Postprint: Visualized Evaluation of Rural Landscape Scenarios Based on Ecologically Meaningful Visual Indicators

Authors: Zhang Xiaotong, Liu Wenping, Xiao He, Zhang Qian, Yu Zhenrong

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Abstract

The key to scenario development lies in identifying and synthesizing the patterns, pathways, and key elements of future changes, thereby enabling targeted scenario simulations. Currently, some studies have begun to conduct visual simulations of rural landscape scenarios by adding or removing certain key landscape elements, but few have incorporated ecologically meaningful visual landscape indicators into the simulation conditions. This study applies ecologically meaningful visual landscape indicators to the scenario design of rural landscape visual evaluation. Through expert predictions on five visual landscape indicators—complexity, naturalness, openness, coherence, and memory representation—and GIS-based objective analysis, design standards for different scenarios were established, and based on these standards, four design scenarios were generated: original current landscape, ecological protection landscape, intensive production landscape, and tourism and recreation landscape. By evaluating the rural landscapes in the four scenarios through local residents, surrounding stakeholders, and university students, this study explores the differences in landscape scenario preferences among different stakeholders and the influencing factors. The results indicate that: participants generally showed little interest in the intensive production landscape scenario; stakeholders closer to the locality demonstrated stronger preference for the tourism and recreation landscape scenario and weaker preference for the ecological protection landscape scenario; there is often a discrepancy between people' s perceptual understanding gained from scenarios and their choices after rational deliberation, and differences in subjective judgment of landscapes largely stem from their personal life backgrounds. Scenario visualization constructed based on ecologically meaningful visual landscape indicators plays an important role in reflecting rural landscape changes and enhancing stakeholder participation in decision-making and design.

Full Text

Assessment of Rural Landscape Scenario Visualization Using Visual Indicators of Ecological Significance

ZHANG Xiaotong[1,2,3], **LIU Wenping** , **XIAO He** , **ZHANG Qian** , **YU Zhenrong** *

[1]China National Engineering Research Center for Human Settlement, Beijing 100044, China; [2]School of Architecture, Tianjin University, Tianjin 300072, China; [3]School of Architecture and Urban Planning, Beijing University of Civil Engineering and Architecture, Beijing 100044, China; College of Horticulture & Forestry Sciences, Huazhong Agricultural University, Wuhan 430070, China; Chongqing Geomatics Center, Chongqing 401121, China; College of Resources and Environmental Sciences, China Agricultural University, Beijing 100193, China

*Corresponding author, E-mail: yuzhr@cau.edu.cn

Abstract

The key to developing scenarios lies in identifying and summarizing the patterns, pathways, and key elements of future change, thereby enabling targeted scenario simulation. While some studies have begun to simulate rural landscape scenarios by adding or removing certain key landscape elements, few have incorporated ecologically meaningful visual landscape indicators into the simulation conditions. This study applies ecologically meaningful visual landscape indicators to the scenario design process for rural landscape visualization evaluation. Through expert expectations and objective GIS-based analysis of five visual landscape indicators—complexity, naturalness, openness, coherence, and imageability—we established design standards for different scenarios and generated four design scenarios: original current landscape, ecological protection landscape, intensive production landscape, and tourism-recreation landscape. Local residents, nearby stakeholders, and university students evaluated these four scenarios, revealing differences in landscape scenario preferences among stakeholder groups and their influencing factors. Results show that participants were generally uninterested in the intensive production landscape scenario. Stakeholders living closer to the area showed stronger preference for the tourism-recreation landscape and weaker preference for the ecological protection landscape. People' s intuitive perceptions from scenarios often differed from their choices after rational consideration, with differences in subjective landscape judgments largely stemming from personal life backgrounds. Scenario visualization based on ecologically meaningful visual indicators plays an important role in reflecting rural landscape changes and enhancing stakeholder participation in decision-making and design.

Keywords: Scenario visualization; Rural landscape; Landscape indicator; Ecological significance; Landscape preference; Visual assessment

Introduction

Rural landscapes represent the visible outcome of interactions among agricultural production, natural resources, and the environment, encompassing pleasant environments and features, heritage and traditions, culture, aesthetics, and other social values [1]. A comprehensive approach to analyzing and evaluating rural landscapes that supports rural development should consider their aesthetic, ecological, regional, and cultural dimensions. Rural landscape evaluation must recognize, maintain, adapt to, and perpetuate regional landscape characteristics constituted by these aspects, analyze dominant natural and human factors, and assess natural ecological value, landscape character, and historical heritage.

Landscape fundamentally possesses a dual nature, comprising an "objective pole" and a "subjective pole." Objectively, landscape consists of real objects and forms existing within a unique physical domain; subjectively, landscape relates to how these concrete forms are seen, observed, appreciated, and understood. The appearance and organizational forms of spatial objects are neutral—they only become "landscape" when observers determine what they can comprehend [1]. Quasi-realistic scenario visualization technology is suitable for combining objective and subjective approaches to evaluate visualized rural landscapes due to its intuitive, accurate, and adjustable characteristics [1-2].

A "scenario" describes the current state, a possible or desired future condition, and the series of elements that can guide its change. Current scenario techniques can refer to "planners and researchers creating a series of different landscape images for the same background area, where these future-expected images can be used to discuss planning needs and results" [2]. Today, the term "scenario" is widely applied in future-oriented research, including trend analysis, forecasting, variable analysis, and sensitivity analysis [3]. Scenarios represent depictions of possible future conditions, sometimes intentionally showing traditional, prototypical, ideal states, or extreme values. Scenarization does not display, predict, or forecast the real future, but rather represents a judgment of trends [2].

At present, the key to obtaining scenarios is identifying and summarizing future change patterns, pathways, and key elements to conduct targeted simulation. In other words, since scenario technology is used to simulate landscapes, certain standards must be implemented. Currently, some studies have begun using the addition or removal of key landscape elements as standards for scenario simulation [1], but few have applied ecologically meaningful visual rural landscape indicators to rural landscape scenario visualization conditions. Ecologically meaningful visual landscape indicators provide objective possibilities for classifying landscape characteristics using quantified features of objective landscape visual preferences. The development of visual landscape indicators has lagged behind that of landscape function indicators [4]. However, recent research addressing human preference needs in landscapes has advanced the application of visual landscape indicators [1,5-6]. Tveit et al. [7] proposed a framework for ecologically meaningful visual landscape indicators, which Ode, Fry, and others [8-9] subsequently summarized and supplemented.

Based on Tveit et al.' s [7] framework, this study selected visual landscape indicators according to their ecological significance to generate different landscape scenarios. Using a GIS platform, we designed four distinct landscape scenarios and selected three types of stakeholders for evaluation. This approach explores preferences for rural landscapes among different stakeholders and their influencing factors, providing references for future rural landscape scenario visualization evaluation techniques and rural landscape development.

1.1 Study Area Overview

This study selected a 6 km^2 sample area at the junction of Dongzhuang Village and Weiziyu Village in Beizhen Town, Miyun District, Beijing, as the landscape survey and mapping scope. Photographs were taken from the highest point of the eastern mountain in Dongzhuang Village toward the west-northwest direction, with the visible range of these photographs serving as the analysis and scenario visualization area [Figure 1: see original paper]. The near boundary was defined by features that significantly obstructed the view, while the far boundary was defined by village boundaries that could no longer be identified.

1.2 Landscape Classification and Mapping

Based on the original three-level land use classification, we constructed a rural landscape classification system encompassing cultivated land, forestland, orchard, grassland, facility agriculture, construction land, and other types. Through field interpretation of remote sensing images, all features with edges longer than 2 meters were mapped, and base maps were digitized in a GIS environment to form a spatial database.

1.3.1 Indicator Determination

Under Tveit et al.' s [7] framework, this study selected five ecologically meaningful visual landscape indicators: complexity, coherence, imageability, naturalness, and openness (Table 1). These indicators were defined through two aspects: "supply" and "demand." To find landscape indicators that could describe the balance degree between supply and demand, we needed to calculate the supply and demand for each of these five criteria separately.

For each indicator' s evaluation criteria, openness, coherence, imageability, and naturalness were scored on a 0-3 scale with four levels. Objective criteria were derived from spatial data statistics using a GIS platform [7]. Openness, imageability, and naturalness were assigned different scores based on each patch' s land use category. Coherence was reassigned values based on the degree of consistency between each patch and surrounding elements. These four indicators were ultimately distributed across four levels through weighted averages of patch area scores. Complexity used the number of patches per unit area as its metric. Due to its discrete nature, seven levels were established, with 0.5 used as the increment unit to maintain consistency with the highest scores of other indicators (Table 2).

1.3.2 Scenario Design

Based on three characteristics of the study area—its location in the Miyun ecological conservation zone, the recent opening of the Beijing-Chengde Expressway passing through the area with promising highway economy prospects, and the emerging small-scale leisure tourism industry based on ecological agriculture—plus the current original landscape, four scenarios were developed for evaluation: original current landscape, ecological protection landscape, intensive production landscape, and tourism-recreation landscape. Subjective demand judgments for each scenario were determined collectively by graduate students from the Landscape Ecology Laboratory of China Agricultural University. Scores were assigned to the original traditional landscape scenario, and subjective demand scores were given to the other three scenarios. Based on the difference between subjective judgment scores and objective analysis scores for the original traditional landscape, the initial subjective judgment scores for the other three scenarios were revised (Table 3), with the revised scores serving as the basis for subsequent scenario design.

After obtaining revised subjective demands, scenario modification strategies were developed through comprehensive analysis of the direction and magnitude of differences in each indicator between different landscape scenarios and the original traditional landscape (Table 4). Using these strategies, the quantity, attributes, and spatial structure of landscape elements in the original traditional landscape scenario were adjusted in the GIS platform. During adjustment, strategies were fine-tuned through calculations of revised scenario indicators until objective analysis scores for each scenario approximated subjective demand scores as closely as possible (Table 5 , Figure 2 [Figure 2: see original paper]), ultimately obtaining land use maps for each scenario (Figure 3 [Figure 3: see original paper]).

Based on the finalized land use maps for each scenario, Photoshop was used to modify the original traditional landscape scenario, ultimately producing visualized landscape scenarios for all four scenarios (Figure 4 [Figure 4: see original paper]).

1.4 Survey of Different Stakeholders

The survey involved three stakeholder groups: (1) local stakeholders–residents within the sample area (46 people: 27 male, 19 female); (2) nearby stakeholders –residents living 5-20 km from the sample area (46 people: 23 male, 23 female); and (3) university students and graduate students majoring in landscape ecology, horticulture, and related fields from China Agricultural University (37 people: 14 male, 23 female).

For local and nearby stakeholders, random surveys were conducted simultaneously in each village. For the student group, participants were assembled through relevant courses, selecting undergraduates and graduate students enrolled in "Landscape Ecology." In the questionnaire, participants first rated each scenario as "good," "normal," or "bad," then selected their most preferred scenario.

2.1 Attitudes of Different Stakeholders Toward the Original Traditional Scenario

While 29.7% of student representatives approved of the original traditional landscape scenario, only five individuals across all three groups held negative attitudes toward it. Overall, the three groups showed relatively consistent judgments about this scenario (Table 6 , Table 7).

Although neutral and positive attitudes toward the original traditional landscape scenario were similar across groups, their reasons differed considerably. Local residents primarily viewed the existing scenario as co-created by their ancestors and themselves, with a rational overall layout; some elderly individuals even considered the current feng shui optimal. They also believed other scenarios would require substantial engineering effort and be difficult to implement. Nearby residents chose this scenario mainly because its landscape element layout matched local characteristics and the overall scenario was relatively open with clear views. Landscape architecture students and graduate students selected this scenario primarily because the landscape was rich in layers, with both open and concentrated elements that were not visually cluttered, integrating production, living, and ecological benefits with reasonable water and tree arrangements. In discussions, most stakeholders who chose this scenario believed that without clear policy direction, the landscape' s existence proved it was currently the most rational development model and should remain the direction for the area' s development for some time.

2.2 Attitudes of Different Stakeholders Toward the Ecological Protection Scenario

Nearly one-quarter of local stakeholders (23.9%) and landscape students/graduate students (24.3%) considered the ecological protection landscape scenario reasonable, while supportive nearby stakeholders reached 34.8%. Meanwhile, nearby stakeholders showed approximately 10% fewer neutral attitudes than the other two groups. In optimal scenario selection, 6.5% of local stakeholders chose the ecological protection landscape scenario, compared to 21.7% and 24.7% for nearby stakeholders and students, respectively. The pattern reveals that the farther stakeholders lived from the area, the more they supported the ecological protection landscape scenario. Nearby stakeholders who chose this scenario primarily cited its large green coverage, strong overall coherence, and more natural, comfortable visual experience. Student groups, beyond perception, also engaged in rational consideration, recognizing the area' s background as an ecological conservation zone and viewing this scenario as a future development trend. Local stakeholders did not support this scenario mainly due to economic concerns, believing excessively high forest coverage would reduce space for other economic development forms.

2.3 Attitudes of Different Stakeholders Toward the Intensive Production Scenario

Approval rates for the intensive production landscape scenario were 8.7% among local stakeholders, 15.2% among nearby stakeholders, and 5.4% among students. Nearly two-thirds of local and nearby stakeholders held neutral attitudes, while 48.6% of students expressed opposition. In single-choice selection, this scenario accounted for less than 5% across all three groups. Clearly, the intensive production landscape scenario was the least preferred among the four scenarios. The few who chose it primarily believed the scenario made full use of existing conditions, emphasized production functions, and could maximize economic benefits. Those who rejected it argued that although the scenario utilized the land within feasible limits—replacing other agricultural land with higher-value orchards and developing facility agriculture and aquaculture—the area was not flat plain. Facility aquaculture could only be built where topography permitted, and the spatial layout, combined with excessive individual buildings (for aquaculture), increased visual clutter and weakened naturalness. This dense, chaotic landscape characteristic was the most important reason for its minimal support.

2.4 Attitudes of Different Stakeholders Toward the Tourism-Recreation Scenario

Preference differences for the tourism-recreation landscape scenario were the most pronounced among the four scenarios: 89.1% of local stakeholders expressed support, compared to 56.5% of nearby stakeholders and 18.9% of students. In exclusive selection, the proportions choosing this scenario were 73.9%, 52.1%, and 45.9% for the three groups, respectively. Preference for this scenario showed the opposite pattern from the ecological protection scenario—the closer stakeholders lived to the area, the stronger their preference. The independent tourism spots set in this scenario were added based on the Jinshuiwan Resort in Beizhen Town (outside the visual range), whose good economic returns were well-known locally and in surrounding areas. Consequently, local and nearby stakeholders chose this scenario for economic development needs. Additionally, the relatively large water area and relatively regular buildings and forest stands became important reasons for its popularity. Student groups, however, considered the scenario too cluttered with excessive landscape elements and unsuitable for local development.

Discussion

Visual landscape indicators based on ecological significance should serve as auxiliary decision-making tools for policymakers to evaluate multifunctional rural landscapes. To be effective, such tools must be simple, reliable, and easily understood while reflecting actual farmland conditions. These requirements demand clear, effective data to achieve information simplification, but such indicators must be premised on ecology. Most scenario research designs involve subjective judgments about local future landscape development, with scenario visualization work being almost entirely qualitative. Quantitative evaluation and integration of qualitative and quantitative approaches represent future directions in landscape research. This study attempted to quantify rural landscape scenario visualization design using ecologically meaningful visual landscape indicators. Future improvements should focus on assessing public sensitivity to different landscape structures across regions, developing deeper understanding of landscape indicators, and achieving seamless connection between landscape "supply" and "demand."

As Weinstoerffer et al. [1] suggest, in rigorous rural landscape evaluation contexts, landscape characteristics must be linked to two fundamental concepts: landscape "supply" and "demand." This dual objective-subjective evaluation represents a new landscape concept that is more realistic and consistent with agricultural problems requiring rapid, concise solutions. Farmers can introduce new elements into existing scenarios through certain actions, thereby enhancing practical impact. The objective aspect of landscape can thus be linked to landscape "supply" —as part of the characteristics farmers introduce into the landscape. Demand, broadly speaking, relates to the subjective aspect of landscape, focusing on its use value. These demands are largely influenced by rural landscape development, such as natural conservation organizations, recreational activities, tourism agencies, or resident organizations.

Due to the continuity and unpredictability of landscape change, and the increasingly complex roles of different stakeholder groups in landscape transformation, the future direction and strategies of rural landscapes have attracted increasing research attention [1-2]. Planners, stakeholders, decision-makers, and scientists all want to understand how rural landscapes will change over future periods. However, future landscapes cannot be accurately predicted because current landscapes will be interactively influenced by natural, human, historical, future technological, economic, and social conditions. Therefore, scenarizing future landscapes based on different landscape characteristic trends and impacts is more feasible than predicting a complete, real future. Consequently, understanding preferences of different stakeholder groups for future landscape characteristics is more practical and feasible than directly simulating a real future scenario.

This study elaborates a four-step continuous process for evaluating rural landscape scenario visualization through ecologically meaningful visual landscape indicators. The first step involves obtaining a database for objective landscape analysis through a rural landscape classification system meeting research needs, field mapping, and digitization. The second step is indicator selection; this study adopted indicators determined through changes between landscape supply and demand, considering both objective and subjective approaches, including complexity, naturalness, openness, coherence, and imageability. The third step involves indicator calculation and scenario visualization design—transforming subjectively judged rural landscape indices into GIS-based databases, adjusting simulation results to match subjective landscape expectations, and ultimately generating scenarios for different development goals. The fourth step involves determining the scope of involved populations or social groups and conducting subjective evaluations.

Through these four steps, this study achieved: (1) constructing visualization standards that comprehensively consider field mapping, objectively existing landscape supply, and differences in landscape demand among different stakeholders, making the evaluation process integrate objective and subjective perspectives; (2) evaluating landscape supply and demand using the same five indicators covering important aspects of ecologically based landscape assessment; and (3) providing a scientifically reasonable basis for rural landscape scenario visualization operations through the objective-subjective relationship of ecologically meaningful visual landscape indicators. Using such indicators for rural landscape scenario visualization evaluation can more directly connect to rural landscape resource management in government decision-making departments.

Although research on multifunctional rural landscapes and scenario visualization technology has entered a new era, no universal standard yet exists to specifically guide rural landscape evaluation and planning projects. Current research directions primarily focus on screening indicator systems that may influence public preference selection and developing technical procedures or general rules for scenario simulation to reduce errors caused by methodological differences.

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Note: Figure translations are in progress. See original paper for figures.