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RESEARCH ARTICLE

The Ecological Safety Assessment and Brand Communication of Ice-Snow Tourism Under the Internet of Things and Deep Learning

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ABSTRACT In the current context of global climate change and threats to the ecological environment, ice and snow tourism destinations face significant challenges in ecological security protection. The urgent question of how to scientifically assess the ecological security status of ice and snow tourism destinations in order to formulate effective management and protection strategies needs to be addressed. The ecological security of ice and snow tourism destinations is not only related to the preservation of the natural environment but also directly affects the sustainable development and brand image of these destinations. Therefore, effectively communicating the brand of ice and snow tourism destinations while protecting the ecology has become an urgent issue. Emerging technologies like the Internet of Things (IoT) and deep learning hold great potential in remote sensing image processing and data analysis and can provide effective tools and methods to address the above-mentioned issues. Therefore, this study focuses on exploring the application of IoT and deep learning in the assessment of ecological security and brand communication in ice and snow tourism destinations, providing more scientifically grounded decision support for the management and development of these destinations. Taking an ice and snow tourism destination in Area C as a case study, this study first analyzes the applications of the IoT and DL in ecological safety assessment. Subsequently, by utilizing the DeeplabV3+ model for land type classification and combining the Drive-Pressure-State-Impact-Response (DPSIR) model and the Environment-Economy-Society (EES) model, the DPSIR-EES model is constructed to assess the ecological safety of ice and snow tourism destinations. The results indicate that, for remote sensing image classification, the overall accuracy of the DeeplabV3+ model reaches 91.56%, and the Kappa coefficient reaches 0.862, significantly surpassing traditional methods, thereby demonstrating its superiority in remote sensing image classification. The ecological safety assessment of the ice and snow tourism destination in Area C reveals that the overall ecological safety remains stable between 0.88 and 0.89. Tourism spatial density is one of the influencing factors on its ecological safety, with an obstacle factor of 0.31, indicating the significance of economic factors in ecological safety. Finally, based on the aforementioned analysis, approaches for shaping and communicating the brand of the ice and snow tourism destination in Area C are proposed. This study holds important practical significance for better environmental protection and enhancing brand value.

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INDEX TERMS Internet of Things, deep learning, ice and snow tourism destination, ecological safety assessment, DeeplabV3+, DPSIR-EES model.

I. INTRODUCTION

A. RESEARCH BACKGROUND AND MOTIVATIONS

Today's tourism industry has become a pivotal driving force behind global economic and cultural development [1], [2]. With the escalating demand for leisure, cultural exploration, and natural experiences, ice and snow tourism, as a distinctive form of travel, has been progressively garnering worldwide attention. The rise of the ice and snow tourism sector has spurred regional economic growth and facilitated the preservation and inheritance of local culture and the natural environment [3], [4]. However, as ice and snow tourism experiences rapid expansion, the associated regions are concurrently confronted with challenges concerning ecological safety and sustainable development [5].

The emergence of the Internet of Things (IoT) and Deep Learning (DL) offers novel prospects for the sustainable development of ice and snow tourism. IoT enables diverse devices and sensors to connect and share data, thus enabling real-time monitoring and management of ice and snow tourism sites [6], [7]. This real-time monitoring aids in gaining a better understanding of visitor behavior, preferences, and environmental impact, facilitating improved planning and management of tourism activities and ecological conservation. Meanwhile, DL, a pivotal branch of artificial intelligence, exhibits robust performance in image recognition, data analysis, and other domains [8], [9]. The application of DL to the analysis of image data in ice and snow tourism enhances classification and recognition accuracy and provides more engaging materials for promoting and marketing attractions.

In this context, this study takes the ice and snow tourism destination in Area C of City Z in Province H as its research subject. The primary goal is to comprehensively explore effective strategies for ecological safety assessment and brand communication of ice and snow tourism destinations by synergistically harnessing IoT and DL technologies. Through the analysis of data related to land use and ecological safety, the aim is to provide scientific decision-making support for the sustainable development of the ice and snow tourism sector. The study emphasizes the value and potential application of IoT and DL in the realm of ice and snow tourism. Through in-depth research and experimentation, it aspires to unveil the intricate relationship between the ecological environment and brand communication of ice and snow tourism destinations, offering beneficial guidance and insights for their sustainable development and image cultivation.

B. RESEARCH OBJECTIVES

This study's primary objective is to comprehensively assess the ecological environment of the ice and snow tourism destination in Area C by analyzing natural resources, ecosystems, and ecological safety status in this region. The intent is to understand the present ecological environment. Furthermore, the study aims to evaluate the applicability of IoT and DL in the ice and snow tourism context. Utilizing IoT sensors and devices, land remote sensing imagery is acquired, and the DeeplabV3+ network is employed for image classification to enhance accuracy in image recognition and categorization, thereby providing superior materials for promotional endeavors. Additionally, the study explores brand communication strategies suitable for the ice and snow tourism destination in Area C.

This study contributes scientific decision-making support for the sustainable development of the ice and snow tourism destination in Area C. Through a comprehensive analysis of diverse data, including land use, ecological safety, and brand communication, targeted recommendations and guidance are furnished for administrators, policymakers, and other stakeholders, aiming to foster the sound development of tourism in the region. Compared to previous research, the innovation in this study can be seen in several aspects. First, it seamlessly integrates IoT and deep learning technologies, utilizing the DeeplabV3+ model for real-time monitoring and assessment of the ecological environment of ice and snow tourism destinations, providing more precise data support. This data-driven approach effectively addresses the limitations of traditional ecological assessment methods, enabling decision-makers to gain a more accurate understanding of ecological security conditions. Second, this study focuses on ecological security and closely ties it with brand communication. By introducing innovative communication strategies, this study aims to strengthen the brand image of ice and snow tourism destinations, emphasizing their advantages in natural landscapes, ecological preservation, and sustainable development to attract more tourists and investors. Finally, this study underscores the importance of sustainability, emphasizing the feasibility of achieving economic growth and societal prosperity while protecting the ecological environment. This comprehensive research approach holds innovative significance in managing and promoting ice and snow tourism destinations, providing new pathways and perspectives for their sustainable development. Therefore, the uniqueness of this study lies in the organic integration of IoT, deep learning, and brand communication strategies, providing a new paradigm for the actual management and promotion of ice and snow tourism destinations. Additionally, the innovation lies in translating theory into practical action, thus offering strong guidance for decision-makers and practitioners in related fields.

II. LITERATURE REVIEW

Ecological environment protection has become increasingly vital in the development of ice and snow tourism destinations. Tang et al. analyzed the role of the Beijing Winter Olympics in driving China's ice and snow tourism. Through literature and on-site investigation, they revealed the current status and challenges of China's ice and snow tourism development, proposing suggestions spanning policy, market, safety, technology, and environment [10]. Their study emphasized the significance of policies and environmental protection in the context of ice and snow tourism, closely related to the ecological security assessment and brand communication strategies addressed. An et al. introduced a comprehensive suitability index based on natural and socio-economic factors to assess the appropriateness and potential of ice and snow tourism, emphasizing the impact of climate change and environmental conservation on its development [11]. Their study underscored the importance of environmental factors related to the ecological security assessment discussed. Zhang and Li proposed a complex evaluation index system for the coupling mechanism among the tourism, urbanization, and ecological environment subsystems in Heilongjiang, observing a steady increase in coupling degree [12]. Their study highlighted the importance of interrelatedness among various subsystems, providing a reference for the construction of the comprehensive evaluation model.

IoT and DL provide novel tools and methods for the management, monitoring, image recognition, and classification of ice and snow tourism destinations. Wise and Heidari elucidated IoT concepts and applications in the tourism and hospitality industries, demonstrating how Internet-connected devices embedded in everyday items foster intelligent opportunities for the tourism sector [13]. This provided crucial background information for the application of IoT technology in ecological security assessment in this study. Tiwari et al. explored the significance of sustainable energy management in tourist destinations and IoT's role therein. They employed the Servqual method to analyze IoT as a technical solution for sustainable energy management [14]. The results underscored the potential of IoT in sustainability, which was related to the application of IoT technology in the ecological security assessment discussed. Paolanti et al. stressed the importance of understanding traffic characteristics in tourism and introduced a DL-based social, geographical data framework for estimating emotions related to the Cilento tourist destination in southern Italy [15]. This is relevant to the application of deep learning technology in land classification and brand communication. These technologies assist site managers in better comprehending the distribution of diverse land types within a scenic area, providing more accurate data support for planning and promotion.

In summary, the literatures reviewed above provide essential background information and relevance for this study, emphasizing the importance of policies, environmental factors, coupling mechanisms, IoT, and deep learning technology in the management of ice and snow tourism destinations, ecological security assessment, and brand communication. However, research on specific ecological environment assessment and brand communication strategies for individual ice and snow tourism destinations remains limited. Therefore, the aim of this study is to bridge the research gap by focusing on the ice and snow tourism destination in Area C. By synergistically employing IoT, DL, and brand communication strategies, this study will explore more effective management and promotional strategies for ice and snow tourism, offering fresh insights and methods for the region's sustainable development.

III. RESEARCH METHODOLOGY

A. APPLICATION OF IoT AND DL IN ECOLOGICAL SAFETY ASSESSMENT

Ecological safety assessment holds pivotal significance in the sustainable development of ice and snow tourism destinations, and the integration of IoT and DL brings innovative applications to this field. Their convergence provides more accurate and real-time methods for monitoring, analyzing, and predicting the ecological environment, contributing to safeguarding ecological safety in ice and snow tourism destinations. The application of these two technologies is illustrated in Figure 1.

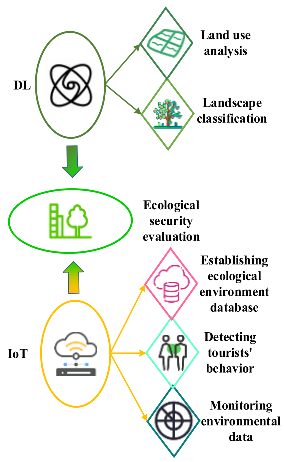

FIGURE 1. Application of IoT and DL in ecological safety assessment.

In Figure 1, within the context of ecological safety assessment, IoT offers a wealth of environmental data to aid in understanding the health of the ecosystem in ice and snow tourism destinations. It also facilitates monitoring of visitor behavior, assisting in evaluating the impact of tourist activities on the ecological environment. Moreover, IoT can establish an ecological environment database by combining historical and real-time data for trend analysis and model predictions [16]. DL demonstrates impressive performance in image recognition, classification, and segmentation, providing robust tools for ecological safety assessment. Particularly in landscape classification and land use analysis within ice and snow tourism destinations, DL achieves high-precision image recognition, enabling the generation of more refined land use maps [17]. This contributes to the detailed assessment of the ecological environment, capturing the distribution characteristics of distinct land types more accurately.

In conclusion, the application of IoT and DL enables real-time monitoring, data analysis, and the construction of predictive models, aiding ice and snow tourism destinations in promptly identifying potential environmental issues, taking effective measures, and achieving sustainable ecological environment management.

B. DeeplabV3+ NEURAL NETWORK MODEL

Among the numerous neural networks, the DeeplabV3+ network employs atrous convolution cores, which means it can effectively capture information at different scales and contexts. This is crucial for remote sensing image classification, which often involves extensive geographical information. DeeplabV3+ utilizes the Atrous Spatial Pyramid Pooling (ASPP) module, allowing the network to process input images in a multiscale manner to capture objects and features of varying sizes. This is highly beneficial for diverse land cover classification in remote sensing images. DeeplabV3+ has demonstrated excellent performance in image segmentation tasks, including remote sensing image classification. It has undergone extensive validation and exhibits high accuracy. The open-source models and code libraries for DeeplabV3+ are available for researchers to use, enabling the construction of models based on previous work and customization to suit specific remote sensing image classification tasks. Given the advantages and characteristics of the DeeplabV3+ network in remote sensing image classification and semantic segmentation tasks, it is selected as the model for this study. The DeeplabV3+ network primarily consists of three components: the backbone convolutional network, the ASPP module, and the Decoder module, as illustrated in Figure 2 [18].

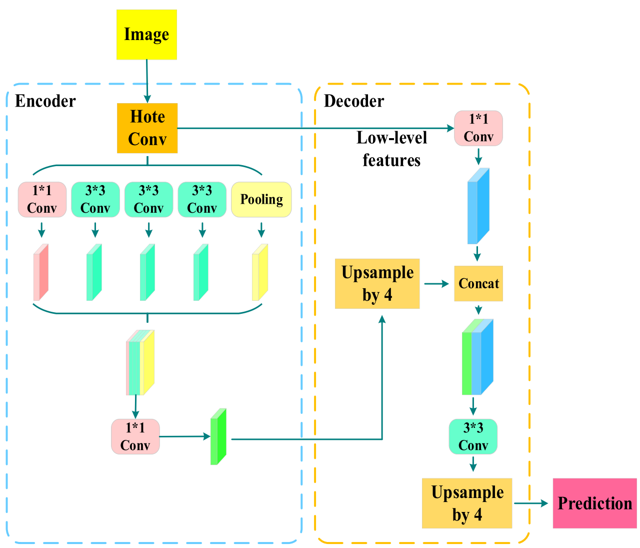

FIGURE 2. The architecture of the DeeplabV3+ Network.

In Figure 2, the DeeplabV3+ network adopts an encoder-decoder architecture. The model introduces various dilation rates within the residual block using a multi-grid approach. The pooling layers primarily serve to reduce the position sensitivity of convolutional layers. The DeeplabV3+ network predominantly employs max-pooling [19]. The network

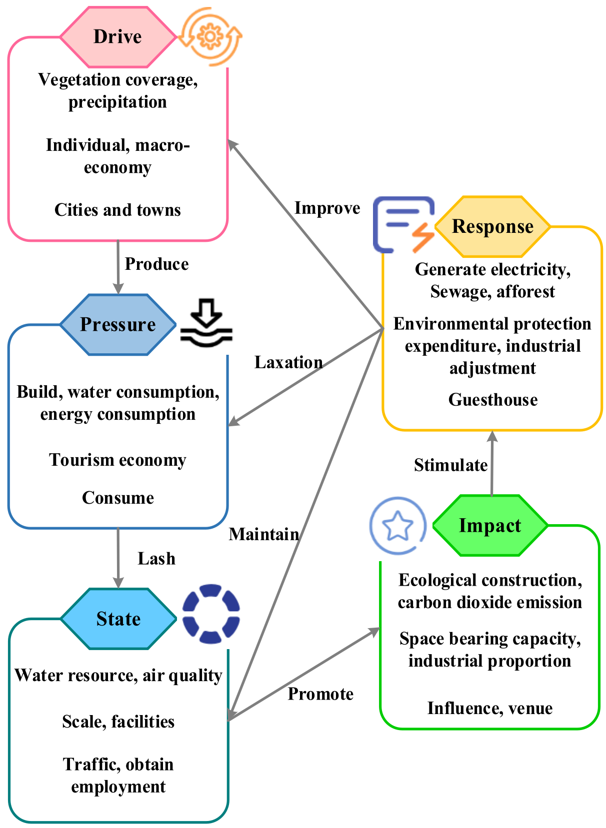

FIGURE 3. DPSIR-EES model for ecological safety assessment of ice and snow tourism destinations.

exhibits exceptional segmentation performance and edge smoothing, characterized by two key aspects: the introduction of diverse dilation rates in residual blocks through the multi-grid approach and the incorporation of Image-level features into the pooling module of the spatial pyramid ASPP, along with the utilization of batch normalization techniques.

C. CONSTRUCTION OF ECOLOGICAL SAFETY ASSESSMENT INDEX SYSTEM FOR ICE AND SNOW TOURISM DESTINATIONS

From the perspective of human activities' impact on the ecological environment, considering the ecological environment's status and corresponding human actions, the Drive-Pressure-State-Impact-Response (DPSIR) model is chosen as the fundamental model for ecological safety assessment of ice and snow tourism destinations. The DPSIR model aims to aid in comprehending and evaluating the impact of human activities on the environment, along with potential management and policy responses [20]. Additionally, the Environment-Economy-Society (EES) model emphasizes the interactions and influences among the three primary aspects: environment, economy, and society [21]. Ice and snow tourism ecosystems possess intricate natural, economic, and social attributes, forming a complex EES composite system. Hence, this study integrates the DPSIR and EES models to construct

TABLE 1. Ecological safety assessment index system for ice and snow tourism destinations.

Objective Level	Primary Indicator	Secondary Indicator	Tertiary Indicator
Ecological security assessment of ice and snow tourist destinations	driving force (D)	D1: Environmental driving force	D1-1: Vegetation coverage (%)
			D1-2: Annual precipitation mm
		D2: Economic drivers	D2-1: Growth rate of regional per capita tourism income (%)
			D2-2: Growth rate of investment in regional ice and snow industry (100 million yuan)
		D3: Social drivers	D3-1: Urbanization rate (%)
	pressure (P)	P1: Environmental pressure	P1-1: Proportion of construction land area to county area (%)
			P1-2: Snowmaking water consumption of county-level ski trails (10,000 m^3)
			P1-3: Energy consumption per unit of GDP (tce/10,000 yuan)
		P2: Economic pressure	P2-1: Tourism Economic Density (yuan/km^2)
			P2-2: Growth rate of regional tourist reception (%)
		P3: Social pressure	P3-1: Consumer Price Index
	State (S)	S1: Environmental state	S1-1: Total capacity of regional ski resort reservoirs (10,000 m3)
			S1-2: PM2.5 concentration (μg/m3)
		S2: Economic status	S2-1: Number of ice and snow tourism enterprises with a scale of over 10 million yuan (units)
			S2-2: Number of ski trails in the area (articles)
			S2-3: Length of regional ski trails (km)
			S2-4: Number of regional ropeways (pieces)
		S3: Social State	S3-1: Social Security and Employment Expenditures (100 million yuan)
			S3-2: Road mileage per capita (m/person)
	Impact (I)	I1: Environmental impact	I1-1: Non-snow season ecological construction ratio of regional ski resorts (%)
			I1-2: Annual growth rate of carbon emissions (million tons)
		I2: Economic Impact	I2-1: Proportion of tourism output value in GDP (%)
			I2-2: The ratio of tertiary output value to GDP (%)
			I2-3: Tourism spatial density (annual tourist reception/km2)
		I3: Social Impact	I3-1: Average value of Baidu Index for ice and snow tourist destinations
			I3-2: Construction grade index of ice and snow tourism venues
	Response (R)	R1: Environmental Response	R1-1: Per capita wind power generation (kWh/person)
			R1-2: Sewage treatment rate (%)
			R1-3: Per capita afforestation area growth rate (%)
		R2: Economic Response	R2-1: Proportion of energy conservation and environmental protection expenditures in total expenditures (%)
			R2-2: Industrial cleaning adjustment rate (%)
		R3: Social Response	R3-1: Growth rate of the number of regional hotels (%)

the DPSIR-EES model for assessing the ecological safety of ice and snow tourism destinations, as depicted in Figure 3.

In Figure 3, the five aspects of ecological safety in ice and snow tourism destinations—Drive (D), Pressure (P), State (S), Impact (I), and Response (R)—mutually reinforce and influence each other. Response improvements drive the development of the driving forces, alleviate ecological pressures, and enhance and maintain the ecological state, which, in turn, promote or lead to impacts. This constructs the ecological safety assessment index system for ice and snow tourism destinations, as illustrated in Table 1 [22], [23], [24].

After obtaining foundational data, the gray relational analysis method is utilized to analyze the ecological safety level under the influence of various factors in the region. The weighted Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method is employed to analyze the ecological safety situation of the ice and snow tourism destination in Area C.

IV. EXPERIMENTAL DESIGN AND PERFORMANCE EVALUATION

A. EXPERIMENTAL MATERIALS

H Province, Z City, Area C, an Ice and Snow Tourism Destination, was selected as the study subject. The ecological environment of Area C's ice and snow tourism destination is favorable, characterized by a temperate monsoon climate in East Asia. The region boasts a forest coverage rate of 67%, with natural resource advantages primarily concentrated in mountainous and forested areas, forming a robust foundation for the sustained development of the ice and snow tourism industry. Abundant ice and snow resources within the area make it one of the most resource-rich, promising, and prospective regions for domestic ice and snow tourism development.

First, an analysis of Area C's land types was conducted. An experimental dataset was created using Landsat series remote sensing images, and comparative experiments were carried out between DeeplabV3+ and traditional supervised classification methods to assess classification accuracy. This exploration aimed to validate the effectiveness and applicability of the DeeplabV3+ model in classifying remote sensing images with rich texture features. The experiment selected Landsat series remote sensing images from 2004, 2009, 2013, 2017, and 2021 to create the experimental dataset. The dataset has a spatial resolution of 30 meters and can identify five land types: forest, grassland, built-up land, water bodies, and unused land. Data augmentation techniques such as rotation, flipping, cropping, noise addition, brightness and contrast adjustment, and color enhancement, were applied to expand the remote sensing images of Area C. This resulted in a total of 69,248 valid samples, which were randomly divided into training and validation sets in a 4:1 ratio.

Subsequently, an ecological safety assessment of Area C's ice and snow tourism destination was conducted based on its land types, and its brand dissemination strategies were studied. The data was collected and included ecological security assessment indicator data for Area C from 2013 to 2021. Most of the data were directly obtained from Area C's county-level statistical yearbooks, government statistical bulletins, and similar sources. For some indicators, data for individual years were missing and obtained through interpolation and exponential smoothing methods.

B. EXPERIMENTAL ENVIRONMENT AND PARAMETERS SETTING

The experimental setup employed an RTX2080TI graphics card with 11GB of memory and a total computer memory of 48 GB. Python served as the development framework. Parameters were configured as follows: a stride of 128 pixels, crop size of 256 × 256 pixels, four channels, a batch size of 8, a learning rate of 0.0003, and the Adam optimization algorithm.

Overall accuracy (OA), recall, F1 score, precision, Intersection over Union (IoU), and Kappa coefficient were utilized to evaluate the classification accuracy of the DeeplabV3+ network:

$$OA = \frac{TP + TN}{TP + TN + FP + FN} \tag{1}$$

$$recall = \frac{TP}{TP + FN} \tag{2}$$

$$precision = \frac{TP}{TP + FP} \tag{3}$$

$$F1 = \frac{2 * precision * recall}{precision + recall} \tag{4}$$

$$IoU = \frac{TP}{TP + FP + FN} \tag{5}$$

In Eqs. (1)-(5), TP represents the true positive values of accurate classification. TN represents the true negative values of accurate classification. FP stands for the false positive values incorrectly classified as positive. FN indicates the false negative values incorrectly classified as negative.

$$Kappa = \frac{p_0 - p_c}{1 - p_c} \tag{6}$$

In Eq. (6), p_0 signifies the overall accuracy of classification. p_c represents the probability of the predicted results matching the actual results completely.

C. PERFORMANCE EVALUATION

1) LAND CLASSIFICATION RESULT ANALYSIS

The dataset was classified using DeeplabV3+ in comparison with the Maximum Likelihood Method, Minimum Distance Method, and Mahalanobis Distance Method. The results are depicted in Figure 4:

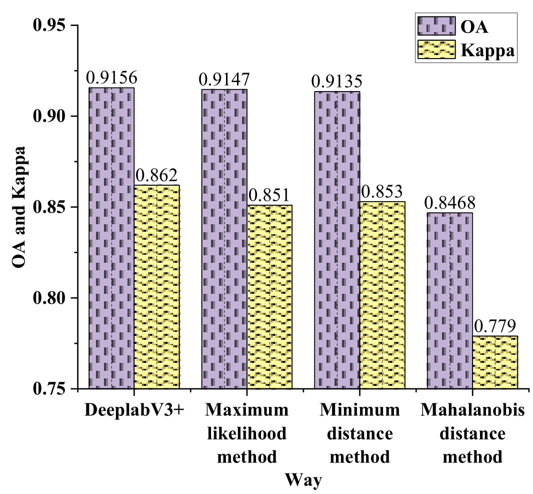

FIGURE 4. Comparison of semantic segmentation model classification results.

In Figure 4, the overall accuracy and Kappa coefficient of the DeeplabV3+ model are 91.56% and 0.862, respectively, representing the best results among the four methods. This data demonstrates a clear advantage of the DeeplabV3+ model over traditional methods. The land remote sensing image classification results for the years 2004, 2009, 2013, 2017, and 2021 are depicted in Figure 5.

In Figure 5, over the course of five years, the overall accuracy of land use classification data in Area C was 96.85%, 89.65%, 96.09%, 91.29%, and 91.56%, for the years 2004,

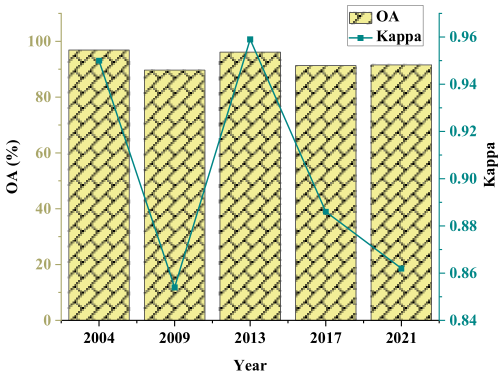

FIGURE 5. Classification accuracy of 5-Year remote sensing images in area C.

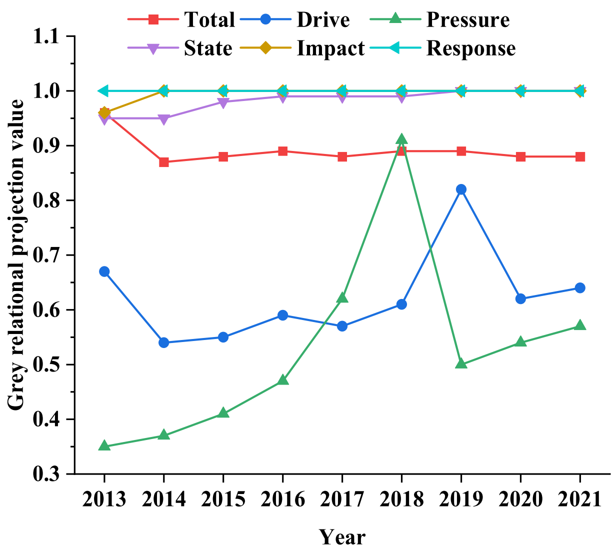

FIGURE 6. Ecological safety gray correlation projection values of ice and snow tourism destination in area C.

2009, 2013, 2017, and 2021, respectively. The Kappa coefficients were 0.95, 0.854, 0.959, 0.886, and 0.862, respectively. The overall accuracy consistently exceeded 89%, and the Kappa coefficient remained above 0.85, indicating that the DeeplabV3+ model exhibited favorable classification performance.

2) ECOLOGICAL SAFETY ASSESSMENT OF ICE AND SNOW TOURISM DESTINATION IN AREA C

The results of the gray correlation projection values for the systematic ecological safety of the ice and snow tourism destination in Area C for the years 2013-2021 are presented in Figure 6:

In Figure 6, the overall ecological safety of the ice and snow tourism destination in Area C remains stable, maintaining values around 0.88 and 0.89, corresponding to the mean levels of ecological safety among various subsystems. Overall, the impact and response systems play a pivotal role, indicating that internal efforts towards improvement and enhancement within the region are the decisive ecological

TABLE 2. Ecological security obstacle factor for ice and snow tourism destinations in area C from 2013 to 2021.

Index	2013	2014	2015	2016	2017	2018	2019	2020	2021
D1-1	0	0	0	0	0	0	0	0	0
D1-2	0	0	0	0	0	0	0	0	0
D2-1	0	0	0	0	0	0	0	0	0
D2-2	0.98	0	0	0.59	0	0.04	0	0	0
D3-1	0	0.01	0	0	0	0	0	0	0
P1-1	0	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.02
P1-2	0.01	0.17	0.1	0.02	0.04	0.04	0.04	0.07	0.07
P1-3	0	0	0	0	0	0	0	0	0
P2-1	0.01	0.52	0.52	0.17	0.45	0.48	0.23	0.41	0.4
P2-2	0	0	0	0	0	0	0	0	0
P3-1	0	0	0	0	0	0	0	0	0
S1-1	0	0	0	0	0	0	0	0	0
S1-2	0	0.01	0.01	0	0	0	0	0	0
S2-1	0.01	0.31	0.18	0.06	0.11	0.09	0.08	0.14	0.12
S2-2	0	0.11	0.04	0.02	0.02	0.04	0.05	0.1	0.09
S2-3	0	0.06	0.06	0.01	0.02	0.01	0.02	0.03	0.03
S2-4	0	0.06	0.01	0.02	0.01	0.02	0.03	0.03	0.04
S3-1	0	0	0	0	0	0	0	0	0
S3-2	0	0.01	0	0	0	0	0	0	0
I1-1	0	0	0	0	0	0	0	0	0
I1-2	0	0	0	0	0	0	0	0	0
I2-1	0	0	0	0	0	0	0	0	0
I2-2	0	0	0	0	0	0	0	0	0
I2-3	0	0.06	0.05	0.02	0.06	0.07	0.09	0.14	0.09
I3-1	0	0	0	0	0	0	0	0	0
I3-2	0	0	0	0	0	0	0	0	0
R1-1	0	0	0	0	0	0	0	0	0
R1-2	0	0	0	0	0	0	0	0	0
R1-3	0	0	0	0	0	0	0	0	0
R2-1	0	0	0	0	0	0	0	0	0
R2-2	0	0	0	0	0	0	0	0	0
R3-1	0	0	0	0	0	0	0	0	0

safety influencing factors. Furthermore, with a focus on vulnerable systems, it was observed that from 2013 to 2017, the ecological security levels of both the driving force and

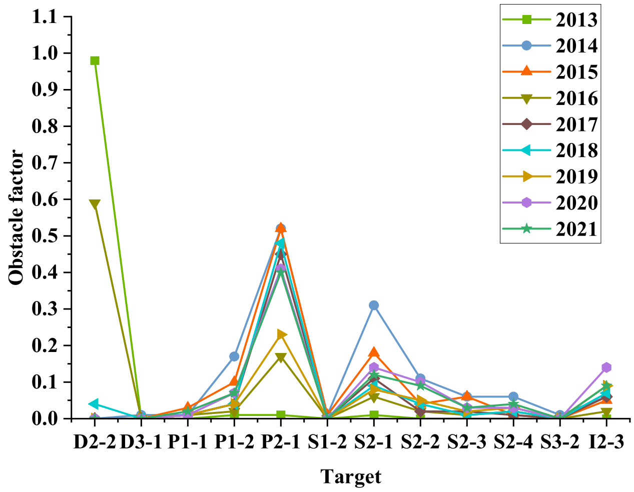

FIGURE 7. Ecological safety barrier factors of ice and snow tourism destination in area C.

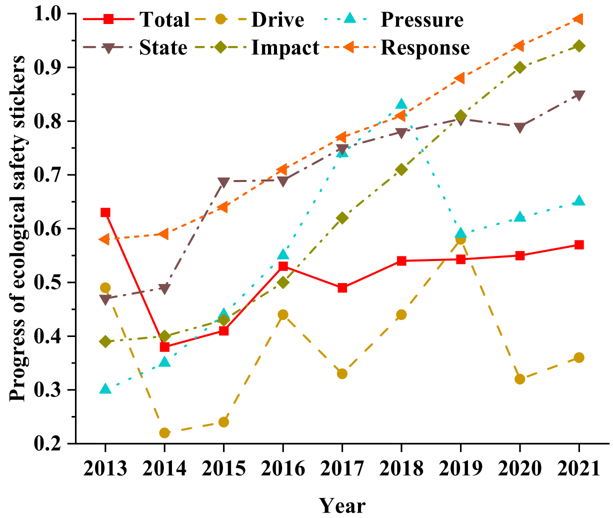

FIGURE 8. Ecological safety sticker schedule of ice and snow tourism destination in area C.

pressure systems were relatively low. This can be attributed, at its core, to the limited level of socio-economic development in the region, which constrained the improvement of regional ecological security. In contrast, in 2018 and 2019, both the pressure and the driving force systems reached their peak levels. This was a result of increased attention from local governments to regional development, thereby promoting the development of these two systems. However, in 2019 and 2020, both the pressure and driving force systems experienced a rapid decline. Some of the ice and snow projects and activities organized in Area C led to significant pressure on ecological security due to factors such as project initiation, a concentration of activities, and a sudden surge in tourists. This led to considerable resource consumption, ecological damage, and tourism capacity stress, resulting in significant ecological system changes. Consequently, this contributed to a decrease in the ecological security levels of the driving force and pressure systems.

The ecological security obstacle factor results for Area C from 2013 to 2021 are presented in Table 2.

This study selected data points from the indicators, with most having non-zero obstacle factors, and were plotted to create a data chart, as shown in Figure 7.

In Table 2 and Figure 7, in recent years, the primary obstacle factors for ice and snow tourism destinations in Area C have included tourism economic density (P2-1), regional ski trail quantity (S2-2), and tourism spatial density (I2-3). On the whole, the ecological safety threat to ice and snow tourism in Area C primarily stems from economic aspects. Among these, the obstacle impact of tourism spatial density is the most significant, with an average barrier factor of 0.12 and reaching a maximum of 0.31. This indicates that the enhancement of socio-economic development in Area C contributes to improving the ecological environment to some extent, yet economic growth also brings about multi-dimensional threats to the ecological environment.

3) ANALYSIS OF ECOLOGICAL SAFETY ALERTS IN ICE AND SNOW TOURISM DESTINATION IN AREA C

The study assessed the ecological security alerts for ice and snow tourism destinations in Area C based on their ecological security proximity. Ecological security alerts for ice and snow tourism destinations are categorized into five levels based on the proximity value: "Huge Alert" for proximity values in the [0, 0.2] range, indicating severe ecological environment degradation in ice and snow tourism destinations with a lack of environmental awareness. "High Alert" for proximity values in the (0.2, 0.4] range, signifying significant ecological environment degradation in ice and snow tourism destinations with weak environmental awareness. "Medium Alert" for proximity values in the (0.4, 0.6] range, indicating relatively serious ecological environment degradation in ice and snow tourism destinations with moderately weak environmental awareness. "Low Alert" for proximity values in the (0.6, 0.8] range, representing ice and snow tourism destinations with moderate ecological environment protection and limited environmental awareness. "No Alert" for proximity values in the (0.8, 1] range, indicating excellent ecological environment quality in ice and snow tourism destinations with strong environmental awareness. The weighted TOPSIS method yielded the ecological safety sticker schedule for the years 2013-2021 in Area C, as depicted in Figure 8.

In Figure 8, from 2013 to 2018, the ecological security of various subsystems experienced a rapid decline in alert levels during a phase of high-speed development. Subsequently, the alert levels of the response, impact, and status systems continued to decrease, reaching a state of no alert in 2018, with ecological security proximity values of 0.81. The impact system and state system reached a state of no alarm in 2019, and the ecological security proximity of these two systems was 0.81 and 0.804, respectively. However, the driving force system remained in a state of intense fluctuation throughout this period, with a proximity value of 0.36 in 2021, declining to a state of high alert. Overall, ecological security and the pressure system both reached their peaks in 2013 and 2018, with proximity values of 0.63 and 0.83, respectively, corresponding to low alert and no alert states. Subsequently, they underwent a "decline-recovery" process. In summary, there is a need to prioritize improving the alert levels of the driving force system, followed by the pressure system, to reduce the overall ecological security alert levels.

4) ANALYSIS OF BRAND COMMUNICATION STRATEGIES FOR ICE AND SNOW TOURISM DESTINATION IN AREA C

Based on the preceding analysis, the ice and snow tourism destination in Area C possesses potential brand communication assets in terms of natural resources, ecological environment, and sustainable development. Through precise landscape classification and ecological safety assessment, Area C can utilize various communication strategies to shape its brand image. These include promoting natural scenery, ecological conservation, marketing brand stories, digital communication, and collaborative promotion.

Using high-resolution remote sensing images and the classification outcomes of DL models, images and videos showcasing the magnificent natural scenery of the ice and snow tourism destination in Area C can be created for promotion across official websites, social media, and tourism brochures. Additionally, leveraging the data from ecological safety assessments and barrier factor analysis, Area C can emphasize its commitment to ecological environment protection and sustainable development, infusing environmental awareness into brand communication to attract eco-conscious tourists. Integrating the historical, cultural, and natural characteristics of Area C, a unique brand story can be crafted, fostering emotional resonance between tourists and the brand and conveying Area C's values and distinctive features through the brand narrative. In essence, highlighting the strengths of Area C's natural landscape, ecological conservation, unique characteristics, and sustainable development can lead to the establishment of a positive, distinct, and captivating brand image, thereby attracting greater attention and participation from tourists.

D. DISCUSSION

In conclusion, in recent years, economic factors have exerted the greatest influence on the ecological safety of ice and snow tourism destinations. Moreover, Ruan et al. innovatively proposed a tourism ecological safety assessment model based on the ecosystem theory, termed "Driving Force-Pressure-State-Impact-Response-Data Envelopment Analysis," for measuring the sustainable development of tourist destinations. This model revealed that key factors affecting tourism ecological safety include the growth rate of the tertiary industry and tourist density [25]. In the Hexi Corridor region context, Li et al. assessed the impact of land use and land cover changes on ecosystem services and ecological safety patterns. Their findings indicated that ecosystem services significantly increased under an ecological protection scenario, and ecological safety in the relevant area was enhanced [26]. Fernández et al. introduced a novel comprehensive index construction method to analyze factors influencing tourism competitiveness. The results indicated that aviation infrastructure, cultural resources, and information and communication technology readiness were critical factors affecting tourism competitiveness [27]. In summary, the ecological safety of tourist destinations is influenced by multiple factors, with economic factors having the most significant impact.

V. CONCLUSION

A. RESEARCH CONTRIBUTION

In order to analyze the ecological safety and brand communication of ice and snow tourism destinations, this study focuses on the ice and snow tourism destination in Area C. The roles of IoT and DL in its ecological safety assessment were examined, and the DeeplabV3+ model and the DPSIR-EES model were employed to evaluate its ecological safety and analyze its brand communication strategies. The following conclusions were drawn from the experiments:

(1) Validation of model superiority: In the field of remote sensing image classification, the experiment employed the DeeplabV3+ model and demonstrated its excellence in this specific application through experimental evaluation. The results showed that the DeeplabV3+ model achieved an overall accuracy of 91.56% and a Kappa coefficient of 0.862, both of which were higher than the results obtained using the Maximum Likelihood method, Minimum Distance method, and Mahalanobis Distance method. This data indicates a significant advantage of the DeeplabV3+ model over traditional methods. This not only validates the performance of the DeeplabV3+ model but also provides robust support for its application in ecological security assessment.

(2) Identification of key factors: The experimental evaluation revealed that the overall ecological security of Area C's ice and snow tourism destinations remains stable, maintaining between 0.88 and 0.89. More importantly, the study successfully identified the major factors influencing ecological security, with economic factors playing a critical role. The high obstruction degree of the tourism spatial density factor underscores its importance in ecological security (with an average obstruction degree factor of 0.12 and a maximum of 0.31). This finding provides vital clues and a basis for the ecological security management of ice and snow tourism destinations.

(3) Provision of brand communication strategy optimization recommendations: The experimental evaluation provides specific recommendations for brand communication. By promoting natural landscapes, ecological conservation measures, digital communication, and collaborative advertising, the experiment places particular emphasis on the advantages of Area C's ice and snow tourism destinations in terms of

natural scenery, ecological preservation, unique features, and sustainable development. These strategies not only enhance brand recognition but also contribute to the protection of the ecological environment and the elevation of brand value.

In summary, the experimental evaluation plays a crucial role in this study. It validates the superiority of the model, provides an understanding of key factors, offers strong support for brand communication, enhances the credibility of the study, and provides feasible scientific evidence, all of which have significant practical implications for the ecological security and brand communication of ice and snow tourism destinations.

B. FUTURE WORKS AND RESEARCH LIMITATIONS

Firstly, this study only selected data from the years 2013 to 2021 as the original data for ecological safety assessment, covering a limited number of years. In future research, extending the study period to cover 20 or 30 years could explore trends in ecological safety changes over a longer timeframe. Secondly, ecological safety assessment and brand communication are complex multi-dimensional issues that additional factors, including policies and socio-cultural aspects, may influence. These factors require further in-depth research and exploration. In future ecological safety assessments, the incorporation of more quantitative models and indicators can lead to more accurate ecological safety assessment and prediction. Additionally, the consideration of dynamic models could predict the impact of different decisions on the ecological environment.

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