

Postprint: Identification of Visual Landscape Key Areas for Hani Rice Terraces Based on Sensitivity-Subjective Preference Matrix

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Abstract

Taking the main visual landscapes of the Hani Rice Terraces Heritage Core Area as the research object, this study applied GIS technology to select three objective factors—relative slope, relative distance, and probability of occurrence—for landscape visual sensitivity analysis, and utilized the Scenic Beauty Estimation method to obtain subjective preferences from 50 professionals. By integrating landscape visual sensitivity and subjective preference scores, a sensitivity-subjective preference matrix was constructed, which divided the visual landscapes of the Hani Rice Terraces Heritage Core Area into four zones with corresponding landscape protection and planning recommendations proposed. The results indicate: Laohuzui and Malizhai Tea Factory are located in the “Visual Landscape Critical Zone” with both high sensitivity and high preference ratings; Duoyishu belongs to the “Natural Development Zone” with high preference rating but low sensitivity; Huangcaoling is the “Priority Improvement Zone” with high sensitivity but low preference rating; Bada, Qingkou, and Quanfuzhuang are the “Secondary Priority Improvement Zones” with both low sensitivity and low preference ratings. By constructing this matrix that combines both objective and subjective evaluation results, GIS effectively quantifies abstract data while preference ratings authentically reflect viewers’ inner perceptions, thereby providing insights for contemporary landscape visual evaluation.

Full Text

Preamble

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Key Area Recognition of Hani Rice Terrace Visual Landscape Based on the Sensitivity-Subjective Preference Matrix

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Abstract

This study examines the primary visual landscapes within the core heritage area of the Hani Rice Terraces. Using Geographic Information System (GIS) technology, we analyzed landscape visual sensitivity through three objective factors: relative slope, relative distance, and sight probability. The scenic beauty estimation (SBE) method was employed to obtain subjective preference values from 50 professionals. By integrating landscape visual sensitivity and subjective preference scores, we constructed a sensitivity-subjective preference matrix that divides the Hani Rice Terrace heritage core area into four distinct zones, with corresponding landscape protection and planning recommendations proposed for each. Results indicate that both sensitivity and preference values were high at the Laohuzui and Malizhai tea factory viewpoints. At Duoyishu, preference was high but sensitivity low. Huangcaoling exhibited high sensitivity but low preference values. Both preference and sensitivity showed lower values for Bada, Qingkou, and Quanfuzhuang. This matrix approach effectively quantifies abstract GIS data while capturing genuine observer perceptions, providing a framework for contemporary landscape visual evaluation.

Keywords: Hani Rice Terrace; landscape visual sensitivity; subjective preference

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Introduction

Visual landscape evaluation constitutes an essential component of landscape assessment systems. Visual landscape refers to geographic entities within a specific area that create strong visual perception and impression for observers. As humans primarily perceive landscapes and resources through vision, and since urbanization processes generate numerous environmental problems that manifest first as visual impacts, visual landscape protection becomes critically important for sustainable landscape development. Determining appropriate protection levels requires scientific and rational evaluation indicators and methods.

Landscape visual sensitivity represents the degree to which a landscape captures observers' attention and reflects its overall conspicuousness. Together with scenic beauty—an aesthetic value manifestation—visual sensitivity serves as a crucial basis for determining landscape protection grades. Research on visual landscapes first emerged in developed countries during the 1960s-1970s, with extensive theoretical and practical work conducted in the UK and US. Current evaluation objects primarily include roadside vegetation, coastal zone heritage, and railway corridor landscapes. Major evaluation schools include the expert school, psychophysical school, cognitive school, and experiential school, broadly categorized into objective approaches (beauty as inherent physical property) and subjective approaches (beauty in the eye of the beholder).

Expert evaluation emphasizes analysis of objective data such as topography and hydrology through mathematical quantification, but often neglects variations caused by observer preferences. Public evaluation stresses subjective perception and reflects innate human landscape preference commonalities, though these subjective results sometimes contradict ecological aesthetics. Recent studies have attempted to combine both approaches, using GIS technology—which offers powerful spatial simulation and comprehensive data analysis capabilities—to integrate objective landscape characteristics with public perception assessments. The Scenic Beauty Estimation (SBE) method, based on psychophysical principles, has been widely applied in forest landscape evaluation.

The Hani Rice Terrace World Cultural Landscape Heritage possesses exceptional aesthetic value, with unprecedented scale and distribution rarely seen among terrace landscapes worldwide. However, climate change and urbanization have caused farmland abandonment and degradation, severely impacting visual landscape quality. This study employs GIS to analyze visual sensitivity and SBE to obtain professional aesthetic preferences, constructing a sensitivity-subjective preference matrix to evaluate protection levels and identify critical visual landscape areas, thereby providing targeted scientific guidance for conservation planning.

1. Study Area and Data Sources

The Honghe Hani Rice Terrace World Cultural Landscape Heritage is located in Yuanyang County, Honghe Prefecture, Yunnan Province, south of the Tropic of Cancer, with geographic coordinates of 22°49' -23°19' N, 102°27' -103°13' E. The region features a subtropical monsoon climate with distinct wet and dry seasons and significant vertical climate variation. The heritage area covers 166.12 km², with elevations ranging from 400-1900 m. Characterized by diverse landforms, abundant hydrological resources, and exceptional aesthetic value, the area features terrace slopes reaching a maximum gradient with up to 3,700 levels. The integrated landscape of vast terraces and mushroom-shaped houses has made it a renowned tourist destination and photography hotspot.

The entire heritage area is distributed across central-western Yuanyang County,

with the core area covering [specific area]. Terraces are primarily distributed between elevations of 800–1800 m. Major viewing platforms in the heritage core area include Bada, Laohuzui, Duoyishu, Malizhai tea factory, Mengpin, and several villages. Data sources include QuickBird imagery, Yuanyang County Digital Elevation Model (DEM), distribution maps of heritage core area viewing platforms obtained through automatic recognition, visual interpretation, and field verification, as well as major road distribution maps. The circular tourist route provides access to seven artificial viewing platforms for visitors to appreciate the terrace scenery.

1.1 Photo Capture and Selection

All photographs were taken by a single investigator with basic photography skills using a Nikon D600 digital camera at a constant height of 1.5 m, with shooting angles approximately parallel to the line of sight. Photos were captured during optimal lighting conditions between 9:00–11:00 and 15:00–17:00. Locations included all seven artificial viewing platforms in the Honghe Hani Terrace heritage core area, with the Laohuzui platform alone comprising 12 viewing points due to its large area and varying visual fields.

Photography proceeded from the leftmost to rightmost extent of the visual field at consistent height, yielding 120 total photographs. Graduate students in landscape ecology conducted preliminary scoring, selecting the highest-quality, most representative photo(s) for each viewing point (at least one per point). For platforms with multiple viewing points, the average score was used. The final selection process identified the best representative photographs for each viewing platform.

1.2 Evaluator Selection

Cultural individual differences are primary causes of aesthetic preference variation, while experts and professional students demonstrate the best discriminatory ability and internal consistency. This study therefore selected 50 professionals as evaluators, including landscape-oriented graduate students, professors, doctoral candidates, master's students in landscape architecture, and professionals engaged in long-term landscape planning and design work.

1.3 Evaluation Method and Data Standardization

The psychophysical SBE method was employed for subjective preference evaluation. Selected photographs were cropped and stitched into slideshows, with each slide reflecting the full visible range of its corresponding viewing point. Evaluators scored each slide according to scenic beauty. To eliminate or reduce differences caused by varying aesthetic attitudes, all evaluation results were standardized using the following formula:

$$Z_{ij} = \frac{R_{ij} - \bar{R}_j}{S_j}$$

where Z_{ij} is the standardized value of evaluator j 's score for viewing platform i , R_{ij} is the raw score, \bar{R}_j is evaluator j 's mean score across all platforms, and S_j is the standard deviation of evaluator j 's scores. The standardized evaluation value for each viewing platform i is:

$$Z_i = \frac{\sum_{j=1}^{N_j} Z_{ij}}{N_j}$$

Data were processed using SPSS and EXCEL. The mean standardized score for each slideshow became the subjective preference score for its corresponding viewing point, with multi-point platforms averaged accordingly.

2. Landscape Visual Sensitivity Evaluation

The sensitivity concept has been applied across multiple disciplines, with landscape visual sensitivity representing the degree to which a landscape captures observers' attention—a comprehensive reflection of landscape conspicuousness. Visual sensitivity analysis involves measuring factors affecting this sensitivity, including relative slope, relative distance, sight probability, and conspicuousness. For observers, greater relative slope between landscape surface and sight line increases visibility and clarity. Most viewing occurs along tourist routes or at designated platforms, where closer relative distances increase observation probability and duration, thereby heightening visual sensitivity. Conspicuousness depends primarily on contrast with surroundings, including line, texture, and dynamic contrasts.

Given the relatively uniform landscape type in the study area—characterized by upper forests, middle villages, and lower terraces with consistent 沟渠 (ditch) patterns—only relative slope, relative distance, and sight probability were selected as evaluation factors. Based on literature review, expert consultation, and local conditions, a set of landscape visual sensitivity evaluation criteria was established.

2.1 Relative Slope Sensitivity

Using ArcGIS terrain analysis functions, slope distribution was derived from the Yuanyang County DEM, with slopes ranging from 0° to 71.3° . Sensitivity zones were classified as: low (0° - 14.5°), medium (14.5° - 30°), and high (30° - 90°). Each viewing platform's viewshed was overlaid with slope gradients to calculate overlapping areas with different sensitivity zones. Area proportions were scored according to evaluation criteria. The ranking of relative slope sensitivity

from high to low was: Malizhai tea factory, Laohuzui, Quanfuzhuang, Bada, Duoyishu, Mengpin, and Qingkou.

2.2 Relative Distance Sensitivity

Based on normal human visual capacity and field conditions, 400 m was selected as the maximum distance for clear appreciation of Hani terrace landscapes. Distance sensitivity zones were defined as: conspicuous zone ($d \leq 400$ m), visible zone ($400 \text{ m} < d \leq 800$ m), and indistinct zone ($800 \text{ m} < d \leq 1600$ m). Since all viewing platforms are located along main roads, these roads served as the baseline for analysis. Viewsheds were overlaid with distance gradient maps to calculate overlapping areas, with proportions scored accordingly. The ranking from high to low sensitivity was: Malizhai tea factory, Laohuzui, Quanfuzhuang, Bada, Duoyishu, Mengpin, and Qingkou.

2.3 Sight Probability Sensitivity

Sight probability sensitivity typically analyzes the percentage of viewing route length from which a landscape is visible. This study divided main roads in the heritage core area into 10 m segments, conducting viewshed analysis for each point. Results displayed both visible and invisible areas, with grid cell values reflecting observation frequency. The most visible areas could be seen from over 40 cutting points. Viewsheds were overlaid with sight probability distribution maps, with overlapping areas calculated and scored. The ranking from high to low sensitivity was: Malizhai tea factory, Laohuzui, Quanfuzhuang, Bada, Duoyishu, Mengpin, and Qingkou.

3. Subjective Preference Evaluation of Hani Terrace Scenic Beauty

Subjective preference scores from 50 professionals are presented in Table 6. All viewing platforms scored above zero, indicating high scenic beauty. Laohuzui achieved the highest standardized score of 0.733, reflecting its status as one of the three core terrace areas with exceptional aesthetic value. Duoyishu scored 0.404, renowned for sunrise and sea-of-clouds photography. Lower scores were recorded for Qingkou (-0.670) and Huangcaoling (-0.938). Qingkou functions primarily as a cultural heritage site showcasing Hani traditions, while Huangcaoling's lower score reflects its proximity to Duoyishu with similar but less favorably positioned views, plus recent construction impacts and farmland abandonment.

The ranking of subjective preference scores from high to low was: Laohuzui, Duoyishu, Mengpin, Bada, Quanfuzhuang, Malizhai tea factory, and Qingkou.

4. Identification of Hani Terrace Visual Landscape Key Areas

4.1 Sensitivity-Subjective Preference Matrix Construction

Adapting Importance-Performance Analysis (IPA) methodology, we constructed a sensitivity-subjective preference matrix with landscape visual sensitivity as the x-axis and standardized subjective preference as the y-axis, using (0,0) as the origin. This approach, widely used in tourism image diagnosis, offers advantages including intuitive visualization and decision-making convenience. In this context, high visual sensitivity represents landscape importance—areas easily noticed by observers where minor disturbances create significant visual impact, warranting priority protection. High subjective preference scores represent performance value, indicating strong visitor recognition and tourism appeal.

The matrix divides the landscape into four quadrants: (1) high sensitivity/high preference—visual landscape key areas; (2) low sensitivity/high preference—secondary priority improvement areas; (3) low sensitivity/low preference—natural development areas; and (4) high sensitivity/low preference—priority improvement areas.

4.2 Comprehensive Evaluation Results

Based on integrated evaluation results, the core area was classified as follows: Laohuzui and Malizhai tea factory fall in Quadrant I (visual landscape key areas); Duoyishu in Quadrant II (secondary priority improvement area); Bada, Qingkou, and Quanfuzhuang in Quadrant III (natural development area); and Huangcaoling in Quadrant IV (priority improvement area). Overlapping viewsheds between zones were reconciled, with key area designations taking precedence.

4.3 Protection and Management Strategies for Different Visual Landscape Types

Visual Landscape Key Areas (Laohuzui and Malizhai tea factory): These require strengthened protection measures to maintain original landscape character. Upper forest areas should preserve native vegetation with strict logging prohibitions. Ditch systems require dedicated maintenance to ensure water supply, and terrace ridges need regular inspection and prompt repair of collapses.

Priority Improvement Area (Huangcaoling): As a strategic development zone requiring resource concentration and scientific planning, Huangcaoling should leverage its panoramic overview advantage. Management should install interpretive facilities to help visitors perceive the entire terrace complex' s spatial structure and unique forest-village-terrace-river pattern. Farmland subsidies should encourage continued cultivation to address abandonment issues.

Secondary Priority Improvement Area (Duoyishu): Despite high scenic beauty, low visual sensitivity due to geographic location limits its discovery. Management should amplify promotion of its famous sea-of-clouds sunrise scenery, establish photography exhibitions and guides, and enhance tourism appeal to attract more visitors.

Natural Development Areas (Bada, Qingkou, Quanfuzhuang): With lower scenic beauty and visual sensitivity, these areas have limited development potential. Transformation strategies could include participatory tourism experiences, allowing visitors to engage in daily farming activities, or cultural heritage showcases similar to Qingkou' s Hani ethnic village concept.

5. Conclusion and Discussion

This study analyzed landscape visual sensitivity for seven viewing platforms in the Hani Rice Terrace heritage core area using relative slope, distance, and sight probability factors through GIS spatial analysis. Sensitivity rankings from high to low were: Malizhai tea factory, Laohuzui, Quanfuzhuang, Bada, Duoyishu, Mengpin, and Qingkou. SBE method yielded subjective preference values from 50 professionals, with rankings from high to low: Laohuzui, Duoyishu, Mengpin, Bada, Quanfuzhuang, Malizhai tea factory, and Qingkou.

Integrating these scores, the sensitivity-subjective preference matrix divided the visual landscape into four zones: Laohuzui and Malizhai tea factory as key areas; Huangcaoling as priority improvement; Quanfuzhuang as secondary priority improvement; and Duoyishu as natural development area. Targeted management recommendations were developed accordingly.

This approach combines GIS spatial analysis with SBE evaluation, effectively quantifying abstract data while authentically reflecting observer perceptions. The method aligns with contemporary landscape evaluation trends and provides a scientific basis for protection grade classification. However, the subjective and objective evaluations remain relatively independent. Future research should better integrate human preferences into emerging technologies like RS, GIS, and 3D visualization for large-scale landscape assessment.

The study acknowledges limitations in temporal and spatial sampling. Unlike conventional gardens, Hani terraces exhibit greater spatial-temporal variation. Spatially, they offer both macro-scale views from platforms and micro-scale perspectives of field-level biodiversity and farming activities. Temporally, seasonal changes, crop presence, water conditions, and lighting effects all influence preference. Future work should incorporate multi-scale, multi-seasonal evaluations and consider emerging natural viewing platforms discovered through social media and photographer networks.

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