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Coupling Coordination of the Digital Economy, Cultural Tourism and Ecological Civilization in a Strategic Overlap Zone: Evidence from the Ningxia Section of the Yellow River Basin, China

Lin Dai
Ningxia Polytechnic University of Business and Technology, Yinchuan 750021, China

ABSTRACT

Resource-constrained regions are expected to digitalize their economies, convert cultural and natural assets into tourism income, and keep resource use within ecological limits at the same time, yet the three trajectories do not reinforce one another automatically. This study examines how the digital economy, the cultural tourism industry and ecological civilization co-evolve in Ningxia, the only provincial-level region located entirely within China's Yellow River Basin and a node of the Belt and Road westward opening, where the two national strategies overlap. Using data for the five prefecture-level cities from 2013 to 2023, we construct a 27-indicator evaluation system, apply entropy-weighted TOPSIS to measure subsystem development, and combine a level-corrected coupling coordination model with relative development analysis to identify the lagging subsystem in each city. The composite development index rose from 0.241 to 0.635 and inter-city disparity narrowed, while subsystem growth differed sharply: the digital economy expanded fastest (+271%), cultural tourism followed a path of growth, pandemic disruption and recovery (+179%), and ecological civilization improved most steadily (+101%). The regional coordination degree climbed from 0.408 (near imbalance) to 0.751 (intermediate coordination); Yinchuan alone entered good coordination. Relative development ratios separate five city types, each requiring a different policy emphasis. In this case coordination depended less on expanding any single subsystem than on converting digital capacity into tourism and environmental governance applications, and on the local skills that such conversion requires.

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KEYWORDS:
coupling coordination, conversion capacity, relative development, type-based governance, resource-constrained regions, ecological civilization

I. INTRODUCTION

Regions that combine a fragile resource base with a narrow industrial structure are now expected to deliver three transformations at once. They are asked to digitalize their economies, to convert cultural and natural assets into tourism income, and to keep resource use within ecological limits. Each agenda follows its own logic. Digital investment lowers the cost of information and coordination and can offset some disadvantages of distance; cultural tourism turns heritage, landscape and hospitality into local income and employment; ecological protection restricts the resource throughput on which earlier growth depended. Whether these agendas reinforce or obstruct one another is not a technical detail but the core of regional sustainability. Work on coupled social-ecological systems has long argued that such subsystems interact through feedback, so that a gain in one may be absorbed, amplified or reversed by the others[1,2].

China offers an unusually explicit setting for this question, because two national strategies assign the same territories two different tasks. The Outline of the Yellow River Basin's Ecological Protection and High-Quality Development Plan, issued in 2021, makes water saving, ecosystem restoration, industrial transformation and cultural transmission the conditions of regional development within the basin[3]. The Belt and Road Initiative, pursued since 2013, has reoriented the western provinces toward Central and West Asia and turned connectivity, trade and cultural exchange into criteria of local performance. Ningxia Hui Autonomous Region sits at the intersection: it is the only provincial-level jurisdiction lying entirely within the Yellow River Basin, and it is a designated node of westward opening, including a national

Corresponding Author: Lin Dai

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integrated computing hub approved in 2022[4]. The two agendas meet in the same five prefecture-level cities, but not in the same way. Yinchuan concentrates population, services and computing capacity; Shizuishan is a coal-based city undergoing industrial transition; Wuzhong and Zhongwei hold stretches of the Yellow River mainstem, the latter combining desert tourism with data centres; Guyuan, in the southern hills, supplies ecological functions while remaining distant from major markets. This configuration makes Ningxia a useful place to observe whether digital capacity, tourism development and ecological governance actually converge.

Three bodies of literature inform the analysis. The first examines digitalization and tourism. Studies of Chinese provinces and cities report that digital infrastructure, platform intermediation and online marketing raise tourism demand and supply efficiency, although the strength of the relationship varies across regions[5,6]. Research on digital heritage and smart destinations adds that digital tools change interpretation, booking and visitor management, while investment in hardware without organizational change yields limited returns[7,8].

The second strand analyses tourism-environment relations. Coupling studies along the Yellow River find that coordination has improved over the past decade yet remains below the high-coordination range, with ecological capacity acting as a binding constraint in arid reaches[9-11]. Work on the Silk Road Economic Belt reaches similar conclusions and adds that public services mediate the tourism-environment relationship[12]. This literature is strong on measurement and thinner on mechanism: ecological limits usually enter as an index rather than as a process operating through water allocation, land use or waste absorption.

The third strand brings the three systems together. Liu et al.[13] construct a digital economy-tourism-environment coupling model for Chinese provinces; Song et al.[14] trace the same system across the Yellow River Basin; Pan et al.[15] extend the exercise to 278 cities and add driving factors. Their common finding is that coordination has improved and that the digital economy often acts as the leading subsystem, while the tourism-environment link remains the weakest edge of the triangle.

Three limitations remain. First, most triadic studies stop at the aggregate coordination score. A single coefficient cannot say whether coordination is produced by balanced development or by three subsystems rising together from a low base, nor which subsystem constrains the others; without that structural information the policy implication collapses into a general call for more coordination. Second, strategy timing is frequently read as strategy effect. When an index accelerates after a policy is issued, the acceleration is attributed to the policy, although the same period contains a global pandemic, a construction-sector contraction and large public investment cycles. Third, evidence from sub-provincial units in water-scarce, multi-ethnic and ecologically fragile regions remains thin, and the five cities of Ningxia differ enough for an average to mislead.

This study therefore asks three questions. First, how have the digital economy, cultural tourism and ecological civilization developed across the five cities, and how do their growth paths differ? Second, at what level have the three systems been coupled and coordinated, and how has that level evolved over space and time? Third, which subsystem lags in each city, and what does that imply for differentiated governance? We treat the two strategies as the institutional context in which the three systems evolve rather than as treatments whose effects can be identified from a before-and-after comparison. Without a counterfactual, the analysis documents patterns and associations; it does not estimate net policy effects[16].

The contribution is threefold. Conceptually, the study specifies the different functional positions that digital capacity, tourism and ecological governance occupy in a strategic overlap zone, and derives the conditions under which they reinforce rather than displace one another. Methodologically, it pairs a level-corrected coordination measure with a relative development measure, so that the aggregate score and the internal structure of each city are read together. Empirically, it provides an eleven-year, city-level account of a region that carries both a basin-wide ecological mandate and an outward-opening mandate, and converts the resulting typology into differentiated policy emphases. The remainder of the paper sets out the framework (Section II), the data and methods (Section III), the results (Section IV), and the discussion and conclusions (Sections V and VI).

II. THEORETICAL FRAMEWORK

A. Two Strategic Logics and Three Functional Positions

Ecological protection and westward opening answer different questions. Protection addresses whether development can be sustained: it sets water availability, pollutant loads and spatial controls as prior conditions, and it treats the basin as a unit whose upstream and downstream interests are linked. Opening addresses how far development can reach: it expands markets, brings in capital and technology, and turns cultural exchange into an instrument of external relations. The two logics are neither identical nor opposed. Openness can finance restoration and industrial upgrading, but it can also raise resource throughput when investment flows into energy-intensive or water-intensive activities. Strict protection raises short-run costs for some sectors, yet it can build long-run asset value by improving environmental quality and the scarcity rents attached to well-managed landscapes.

Within this double mandate the three subsystems occupy distinct positions. The digital economy is the technological linkage: it lowers the cost of information, extends market reach beyond a limited local demand base, and supplies the

monitoring and scheduling tools through which water, waste and visitor flows can be managed. Cultural tourism is the industrial carrier: it is the main channel through which cultural and ecological assets are converted into income, and it is also the sector most exposed to shifts in demand, mobility and image. Ecological civilization is both resource base and value standard: it defines the carrying capacity within which the other two operate, and it supplies the legitimacy that cultural narratives and green destinations trade on.

The three positions are not symmetric. Digital capacity can grow without being used, tourism can grow without improving livelihoods, and ecological performance can improve while remaining economically idle. Coordination is therefore a property of the relations among the three, not of any one of them.

B. Interaction Mechanisms and Research Propositions

Digitalization affects tourism through three channels (P1). In supply, it allows cultural resources to be digitized, interpreted and presented in forms that can travel; in market access, platforms and social media reduce the cost of reaching visitors beyond the region; in management, reservation systems, flow monitoring and yield management raise the productivity of a fixed stock of rooms, guides and sites. These channels are conditional. If digital investment stays at the level of equipment purchase, platform display and promotion, and does not enter product design and daily operations, the result is a build-first, apply-later pattern in which the index rises while service quality does not. Absorptive capacity, firm size and staff skills therefore mediate the relationship.

Digitalization also affects ecological governance, but with a qualification (P2). Remote sensing, sensor networks and data platforms improve the timeliness of environmental information, the scheduling of water deliveries, the tracing of pollution sources and the targeting of restoration. At the same time, data centres and computing clusters consume electricity and water for cooling; in a region that hosts a national computing hub while facing tight water quotas, the ecological dividend depends on the energy mix and on how cooling water is sourced and recycled. Digitalization is thus not intrinsically green.

Tourism and ecology interact in both directions (P3). Ecological quality is an input to tourism: air quality, water quality, vegetation cover and settlement environment determine attractiveness and support the shift from sightseeing to ecotourism, wellness and study travel. Tourism is also a mechanism of value capture: revenue, employment and brand recognition give ecological improvements an economic return, which can justify continued protection, an argument long made in the heritage-tourism literature[17]. The reverse effect is equally real. Visitor concentration, facility construction and road access raise water demand, waste generation and disturbance, particularly where carrying capacity is low. Whether the net effect is protective or extractive depends on scale, seasonality and the institutions that allocate revenue and manage access.

Two further propositions concern the system as a whole. P4 holds that, if the three subsystems improve at different speeds and respond differently to external shocks, the aggregate coordination level will rise unevenly rather than smoothly. P5 holds that, because the cities differ in economic base, resource endowment, industrial structure and administrative function, their coordination levels should be expected to diverge, and the divergence should reflect which subsystem is relatively weak rather than how much investment each has received. These expectations are examined descriptively in Section IV rather than tested as causal hypotheses.

C. From Pairwise Links to System-Level Coordination

Three pairwise relationships do not add up to a system. Feedback makes the whole behave differently from its parts: digital capacity raises tourism productivity and monitoring capacity; improved environment raises tourism quality and provides new data-generating scenes for digital tools; tourism revenue can finance both digital maintenance and protection. Where these loops close, a self-reinforcing trajectory becomes possible: as resilience theory argues, redundancy and feedback allow a system to absorb disturbance rather than transmit it[18]. Where one link is missing, the system can display high development with low coordination: digital infrastructure expands while tourism firms do not use it, or ecological quality improves while no product converts it into visitor demand.

This distinction between a level problem and a structural problem motivates the design. The coupling coordination degree answers how far the three subsystems have moved toward a common trajectory; the relative development degree answers which subsystem is out of line. Read together, they locate each city in a two-dimensional space and support a typology whose categories correspond to different policy tasks. Figure 1 summarizes the framework, from the two strategic logics through the three functional positions and their interactions to the diagnosis and the type-based response.

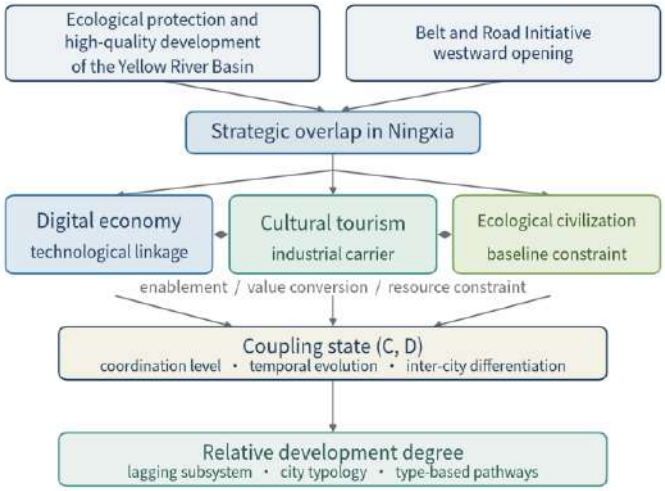

FIG. 1. Analytical framework linking the two national strategies, the three subsystems and type-based governance.

III. METHODOLOGY

A. Study Area and Period

Ningxia Hui Autonomous Region covers 66,400 km² in the upper-middle reaches of the Yellow River and had approximately 7.29 million residents in 2023. The Yellow River mainstem passes through Zhongwei, Wuzhong, Yinchuan and Shizuishan, while the southern city of Guyuan is linked to the basin through the Qingshui River and its tributaries. The region is arid to semi-arid, with annual precipitation declining from 400-600 mm in the southern hills to below 200 mm in the northern plains and with high evaporation; water availability per capita is among the lowest of China's provincial units, and allocations are administered through basin-level quotas. The Helan Mountains in the north-west and the Liupan Mountains in the south provide the principal ecological barriers, and large shares of the territory are assigned ecological or agricultural functions that limit construction.

The five cities differ in function and in economic scale. In 2023, gross domestic product ranged from RMB 43.7 billion in Guyuan to RMB 268.6 billion in Yinchuan, and population from 0.75 million in Shizuishan to 2.91 million in Yinchuan. Yinchuan combines provincial administration, services and the computing hub; Shizuishan carries the legacy of coal mining and heavy industry together with severe ecological repair obligations; Wuzhong relies on irrigated agriculture and food processing; Zhongwei pairs desert tourism at Shapotou with data-centre investment; Guyuan remains the least urbanized and most dependent on ecological compensation and transfer payments. The period 2013-2023 was chosen because 2013 marks the launch of the Belt and Road Initiative and 2023 is the latest year for which a complete set of prefecture-level indicators is available[19].

B. Indicator System and Data

The indicator system follows four principles: relevance to the theoretical functions of each system, coverage of both capacity and use, consistency of definition across cities and years, and regional fit. Each system is represented by nine indicators in three dimensions, giving 27 indicators in total (Table I).

The digital economy is measured through infrastructure, digital industrialization and industrial digitalization. Infrastructure captures the stock of connectivity; digitalization of industry captures the scale of the local digital sector; and industrial digitalization captures whether firms actually transact and manage online. The third dimension matters because infrastructure without application is the pattern that the framework identifies as a conversion failure. Cultural tourism is measured through industry scale, cultural resources and service capacity, so that the index reflects both demand (revenue and arrivals) and the supply base (scenic areas, heritage items, facilities, hotels, agencies and staff) on which future demand depends. Ecological civilization is measured through resource endowment, resource pressure, governance and environmental quality. The endowment indicator records per-capita water availability as a positive base condition; the pressure indicators, expressed per unit of output, prevent the index from rewarding environmental quality that is purchased with inefficient resource use.

TABLE I. Indicator System for the Three Subsystems

System	Dimension	Indicator	Unit	Sign
Digital economy	Digital infrastructure	Internet broadband subscribers	10^4 households	+
		Mobile phone subscribers	sets / 100 persons	+
		Optical cable length	km	+
	Digital industrialization	Telecom business volume	RMB million	+
		Revenue of software and IT services	RMB million	+
		Share of digital-sector employment	%	+
	Industrial digitalization	E-commerce transaction value	RMB million	+
		Enterprises with e-commerce activity	%	+
		Digital financial inclusion index	index	+
Cultural tourism	Industry scale	Total tourism revenue	RMB million	+
		Total tourist arrivals	10^4 person-trips	+

System	Dimension	Indicator	Unit	Sign
		Tourism revenue as share of GDP	%	+
	Cultural resources	A-grade scenic areas	count	+
		Intangible cultural heritage items	count	+
		Public cultural facilities	count	+
	Service capacity	Star-rated hotels (3-star and above)	count	+
		Travel agencies	count	+
		Tourism employment	10^4 persons	+
Ecological civilization	Resource endowment and pressure	Water resources per capita	m^3 / person	+
		Energy consumption per RMB 10,000 GDP	tce / RMB 10^4 GDP	-
		Water consumption per RMB 10,000 GDP	m^3 / RMB 10^4 GDP	-
	Ecological governance	Wastewater treatment rate	%	+
		Harmless treatment rate of domestic waste	%	+
		Green coverage of built-up areas	%	+
	Environmental quality	Days with good or excellent air quality	%	+
		Surface water at Grade III or better	%	+
		Forest coverage rate	%	+

Note: '+' denotes a positive indicator, for which higher values increase the subsystem index; '−' denotes a negative indicator. All indicators are measured annually for the five prefecture-level cities, 2013–2023; where a municipal series is not separately published, the value is derived as described in the data subsection below.

Data were assembled from the Ningxia Statistical Yearbook and the China City Statistical Yearbook for 2014-2024, the Ningxia culture and tourism statistical bulletin, the regional ecological environment status bulletin, the Ningxia water resources bulletin, and the statistical communiques of the five cities. Telecom business volume, one of the digital indicators, has been calculated at constant prices since 2019, so part of its measured growth after 2019 reflects the change in calculation basis rather than service expansion alone. The digital financial inclusion index is taken from the Peking University series[20]. All indicators were normalized by min-max scaling applied to the pooled city-year panel, so that the indices are relative to the observed range rather than absolute: values are comparable across the cities and years of this study but not with indices computed on other panels. Where a city-year observation was missing, linear interpolation between adjacent years was used, and where the statistical definition changed, series were backcast to the most recent definition. Because several indicators are only published at the regional level, city values for those items were allocated using the cities' shares of the relevant aggregate, a procedure that introduces measurement error and is treated as a limitation.

C. Entropy-Weighted TOPSIS

Weights were assigned by the entropy method, which rewards indicators that discriminate between observations rather than indicators that are merely large in magnitude. After normalization, the share of observation i in indicator j and the entropy of that indicator are computed, and weights are obtained from the degree of diversification:

$$x'_{ij} = \frac{x_{ij} - \min_j \{x_{ij}\}}{\max_j \{x_{ij}\} - \min_j \{x_{ij}\}} \quad (1)$$

$$p_{ij} = \frac{x'_{ij}}{\sum_i x'_{ij}}, \quad e_j = -\frac{1}{\ln m} \sum_i p_{ij} \ln p_{ij}, \quad w_j = \frac{1 - e_j}{\sum_j (1 - e_j)} \quad (2)$$

The weighted normalized matrix was then evaluated by the distance-to-ideal method. For each city and year, the distances to the positive and negative ideal solutions give a closeness coefficient that is bounded between zero and one and is interpreted as the comprehensive development index of the subsystem:

$$U = \frac{d^-}{d^+ + d^-}, \quad d^{\pm} = \sqrt{\sum_j w_j \left(x'_{ij} - x_j^{\pm}\right)^2} \quad (3)$$

The procedure was implemented in Python 3.11. Indices are reported to three decimals, and differences smaller than 0.005 are not treated as substantive.

D. Coupling Coordination with Level Correction

The coupling degree expresses how closely the three subsystems move together, while the coordination degree combines coupling with the level of development. For three subsystems the coupling degree is:

$$C = \left[\frac{3\, U_D U_T U_E}{(U_D + U_T + U_E)^3}\right]^{1/3} \quad (4)$$

Eq. (4) is bounded above by 3^(-2/3) ≈ 0.481 rather than by unity, so that its upper range is never used in practice. A second property is that the formula rewards agreement regardless of level, so that three subsystems that all stagnate at a low value appear strongly coupled. Both properties bear on the present case, which contains cities at very different levels. We therefore adopt the level-corrected formulation proposed by Wang et al.21 , in which coupling obtained at a low development level is discounted rather than rewarded. For n subsystems the corrected coupling degree is:

$$C_c = \sqrt{\left[1 - \frac{\sum_{i>j}|U_i - U_j|}{\sum_{m=1}^{n-1} m}\right] \times \left(\prod_{i=1}^{n} \frac{U_i}{\max U_i}\right)^{\frac{1}{n-1}}} \quad (4a)$$

where the first factor penalizes pairwise dispersion among the subsystems and the second penalizes low levels relative to the leading subsystem; for n = 3 the denominator of the first factor is 3. Cc equals unity only when the three indices are equal, declines as any one of them falls behind, and, unlike eq. (4), uses the whole interval [0, 1]. The comprehensive development level, defined as the unweighted mean of the three subsystem indices (α = β = γ = 1/3, the weights used throughout), and the coordination degree are then:

$$T = \frac{U_D + U_T + U_E}{3}, \quad D = \sqrt{C_c T} \quad (5)$$

where Cc denotes the corrected coupling degree of eq. (4a). D is classified according to the ten-level scheme widely used in Chinese coordination studies[22,23]: values between 0.3 and 0.4 indicate slight imbalance, 0.4-0.5 near imbalance, 0.5-0.6 marginal coordination, 0.6-0.7 primary coordination, 0.7-0.8 intermediate coordination, and 0.8-0.9 good coordination. Two benchmark years (2013 and 2023) are reported because the coordination degree is computed from the subsystem indices, which are themselves reported for the benchmark years only.

E. Relative Development Degree and Typology

Because D is a composite of coupling and level, a rising D may reflect growth in T rather than closer interaction. To recover the internal structure, pairwise ratios of the subsystem indices were computed:

$$R_{ij} = U_i / U_j, \quad i, j \in \{D, T, E\},\ i \neq j \quad (6)$$

A ratio above one indicates that the numerator subsystem leads; below one, that it lags. Deviations of up to 5% from unity were treated as parity, deviations of 5% to 15% as a mild imbalance and deviations above 15% as a pronounced imbalance. The bands are conventional rather than statistical, so the typology records configurations rather than significant differences. Each city was then located by its coordination grade and by the identity of its lagging subsystem, and cities with the same combination were grouped into a type. The typology is descriptive: it summarizes configurations, and the labels attached to it are analytical short-hands rather than rankings.

F. Scope of Inference

Three constraints on interpretation should be stated at the outset. The design has five units and eleven years, which is insufficient for panel estimation with city and year effects; accordingly no regression is reported. The strategies are not quantified as treatment intensity, so their contribution cannot be separated from concurrent shocks, including the 2020-2022 pandemic and the contraction of construction and real estate. Finally, the indices measure observable inputs and outputs, not the quality of institutions or the implementation of policy. The results therefore describe the state and structure of coordination; they do not establish why a particular city occupies its position.

IV. RESULTS

A. Development Levels of the Three Subsystems

The composite index, averaged across the three subsystems and the five cities, rose from 0.241 in 2013 to 0.635 in 2023 (Table II). The increase was not distributed evenly. The digital economy index grew from 0.168 to 0.623, an increase of 271% and the fastest of the three; cultural tourism rose from 0.214 to 0.598 (+179%); ecological civilization rose from 0.341 to 0.685 (+101%), starting from the highest base and ending with the highest level.

TABLE II. Comprehensive Development Indices of the Three Subsystems, 2013 and 2023

City	Digital economy	Cultural tourism	Ecology	Composite 2023
Yinchuan	0.241 → 0.851	0.298 → 0.724	0.412 → 0.783	→ 0.786
Shizuishan	0.187 → 0.612	0.198 → 0.543	0.367 → 0.724	→ 0.626
Wuzhong	0.165 → 0.584	0.205 → 0.589	0.325 → 0.671	→ 0.615
Guyuan	0.092 → 0.478	0.167 → 0.498	0.298 → 0.619	→ 0.532
Zhongwei	0.154 → 0.589	0.201 → 0.637	0.303 → 0.628	→ 0.618
Regional mean	0.168 → 0.623	0.214 → 0.598	0.341 → 0.685	→ 0.635

Note: values are comprehensive development indices in [0,1] obtained by entropy-weighted TOPSIS. The regional mean is the unweighted average of the five cities. Values before and after the arrow refer to 2013 and 2023. The composite index is the unweighted mean of the three subsystem indices; the regional composite for 2013 (0.241) is the mean of the five city composites.

The digital economy also shows the widest dispersion. Yinchuan reached 0.851, more than 1.7 times the value of Guyuan (0.478), a gap consistent with the concentration of backbone networks, computing capacity and digital service firms in the provincial capital. The growth pattern is nonetheless convergent: Guyuan started from 0.092, the lowest value in the panel, and recorded the largest proportional gain (420%). The smallest proportional gains were recorded by Shizuishan (227%) and Yinchuan (253%), the two cities with the highest initial digital indices. Convergence of this kind is commonly observed in

infrastructure diffusion, in which the marginal cost of extending coverage to under-served areas falls once backbone capacity exists.

Cultural tourism followed a path rather than a trend line. Growth before 2020 coincided with rising domestic demand and with investment in scenic areas and hotels. Arrivals and revenue fell sharply in 2020 and 2021, when cross-regional mobility was restricted, and recovered from 2022 onward; by 2023 the regional index had recovered well above its 2013 level. Because the recovery was concentrated in destinations with established brands and access, the shock did not affect the cities equally: Yinchuan (0.724) and Zhongwei (0.637) ended the period well above Shizuishan (0.543) and Guyuan (0.498), although all four had been closer together in 2013.

Ecological civilization improved most steadily and with the smallest dispersion. Every city gained; relative dispersion fell, although the absolute gap between the highest and lowest values widened slightly because the leading cities improved faster. Shizuishan (0.724) ranked second only to Yinchuan (0.783), a result that sits uneasily with its reputation as a pollution-intensive industrial city: the index is consistent with a decade of mine closure, subsidence treatment, lake restoration and air-quality improvement, which raised measured environmental quality faster than the local economy grew. Guyuan (0.619), despite hosting the Liupan Mountain ecological barrier, recorded the lowest ecological index, a reminder that measured ecological performance depends on fiscal capacity and management as much as on natural endowment.

Taken together, the three subsystems improved, but the ordering changed. In 2013 ecology led and the digital economy trailed by a wide margin; by 2023 the digital economy had become the leading subsystem in Yinchuan and had closed much of the gap in the other four cities without displacing ecology as the leading subsystem there. Convergence across cities also occurred at the aggregate level: the coefficient of variation of the composite index fell from 0.18 to 0.13, and the proportional gains of Guyuan (+186%), Zhongwei (+182%) and Wuzhong (+165) exceeded those of Shizuishan (+150) and Yinchuan (+148). Rising levels were therefore accompanied by a narrowing of the inter-city gap, although absolute differences remained large.

B. Spatial Differentiation

The 2023 pattern shows three distinct geographies rather than one common gradient (Figure 2). The digital economy displays a core-periphery structure centred on Yinchuan, with an intermediate ring formed by Shizuishan, Wuzhong and Zhongwei, whose values fall within a narrow band of 0.584 to 0.612, and a periphery formed by Guyuan. The pattern follows the administrative and network hierarchy rather than proximity to the river.

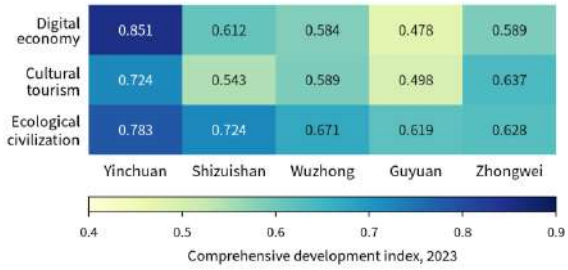

FIG. 2. Comprehensive development indices of the three subsystems by city, 2023.

Cultural tourism shows a dual-core structure that extends along the Yellow River. Yinchuan and Zhongwei form the two cores, the first through service capacity and the second through the Shapotou brand and the desert resort cluster; Wuzhong and Shizuishan occupy the middle, and Guyuan trails despite holding the Liupan Mountain and Long March heritage resources. The contrast between Guyuan's resource endowment and its tourism index points to accessibility and facility quality rather than to the absence of attractions.

Ecological civilization shows a north-high, south-low gradient, from Yinchuan and Shizuishan through Wuzhong and Zhongwei to Guyuan. This gradient runs against the distribution of precipitation, which is higher in the south. The explanation is institutional and fiscal: the northern cities command larger budgets for treatment plants, district heating conversion, green space and monitoring, and they host the industrial and urban sources whose emissions are easiest to measure and regulate. The south, with dispersed rural settlements and limited own-source revenue, achieves ecological protection largely through land-use restriction and transfers, which register less strongly in an index built on treatment rates and built-up area indicators.

The three geographies intersect in ways that matter for policy. Yinchuan is advantaged on all three dimensions; Shizuishan is advantaged on ecology but disadvantaged on tourism; Zhongwei is advantaged on tourism and average on the other two; Wuzhong is average everywhere; Guyuan is below average everywhere but improving fastest. A single regional programme would therefore address none of these situations precisely.

C. Coupling Coordination: Level, Trajectory and Structural Reading

The regional coordination degree rose from 0.408 in 2013, a state of near imbalance, to 0.751 in 2023, intermediate coordination, an increase of 83.9% over the period (Table III and Figure 3). By 2023 Yinchuan had entered good coordination (0.841), Zhongwei (0.771), Wuzhong (0.747) and Shizuishan (0.724) had entered intermediate coordination, and Guyuan (0.670) had entered primary coordination. Yinchuan alone crossed into good coordination, and the regional mean sat at the lower half of the intermediate-coordination band.

TABLE III. Coupling Coordination Degree by City, 2013 and 2023

City	2013	2023	Change (%)	Grade
Yinchuan	0.491	0.841	+71.4	Good coordination
Shizuishan	0.413	0.724	+75.4	Intermediate coordination
Wuzhong	0.406	0.747	+84.0	Intermediate coordination
Guyuan	0.334	0.670	+101.0	Primary coordination
Zhongwei	0.398	0.771	+93.5	Intermediate coordination
Regional mean	0.408	0.751	+83.9	Intermediate coordination

Note: grades follow the ten-level classification in ref. 22: 0.3–0.4 slight imbalance, 0.4–0.5 near imbalance, 0.5–0.6 marginal coordination, 0.6–0.7 primary coordination, 0.7–0.8 intermediate coordination, 0.8–0.9 good coordination. Change is measured between 2013 and 2023. Coordination degrees are computed directly from the benchmark indices in Table II by eq. (4a) with $D = \sqrt{(Cc \cdot T)}$, so Tables II and III are mutually reproducible; the annual panel is used for the entropy weights, and sensitivity checks are available from the authors. Because Cc is nonlinear in the subsystem indices and penalizes dispersion, the values are not recovered by applying the uncorrected eq. (4).

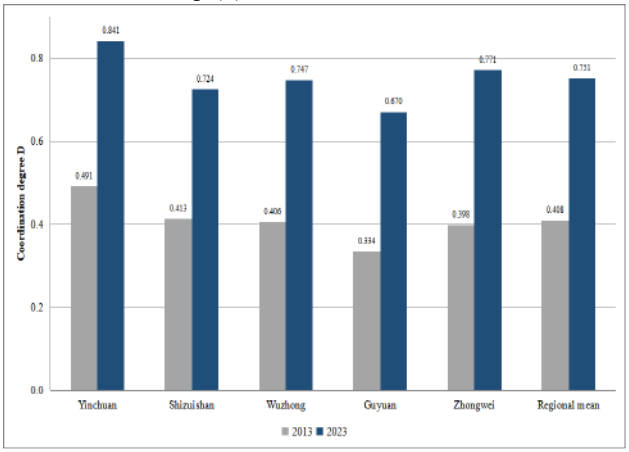

FIG. 3. Coupling coordination degree by city and regional mean in the benchmark years 2013 and 2023.

Growth rates were inversely related to initial levels. Guyuan, which began at 0.334, recorded the largest proportional gain (+101.0%), followed by Zhongwei (+93.5%), Wuzhong (+84.0%), Shizuishan (+75.4%) and Yinchuan (+71.4%), whose absolute improvement (0.350) was nevertheless the largest in the panel. The pattern is consistent with the diffusion of infrastructure and with the concentration of the pandemic shock in the mature destinations: cities whose tourism sector was smaller before 2020 had less to lose and could convert post-2022 recovery into a larger proportional gain.

The rapid gain over the period coincides with the promulgation of the basin outline and with the approval of the computing hub, and it is tempting to read the coincidence as an effect of the two strategies. Several considerations argue against that reading. The window contains the pandemic, the subsequent recovery of domestic travel, a national wave of infrastructure investment and a sharp contraction in real-estate construction, which reduced pressure on land and energy in some cities. The synchronisation of policy and index movement is therefore consistent with a strategy contribution but does not identify one.

A second caution concerns the arithmetic of D. Because D is the geometric mean of coupling and the development level, part of its rise reflects the growth of T rather than closer interaction among the subsystems. In the present case all three indices rose, so a substantial share of the improvement in D is level-driven. This is not a defect of the measure but a reason to read it alongside the relative development ratios, which show whether the three subsystems moved together or one of them fell behind.

D. Relative Development and a Five-Type Typology

The 2023 ratios separate the cities clearly (Table IV and Figure 4). In Yinchuan all three ratios cluster around unity (D/T = 1.18, D/E = 1.09, T/E = 0.92), which indicates balanced development with a modest digital lead and no pronounced short board. In Shizuishan the digital index exceeds tourism by 13% and tourism stands at three quarters of the ecological index, so the lagging subsystem is clearly tourism. In Wuzhong both D/E (0.87) and T/E (0.88) lie 12-13% below unity, so ecology leads by a small margin while digital capacity and tourism lag mildly, a configuration of near-parity without advantage. In Guyuan the digital and tourism indices both fall well below the ecological index (D/E = 0.77, T/E = 0.80). In Zhongwei tourism slightly exceeds ecology (T/E = 1.01) while the digital index trails both by 6-8% (D/T = 0.92, D/E = 0.94), so tourism leads mildly and digital capacity follows.

TABLE IV. Relative Development Ratios and City Types, 2023

City	D/T	D/E	T/E	Lagging system	City type
Yinchuan	1.18	1.09	0.92	No clear lag	Comprehensive leader
Shizuishan	1.13	0.85	0.75	Cultural tourism	Ecology-led
Wuzhong	0.99	0.87	0.88	Digital economy and cultural tourism (mild)	Balanced-transitional
Guyuan	0.96	0.77	0.80	Digital economy and tourism	Catch-up
Zhongwei	0.92	0.94	1.01	Digital economy (mild)	Tourism-driven

Note: a ratio above 1 indicates that the numerator subsystem leads the denominator subsystem, and a ratio below 1 that it lags. Ratios between 0.9 and 1.1 are treated as approximate parity. D, T and E denote the digital economy, cultural tourism and ecological civilization indices respectively.

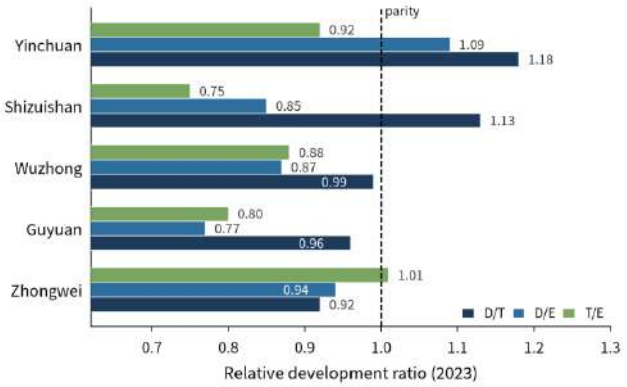

FIG. 4. Pairwise relative development ratios by city, 2023 (parity = 1.0).

The first type, comprehensive leader, is represented by Yinchuan: the highest coordination degree, the highest values on all three subsystems and broad balance among them. Its advantage is not the absence of a short board but the presence of closed loops, in which computing capacity, tourism services and ecological investment reinforce one another. The risk attached to this type is that the loops remain local: the city's coordination can rise while the surrounding cities supply visitors, labour and ecological services without capturing equivalent gains.

The second type, ecology-led, is represented by Shizuishan: ecological performance is strong relative to the other two subsystems, and tourism is the weakest link. The configuration reflects a successful repair programme that has not yet been matched by a product strategy. The third type, balanced-transitional, is represented by Wuzhong: all three subsystems sit in the middle range and coordination is low within the primary band. Parity of this kind is stable but inert, since no subsystem generates the surplus needed to pull the others up.

The fourth type, catch-up, is represented by Guyuan: all three subsystems are lowest, yet all three improved fastest and the coordination gain was the largest in the region. Its constraint is not one missing subsystem but the combination of market distance, a thin service sector and a land-use regime that restricts development in the ecological function zones. The fifth type, tourism-driven, is represented by Zhongwei: tourism leads, ecology is close behind and digital capacity lags, which is the reverse of the digital-first pattern found in the provincial capital. Its coordination degree (0.771) now exceeds the 2013 level of every city in the region, Yinchuan included, which suggests that in a resource-limited city tourism can serve as the first mover while digital capacity catches up through the data-centre route.

V. DISCUSSION

A. Three Obstacles to Conversion

The results point to three obstacles that recur across the cities and that are better described as conversion failures than as resource shortages. The first is the gap between digital capacity and its application in industry and governance. Digital infrastructure spread widely and quickly, but the ratios show that in Shizuishan and Wuzhong the digital index stands at or above the tourism index without a corresponding gain in tourism performance. Where digital investment is treated as a construction target, the index rises while the operating routines that would turn connectivity into bookings, yield management, water scheduling or pollution tracing remain unchanged. The obstacle is organizational and human rather than financial, and it is concentrated in small tourism firms, in county-level environmental agencies and in establishments that lack staff able to use the systems provided. The distinction between access and use is familiar from research on digital inequality, where connectivity alone has repeatedly proved insufficient to produce capability[24,25].

The second obstacle is the weak realization of ecological value. In Shizuishan and Guyuan ecological indices are high relative to the other two subsystems, yet tourism and income are low. Restoration has produced environmental quality but not a product: sites are protected and monitored but not interpreted, packaged or connected to transport and accommodation; green certification is absent, so no price premium attaches to ecological quality; and compensation mechanisms transfer costs without creating markets. The result is the configuration that local policy documents describe as an ecological highland with an economic lowland. It is a failure of the value-capture link, not of protection itself.

The third obstacle is the uneven strength of the internal drivers of tourism growth. Yinchuan and Zhongwei recovered strongly after 2022 because they hold brands, access and accommodation capacity that can be reactivated quickly. Guyuan holds comparable natural and heritage resources but lacks the transport connections and service depth that would convert them into overnight stays, and Wuzhong, although located on the river and close to the capital, lacks a flagship attraction able to anchor a visit. Growth that depends on a single icon is also fragile: it concentrates risk in one asset and one season.

B. Type-Based Governance Pathways

For the comprehensive leader the task is to convert internal closure into regional circulation. Yinchuan can operate as a platform rather than as a competitor: opening its computing and data services to tourism firms and environmental agencies in the other four cities, hosting a shared digital archive of Yellow River heritage, and organising multi-destination itineraries that keep visitors in the region for longer. The relevant indicator is not the city's own index but the share of its digital and cultural services used outside its boundary.

For the ecology-led city the task is to build a product on the repair. Shizuishan can combine industrial heritage with restored wetlands and subsidence lakes into study-travel and industrial-heritage routes, adopt a green-destination certification that ties accommodation and transport providers to measurable standards, and use environmental monitoring data as a visitor-facing narrative rather than only as an internal compliance tool. The pathway works only if the certification carries a price premium or a procurement advantage; otherwise it adds cost without adding demand.

For the balanced-transitional city the task is to create one advantage rather than to improve all three marginally. Wuzhong's position on the river and its food and craft traditions suggest a route based on a single anchor product, supported by closer integration with the capital's visitor market and by digital booking and interpretation that lower the cost of reaching it. Marginal investment spread evenly across three subsystems is what produced the present parity, and further spreading would reproduce it.

For the catch-up city the task is to sequence rather than to balance. Guyuan cannot close all three gaps at once; the sequence that fits its endowment starts with access and service capacity, since the resources are already present, and uses ecological and heritage interpretation to raise the value per visitor before expanding volume. Digital investment in this sequence is best directed at distribution and booking rather than at showcase infrastructure, because the constraint is demand reach, not local processing power.

For the tourism-driven city the task is to keep the loop closed. Zhongwei's combination of a strong destination brand and a growing computing sector is unusual, but the two currently run in parallel: the data centres serve national clients while the destination serves visitors, and neither uses the other. Linking them, through visitor analytics, energy-and-water disclosure for tourism facilities and digital interpretation of the desert environment, would convert coexistence into interaction and protect the tourism asset from the resource pressures that data-centre growth can create.

Across all five types, three instruments recur. Spatial coordination is needed because computing capacity, tourism projects and ecological red lines are planned by different agencies on different time horizons. Funding coordination is needed because digital, cultural and environmental budgets are separately appropriated and rarely combine at the project level. And performance assessment should report the coordination degree and the lagging subsystem together, so that a city is not rewarded for raising an index that its neighbours cannot use.

C. Implications for Social Science Research and Education

For social science research, the case supports three observations. First, coupling metrics are diagnostic instruments, not verdicts. A coordination score summarizes a relationship among subsystems, and its interpretation depends on which subsystem is out of line; studies that report only D leave the policy question unanswered. Second, the concept of conversion deserves more attention than the concept of capacity. Much of the literature measures whether digital, tourism or ecological capacity exists, while the differences that matter in this case arise at the point where capacity is or is not used. Third, the treatment of strategy as context rather than as treatment is a discipline worth keeping: without a counterfactual, policy-attentive research can still be rigorous if it states what it observes and what it cannot.

For education and training, the obstacles identified above are largely skills obstacles, and they have curricular counterparts. The conversion of digital capacity into tourism performance depends on staff in small and medium tourism enterprises who can operate booking, analytics and content systems, and on vocational programmes that treat digital tools as part of service work rather than as a separate subject. The conversion of ecological quality into visitor value depends on interpreters, guides and heritage educators able to explain restoration, hydrology and industrial history to non-specialist audiences, and on language capacity for the outward-facing market that the westward-opening strategy implies. The conversion of monitoring data into public legitimacy depends on environmental education that makes the data intelligible to residents, since protection sustained only by enforcement is expensive and fragile.

These implications are specific to a region with a thin service sector and a large public sector, and they suggest a division of labour between the cities. Yinchuan is positioned to supply advanced training and digital services; Shizuishan's

transition creates demand for industrial-heritage and environmental-restoration skills; Guyuan's ecological mandate creates demand for conservation and interpretation skills that can be delivered through networks rather than through new campuses. Treating education as a shared regional infrastructure rather than as five separate systems is consistent with the coordination logic that the empirical results describe.

D. Limitations

Four limitations qualify the findings. The indicator system depends on what is published consistently for five cities over eleven years, which excludes, for example, separate measures of inbound tourism, visitor expenditure per day and ecosystem-service values; the allocation of some regional indicators to cities by shares introduces measurement error. The analysis is conducted at the prefecture level, where internal contrasts between an urban core and its rural counties disappear. The short panel and the absence of a counterfactual prevent causal attribution of the observed acceleration to either strategy. Finally, the period ends in 2023, a year of unusually strong recovery in domestic travel, so the final values may overstate the durable level rather than the trend. The results are reported as point estimates without quantified uncertainty and should be read as a structured description of coordination rather than as precise measurements.

VI. CONCLUSION

This study examined how the digital economy, cultural tourism and ecological civilization co-evolved in the five cities of the Ningxia section of the Yellow River Basin between 2013 and 2023, in a setting where a basin-wide protection mandate and an outward-opening mandate overlap. Four conclusions follow.

First, all three subsystems improved and the composite index rose from 0.241 to 0.635, but their growth paths diverged: the digital economy expanded fastest and converged across cities, cultural tourism passed through growth, disruption and recovery, and ecological civilization improved most steadily from the highest base. Second, coordination rose from near imbalance to intermediate coordination and Yinchuan alone entered good coordination; the timing of the gain is consistent with the two strategies but cannot be attributed to them, and part of the improvement reflects rising levels rather than closer interaction. Third, the cities occupy five distinct configurations, comprehensive leader, ecology-led, balanced-transitional, catch-up and tourism-driven, defined by which subsystem lags rather than by how much each has invested. Fourth, the binding constraint is conversion rather than capacity: digital infrastructure, restored environments and heritage assets exist in all five cities, but the organizational, commercial and human links that turn them into tourism income, governance capacity and legitimate protection are unevenly developed.

The implication for policy is that coordination should be governed as a relationship rather than as a target. Cities at different positions require different sequences, and a regional programme that distributes investment evenly across subsystems will reproduce the parity it is meant to overcome. The implication for research is that coordination measures should be reported with their structural decomposition, and that strategy-attentive studies should distinguish what they observe from what they can identify. Extending the analysis to county units, to inbound tourism and to the water and energy footprints of computing infrastructure would test whether the conversion logic holds at finer scales.

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DISCLOSURE

The authors report no conflicts of interest in this work. The study was conducted with publicly available statistical data and did not involve human participants. The city-level indicator panel compiled for the analysis and the computation code for eqs. (1)-(6) are available from the corresponding author on reasonable request.

REFERENCES

1. Ostrom E. A general framework for analyzing sustainability of social-ecological systems. Science. 2009;325(5939):419-422. doi:10.1126/science.1172133
2. Liu J, Dietz T, Carpenter SR, Folke C, Alberti M, Redman CL, et al. Complexity of coupled human and natural systems. Science. 2007;317(5844):1513-1516. doi:10.1126/science.1144004
3. Central Committee of the Communist Party of China, State Council. Outline of the Yellow River Basin ecological protection and high-quality development plan. Beijing: Government of China; 2021. Available from: http://www.gov.cn/zhengce/2021-10/08/content_5641438.htm
4. National Development and Reform Commission, Cyberspace Administration of China, Ministry of Industry and Information Technology, National Energy Administration. Reply on approving the launch of the national integrated computing network hub node in Ningxia. Beijing; 2022 Feb 16 [in Chinese].
5. Yu M, Ma B, Liu D, Zhang A. Is the digital economy empowering high-quality tourism development? A theoretical and empirical research from China.

PLOS ONE. 2024;19(5):e0303087. doi:10.1371/journal.pone.0303087
6. Wang Y, Li Y, Zheng L, Zhang Y. Research on the coordinated measurement and spatiotemporal evolution of digital economy empowering ecotourism. PLOS ONE. 2025;20(5):e0323723. doi:10.1371/journal.pone.0323723
7. Dayoub B, Yang P, Omran S, Zhang Q, Dayoub A. Digital Silk Roads: leveraging the metaverse for cultural tourism within the Belt and Road Initiative framework. Electronics. 2024;13(12):2306. doi:10.3390/electronics13122306
8. Liu Z, Zhang M, Osmani M. Building information modelling driven sustainable cultural heritage tourism. Buildings. 2023;13(8):1925. doi:10.3390/buildings13081925
9. Wang H, Xu Y, Li C. Coupling coordination and spatio-temporal pattern evolution between ecological protection and high-quality development in the Yellow River Basin. Heliyon. 2023;9(10):e21089. doi:10.1016/j.heliyon.2023.e21089
10. Wu K, Xing A, Wei G, Xin H, Wei Y, Su L, et al. Evaluation of coupling coordination degree between tourism urbanization and ecosystem services in urban agglomerations of the Yellow River Basin. Scientific Reports. 2025;15(1):22427. doi:10.1038/s41598-025-05455-6
11. Yang S, Zhang Z, Zhang J, Bai X, Hu F, Zhang K, et al. The coupling relationship and driving mechanism between ecological environment and high-quality economic development in the Middle Yellow River Basin. Scientific Reports. 2025;15(1):10688. doi:10.1038/s41598-025-94462-8
12. Yang S, Guo W, Xu T, Liu T. The coordinated evolution of ecological environment, public service and tourism economy along the Silk Road Economic Belt under dual-carbon targets. Chinese Journal of Population, Resources and Environment. 2024;22(1):34-47. doi:10.1016/j.cjpre.2024.03.004
13. Liu M, Lu M, Li Z. Coupling coordination analysis on digital economy-tourism development-ecological environment. Journal of Cleaner Production. 2024;470:143320. doi:10.1016/j.jclepro.2024.143320
14. Song H, Zhang X, Wu X. Research on the spatial-temporal evolution and driving mechanism of coupling coordination among digital-tourism-environment in the Yellow River Basin. Sustainability. 2024;16(13):5339. doi:10.3390/su16135339
15. Pan Z, Luo Y, Wang Y, Ji J, Lai B. Coupling coordination and driving mechanism between tourism development, ecological conservation and digital economy: insights from 278 Chinese cities. Scientific Reports. 2025;15(1):37445. doi:10.1038/s41598-025-21169-1
16. Imbens GW, Rubin DB. Causal inference for statistics, social, and biomedical sciences: an introduction. Cambridge: Cambridge University Press; 2015.
17. Timothy DJ, Boyd SW. Heritage tourism in the 21st century: valued traditions and new perspectives. Journal of Heritage Tourism. 2006;1(1):1-16. doi:10.1080/17438730608668462
18. Holling CS. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics. 1973;4:1-23. doi:10.1146/annurev.es.04.110173.000245
19. Ningxia Bureau of Statistics. Ningxia statistical yearbook 2014-2024. Beijing: China Statistics Press; 2014-2024.
20. Guo F, Wang J, Wang F, Kong T, Zhang X, Cheng Z. Measuring the development of China's digital financial inclusion: index compilation and spatial characteristics. China Economic Quarterly. 2020;19(4):1401-1418. [in Chinese]
21. Wang S, Kong W, Ren L, Zhi D, Dai B. Research on misuses and modification of the coupling coordination degree model in China. Journal of Natural Resources. 2021;36(3):793-810. doi:10.31497/zrzyxb.20210319 [in Chinese]
22. Liao C. Quantitative judgement and classification system for coordinated development of environment and economy. Tropical Geography. 1999;19(2):171-177. [in Chinese]
23. Liu Y, Li R, Song X. Analysis of the coupling degree between urbanization and the ecological environment in China. Journal of Natural Resources. 2005;20(1):105-112. [in Chinese]
24. van Dijk JAGM. The deepening divide: inequality in the information society. Thousand Oaks: Sage; 2005.
25. Warschauer M. Technology and social inclusion: rethinking the digital divide. Cambridge: MIT Press; 2003.