255	0.9929,0.9324,0.6619	0.4987,0.6259,0.2902	0.6803,0.6041,0.7002	1,1,1

TABLE 5 Comparison matrix of the "Psychological Awareness Dimension."

	C21	C22	C23	C24
C21	1,1,1	1.0491,1.5280,0.3771	0.8283,0.7577,0.5826	0.3230,0.5286,1.2009
C22	1.1562,1.4619,1.2499	1,1,1	0.8822,0.9797,0.2842	0.9585,1.2301,1.7151
C23	1.0491,1.5280,1.3533	1.8603,1.5086,1.1335	1,1,1	1.2181,1.7741,2.3450
C24	0.8327,1.2301,1.2154	1.9358,1.6915,1.9386	1.6819,1.1832,0.8210	1,1,1

3.3 Calculate the comparison matrix

In the study of SLUM in China, expert evaluation is the key link to evaluate the relative importance of different factors. In this process, rather than providing precise numerical ratings, the experts express their evaluations through vague numbers, as shown in Table 1. It can better reflect their understanding of the uncertainty of different management practices and their degree of preference. These fuzzy values form a preliminary comparison matrix. These preliminary matrices may be discussed and optimized within the expert group in order to reach consensus or at least to understand differences of opinion. After completing this step, the fuzzy judgments of five groups of 35 experts were synthesized using geometric average method to form a final fuzzy comparison matrix covering the main factors and their sub-factors. The factor comparison matrix and sub-factor comparison matrix obtained in this process are respectively recorded in the data table, as shown in Tables 3–8. Further analysis showed that all the comparison matrices were consistent, that is, their consistency ratio was less than 0.1, indicating that these matrices were statistically acceptable, ensuring the reliability of the evaluation results.

The described methodology integrates Chang's fuzzy Analytic Hierarchy Process (FAHP) with MATLAB for a comprehensive analysis in the context of SLUM decision-making. This approach begins by adopting Chang's extent analysis method to process fuzzy judgments into quantifiable weights. These weights represent the relative importance of six identified factors (C1—C5), as shown in Tables 3–8. The process involves several key steps:

1. Fuzzy Evaluation Matrix Application: Utilizing the fuzzy evaluation matrix, the weights of the factors (C1-C5) are determined. This matrix forms the basis for subsequent calculations.
2. Calculation of Fuzzy Synthetic Extent Values: Equations 5–10 are employed to calculate the fuzzy synthetic extent value for each factor. This value is crucial in understanding the degree of impact or importance of each factor within the overall decision-making framework.
3. Computing Weights of Factors and Sub-Factors: FAHP is applied to determine the precise weights of both factors and their respective sub-factors. This is achieved through a detailed analysis that takes into account the relative significance of each element in the decision-making process.
4. Degree of Possibility Calculation: Eq. 11 is used to calculate the degree of possibility for each factor relative to others. This step is essential to understand how each factor compares against others in terms of importance or influence.

TABLE 6 Comparison matrix of the "Policy and Governance Dimension."

	C31	C32	C33	C34
C31	1,1,1	1.0491,1.5280,0.8464	0.8067,0.4295,0.9596	0.1598,0.9276,0.7590
C32	0.4787,0.6544,0.9532	1,1,1	0.2262,0.9901,0.3568	1.8315,1.5589,1.7335
C33	0.7616,0.5714,0.9340	1.2323,1.1893,1.1335	1,1,1	1.2181,1.7741,2.3450
C34	1.4067,1.1106,1.1099	1.4587,1.5389,1.2009	0.4264,0.5637,0.8210	1,1,1

TABLE 7 Comparison matrix of the "Environmental Dimension."

	C41	C42	C43	C44
C41	1,1,1	1.0491,1.5762,1.7083	1.9848,1.2451,1.5283	1.1851,1.3774,1.2009
C42	0.4787,0.6545,0.9532	1,1,1	0.8822,0.5136,0.9335	0.2460,1.2301,1.7151
C43	1.0491,1.5258,1.7172	1.6269,0.7859,1.1335,	1,1,1	1.2181, 1.7741,2.3449
C44	0.8327,0.8961,0.7272	0.8375,0.2689,0.8615	0.7133,0.5637,0.8210	1,1,1

TABLE 8 Comparison matrix of the "Economic and Technological Dimension."

	C51	C52	C53	C54
C51	1,1,1	1.0134,1.5579,1.4275	1.3077,1.3461,1.2055	1.4028,0.8130,1.2009
C52	1.3734,2,1.7393	1,1,1	0.9415,0.1482,0.7485	0.3071,0.5628,0.5283
C53	0.3270,0.1693,0.3874	1.9638,0.7859,1.1335	1,1,1	1.2181,1.7741,2.3450
C54	0.7769,0.3384,0.766	0.1257,0.2644,0.2022	0.4111,0.5637,0.8201	1,1,1

5. Normalization of the Weight Vector: Finally, Eq. 12 is used for normalizing the weight vector. Therefore, based on Eq. 12, the normalized weight vector W can be obtained as:

$W = (W_{C1}, W_{C2}, W_{C3}, W_{C4}, W_{C5},)^T = (0.2790, 0.2329, 0.1565, 0.1514, 0.1802)^T$

Similarly, the weight vectors W_1, W_2, W_3, W_4, W_5 of sub-factors are calculated shown as below:

$W_1 = (W_{C11}, W_{C12}, W_{C13}, W_{C14}, W_{C15}) = [0.1999, 0.2815, 0.1823, 0.1976, 0.1386]^T$

$W_2 = (W_{C21}, W_{C22}, W_{C23,} W_{C24})) = [0.195,0.205,0.309,0.291]^T$

$W_3 = (W_{C31}, W_{C32}, W_{C33}, W_{C34}) = [0.156,0.227,0.324,0.293]^T$

$W_4 = (W_{C41}, W_{C42}, W_{C43}, W_{C44}) = [0.313,0.214,0.307,0.166]^T$

$W_5 = (W_{C51}, W_{C52}, W_{C53}, W_{C54}) = [0.310,0.202,0.295,0.193]^T$

The result of this approach is a set of normalized weight vectors of factors and subfactors, providing a clear and quantifiable view of their respective importance in SLUM decision-making. This approach, which combines FAHP and MATLAB, enables precise and systematic analysis, facilitating informed and balanced decisions based on the relative importance of various factors and sub-factors.

Table 9 shows in detail the final weights of each factor and sub-factor calculated according to Chang's method. In the process of multi-criteria decision-making, the global weights of sub-factors are calculated by multiplying their local weights with the weights of the corresponding main factors. This multiplication reflects the principle that the importance of a sub-factor is not only determined by its intrinsic value (local weight) but also by the significance of the broader category (main factor) to which it belongs. The local weights of sub-factors are derived from pairwise comparisons within each main factor, reflecting their relative importance in that specific category. These local weights are then scaled by the weight of the main factor, but at a higher level, reflecting the overall priority of each main factor in the context of the decision-making problem. This approach ensures that the global weights accurately represent the combined effect of both the intrinsic importance of the sub-factors and the overarching significance of their respective main factors.

4 Research results and discussion

4.1 Local weight ranking and analysis of first-level factors

The decision-making process in this study involves assigning weights to different criteria, with the criterion with the highest weight considered to be the most important. The FAHP priority weight estimates for each criterion were used to determine the criteria with the highest weight, and the results are shown in Table 9; Figure 6. According to the calculation results, the weight value of cultural diversity dimension is 0.2790, which indicates that it is crucial to consider cultural factors in SLUM, as shown in

TABLE 9 The Local weights of the factors and the global weights of the sub-factors.

Factors and sub-factors	Local weight	Global weight	Rank
Cultural Diversity Dimension (C1)	0.2790		
Values and Beliefs (C11)	0.1999	0.0558	5
Cultural Adaptability (C12)	0.2815	0.0785	1
Compatibility of Land Use with Cultural Traditions (C13)	0.1823	0.0509	8
Cultural Influence (C14)	0.1976	0.0551	6
Community Participation and Development (C15)	0.1386	0.0387	15
Psychological Awareness Dimension (C2)	0.2329		
Risk Perception (C21)	0.195	0.0454	14
Psychological Driving Factors (C22)	0.205	0.0477	10
Cognitive Biases (C23)	0.309	0.0720	2
Psychological Belonging (C24)	0.291	0.0678	3
Policy and Governance Dimension (C3)	0.1565		
Perfection of Land Laws (C31)	0.156	0.0244	21
Environmental Protection Policies (C32)	0.227	0.0355	17
Sustainability of Land Use Planning (C33)	0.324	0.0507	9
Land Dispute Resolution Mechanisms (C34)	0.293	0.0459	13
Environmental Dimension (C4)	0.1514		
Biodiversity Conservation (C41)	0.313	0.0474	11
Pollution Control and Clean Production (C42)	0.214	0.0324	19
Soil and Water Conservation and Forestry Management (C43)	0.307	0.0465	12
Greenhouse Gas Emission Control (C44)	0.166	0.0251	20
Economic and Technological Dimension (C5)	0.1802		
Market Allocation of Land Resources (C51)	0.310	0.0559	4
Output and Profit of Agricultural Land (C52)	0.202	0.0364	16
Land Resource Monitoring and Assessment Technology (C53)	0.295	0.0532	7
Land Protection and Efficient Use Technology (C54)	0.193	0.0348	18

Figure 6. Cultural diversity is an important aspect that must be considered in SLUM in China. This dimension includes a variety of elements, including values and beliefs, cultural adaptation, compatibility between land-use and cultural traditions, cultural impact, community participation and development. First, values and beliefs play an important role in shaping land-use practices. In China, different cultural groups may have different views on the relationship between people and the environment, which may affect how they use land. Understanding and respecting these diverse values and beliefs is essential to designing effective and sustainable land management strategies. Second, cultural adaptation is essential in the face of changing environmental conditions and land-use patterns. China's vast and diverse cultural landscape requires adaptable land-use methods to meet changing social needs and environmental challenges. This adaptation includes the recognition and inclusion of traditional knowledge and practices that have been proven to be sustainable over time. Third, ensuring compatibility between land-use practices and cultural traditions is essential to maintaining cultural heritage and identity. Many cultural traditions in China are closely associated with specific landscapes and ecosystems. Balancing development needs with preserving cultural traditions is key to achieving SLUM. In addition, cultural influences shape the way communities interact with and use land resources. Cultural practices, such as traditional agricultural techniques or spiritual connections to certain landscapes, can have a profound impact on land-use decisions. Recognizing these cultural influences and incorporating them into land management strategies can lead to more sustainable and culturally sensitive approaches. Community participation is also key to successful land-use management. Involving local communities in the decision-making process fosters ownership and responsibility for land. It ensures that the diverse perspectives, knowledge and needs of communities are taken into account, leading to more inclusive and sustainable land management practices. Finally, community

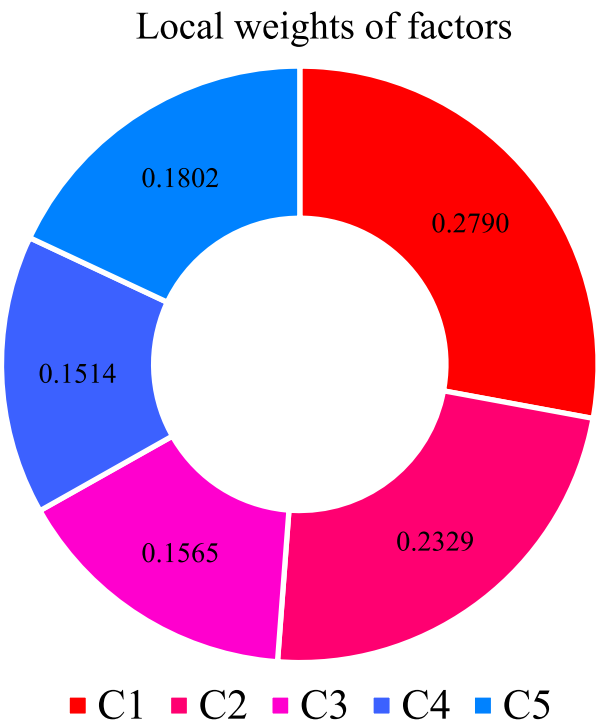

FIGURE 6
Global weights of the sub-factors.

development should go hand in hand with SLUM. The long-term sustainability of land-use practices can be enhanced by promoting economic opportunities, social welfare and environmental management within communities. This holistic approach recognizes that SLUM is not only about environmental protection, but also about improving the quality of life of communities. In conclusion, the cultural diversity dimension is an integral part of achieving SLUM in China. By considering values and beliefs, cultural adaptability, compatibility with traditions, cultural impact, community engagement and development, decision makers and stakeholders can develop strategies that are both environmentally sustainable and culturally sensitive. Embracing cultural diversity not only protects China's rich cultural heritage, but also contributes to the long-term wellbeing of communities and ecosystems.

The weight value of psychological awareness dimension is 0.2329. This dimension involves the status and characteristics of land-users and managers at the cognitive, emotional and psychological levels, which directly affect the decision-making and behavior pattern of land-use. Risk perception is one of the core elements of psychological consciousness. It describes an individual's perception and assessment of potential risks in land-use. These risks may involve economic losses, environmental degradation, social stability and many other aspects. The level of individuals' awareness of these risks determines the degree of care they take in land-use and the risk control measures they take. The research shows that the level of risk perception is closely related to the individual's information access channel, experience background and education level. Psychological drivers explain why individuals choose particular land-uses in the absence of obvious external pressures. These factors may include an individual's values, beliefs, and long-term goals. For example, strong environmental awareness may drive individuals to prioritize the ecological benefits of land over short-term economic gains. Psychological drivers play an indispensable role in promoting behavioral changes in sustainable land-use. Cognitive bias refers to the phenomenon of deviation from rational judgment caused by the limitation of information processing or psychological presupposition in the process of land-use decision-making. These deviations can lead to overexploitation or improper protection of land resources. For example, managers may lose sight of the long-term implications of environmental protection policies due to excessive optimism or lack of sense of disaster. Psychological belonging and social identity are the psychological needs of individuals seeking emotional connection with land and social belonging in land-use. Individuals with a strong sense of belonging may be more inclined to maintain land resources and promote sustainable development of the community. Social identity is concerned with how individuals perceive their role in society and how they express that role through land-use. Social identity can strengthen connections among community members to promote sustainable land-use practices. In conclusion, the impact of psychological consciousness on China's land sustainable management system cannot be ignored. Improving understanding of the psychological state of land-users and managers, especially their risk perception, psychological drivers, cognitive biases, psychological belonging and social identity, is essential for developing more humane, accurate and effective land management policies and measures. This requires that not only economic, environmental and technical factors should be considered in the formulation of land management strategies, but also psychological motivations should be deeply explored to improve the development of land-use in China in a more sustainable direction.

From the economic opinion, the market-oriented allocation of land resources is an important means to improve the efficiency of land-use management. The weight value of economic and technological dimension 0.1802. The market mechanism can effectively guide the transfer of land resources to more efficient uses, because the market price mechanism can reflect the scarcity of land resources and the demand changes of economic activities. In practice, through land auction, leasing and other market-oriented means, not only improve the transparency and justice of land resource allocation, but also stimulate the potential economic value of land, and improve the rational circulation and optimal allocation of land resources. For agricultural land, increasing its output and returns is central to achieving agricultural sustainability. Through improved planting structures, the introduction of efficient farming techniques and high-quality crop varieties, agricultural output per unit area can be effectively increased, while reducing negative environmental impacts. In addition, the progress of agricultural technology and science also includes the application of precision agriculture, which through the combination of information technology and agricultural technology, improves the level of fine management of agricultural production and further improves the efficiency of land output. At the technical level, the progress of land resource monitoring and evaluation technology has significant significance for realizing the sustainable use of land resources. The application of geographic information system

(GIS), remote sensing technology, big data analysis and other modern technical means makes the monitoring of land resources more accurate and timely, and provides scientific data support for policy making. The application of these technologies not only improves the accuracy of land resource assessment, but also optimizes the quality of land management and planning. Finally, the development and application of land protection and efficient utilization technology is directly related to the realization of land resource sustainability. This includes soil improvement techniques, water-saving irrigation techniques, and sustainable land management techniques that help maintain land productivity, prevent land degradation, and enhance land versatility and ecological benefits. Taken together, the economic and technological dimensions play a crucial role in SLUM in China. They not only provide a market mechanism for the efficient allocation of land resources, but also promote the technological innovation of agricultural production, and ensure the scientific land-use decision-making and the effectiveness of land resource protection through advanced monitoring and evaluation techniques. With the continuous development of China's economy and technology, the economic and technological dimensions will continue to play a key role in promoting the sustainable use of land resources.

The weight value of policy and governance dimensions is 0.1565. This dimension covers many aspects, such as the improvement of land laws, environmental protection policies, the sustainability of land-use planning, and land dispute resolution mechanisms, which play a key role in ensuring the long-term sustainable use of land resources and maintaining social harmony and stability. The maintenance of biodiversity is a primary consideration in the environmental dimension, as it relates to the integrity of ecosystems and their resistance to environmental change. The commitment to biodiversity conservation is reflected in China's land planning policies through the development of ecological corridors, the establishment of nature reserves, and the implementation of species recovery programs. These policy measures are aimed at preventing habitat destruction and ecological degradation caused by excessive urbanization and agricultural expansion, thereby ensuring the health and diversity of natural communities. With China's rapid economic growth, industrial pollution control and cleaner production have become particularly critical. To address this challenge, policymakers have taken a number of measures, such as strengthening pollutant discharge standards, promoting clean technology and circular economy concepts, and implementing efficient wastewater treatment and solid waste management strategies. These efforts aim to reduce the negative impact of industrial activities on soil and water resources in order to achieve a greener industrialization path. In addition, soil and water conservation and forestry management measures play a crucial role in combating soil erosion in some parts of China. For example, conservation measures such as afforestation, land cover and terracing have been effective in slowing land erosion and enhancing soil water retention. At the same time, sustainable forest management practices ensure a sustainable supply of forest resources, facilitate the provision of ecosystem services and contribute to the maintenance of biodiversity. Finally, as the world's largest greenhouse gas emitter, China has also placed a strong emphasis on greenhouse gas emission control in SLUM. By improving energy efficiency, promoting the use of renewable energy, and optimizing agricultural practices and land-use patterns, China is reducing methane and carbon dioxide emissions from its agricultural land-use. This not only helps the country fulfill its international environmental commitments, such as the Paris Agreement, but also plays a positive role in the mitigation of global climate change. In summary, by integrating the environmental dimension into land-use management, China not only protects its own natural resources and ecosystems, but also contributes to global environmental governance. By implementing these environmental protection strategies, China is demonstrating its determination to maintain and add value to its environmental capital over the long term, as well as its commitment to achieving the Sustainable Development Goals.

In China, the environmental dimension occupies a crucial position in sustainable land-use management, especially in the context of the pursuit of balance between economic development and environmental protection. Even if the environment dimension has a weight value of 0.1514, it is still a significant part of the overall strategy. The maintenance of biodiversity is a primary consideration in the environmental dimension, as it relates to the integrity of ecosystems and their resistance to environmental change. The commitment to biodiversity conservation is reflected in China's land planning policies through the development of ecological corridors, the establishment of nature reserves, and the implementation of species recovery programs. These policy measures are aimed at preventing habitat destruction and ecological degradation caused by excessive urbanization and agricultural expansion, thereby ensuring the health and diversity of natural communities. With China's rapid economic growth, industrial pollution control and cleaner production have become particularly critical. To address this challenge, policymakers have taken a number of measures, such as strengthening pollutant discharge standards, promoting clean technology and circular economy concepts, and implementing efficient wastewater treatment and solid waste management strategies. These efforts aim to reduce the negative influence of industrial activities on soil and water resources in order to achieve a greener industrialization path. In addition, soil and water conservation and forestry management measures play a crucial role in combating soil erosion in some parts of China. For example, conservation measures such as afforestation, land cover and terracing have been effective in slowing land erosion and enhancing soil water retention. At the same time, sustainable forest management practices ensure a sustainable supply of forest resources, facilitate the provision of ecosystem services and contribute to the maintenance of biodiversity. Finally, as the world's largest greenhouse gas emitter, China has also placed a strong emphasis on greenhouse gas emission control in SLUM. By improving energy efficiency, promoting the use of renewable energy, and optimizing agricultural practices and land-use patterns, China is reducing methane and carbon dioxide emissions from its agricultural land-use. This not only helps the country fulfill its international environmental commitments, such as the Paris Agreement, but also plays a positive role in the mitigation of global climate change. In summary, by integrating the environmental dimension into land-use management, China not

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4.2 Global weights ranking of sub-factors

The global weight ranking of the sub-factors is shown in Figure 7. In China's SLUM, cultural adaptation (C12) has the highest global weight (0.0785), reflecting the critical importance of response and adaptation to evolving socio-cultural needs and conditions in land management decision-making. This suggests that management strategies must be flexible and able to adapt to a wide range of cultural dynamics, including urbanization, technological change and social transformation. Cultural adaptation plays a central role in the management of sustainable land-use in China, which is closely related to China's diverse cultural background and rapidly changing socio-economic environment. With globalization and internal migration, various cultures and lifestyles come together, creating new requirements and challenges for land-use. For example, traditional farming communities may need to adapt to the pressures of urbanization while maintaining their cultural heritage. Cultural adaptation requires policymakers and land managers to deeply understand and respect local cultures and how they affect land-use when planning and executing land-use decisions. This is not just about preserving cultural sites or avoiding the destruction of cultural landscapes, but also about how traditional knowledge and practices can be integrated into modern land management frameworks as resources for sustainable development. In addition, cultural adaptation requires managers to identify and adapt to new needs brought about by social change, such as leisure space, urban green space, and the balance between agriculture and industry. In urban planning, for example, adaptability may take the form of adapting the design to accommodate community activities, or reserving space in a new development zone for the establishment of future cultural facilities. Ultimately, the goal of cultural adaptation is to create a flexible land management system that responds simultaneously to the needs of environmental protection and the cultural values of the community, ensuring that land-use decisions contribute to harmonious economic, social and cultural development. In China, this means balancing rapid urban expansion with the preservation of traditional ways of life in rural areas. By placing cultural adaptation at its core, land management strategies can more fully address this challenge to achieve long-term sustainable land-use.

This is closely followed by cognitive bias (C23) (global weight 0.0720), the importance of which points to the need to be aware of and correct potential cognitive misunderstand-ings when formulating land policies and implementing land-use planning. Recognizing and countering these biases, which can lead to unequal resource distribution or underes-timation of environmental impacts, is key to promoting more just and sustainable land management. Cognitive bias is an important factor in the decision-making process of SLUM in China. These biases may stem from traditional ideas, limitations of experience, or misunderstandings and judgment errors caused by infor-mation asymmetry. The existence of cognitive biases requires that measures be taken in land management to identify and correct these biases. One approach is to balance different perspectives and expertise through multidisciplinary teamwork in order to fully assess the consequences of decisions from all perspectives. In addition, through an open and transparent deci-sion-making process and active public participation, more perspectives can be provided and critical thinking promoted, thereby reducing the impact of bias. On the other hand, decision models and tools, such as multi-criteria Decision Analysis (MCDA) or group De-cision support systems (GDSS), can also help managers identify potential cognitive biases and provide a more objective and scientific basis for decision-making. These methods en-able systematic analysis of complex land management issues, ensuring that different in-terests and values are balanced in the decision-making process. In a country as diverse as China, identifying and managing cognitive biases is critical to ensuring the fairness, effec-tiveness, and sustainability of land-use policies. Only through in-depth understanding and overcoming these psychological barriers can land-use strategies that are consistent with economic development and respect ecological balance and social justice be formu-lated.

Psychological belonging (C24) holds a significant role in the assessment model, with a global weight value of 0.0678. It emphasizes the importance of strengthening community members' emotional connection to the land and their responsibility for its sustainable management. This sense of belonging goes beyond mere emotions; it represents a deep identification with the land and its culture, particularly in a culturally rich country like China, where land is closely tied to heritage and identity. Enhancing this psychological belonging can motivate community members to actively engage in land conservation and sustainable use. For instance, when implementing land remediation or urban renewal projects, respecting and preserving the sense of belonging among local residents can reduce community resistance and increase project acceptance. In China, traditional villages and land use practices are deeply embedded with cultural and spiritual values, making it imperative to maintain these values during development and modernization. Cultivating emotional ties through education and community involvement can encourage active land resource conservation and rational utilization. Psychological belonging is also closely linked to land identity, especially concerning the preservation of national culture and sustainability in minority areas. Land management strategies in these regions must be thoughtfully designed to support economic growth without compromising cultural identity and a sense of place. In China's SLUM, emphasizing psychological belonging is crucial not only for environmental protection and social harmony but also for the preservation of cultural diversity and community cohesion. Prioritizing psychological attribution in land management decisions ensures that development benefits people's wellbeing and the environment without sacrificing cultural heritage and social stability. Additionally, the global weight of market resource allocation (C51) at 0.0559 underscores the role of market mechanisms in resource allocation. It also highlights the necessity of policy intervention to ensure the sustainability and equity of land use. In an ideal market economy, resource allocation relies on

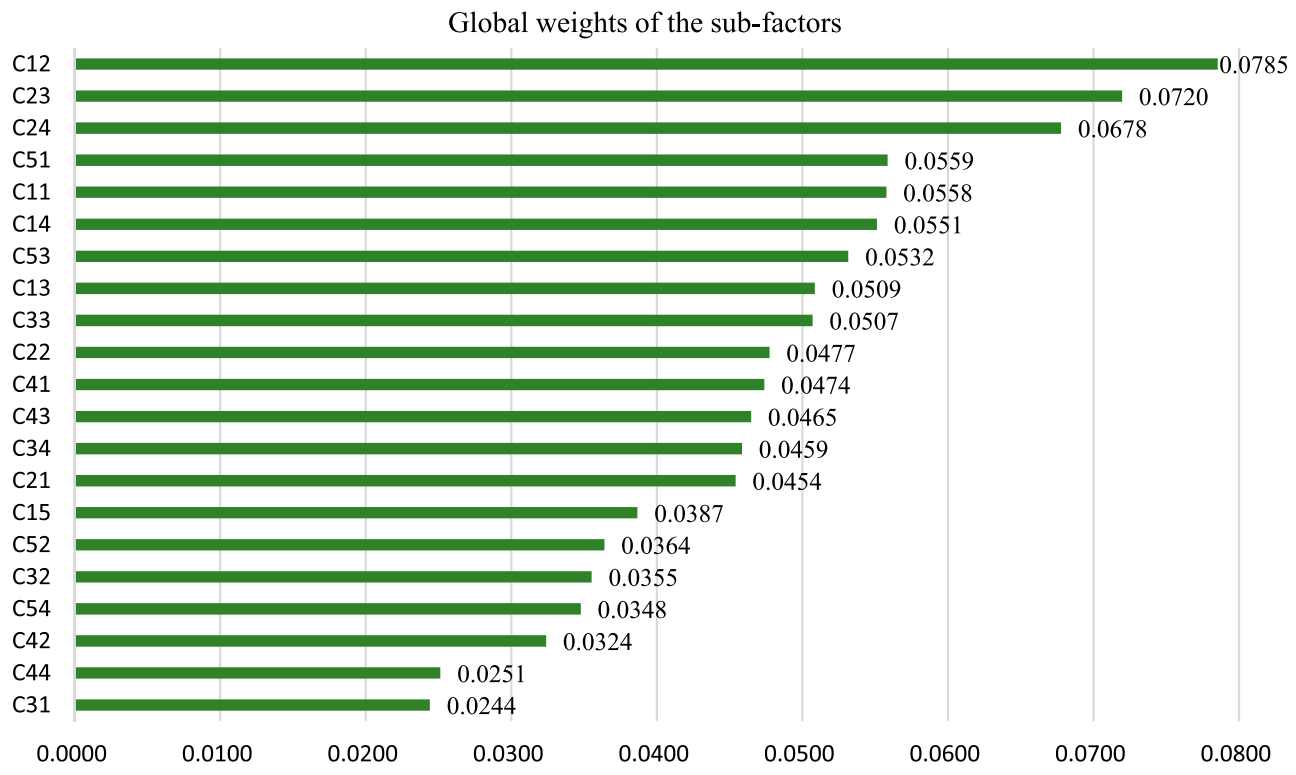

FIGURE 7
Global weights of the sub-factors.

market mechanisms, with prices reflecting supply and demand, guiding consumer and producer behavior. However, in land resource management, unchecked market mechanisms can lead to resource misallocation and environmental issues. Thus, sustainable land management in China requires a combination of market resource allocation and policy guidance and intervention. Ultimately, balancing ecological protection, social justice, and economic efficiency in land management necessitates strong government supervision and the effective operation of market mechanisms. Only through this synergy can long-term sustainable land resource use be realized.

Values and Beliefs (C11) (global weight 0.0558) are almost equal to the weight assigned by the market, highlighting the importance of integrating local and community values in land management. Land management strategies must respect and use these values to promote and guide sustainable land-use. Values and Beliefs play a fundamental role in SLUM in China. They are important cultural building blocks that shape land-use patterns, environmental policies, and civic behavior. In a country as rich in history and culture as China, traditional values and beliefs have a profound impact on understanding and guiding land-use. Traditional Chinese values that emphasize harmony with nature, such as the Taoist concept of non-governance and the Confucian concept of conserving land, coincide with the modern concept of sustainable development. However, industrialization and urbanization in the process of modernization have challenged and sometimes conflicted with these traditional beliefs. The pursuit of rapid economic growth often makes the short-term economic value of land resources outweigh the long-term ecological and social value. Incorporating Chinese values and beliefs into land-use decisions means balancing the needs of economic development and environmental protection. This requires strengthening sustainable values in national planning and local governance, and ensuring respect for ecological balance and social responsibility in land-use. For example, increasing the value of ecological services by focusing on farmland conservation, curbing sprawling urban land-use, and restoring and protecting natural ecosystems. In terms of education and public outreach, promoting the values of sustainable land-use can increase public awareness and participation in land conservation. Values of sustainable development can be fostered at all levels of society by promoting a lifestyle that uses land economically, encouraging public participation in environmental protection activities, and disseminating environmental ethics through the media and education system. Policymakers and social leaders should also lead by example and demonstrate their commitment to these values by protecting land resources through transparent and fair policies and laws that provide the public with an example of following sustainable land-use. In conclusion, the role of values and beliefs in SLUM in China is multidimensional, shaping not only individual and collective behavior, but also policy formulation and implementation. In the face of the dual challenges of global environmental change and domestic socio-economic pressures, reaffirming and strengthening traditional values of living in harmony with nature will be critical to achieving the goals of sustainable land management.

Cultural impact (C14) has the global weight (0.0551), but this does not mean that its impact can be ignored. This factor emphasizes the profound influence of cultural dimensions in shaping land-use

patterns and management decisions, especially in the context of China's vast geographical size and cultural diversity. The Influence of Cultural Influence on the management of sustainable land-use in China is multi-layered. It indirectly influences the land-use pattern and management strategy by shaping social norms, behaviors and expectations. China is a culturally diverse and profound country, and its land management practice is not only influenced by legal and economic factors, but also deeply influenced by historical tradition and social culture. For example, traditional values that value agriculture and land as the basis of life have fundamental implications for the conservation and use of rural land. Systems such as collective land ownership and household responsibility reflect China's unique cultural influence, and these systems have played an important role in ensuring food safety and safeguarding farmers' rights and interests. Cultural factors also play a key role in urban planning and land-use. The design of urban public space, the planning of residential areas and the protection of historical and cultural heritage often reflect the respect and protection of cultural traditions. In the process of rapid urbanization in China, how to balance the needs of modern development with the protection of cultural heritage is a key issue. Under the influence of globalization and marketization, cultural influence can also lead to conflicts and problems in land-use. Exotic lifestyles and consumption patterns may conflict with indigenous land-use practices and environmental protection, and may sometimes threaten the sustainability of land resources. Therefore, in land management, cultural influence needs to be carefully considered and integrated into the framework of sustainable development. The positive impact of culture on sustainable land management can be strengthened through education, media advocacy and citizen engagement. In addition, policymakers need to have a deep understanding of local cultural values and social habits in order to formulate and implement land management policies more effectively. The global weight of cultural influence suggests that any land-use policy or practice must adapt to and respect local cultures, while educating and guiding the public to understand and support the importance of sustainable land management. In this way, cultural influence can be an important force in moving China's land management in a more sustainable direction. Taken together, these weights reflect the complex role of cultural and psychological factors in SLUM in China. They suggest that in order to promote efficient and sustainable land-use, policymakers and managers must consider the effects of everything from cultural adaptation to cognitive biases, from psychological belonging to perceived market mechanisms, and inherent values and beliefs.

The search for SLUM requires a multifaceted approach that harmoniously combines cultural traditions with modern ecological requirements. The compatibility of land use with cultural traditions (C13) is not only for the preservation of heritage, but is also an important tool for promoting community participation and development (C15). This engagement is essential to enhance risk perception (C21) and psychological drivers (C22), both of which are important to foster a proactive land conservation stance. The legal framework governing land (C31) is essential to ensure a balance between cultural and ecological needs. These laws must be refined to reflect contemporary environmental protection policies (C32) that are an integral part of the sustainability of land use planning (C33). An effective land dispute resolution mechanism (C34) is also necessary to resolve conflicts arising from competing land use interests. Biodiversity conservation (C41) is closely related to pollution control and cleaner production (C42) because together they contribute to the ecological resilience of land resources. At the same time, soil and water protection, together with forestry management (C43), underpins the viability of agricultural lands, which is directly related to the yields and profits of these lands (C52). The role of technology through Land Resource Monitoring and Assessment (C53) and Land Conservation and Effective Use Technology (C54) cannot be overemphasized. It is able to predict trends and the impact of land-use decisions, allowing for a more strategic approach to land management. Taken together, the interplay of these factors creates a complex and coherent system in which the sustainability of land use is constantly negotiated and adjusted according to cultural sensitivities, community inputs, ecology, and technological advances. Implementing these intertwined aspects through policies and practices is essential to achieving a sustainable balance in land use management.

4.3 Balancing cultural traditions with modern ecological

4.3.1 Integrating traditional agricultural practices with modern sustainability methods

Adaptation of Ancient Techniques: Ancient Chinese agricultural methods, such as the use of specific crop varieties and cultivation methods tailored to local conditions, can be adapted to modern agroecological practices. For example, climate models and soil analysis are used to determine when and how crops are most suitable for planting, while retaining traditional methods such as crop rotation and intercropping.

Enhanced Soil Management: In ancient times, it was a common practice to maintain soil health by adding organic matter and reducing soil turning. Modern sustainable agriculture can adopt these principles, such as maintaining soil fertility and structure through the use of organic fertilizers, green manure crops, and conservation tillage. In addition, modern technologies such as soil testing can be used to more precisely determine the needs of the soil, thus making fertilizers and farming methods more efficient and environmentally.

Biodiversity conservation: In traditional Chinese agriculture, diverse crops and varieties not only enrich people's diet, but also help maintain the balance of the ecosystem. For example, a mix of varieties can prevent soil nutrient depletion and increase resistance to pests and diseases. Modern agriculture can take inspiration from this by promoting diverse cultivation that not only protects traditional varieties, but also uses genetic engineering to breed crops that are better adapted to contemporary challenges, such as climate change and pests and diseases.

Sensor-Based Irrigation Systems: Modern sensor technology can be integrated into traditional irrigation practices. Sensors can provide real-time data on soil moisture levels, temperature, and other environmental factors. This information allows for more precise water application, ensuring that crops receive the optimal amount of water at the right time. By combining this technology with traditional methods such as the ancient Chinese canal systems or terrace irrigation, water usage can be optimized, leading to significant savings and reduced water wastage.

4.3.2 Integrating cultural heritage and modern technologies

Cultural heritage as a platform for ecological education. Cultural heritage is vital as a dynamic site for ecological learning. By organizing studies and visits at these sites, participants can learn about traditional ecological knowledge and practices, demonstrating their relevance to contemporary society. These initiatives have helped to raise public awareness of sustainable development and foster a culture of environmental management.

Innovative use of technology in heritage conservation. The application of modern technologies such as 3D scanning and virtual reality is changing the field of heritage conservation. These tools not only facilitate meticulous documentation and conservation of cultural heritage sites, but also enhance public engagement through virtual Tours and interactive experiences. They are invaluable in planning restoration projects and raising public awareness of the importance of heritage conservation.

Protection and renovation of historical sites. In China's urban landscape, the preservation and adaptive reuse of historical sites are of Paramount importance. This includes not only preserving these sites, but also creatively adapting them to contemporary use without compromising their historical authenticity. Transforming historic buildings into community centres, museums or environmentally sustainable commercial Spaces ensures that they continue to play an active role in the urban fabric.

Collaboration with academia and cultural institutions. Collaboration with universities, cultural institutions and research institutions is essential to integrate diverse expertise in the fields of heritage conservation, urban sustainability and Chinese cultural studies. Such collaboration is key to fostering innovation in urban development. By tapping into the rich knowledge and resources of these academic and cultural sectors, urban planners and developers can ensure that their projects are not only sustainable and efficient. Such cooperation is essential to respect and promote cultural heritage and meet modern needs.

4.3.3 Cultural landscape conservation in urban planning

Integrating Traditional Chinese Architectural Principles with Green Building Practices. Traditional Chinese architecture offers a wealth of knowledge in terms of design, materials, and spatial organization, which can be harmoniously integrated with modern green building practices. This integration could focus on energy efficiency, use of sustainable materials, and incorporating natural elements into urban spaces, all while respecting the aesthetic and functional aspects of traditional Chinese architecture.

Landscape Urbanism. Landscape urbanism, which emphasizes the role of natural landscapes in urban planning, can be tailored to reflect Chinese cultural traditions. This might involve creating urban parks and green spaces that reflect traditional Chinese garden designs, using indigenous plants, and incorporating elements like pagodas, stone bridges, and water features that are symbolic of Chinese culture.

Emphasizing Feng Shui in Urban Design. Feng Shui, an ancient Chinese practice, focuses on harmonizing individuals with their surrounding environment. Urban planners and architects can incorporate Feng Shui principles to create a balance between the built environment and natural elements. This includes the thoughtful placement of buildings, water bodies, and green spaces to enhance the flow of "Chi" (energy) and create a harmonious, sustainable urban landscape.

Policy Framework and Incentives. Governments can play a pivotal role by establishing policies that encourage the integration of cultural heritage into urban development. This could include financial incentives for developers who incorporate traditional elements into their designs, regulations that protect historic sites, and funding for research into sustainable practices that align with Chinese cultural traditions.

5 Conclusion

This study explores in depth the central role of cultural diversity unique to China in SLUM. Using an assessment model constructed by fuzzy Analytic Hierarchy Process (FAHP), this study quantifies and reveals how intangible cultural factors affect land-use patterns and policy acceptance. The results show that cultural background and psychological awareness have a profound impact on the behavior of land-users and their responses to policies.

Firstly, this paper takes into account cultural, psychological, economic, technological and environmental factors to explore the complexity and diversity of SLUM in China. The findings suggest that factors such as cultural adaptation, cognitive biases, psychological belonging, market resource allocation, values and beliefs, and cultural influences play an important role in determining land management strategies and practices. The centrality of cultural adaptation to land management decisions reflects the importance of responding to and adapting to evolving socio-cultural needs and conditions. This requires management strategies to be flexible and able to adapt to a wide range of cultural dynamics, including urbanization, technological change and social transformation. The importance of cognitive bias highlights the need to be aware of and correct potential cognitive misunderstandings when formulating land policies and implementing land-use planning. The prominent position of psychological belonging highlights the importance of strengthening the emotional connection and responsibility of members within the community to the land. The role of market allocation of resources is to guide the transfer of resources to more efficient uses, while emphasizing the need for policy intervention to ensure the sustainability and equity of land-use. Values and beliefs are almost equally weighted with market allocations, suggesting that integrating local and community values in land management is critical. Although the cultural influence has the lower weight, its far-reaching influence cannot be ignored in the context of China's vast geographical size and cultural diversity. The pursuit of SLUM requires a multifaceted approach that harmoniously combines cultural traditions with modern ecological requirements. Compatibility of land-use with cultural traditions, community participation and development, risk perception and psychological drivers, legal frameworks, environmental protection policies, biodiversity conservation, pollution control, soil and water conservation, forestry management and greenhouse gas emission control are all key to achieving this goal.

Secondly, in the context of traditional Chinese culture, SLUM must recognize the profound impact of cultural traditions on land-use patterns. China's land management cannot be separated from its cultural context, especially the agricultural culture, the concept of

feng shui and the traditional pursuit of natural harmony. Traditional agricultural culture emphasizes harmonious coexistence with nature, and traditional knowledge can guide modern agricultural practice to ensure that crops are cultivated in harmony with natural laws. The concept of Feng Shui reflects respect for and protection of the land environment and helps to promote sustainable land-use. China's collectivist cultural background is also important in land management, emphasizing the value of collective wellbeing and harmony can promote community participation in land planning and conservation activities. Therefore, the integration of traditional Chinese culture into land management strategies not only enhances the cultural rationality and social acceptability of land-use, but also provides support for the realization of ecological and social harmony. Future land management practices need to pay more attention to the excavation and utilization of these cultural resources in order to protect and promote the uniqueness and sustainability of land-use in China.

Thirdly, in the process of analyzing China's SLUM, the role of individual and group psychological awareness cannot be ignored. Individual psychological awareness concerns perceptions, motivations, and behaviors of land-users, while group psychological awareness concerns interactions, collective memory, and shared values among community members. These two levels interact in determining the effectiveness of land management and together create a complex decision-making environment. Individual psychological awareness highlights the importance of education and information dissemination in shaping attitudes and behaviours towards sustainable land-use. Raising individual awareness of the scarcity of land resources and the value of ecological services through education and advocacy can inspire more responsible land-use behavior. In addition, understanding individual psychological awareness can also help to identify and mitigate cognitive biases that can lead to land resource misuse. At the same time, group psychological awareness is related to the social structure and cultural traditions of the community, which emphasizes how community members define and maintain sustainable land-use patterns through collective action and social norms. At this level, community participation becomes a key factor that not only facilitates the sharing of knowledge and resources, but also enhances the social legitimacy and effectiveness of policy implementation.

Finally, the interplay of these factors creates a complex and coherent system in which the sustainability of land-use is constantly negotiated and adjusted according to cultural diversity, community inputs, ecology, and technological advances. China faces unique challenges and opportunities in achieving SLUM. By integrating these diverse factors into a land management strategy that is both culturally sensitive and responsive to economic and environmental needs, China can not only protect its rich cultural heritage, but also provide a useful global example of sustainable land management.

Future research directions could also incorporate artificial intelligence (AI) technologies to better address the complexity and challenges of SLUM in China. Machine learning and data analysis methods can be used to analyze large-scale land use data to identify potential patterns and trends, which can provide more data support for policy making. AI can also be used to predict land use change and environmental impacts, helping decision makers better plan and manage land resources.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the patients/ participants or patients/participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

YW: Methodology, Software, Writing–original draft, Writing–review and editing. JZ: Formal Analysis, Resources, Validation, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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