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Research on the Comprehensive Measurement of Low Carbon Cultural and Tourism Development Level in Rural Areas and the Transmission Mechanism of Digital Intelligence Empowerment

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Abstract: Against the dual background of the "dual carbon" goal and the rural revitalization strategy, the rural cultural and tourism industry, as an important lever to promote rural economic transformation, has become a hot research topic in terms of its low-carbon development path. This study takes the core idea of "reducing carbon emissions and increasing green benefi ts" to explore how the rural cultural and tourism industry can achieve low-carbon development through the application of digital technology. By constructing an evaluation index system covering fi ve dimensions: industrial prosperity, ecological livability, civilized rural culture, eff ective governance, and affl uent living, and based on 1233 valid questionnaire data, this study systematically analyzes the regional diff erences in rural low-carbon cultural tourism development and the transmission mechanism of digital empowerment. Research has found that the development of digital and low-carbon tourism in rural areas of China presents an extremely uneven spatial pattern, with Jiangsu's comprehensive score (92.8) being 36.0 points higher than the western region's (56.8), and the regional comprehensive diff erence coeffi cient reaching 38.7%. The research provides theoretical basis and practical reference for the development of low-carbon tourism in rural areas.

Keywords: Digital Intelligence Empowerment; Rural Revitalization Dual Carbon Targets; Low Carbon Cultural Tourism; Comprehensive Evaluation

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1. Introduction

Against the backdrop of deepening global climate governance and the comprehensive implementation of China's "dual carbon" goals, low-carbon development has become the core direction of economic and social transformation. At the same time, the rural revitalization strategy continues to deepen, and the rural cultural and tourism industry, as an important lever to activate the rural economy and activate ecological resources, is ushering in a period of rapid development opportunities. However, during the process of industrial expansion, issues such as rising energy consumption, increased carbon emissions, and increased ecological pressure have become increasingly prominent. Balancing economic development with ecological protection, and achieving synergy between "carbon reduction" and "effi ciency enhancement", has become a key proposition for the high-quality development of rural cultural tourism. Digital technology has provided new impetus for the low-carbon

cultural and tourism transformation in rural areas, but a systematic measurement system and transmission mechanism research have not yet been formed. This article explores the current situation and influencing factors of carbon emissions in rural cultural tourism, constructs a comprehensive evaluation system for low-carbon development level, reveals the intermediary transmission path of digital empowerment, and provides theoretical basis and practical guidance for the sustainable development of rural low-carbon cultural tourism.[1]

2. Literature Review and Theoretical Basis

2.1 Review of Domestic and Foreign Literature

Based on the theories of "promoting agriculture through digital commerce" and industrial integration, domestic research has constructed a digital intelligence empowered rural agricultural cultural tourism integration system. Wujiang et al. proposed the framework of "element empowerment platform construction business upgrading"; Liu Bojun focuses on the digital shaping of brand IP; Wu Cong and others pointed out that short videos and live broadcasts can enhance the exposure of rural cultural tourism; Ye Yinning emphasized the full process of digital transformation; Li Ying analyzes the impact of social media content on brand communication. Foreign research started earlier, and Khiaolek (2025) explores the low-carbon path of renewable energy in the tourism industry; Hu (2025) analyzes the impact of tourists' low-carbon behavior on green consumption; Bai (2026) evaluates digital technology and heterogeneous green innovation. Both domestically and internationally are extending towards digitization and greenization, but domestically, there is a focus on policy integration and practice, while abroad places more emphasis on sustainable frameworks and community governance. There is still research space for the comprehensive chain of "digital intelligence empowerment - low-carbon transformation - high-quality development".[2]

2.2 Theoretical Basis

The theory of carbon neutrality in tourism revolves around the control of carbon emissions throughout the entire lifecycle, achieving dynamic balance through source carbon reduction (energy cleanliness), process efficiency improvement (smart management), and end of pipe offsetting (carbon trading). The stakeholder theory emphasizes the collaborative governance of multiple entities such as government, enterprises, village collectives, villagers, and tourists, clarifies the rights and responsibilities of all parties, and solves the dilemma of "subject failure".[3]

3. Construction of an Indicator System for Empowering Low-Carbon Tourism in Rural Areas with Digital Intelligence

3.1 Principles for Constructing Indicator System

The selection of indicators should be in line with the core connotation of empowering rural low-carbon tourism with digital intelligence, which not only reflects the depth of application of digital technology in rural tourism, but also covers the core characteristics of low-carbon tourism such as carbon emissions and resource recycling. This article refers to the "Rural Revitalization Strategy Plan (2018-2022)" and the "Digital Rural Development Strategy Outline" (2019), and constructs evaluation indicators from five levels: "prosperous industries, livable ecology, civilized rural culture, effective governance, and prosperous life". When selecting evaluation indicators, multiple dimensions should be measured to ensure that each dimension is interrelated and progressive, while eliminating redundant indicators to avoid indicator overlap. Priority should be given to selecting indicators that can be directly obtained or indirectly quantified through statistical or research data, ensuring that the indicators can be collected, calculated, and compared in practice.[4]

3.2 Construction of Evaluation Indicator System

This article constructs primary indicators from five aspects and selects 20 secondary indicators to construct an evaluation system. The design of indicators for each dimension is as follows:

Industrial prosperity is the economic foundation for empowering low-carbon tourism in rural areas with digital intelligence. Four indicators are selected: the proportion of digital economic income from rural tourism, the digital development rate of low-carbon tourism products, the coverage rate of digital tourism marketing, and the energy consumption intensity per unit of GDP in the tourism industry. Ecological livability is the core foundation of low-carbon tourism in rural areas. Six indicators

were selected, including the utilization rate of clean energy in scenic spots, the rate of resource utilization of tourism waste, the per capita carbon emissions of tourism activities, the coverage rate of rural greening, the compliance rate of water/air quality in tourist areas, and the coverage rate of intelligent monitoring of ecological environment. Rural cultural civilization is the cultural support, and four indicators are selected: the digital filing rate of rural cultural resources, the incidence rate of low-carbon civilized behavior among tourists, the complaint rate of uncivilized tourism behavior, and the promotion and popularization rate of low-carbon tourism concepts. Effective governance is a guarantee condition, and four indicators are selected: coverage rate of smart tourism supervision platforms, deployment rate of intelligent monitoring equipment for tourism environment, incidence rate of tourism safety accidents, and average processing time of tourism complaints. Wealthy living is the development goal, and two indicators are selected: per capita income of rural tourism industry residents and the proportion of low-carbon employment positions related to digital intelligence.

Table 1 Evaluation Indicators for Empowering Rural Low Carbon Tourism with Digital Intelligence

Comprehensive Indicator	First-level Indicator	Second-level Indicator	Indicator Attribute
Rural Revitalization Level	Industrial Prosperity	Proportion of digital economy income from rural tourism (%)	+
		Digital development rate of low-carbon tourism products (%)	+
		Coverage rate of digital tourism marketing (%)	+
		Energy consumption intensity per unit GDP of tourism industry (ton of standard coal/10,000 yuan)	–
	Ecological Livability	Utilization rate of clean energy in scenic spots (%)	+
		Resource utilization rate of tourism waste treatment (%)	+
		Per capita carbon emission of tourism activities (kg/person)	–
		Rural green coverage rate (%)	+
		Compliance rate of water quality and air quality in tourist areas (%)	+
		Coverage rate of intelligent ecological environment monitoring (%)	+
	Social Civility	Digital filing rate of rural cultural resources (%)	+
		Incidence rate of low-carbon civilized behaviors of tourists (%)	+
		Complaint rate of uncivilized tourism behaviors (%)	–
	Effective Governance	Popularization rate of low-carbon tourism concept publicity (%)	+
		Coverage rate of intelligent tourism supervision platforms (%)	+
		Layout rate of intelligent tourism environment monitoring equipment (%)	+
		Incidence rate of tourism safety accidents	–
		Average handling time of tourism complaints (hours)	–
	Prosperous Life	Per capita income of residents employed in rural tourism (yuan/person)	+
		Proportion of jobs related to digital-intelligent low-carbon development (%)	+

3.3 Sample Size Determination and Reliability Testing

This study comprehensively applies probability sampling theory and empirical criteria of multivariate statistical models to scientifically measure the target sample size. Based on the Kirkland sample size calculation formula, under the conditions of 95% confidence level and 5% allowable error, the theoretical sampling size limit is 384 samples. At the practical implementation level, an expanded sampling strategy that integrates online and offline methods was adopted. A total of 1350 original questionnaires were collected in the formal study. After strict data cleaning and quality control, the final effective sample size was determined to be 1233, and the effective questionnaire collection rate was as high as 91.33%. The actual retained effective sample size is 3.2 times the critical value of classical statistical theory (384 samples), providing a solid data foundation for the robustness of subsequent empirical analysis.[5]

4. Analysis and Comprehensive Evaluation of Regional Differences in Rural Tourism

4.1 Data Sources and Research Methods

The total effective sample N is 1233, and the regional groups are: Jiangsu (400, 32.44%), Eastern Other (300, 24.33%), Central (300, 24.33%), and Western (233, 18.90%). This study uses the coefficient of variation (CV) to quantify the degree of uneven development between regions, with larger CV values indicating more significant regional differences. The comprehensive evaluation score adopts the equal weight method to construct the evaluation model, and the weights of each dimension are 0.2.

4.2 Empirical Analysis of Regional Differences

The usage structure of digital intelligence services shows a significant gradient differentiation. The regular usage rate of Jiangsu Smart Services is 52.00%, which is 3.06 times that of the western region (17.00%), and the never used rate is only 9.00%; The utilization rate in the western region has never reached as high as 48.00%, indicating a significant digital divide. The coefficient of regional differences in the use of digital intelligence services is CV=36.2%.

The driving effect of digital services on tourism willingness exhibits regional heterogeneity. The willingness recognition rate of Jiangsu tourists driven by digital intelligence (strongly agree+somewhat agree) reached 91.00%, while in the western region it was only 54.00%. The difference in willingness between Jiangsu and the western region was 37.00%. The coefficient of regional differences in willingness driven by digital intelligence is CV=31.5%.

The satisfaction with regional services shows a leading trend in Jiangsu and a decreasing trend in the central and western regions. The overall satisfaction rate (very satisfied+relatively satisfied) in Jiangsu is 90.00%, while in the western region it is only 48.00%; The satisfaction level in central China is 19 percentage points lower than that in Jiangsu. The coefficient of regional difference in satisfaction is CV=33.8%.

The willingness for low-carbon tourism is highly positively correlated with regional economy and cognitive level. The comprehensive proportion of low-carbon willingness in Jiangsu is 92.00%, followed by 87.00% in the eastern region, 74.00% in the central region, and 59.00% in the western region; Jiangsu's low-carbon willingness is 1.56 times that of the western region. The coefficient of regional difference in low-carbon willingness is CV=28.9%.

The cognitive depth of low-carbon functions in digital intelligence shows regional stratification. Jiangsu ranks first in the recognition of three core functions: low-carbon route optimization, carbon emission monitoring, and environmental science popularization. The average recognition of core functions in the western region is 22 percentage points lower than Jiangsu. The coefficient of difference in functional cognitive regions is CV=17.6%.

4.3 Comprehensive Evaluation Analysis

Based on the comprehensive score model, the ranking of regional comprehensive development is: Jiangsu (92.8)>Eastern Other (86.4)>Central (72.6)>Western (56.8). Jiangsu's comprehensive score is 36.0 points higher than that of the western region, with a regional comprehensive difference coefficient of CV=38.7%, indicating that the development of rural smart low-carbon tourism in China presents an extremely uneven spatial pattern and urgently needs to implement differentiated regional development strategies.

5. Suggestions for the Development Path of Low Carbon Tourism in Rural Areas

5.1 Improve the Comprehensive Measurement System of Low-Carbon Culture and Tourism to Achieve Accurate Diagnosis

An indicator system should be constructed from four dimensions: ecological environment, low-carbon facilities, cultural and tourism benefits, and digital support. The entropy method combined with TOPSIS method should be used to comprehensively measure the level of development. Based on the measurement results, divide the development ladder and implement targeted measures to fill the gaps in areas with weak low-carbon foundations and lagging digitalization, in order to avoid homogeneous construction and provide data basis for differentiated policies.

5.2 Strengthen the Digital Infrastructure and Connect the Technology Transmission Path

Digital infrastructure is an important foundation for achieving technology transmission. Digital empowerment requires the underlying support of 5G, the Internet of Things, and big data platforms to build an integrated digital system of "resources operations services". Monitor carbon emissions and intelligently regulate energy consumption in scenic areas through AI; Developing low-carbon immersive experiences using VR/AR technology; Using big data to accurately push green routes and low-carbon products, achieving efficient transmission of technology ecology industry.

5.3 Promote the Upgrading of Low-Carbon Business Models and Build a Green Development Model

Low carbon tourism must form a large-scale development format. We must strictly control the development intensity of scenic spots, promote photovoltaic, energy-saving buildings, electric transportation, and renovate green homestays and low-carbon public toilets. Promote garbage classification, sewage resource utilization, ecological circular agriculture, and reduce carbon emission intensity. At the same time, by developing low-carbon cultural and tourism products such as ecological research and learning, health and leisure, and carbon sequestration experience, we guide tourists to travel green and consume simply, forming a low-carbon production low-carbon consumption loop.

5.4 Establish a Sound Collaborative Guarantee Mechanism and Strengthen Long-Term Empowerment

The government needs to play an irreplaceable and important role. By introducing low-carbon cultural and tourism special policies, setting up special funds for digital transformation and ecological compensation, building a government enterprise village collective villagers collaborative governance system, and strengthening carbon trading and ecological incentives. Strengthen the training of talents in digital technology and low-carbon management, cultivate local composite talents, and enhance the quality of rural low-carbon cultural and tourism development through the four-dimensional linkage of measurement, empowerment, low-carbon, and guarantee.

6. Conclusion

Based on the background of the "dual carbon" goal and rural revitalization strategy, with the core of empowering low-carbon development of rural culture and tourism through digital intelligence, this study systematically sorted out the current development status, core issues, and internal mechanisms of low-carbon tourism in rural areas through multi method research and multi-dimensional analysis, and constructed a development path system that combines theoretical and practical aspects. Research has confirmed that digital technology is an important lever for promoting the low-carbon transformation of rural culture and tourism. The low-carbon development of rural culture and tourism is a systematic project that requires the collaborative efforts of the government, industry, and the public. Only by using digital technology as a link and connecting the transformation chain of "cognition willingness behavior development" can we truly achieve low-carbon and high-quality development of rural cultural and tourism industry, allowing rural areas to maintain the beauty of ecological foundation and radiate the vitality of economic development, injecting sustained cultural and tourism momentum for the dual realization of rural revitalization and "dual carbon" goals.

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Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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