

Unveiling interprovincial geographic patterns of 5A-level tourism cultural ecosystem service flows and tourist preferences in China's metacoupled systems

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ABSTRACT

In the metacoupling Anthropocene, tourism-based culture ecosystem services flows (CESF) can establish non-material bridges from the natural to the human system, even across vast geographic distances. However, there remains a knowledge gap regarding investigation of nature-related tourist travel patterns at geographic flow scales. To address this gap, we analyzed the intracoupling (within-province), pericoupling (adjacent-province), and telecoupling (distant-provincial) flow patterns using a sample of 143,681 5A attractions travel comments with Internet Protocol (IP) location data. Emotional preferences derived from travel reviews were then quantified using machine learning models in China's post-COVID-19 pandemic era. The results showed significant spatial differences in nature-based 5A-level CESF, China's telecoupling performance of CESF (0.34) is higher than pericoupling (0.20), but intracoupling (0.46) remains dominant. Tourists from northeastern provinces exhibited a preferences for telecoupling, while those from southwestern provinces showed intracoupling patterns. Forest ecosystems contribute nearly one-third (30.70%) of cultural services and are primarily characterized by intracoupling patterns. Sentiment analysis indicated that tourists' emotional preferences vary with travel distance, with long-distance tourists tending to appreciate indigenous cultures. Overall, this study provides new insights into investigating the dynamics of CESF, which could inform policy actions aimed at revitalizing the tourism sector.

1. Introduction

Nature-based tourism activities are often closely connected with cultural ecosystem services flows (CESF) (Heslinga et al., 2018; Yan & Hongzhong, 2020). Tourist flows intensify the people-nature nexus (Nikolova et al., 2021), offering new horizons to understand CESF patterns (Milcu et al., 2013; Willis, 2015). User-based CESF often leads to a

win-win situation (Heslinga et al., 2018), directly promoting sustainable development goals (SDGs) in indigenous areas (Dwyer, 2022) and providing intangible benefits for tourists at higher levels of the Maslow hierarchy (Yousaf et al., 2018), such as psychological health, artistic enrichment, and physiological benefits (Cheng et al., 2019; Kosanic & Petzold, 2020; La Rosa et al., 2016). However, the pattern of CESF is complex and difficult to quantify (Plieninger et al., 2013), influenced by

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multiple factors such as economic, social, climatic, disasters, geopolitical, and epidemic factors (Henok, 2021). There remains a significant knowledge gap (Mengist et al., 2020).

After the publication of the Millennium Ecosystem Assessment report (ME., 2001), researchers have been dedicated to using traditional models to investigate tourists' perceptions of natural landscapes, thereby revealing the value and flow patterns of cultural ecosystem services (Cheng et al., 2019). These methods include field surveys (Palomo et al., 2013), questionnaires administered on-site, via telephone, or over the internet (Xu et al., 2019), participatory GIS mapping (Wu, 2013), empirical evaluation (Brown et al., 2016), geographical information technology (Karasov et al., 2020), spatial display (Wang et al., 2021) and others (Plieninger et al., 2013). While CESF based on supply and demand relationships has been widely researched and promoted, traditional survey methods are limited to landscape-scales due to data availability and practical considerations (Chen et al., 2023; Nahuelhual et al., 2013).

The advent of the big data era has revolutionized traditional research paradigms (Happ & Ivancsó-Horváth, 2018). The influx of multi-source big data has injected new vigor into research on tourism-based CESF, leveraging sources such as mobile phone signaling (Chen et al., 2023), social media (Ghermandi et al., 2020), travel blog postings (Muldoon et al., 2023), and short video apps (Zhao et al., 2022). Datasets encompassing various flows have been collected to scrutinize traveler behavior, movement, and preferences (Nikolova et al., 2021). Online blog photos have been utilized to discern tourists' perceptions and values regarding valley and vineyard landscapes (Bachi et al., 2020). Utilizing geolocated tourism blog data, investigations have been conducted into the spatio-temporal behavior patterns of Chinese tourists traveling to Nordic countries (Zheng et al., 2021). Some studies have examined the flow trajectories of tourists using Tencent Location Big Data (Pan & Lai, 2019) and the Baidu Migration Index (Yang et al., 2021). However, large-scale population migration indices often struggle to distinguish between tourism and commuting. The Chinese government encourages online platforms to be transparent about users' IP locations starting from August 2022. We observed that on the Chinese tourism sharing platform Ctrip (vacations.ctrip.com), tourist comments often include IP locations, enabling accurate indication of tourists' flows from their residence to destination. This facilitates a more precise and efficient depiction of tourism-based CESF. Nonetheless, currently, few studies have integrated this data into research.

Navigating the flows of tangible and intangible elements, including materials, capital, and information, is essential for sustainable development in a complex networked world (Liu et al., 2016; Shahbaz et al., 2021). The impact of distant systems is greater than that of adjacent systems, contrary to Tobler's First Law (Manning et al., 2023). This phenomenon is evidenced by factors such as cross-national tourism (Bowden, 2003), El Niño (Liu, 2023), virtual land in cross-border trade (Carlson, Taylor, et al., 2020), and shifting environmental impacts (Zhao et al., 2021). In 2017, Liu (2017) presented a comprehensive metacoupling framework, comprising intracoupling (e.g., human-nature interactions through CESFs within a province), pericoupling (e.g., human-nature interactions through CESFs between adjacent provinces) and telecoupling (e.g., human-nature interactions through CESFs between distant provinces) (Liu, 2017), offering innovative perspectives on comprehending and exposing human-ecosystem connections. Together, intracoupling, pericoupling and telecoupling constitute metacoupling (Liu, 2023). This framework is extensively used in research on ecosystem service flows (Liu et al., 2018; Zhang et al., 2023), encompassing food provision (Carlson et al., 2020), wind and sand control (Xie et al., 2019), carbon sequestration (Wang et al., 2022), soil conservation (Zhao et al., 2018), pollination, and species migration (Xu et al., 2020). Currently, no scholars concerning CESF research have utilized the metacoupling framework to reveal tourist behavior preferences and patterns.

The COVID-19 pandemic has reshaped the spatial dynamics of

tourism flows, introducing complexity into tourist preferences (Yang et al., 2021), especially concerning long-distance travel. Extensive research has delved into the factors influencing tourist preferences, encompassing economic, social, environmental, cultural, political, and disaster-related elements (Henok, 2021). With the proliferation of internet media technology, the methodology of analyzing tourist emotional preferences through keyword extraction from social media blogs (Yan et al., 2018) and examining tourists' digital footprints (Mou et al., 2020) has gained popularity. Social blogging and shared photographs are frequently utilized to illuminate the performance of cultural services and tourists' cognitive processes (Ghermandi et al., 2020). The adoption of machine learning for tourist sentiment analysis is on the rise, offering more robust outcomes compared to traditional methods (Wawre & Deshmukh, 2016). Natural language processing techniques within the realm of artificial intelligence enable the extraction of quantified sentiment datasets from shared tourist content, such as online tourism reviews (Schuckert et al., 2015), through generative mechanisms. Average semantic orientation (Jabreel et al., 2017), convolutional neural networks (Martín et al., 2018), and sentiment word vector methods based on machine learning (Li et al., 2018) are utilized to discern tourist sentiment from textual comments. Exploring tourist emotional preferences based on their behavior and perceptions furnishes valuable insights for tourism managers to enhance local tourism experiences and devise effective tourism strategies (Ghermandi et al., 2020).

The Chinese government is actively promoting cross-regional tourism to stimulate domestic tertiary economic growth (Zhang & Zhang, 2023), mitigate urban-rural inequality (Tan et al., 2023), enhance tourism sustainability (Buhalis et al., 2023), and offset the negative socioeconomic effects of the COVID-19 pandemic (Fan et al., 2023). However, the current understanding of the cross-border pattern of CESF and tourist preferences in China is limited (Xie et al., 2019). To bridge this research gap, we investigated the cross-provincial CESF using comment blog datasets and the metacoupling framework. Subsequently, we extracted tele-distance traveler flow sentiment preferences from comments data using SnowNLP machine learning tools. Our study aims to address the following three questions: (1) What is the geospatial pattern of CESF at the provincial level in China? (2) What are the performances of CESF at the provincial- and ecosystem-scales within the metacoupling framework? (3) What are the main emotional preferences of tourists and their impact on tele-distance travel?

2. Materials and methods

2.1. Location of nature-based 5A scenic sites in China

With a territorial area of 9.6 million km², China boasts diverse climatic zones and topography, resulting in a wide array of breathtaking natural landscapes (Chen et al., 2022). These landscapes span from diverse tropical, marine, and biodiversity-rich areas in South China to polar landscapes in North China; from mountain landscapes with abundant vegetation to desert and oasis landscapes in Northwest China (Fig. 1). All ecosystem types can offer cultural services that are intangible and potentially beneficial to humans (Daniel et al., 2012). The Chinese government has categorized scenic areas into five grades from A to AAAAA (5A), with more A's indicating higher grades, based on various factors, including the number of tourists, popularity, and public recognition (mct.gov.cn). Here, we spatially depict the distribution of scenic areas, focusing on 5A scenic areas as of the deadline on December 31, 2022 (Fig. 1).

In addition, by utilizing ecosystem classification labeling (naturese.rve.org) and considering the diverse characteristics of Chinese ecosystem landscapes, we categorized nature-based tourist attractions into twelve types (Fig. 1). Unique cultural services to humans are also provided by novel ecosystems such as belowground and cryosphere ecosystems (Fig. 1). Biodiversity is highlighted because tourists predominantly engage in observing a variety of flora and fauna, such as



Fig. 1. The spatial distribution of China's 5A scenic site with 12 examples of cultural ecosystem services types, each accompanied by corresponding photos. (The spatial location of scenic spots was displayed using Google Maps (google.com.hk/maps) and Arcmap 10.2 tools (esri.com). The base Chinese map data was sourced from the CnOpenData (cnopendata.com), which is publicly available. The dots, represented in various colors, indicate both the type of ecosystem and the spatial placement of the viewpoints. These colors align with the preservation of the indicator lines and dots used in the case viewpoints. I: Arctic village, Mohe, Heilongjiang; II: Lianzhou Underground River, Qingyuan City; III: Shennongjialin, directly administered forestry reserve, Hubei; IV: Wild Animal Park, Shanghai; V: Suzhou Garden, Jiangsu; VI: Xixi National Wetland Park, Hangzhou; VII: Wuzhizhou Island, Sanya; VIII: Detian Transnational Waterfall Scenic Area, Guangxi; IX: Yarlung Tsangpo Grand Canyon, Tibet; X: World Devil City, Karamay, Xinjiang; XI: Yili Nalati Tourist Scenic Area, Xinjiang; XII: Alxa League Poplar Forest Tourist Area, Inner Mongolia. All scenic images were donated to Ctrip travel sharing platform (vacations.ctrip.com).).

migratory birds and animal diversity in zoos (Fig. 1 IV). Urban landscape ecosystems are also emphasized because humans intentionally exploit urban ecosystems to fulfill the demand for cultural amenities over short commutes, such as urban parks (Fig. 1 X). Additionally, we propose the mountain and water ecosystem type, as it is commonly found in tourist attractions (20.28% of all scenic spots, Table S4).

2.2. Data sources and pre-processing

In this study, we utilized user datasets from travel blogs, including IP locations and comments, as a crucial data input for assessing CESF

patterns (Fig. 2). Acquiring precise data on China's tourist population flows at the provincial level is indeed a challenging task (Paolanti et al., 2021). We identified agent-based quantitative information on tourist flows using IP locations from Ctrip.com's attraction comments. Note that the IP location refers to the province associated with a long-term IP address, which is difficult to change with the movement of tourists. This differs from IP addresses that change rapidly with different network interfaces.

We identified tourist mobility routes across regions by establishing connections between the IP locations of commenters and their tourist destinations. For instance, when a visitor with an IP location from

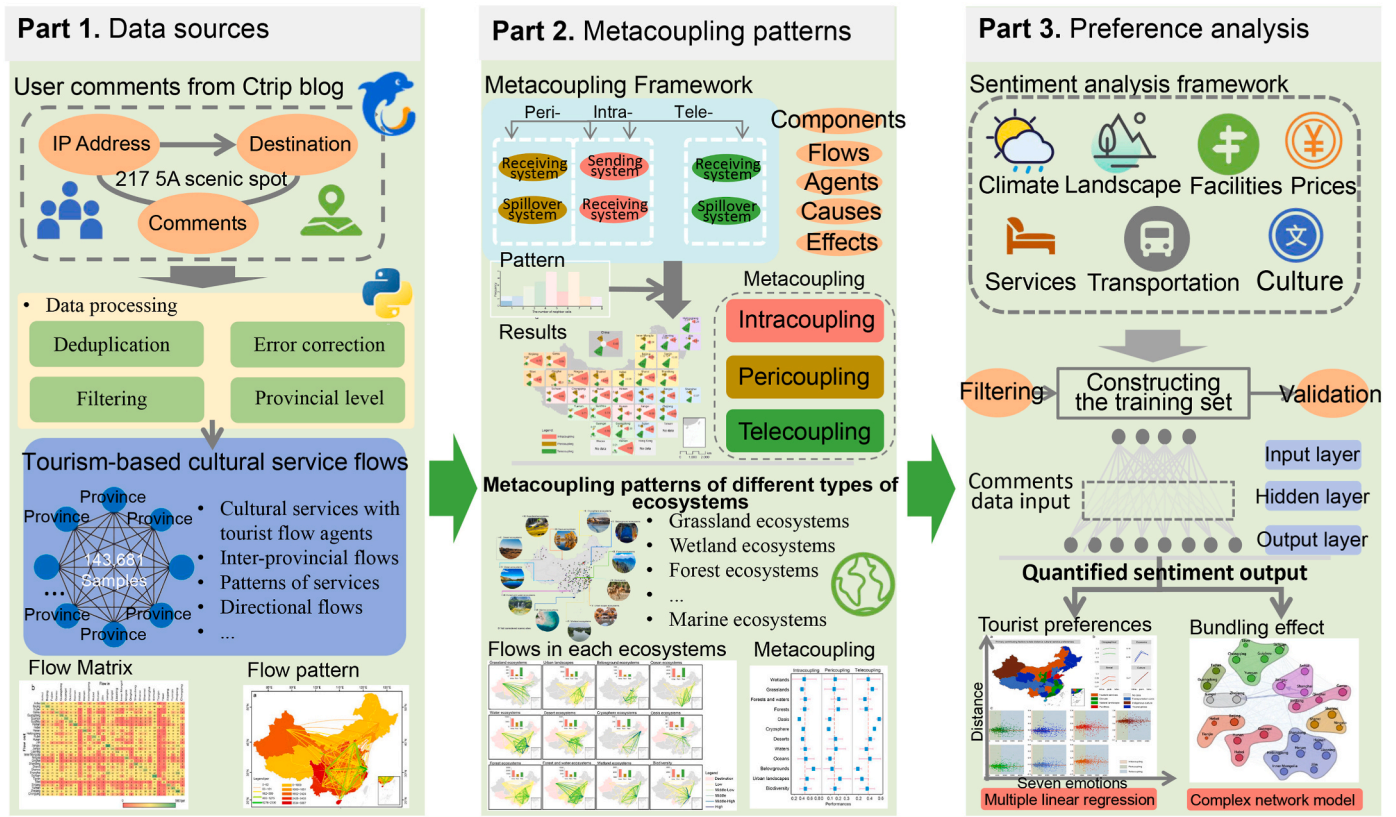


Fig. 2. The technological framework depicted in this study.

Beijing posts comments on a tourist site in Sichuan’s Jiuzhaigou and enjoys cultural services in Sichuan, it is evident that they traveled from Beijing to Sichuan. To implement this criterion, we selected the Ctrip travel platform (vacations.ctrip.com) as the source of visitor IP acquisition through comments. As a leading platform in the online travel industry, Ctrip has approximately 84 million active users (Zheng, 2024). The number of scenic spot comments on Ctrip significantly surpasses those on other travel platforms, providing a more credible sample volume for this work. The IP location information on the Ctrip platform was officially made public in August 2022, and we obtained comments on all 5A nature-based attractions and their corresponding IP locations up to September 13, 2023. In this study, we focus exclusively on reviews of

5A-rated attractions. These attractions were selected for their broad regional influence, high frequency of tourist interactions, and ability to generate a substantial volume of reviews, ensuring a robust data sample. Other challenges, such as handling ratings below 5A (from 4A to A), difficulties in obtaining IP location data, large amounts of invalid statistics, and limited review availability, were also encountered. Finally, we conducted searches and obtained a total sample size of 202,557. Subsequently, we eliminated duplicate entries based on commentator names, comments without IP location information, and removed samples with IP locations in foreign territories. In the end, our study acquired 143,681 valid samples as data input and constructed a 31 × 31 directedness matrix (Fig. 4b).

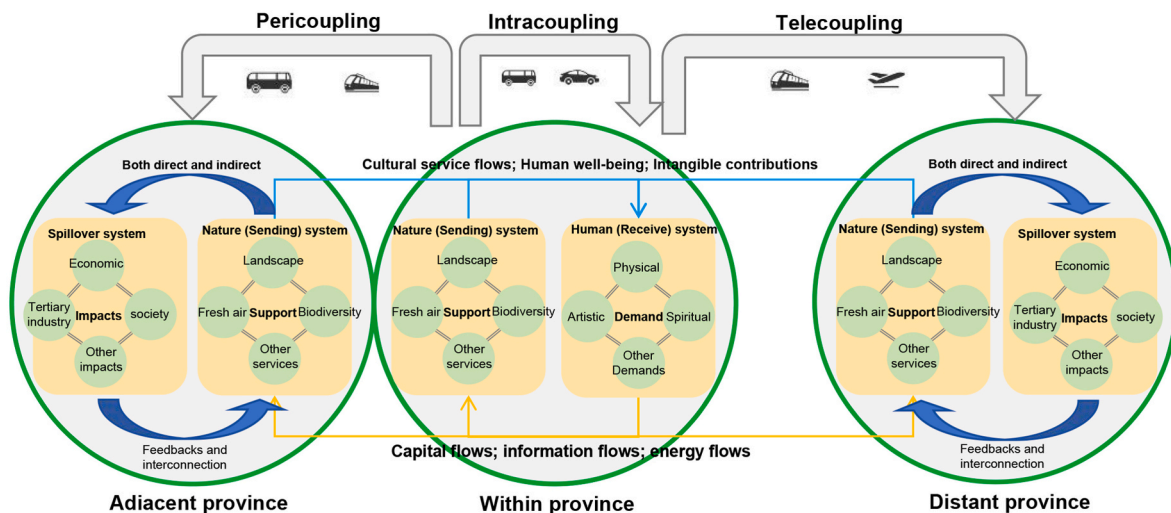


Fig. 3. Metacoupling framework concerning the CESF and tourism cross-provinces.

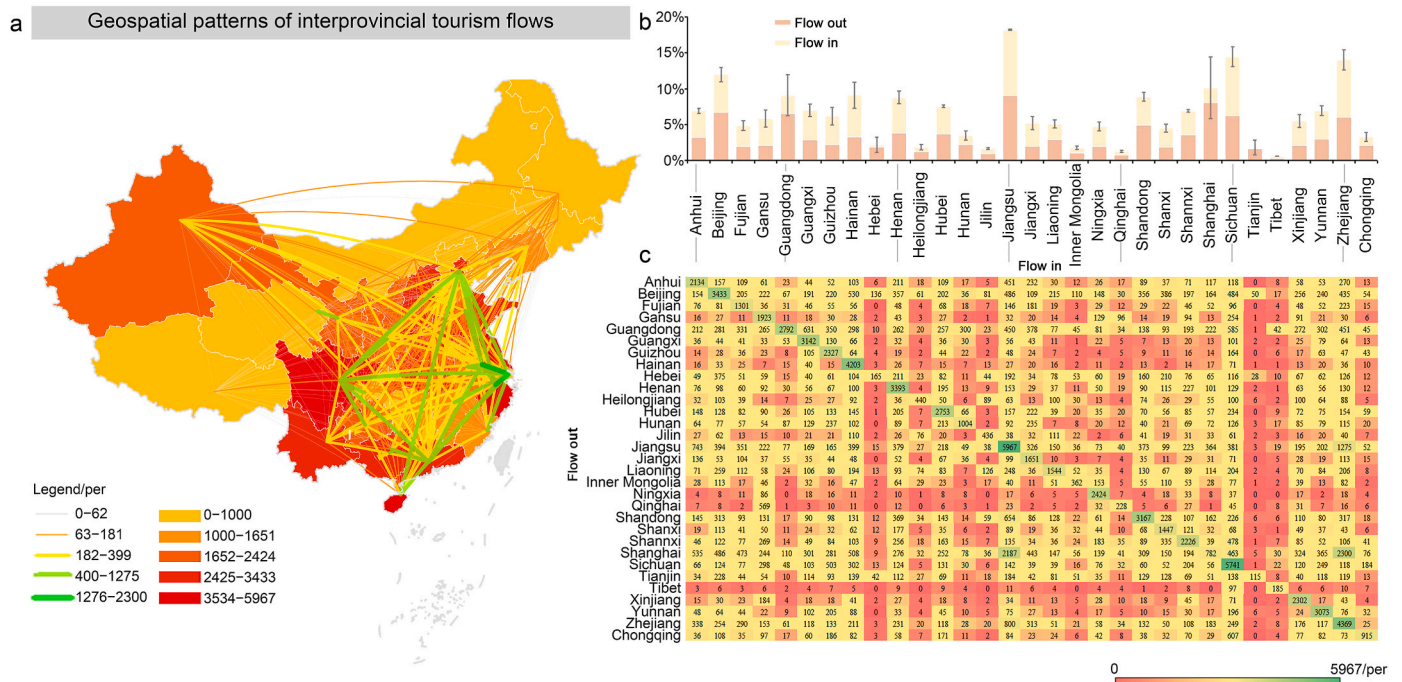


Fig. 4. Interprovincial flow patterns of tourism-based cultural services. (a. Spatial patterns of interprovincial tourism flows; b. Percentage of inflows and outflows concerning each province; c. Directed tourism flows matrix.)

In addition, we collected auxiliary data on 318 5A tourist attractions (with a deadline of December 31, 2022) from official portals of the Ministry of Culture and Tourism (mct.gov.cn) and each province, autonomous regions, and municipalities. We manually screened the public list of scenic spots provided by the China Tourism and Landscape Association (china-npa.org) to emphasize nature-based ecosystem cultural services. Excluded from consideration were museums, art galleries, memorials, amusement parks, commercial streets, urban architectural scenic spots, and shooting ranges, as they are not relevant to this study. Representative natural landscapes included waterfalls, glaciers (Fig. 1 I), hills, zoos (providing biodiversity services, such as Fig. 1 IV), grottoes (Fig. 1 X), mountains, lakes, water, hot springs, canyons, national parks, ecological restoration results of poplar forests, and others (Fig. 1 VII). Following manual screening, we eliminated unsuitable scenic spots, resulting in a total of 217 scenic locations with a 5A rating (Table S4).

2.3. Methodology

To uncover the geospatial pattern of tourism-based CEFs and tourist sentiment preferences across metacoupled framework, this work comprises three main parts (Fig. 2). Firstly, we gathered 143,681 valid user comment data from Ctrip travel blogs. Secondly, we analyzed the spatial patterns and levels of CEF at both provincial and 12 ecosystem scales using the metacoupling framework. Thirdly, we developed a sentiment analysis framework to investigate tourist sentiment preferences and contributions during tele-distance travel, employing machine learning models and multiple regression models. The workflow for this research is depicted in Fig. 2.

2.3.1. Quantifying CEF level based on metacoupling framework

Here, we present a theoretical framework aimed at elucidating the pattern of CEF across metacoupled systems (Fig. 3). This theoretical framework emphasizes the connections between natural (sending) systems and human (receiving) systems, utilizing cultural services as a crucial bridge. It takes into account the interplay between human and natural systems by simultaneously examining intracoupling, pericoupling, and telecoupling (Fig. 3). Within this framework, individuals

actively pursue cultural experiences (such as landscapes, biodiversity, and other ecosystem services) and endeavor to fulfill their needs through transportation, termed as user movement-based cultural services (Costanza, 2008). Note that, to reveal the relative differences in cultural services across geographic regions, we propose the hypothesis that each visitor receives the same amount of experience and value from cultural services. The theoretical framework is shown in Fig. 3.

Our goal was to assess intracoupling, pericoupling and telecoupling CEF within the metacoupled systems. Initially, we constructed a 31 × 31 directivity matrix of cross-provincial flows (Fig. 4b). Subsequently, we developed a mobility classifier for each province to distinguish metacoupling patterns, which was derived from the neighborhood weights of the vector in Geoda software (Fig. S2). These classifiers were then integrated into the flow matrix to calculate the actual performance of intracoupling, pericoupling, and telecoupling flows. Finally, drawing on methodologies from previous studies (Carlson, Taylor, et al., 2020), we utilized the proportion of CEF flow to determine the level of metacoupling performance. The formulas utilized are as follows:

$$R_{intra} = \frac{N_r}{\sum_1^n Total_r} \tag{1}$$

$$R_{peri} = \frac{\sum_0^i N_r}{\sum_1^n Total_r} \tag{2}$$

$$R_{tele} = \frac{\sum_0^j N_r}{\sum_1^n Total_r} \tag{3}$$

where R_{intra} , R_{peri} , and R_{tele} represent the performance of intra-, peri-, and tele-coupling in the province r , respectively. $Total_r$ represents the total number of travelers from province r to another provinces, and n represents all provinces except province r , thus n equal 30, in above formulas. Benchmarked against province r , i and j represent periprovincial and

teleprovincial, respectively.

2.3.2. Sentiment analysis

To assess tourists' preferences for cultural services from tourism blog comments, this study introduces a sentiment analysis model. This model categorizes the emotions or attitudes expressed in subjective texts (Mehraliyev et al., 2022), allowing for the quantification of tourism comments through large-scale text data processing and the identification of general patterns. This approach helps mitigate the subjectivity and randomness often associated with traditional survey models (Song et al., 2022). By analyzing tourism comments overall using this model, we can uncover tourists' behavioral preferences for tourism. The factors influencing tourists' preferences for accessing cultural services are diverse, particularly in the post-pandemic era (Zhang et al., 2022a). Here, we propose a framework for quantifying tourist sentiment based on user comments (Table 1).

This study introduced the natural language processing (NLP) method, SnowNLP, to analyze tourists' preferences for cultural services hidden behind comments. SnowNLP is a Python library used for Chinese text segmentation, part-of-speech tagging, text classification, and more (Song et al., 2022). The tool includes a universal dictionary where each term is assigned a part-of-speech code (e.g., noun, verb, adjective, adverb). Based on context and semantic information, our text mining automatically structures text into phrases (Zhang et al., 2022b). First, we cleaned the data from travel blog comments, removing noise such as blank spaces, duplicates, and irrelevant data, resulting in a total of 94,469 comments (Fig. 2). Second, we constructed seven different emotion training models, derived from valuable comments comparisons and manual reviews (Table S1). Third, we inputted the training models into the sentiment analysis model and used Python software to score the emotional polarity of each comment. Finally, we randomly selected 140 comments as the test set to evaluate its accuracy. The emotional values were normalized to a range between -1 and 1 (Liu et al., 2024). Overall, the semantic classification accuracy of this experiment exceeded 75%, and the evaluation accuracy of the seven indicators can be found in Table S4.

2.3.3. Multiple linear regression

To investigate the factors influencing interprovincial long-distance tourism under the metacoupling framework, we introduced a multiple

Table 1

Sentiment assessment framework. (After reviewing several papers regarding factors influencing tourists (Henok, 2021), we identified seven indicators that could be related to long-distance travel. Among these indicators, travel distance subtly influences tourists' emotions.

Pillars	Indicators	Significance
Geographical	Climate	Tourists tend to access cultural services in long-distance regions with comfortable climates
	Natural landscape	The beautiful natural landscapes serve as the most compelling evidence attracting tourists to long-distance travel
Cultural	Indigenous culture	Incorporating indigenous culture into their tourism experiences is an important factor influencing tourism sentiment
Economic	Tourist expenses	The expenses of hotels, tickets, and other amenities are vital factors that determine tourists' travel preferences
	Transportation costs	Transportation costs, specifically monetary expenses, directly influence tourists' destination choices for long-distance travel
Social	Facilities	Tourists often consider the level of infrastructure at the destination when traveling across regions.
	Tourism services	The tourism service quality of tourist attractions is often commented by tourists on blogs.

linear regression model. Most studies tend to examine tourist flows by primarily focusing on economic factors (Henok, 2021). We aimed to reveal the influencing factors of interprovincial long-distance tourism under the metacoupling framework. Here, we introduce a multiple linear regression model to explore the relationship between seven tourism sentiment preference indicators and travel distance. In multiple linear regression, understanding the contribution of each variable can typically be reflected by regression coefficients (Cao et al., 2023). We conducted a collinearity test on the seven independent variables using the variance inflation factor (VIF) test (Toosi et al., 2022), and the results indicate no collinearity among these indicators. The regression coefficients indicate the degree of influence of each independent variable on the dependent variable (Cao et al., 2023). The causality of each province is simulated iteratively using the following formula:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_p x_p + \varepsilon \quad (4)$$

Where y represents the dependent variable (the explained variable), x represents the independent variables (the explanatory variables). β represents the coefficients of each variable, i.e., the explanatory variables. P denotes the number of explanatory variables, i.e., a p -dimensional linear regression model. ε represents the random error term. In this study, tourist travel distance is the dependent variable, while the sentiment level of the seven variables represents the independent variables, i.e., $p = 7$ in this formula. In cases where the model is significant, a positive coefficient indicates a positive effect on the long-distance cultural service experience. The higher the coefficient, the greater the contribution of this tourist preference to the factors influencing long-distance cultural services.

2.3.4. Modularity classification in network models

In our study, we utilized a complex network model unveil the bundle patterns of CESF. This method facilitated the quantification of functional connectivity between distant systems (Yang et al., 2022), offering advantages in identifying distant linked components (Chung et al., 2020), analyzing spatial dynamics across scales, and studying long-distance feedback mechanisms and spillover effects. This method is commonly employed in the study of directed networks (Cao et al., 2023).

The modularity class is often employed to determine community stability, boundary lines, and weights within a network, aiding in the identification of regional bundles. This method is crucial for reevaluating the regionalization of cultural services, providing an unprecedented perspective on the management of cultural service clusters and cross-border tourism connections (Li et al., 2022a; Liu et al., 2023).

This paper utilizes social network analysis to construct a metacoupling network model, denoted as $G = (N, E, W)$, for interprovincial CESF in China. To achieve self-organized learning and recognition, we utilized an unmoderated method for the model, resulting in the identification of nine valuable communities. We then imported this matrix into Gephi 0.10.2 software (gephi.org) for indicator calculation. The formulas are as follows:

$$G = (N, E, W) \quad (5)$$

$$Q = \sum \left(\frac{I}{E} - \left(\frac{2I + O}{2E} \right)^2 \right) \quad (6)$$

where, N represents the provincial nodes of the CESF network, E comprises cross-provincial cultural service edges (flows) totaling 906 drains with clear directionality (Fig. 4c), and W denotes the weights of tourist traffic between provinces. A weighted matrix corresponding to the CESF between the two provinces (Fig. 4a). I represents the number of edges where both endpoints are in the same community, and O denotes the number of edges where one of the endpoints is in the community and the other endpoint is not. The values of Q in the three communities are calculated and then summed up to obtain the required values.

3. Results

3.1. The geospatial pattern of CESF networks

We observed a significant spatial heterogeneity in CESF, where the attenuation of flow intensity is associated with an expansion of radiation coverage (Fig. 4a). Notable spatial disparities in CESF were observed, with low flow intensities observed in the Northwest (10.45%) and the Northeast (5.05%) of China (Table S3). A closed network pattern of elevated CESF has been established in provinces exhibiting a high-level flow, including Beijing, Sichuan, Hainan, Guangdong, Shanghai, and Jiangsu (Fig. 4a). Particularly, Jiangsu and Shanghai shine brightly in the evidence presented (Fig. 4a). Moreover, we observed a secondary tier within the flows networks characterized by cities located in Xinjiang, Yunnan, Guangxi, Liaoning, Henan, and Shandong, which exhibit a much wider radius (Fig. 4a). The lowest tier of the network encompasses far-reaching areas such as Heilongjiang and Tibet.

In terms of directed outflows and inflows, Jiangsu, Zhejiang, and Sichuan constitute distant inflow tele provinces (Fig. 4b and c). North and Southwest China are also typically high-intensity areas for inflow remote provinces (Fig. 4b and c). Interestingly, there is a significant decrease in outflows in Southwestern China compared to inflows within provinces (Fig. 4b). This suggests that individuals in Southwest China are more likely to seek cultural services within provinces. In contrast, Shanghai, Guangdong, and Hainan—primarily situated in the Southeastern coastal region—display considerably higher outflows than inflows (Fig. 4b). Cultural services in distant provinces seem to be more

attractive to these regions.

3.2. Metacoupling of CESF

3.2.1. Metacoupled pattern in national and provincial scales

We observed that, at the national level, CESF is still predominantly dominated by intracoupling (0.46). Notably, higher levels of telecoupling (0.34) is revealed compared to pericoupling (0.20) (Fig. 5). These results imply that CESF tend to favor interactions with tele-provinces over those with peri-provinces. Provincially, about 19 provinces are characterized by intracoupling dominance (61.29%); pericoupling and telecoupling constitute 6.45% and 32.26%, respectively (Table S1).

Regionally, the pattern of metacoupling performances exhibits notable spatial variation and cluster effects (Fig. 5). For instance, the northeastern regions, including Heilongjiang, Jilin, and Liaoning, demonstrate a prevalence of telecoupling, with performances of 0.68, 0.51, and 0.56, respectively. In contrast, the impact of intracoupling becomes more evident in the northwestern regions (Xinjiang, Gansu, and Ningxia), southwestern regions (Yunnan, Sichuan, Guizhou, and Guangxi), and the South regions, such as Hainan (Fig. 5). Additionally, we have identified some provinces that deviate significantly from the typical trend (Fig. 5). For instance, Shanghai's CESF shows intra- and peri-coupling of 0.93, while Beijing and Tianjin lean towards telecoupling cultural services, with values of 0.63 and 0.83 noted, respectively (Fig. 5). Meanwhile, Qinghai tops the provinces with the highest performance of 0.61 for pericoupling (Fig. 5).

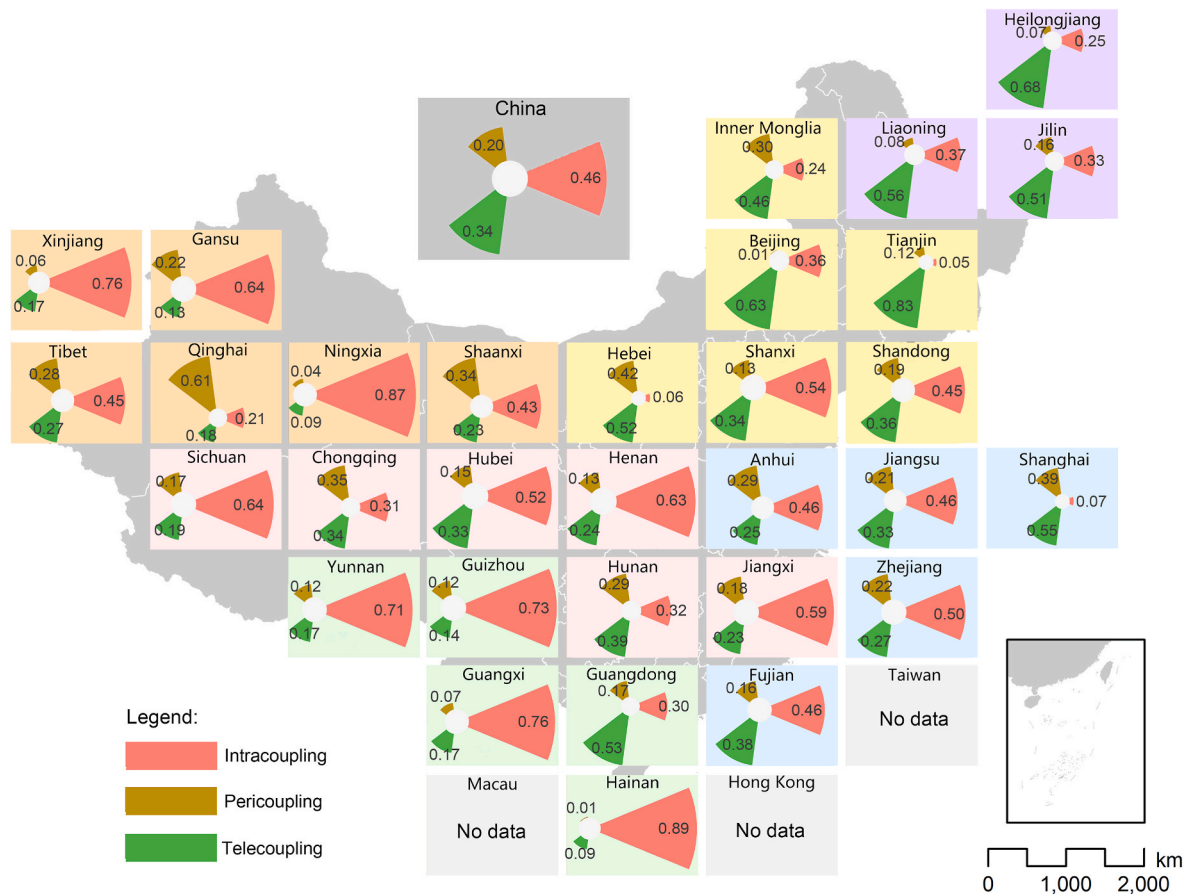


Fig. 5. Metacoupling of culture service flows at the national and provincial levels. (We employed 32 rose diagrams to illustrate the metacoupling performances of national and provincial levels, encompassing intracoupling, pericoupling and telecoupling. The color variation in each square bottom plot differentiates between macro-geographic regions of China, including the Northwest, Southwest, Northeast, South, North, and East China (Reference: Resource and Environmental Science Data Center China's geographic classification - www.resdc.cn). Higher performance is indicated by larger petals, and values on each petal are labeled for better illustration.).

3.2.2. Metacoupled pattern concerning ecosystem types

Significant spatial differences were observed in CESF across various ecosystems (Fig. 6). Southern China, in particular, exhibits a high incidence of CESF, primarily in forests, water, and biodiversity ecosystems (Fig. 6). Notably, forest, water, and desert ecosystems display a broader radial scale compared to marine, subsurface, and oasis ecosystems (Fig. 6). Approximately one-third of visitors access cultural services from forest ecosystems (Figs. 6 and 30.70%), followed by combined forest and water ecosystems (14.88%), water (12.62%), and urban landscape ecosystems (11.71%) (Fig. 6). Moreover, 9.80% of tourists prefer cultural services provided desert ecosystem, surpassing the preference for marine (7.96%) and wetlands ecosystem cultural services (4.78%). These findings underscore the enormous potential for developing tourism in China's arid and semi-arid regions.

We also observed that rare ecosystem cultural services, such as oases and cryosphere ecosystems, exhibited the strongest telecoupling performances with values of 0.58 and 0.49, respectively (Fig. 7). Notably, there is a similarity in the high performance of intracoupling and pericoupling among tourist behaviors, particularly in forests, urban landscapes, and water ecosystems (Fig. 7). However, they demonstrate lower levels in telecoupling. Overall, forest ecosystems provide approximately one-third (30.70%) of cultural services in China (Fig. 6). Nevertheless, the prevailing ecosystems, such as forests and urban landscapes, are still dominated by intra- and peri-coupling (Fig. 7). In contrast, specialized ecosystem services, such as oases and cryosphere ecosystems, can attract visitors from distant provinces (Fig. 7).

3.3. Tourist sentiment preferences and influencing factors

3.3.1. Tourist sentiment preferences across metacoupled systems

We quantified the sentimental value of tourists from comments within the metacoupling framework and found significant variations in tourist emotional preferences (Fig. 8). Specifically, tourists' preferences for geographical, economic, and social factors exhibited fluctuating inverted-V shaped patterns, with the highest emotional value observed in the pericoupling state, with mean values of 0.178, 0.187, and 0.289, respectively (Fig. 8b). This indicates that CESF in neighboring provinces is more likely to satisfy tourists' emotional needs. The trend in the economic dimension was most pronounced under the telecoupling pattern, suggesting that transportation costs and tourism price indices still significantly influence tourists' long-distance travel (Fig. 8b). In contrast, the cultural dimension exhibited a distinctive pattern, with the highest emotional value observed under the telecoupling pattern, at 0.475 (Fig. 8b). Long-distance tourist flows place greater emphasis on obtaining cultural emotional value.

Furthermore, we revealed the relationship between travel flow distance and sentimental value, finding that the sentimental value of tourists' cultural services generally decreases with increasing distance, with six out of seven fitted functions exhibiting slopes less than 0 (Fig. 8c). In the economic, social, and geographical pillars, closer-distance tourism tends to achieve a more outstanding emotional value (Fig. 8c). We note that the discretization trend of tourists' emotional value increases with distance, indicating that this uncertainty may be influenced by more imperceptible factors (Fig. 8c). Additionally, the relationship between emotional value in the cultural pillar and distance is positive, implying that tourists are more willing to obtain cultural services from indigenous cultures in long-distance travel.

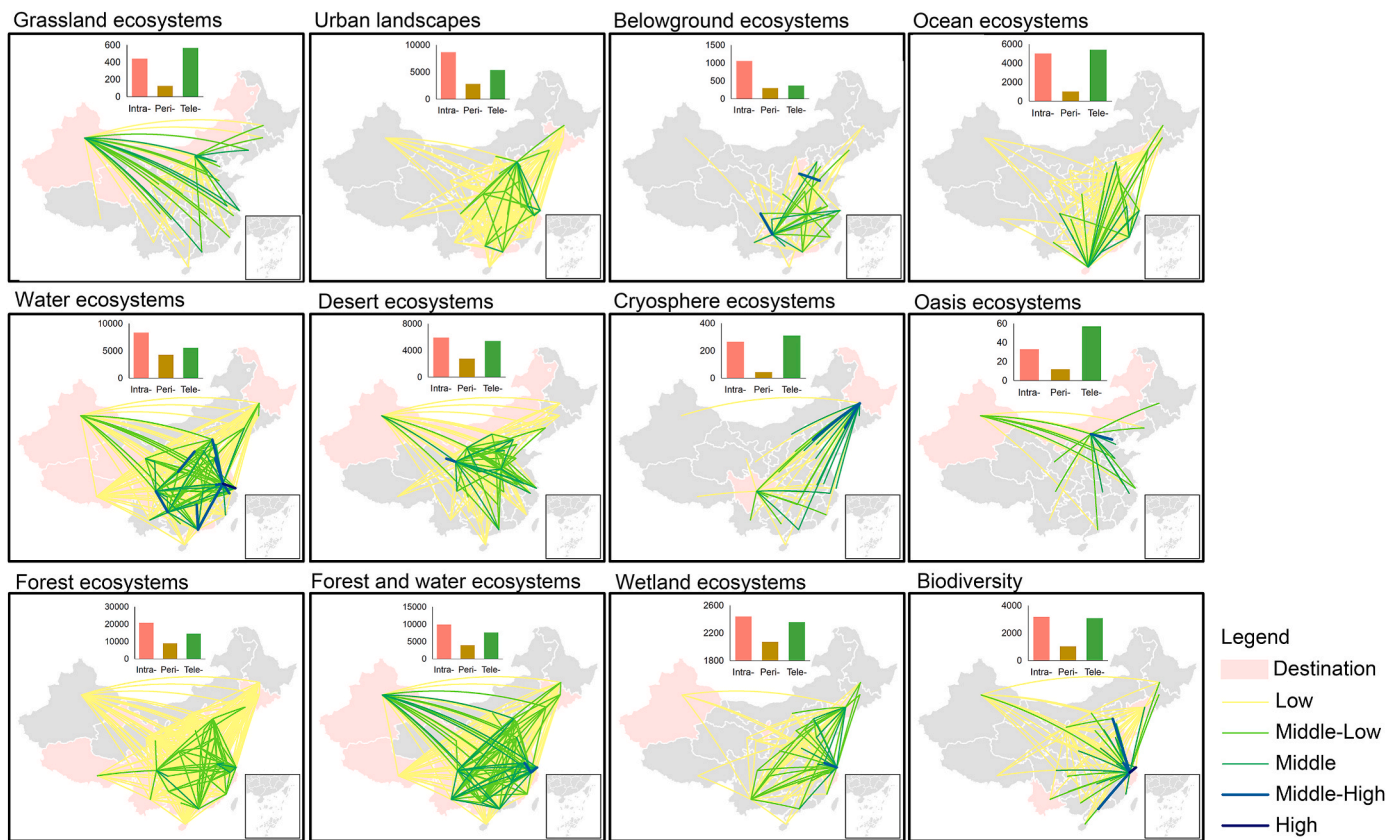


Fig. 6. The geospatial pattern of CESF and its performances across twelve ecosystems. (Cross-provincial flows of cultural services within twelve ecosystems are visually represented using ArcMap 10.2 tools. The intensity is categorized into five levels using the natural breakpoint method, allowing for the visualization of spatial differences in the flow lines. The pink areas on the base map represent destinations (receiving systems), while each subplot provides the count of tourists originating from intraprovincial, periprovincial, and teleprovincial sources.).

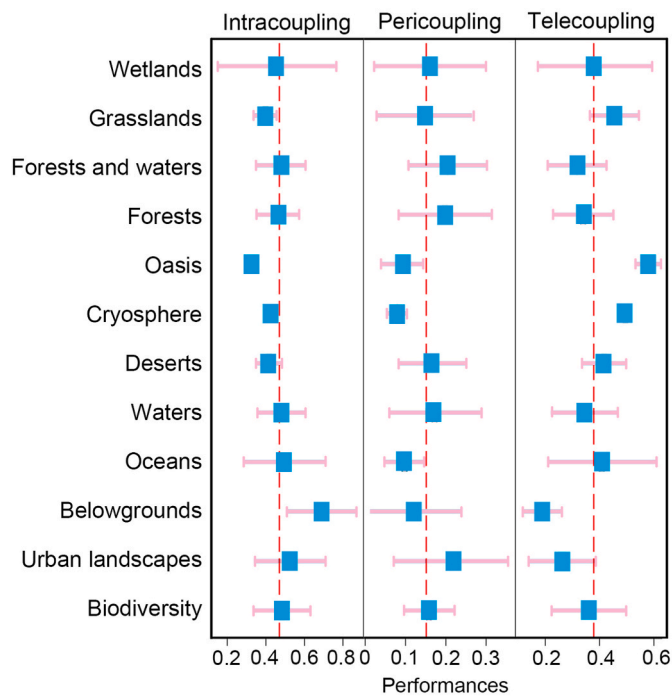


Fig. 7. The metacoupling pattern of CESF performance concerning twelve ecosystems. (The x-axis displays our quantified metacoupling values, while the blue dots indicate the mean values. The pink horizontal line represents the error bar, measuring the standard deviation. The red vertical line represents the mean value of metacoupling performances.)

3.3.2. The influencing factors of tele-distance tourism flows

We deduced the main influencing factors of tele-distance tourism at the provincial scale, aiming to reveal the spatial pattern of tourist emotional differences (Fig. 8a). We found that the economic pillar remains the most critical factor influencing tele-distance tourism, affecting over 60% of provinces, with the most pronounced impact observed in the Northeast and Western regions (Fig. 8a). Following this are climate and social factors, which predominantly affect provinces in the northern and southeastern regions (Fig. 8a). Only in Xinjiang is the primary influencing factor the indigenous culture (Fig. 8a). Overall, long-distance tourists tend to favor indigenous cultures, while the economic pillar remains a significant factor influencing long-distance tourism flow. This insight may provide new perspectives for nature-based tourism planners and managers in offering cultural services.

3.4. Bundle patterns in China's CESF

We then identified nine bundles (Fig. 9) and observed that the impacts of these bundles on the surrounding regions are highly noticeable (Fig. 5). Specifically, the highest bundles are located in the northeastern region of China, encompassing the regions of Shandong, Heilongjiang, Liaoning, Jilin, and Inner Mongolia, among others. Following closely is the Southwest region, which includes Chongqing, Sichuan, Guizhou, Yunnan, and Tibet (Fig. 9). We also found small bundles, such as the Fujian-Guangdong, the Jiangxi-Zhejiang, and the Jiangsu-Anhui-Shanghai bundles. There are also bundles with both high and low degree configurations, including the Tianjin and the Hebei-Beijing bundle, as well as the Shaanxi-Shanxi-Ningxia bundle (Fig. 9). Interestingly, the Southern Chinese province of Hainan is included in the cluster of Northern Chinese regions (Fig. 9). Our findings suggest that Hainan and Northern China have a strong cultural connection, particularly evident in the high-quality flow patterns between Beijing, Shandong, and Hainan.

4. Discussion

4.1. Theoretical components of tourism-related CESF based on the metacoupling framework

This study unveiled the pattern of tourism-related cultural service flows based on the metacoupling framework (Fig. 3), with results indicating that pericoupling performance dominates (Fig. 5). Tourists generally choose destinations within the province to obtain cultural service experiences, as evidenced by the high intracoupling performance in the southwestern region (Fig. 5). Proximate attractions are often more popular due to their lower time and cost requirements (Henok, 2021). However, this is not universally true, as evidenced by a significant preference among tourists from Northeastern China for long-distance travel (Table S2). The differences in tourist flow patterns between provinces are pronounced and influenced by geographical, economic, social, climatic, and recent land cover changes (Paracchini et al., 2014; Zoderer, Tasser, et al., 2016). It is essential to recognize that nearly one-third of tourists derive their well-being from forest ecosystems (Fig. 7), with natural forests playing an indispensable role in cultural services (Schirpke et al., 2020). The Chinese government is attempting to tap into the potential of cultural services through initiatives such as green spaces (Zhang et al., 2022b), greenways (Cheng et al., 2021), development at the urban-rural interface (Arslan et al., 2021), and urban park. Therefore, it is necessary to incorporate nature-based ecological restoration solutions into the construction of cultural services, such as the cultural service potential of national parks (Bachi et al., 2020) and the wildland-urban interface (Chen et al., 2024). This bottom-up approach to cultural service experiences can produce win-win outcomes for both tourists and indigenous people (Heslinga et al., 2018).

The flow of cultural services based on tourism is a complex system that generates cascading reactions in the interaction between distant humans and nature, such as the flow of energy, materials, and money (Fig. 10). While enjoying cultural services, attention must also be paid to ecological safety and sensitivity, as high human footprint may exceed the ecological carrying capacity of the region, leading to ecological damage (Xiaobin et al., 2021). For example, during the initial stages of constructing the Wolong Giant Panda Park, habitat loss for wild pandas and food scarcity occurred due to the decline of bamboo forests (Connor et al., 2022).

Within the flow components, the integration of technology and management brought by tourists, as well as the blending of cultures with indigenous peoples, can have direct or indirect impacts, such as changes in management practices, lifestyles, and consumption patterns (Fig. 10). This influence may dilute indigenous cultural heritage (Liu et al., 2024; Qiu et al., 2022). Additionally, we argue that the agents involved are diverse, including self-driving, group travel, and other forms (Perrine et al., 2020). Virtual tourism provides a new mode of representation for the flow of cultural services (Buhalis et al., 2023; Liu et al., 2022). Representations in the form of online media are becoming more prevalent (Van Nuenen & Scarles, 2021). We also investigated the reasons and components influencing long-distance tourism, which encompass a wide range of factors and can have profound domino effects (Fig. 10). Among them, the most critical influencing factors remain the value of tourism and transportation costs (Fig. 8a). Friction of distance refers to the time and monetary costs of long-distance travel, limiting the flow between home countries and more distant destinations (Henok, 2021). Cultural indicators are essential for sustaining the attraction of long-distance tourist travel (Fig. 8c). Therefore, the integration of natural tourism development with indigenous culture may be the key to sustainable tourism.

4.2. The characteristics of cross-regional tourism flows in the post-COVID-19 epidemic era

Patterns of global tourism and traveler movements across regions

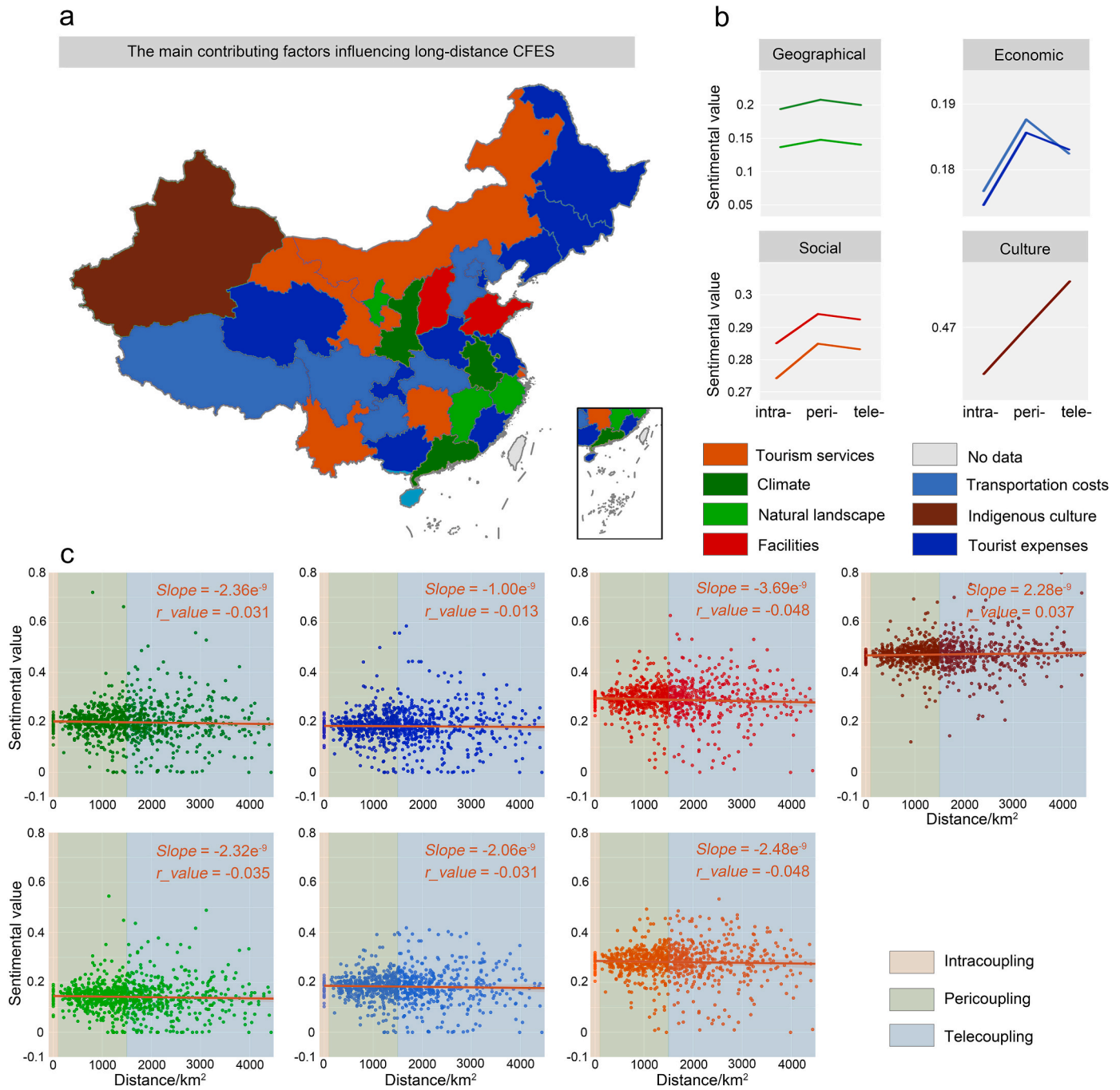


Fig. 8. Tourists' sentiment preferences and their influencing factors under metacoupling framework. (a. The main influencing factors of long-distance tourism flow and their provincial-scale patterns; b. The average sentiment value of the seven indicators under the metacoupling framework; and c. The linear regression relationship between flow distance and sentiment value. To distinguish intracoupling, pericoupling, and telecoupling patterns at the distance scale, we established the provincial flow average span as the threshold level (Fig. 8c). In Fig. 8a, we spatially displayed the main influencing factors, i.e., the maximum fitting coefficients. For detailed results, please refer to Table S4.).

have been affected as never before by the COVID-19 pandemic (Jeon & Yang, 2021). Previous research indicates that pandemics have a significant impact on tourists' destination choices and travel behavior (Li et al., 2022b). In the post-COVID-19 era, the recovery of tourist flows in metropolitan cities has been sluggish compared to the faster recovery in rural areas and natural scenic spots. Simultaneously, the radius of attraction for tourist destinations has shrunk significantly, and the tourist market has become more concentrated. Short-haul and peripheral travel have become mainstream, with tourists preferring destinations closer to home (Jeon & Yang, 2021). Our findings show that the

predominance of intra-coupling is mostly distributed in the south-western provinces and is most conspicuous in forest ecosystems (Figs. 3 and 4). This may indicate that more accessible cultural services are derived from tourism-based ecosystems. Nature-based tourism may be more resilient during pandemics.

In addition, the COVID-19 pandemic has become a catalyst for the sustainable transformation of the tourism industry (Viana-Lora et al., 2023). Cross-regional tourism exchanges hold promise for rapid post-pandemic recovery (Ivanov et al., 2021). Capturing changes in tourists' behavioral and emotional values toward nature-based tourism

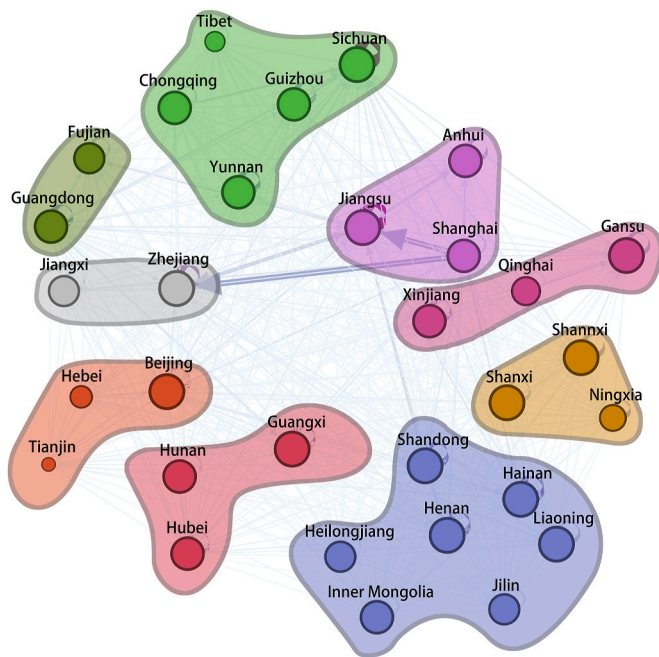


Fig. 9. The bundles patterns of China's tourism flows. (China's 31 provinces were classified into 9 clusters, as denoted by the varying colors of the facets. The arrows illustrate the directed CESF with their respective quantities. Larger point signifies higher total degrees (out- and in-degree).).

in the post-pandemic era is crucial for guiding the future direction of the industry (Jeon & Yang, 2021). Increased emphasis on health and safety among tourists has led to the greater popularity of outdoor activities and nature-based attractions. The rising demand for ecotourism and sustainable tourism reflects tourists' desire to connect with the natural environment. The combination of indigenous cultures and natural attractions is particularly appealing to long-distance travelers (Fig. 8). Increased interest in cultural experiences, especially in engaging with local communities and traditional cultures, is a notable feature of the post-COVID-19 era. Tourism activities are becoming more integrated into local communities, encouraging tourists to interact with residents to support the local economy and promote green tourism.

4.3. Emotional preferences concerning culture ecosystem services of long-distance travelers

In the post-pandemic era, tourists' preferences for travel have become increasingly unpredictable (Chansuk et al., 2022; Chirumlay & Kanitkar, 2022). The COVID-19 pandemic has altered respondents' travel preferences in various ways, such as a tendency to choose natural/outdoor/uncrowded destinations (Fan et al., 2023). Investigating visitor behavior and preferences for ecosystems is crucial to quantify the function and value of cultural services, as demonstrated by direct and indirect surveys in U.S. National parks (Palomo et al., 2013), the Alps (Zoderer et al., 2016), and semi-urban ecosystems (Cabana et al., 2020). This research showed different patterns of CESF at provincial (Fig. 4) and ecosystem type (Fig. 7) scales. For instance, tourists in Southwest China tend to receive more local cultural services (Fig. 5). The impact of land cover changes (Ghermandi et al., 2020) and destination natural disasters (Rosselló et al., 2020) on tourism cannot be underestimated. Semi-urban and forest ecosystems are generally best suited for short-distance tourism, whereas the implementation of cultural services in specialized ecosystems may result in telecoupling impacts (Fig. 7). Overall, nature-based tourism provides a new platform for connecting ecosystems and human behavior. Exploring the potential cultural service functions from ecosystems such as forests, grasslands, will be the

primary focus of future efforts to better understand the human-nature flow relationships.

The paper constructed a framework of tourists' emotional preferences for long-distance travel (Table 1), drawing upon diverse preference data extracted from travel blog comments (Fig. 8c). The findings highlighted that transportation costs and travel expenses are the main influencing factors (Fig. 8c), aligning with findings from both international and local tourism studies (Henok, 2021). This observation holds true for most tourists and is particularly notable in less developed regions (Rogerson & Baum, 2020). Importantly, cultural services demonstrate significantly positive effect on long-distance travel (Fig. 10). Integrating indigenous culture with nature-based attractions emerges as a pivotal strategy for sustainable tourism and attracting long-distance tourists. The internet and information dissemination play crucial roles in shaping preferences for cultural service flows among various stakeholders (Bachi et al., 2020), influencing the marketing strategies of tourism operators and contributing to the unpredictability of tourist flows (Li et al., 2021). Overall, while tourist emotional values vary and diverge with increasing distance, this research captures valuable insights that can inform competitive tourism development strategies for tourism managers.

4.4. Recommendations for sustainable tourism management and development under the metacoupling framework

The cross-province flow of cultural services in China presents significant untapped potential, necessitating top-down policies (Kubickova & Campbell, 2020) on tourism management and services to cater to diverse human needs. Incorporating CESF into management and landscape planning efforts has been lagged behind (Liu et al., 2023; Ruhl et al., 2021). Based on this study, enhancing collaboration in tourism between provinces, driven by the bundle patterns in cultural services (Fig. 9), is crucial for target-oriented management (Balas & Abson, 2022). Long-term planning programs for tourism development are necessary to support future human well-being needs (Chen & Quan, 2021). This planning involves the coexistence of ecosystem cultural services and other services (Xu et al., 2018). Managers need to focus on enhancing tourists' cultural service experiences (Fig. 8c). Integrating indigenous cultures with tourism development may be particularly appealing to long-distance travelers (Fig. 8c). The preference of long-distance tourists for cultural emotional value, along with health-related factors (Yang et al., 2021), is significant. Incorporating health and hygiene into cultural services and establishing crisis management systems can be beneficial (Yang et al., 2021).

Inequality in the spatial pattern of tourism flows persists in China, indicating that the western region possesses potential for development in nature-based tourism (Teles Da Mota & Pickering, 2020). This program is robust for its ability to significantly alleviate income inequality (Liu et al., 2023). Additionally, our research underscores the importance of managing tourist flows due to the noticeable spatiotemporal convergence of Chinese tourists (Fig. 6). Specifically, during holidays, popular tourist destinations and netflix attractions become overcrowded (Yang et al., 2022). Government officials should formulate policies focusing on regulating human traffic to prevent human activities from exceeding the tourism carrying capacity (Zekan et al., 2022). This reflects a win-win outcome for tourism-related cultural services, balancing economic development with cultural service experiences (Heslinga et al., 2018).

Community-based tourism (CBT) initiatives have been widely accepted as a favorable form of tourism activity (Gutierrez, 2023; Zeren et al., 2024). Community participation significantly impacts residents' support for tourism development (Nugroho & Numata, 2022). Distant tourist flows also have a direct or indirect impact on the management of cultural services in local communities. Tourists from distant areas can help local communities manage tourism resources by participating in the decision-making process. Positive or negative feedback from tourists

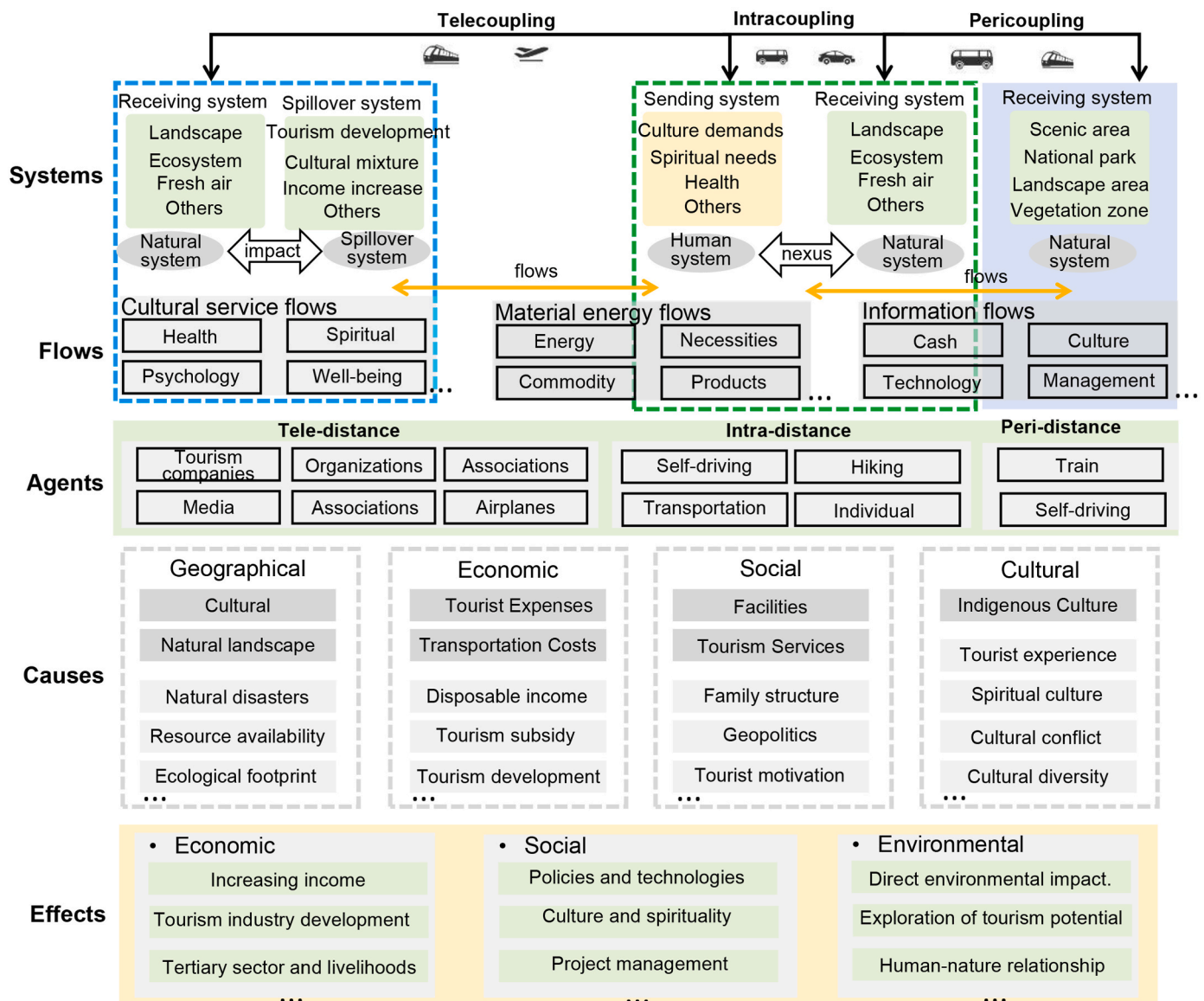


Fig. 10. The theoretical framework for the tourism-based CESF encompasses 5 components.

can be used to improve policies and regulations related to indigenous peoples' scenic areas, ensuring sustainable tourism development and long-term benefits. Community-based tourism development models have a wide range of potential impacts, such as poverty alleviation and biodiversity conservation (Gidebo, 2023; Liu et al., 2024). Culturally relevant emotional values are more likely to resonate with tourists, providing opportunities to promote local cultural traditions, such as traditional crafts, music, and dance performances. Community-level scenic management needs to consider the participation of tourists from metacoupling patterns and to focus on their differentiated experiences of cultural services. These pathways can positively contribute to the Sustainable Development Goals (specifically SDGs 1, 5, and 11) (Pasanchay & Schott, 2021).

4.5. Limitations and uncertainties

In this work, we provide new insights into revealing CESF flows by linking travelers' IP locations to their destinations. However, several challenges and uncertainties remain in our work. Regarding the original data entry, our study focused solely on investigating the flow patterns of China's 5A scenic spots (Table S4) due to issues such as the lack of open

IP location data, access restrictions, and other limitations. We did not consider other travel platforms besides Ctrip, such as Tuniu (tuniu.com/) and Qunar (qunar.com/), because the latter does not capture or disclose travelers' IP locations. Additionally, we have not accounted for the exclusion of malicious, false, or misleading comments about each attraction, which may only represent a small percentage. Despite the widespread use of ticket prices to estimate the ecosystem service value provided by ecosystems (Hou et al., 2020), quantifying the flows of cultural service value posed a challenge due to incomplete visitor participation in comments. We were also unable to gather more detailed information about visitors, such as specific age groups.

In terms of our findings, while our research results indicated that intercoupling is most prominent (Fig. 4), it is possible that non-famous attractions may exhibit even more pronounced levels of intercoupling (Ye et al., 2020). We did not consider more detailed types of cultural ecosystem services, such as spiritual, educational, and artistic services, due to data limitations. Regarding tourist sentiment preferences, we did not account for additional factors such as education, small family sizes, delayed marriages, geopolitical factors, peace, and security (Henok, 2021), as obtaining reliable information from comments proved challenging. We did not compare pre-pandemic tourism data because the

Chinese government issued regulations on the management of Internet user account information and encouraged network platforms to publish IP locations starting from August 2022. Additionally, emerging technologies in the tourism system, such as virtual reality (Buhalis et al., 2023), were not included in the scope of our study. The interaction of tourism flows between China and other countries was also not considered (Fig. 2). These challenges may be addressed in future research driven by the disclosure of visitor big data.

5. Conclusion

Utilizing the metacoupling framework and sentiment analysis model, we investigated the spatial patterns of interprovincial 5A-level CESF and tourist preferences in China. Our study unveiled a spatial pattern characterized by a decrease in CESF density associated with an expansion of coverage. Nationally, the CESF is predominantly characterized by intracoupling (0.46), followed by telecoupling (0.34) surpassing pericoupling (0.20). Northeastern provinces show a greater inclination towards telecoupling CESF, while Southwestern China predominantly exhibits intracoupling CESF. Forest ecosystems contribute nearly one-third of cultural services (30.70%), indicating that the potential for cultural services in desert ecosystems deserves future attention. Transportation costs and tourism expenses are significant factors influencing tele-distance travel, but tele-distance tourists show a stronger preference for indigenous culture. Finally, we delineated five key components of cultural service flows and proposed recommendations aimed at achieving sustainable tourism development in China.

Data acquisition

Scenic spot location data: We have collected the names, X and Y coordinate systems and other specific information for all China's A-rated scenic spots (from A to 5A about 11,921 samples). **Codes:** The code for Python spiders to scrape Ctrip comments (as an example of a 5A scenic area in Jiuzhaigou, Sichuan Province) is available for free. All of the above datasets are available from 10.6084/m9.figshare.24439540. Any request can be made by contacting the corresponding author via email.

Impact statement

Our study holds significant importance in comprehending the post-COVID-19 travel patterns and preferences of Chinese tourists across provinces. Our research findings indicate the necessity of implementing suitable local tourism-related policies, which should consider significant spatial disparities in tourist flows within the metacoupling framework. Forest cultural services, which account for a one-third share, require due attention in tourism development. Furthermore, long-distance travel accentuates the preference for indigenous cultures, inspiring new perspectives in tourism development. Overall, our findings bridge the knowledge gap in previous research and offer insightful perspectives for sustainable tourism. The policy actions endorsed by our findings may stimulate the recovery of nature-based tourism after COVID-19 pandemic, along with multiple benefits such as alleviating urban-rural inequality and eradicating relative poverty.

CRediT authorship contribution statement

Tao Liu: Writing – original draft, Visualization, Software, Methodology, Conceptualization. **Le Yu:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Jianguo Liu:** Methodology, Conceptualization. **Zhenci Xu:** Methodology, Conceptualization. **Xin Chen:** Writing – review & editing, Funding acquisition. **Hui Wu:** Visualization, Methodology. **Shijun Zheng:** Visualization. **Qiang Zhao:** Writing – review & editing. **Peng Gong:** Supervision, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that would have influenced the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.apgeog.2024.103432>.

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