Postprint: Assessment of Cultural Ecosystem Services in the Guanzhong-Tianshui Economic Zone Based on the SolVES Model

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Abstract

As human demands for ecosystem services continue to increase, the assessment of ecosystem services has gradually emerged as a prominent research focus. Among these, cultural services are frequently overlooked in research and pose significant measurement challenges due to their intangible nature. This study selects the Guanzhong-Tianshui Economic Zone as the research area, employing the SolVES model to generate five value index maps and an aggregated value map for assessing the cultural services of ecosystems in this region. The results demonstrate that: aesthetic values are elevated in regions such as the Qinling Mountains and urban parks; recreational values are higher in cities with abundant recreational opportunities and convenient transportation, as well as in the northern foothills of the Qinling Mountains; cultural and historical values are concentrated in urban areas with profound historical and cultural heritage; spiritual values are higher in forest parks featuring mountainous terrain in close proximity to urban areas. The application of the SolVES model across large-scale regions has proven effective, concurrently providing a scientific basis for governmental ecological construction and planning.

Full Text

Assessment and Analysis of Social Values of Cultural Ecosystem Services Based on the SolVES Model in the Guanzhong-Tianshui Economic Region

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Abstract

With the continuous development of society, demand for ecosystem services has steadily increased in recent years, making ecosystem service assessment a prominent research focus. Among these services, cultural ecosystem services are often neglected and difficult to measure due to their intangible nature. This study selected the Guanzhong-Tianshui Economic Region as the research area and employed the SolVES model to generate five value index maps, using their sum to assess cultural ecosystem services in the region. The Social Values for Ecosystem Services (SolVES) model, built upon geographic information system (GIS) technology, was developed to incorporate quantified and spatially explicit measures of social values into ecosystem service assessment. SolVES 3.0 extends this functionality, providing an improved public-domain tool for decision-makers and researchers to evaluate ecosystem services and facilitate discussions among diverse stakeholders regarding tradeoffs among ecosystem services across various physical and social contexts, from forest and rangeland to coastal and marine ecosystems. Model input data are divided into two components: social survey data derived from questionnaires and environmental index data.

Results indicate that aesthetic value is higher in the Qinling Mountains and urban parks, while recreation value is elevated in cities and the northern foothills of the Qinling Mountains where recreational opportunities and transportation access are abundant. Cultural and historical values concentrate in urban areas with profound historical and cultural heritage. Spiritual value is higher in forested park areas near cities and mountains. Application of the SolVES model in large-scale regions has proven effective, providing a scientific basis for government ecological construction and planning. By understanding cultural ecosystem service values, governments can rationally allocate resources and determine priority protected areas at temporal and spatial scales, overcome limitations at all levels, correctly handle the relationship between socioeconomic development and ecological environmental protection, and achieve coordinated, unified development of economy, society, and ecology. Finally, this study discusses model sensitivity to large-scale application, contributing to improvements in ecosystem service assessment and the refinement and localization of the SolVES model.

Keywords: SolVES model; ecosystem services; cultural service; Guanzhong-Tianshui Economic Region; spatial analysis

1. Introduction

Since the concept of ecosystem services was proposed in the early 1970s, it has gradually gained recognition and widespread use, with discussions becoming a major research topic [1]. Scholars worldwide have conducted extensive research on ecosystem service classification and meaning, as well as human activity impacts [2-3], examining how climate change and land use policies affect ecosystems [4-6] and evaluating the economic value of global ecosystem services [7]. Ecosystem services mainly include provisioning services, cultural services, and supporting services. Cultural services refer to benefits people obtain from ecosystems through spiritual enrichment, recreation, and aesthetic experiences [8]. Studying ecosystem cultural services facilitates comprehensive understanding of ecosystems, enabling government decision-making to consider not only ecological value but also social cultural values [9], thereby promoting regional resource development and protection while providing guarantees for sustainable management and scientific decision-making regarding cultural service functions [10].

Previous research has primarily focused on human impacts on ecosystem services and monetized valuation, while cultural services—due to their intangible and subjective characteristics—have often been neglected, avoided, and proven difficult to quantify and evaluate. Currently, domestic research on ecosystem cultural services, particularly large-scale regional studies, remains scarce. Foreign scholars have attempted assessments using methods combining questionnaires with ecological physical models [12], PPGIS, or comparative analyses with other models [13-16]. However, most foreign studies concentrate on smaller areas such as forest parks, with few examining large regions or discussing model application sensitivity. Based on the characteristics of the Guanzhong-Tianshui Economic Region, this paper selected multiple indicators corresponding to cultural services for quantification using the SolVES model, generating five value index maps and a summed value map. The model demonstrated good performance in large-scale regional application, providing support and recommendations for sustainable management and protection of regional cultural service resources while exploring model sensitivity in extensive areas.

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2. Study Area

The Guanzhong-Tianshui Economic Region, designated as a key development zone in China' s Western Development Strategy, covers a vast area with diverse topography and landforms. Its main component is the Guanzhong Plain, extending westward to include the Wei River Valley in Tianshui, Gansu Province. The region boasts a long and profound history, represented by the thirteen-dynasty ancient capital Xi' an, and features rich tourism resources with enormous future development potential. The southern portion comprises the Qinling Mountains, while the northern area includes loess hills.

[Figure 1: see original paper] Location of Guanzhong-Tianshui Economic Region

3. Methods

3.1 The SolVES Model

SolVES (Social Values for Ecosystem Services) is a geographic information system application jointly developed by the U.S. Geological Survey's Earth Science and Environmental Change Center and Colorado State University. This study utilized SolVES 3.0, which comprises multiple modules with specific functions that can interconnect with other sub-modules and script data to perform additional calculations. The model employs value transfer methods and consists of several sub-modules, including the Ecosystem Service Function Social Value Module, Maximum Entropy Model, Value Mapping Module, and Value Transfer Mapping Module [17].

[Figure 2: see original paper] Maxent maximum entropy model analysis process flow

3.2 Maximum Entropy Model

The maximum entropy model was originally used to fit species geographic distributions. SolVES applies value transfer methodology, using the model to generate new points in areas lacking point data and output logistic surfaces where each grid cell represents the probability of species survival under given environmental conditions. Based on observed point data and similar environmental variables, the model transfers value type values from known point areas to regions lacking data, achieving prediction and assessment. SolVES 3.0 provides a relatively complete assessment tool that facilitates discussion of ecosystem services across different natural and human environments. This study used social survey data and relevant natural environmental index data obtained in the Guanzhong-Tianshui Economic Region as the foundation for generating regional value maps.

3.3 Social Survey Data

Social survey data were collected through questionnaire distribution in the Guanzhong-Tianshui Economic Region, yielding valid responses with an 82.08% efficiency rate. The survey comprised four sections: basic information affecting questionnaire validity, social demographic characteristics of respondents, attitudes and preferences, and classification of 12 different value types [18] (Value Index), which captured respondents' ratings for ecosystem cultural service indicators in the region. After field investigation and research, and based on the natural and historical cultural environment of the study area, this paper selected five indicators—aesthetic, cultural, historical, recreation, and spiritual—for investigation.

The Description of 12 value types

3.4 Environmental Index Data

The SolVES model requires loading multiple environmental index data layers describing the study area' s natural environment, as shown in [Figure 3: see original paper]: elevation data (ELEV); slope data (SLOPE); hillshade data (HILLSHADE); distance to water data (DTW); distance to roads data (DTR); and land use/land cover data (LULC). All environmental index data have a spatial resolution of 30 m.

[Figure 3: see original paper] The environmental data layers

To understand indicator importance, emails were sent to university scholars and folklore experts familiar with the Guanzhong-Tianshui region, requesting they rate the importance of selected indicators on a ten-point scale (1-10). Feedback was analyzed using the Delphi method to obtain corresponding weights and generate final summed values.

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4. Results

4.1 Cultural Service Distribution

The SolVES model generates maps that provide geographic and statistical displays of value indices for each cultural service indicator. Aesthetic value hotspots appear primarily in the Qinling Mountains, with scattered high-value points in urban fringe areas. Cultural value is relatively high across the entire Guanzhong Plain portion of the economic region, with hotspot areas concentrated in core cities such as Xi' an and Tianshui, alongside many scattered distributions in districts, counties, and villages. Historical high-value areas show similar distribution patterns to cultural value, concentrating in historically rich urban areas like Xi' an, but differ by displaying low values elsewhere. Recreation value shows extensive distribution, forming hotspots at the interface between the Qinling Mountains and Guanzhong Plain, particularly on the northern slopes of the Qinling Mountains. Spiritual value concentrates mainly along the northern side of the Qinling Mountains, roughly following the boundary between mountains and plain, forming several hotspots. The combined map integrates these five indicators, revealing higher comprehensive values in flat terrain and urban-concentrated areas, while regions with minimal human activity show lower values.

[Figure 4: see original paper] The mapping social value index

4.2 Distribution Characteristics Analysis

Aesthetic value hotspots in the Qinling Mountains align with well-known scenic areas such as Lishan and Cuihua Mountains, while scattered high-value points

in urban areas are typically near parks with substantial vegetation coverage. This indicates that people derive greater cultural value from areas with better vegetation cover. Cultural value hotspots correspond with urban regions possessing deep cultural accumulation, extensive historical heritage, and rich human resources. Cities such as the thirteen-dynasty ancient capital Xi' an and Tianshui have profound distinctive cultures that form cultural hotspots, with discrete high-value points also appearing at ancient tomb sites and temples. Since plains facilitate cultural activities and inheritance, high-value areas form in lower-altitude, gentler-sloping plain regions, with other scattered high-value points associated with temples dispersed in mountains. Historical value distribution resembles cultural value, concentrating in historically profound urban areas, though cultural value is lower elsewhere. Areas surrounded by abundant recreation opportunities show higher recreation value, such as cities with numerous parks and entertainment facilities enabling frequent recreational activities. The northern foothills of the Qinling Mountains serve as ideal recreation venues, providing convenient access to both urban centers and nature, thereby driving recreation-oriented industry development. Additional scattered high-value points may relate to specific group interests such as mountain climbing or jungle adventures. Higher spiritual values distribute in forest park areas with mountains and rivers, offering excellent opportunities to relieve mental pressure and recuperate physically and mentally through beautiful scenery and high vegetation coverage.

The combined map synthesizes aesthetic, cultural, historical, recreation, and spiritual indicators, demonstrating higher values in flat terrain and urban-concentrated areas. Governments can prioritize areas with higher value indices when formulating protection and management policies, giving greater attention to hotspot regions. Conversely, areas with lower value indices can be prioritized for development to promote regional progress. After obtaining ecosystem cultural service values, governments can conduct scientific ecological planning, achieve rational resource allocation and priority protected area determination at temporal and spatial scales, provide scientific foundations for ecological function zoning and construction planning, correctly handle relationships between socioeconomic development and ecological environmental protection, and overcome cognitive limitations at all levels to achieve coordinated ecological development [19].

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5. Discussion

5.1 Environmental Index Uncertainty

Analysis revealed that the five indicators are closely related to land use type and vegetation. This study further explored the impact of environmental indices other than land use type on model operation. After removing the land use/land cover (LULC) environmental index, both high and low values of the

five cultural service indices increased significantly, with expanded distribution areas. However, the overall distribution trend remained similar to previous results. Without LULC, aesthetic and recreation values (which correlate strongly with vegetation cover) could not form high-value areas near the Qinling Mountains, and urban areas could not form hotspots. This indicates that land use is a significant environmental factor affecting model results.

[Figure 5: see original paper] The new mapping social value index

5.2 Impact of Environmental Indices on Different Cultural Services

Different cultural service indicators are influenced by different environmental indices. Taking cultural value as an example, newly generated aesthetic value high-value areas coincide with lower elevation regions, while value indices are lower at higher elevations, indicating aesthetic value distribution is significantly affected by elevation. Cultural value distribution is greatly influenced by distance to roads, with high-value areas matching regions closer to roads—value indices increase as distance to roads decreases. Historical value distribution is simultaneously affected by both factors, with high-value areas coinciding with regions near roads. Different environmental indices have varying impacts on different cultural service indicators, suggesting that more suitable environmental indices should be selected based on specific regions. To more comprehensively reflect actual regional conditions, it is best to select more environmental indices to estimate cultural services, as the model uses identical environmental indices for different landscape types [20], which introduces some error but still yields good results overall for SolVES application in the Guanzhong-Tianshui Economic Region.

[Figure 6: see original paper] The new mapping social value index and environmental index layer contrast map

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6. Conclusion

Research on ecosystem cultural services has long been neglected and has only gradually gained attention abroad in recent years. This study attempts to combine subjective human survey data with objective natural environmental data, systematically integrating public-level cultural services into ecosystem service research [21-22]. Through practical research and result analysis in the Guanzhong-Tianshui Economic Region, this paper preliminarily assessed distribution characteristics of five ecosystem cultural service indicators in the region, explored distribution principles, and examined model sensitivity. Results demonstrate that the SolVES model can serve as a scientific tool for further ecosystem service research, providing references for ecosystem cultural service research and scientific management.

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