Participatory Rural Historical Landscape Assessment Based on 3D Electronic Sand Table: A Case Study of Duimenshan Village in Guizhou Province (Postprint)

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Abstract

Analyzing the evolution patterns of rural historical landscapes can provide a decision-making and governance basis for sustainable rural development. However, challenges persist in research methodologies and supporting tools regarding how to employ approaches readily accepted by local villagers to excavate their landscape memory and indigenous knowledge, reconstruct rural historical landscapes, and conduct comprehensive assessments. This study takes Duimenshan Village in Zhenfeng County, Guizhou Province as a case study, utilizing a self-developed 3D electronic sandbox tool combined with participatory rural appraisal techniques, through which local villagers independently reconstructed historical landscapes for four periods: 1958, 1980, 1995, and 2015. The analytical tools of the 3D electronic sandbox were employed to analyze land use, ecosystem service values, and landscape pattern metrics of the reconstructed historical landscapes. The results demonstrate that changes in objective assessment data across different periods exhibit strong correlations with important historical events that caused landscape transformations in the village: although the household responsibility system was implemented in 1980, local constraints prevented structural changes in villagers' production and lifestyle, resulting in no significant landscape changes. However, after large-scale tobacco cultivation began in 1995, the proportion of paddy fields in Duimenshan Village declined rapidly, and is now basically equal to that of dry land. This directly led to a reduction in paddy fields (a type of wetland) as significant contributors to ecosystem service value, causing a notable decline in ecosystem service value across the entire area. Furthermore, due to the rapid increase and even distribution of various public management and service facilities over the past two decades, landscape diversity has shown significant growth. It can be concluded

that the 3D electronic sandbox has been successfully applied for the first time in this investigation of rural historical landscapes, effectively resolving technical communication barriers between planners and local villagers through an efficient technological approach.

Full Text

Participatory Evaluation of Rural Historic Landscape Based on the 3D e-Sandbox: A Case Study in Duimenshan Village in Guizhou Province

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Abstract: Understanding the trend in historical rural landscape evolution could support decision-making and governance for sustainable rural development. Local villagers are the necessary source of knowledge on the changes in historical rural landscape, they can play an extremely important role in the restoration of rural landscapes. However, the platform for intuitively and interactively supporting various stakeholders in participating in the restoration of historical rural landscapes is still short.

The objective of this study was to excavate the landscape memory and local knowledge, and then to restore and evaluate the rural historical landscape changes using more acceptable way for local villagers. This paper took Duimengshan Village, Zhenfeng County of Guizhou Province as the case study. The landscapes were analyzed in four historical periods (1958, 1980, 1995 and 2015) for restoration using the 3D e-Sandbox tool and participatory rural appraisal. The results showed that local villagers could easily participate in landscape restoration processes using the 3D e-Sandbox tool. Although the land was divided into households from 1980, the production and lifestyle of the villagers had no structural changes due to the local conditions, leading to insignificantly landscape

changes. However, the proportion of paddy fields in Duimenshan Village decreased rapidly since the introduction of large-scale tobacco cultivation in 1995. This also directly led to the ecological services value decreased significantly as the paddy field (a type of wetland) as an important contributor to the value of ecological services.

Moreover, because of the rapidly increase and uniform distribution of public service facilities in the past 20 years, the landscape diversity had increased significantly. It was concluded that the 3D e-Sandbox could solve technical problems in participatory rural historic landscape restoration like the poor communications between planner and local people.

Keywords: Participatory; Rural historic landscape; Landscape restoration; 3D e-Sandbox; Rural planning and landscape design

Introduction

The past and present of rural areas are the result of long-term production and living activities by local people, who remain the creators of future rural development. To identify pathways for sustainable rural development, it is essential to understand not only the current state of rural areas but also their historical evolution, as this provides better insight into rural development mechanisms. Rural landscape history offers a medium for grasping these historical transformations [1-5]. As an accumulative and identifiable overlay of distinctive landscape elements, rural landscapes objectively record the background, causes, processes, and internal mechanisms of rural development in both temporal and spatial dimensions. This helps us understand how past landscapes formed through economic activities, what changes have occurred, and why these changes happened [6-7], thereby providing a scientific basis for predicting future rural development directions and formulating appropriate governance strategies.

Current ecological history research is based on multidisciplinary communication, seeking dialogue between natural and humanistic cultures to explore the ecological relationships between humans and various ecological elements in their living spaces and their historical trajectories [8]. Rural landscape ecological knowledge is primarily obtained through natural science approaches, such as using the historical range of variability method to study changes in rural historical landscapes across temporal and spatial scales. Alternatively, rural historical landscapes can be acquired through non-scientific pathways [9], such as local ecological knowledge and experience gained from farmers' daily work.

As direct creators, users, and maintainers of local landscapes, villagers who have long engaged in production and living activities in specific areas have not only personally experienced past and present landscapes but have also accumulated rich knowledge of rural landscapes through generations of building and managing these environments [2,10-11]. Villagers possess the most intimate understanding of landscape transformation processes, are most aware of problems in local agricultural landscapes, and are best qualified to explain the underlying natural and human driving factors [12], making them local "landscape ecologists." Their unique wisdom in handling local human-land relationships plays an irreplaceable role in maintaining and improving local landscapes and villagers' livelihoods [7,13-15]. Therefore, when scientists and planners study the formation, transformation, and driving factors of specific rural landscapes, they need to employ methods easily understood by non-professionals to excavate local landscape knowledge retained in community members' collective memory and develop new research approaches based on this knowledge, which is significant for broadening and enriching landscape change research methods and content.

Similar to using remote sensing imagery to evaluate current landscapes [16-18], reconstructing historical landscapes through remote sensing images from different periods is one of the most important methods for historical landscape research [3,19-20]. However, the extensive application of remote sensing imagery has only occurred in recent decades, with limited coverage in rural areas, making it insufficient for obtaining comprehensive historical landscape data. Consequently, rural historical landscape restoration cannot proceed without the participation of local residents.

White [21], Wang et al. [10], and Wang Xiaojun et al. [22] creatively employed Participatory Geographic Information Systems (PGIS) methods combined with high-resolution orthophotos and Participatory Rural Appraisal (PRA) tools to excavate villagers' memory-based local landscape knowledge as a data source for village historical landscape research. With the development of information technology, PGIS can now be applied to participatory landscape generation processes through various platforms including desktop applications [23], mobile applications [24], and web applications [25].

Landscape visualization forms the foundation for human cognition, description, and communication about landscapes. Therefore, visualization methods play a crucial role in historical landscape restoration research. With technological advances, landscape visualization has evolved from original sketches and paper maps to electronic maps (such as CAD drawings), GIS maps, and three-dimensional models. Currently, PGIS typically uses two-dimensional maps as the primary expression method [10,21]. However, due to their high level of abstraction, 2D maps struggle to convey planners' intentions to different stakeholders, especially in rural historical landscape restoration where participants are mostly local villagers lacking professional mapping and map-reading knowledge, which somewhat limits public participation [26-27]. The 2D map representation has constrained the application of traditional PGIS in rural landscape research. If PGIS-based methods could provide real-time and intuitive visual feedback to villagers, communication between evaluators and villagers would be smoother, and knowledge exchange would be more efficient [5,28-30]. Indeed, visualization has become one of the core issues in PGIS development [31].

Many scholars have conducted extensive exploration and research on developing and applying 3D landscape modeling technologies [3,28,32-39]. However, traditional 3D landscape generation using software such as 3D Max and CAD is time-consuming and labor-intensive, typically used only for static display of final landscape planning schemes and difficult to apply interactively in public participation processes. 3D PGIS based on 3D visualization technology will have broad application prospects in rural historical landscape restoration and participatory landscape planning.

Methods

This study used Duimenshan Village in Guizhou as a case study, combining a more accessible and understandable 3D electronic sandbox tool with participatory rural appraisal techniques to restore villagers' memory-based rural historical landscapes from both spatial and temporal dimensions. Simultaneously, the analysis tools of the 3D electronic sandbox were used to analyze land use, ecological service values, and landscape pattern indicators in the restored historical landscapes. By comparing objective analysis data with participants' recollections of major village events and agricultural calendars from different periods, we validated the effectiveness and authenticity of the 3D electronic sandbox tool combined with participatory rural appraisal techniques for restoring rural historical landscapes, providing a methodological basis for rural historical landscape research.

This study was based on PGIS methods and current high-resolution remote sensing orthophotos, employing PRA tools including semi-structured interviews, agricultural calendars, event chronologies, and group discussions to conduct landscape surveys and evaluations in the village. Due to the high level of local participation required for rural historical landscape restoration, the restoration and evaluation tool used in this study was the "Xiangyi Rural Settlement-Participatory Village Spatial Design Electronic Sandbox" independently developed by Beijing Renju Technology Development Co., Ltd., hereinafter referred to as the "Xiangyi 3D Electronic Sandbox."

Learnability and interoperability are considered the two most important characteristics of 3D landscape visualization [40]. The Xiangyi 3D Electronic Sandbox, built on 3D GIS, provides participants in rural historical landscape restoration with an easy-to-use and understandable 3D landscape restoration communication platform. Participants, including researchers and local villagers, can use rich interactive landscape generation tools on this platform to conveniently and quickly create 3D models of local historical landscape elements such as roads, environmental features, boundary lines, and buildings in a virtual 3D environment. Simple mouse-click drawing and drag-and-drop operations even allow local villagers to operate the system themselves. The 3D visualization method enables participants, especially local villagers without any professional background, to intuitively describe historical landscapes from memory. Meanwhile, the electronic sandbox' s GIS-based spatial data management and analysis capabilities provide rich analytical tools for real-time evaluation after rural landscape restoration, such as 2D land use distribution map output tools, land use balance sheet analysis tools, ecological service value analysis tools, and space syntax analysis tools.

The specific methodology was as follows: First, based on printed current high-resolution remote sensing orthophotos, we conducted group discussions with participating villagers to review major events in the village during the recallable period and agricultural calendars from different periods. From this, we identified key time nodes for historical landscape restoration. Second, researchers and villagers jointly created landscapes for each historical node in the Xiangyi 3D Electronic Sandbox. Finally, based on functions such as land use change analysis, ecological service value evaluation, and landscape pattern analysis in the Xiangyi 3D Electronic Sandbox, we conducted scientific analysis of the restored historical landscape data.

2.1 Study Area

The study area is located in Duimenshan Village, Longchang Town, Zhenfeng County, Qianxinan Buyi and Miao Autonomous Prefecture, Guizhou Province, between 25°27 05 –25°27 25 N, 105°27 53 –105°28 19 E, comprising three groups: Shangzhai, Xiazhai, and Pangjiawan. The terrain is generally lower in the north and higher in the south, representing typical low hilly landforms. The elevation ranges from 1,294 to 1,370 m. The area has a subtropical monsoon humid climate with mild temperatures, an annual average temperature of 16.6°C, annual rainfall of 1,000–1,400 mm, and a frost-free period of 260–340 days. Village residents include Buyi, Miao, and Han ethnic groups. The current primary economic activity is flue-cured tobacco cultivation and processing, supplemented by rice, corn, and coix seed cultivation. The study area is only 20 km from Zhenfeng County seat and about 100 km from Xingyi City.

2.2 Data Collection

This study invited nine local villagers to participate in the historical landscape restoration of Duimenshan Village, including two former and current village heads and cadres, and seven elders over 60 years old familiar with village history. Participants and researchers reviewed and recorded major village events and agricultural calendars from different periods. Based on this, we categorized and organized major events affecting local historical landscape changes as time nodes for historical landscape restoration, ultimately selecting 1958, 1980, 1995, and 2015 as the key years for local historical landscape restoration and evaluation (Table 1).

Based on 2015 high-resolution remote sensing imagery, we used landscape element creation tools in the Xiangyi 3D Electronic Sandbox to create the current landscape of Duimenshan Village (represented by 2015). First, we used the village boundary tool to establish the study area scope. Then, we used road and auxiliary line tools to create road networks and environmental elements (water areas, rivers, etc.), with the system automatically creating parcel objects in real-time using roads and auxiliary lines as boundaries. Finally, we used building generation tools to drag buildings from the building database into parcels. Using the 2015 landscape as a foundation, researchers, with villagers' participation and guidance, restored landscapes from other periods through addition, deletion, movement, and modification operations in the Xiangyi electronic sandbox based on on-site recall and discussion. Historical landscape restoration based on the Xiangyi 3D Electronic Sandbox had two key points: First, the approach of researchers operating the system with villagers providing on-site guidance greatly improved efficiency. Second, due to the historical continuity of landscape changes, restoring earlier historical landscapes by modifying later landscapes was more time-efficient than completely rebuilding them. Working from recent to distant periods, we successively completed landscape restoration for Duimenshan Village in 1995, 1980, and 1958 (Figure 1 [Figure 1: see original paper]).

2.3 Data Analysis Methods

Historical landscapes restored on the 3D electronic sandbox automatically generate rasterized files with land use attributes suitable for landscape pattern analysis. We then used the analysis tools of the 3D electronic sandbox to analyze historical landscapes of Duimenshan Village using land use, ecological service value, and landscape pattern indices. Land use classification and statistical calculations for different periods were conducted according to the "Current Land Use Classification Standard (GB/T 21010–2007)." Based on the "Unit Area Ecosystem Service Value Equivalent (Revised) Table" revised by Zhang Xiaotong [41] from Xie Gaodi et al. [42] and Pan Ying et al. [43]' s "Unit Area Ecosystem Service Value Equivalent Table for China' s Terrestrial Ecosystems," we calculated ecological service values for climate regulation, water conservation, soil formation and protection, waste treatment, biodiversity conservation, food production, raw materials, and cultural entertainment. For landscape pattern analysis, we selected seven landscape spatial pattern indices including Shannon's diversity index, Shannon' s evenness index, patch richness, patch density, contagion, connectance index, and landscape shape index [44-45] to analyze changes in landscape diversity, fragmentation, evenness, aggregation, and shape complexity at the patch scale.

Results

3.1 Landscape Scenario Changes in Duimenshan Village

3.1.1 Duimenshan Village Landscape in 2015 The 2015 landscape of Duimenshan Village is shown in Figure 1a-1 and Figure 1a-2. Village access roads enter from the north, west, and south, with group roads branching off to connect residential clusters in the southeast following the mountain terrain. Household connecting roads link individual residences, forming a relatively dense network. The overall road network pattern is free-form, with three levels of roads interconnecting to create a dense, free-form network linking every household.

Residential buildings are primarily one- or two-story detached houses, with some three- or four-story buildings in certain areas. The upper and lower group residences are built against the mountain, facing south, extending from the southeastern foothill westward to between two mountains and northward to the northern foothill. Pangjiawan residences extend along a northwest village access road into the village to the western foothill.

The village contains one primary school in the northwest, one kindergarten in the central area, one village committee in the central area, one clinic next to the village committee, two small shops in the northwest, and one villager activity square south of a river gully in the northwest. Two east-west rivers run through the northern part of the village, with one north-south river in the west, all with small water surface areas. Additionally, three ponds are distributed in the northern part of the village. Agricultural land is distributed in the northern area, some central areas, and southern foothill area, with nearly half being dry land and half paddy fields. Paddy fields are mainly distributed in the eastern area and some western areas, while dry land is primarily in the northwest, central, and southern foothill areas. Forest land is mainly distributed on the slopes of the two southern mountains and in the area between them.

3.1.2 Duimenshan Village Landscape in 1995 The 1995 landscape of Duimenshan Village is shown in Figure 1b-1 and Figure 1b-2. Village access roads entered from the north, west, and south, with group roads branching off to connect the upper and lower groups in the southeast. Household connecting roads linked residences, with slightly fewer roads than in 2015. The road network pattern was similar to 2015, overall free-form, with three levels of roads interconnecting to form a dense, free-form network linking every household.

Residential buildings were primarily one- or two-story detached houses. The upper and lower group residences were built against the mountain, facing south, mainly distributed at the southeastern foothill and in the central-southern area between the two mountains. Pangjiawan residences extended along a northwest village access road into the village to the western foothill.

The village had one small shop in the northwest. Two east-west rivers ran through the northern part, with one north-south river in the west, all with small water surface areas. Agricultural land was distributed in the northern, central, and southern foothill areas, with more area than in 2015. Nearly 90% of agricultural land was paddy fields, mainly distributed in the central and northern areas, while dry land was only in a small area at the southern foothill. Forest land was mainly distributed on the slopes of the two southern mountains and in the area between them, slightly larger in area than in 2015. Several agricultural plots in the southwestern corner of the village in 2015 were forest land in 1995.

3.1.3 Duimenshan Village Landscape in 1980 The 1980 landscape of Duimenshan Village is shown in Figure 1c-1 and Figure 1c-2. The village had two road levels: village access roads and household connecting roads. Village access roads entered from the north, west, and south, while household connecting roads were mainly concentrated at the southern foothill to connect residences. With fewer residential buildings than in 1995, the number of roads was slightly less. The road network pattern was simpler than in 1995, overall free-form, with two levels of roads interconnecting to form a free-form network linking each household.

Residential buildings were primarily one-story houses, including some small thatched cottages, facing south. They were mainly distributed at the southeastern foothill and in the central-southern area between the two mountains, but with fewer buildings. Pangjiawan residences extended along a northwest village access road into the village to the western foothill.

The village had one small shop in the northwest. Two east-west rivers ran through the northern part, with one north-south river in the west, all with small water surface areas. Agricultural land was distributed in the northern, central, and southern foothill areas, slightly larger in area than in 1995. Nearly 95% of agricultural land was paddy fields, mainly distributed in the central and northern areas, while dry land was only in a small area at the southern foothill. Except for increased paddy field area, the distribution of paddy and dry land was similar to 1995. Forest land was mainly distributed on the slopes of the two southern mountains and in the area between them, with little change in area compared to 1995.

3.1.4 Duimenshan Village Landscape in 1958 The 1958 landscape of Duimenshan Village is shown in Figure 1d-1 and Figure 1d-2. The village still had two road levels, but with narrower surfaces. Village access roads entered from the north, west, and south, while household connecting roads were mainly concentrated at the southern foothill to connect residences. The road network pattern was simpler, overall circular, with two levels of roads interconnecting to form a simple circular network linking each household.

Residential buildings were primarily one-story houses and some small thatched cottages, facing south, with fewer buildings overall. They were mainly distributed at the southeastern foothill, with some small thatched cottages along the road in the northern part between the two mountains. Pangjiawan had only a few scattered buildings at the western foothill.

Two east-west rivers ran through the northern part, with one north-south river in the west, all with small water surface areas. Except for scattered residences at the southern foothill and between mountains, rivers, and forest land on mountain slopes, the entire village area was agricultural land, larger in area than in 1980. Nearly 95% was paddy fields, with dry land only in a small local area at the southern foothill. Forest land was mainly distributed on the slopes of the two southern mountains and in the area between them. Many residences at the foothills in 1980 were forest land in 1958, and forest land in the southern area between the two mountains was cut down during the Great Leap Forward.

3.2 Land Use Change Analysis

From 1958 to 2015, forest land in Duimenshan Village showed an overall decreasing trend, while residential land and transportation land showed overall increasing trends. Public management and service land increased significantly between 1995 and 2015. Due to the introduction of tobacco cultivation, the proportion of paddy fields in cultivated land decreased from 97.76% to 43.79% between 1995 and 2015, while the proportion of dry land increased from 0.211% to 55.59%. Other land use types showed little change (Table 2).

3.3 Ecological Service Value Analysis

The ecological service value of Duimenshan Village showed an overall decreasing trend, particularly decreasing by 50.54% between 1995 and 2015, while decreasing by 9.71% between 1958 and 1995. Taking 1995–2015 as an example, the ecological service values of climate regulation, entertainment culture, waste treatment, and water conservation decreased most significantly, by 57.83%, 56.01%, 52.56%, and 52.39% respectively. The raw material function was basically unaffected, while food production function increased by 76.42 due to increased agricultural land (Table 3).

3.4 Landscape Pattern Analysis

Patch richness in Duimenshan Village increased year by year, indicating a diversification trend in land use types, particularly surging between 1995 and 2015, which shows that these 20 years were a period of rapid spatial landscape change. Shannon’ s diversity index, Shannon’ s evenness index, patch density, and landscape shape index also surged during this period, reflecting a trend of balanced and discrete increase in various land use types. Additionally, various types of construction land can be considered as dominant patch types developing in an aggregated manner, with gradually increasing connectivity in the landscape. Connectivity decreased significantly between 1958 and 1980, mainly because forest land that originally existed as corridors was cut and fragmented, weakening its spatial structural connectivity. The significant increase in landscape shape index during 1958–1980 and 1995–2015 indicated increased patch edge complexity. From the perspective of land use change, this mostly resulted from increased edge complexity after agricultural and forest land was encroached upon by other land uses (Table 4).

3.5 Correlation Analysis Between Land Use, Ecological Service Value, and Landscape Pattern

Landscape changes in Duimenshan Village mainly occurred in two stages: 1958–1980 and 1995–2015, with relatively stable changes between 1980 and 1995. Between 1958 and 1980, forest land as landscape corridors was cut and fragmented due to the Great Leap Forward movement, seriously reducing landscape spatial connectivity. Although the total amount was not large, the scattered expansion of residential land as a rare patch type significantly increased overall landscape fragmentation. However, because the overall land use type proportions changed little, ecological service value did not change significantly.

As shown in Figure 2 [Figure 2: see original paper], although land was divided into households in 1980, villagers' production and lifestyle did not undergo structural changes due to local constraints, resulting in no significant landscape changes. However, after large-scale tobacco cultivation began in 1995, the proportion of paddy fields in Duimenshan Village decreased rapidly, and currently is basically equal to the proportion of dry land. This directly led to a significant decrease in overall ecological service value as paddy fields (a type of wetland) are important contributors to ecological service value. Additionally, due to the rapid increase and uniform distribution of various public management and service facilities over the past 20 years, landscape diversity has increased significantly.

Discussion and Conclusion

Rural historic landscapes are important bases for studying rural historical development and conducting rural landscape development planning. Remote sensing imagery extraction is often limited by data availability and cannot meet the needs of historical landscape restoration. Villagers' memories of historical landscapes thus become an important data source for rural historical landscape restoration. However, constrained by the cost and efficiency of traditional research methods and representation means, conventional methods based on 2D maps and survey forms cannot enable rural villagers to intuitively participate in historical landscape restoration. In participatory rural planning and projects based on conventional PGIS platforms, villagers' opinions require planners to make multiple trips before being accurately expressed on maps, consuming excessive time. Meanwhile, due to technical and equipment limitations, the visualization of results is not high, preventing PGIS planning platforms from being widely applied in actual rural historical landscape restoration and rural planning. Therefore, rural historical landscape restoration requires an easy-to-use platform system that integrates 3D landscape design and landscape pattern analysis for villager participation.

This study explored a method using 3D electronic sandbox to solve the above problems of villager participation and real-time landscape evaluation in rural historical landscape restoration. The "Xiangyi Rural Settlement-Participatory Village Spatial Design Electronic Sandbox" (hereinafter referred to as Xiangyi Electronic Sandbox) used in this paper is a 3D PGIS platform integrating multiple geospatial technology achievements with a user-friendly interface and strong operability. Practical results show that the historical landscape restoration method based on Xiangyi Electronic Sandbox enables face-to-face communication between planners and villagers, making the planning communication process smoother and greatly improving participation quality in planning decisions. This software is easier for planners to master, making research on restoring rural historical landscapes from villagers' memories a task that does not require strong professional expertise.

This study took Duimenshan Village in Guizhou as a case study, successfully restoring rural historical landscapes from villagers' memory across spatial and temporal dimensions by combining the more accessible 3D electronic sandbox tool with participatory rural appraisal techniques. This truly reproduced villagers' memories of rural historical landscapes and visualized them in real-time as 3D restoration landscape maps on the electronic sandbox. We also listened to their views on the causes of landscape changes, achieving real-time communication between researchers and villagers and maximizing the effectiveness and authenticity of communication actions. In rural planning and management actions, the PGIS-based rural (historical) landscape survey and planning method, highly integrated with the 3D electronic sandbox tool, maximally ensures consistency between discussion processes and results, truly achieving villager participation in rural planning and management processes.

Using the landscape analysis methods provided by the system, we analyzed Duimenshan Village' s historical landscapes in terms of land use structure, landscape pattern indices, and ecological service values. The results show that landscape pattern changes in Duimenshan Village were significant, with landscapes becoming more dispersed and diversified, and ecological service values declining. The changes in Duimenshan Village' s historical landscape pattern coincided with historical major event nodes, indicating that the main causes of landscape pattern changes are closely related to major historical events.

This research case demonstrates that the participatory historical landscape restoration method solves the limitations of historical remote sensing data and can restore more distant rural historical landscapes. Second, the participatory historical landscape restoration method, through discussions and meetings with participants, excavates deeper historical stories, traditional cultures, customs, and historical events behind landscape changes, providing more detailed information for future village planning and management. Compared with traditional 2D GIS-based PGIS, 3D electronic sandbox landscapes are easier for villagers to understand and participate in. The Duimenshan Village case study shows that in actual use, villagers can more easily describe historical landscapes in a 3D environment, quickly identify historical environmental changes, and discover researchers' errors. The 3D electronic sandbox was successfully applied for the first time in this rural historical landscape survey. Through effective technical means, it truly solved the technical communication problems between planners and local villagers that previously hindered information exchange and communication. It is expected to effectively improve the quality and efficiency of rural landscape planning and design. As a multi-professional integrated yet low-threshold rural design communication platform, it well resolves the contradiction between the single functionality of traditional tools and the complexity of GIS tools in the field of planning and design tools, providing a one-stop design platform that can improve planning efficiency for professional designers while pioneering a pathway for non-professionals to directly participate in design and decision-making processes. This enables professional designers and villagers to truly reach consensus on planning outcomes, achieving "seamless" integration of local and scientific knowledge. Its additional process evaluation function also provides real-time decision support for all stakeholders involved in design, representing an innovation in rural landscape planning and design methods.

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