

Forestry Leisure Tourism Development Efficiency in China: Dynamic Evolution, Spatial Spillovers, and Configurational Pathways

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Abstract

This study investigates forestry leisure tourism development efficiency (FLTE) across China's provinces and its dynamic, spatial, and configurational determinants. Super-SBM and global Malmquist–Luenberger models measure efficiency and decompose its temporal change, while a spatial Durbin model estimates local and interregional spillover effects. Fuzzy-set qualitative comparative analysis identifies configurations associated with efficiency enhancement and non-enhancement, and XGBoost-SHAP provides supplementary evidence on nonlinear predictive contributions. The results show that efficiency improvement is the primary source of FLTE growth. Tourism development foundations and ecological environmental quality provide important support, although their effects differ between local and neighbouring provinces. No single condition is sufficient for high efficiency; rather, improvement arises from multiple complementary conditions. These findings clarify how forestry resources are converted into sustainable tourism outcomes and demonstrate the importance of resource-use efficiency, interregional coordination, and differentiated development strategies.

1. Introduction

With the continued advancement of the Sustainable Development Goals, coordinated economic, social, and regional development has become an important issue on national development agendas. The United Nations 2030 Agenda for Sustainable Development emphasizes development quality, social well-being, and shared development opportunities beyond economic expansion (Nations, 2015). Against persistent regional disparities and industrial transformation, improving resource allocation efficiency and regional coordination has therefore become important for sustainable development.

This principle is particularly relevant to tourism. Tourism can stimulate employment, consumption, and related industries (Lee & Chang, 2008), but rapid expansion may also increase resource inputs, reinforce extensive development patterns, and exacerbate regional imbalances and input–output inefficiencies (Buckley, 2012). Tourism development further involves interactions among resource allocation, infrastructure, industrial integration, public services, and market demand (Haugland et al., 2011), which, without appropriate planning, may lead to redundant inputs, industrial homogenization, and inadequate service provision (Butler, 1980). Improving tourism development efficiency is therefore important for shifting tourism from scale-oriented expansion toward sustainable development (Wang et al., 2021).

Within this context, forestry leisure tourism represents a form of forestry–tourism integration that generates inter-industry linkages and contributes to regional economic development (Qiu et al., 2023). It relies on forest resources, ecological landscapes, forest land, and forestry-related cultural resources and is shaped by infrastructure, market demand, service capacity, and regional economic conditions (Winter et al., 2020). Unlike conventional sightseeing tourism and traditional forestry production, forestry leisure tourism integrates forest ecological spaces with leisure experiences and tourism consumption. Its development efficiency therefore reflects how effectively forestry resources, leisure spaces, labour, services, and related inputs are transformed into tourism outputs.

Improving forestry leisure tourism development efficiency (FLTE) is important for the sustainable development of forestry leisure tourism (Huang et al., 2022). Efficient resource allocation and industrial organization can facilitate the transformation of forestry resource advantages into tourism development outcomes. Examining FLTE therefore provides a means of assessing how effectively limited inputs are transformed into development outputs while supporting long-term sustainability.

However, compared with conventional tourism, forestry leisure tourism combines strong dependence on forestry resources with tourism-industry integration, while its statistical monitoring, efficiency evaluation, and management systems remain underdeveloped. Three issues require further investigation. First, although DEA has been widely used to evaluate multiple-input–multiple-output efficiency in tourism, existing applications remain highly concentrated in the hotel sector, leaving the joint transformation of forestry and tourism-related inputs into development outputs insufficiently examined (Barros, 2005). Second, insufficient attention has been paid to the spatial dependence and spillover effects of FLTE across regions (Ma et al., 2015). Third, studies focusing mainly on the net effects of individual factors provide limited understanding of how multiple conditions jointly shape FLTE (Fiss, 2007)

To address these issues, this study examines FLTE across 31 provinces in China. First, an input–output indicator system is constructed, and the Super-SBM model and GML index are used to measure provincial FLTE and examine its regional disparities and dynamic evolution. Second, the spatial Durbin model (SDM) is employed to investigate spatial dependence and spillover effects. Third, fuzzy-set qualitative comparative analysis (fsQCA) is used to identify configurational pathways associated with FLTE enhancement and non-enhancement. XGBoost-SHAP is additionally employed as a supplementary analysis of nonlinear predictive contributions. Together, these approaches link efficiency measurement and dynamic evolution with spatial interactions and configurational mechanisms (Fig. 1).

This study makes four main contributions. First, it extends research on forestry leisure tourism by systematically examining provincial FLTE and regional disparities across China. Second, it integrates efficiency measurement, spatial econometric analysis, and configurational analysis to examine dynamic efficiency change, spatial spillovers, and combinations of multiple conditions. Third, it links forestry resources, tourism development, and regional development through the lens of development efficiency, clarifying how forestry-related inputs are transformed into tourism outcomes. Fourth, it provides differentiated policy implications based on efficiency differences, spatial effects, and configurational pathways, supporting resource allocation, regional coordination, and the sustainable development of forestry leisure tourism.

2. Literature Review

2.1 Conceptualization and Measurement of FLTE

Forestry leisure tourism development efficiency (FLTE) can be understood from an input–output perspective as the efficiency with which forestry and tourism-related inputs are transformed into tourism

outputs. Existing tourism-efficiency studies have developed various indicator systems involving capital, labour, tourism resources, services, visitor flows, and tourism revenue (Cracolici et al., 2008), while research on forest parks and nature-based tourism further emphasizes forest resources, landscape space, and leisure services (Marcouiller, 1998). These studies provide a basis for FLTE measurement, although further integration is needed in indicator selection and spatial-scale evaluation.

DEA-based models are well suited to efficiency evaluation involving multiple inputs and outputs. The SBM model incorporates input and output slacks (Tone, 2001), while the Super-SBM model further distinguishes efficient decision-making units and improves cross-regional comparability (Andersen & Petersen, 1993). Previous studies have demonstrated its applicability to tourism and resource-allocation efficiency (Peng et al., 2017). Given the multiple resource, labour, leisure-space, and service inputs involved in forestry leisure tourism, this study adopts a multidimensional input–output framework to evaluate provincial FLTE and its spatiotemporal evolution (Table 1)..

Table 1
FLTE indicator system

Category	Dimension	Indicator	Description
Input	Capital input	Expenditure on culture, sports, and media	Government investment in tourism-related public services
	Labor input	Urban employees in the culture, sports, and entertainment industries	Human-resource input in leisure-tourism-related industries
	Leisure-space supply	Total park area	Supply of green and outdoor leisure spaces
	Leisure-tourism carrier supply	Number of A-rated tourist attractions	Supply and carrying capacity of tourism attractions
Output	Visitor reception scale	Number of forestry leisure tourism visits	Visitor reception scale of forestry leisure tourism
	Tourism economy	Forestry leisure tourism revenue	Economic output of forestry leisure tourism

2.2 Spatial Effects of FLTE

The spatial effects of forestry leisure tourism development efficiency remain underexplored. Existing studies have largely explained tourism efficiency or forest tourism performance through local resource endowments, investment, service provision, and industrial foundations, with less attention to interregional linkages (Nurmatov et al., 2021). However, tourist flows, transport connectivity, market interactions, and industrial collaboration can transmit development effects across regional boundaries, and previous studies have demonstrated spatial dependence and spillover effects in tourism development and efficiency (Yang & Wong, 2012)

This spatial perspective is particularly relevant to FLTE, which may be influenced by both local forestry resources and tourism conditions in neighbouring regions. Spatial econometric approaches can capture such interregional interactions and distinguish local effects from spillover effects (LeSage & Pace, 2009). Accordingly, this study examines the spatial dependence and spillover effects of FLTE across China's provinces.

2.3 Configurational Analysis of the Factors Influencing FLTE

Forestry leisure tourism development efficiency may result from the joint influence of multiple conditions rather than the independent effect of a single factor. Based on set-theoretic logic, fsQCA examines how different combinations of conditions are associated with the same outcome (Woodside, 2013) and has been increasingly applied in tourism and sustainable development research (Geremew et al., 2024).

Unlike conventional regression approaches that focus on the net effects of individual variables, fsQCA captures causal complexity, asymmetry, and equifinality (Fiss, 2011) and identifies alternative configurations associated with different outcomes (Schneider & Wagemann, 2012). This approach is therefore suitable for explaining how provinces with different development conditions may achieve similar FLTE outcomes. Accordingly, this study employs fsQCA to identify configurational pathways associated with optimized and non-optimized FLTE.

2.4 Summary and Research Questions

Existing research provides important foundations for understanding tourism development efficiency, spatial interactions, and configurational mechanisms. However, research on forestry leisure tourism development efficiency (FLTE) remains limited in three respects: (1) the lack of an integrated framework for evaluating the transformation of multidimensional forestry and tourism-related inputs into development outputs and their dynamic evolution; (2) insufficient attention to the spatial dependence and spillover effects of FLTE; and (3) limited understanding of how multiple conditions jointly shape FLTE through different configurational pathways.

Accordingly, this study addresses three research questions:

1. What efficiency levels, regional disparities, and dynamic changes characterize FLTE across China's provinces from 2013 to 2023, and are these changes driven primarily by efficiency improvement or technological change?
2. Does FLTE exhibit significant spatial dependence and spatial spillover effects, and do different influencing factors generate distinct effects within provinces and across neighbouring provinces?
3. Which combinations of conditions are associated with optimized FLTE, and which configurations lead to non-optimized FLTE?

To address these questions, this study integrates efficiency measurement and dynamic decomposition, spatial econometric analysis, and configurational analysis to examine the dynamic evolution, spatial

interactions, and configurational pathways of FLTE, thereby providing empirical evidence for improving FLTE and promoting the sustainable and coordinated development of forestry leisure tourism across regions.

3. Analytical Framework and Research Methods

3.1 Model Integration and Research Pathway

This study develops an integrated analytical framework to examine FLTE across China's provinces (Fig. 2). First, Super-SBM and GML are used to assess FLTE and its dynamic evolution. Second, spatial autocorrelation analysis and the SDM are employed to examine spatial dependence and spillover effects. Third, fsQCA is used to identify configurational pathways associated with optimized and non-optimized FLTE. XGBoost-SHAP is additionally employed as a supplementary analysis of nonlinear predictive contributions.

3.2 Data Sources

This study uses panel data for China's 31 provincial-level regions from 2013 to 2023. Data were collected primarily from authoritative statistical yearbooks and official databases.

For FLTE measurement, the input indicators include expenditure on culture, sports, and media; urban employees in the culture, sports, and entertainment industries; park area; and the number of A-rated tourist attractions. Because province-level data on dedicated inputs for forestry leisure tourism are unavailable, these indicators are used as proxies for government support, labour input, leisure-space input, and tourism-carrier provision, respectively. Data were obtained from the China Cultural Statistics Yearbook, China Statistical Yearbook, China Urban Construction Statistical Yearbook, and China Tourism Yearbook. The output indicators are forestry leisure tourism visits and revenue, obtained primarily from the China Forestry and Grassland Statistical Yearbook and provincial statistical yearbooks.

Five factors are considered in the analysis of FLTE: urbanization level, tourism development foundation, industrial structure, leisure demand level, and ecological environmental quality. Relevant data were obtained primarily from the China Statistical Yearbook, provincial statistical yearbooks, the China Culture and Tourism Statistical Yearbook, and the Google Earth Engine platform.

3.3 Research Methods

3.3.1 Super-SBM Model with Desirable Outputs

To measure forestry leisure tourism development efficiency (FLTE) across China's provinces, this study employs the non-radial and non-oriented Super-SBM model. The model incorporates input and output slacks and distinguishes efficient decision-making units (DMUs) through its super-efficiency formulation, thereby improving the discriminatory power of provincial efficiency estimates (Tone, 2001). Indicator

weights are determined endogenously without subjective weighting, and all indicators are standardized before estimation. The model is specified as follows:

$$\backslash \text{varvec} \rho = \min \frac{\frac{1}{m} \sum_{i=1}^m \frac{x_i}{x_{io}}}{\frac{1}{s} \sum_{r=1}^s \frac{y_r}{y_{ro}}}$$

$$\text{s.t.} \begin{cases} x_i \geq \sum_{j=1, j \neq o}^n x_{ij} \lambda_j, & i = 1, 2, \dots, m \\ y_r \leq \sum_{j=1, j \neq o}^n y_{rj} \lambda_j, & r = 1, 2, \dots, s \\ \lambda_j \geq 0 \\ x_i \geq x_{io}, & y_r \leq y_{ro} \end{cases}$$

where x and y denote the input and desirable-output variables, respectively; m and S represent the numbers of input and output indicators; n denotes the number of DMUs; s_i^- and s_r^+ are the corresponding slack variables; and λ represents the DMU weight determined through linear programming. A higher efficiency score indicates higher FLTE; a score below 1 indicates relative inefficiency, whereas a score above 1 indicates a super-efficient DMU.

3.3.2 Global Malmquist-Luenberger (GML) Index

To examine the dynamic evolution of forestry leisure tourism development efficiency (FLTE), this study employs the Global Malmquist-Luenberger (GML) index. Based on a global production frontier, the GML index enables intertemporal comparison and decomposes productivity change into global efficiency change (GEC) and global technological change (GTC), thereby identifying the sources of FLTE change. The GML index is calculated as follows:

$$GML_t^{t+1} = \frac{1 + D_G(x^t, y^t)}{1 + D_G(x^{t+1}, y^{t+1})}$$

where x and y denote the input and output vectors of a decision-making unit (DMU), respectively, and D_G denotes the distance function relative to the global production frontier. The GML index measures the change in FLTE between two consecutive periods. A value greater than 1 indicates improvement, a value equal to 1 indicates no change, and a value below 1 indicates decline.

3.3.3 Global Spatial Autocorrelation

To examine the spatial autocorrelation of forestry leisure tourism development efficiency (FLTE) across China's provinces, this study employs the global Moran's I statistic. A contiguity-based spatial weight matrix is used, with a value of 1 assigned to provinces sharing a common boundary and 0 otherwise. Global Moran's I is calculated as follows:

$$I = \frac{\sum_{i=1}^n \sum_{j=1}^n W_{ij} (X_i - \bar{X})(X_j - \bar{X})}{S^2 \sum_{i=1}^n \sum_{j=1}^n W_{ij}}$$

In this formulation, I denotes the global Moran's I statistic; n represents the number of provinces; W_{ij} denotes the spatial weight between provinces i and j ; X_i and X_j represent the FLTE values of provinces i and j , respectively; $\bar{X}$ denotes the mean FLTE; and S^2 represents the variance of FLTE. A significantly positive Moran's I indicates positive spatial clustering of FLTE, whereas a significantly negative Moran's I indicates spatial dispersion. An insignificant Moran's I suggests that the spatial autocorrelation of FLTE is not statistically significant.

3.3.4 Construction of the Spatial Weight Matrix

A row-standardized contiguity-based spatial weight matrix is used to represent spatial relationships among China's provinces. A value of 1 is assigned when two provinces share a common boundary and 0 otherwise. Row standardization ensures that the weights in each row sum to 1, allowing the spatial lag term to represent the weighted influence of neighbouring provinces.

$$W_{ij} = \begin{cases} 1, & \text{when provinces } (i) \text{ and } (j) \text{ are adjacent,} \\ 0, & \text{when provinces } (i) \text{ and } (j) \text{ are not adjacent.} \end{cases}$$

(W_{ij}) represents the spatial weight between province (i) and province (j) .

3.3.5 Spatial Econometric Model

To examine the spatial spillover effects of the factors influencing forestry leisure tourism development efficiency (FLTE), this study employs the spatial Durbin model (SDM). By incorporating spatial lags of both the dependent and explanatory variables, the SDM captures spatial dependence and spillover effects. The model is specified as follows:

$$FLTE_{it} = \rho WFLTE_{it} + \beta X_{it} + \theta WX_{it} + \epsilon_{it}$$

Using standard notation, $FLTE_{it}$ denotes the forestry leisure tourism development efficiency of province i in year t . The spatially lagged dependent variable, $WFLTE_{it}$, captures the influence of FLTE in neighbouring provinces on the FLTE of province i . X_{it} denotes the vector of influencing factor, WX_{it} represents its spatially lagged term. The parameters ρ , β and θ are to be estimated, and ϵ_{it} denotes the random error term.

3.3.6 Fuzzy-Set Qualitative Comparative Analysis (fsQCA)

To identify the configurational pathways associated with forestry leisure tourism development efficiency (FLTE), this study employs fuzzy-set qualitative comparative analysis (fsQCA). Unlike conventional regression methods that focus on the net effects of individual variables, fsQCA examines how combinations of conditions are associated with an outcome and allows multiple configurations to produce the same outcome (Ragin, 2008). This approach is therefore used to identify alternative configurational pathways associated with optimized and non-optimized FLTE.

3.3.7 XGBoost-SHAP Supplementary Analysis

XGBoost-SHAP is employed as a supplementary analysis to examine the nonlinear predictive contributions of the influencing factors to FLTE. XGBoost captures potential nonlinear relationships among the explanatory variables and FLTE (Chen & Guestrin, 2016), while SHAP values are used to interpret their relative contributions to model predictions (Lundberg & Lee, 2017). This analysis complements the SDM and fsQCA results and is not used for causal identification.

3.4 Selection of Influencing Factors

Based on the formation mechanisms of forestry leisure tourism development efficiency (FLTE) and related tourism-efficiency research, this study selects five influencing factors: urbanization (URB), tourism development level (TDL), industrial structure (IS), leisure demand (LD), and ecological environmental quality measured by annual mean NDVI (Table 2).

URB reflects infrastructure and market agglomeration but may also exert pressure on ecological space. TDL represents the tourism foundation and service capacity for transforming forestry resources into tourism outputs. IS captures industrial coordination and tourism-related integration, while LD reflects market demand for leisure and tourism consumption. Annual mean NDVI represents vegetation coverage and ecological environmental quality, providing the ecological resource base for forestry leisure tourism.

Table 2
Factors influencing FLTE

Variable type	Dimension	Abbreviation	Indicator	Definition
Dependent variable	Forestry leisure tourism development efficiency	FLTE	Forestry leisure tourism development efficiency	Input–output efficiency of provincial forestry leisure tourism development
Explanatory variable	Urbanization level	URB	Urbanization rate	Regional urbanization and population concentration
Explanatory variable	Tourism development foundation	TDL	Tourism development level	Regional tourism foundation and development capacity
Explanatory variable	Industrial coordination level	IS	Industrial structure	Regional industrial structure and coordination
Explanatory variable	Leisure consumption demand	LD	Leisure demand level	Residents’ leisure consumption and tourism demand
Explanatory variable	Ecological environmental quality	NDVI	Annual mean NDVI	Vegetation coverage and ecological environmental quality

4. Results

4.1 Spatiotemporal Evolution of FLTE

4.1.1 Spatial and Regional Patterns of FLTE

From 2013 to 2023, the mean FLTE across China's provinces increased from 0.0941 to 0.1558, representing a cumulative increase of 65.56% (Fig. 3). The overall trend was upward but fluctuating: FLTE rose to 0.1988 in 2018, declined after 2019, and recovered to 0.1558 in 2023. Nevertheless, the full-period mean was only 0.1502, indicating substantial room for improving the transformation of forestry leisure tourism inputs into outputs.

Clear regional disparities were observed. The central region recorded the highest mean FLTE (0.1932), followed by the western (0.1697) and eastern (0.1277) regions, while the northeastern region had the lowest mean (0.0614). Thus, FLTE did not exhibit a simple "high in the east and low in the west" pattern; instead, it was characterized by relatively high efficiency in the central region and substantial differentiation across and within regions.

At the provincial level, Guizhou (0.7325), Guangdong (0.4584), and Guangxi (0.3925) had the highest full-period mean FLTE, whereas Tianjin (0.0029), Qinghai (0.0132), and Shanghai (0.0151) had the lowest. High-efficiency provinces were relatively limited and concentrated mainly in parts of southwestern, southern, and central China, demonstrating pronounced interprovincial disparities in FLTE.

4.1.2 Dynamic Changes and Drivers of FLTE

The GML index was used to assess the dynamic evolution of FLTE and decompose its changes into efficiency change and technological change (Fig. 4). From 2013 to 2023, the mean GML index was 1.4911, indicating an overall improvement in FLTE. The index remained generally above 1 during 2014–2019, suggesting continued improvement in the transformation of forestry leisure tourism inputs into outputs. It fell below 1 during 2020–2022, indicating a temporary decline in efficiency improvement, before recovering markedly in 2023. Overall, FLTE exhibited a fluctuating rather than continuous improvement pattern.

The decomposition results further show that the mean efficiency change index was 1.8889, higher than the mean technological change index of 1.4275. This indicates that the improvement in FLTE was driven primarily by efficiency change, reflecting better allocation and transformation of existing forestry resources and leisure-service inputs. Technological change also contributed positively, but its comparatively smaller contribution suggests that technology-related improvements had not yet become the dominant driver of FLTE growth.

4.2 Spatial Spillovers of FLTE

4.2.1 Spatial Dependence and Model Selection

Before spatial econometric estimation, all explanatory variables were standardized using the Z-score method, and multicollinearity was assessed using the variance inflation factor (VIF). As shown in Table 3, the maximum VIF was 2.78, well below the conventional threshold of 10, indicating no serious multicollinearity among the explanatory variables.

Global Moran’s I was then used to test the spatial dependence of FLTE. As shown in Table 4, Moran’s I was positive and statistically significant throughout 2013–2023, indicating significant positive spatial autocorrelation in provincial FLTE and supporting the use of a spatial panel model.

Model specification was determined using LM and robust LM tests, Wald and likelihood-ratio (LR) tests, and the Hausman test (Table 5). The LM tests confirmed both spatial lag and spatial error dependence, while the Wald and LR tests rejected reducing the SDM to either the SAR or SEM. The Hausman test rejected the random-effects specification, and further LR tests supported both provincial and time fixed effects. Accordingly, a two-way fixed-effects SDM was selected for subsequent analysis.

Table 3
Multicollinearity test

Variable	VIF	1/VIF
x1	2.78	0.360146
x2	1.84	0.542742
x3	1.87	0.535143
x4	2.21	0.453230
x5	1.59	0.628453
Mean VIF	2.06	

Table 4
Global spatial autocorrelation

year	Moran's I	E(I)	Sd(I)	Z	P-value
2013	0.3183	-0.0333	0.1190	2.9560	0.0031***
2014	0.3282	-0.0333	0.1188	3.0428	0.0023***
2015	0.4231	-0.0333	0.1189	3.8380	0.0001***
2016	0.4108	-0.0333	0.1181	3.7609	0.0002***
2017	0.5032	-0.0333	0.1190	4.5084	0.0000**
2018	0.4971	-0.0333	0.1114	4.7608	0.0000***
2019	0.3469	-0.0333	0.1064	3.5742	0.0004***
2020	0.3870	-0.0333	0.1087	3.8662	0.0001***
2021	0.4224	-0.0333	0.1123	4.0591	0.0000***
2022	0.3920	-0.0333	0.1117	3.8069	0.0001**
2023	0.5108	-0.0333	0.1201	4.5319	0.0000***

Table 5
Spatial panel model tests

Test		Statistic	P-value
LM Test for Spatial error	Lagrange multiplier	49.872	0.0000***
	Robust Lagrange multiplier	47.827	0.0000***
LM Test for Spatial lag	Lagrange multiplier	7.114	0.0080***
	Robust Lagrange multiplier	5.069	0.0240***
LR-Test	Both-Ind	43.65	0.0000***
	Both-Time	518.49	0.0000***
Wald-Test	SDM → SAR	18.12	0.0030***
	SDM → SEM	16.83	0.0050***
LR-Test	SDM → SAR	17.62	0.0035***
	SDM → SEM	17.01	0.0045***
Hausman test		37.07	0.0000***

4.2.2 Direct Effects on FLTE

Because SDM coefficients do not directly represent marginal effects in the presence of spatial spillovers, they are decomposed into direct, indirect, and total effects using the partial-derivative approach, representing local, neighbouring, and overall effects, respectively. As shown in Fig. 5, urbanization (x1) and industrial structure (x3) have significant negative direct effects on local FLTE at the 5% level, whereas tourism development (x2), leisure demand (x4), and annual mean NDVI (x5) have significant positive direct effects at the 1% level. The specific results are as follows:

(1) Urbanization (x1) has a significant negative effect on local FLTE, indicating that a higher level of urbanization does not necessarily improve forestry leisure tourism development efficiency. One possible explanation is that intensified land development during urbanization places pressure on ecological space and forestry leisure resources, thereby constraining local FLTE.

(2) Tourism development (x2) has a significant positive effect on local FLTE, indicating that stronger tourism infrastructure, service capacity, and market attractiveness contribute to higher forestry leisure tourism development efficiency.

(3) Industrial structure (x3) has a significant negative effect on local FLTE, suggesting that changes in industrial structure have not yet been effectively translated into efficiency advantages for forestry leisure tourism. Insufficient coordination between industrial development and ecological leisure functions may therefore constrain local FLTE.

(4) Leisure demand (x4) has a significant positive effect on local FLTE, indicating that stronger resident leisure consumption demand promotes forestry leisure tourism resource development, product supply, and service efficiency.

(5) Annual mean NDVI (x5) has a significant positive effect on local FLTE, indicating that better vegetation coverage strengthens ecological environmental quality and forestry landscape attractiveness, thereby contributing to higher local FLTE.

4.2.3 Cross-Provincial Spatial Spillover Effects

The spatial spillover results show that all five factors have significant effects on FLTE in neighbouring provinces, confirming that the influences on FLTE extend beyond provincial boundaries.

(1) Urbanization (x1) has a significant positive spillover effect on FLTE in neighbouring provinces, indicating that higher urbanization in one province may improve FLTE in surrounding provinces through stronger transport linkages, the diffusion of public services, and regional factor mobility.

(2) Tourism development (x2) has a significant positive spillover effect on FLTE in neighbouring provinces, suggesting that tourism development in one province can benefit surrounding provinces through tourist flows, regional tourism cooperation, and tourism market diffusion.

(3) Industrial structure (x3) has a significant positive spillover effect on FLTE in neighbouring provinces, indicating that industrial restructuring may promote FLTE in surrounding provinces through industrial

collaboration, service-sector diffusion, and regional division of labour.

(4) Leisure demand (x4) has a significant negative spillover effect on FLTE in neighbouring provinces, suggesting that stronger leisure demand in one province may attract tourists, capital, and service resources, thereby generating competitive pressure on surrounding provinces and constraining their FLTE.

(5) Annual mean NDVI (x5) has a significant negative spillover effect on FLTE in neighbouring provinces, indicating that better ecological environmental quality may strengthen the attractiveness of local forestry leisure tourism and generate a substitution effect on surrounding provinces.

4.2.4 Robustness Checks

To assess the robustness of the SDM estimates, three alternative specifications were employed: winsorization, replacement of the spatial weight matrix, and adjustment of the sample period. All specifications controlled for individual and year fixed effects. The results show that the direction and statistical significance of the estimates remain broadly stable across the three specifications, indicating that the main findings are robust to extreme values, alternative spatial-weight specifications, and changes in the sample period (Appendix Table A1).

4.3 Configurational Pathways of FLTE

4.3.1 Variable Calibration and Fuzzy-Set Construction

Before the configurational analysis, the outcome and causal conditions were calibrated into fuzzy-set membership scores ranging from 0 to 1. Following established calibration practices, the direct calibration method was applied, with the 75th, 50th, and 25th percentiles set as the thresholds for full membership, the crossover point, and full non-membership, respectively (Sukhov et al., 2023). To avoid ambiguity at the crossover point, calibrated scores of 0.500 were adjusted to 0.501 (Fiss, 2011). The calibration anchors are reported in Table 6.

Table 6
Calibration anchors

Variable	Fact calibration anchor points:		
	75% full in	50% crossover point	25% full out
FLTE	0.229	0.079	0.031
URB	0.667	0.593	0.526
TDL	0.160	0.121	0.087
IS	0.554	0.515	0.465
LD	0.116	0.108	0.099
NDVI	0.823	0.788	0.687

4.3.2 Necessary-Condition Analysis

Following (Schneider & Wagemann, 2012), a condition is considered necessary for an outcome when its consistency exceeds 0.90. Accordingly, the consistency and coverage of each condition and its negation were examined for both FLTE enhancement and non-enhancement (Table 7). The results show that the consistency values of all conditions and their negations are below 0.90, indicating that no single condition is necessary for either FLTE enhancement or non-enhancement. Thus, FLTE outcomes depend on combinations of multiple conditions rather than any individual factor, supporting further configurational analysis.

Table 7
Necessity analysis of individual conditions

	FLTE Enhancement		FLTE Non-Enhancement	
	Consistency	Coverage	Consistency	Coverage
A1	0.542054	0.518276	0.579078	0.604678
~A1	0.586540	0.560620	0.538670	0.562291
B1	0.696987	0.671054	0.419523	0.441119
~B1	0.419521	0.398228	0.687158	0.712366
C1	0.541882	0.516470	0.560259	0.583172
~C1	0.562662	0.539512	0.535467	0.560731
D1	0.647954	0.620768	0.454302	0.475333
~D1	0.452357	0.431506	0.637548	0.664181
E1	0.777058	0.728132	0.358132	0.366495
~E1	0.323928	0.316051	0.734336	0.782479

4.3.3 Configurational Pathways for FLTE Enhancement and Non-Enhancement

To identify sufficient configurations for FLTE enhancement and non-enhancement, the raw consistency, PRI consistency, and frequency thresholds were set at 0.80, 0.70, and 1, respectively (Ragin, 2008). Comparison of the intermediate and parsimonious solutions identified six pathways for FLTE enhancement and two for non-enhancement (Fig. 6). The enhancement pathways achieved an overall solution coverage of 0.665 and consistency of 0.849, while the corresponding values for the non-enhancement pathways were 0.414 and 0.864.

(1) Tourism development–ecological environment synergy (S1–S2). S1 combines high tourism development, non-high industrial structure, and high NDVI, whereas S2 combines high tourism development, high leisure demand, and high NDVI. These pathways highlight the joint role of tourism development and ecological environmental quality in FLTE enhancement.

(2) Low urbanization pressure–ecological resource support (S3–S4). S3 combines non-high urbanization, high tourism development, non-high industrial structure, and non-high leisure demand, whereas S4 combines non-high urbanization, high industrial structure, non-high leisure demand, and high NDVI. These pathways indicate that relatively low urbanization pressure can support FLTE enhancement when combined with tourism, industrial, or ecological conditions.

(3) Urbanization–demand–ecological synergy (S5–S6). S5 combines high urbanization, high tourism development, non-high industrial structure, and high leisure demand, whereas S6 combines high urbanization, non-high industrial structure, high leisure demand, and high NDVI. These pathways indicate that high urbanization can also support FLTE enhancement when combined with favourable tourism, demand, or ecological conditions.

For FLTE non-enhancement, H1 combines non-high tourism development, non-high industrial structure, and non-high NDVI, whereas H2 combines non-high urbanization, non-high tourism development, and non-high NDVI. Both pathways contain non-high tourism development and non-high NDVI, indicating that weak tourism development foundations and ecological environmental quality are common constraints on FLTE improvement.

Overall, the enhancement and non-enhancement pathways are not simple mirror images, confirming the configurational complexity and causal asymmetry of FLTE.

4.3.4 Robustness Analysis

To assess the robustness of the fsQCA results, the PRI consistency threshold was increased from 0.70 to 0.75 and the raw consistency threshold from 0.80 to 0.85. The main configurational pathways remained substantively unchanged after these adjustments, while solution coverage and consistency showed no substantial fluctuations, confirming the robustness of the configurational results (Appendix Table A2).

5. Discussion

This study reveals distinct dynamic, spatial, and configurational characteristics of forestry leisure tourism development efficiency (FLTE) across China's provinces. First, FLTE improvement was driven primarily by efficiency change rather than technological change. Second, the influencing factors exhibited differentiated direct and spatial spillover effects. Third, FLTE enhancement and non-enhancement resulted from multiple combinations of conditions, demonstrating configurational complexity and causal asymmetry. These findings provide a basis for discussing the dynamic drivers, spatial effects, and configurational mechanisms of FLTE.

5.1 Dominant Role of Efficiency Change in FLTE Evolution

The results indicate that efficiency change was the primary driver of FLTE improvement across China's provinces. This finding is consistent with research showing that tourism efficiency depends not only on the scale of resource inputs but also on technical efficiency, infrastructure, management, and service quality (Liao et al., 2023). In forestry leisure tourism, the dominant role of efficiency change suggests that recent improvements have resulted mainly from better allocation and utilization of existing resources and more effective conversion of tourism inputs into outputs.

By contrast, technological change made a smaller contribution to FLTE growth, indicating that digital applications, smart management, and service innovation have not yet been fully translated into efficiency gains across provinces. Further improvement therefore requires both continued optimization of resource allocation and service organization and stronger integration of technological innovation into forestry leisure tourism development.

5.2 Direct Effects of Multiple Factors on FLTE

The direct effects estimated by the SDM reveal differentiated influences of the five factors on FLTE. Previous research shows that urban expansion and built-up land growth can alter land-use structures and reduce ecosystem-service capacity (Yuan et al., 2019). Building on this research, the present study further finds that urbanization has a significant negative effect on FLTE. Built-up land expansion may place pressure on forests and green spaces, while the concentration of resources in industry, real estate, and urban infrastructure may weaken the ecological and input foundations of forestry leisure tourism.

Second, previous research indicates that tourism efficiency depends on tourism-industry foundations and broader socioeconomic conditions (Guo et al., 2022). Consistent with this evidence, the present study further finds that tourism development has a significant positive effect on FLTE. Stronger reception capacity, service systems, market promotion, and resource utilization facilitate the conversion of forestry ecological resources into tourism products and economic outputs.

Third, previous research also shows that industrial-structure optimization does not always improve tourism efficiency and may be inhibitory under certain conditions (Li & Zhang, 2022). Building on this finding, the present study further shows that industrial structure has a significant negative effect on FLTE, suggesting that industrial restructuring has not yet generated sufficient momentum for forestry leisure tourism. Industrial upgrading may still favour traditional or capital-intensive sectors, while ecological industries, culture–tourism integration, and green services remain underdeveloped.

In addition, research on forest recreation emphasizes that changes in visitor demand influence resource allocation and service provision (Dugstad et al., 2024). On this basis, the present study further finds that leisure demand has a significant positive effect on FLTE. Growing demand for forest wellness, ecological sightseeing, and outdoor recreation encourages tourism-product optimization and improves service efficiency.

Finally, previous research shows that NDVI reflects vegetation coverage and ecological environmental quality in tourism destinations (Wu & Chen, 2016). The present study further finds that annual mean NDVI has a significant positive effect on FLTE. Better vegetation coverage strengthens the landscape attractiveness and experiential value of forestry resources and supports forest tourism, ecological wellness, and nature education.

5.3 Spatial Spillover Effects of Multiple Factors on FLTE

The spatial spillover estimates show that the five factors also affect FLTE in neighbouring provinces through regional linkages. New economic geography research indicates that urbanization and economic agglomeration can generate diffusion effects through infrastructure, market expansion, and factor mobility (Fujita & Thisse, 2002). Building on this research, the present study further finds that urbanization has a significant positive spatial spillover effect despite its negative direct effect. It may therefore pressure local ecological space while benefiting neighbouring provinces through transport connectivity, public-service spillovers, and market expansion.

Previous research shows that domestic and inbound tourism flows generate spatial spillovers shaped by infrastructure, attractions, and urban income (Yang & Wong, 2012). On this basis, the present study further finds that tourism development positively affects neighbouring FLTE through coordinated tourism routes, shared visitor markets, and tourism-brand diffusion.

Previous research also finds that tourism-industry agglomeration affects surrounding regions through spatial linkages (Kim et al., 2021). Building on this evidence, the present study further shows that industrial structure has a significant positive spillover effect. Tourism-related transport, information, and organizational services may diffuse through industrial collaboration and market linkages, improving resource-conversion capacity in neighbouring provinces.

Recent research shows that tourism demand is spatially interdependent across neighbouring destinations, with demand spillovers reflecting both competitive and complementary relationships (Jiao et al., 2025). The present study further finds that leisure demand has a significant negative spillover effect on neighbouring FLTE. Rising local demand may concentrate tourists, consumption, capital, and tourism-service resources within a province, causing tourist diversion and market competition that constrain efficiency improvement in surrounding provinces.

Finally, previous research indicates that NDVI reflects vegetation coverage and ecological environmental quality in tourism destinations (Wu & Chen, 2016). The present study further shows that annual mean NDVI has a significant negative spillover effect. Although ecological quality strengthens local tourism attractiveness, it may draw tourists and consumption away from neighbouring provinces, creating a substitution effect that weakens their relative advantages.

5.4 Configurational Mechanisms of FLTE

The fsQCA results show that FLTE enhancement arises from multiple configurations rather than a single factor. Previous research indicates that destination competitiveness depends on interactions among tourism resources, supporting conditions, and management (Zhang et al., 2012). Building on this research, the present study further identifies the S1–S2 tourism development–ecological environment synergy pathways. Tourism foundations improve service provision, market access, and resource conversion, while ecological quality enhances the attractiveness of forestry resources, jointly converting ecological advantages into tourism outputs and efficiency gains.

Previous research shows that urban expansion can affect land use, biodiversity, and ecosystem functions (Seto et al., 2012). On this basis, the present study further identifies the S3–S4 low urbanization pressure–ecological resource support pathways. Lower urbanization pressure helps preserve ecological space and, when combined with tourism, industrial, or ecological support, promotes efficiency improvement. The relationship between urbanization and FLTE is therefore conditional rather than simply linear.

Recent research conceptualizes urban tourism as a networked tourism–industrial complex shaped by urban conditions, tourism services, resource endowments, and demand (Yang et al., 2022). Building on this perspective, the present study further identifies the S5–S6 urbanization–demand–ecological synergy pathways. Urbanization can support FLTE when effectively combined with tourism development, leisure demand, and ecological advantages, although it is insufficient on its own.

The non-enhancement configurations reveal additional constraints. Previous research indicates that nature-based tourism requires ecological resources, effective management, services, and environmental protection (Newsome et al., 2013). On this basis, the present study further finds that the H1 tourism–ecological foundation deficiency is associated with non-enhanced FLTE. Simultaneously weak tourism development and ecological quality constrain the conversion of forestry resources into tourism products and stable outputs.

Research also shows that transport improvements can stimulate regional tourism and generate spillovers across destinations (Tian et al., 2022). Building on this research, the present study further identifies the H2 low urbanization–tourism–ecological constraint. Low urbanization, weak tourism development, and poor ecological conditions jointly restrict accessibility, service capacity, and the resource foundation of forestry leisure tourism, making improvement through any single factor difficult.

Overall, enhancement and non-enhancement pathways are not simple mirror images. Similar FLTE outcomes can arise from different combinations, while the absence of enhancement conditions does not necessarily produce non-enhancement. This confirms the configurational complexity and causal asymmetry of FLTE and the importance of coordinated interactions among multiple conditions.

5.5 Supplementary Interpretation of Nonlinear Effects Using XGBoost-SHAP

As a supplementary analysis, XGBoost-SHAP was used to examine the nonlinear predictive contributions of the influencing factors to FLTE. Our study further shows that annual mean NDVI and tourism development have the strongest predictive contributions, further highlighting the importance of ecological environmental quality and tourism development foundation in explaining FLTE differences. However, XGBoost-SHAP reflects predictive rather than causal relationships and therefore serves only as supplementary evidence rather than causal validation of the SDM or fsQCA results (Appendix Fig S1).

5.6 Research Limitations and Future Directions

Although this study systematically examines the spatiotemporal evolution, spatial spillover effects, and configurational pathways of forestry leisure tourism development efficiency across China's provinces, several limitations remain because of data availability, spatial scale, and methodological design.

5.6.1 Limitations of the Research Scope

This provincial-level analysis provides a macro-level perspective but may obscure heterogeneity among cities, counties, and individual destinations. Treating forestry leisure tourism as an integrated sector may also mask differences among specific types of tourism activities. Future research could examine finer spatial scales and distinct forms of forestry leisure tourism by combining operational data, visitor surveys, and remote-sensing information.

5.6.2 Limitations of the Temporal Scale

The 2013–2023 panel captures the recent evolution of FLTE but may not reveal longer-term changes associated with policy adjustments, tourism development cycles, and external shocks. As more consistent data become available, future research could extend the study period to assess the long-term evolution and stability of FLTE.

5.6.3 Methodological Considerations and Future Extensions

Methodological limitations also remain. The SDM identifies spatial relationships rather than the causal effects of specific policies or institutions, while XGBoost-SHAP captures nonlinear predictive rather than causal relationships. Future research could incorporate more detailed information on climate and environmental constraints, tourist behaviour, and institutional conditions and combine richer multiscale data with causal inference methods to examine the mechanisms underlying FLTE more rigorously.

5.7 Analytical Contribution

FLTE involves the conversion of forestry resources into tourism outputs while also being shaped by regional interactions and combinations of development conditions. A single analytical perspective cannot fully capture these dimensions. Accordingly, this study integrates forestry resource management, tourism economics, spatial geography, and complexity science within a unified analytical framework.

First, Super-SBM and GML connect static efficiency measurement with dynamic decomposition. Super-SBM evaluates the conversion of forestry leisure tourism inputs into outputs, while GML distinguishes efficiency change from technological change. Their combination explains not only provincial efficiency levels but also their intertemporal evolution.

Second, SDM incorporates spatial dependence and separates direct from spillover effects, extending the analysis beyond individual provinces. It captures interregional linkages arising from tourism flows, infrastructure, and markets that conventional efficiency analysis may overlook.

Third, fsQCA complements the net-effect perspective by identifying multiple configurations associated with FLTE enhancement and non-enhancement. It reveals equifinality and causal asymmetry, showing that similar efficiency outcomes can emerge from different combinations of conditions.

Taken together, these methods provide complementary rather than competing explanations of FLTE. Their integration connects efficiency change, spatial interaction, and configurational complexity, offering a multidimensional framework for understanding how forestry leisure tourism efficiency evolves and differs across regions.

6. Management Implications

Based on the dynamic, spatial, and configurational findings, this study proposes four management implications for improving FLTE and promoting the sustainable development of forestry leisure tourism.

6.1 Promoting Synergy Between Resource-Allocation Optimization and Technology Adoption

The results indicate that efficiency change is the primary driver of FLTE improvement, while technological change makes a comparatively smaller contribution. Policymakers should therefore prioritize the efficient use of existing resources while strengthening the practical application of relevant technologies.

Specifically, a “Forestry Leisure Tourism Resource Optimization Fund” and an “Effectiveness-Evaluation Mechanism for Technology Adoption” could jointly support the renovation of underperforming destinations, revitalization of underutilized spaces, facility upgrading, and adoption of proven technologies for smart reservations, visitor-flow management, facility scheduling, and resource monitoring, with continued support linked to improvements in facility utilization, service quality, and input–output performance.

6.2 Direct Effects Within Provinces: Strengthening Ecological-Space Governance and Tourism-Service Conversion

The results show that tourism development, leisure demand, and annual mean NDVI positively affect local FLTE, whereas urbanization and industrial structure exert negative effects. Provincial policies should therefore strengthen ecological-space protection and tourism-service conversion while coordinating urban expansion and industrial restructuring with ecological conservation.

Specifically, an “Ecological-Space Governance Plan” should restrict the conversion of forestlands, wetlands, green spaces, and ecological corridors into built-up land and prioritize the protection of forest parks, wetland parks, nature reserves, and peri-urban ecological spaces. A “Tourism-Service Conversion Enhancement Plan” should improve transport connectivity, visitor services, interpretation systems, safety

facilities, and public-health infrastructure in ecologically rich but tourism-weak regions, thereby converting ecological advantages into tourism outputs without compromising conservation.

6.3 Spatial Indirect Effects: Establishing Regional Linkages and Spillover-Compensation Mechanisms

The results indicate that urbanization, tourism development, and industrial structure generate positive spatial spillover effects on FLTE in neighbouring provinces, whereas leisure demand and annual mean NDVI generate negative spillovers. Infrastructure, tourism services, and industrial collaboration can generate benefits beyond provincial boundaries, while concentrated leisure demand and high-quality ecological resources may divert visitors and intensify regional competition. Cross-provincial coordination is therefore needed to strengthen positive spillovers while mitigating adverse competitive effects.

Specifically, a “Regional Service-Capacity Diffusion Plan” should encourage provinces with stronger tourism and industrial foundations to share service standards, management expertise, marketing channels, and product-development practices with neighbouring regions. An “Ecological Attractiveness Compensation and Visitor-Coordination Mechanism” should coordinate cross-provincial tourism routes, visitor flows, benefit sharing, and ecological compensation to reduce tourist diversion and competitive substitution among neighbouring provinces.

6.4 Implementing Differentiated Improvement Strategies Based on Configurational Pathways

The results indicate that FLTE enhancement depends on multiple combinations of conditions, with tourism development and annual mean NDVI serving as important supporting conditions across several pathways. In contrast, non-enhancement pathways are characterized mainly by weak tourism development foundations and ecological environmental quality. Forestry leisure tourism policies should therefore move beyond uniform investment approaches and adopt differentiated strategies according to regional configurational characteristics.

Specifically, a “Configurational Pathway-Based Improvement Plan” should be implemented. Tourism–ecological synergy regions should improve tourism-service quality, ecological tourism products, and resource-conversion capacity. Low urbanization pressure–ecological resource support regions should prioritize low-impact facilities, ecological trails, forest education, rural homestays, and outdoor recreation. Urbanization–demand–ecological synergy regions should strengthen peri-urban forestry leisure tourism through reservation systems, capacity monitoring, and time-slot management. Regions with weak tourism and ecological foundations should defer large-scale expansion and prioritize ecological restoration, essential infrastructure, and basic tourism services.

7. Conclusion

This study examines the dynamic evolution, spatial spillovers, and configurational pathways of forestry leisure tourism development efficiency (FLTE) across 31 Chinese provinces from 2013 to 2023. The results reveal pronounced regional disparities and significant spatial dependence. Dynamic decomposition further shows that FLTE growth was driven primarily by efficiency change rather than technological change, underscoring the importance of improving the allocation and utilization of existing resources.

The spatial analysis demonstrates that the factors influencing FLTE generate differentiated local and cross-provincial effects. Forestry leisure tourism development is therefore shaped not only by local tourism and ecological conditions but also by interregional linkages, resource flows, and competition among neighbouring provinces.

The fsQCA results reveal that FLTE enhancement and non-enhancement arise from different combinations of conditions, confirming configurational complexity and causal asymmetry. Supplementary XGBoost-SHAP analysis further identifies ecological environmental quality and tourism development as the strongest predictive contributors, without implying causal relationships. These findings support the adoption of differentiated rather than uniform regional development strategies.

The sustainable development of forestry leisure tourism consequently requires coordinated improvements in resource utilization, ecological protection, tourism-service conversion, and regional collaboration. Provinces should respond to their specific efficiency constraints and configurational conditions while strengthening positive spatial spillovers and mitigating competitive effects.

Overall, the integrated framework links dynamic efficiency change, spatial interaction, and configurational pathways, providing multidimensional evidence on provincial FLTE in China. Future research could extend the analysis to cities, counties, and individual destinations and incorporate visitor behaviour, destination operations, climatic and environmental conditions, and local governance to examine the long-term and micro-level mechanisms of FLTE.

Declarations

Additional Information

Competing interests

The authors declare no competing interests.

Ethics statements

As requested, two separate ethics statements have been added after the References section of the revised manuscript:

Ethical Approval

This article does not contain any studies with human participants performed by any of the authors.

Informed Consent

Not applicable

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Author Contribution

Z.M. and C.H. conceived and designed the study. Z.M. collected and organized the data, conducted the Super-SBM, GML, spatial econometric, fsQCA, and XGBoost-SHAP analyses, prepared the figures and tables, and drafted the manuscript. T.W. contributed to data collection, data organization, and manuscript revision. Z.L. contributed to the interpretation of the results and manuscript revision. C.H. supervised the study, provided guidance on the research design, and critically revised the manuscript. All authors have read and approved the final version of the manuscript.

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During the preparation of this manuscript, the authors used ChatGPT (OpenAI) for language editing and improving the clarity and readability of the manuscript. The authors reviewed and edited the output and take full responsibility for the content of this publication.

Data Availability

The province-year datasets and supporting materials used in this study are provided in the accompanying Supplementary Data and Code archive. The archive includes the raw and MATLAB-compatible data used for the Global Super-SBM analysis; the corresponding efficiency and productivity-index outputs; the level-form and natural-log panel datasets, spatial-weight matrix and Stata command file used for the spatial econometric analysis; the case-level input data and calibration anchors used for the fsQCA analysis; and the XGBoost-SHAP input data and corresponding figure. The principal study datasets contain 341 observations covering 31 Chinese provinces from 2013 to 2023. The underlying statistical series were compiled from the sources described in the manuscript. No human-participant or personally identifiable data are included.

References

1. Andersen P, Petersen NC (1993) A procedure for ranking efficient units in data envelopment analysis. *Manage Sci* 39(10):1261–1264. <https://doi.org/10.1287/mnsc.39.10.1261>
2. Barros CP (2005) Measuring efficiency in the hotel sector. *Annals Tourism Res* 32(2):456–477. <https://doi.org/10.1016/j.annals.2004.07.011>
3. Buckley R (2012) Sustainable tourism: Research and reality. *Annals Tourism Res* 39(2):528–546. <https://doi.org/10.1016/j.annals.2012.02.003>
4. Butler RW (1980) The concept of a tourist area cycle of evolution: Implications for management of resources. *Can Geogr* 24(1):5–12. <https://doi.org/10.1111/j.1541-0064.1980.tb00970.x>
5. Chen T, Guestrin C (2016) XGBoost: A scalable tree boosting system. *Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, New York, NY
6. Cracolici MF, Nijkamp P, Rietveld P (2008) Assessment of tourism competitiveness by analysing destination efficiency. *Tour Econ* 14(2):325–342. <https://doi.org/10.5367/000000008784460427>
7. Dugstad A, Ceria A, Comerros M, Oleson KLL (2024) Exploring the Influence of Activity Participation on the Economic Value of Nature-Based Recreation in the Sierra Nevada. *J Environ Manage* 360:121081. <https://doi.org/10.1016/j.jenvman.2024.121081>
8. Fiss PC (2007) A set-theoretic approach to organizational configurations. *Acad Manage Rev* 32(4):1180–1198. <https://doi.org/10.5465/amr.2007.26586092>
9. Fiss PC (2011) Building better causal theories: A fuzzy set approach to typologies in organization research. *Acad Manag J* 54(2):393–420. <https://doi.org/10.5465/amj.2011.60263120>
10. Fujita M, Thisse J-F (2002) *Economics of Agglomeration: Cities, Industrial Location, and Regional Growth*. Cambridge University Press. <https://doi.org/10.1017/cbo9780511805660>
11. Geremew YM, Huang W-J, Hung K (2024) Fuzzy-Set Qualitative Comparative Analysis as a mixed-method and analysis technique: A comprehensive systematic review. *J Travel Res* 63(1):3–26. <https://doi.org/10.1177/00472875231168619>
12. Guo B, Zheng X, Wang Y, Li J, Liu Y (2022) Do socio-economic factors matter? A comprehensive evaluation of tourism eco-efficiency determinants in China based on the Geographical Detector Model. *J Environ Manage* 320:115812. <https://doi.org/10.1016/j.jenvman.2022.115812>
13. Haugland SA, Ness H, Grønseth B-O, Aarstad J (2011) Development of tourism destinations: An integrated multilevel perspective. *Annals Tourism Res* 38(1):268–290. <https://doi.org/10.1016/j.annals.2010.08.008>
14. Huang X-j, An R, Yu M-M, He F-f (2022) Tourism efficiency decomposition and assessment of forest parks in China using dynamic network data envelopment analysis. *J Clean Prod* 363:132405. <https://doi.org/10.1016/j.jclepro.2022.132405>
15. Jiao X, Chen JL, Li G, Liu T (2025) From Tourism Demand to Destination Competitiveness: A Spatial Spillover Perspective. *Tour Manag* 111:105236. <https://doi.org/10.1016/j.tourman.2025.105236>

16. Kim YR, Williams AM, Park S, Chen JL (2021) Spatial spillovers of agglomeration economies and productivity in the tourism industry: The case of the UK. *Tour Manag* 82:104201.
<https://doi.org/10.1016/j.tourman.2020.104201>
17. Lee C-C, Chang C-P (2008) Tourism development and economic growth: A closer look at panels. *Tour Manag* 29(1):180–192. <https://doi.org/10.1016/j.tourman.2007.02.013>
18. LeSage J, Pace RK (2009) *Introduction to Spatial Econometrics*. CRC.
<https://www.routledge.com/Introduction-to-Spatial-Econometrics/LeSage-Pace/p/book/9781420064247>
19. Li Y, Zhang Y (2022) Spatial-temporal evolution and influencing factors of tourism eco-efficiency in China's Beijing-Tianjin-Hebei region. *Front Environ Sci* 10:1067835.
<https://doi.org/10.3389/fenvs.2022.1067835>
20. Liao Z, Zhang L, Liang S (2023) Spatio-temporal pattern evolution of China's provincial tourism efficiency and development level based on DEA-MI model. *Sci Rep* 13:20227.
<https://doi.org/10.1038/s41598-023-46884-5>
21. Lundberg SM, Lee S-I (2017) A unified approach to interpreting model predictions. *Adv Neural Inf Process Syst* 30
22. Ma T, Hong T, Zhang H (2015) Tourism spatial spillover effects and urban economic growth. *J Bus Res* 68(1):74–80. <https://doi.org/10.1016/j.jbusres.2014.05.005>
23. Marcouiller DW (1998) Environmental resources as latent primary factors of production in tourism: The case of forest-based commercial recreation. *Tour Econ* 4(2):131–145.
<https://doi.org/10.1177/135481669800400202>
24. Nations U (2015) *Transforming our world: The 2030 Agenda for Sustainable Development*.
<https://docs.un.org/a/res/70/1>
25. Newsome D, Moore SA, Dowling RK (2013) *Natural Area Tourism: Ecology, Impacts and Management* (2nd ed.). Channel View Publications.
<https://www.channelviewpublications.com/page/detail/Natural-Area-Tourism/?k=9781845413810>
26. Nurmatov R, Lopez F, X. L., Coto Millan P (2021) Tourism, hospitality, and DEA: Where do we come from and where do we go? *Int J Hospitality Manage* 95:102883.
<https://doi.org/10.1016/j.ijhm.2021.102883>
27. Peng H, Zhang J, Lu L, Tang G, Yan B, Xiao X, Han Y (2017) Eco-efficiency and its determinants at a tourism destination: A case study of Huangshan National Park, China. *Tour Manag* 60:201–211.
<https://doi.org/10.1016/j.tourman.2016.12.005>
28. Qiu Y, He D, Xu Z, Shi X (2023) The Role of the Forest Recreation Industry in China's National Economy: An Input-Output Analysis. *Sustainability* 15(12):9690.
<https://doi.org/10.3390/su15129690>
29. Ragin CC (2008) *Redesigning Social Inquiry: Fuzzy Sets and Beyond*. University of Chicago Press.
<https://press.uchicago.edu/ucp/books/book/chicago/R/bo5973952.html>

30. Schneider CQ, Wagemann C (2012) Set-Theoretic Methods for the Social Sciences: A Guide to Qualitative Comparative Analysis. Cambridge University Press.
<https://doi.org/10.1017/cbo9781139004244>
31. Seto KC, Güneralp B, Hutyrá LR (2012) Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences*, 109(40), 16083–16088. <https://doi.org/10.1073/pnas.1211658109>
32. Sukhov A, Friman M, Olsson LE (2023) Unlocking potential: An integrated approach using PLS-SEM, NCA, and fsQCA for informed decision making. *J Retailing Consumer Serv* 74:103424.
<https://doi.org/10.1016/j.jretconser.2023.103424>
33. Tian F, Yang Y, Jiang L (2022) Spatial Spillover of Transport Improvement on Tourism Growth. *Tour Econ* 28(5):1416–1432. <https://doi.org/10.1177/1354816620982787>
34. Tone K (2001) A slacks-based measure of efficiency in data envelopment analysis. *Eur J Oper Res* 130(3):498–509. [https://doi.org/10.1016/s0377-2217\(99\)00407-5](https://doi.org/10.1016/s0377-2217(99)00407-5)
35. Wang H, Xu S, Xie Q, Fan J, Zhou N, Li J (2021) Study on the temporal and spatial differentiation of provincial tourism efficiency in Eastern China and influencing factors. *Complexity*, 2021, 4580917.
<https://doi.org/10.1155/2021/4580917>
36. Winter PL, Selin S, Cervený L, Bricker K (2020) Outdoor recreation, nature-based tourism, and sustainability. *Sustainability* 12(1):81. <https://doi.org/10.3390/su12010081>
37. Woodside AG (2013) Moving beyond multiple regression analysis to algorithms: Calling for adoption of a paradigm shift from symmetric to asymmetric thinking in data analysis and crafting theory. *J Bus Res* 66(4):463–472. <https://doi.org/10.1016/j.jbusres.2012.12.021>
38. Wu S-T, Chen Y-S (2016) Examining eco-environmental changes at major recreational sites in Kenting National Park in Taiwan by integrating SPOT satellite images and NDVI. *Tour Manag* 57:23–36. <https://doi.org/10.1016/j.tourman.2016.05.006>
39. Yang Y, Wong KKF (2012) A spatial econometric approach to model spillover effects in tourism flows. *J Travel Res* 51(6):768–778. <https://doi.org/10.1177/0047287512437855>
40. Yang Z, Zhang S, Liu J, Sun H (2022) Network of Tourism-Industrial Complex in Cities: Typologies and Implications through a Critical Literature Review. *Int J Environ Res Public Health* 19(9):4934. <https://doi.org/10.3390/ijerph19094934>
41. Yuan S, Zhu C, Yang L, Xie F (2019) Responses of ecosystem services to urbanization-induced land use changes in ecologically sensitive suburban areas in Hangzhou, China. *Int J Environ Res Public Health* 16(7):1124. <https://doi.org/10.3390/ijerph16071124>
42. Zhang H, Gu CL, Gu LW, Zhang Y (2012) Determinants of tourism destination competitiveness in China. *J China Tourism Res* 8(1):97–116. <https://doi.org/10.1080/19388160.2012.648461>

Figures

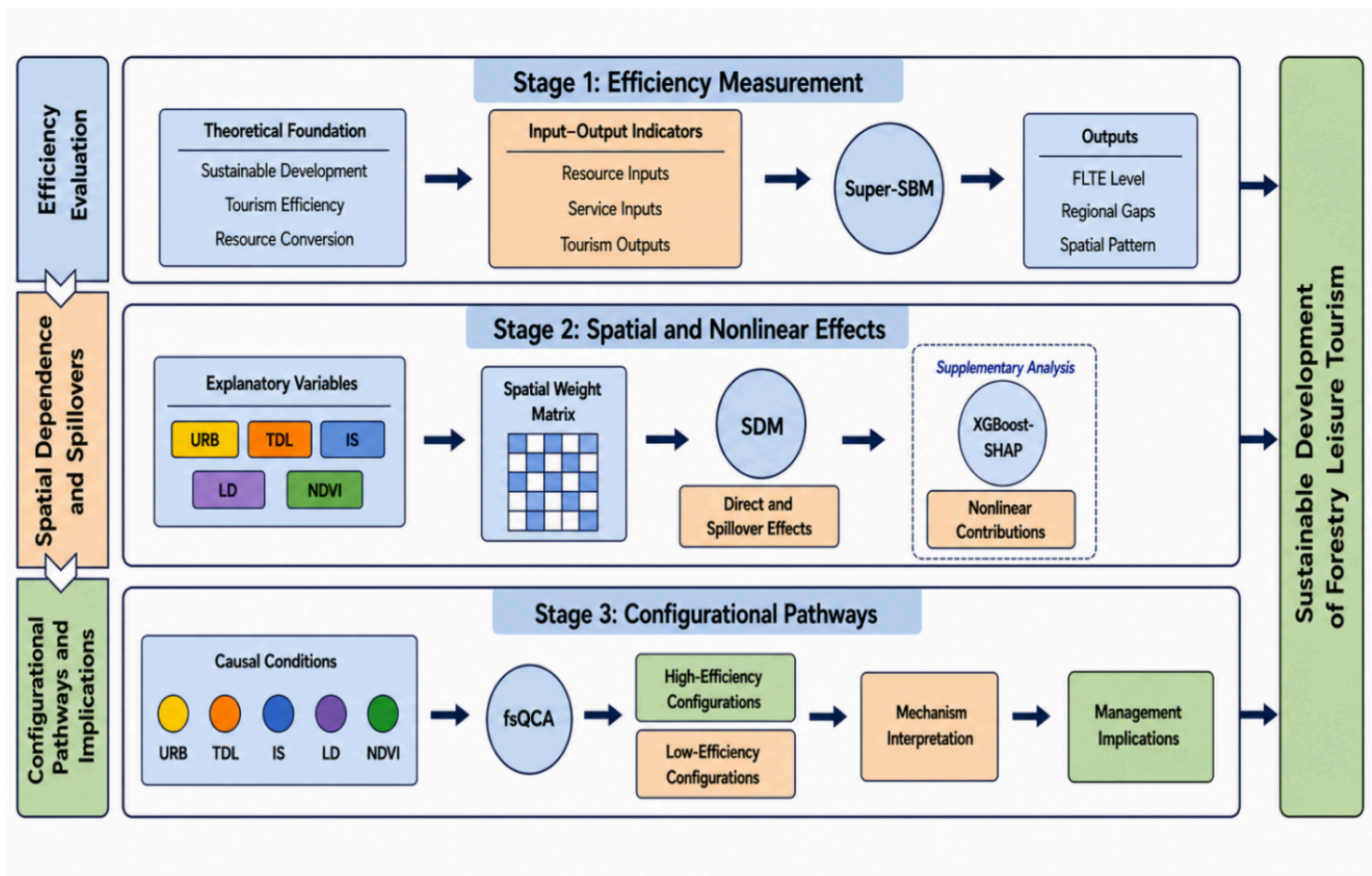


Figure 1

Research analytical framework.

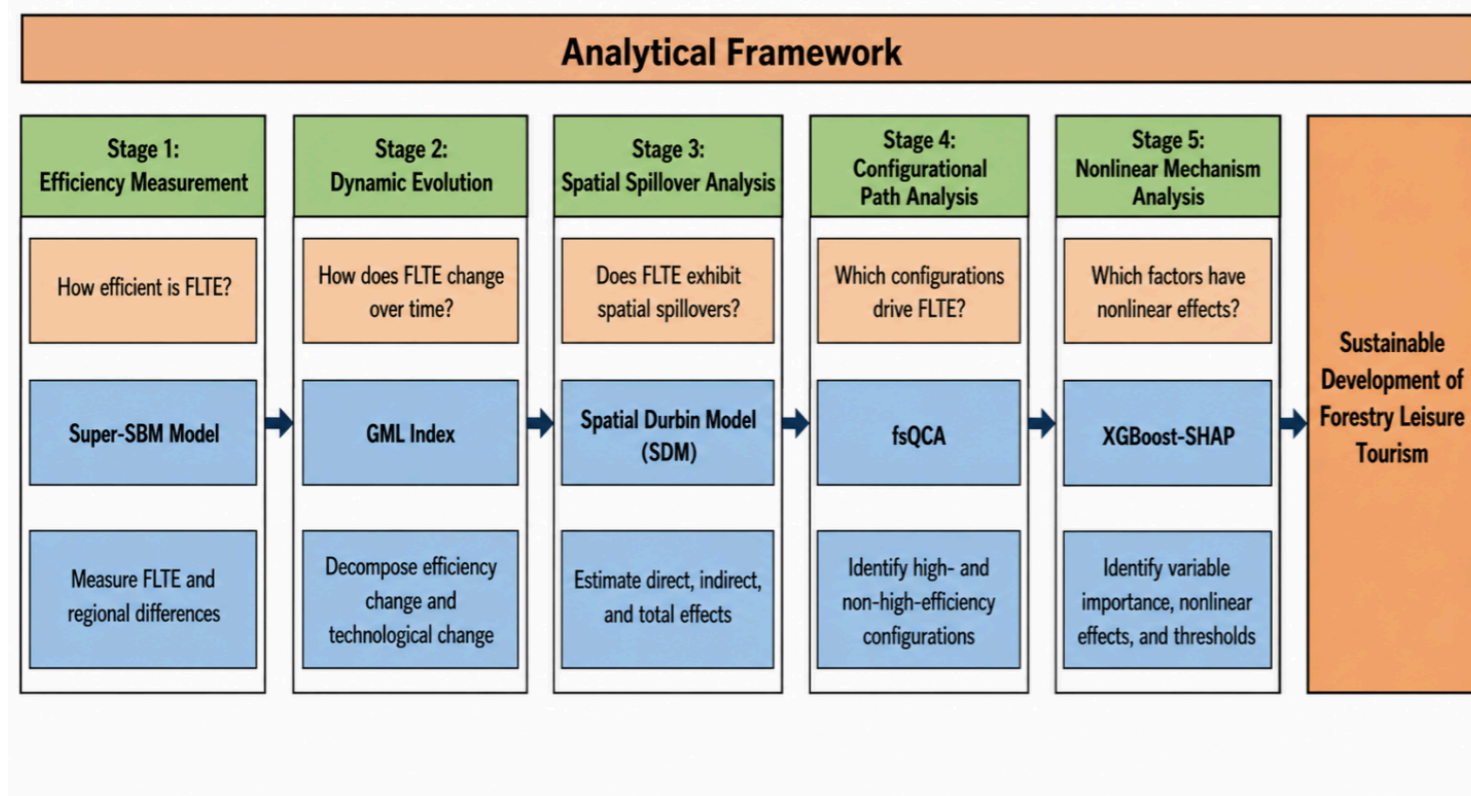


Figure 2

Analytical Framework for FLTE

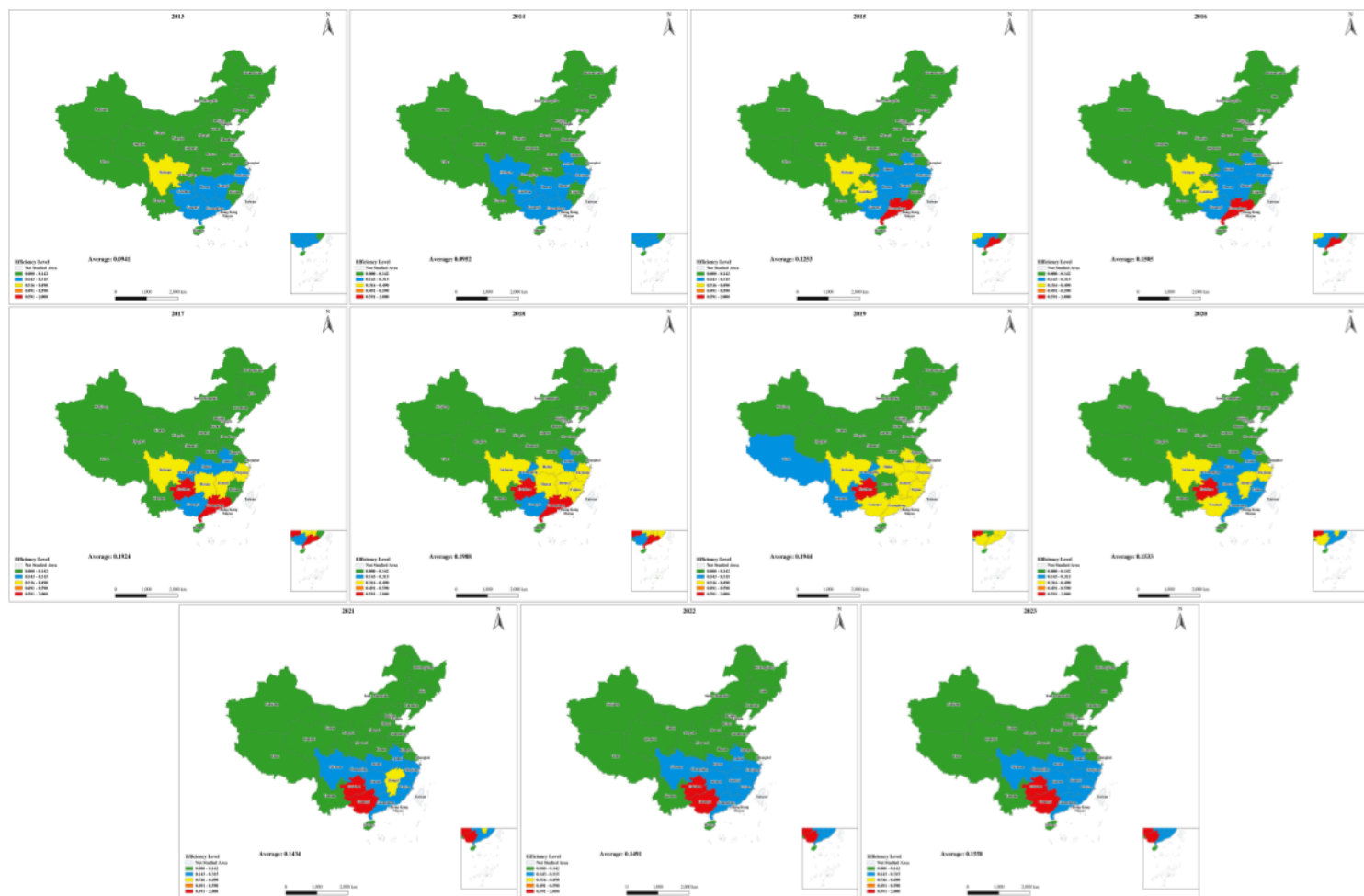


Figure 3

Spatial distribution of FLTE

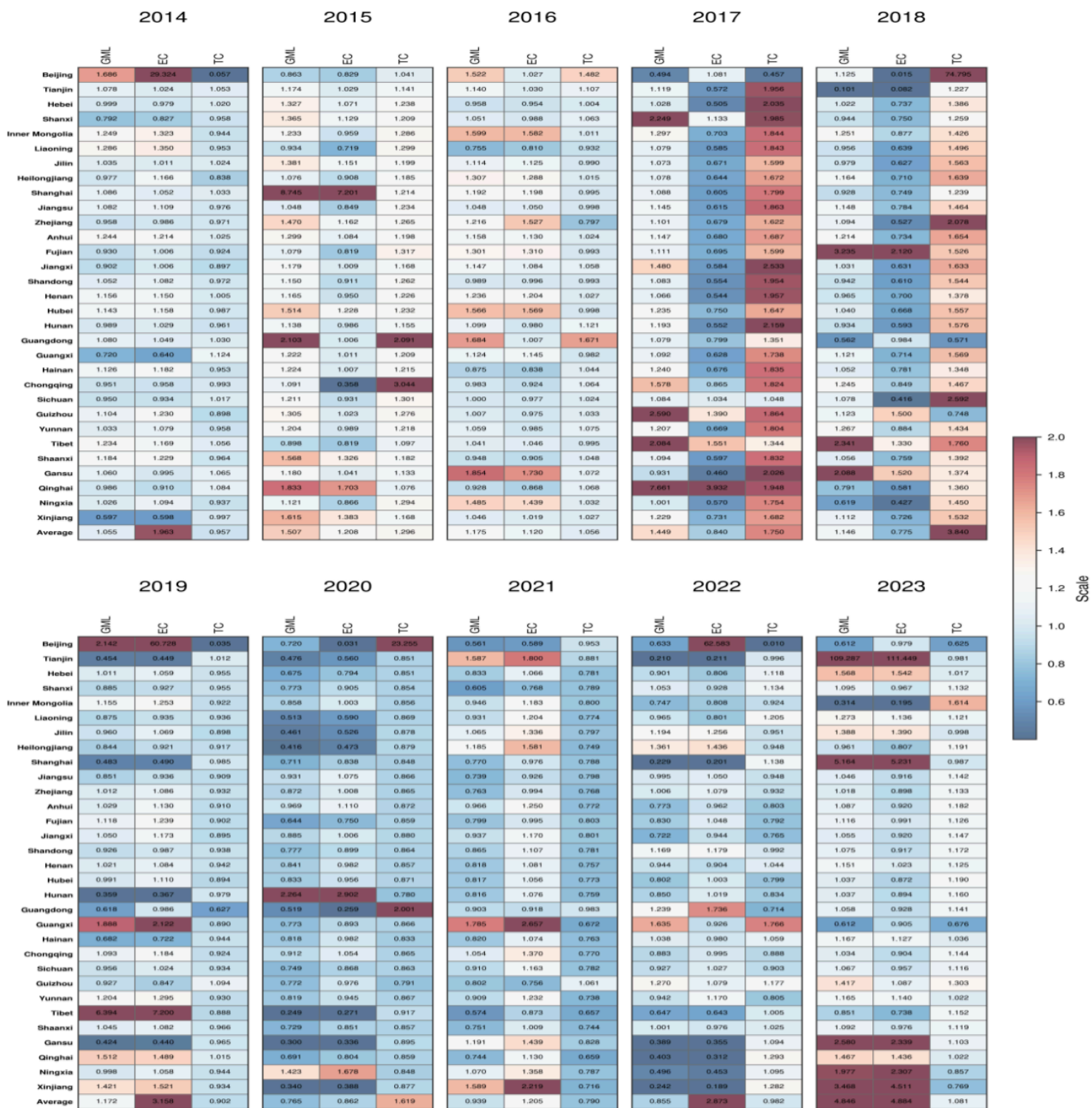


Figure 4

GML index decomposition of FLTE

Estimation Results of Spatial Spillover Effects

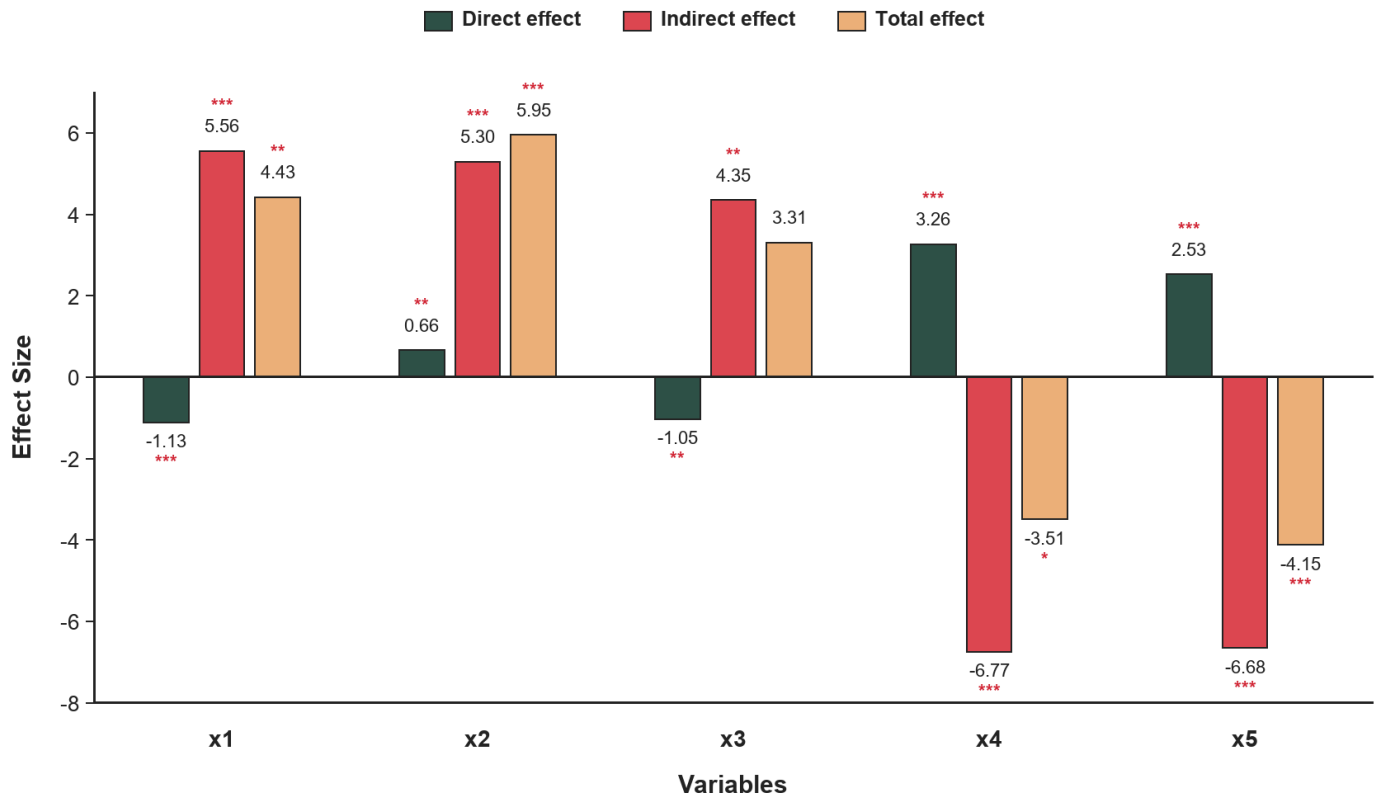


Figure 5

Estimated spatial spillover effects

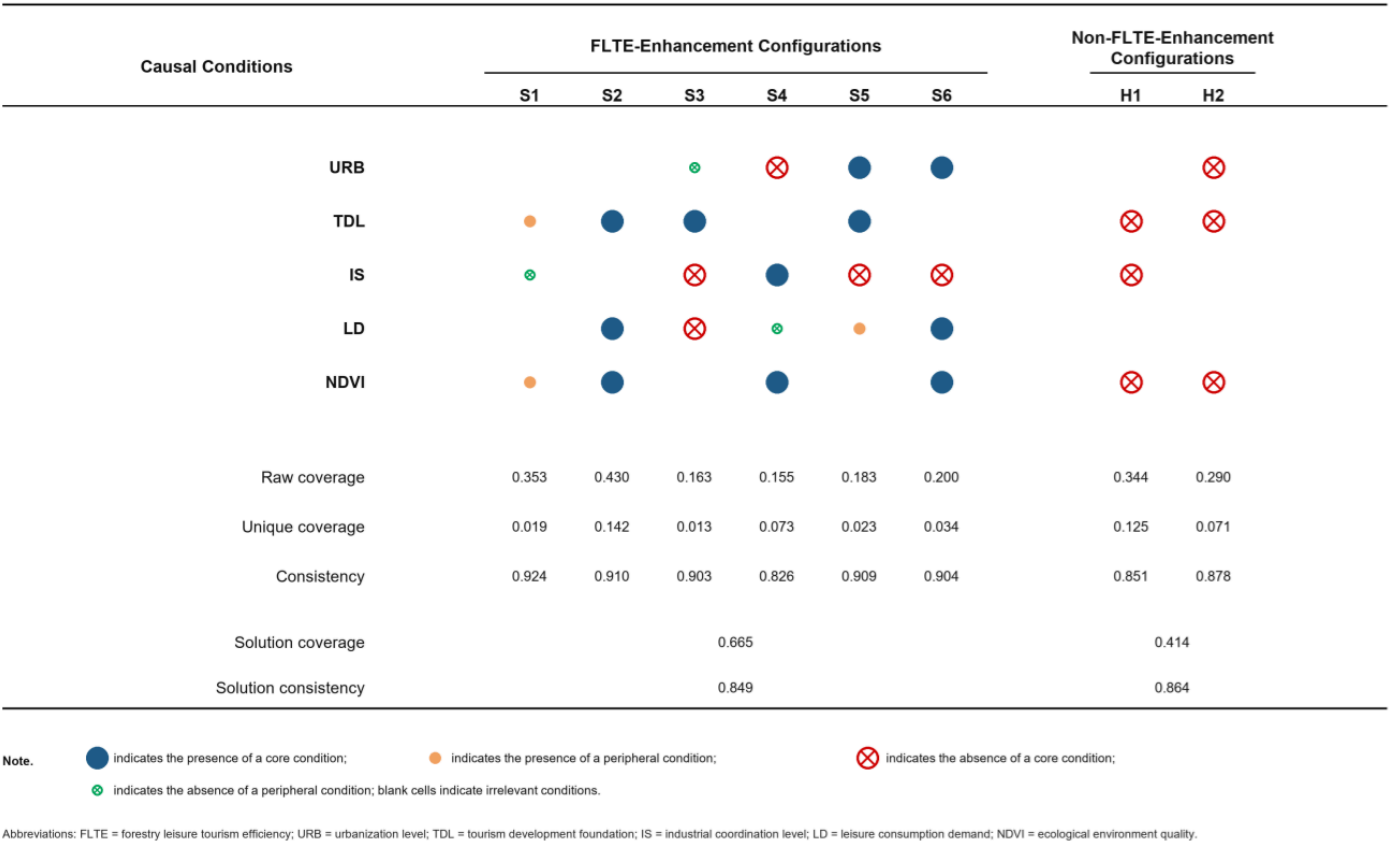


Figure 6

Configurational Pathways for FLTE Enhancement and Non-Enhancement

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SupplementaryInformation.docx](#)
- [HSSCCurrentDataandCodePackage.zip](#)
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