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Research article

# Distinguishing the impact of tourism development on ecosystem service trade-offs in ecological functional zone

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ABSTRACT

Tourism in ecological functional zones (EFZs) is rapidly becoming an increasing trend; however, its impact on ecosystem services remains poorly understood owing to the absence of a consistent quantification framework. This study uses the Taihang Mountains (THM), an EFZ in China, as an example to develop a framework for evaluating the direct and indirect impact pathways of scenic spots on the trade-offs between multiple ecosystem services by identifying the linkages between scenic spot development, socioeconomic change, land use transitions, and ecosystem services. The results show that the continued conversion of agricultural land, grassland, and forest to constructed land around scenic spots in 2000–2020 was accompanied by a decline in water yield (WY) and habitat quality (HQ); while food production (FP), carbon storage (CS), and soil retention (SR) increased. Land use and ecosystem service changes around scenic spots in the THM also exhibited significant spatial gradient effects. In particular, a 10-km buffer area was identified as a distinct “influence zone” where the ecosystem services trade-offs and land use changes were the most pronounced. In 2010, scenic spot revenue was the dominant factor that increased the trade-offs between SR with FP and CS via direct pathways. However, in 2020, the dominant factor was scenic spot level, which shifted the impact toward the relationship between CS and WY and HQ by intensifying the trade-offs to facilitating synergies. This was accomplished in an indirect manner, such as the facilitation of local population growth, industrial restructuring, and infrastructure development. This study reveals the varying effects of scenic spot development via different pathways, thereby providing useful insights for global EFZs to more precisely design policies that can adequately balance human activities with ecosystem services.

## 1. Introduction

Tourism is one of the world’s largest economic sectors, but relies heavily on ecosystem services (ESs) to sustain its activities (Pueyo-Ros, 2018; Streimikiene et al., 2021; World Travel and Tourism Council, 2020). ESs refer to the direct and indirect benefits obtained from ecosystems, and are typically divided into four categories: supporting services, provisioning services, regulating services, and cultural services (de Groot et al., 2002; Ecosystem Millennium Assessment and Institute, 2003; 2005; Hasan et al., 2020). Supporting and provisioning services, which include intangible biological processes (e.g., water filtration) and tangible products (e.g., food, energy), are basic needs for tourists. Regulating services (e.g., air quality, climate regulation) play an influential role in tourists’ destination choices, as indicated by studies linking the tourism climatic index with air pollution (Adiguzel et al., 2022; Cetin, 2019; Zhang et al., 2020; Zhou et al., 2019). Cultural ESs play a significant part in attracting tourists and determining their level of satisfaction by offering enriching and inspiring experiences often via touristic or recreational opportunities (Buckley et al., 2021; Roux et al., 2020; Taff et al., 2019). However, tourism’s inherent reliance on natural resources and ESs inevitably imposes negative impacts, such as increased carbon emissions (Eyuboglu and Uzar, 2020), habitat

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destruction (Tolvanen and Kangas, 2016), and overuse of water resources (Chen et al., 2021; LaVanchy, 2017). Both the benefits and costs of tourism must therefore be considered to reach a sustainable compromise to preserve the natural resources over the long term (Cetin and Sevik, 2016; Chen, 2020a; Drius et al., 2019).

Climate change and additional impacts related to human activity have put the planet under unprecedented pressure (Rockström et al., 2009, 2021). Such pressure is particularly worrisome for natural areas that are becoming increasingly impacted by the effects of tourism. To reverse this trend, the United Nations has proposed the protection, restoration, and promotion of sustainable ecosystem use (United Nations, 2015). The preservation of regions with important ecological functions is therefore a crucial approach to implementing this proposition. Examples include protected areas at the national scale (Maxwell et al., 2020; UNEP-WCMC and, 2018) and ecological networks at the cross-regional scale, such as National Development and Reform Commission, 2017 in the European Union (Mücher et al., 2009). China has also proposed ecological planning strategies and defined 63 crucial ecological functional zones (EFZs) based on ecosystem types and services, as well as sensitivity and vulnerability (Xu et al., 2018), that cover 49% of China's territory, equating to 3.26% of the Earth's total land area (Ministry of Ecology and Environment of the People's Republic of China, 2015). These EFZs are thus of great importance for the global conservation of ecological security and the provision of ESs. To maintain and enhance the provision of ecological goods and services, large-scale socio-economic development is restricted within EFZs, as is the case with other ecologically significant areas (Assunção et al., 2015; Dudley, 2008; Hiedanpää, 2002; Sun et al., 2021). However, the extent of constrained development poses a challenge for simultaneously protecting ecological security and promoting economic growth (Dhakal et al., 2022; Specht et al., 2019; Zhao et al., 2020).

In contrast to the USA, Canada, and Australia, where protected areas tend to have low population densities, China has significant populations residing in its EFZs, reaching more than 180 million people in 2018 (National Development and Reform Commission, 2017 ; Qiang et al., 2021). The livelihood of people living in Chinese EFZs therefore poses a complex issue that cannot be ignored. In the context of limiting large-scale industrial development, tourism is strongly promoted within the EFZs as it can be an important initiative to coordinate ecological security and economic development (Chen, 2020b; Shi et al., 2019). While the growth of the tourism industry can bring jobs and revenue, it may also have direct and indirect negative impacts on ESs (Chen, 2020a). Nature-based recreational activities (e.g., hiking, camping, mountain biking, wildlife viewing) comprise much of the direct human use of EFZs (Gutzwiller et al., 2017; Pickering et al., 2010), which are inevitably associated with ecological losses such as a reduction of wildlife, soil, and vegetation (Evju et al., 2021; Salesa et al., 2019; Taff et al., 2019; Tolvanen and Kangas, 2016), thereby placing a direct influence on the ESs.

Tourism can also indirectly influence ESs by inducing socio-economic development and land use change (Chen, 2020b; Pueyo-Ros, 2018). Tourism facilities and transportation options regularly need to expand to maintain their touristic appeal, but tourist-oriented transformations consequentially increase the proportion of built-up land within EFZs and reduce the amount of farmland and ecological land (Liu et al., 2018; Yang et al., 2016). Tourism development can also drive shifts in the local economy and service industry (Brink et al., 2009; Lun et al., 2021) and stimulate population growth (Liu et al., 2021b; Salvati, 2019; Taylor et al., 2009), which further enhances the amount of built-up land for catering, hospitality, and residential living use and reduces the amount of ecological and agricultural land (Gascón, 2016; Münster and Münster, 2012; Pandya et al., 2022; Xi et al., 2014). These socio-economic changes ultimately affect the ESs by acting on the land use spatial pattern and structure (de Groot et al., 2010; Shi et al., 2023).

Previous studies have addressed the relationship between tourism development and ESs, which have been helpful for informing policy makers, but considerable research is still required. For example, most prior studies have focused on the interrelationships between tourism and individual ESs (Drius et al., 2019; Li et al., 2020; Lopes et al., 2015; Mendoza-González et al., 2012), while the impacts of tourism on ESs trade-offs have not been reported. Understanding how ESs interactions evolve with tourism development can help prevent avoidable losses by prioritizing the search for effective solutions that mitigate trade-offs, enhance synergies, and maximize desired values. A growing number of studies are now focusing on the trade-off analysis of ESs over temporal scales (Kertész et al., 2019; Li et al., 2020; Rimal et al., 2019; Schirpke et al., 2020), because a single snapshot in time often does not provide policymakers with sufficient information regarding the relationships between tourism and ESs, thereby resulting in incomplete or inaccurate policy decisions. Furthermore, the impacts of tourism on neighboring areas can be often complex or multifaceted with regards to elements such as location, culture, economy, and management (Mao et al., 2014; Ristić et al., 2019), which results in distance-dependent impacts (Olaniyi et al., 2020; Truchet et al., 2016) or"tourism island" or "tourism enclave" effects (Tian et al., 2020) that reflect the isolated development of tourism areas from the surrounding communiti es (Tian et al., 2020). Such isolation includes environmental, economic, and cultural fields, in which touristic areas gradually become relatively closed systems, which can be detrimental to development (Li et al., 2014). The identification of spatial disparities among tourism impacts can thus allow the detection of potential problems caused by tourism development and assist with the implementation of specific strategies.

Achieving a balance between human well-being and environmental sustainability requires a deep understanding of the trade-offs that exist between ESs (Chen, 2020a; Liu et al., 2022). Previous efforts to assess the impacts of tourism on these services using methods such as ESs valuation (Chen, 2020a), regression analysis (Liu et al., 2022; Lopes et al., 2015), causal analysis (Wang et al., 2022), and qualitative analysis (Beltrame et al., 2013) only determined if tourism had any effect on ESs, which did not provide a complete picture of its direct and indirect impacts. For instance, tourism development can lead to the direct loss of vegetation (e.g., tourist trampling) (Jahani et al., 2020) and indirectly impact vegetation via tourism urbanization, which involves the expansion of population and built-up land (Liu et al., 2021b; Saha and Paul, 2021). As requirements for a comprehensive understanding of environmental impacts become increasingly binding, project managers and developers are faced with greater challenges (Chen, 2020a). Therefore, it is crucial to prioritize the need for a complete assessment of the impacts that tourism have on ESs. A more comprehensive approach is therefore necessary to fully understand the effects of tourism on ESs and develop sustainable tourism practices that will benefit both humans and the environment. The structural equation model (SEM) combines the benefits of path analysis and factors analysis, allowing both the direct and indirect impacts of presumptive causal linkages to be examined, and identifying intermediary mechanisms and processes (Grace et al., 2012; Li et al., 2022a; Sutton-Grier et al., 2010). Building upon previous research (Chillo et al., 2018), this study applies the SEM to quantify the direct and indirect effects of tourism on ESs in the Taihang Mountains (THM) in China. Tourism may be detrimental or beneficial for EFZs depending on the planners' compatibility with conservation goals (Balmford et al., 2009). He nce, tourism in EFZs must recognize its reliance and impacts on ESs and act at the technical and policy level to create a long-term compromise that protects natural resources (Drius et al., 2019).

The THM are a fitting example for the aims of this study because they serve as a crucial ecological barrier and water resource protection zone for the North China Plain (Liu et al., 2019), as well as a well-known tourist destination owing to its abundant attractions, which include five World Heritage Sites, four Global Geoparks, and eight national nature reserves, along with hundreds of scenic spots, and are situated in a prime location in the Beijing-Tianjin-Hebei urban agglomeration, one of China's three major urban agglomerations. Tourism in the THM has surged in recent decades, with the number of tourists increasing from less than 100 million in 2000 to 590 million in 2019 (The State Council, 2020). Nevertheless, tourism growth in this region is expected to have negative environmental consequences, making the THM an ideal subject for examining and quantifying the impact of tourism on ESs. Here, we identified the impact pathways of tourism development on the relationships between socio-economic factors and ESs status using the THM as a case study. Specifically, the operationalization of the framework was demonstrated using the SEM to quantify the interactions between different components of scenic development and to identify the pathways that influence the ESs trade-offs based on analyses of the spatial-temporal pattern of land use/land cover change and ESs. We concluded with targeted recommendations and countermeasures for the sustainable development of EFZs.

## 2. Materials and methods

### 2.1. Study area

The THM is a typical mountainous region (34°58′–40°79′ N, 110°23′–116°57′ E) located in the transition zone from the Loess Plateau to the North China Plain (Fig. 1). The THM has a temperate continental climate, average annual temperature of 10.7 °C, and average annual precipitation of 505 mm (Zhao et al., 2020). The THM spans across four Chinese provinces (Beijing, Hebei, Henan, and Shanxi) with a total administrative area of 13.7 $\times$ $10^4$ $km^2$ and resident population of approximately 30.3 million (Liu et al., 2019). There are 39 key ecological functional areas and 29 major agricultural production areas within the study area, where water conservation, soil conservation, and food production are important ESs and functions (Zhao et al., 2020). The THM are also one of the most mature areas for the development of mountain-based tourism in China, with 14 scenic spots with classification grades of 5A (scenic spots in China are graded from high to low as 5A, 4A, 3A, 2A, and 1A) and 124 scenic spots with classification grades of 4A in 2019, achieving a total tourism revenue of 436.97 billion yuan (approximately US$ 676.98 million) (The State Council, 2020).

### 2.2. Framework components and hypothesized pathways

Fig. 2 depicts a framework that was created to uncover the various pathways through which multiple factors impact ESs trade-offs. The framework comprises four key elements, namely, scenic spot development, socio-economic development, land cover/use change, and ESs trade-offs. The connections between these interconnected components form the pathways through which multiple factors impact ESs trade-offs, with socio-economic and land cover/use factors acting as intermediary variables. This means that tourism development initially impacts socio-economic factors, which then subsequently impact ESs trade-offs (Fig. 2a).

A scenic spot is defined in this study as an independent area within an ecological functional area that has a defined territorial extent and provides appropriate services and facilities, where the main function is to carry out tourism services (e.g., cultural ESs) (Ma and Zou, 2022; Zhang et al., 2021). As indicated in previous studies (Chillo et al., 2018; Li et al., 2020; Mendoza-González et al., 2012), we first hypothesized that the change of land use would influence the trade-offs between ESs. Because farmland, forest, and grassland are the three main land use categories of the THM and the development of scenic spots requires a certain amount of land for support, we selected farmland, vegetation (including forest, shrubs, and grassland), and constructed land as the key indicators of land use change. Furthermore, we hypothesized that land use change is influenced by socio-economic factors including population, tourism contributions (i.e., tourism revenue as a share of gross domestic product in the region), and road construction. We also hypothesized that the development of scenic spots impacts population, tourism contributions, and road construction. Previous studies have shown that tourism growth encourages population concentration, transformation of the industrial structure, and expansion of the supporting infrastructure (Li et al., 2014, 2020; Xi et al., 2014; Zubair et al., 2011).

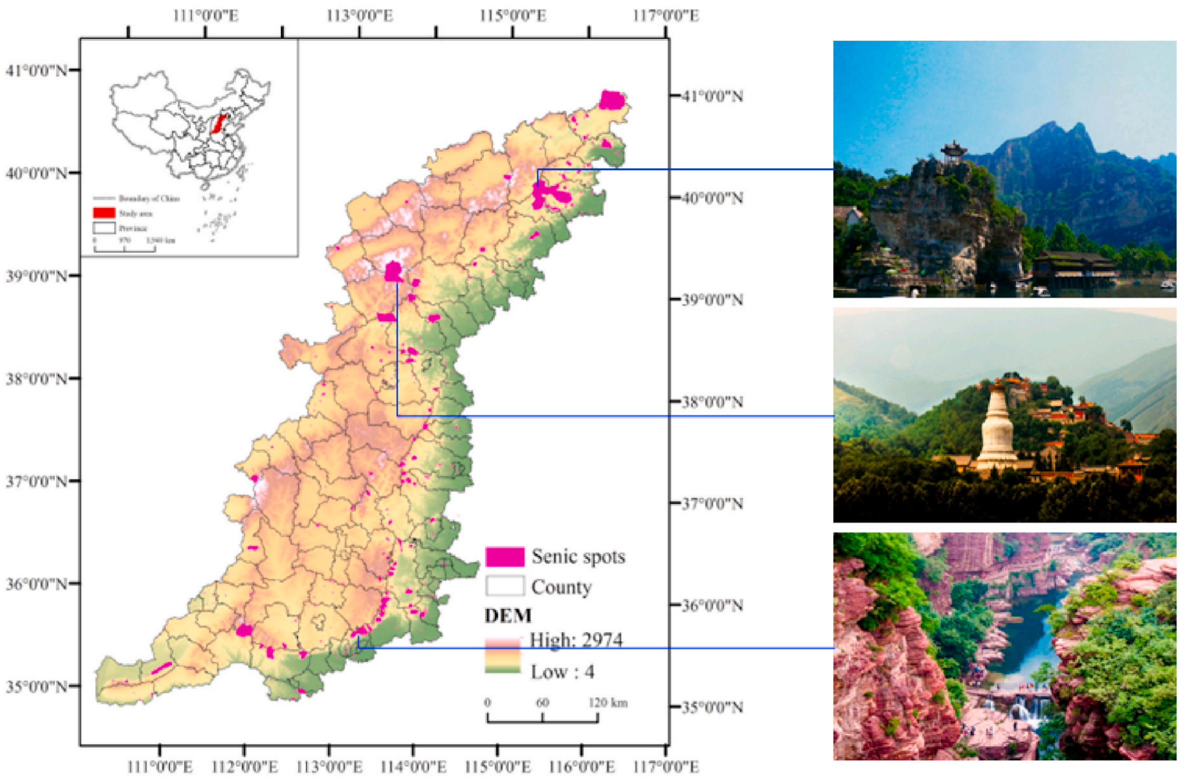

**Fig. 1.** Study area.

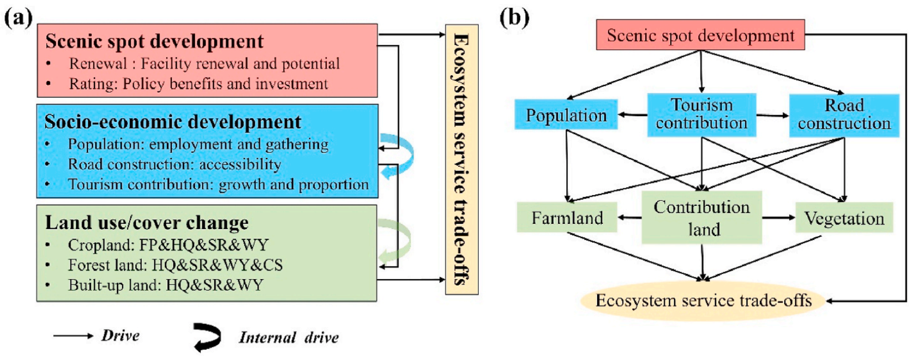

**Fig. 2.** Conceptual framework and hypothetical pathways of scenic development: (a) the causes and consequences framework and (b) the hypothetical pathways in the context of the ESs trade-offs. FP (food production); HQ (habitat quality); SR (soil retention); WY (water yield); CS (carbon sequestration).

These hypothesized linkages form three-step pathways through which the development of scenic spots has affected these three social-economic factors, and in which social-economic factors affect the land use, which affect the trade-offs of ESs (Fig. 2b). In addition, we hypothesized that these three socio-economic factors are linked and that the linkages among them constituted longer pathways through which the development of scenic spots affects land use. For example, we hypothesized that tourism contributions positively affect population and road construction. This is because tourism activities are often labor-intensive and tourism development can further contribute to the construction of roads (Currie and Falconer, 2014; Shaw and Williams, 1994). We also hypothesized that constructed land has a negative influence on farmland and ecological space because the expansion of constructed land will inevitably reduce the area of other land types, provided that the land area remains unchanged.

### 2.3. Data and source

In this study, appropriate indicators were chosen based on prior studies and the availability of data to differentiate the impacts resulting from the various pathways (Table 1). We used buffer zone analysis to more clearly demonstrate potential spatial differences concerning the impact of scenic spots on neighboring land use and ESs. We began at the edge of the scenic spot, set a radius of 1 km, and superimposed outward to create buffer zones. We chose 15 km as the radius around a scenic area because buffer zones commonly extended into other scenic spots beyond that distance (Fig. S1). Land use and land cover data in 2000 and 2020 were obtained from the GlobeLand30 (http://www.globallandcover.com). More than 10,000 images were collected and classified to produce the dataset using a pixel-object-knowledge (POK)–based approach (Chen et al., 2015). This dataset includes 10 land cover types, namely, open water, wetland, constructed land, farmland, permanent snow/ice,

**Table 1**
Data source and description.

| Data | Data source | Note | Relevant section |
|---|---|---|---|
| Scenic spot revenue | Statistical Yearbook of counties in Taihang | Scenic spot revenue data for 2019 was used instead of 2020 in this paper due to the impact of the epidemic on tourism | Used for SEM |
| Scenic spot rating | Statistical Yearbook of counties in Taihang/ Ministry of cultural and tourism of the People's Republic of China | Scenic spots were graded from from 1A to 5A. In this paper 5A was assigned 5 points, 4A 4 points, 3A 3 points, 2A 2 points and 1A 1 points. And the scenic spot rating of the counties is the sum of the scenic spot scores | Used for SEM |
| Population | http://www.resdc.cn | Resolution is 1000m × 1000m | Used for SEM |
| Tourism contribution | Statistical Yearbook of counties in Taihang | Tourism as a share of GDP was used as a proxy for tourism contribution. Tourism income data for 2019 was used instead of 2020 in this paper due to the impact of the epidemic on tourism | Used for SEM |
| Roads construction | https://www.openstreetmap.org | Substitute the 2010 road data with the 2014 data. In this paper we used the road density as the proxy of roads construction | Used for SEM |
| Land use/land cover | http://www.globallandcover.com | Resolution is 30m × 30m | Used for SEM and WY, SR, FP,HQ and CS assessment |
| Digital Elevation Model | http://www.gscloud.cn/, http://www.resdc.cn | Resolution is 30m × 30m | Used for SR assessment |
| Annual average precipitation | http://data.cma.cn/site/index.html?tdsourcetag-=-s_pcqq_aiomsg | Resolution is 1000m × 1000m | Used for SR and WY assessment |
| Rainfall erosivity index | Defined according to the literatur e(Berg et al., 2016; Kovacs et al., 2013) and mean annual precipitation | Resolution is 30m × 30m | Used for SR assessment |
| Soil erodibility | Standards for classification and gradation of soil erosion (SL190-2007) | Resolution is 30m × 30m | Used for SR assessment |
| Reference evapo-transpiration | http://www.cgiar-csi.org/data/global-aridity-and-pet-database | Resolution is 30m × 30m | Used for WY assessment |
| Plant-available water content | Defined according to the LULC and InVEST user's guide | Resolution is 30m × 30m | Used for WY assessment |
| Depth to root restricting layer | Defined according to the LULC and InVEST user's guide | Resolution is 90m × 90m | Used for WY, SR, FP and CS assessment |
| Watersheds | http://ngcc.sbsm.gov.cn/article/xxfw/bgxz/ | Shapefile determined by DEM raster using ArcGIS tool | Used for WY, SR, FP and CS assessment |
| NDVI | https://www.resdc.cn/ | Resolution is 1000m × 1000m | Used for FP assessment |
| Grain production | Statistical Yearbook of counties in Taihang | Total grain production statistics of county | Used for FP assessment |
| NPP | https://www.usgs.gov/ | Resolution is1000m × 1000m | Used for CS assessment |

Note: SEM (Structural equation model); FP (food production); HQ (habitat quality); SR (soil retention); WY (water yield); CS (carbon sequestration).

forest, shrub land, grassland, bare land, and tundra. In our study area, only eight types of land cover were without permanent snow/ice and tundra, as discussed further in the Supplementary Material.

### 2.4. Land use dynamic degree

The land use dynamic degree can reflect the rate and magnitude of change over time for various land use types in a study area, including the single land use dynamic degree (SLUDD) and integrated land use dynamic degree (ILUDD) (Chen et al., 2019). The SLUDD (Eq. (1)) indicates the speed and degree of change of a certain single land use type, while the ILUDD (Eq. (2)) indicates the overall rates of land use/land cover change (Degefu et al., 2021; Song and Deng, 2017). The SLUDD and ILUDD were calculated as follows:

$$S_i = \left[\frac{U_{it2} - U_{it1}}{U_{it1}}\right] \times (t_2 - t_1)^{-1} \times 100\% \tag{1}$$

$$S = \left[\frac{\sum_{i=1}^{n} \Delta U_{i-j}}{2\sum_{i}^{n} U_{it1}}\right] \times (t_2 - t_1)^{-1} \times 100\% \tag{2}$$

where $S_i$ is the SLUDD of land use type $i$, $S$ is the ILUDD of the entire area, $U_{it2}$ is the area of land use type $i$ at time $t_2$, $U_{it1}$ is the area of land use type $i$ at time $t_1$, $t_2$-$t_1$ is the study time period, and $\Delta U_{i-j}$ is the area of land transformed from type $i$ to non-type $i$ land in the time period $t_2$-$t_1$.

### 2.5. Ecosystem services assessment

This study assessed five vital ESs in the THM that have been previously identified as crucial, namely, habitat quality (HQ), carbon sequestration (CS), soil retention (SR), food production (FP), and water yield (WY) (Chen et al., 2022; Feng et al., 2021; Gao et al., 2018; Liu et al., 2019; Yu et al., 2021). A more detailed explanation of the rationale for selecting these ESs is provided in the Supplementary Material. A combination of measurable proxies from statistical surveys and a biophysical indicator (NPP) were used with the InVEST model (version 3.10) to construct indicators for the supply ESs, because direct measurements of many services were not feasible. Table 2 summarizes the ESs, and Table 1 lists the data sources and availability. The relevant input parameters and settings and verification are listed in Table S1-3 of the Supplementary Material.

We created 6000 random points within the buffer zone to analyze the correlations between the ESs around the scenic spot. These points were distributed in the four provinces of the THM as follows: 8.27% in Beijing, 33.55% in Hebei, 14.40% in Henan, and 43.78% overall in Shanxi (Table S4). The corresponding values for each type of ecosystem service were extracted at these points (Yang et al., 2021). Prior to analysis, the min-max normalization method was applied to standardize the data range for each ecosystem service (0–1 in this study). We then utilized the Spearman's correlation, a non-parametric statistical method that measures the correlation between two variables, to detect potential synergies and trade-offs among the various ESs. This approach has been frequently applied in previous trade-off studies (Ament et al., 2017; Cao et al., 2020; Castro et al., 2014). A positive correlation between two ESs indicates a positive synergy, whereas a negative correlation suggests a trade-off.

**Table 2**
Methods for quantifying ecosystem services.

| ESs | Description | Method |
|---|---|---|
| Food Production (FP) | Yield of grain | Measurable proxies |
| Carbon sequestration (CS) | Carbon sequestered each year in plants | Biophysical indicators by NPP |
| Water yield (WY) | Annual rainfall minus annual actual evapotranspiration | InVEST model water yield mod ule (Sharp et al., 2016) |
| Soil retention (SR) | The capacity of a land parcel to retain sediment | InVEST model Sediment delivery ratio (SDR) model (Sharp et al., 2016) |
| Habitat quality (HQ) | The suitability of a area to provide habitat for biodiversity | InVEST model Habitat Quality (HQ) model (Sharp et al., 2016) |

### 2.6. Structural equation model

The SEM is extensively used in ecological research for analyzing intricate relationships. One of the benefits of the SEM is its ability to examine intricate causal relationships and elucidate pathways of interactions among various factors (Fan et al., 2016). The SEM has been used to analyze linkages between ecosystem structures and functions (Sutton-Grier et al., 2010), assess relationships between different factors and ESs (Awuah et al., 2020), and identify the direct and indirect effects of different factors on ESs (Chillo et al., 2018; Cui et al., 2022). This study uses the SEM to quantify a multivariate causal network of scenic spot development, socio-economic development, land cover/use, and ESs trade-offs. The model includes scenic spot development indicators, socioeconomic indicators, land use indicators, and ESs. The scenic spot development indicator consists of two observed variables: scenic spot income and scenic spot rating. The socio-economic indicator is composed of three variables: population density, tourism revenue as a share of gross domestic product in a region, and road density. The land cover/use indicator is evaluated based on the proportion of farmland, vegetation, and constructed land in a region. The trade-offs between FP, WY, CS, SR, and HQ are used as the ESs trade-offs indicators. Using the available data, 65 counties (districts) in the study area were selected to analyze the pathways of scenic spots on the ESs trade-offs in 2010 and 2020.

The analysis consisted of the following three steps. If the variables showed significant correlations, Spearman correlation analysis was applied prior to testing to measure the interactions between variable pairs. A variance inflation factor (VIF) was also calculated to avoid any multicollinearity effects on the model performance, for which VIF values should be below 3.0. Path analysis with the SEM was then applied to determine whether the proposed correlations in Fig. 2b were valid (Yang et al., 2016). Three statistical measures were used to assess the adequacy of the SEM: the comparative fit index (CFI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). The standard threshold for statistical significance was set at $p < 0.05$. Path coefficients were used to calculate the effect of each pathway to understand how scenic spot development type affected the trade-offs of the ESs. The SEM analysis was conducted using the lavaan package (lavaan 0.6–4) in R (version 3.5.0; R Core Team, 2019).

## 3. Results

### 3.1. Land use transition and socio-economic development in the THM

The tourism industry in the study area underwent significant growth between 2000 and 2020. The average tourism revenue increased from 906 million yuan (~US$ 134 million) in 2010 to 6.073 billion yuan (~US$ 880 million) in 2020 (Fig. 3a). The scenic rating score also consistently increased, rising from 2.31 in 2000 to 8.37 in 2010 and further to 16.08 in 2020 (Fig. 3a). As the tourism industry expanded, its contribution to the region's economy, population density, and road density around the scenic spots also increased. Tourism contributions nearly doubled over a 10-year period, from 25.62% in 2010 to 48.62% in 2020 (Fig. 3b). The population density also increased from 410.30 person/km$^2$ in 2000 to 483.31 person/km$^2$ in 2020, and the road density increased by a factor of 7.83, from 0.12 km/km$^2$ in 2000 to 0.94 km/km$^2$ in 2020 (Fig. 3b). Overall, the study period showed a rising trend in the

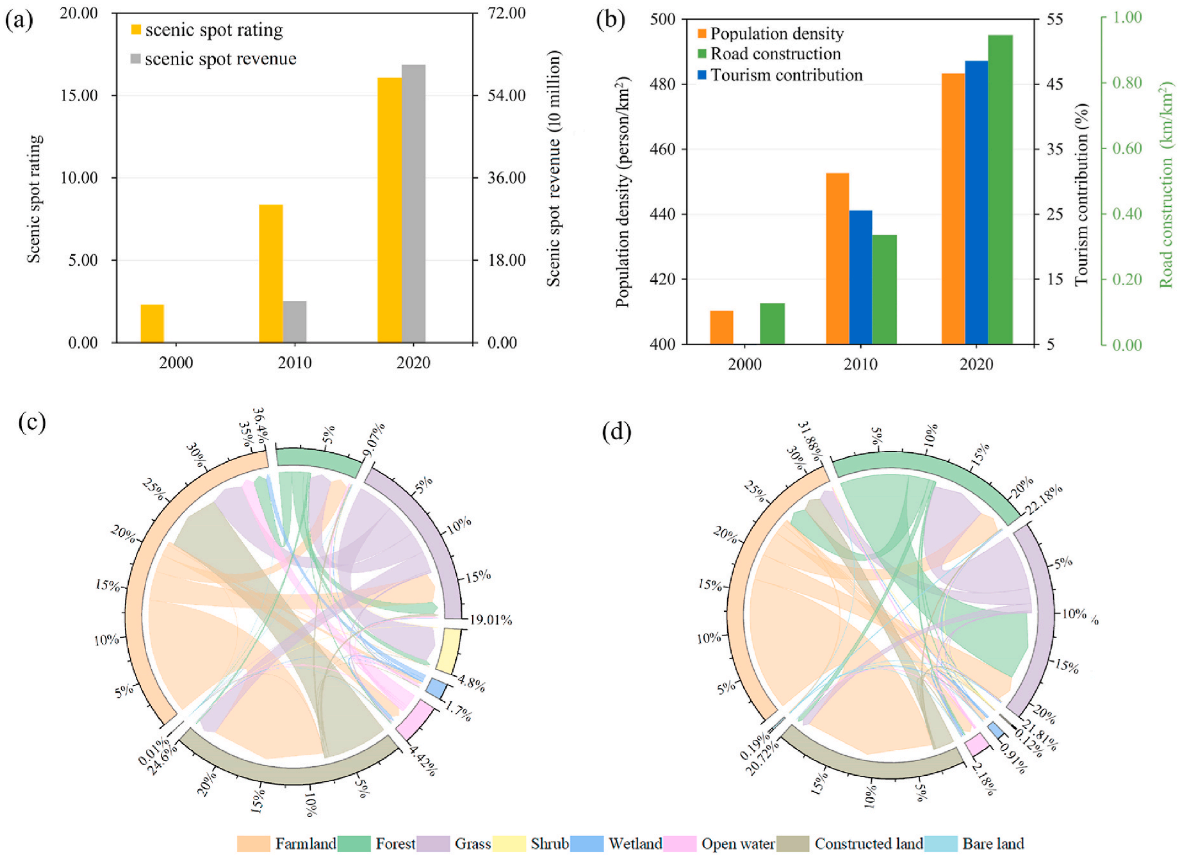

**Fig. 3.** Land use transition and socio-economic indicators around scenic spots from 2000 to 2020: (a) the indicators of scenic spot development; (b) the indicators of socio-economic development. (c) Land use transition from 2000 to 2010; (d) land usetransition from 2010 to 2020; *The data of scenic spot income and tourism contribution in 2000 are not available.

development of scenic spots and the socio-economic status of the surrounding area.

The three main land use categories throughout the research period were farmland, forest, and grassland (Fig. S3). The proportion of farmland and grassland increased with increasing distance from the scenic spot (Fig. S4a-c), whereas the opposite trend was observed for the proportion of forest. We also found that smaller ILUDD values were associated with larger distances from the scenic spots (Fig. S4d). The ILUDD decreased with increasing distance from 2000 to 2010, especially in the 1–3 km range, but tended to increase in the 1–2 km range and decrease in the 2–15 km range from 2010 to 2020. The ILUDD was also significantly higher in 2010–2020 than in 2000–2010. Notably, the SLUDD of farmland from 2000 to 2020 was found to be consistently negative (from −0.15% in 2000–2010 to −0.57% in 2010–2020) (Table S5), and was mostly transformed into constructed land, grassland, and forest. In 2000–2010, the conversion of farmland to constructed land, grassland, and forest, occurred over areas of 1050.78, 266.47, and 156.00 km$^2$, respectively; while in the period of 2010–2020, these changes were 1897.69, 368.75, and 359.12 km$^2$, respectively. Shrubland, constructed land, and bare land continued to grow in 2000–2020, with growth rates of 102.42%, 2.93%, and 3.69%, respectively. Growth on shrubland was mainly caused by the conversion of grassland (88.16% of shrub growth) in 2000–2010 (Fig. 3c) and forests (56.33% of shrub growth) in 2010–2020 (Fig. 3d). The conversion of cropland was also a major factor in the expansion of bare land over the study period. A falling tendency was followed by a rising trend in grassland, wetland, and open water, whereas the exact reverse was true for forest (Table S5).

### 3.2. Spatial-temporal patterns and trade-offs of ecosystem services

The spatial changes of FP, CS, WY, SR, and HQ exhibited significant spatial heterogeneity across the region (Fig. 4). Specifically, the southeastern area of the THM showed the main concentration of high FP values in the area, with a subsequent shift northward (Fig. S5). According to statistical data from the THM yearbooks between 2000 and 2020, food production climbed from 9.5 million tonnes in 2000 to 13.5 million tonnes in 2010 and then to 12.8 million tonnes in 2020. Spatially, the FP increase was concentrated in the southeastern part of the study area, with a significantly lower vadose increase around the scenic spot. Areas with high CS values were concentrated in the central part of the study area with high forest cover, increasing rapidly from 82.01 million tonnes in 2000 to 143.33 million tonnes in 2020 (Fig. S6), with higher CS increases of the vadose in areas that were spatially closer to the scenic spot perimeter (Fig. 4). The southeastern part of the study area was predominantly a high-WY area, but showed a 5.30% decrease from 1549 million m$^3$ in 2000 to 1471 million m$^3$ in 2020 (Fig. S6), with the decreases more strongly concentrated in the southeastern and southern parts of the study area. The SR increased continuously from 2397.46 million tonnes in 2000–3071.35 million tonnes in 2020 (Fig. S6), with the highest vadose increase concentrated in the central part of the study area, in addition to a relatively high vadose increase in areas close to the scenic spot perimeter. The distribution of HQ was similar to that of SR and CS (Fig. S6), but showed a small decrease of 3.42% during the study period, with a sporadic distribution of increases and decreases around the scenic perimeter.

The analysis of trade-offs and synergies among the ESs revealed differences across the buffer scales (Fig. S7). Particularly noteworthy is the observation that the maximum trade-off or synergistic effects

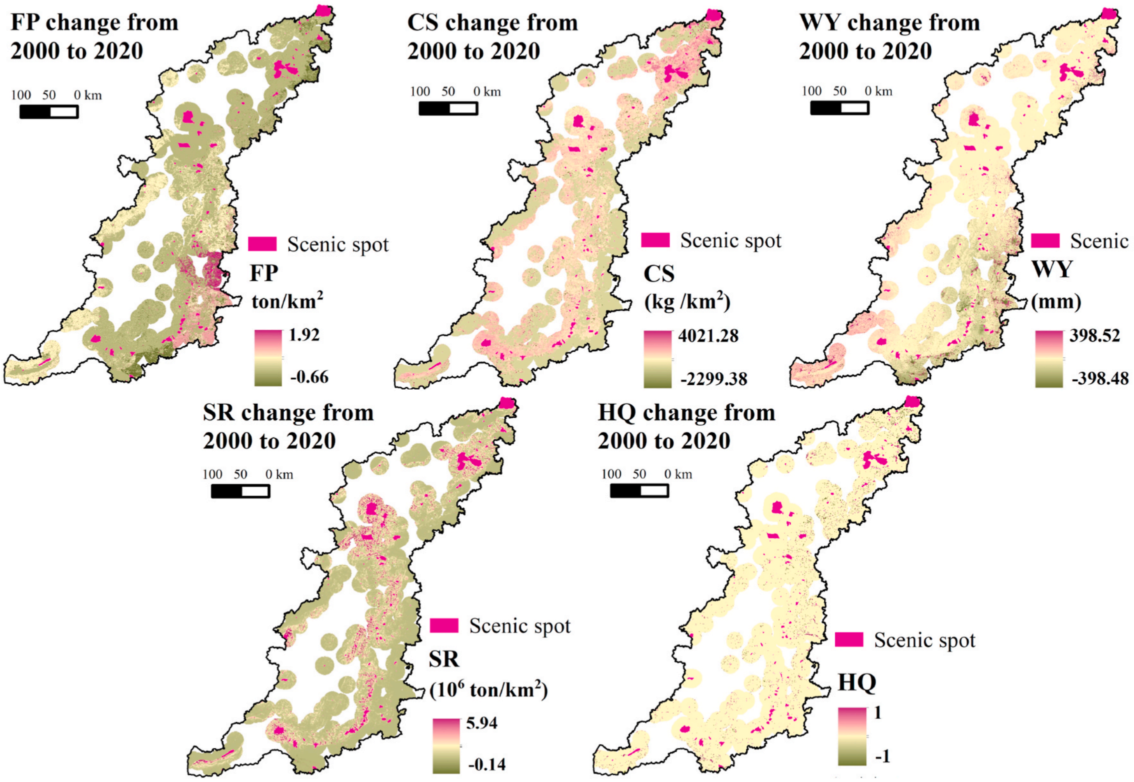

**Fig. 4.** Spatial change of ESs in 2000, 2010, and 2020. Abbreviations: FP: food production; CS: carbon sequestration; WY: water yield; SR: soil retention; HQ: habitat quality.

between the ESs occurred within the 0–10 km buffer range (Fig. S7). The bar chart in Fig. S8 illustrates a disparity in the mean value of the trade-offs and synergies among the ESs before and beyond the 10-km buffer zone, while the trend analysis in Fig. S9 demonstrates more pronounced changes. We thus analyzed the trade-offs and synergistic relationships of the five ESs in the 10-km buffer zone of the scenic spot from 2000 to 2020 ($n = 5000$) (Table 3). FP showed a highly significant trade-off relationship with CS, SR, and HQ, and a high degree of a synergetic relationship with WY. Carbon storage demonstrated a strongly positive and annually increasing correlation with SR and HQ, and a significantly negative correlation with WY. There was also an increasingly negative correlation between WY, SR, and HQ between 2000 and 2020, while a significant inverse relationship was observed between SR and HQ.

### 3.3. *Impact pathways of scenic spots on ecosystem services trade-offs*

The SEM revealed the primary pathways by which scenic spot development affected the synergies and trade-offs between ESs in both direct and indirect manners (Fig. S5, S10), while the dominant elements and direction of influence significantly changed over time. Specifically, the scenic spot revenue had a significant influence on the relationship among ESs in 2010, but in 2020, the scenic spot rating had a significant impact.

**Table 3**
Trade-offs over time between ecosystem services.

| | Year | CS | WY | SR | HQ |
|---|---|---|---|---|---|
| FP | 2000 | −.458** | .086** | −.168** | −.647** |
| | 2010 | −.439** | .036** | −.172** | −.580** |
| | 2020 | −.387** | .040** | −.133** | −.525** |
| CS | 2000 | | −.193** | .243** | .690** |
| | 2010 | | −.227** | .282** | .719** |
| | 2020 | | −.297** | .287** | .732** |
| WY | 2000 | | | −.058** | −.312** |
| | 2010 | | | −.072** | −.347** |
| | 2020 | | | −.095** | −.417** |
| SR | 2000 | | | | .264** |
| | 2010 | | | | .280** |
| | 2020 | | | | .280** |

**: $p < 0.001$.

In 2010, the scenic spot revenue had a significant dominant influence on the trade-off relationship of FP-SR and the synergistic relationship of CS-SR and SR-HQ (Fig. 5a and Table 4), with impact coefficients of 0.302, −0.105, and −0.362, respectively. This suggests that a 1% increase in scenic spot revenue in the study area would result in a 0.302% increase in the trade-off effect of FP-SR, and 0.105% and 0.362% reductions in the synergistic effect of CS-SR and SR-HQ. In contrast, scenic spot revenue exerted little influence on the trade-offs and synergies between the WR and other ESs in 2010. For the direct pathways, the partial effect of scenic revenue on the SR-FP relationship was positive (0.489, $p < 0.001$), whereas the partial effects on the SR-HQ and SR-CS relationships were significantly negative (−0.388, −0.501, $p < 0.001$). For indirect pathways, 11 showed statistical significance ($p < 0.01$). Scenic spot revenue was been found to have a significant positive impact on the trade-off between the SR and FP, as it encouraged population clustering and boosted tourism contributions. However, scenic spot revenue can also result in the expansion of constructed land, limiting the potential synergy of SR-HQ and SR-CS.

In 2020, the impacts of the scenic spot level on the trade-offs and synergies between different ESs were more pronounced (Fig. 5b, Table 5), especially for CS-FP, CS-HQ, and CS-WY. The total effects of the scenic spot level were −0.491, 0.279, and 0.377, respectively, indicating that a 1% increase in scenic spot level in the study area would result in a 0.491% decrease in the trade-off between CS-FP, and a 0.279% and 0.377% increase in the synergy of CS-HQ and CS-WY, respectively. The influence of the scenic spot rating on the trade-offs and synergies between the SR and other ESs in 2020 did not pass the significance test ($p > 0.1$). For the direct pathways, the partial effect of the scenic spot level on CS-FP was significantly negative (−0.525, $p <$

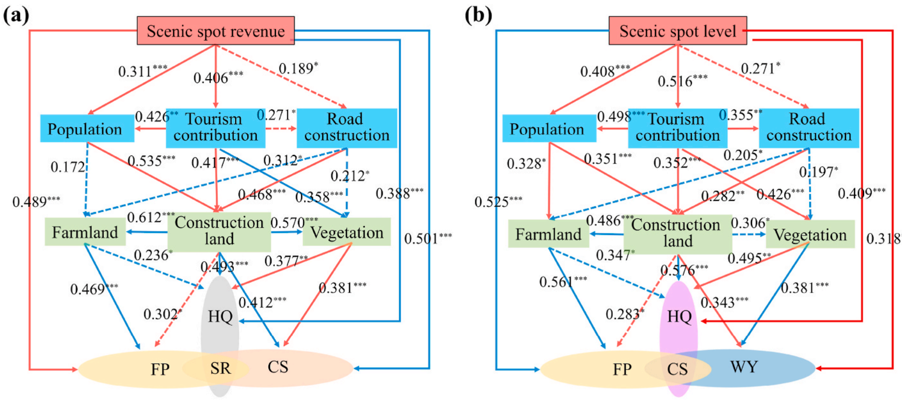

**Fig. 5.** Dominant effects of scenic spot on ecosystem services trade-offs in (a) 2010 and (b) 2020. Red and blue arrows indicate positive and negative impacts, respectively; solid arrows represent highly significant pathways ($p \leqslant 0.05$); dashed arrows represent low significant pathways ($p > 0.05$). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

**Table 4**
The dominant effects of pathways through which the scenic spot revenue influenced ecosystem service trade-offs in 2010.

| Dominant pathways | Effects | | |
|---|---|---|---|
| | SR&FP | SR&HQ | SR&CS |
| **Direct pathway:** | | | |
| Scenic spot revenue→ | 0.489 | −0.388 | −0.501 |
| **Indirect pathways:** | | | |
| Scenic spot revenue→Population→Constructed land→ Farmland → | 0.048 | | |
| Scenic spot revenue→ Tourism contribution→Constructed land→Farmland→ | 0.049 | | |
| Scenic spot revenue→Tourism contribution→Population→Constructed land→ Farmland → | 0.091 | | |
| Scenic spot revenue→Population→Constructed land→ | | −0.082 | |
| Scenic spot revenue→ Tourism contribution→Population→Constructed land→ | | −0.046 | |
| Scenic spot revenue→ Tourism contribution→Constructed land→ | | −0.083 | |
| Scenic spot revenue→ Tourism contribution→Constructed land→ Vegetation → | | −0.036 | |
| Scenic spot revenue→ Tourism contribution→ Vegetation → | | | −0.037 |
| Scenic spot revenue→ Tourism contribution→Population→Constructed land→ Vegetation → | | | −0.020 |
| Scenic spot revenue→ Tourism contribution→Population→Constructed land→ | | | −0.046 |
| Scenic spot revenue→Population→Constructed land→Forest→ | | −0.036 | −0.036 |
| Total | 0.302 | −0.105 | −0.362 |

**Table 5**
The dominant effects of pathways through which the scenic spot level influenced ecosystem services trade-offs in 2020.

| Dominant pathways | Effects | | |
|---|---|---|---|
| | CS&FP | CS&HQ | CS&WY |
| **Direct pathway:** | | | |
| Scenic spot level → | −0.525 | 0.409 | 0.318 |
| **Indirect pathways:** | | | |
| Scenic spot level →Population→ Farmland → | −0.075 | | |
| Scenic spot level →Population→Constructed land→ Farmland → | 0.039 | | |
| Scenic spot level → Tourism contribution→Constructed land→ Farmland → | 0.050 | | |
| Scenic spot level →Tourism contribution→Population→Constructed land→ Farmland → | −0.047 | | |
| Scenic spot level →Population→Constructed land→ | | 0.082 | |
| Scenic spot level → Tourism contribution→Population→Constructed land→ | | 0.052 | |
| Scenic spot level → Tourism contribution→Constructed land→ | | 0.105 | |
| Scenic spot level → Tourism contribution→Constructed land→ Vegetation → | | −0.109 | |
| Scenic spot level → Tourism contribution→ Vegetation → | | | 0.084 |
| Scenic spot level → Tourism contribution→Population→Constructed land→ | | | −0.031 |
| Scenic spot level → Tourism contribution→Constructed land→ | | | −0.062 |
| Scenic spot level → Population→Constructed land→ | | | −0.049 |
| Total | −0.491 | 0.279 | 0.377 |

0.001), while the effects on CS-WY and CS-HQ were positive (0.409, 0.318, $p < 0.001$). In this study, 16 indirect pathways were found to have statistical significance ($p < 0.01$). The results show that the scenic spot level had a negative effect on the CS-FP trade-off by promoting population agglomeration and tourism contribution, resulting in changes to cropland use. Nevertheless, the CS-HQ and CS-WY relationships were primarily influenced by changes in constructed land and vegetation.

## 4. Discussion and implications

### *4.1. Discussion*

The land use pattern and ESs around the scenic spots in the THM changed over the study period owing to ecological conservation policies and urbanization around the scenic spots (Hu et al., 2021). Between 2000 and 2010, the conversion of farmland to constructed land (owing to residential land expansion and urban construction led to decreases in CS, SR, WY, and HQ (Yang, 2021). However, the ESs supply analysis indicated an increase in CS and SR, which can be attributed to ecological conservation initiatives such as the Natural Forest Conservation Program (NFCP) and Grain for Green Program (GFGP) (Table S6). The implementation of NFCP and GFGP has resulted in a reduction of soil and water loss and strengthening of the forest carbon sink (Liu et al., 2008). Despite a decrease in the total area of farmland, the FP was improved owing to advancements in agricultural production technologies, such as the increased use of agricultural machinery, fertilizers, and pesticides (Shi et al., 2020; Zhang et al., 2019). During the period of 2010–2020, the implementation of ecological conservation initiatives (e.g., NFCP, GFGP) (Table S6) played a crucial role in continuously increasing the total supply of CS and regulating services for SR. Despite a slight decrease in forest area (Table S5), the time-lag effect of these initiatives resulted in a significantly greater supply of CS and SR compared with those in 2000–2010 (Gong et al., 2022; Li et al., 2022b). However, these initiatives in turn led to increased water consumption and evapotranspiration, thus reducing WY, which has also been in reported in other related studies (Hu et al., 2021). The development of scenic spots contributed to the clustering of the surrounding tourism services and expansion of constructed land (Xi et al., 2014). Rapid urbanization and the addition of road networks around the scenic spots have been shown to negatively affect HQ (Ouyang et al., 2021). Meanwhile, although the ecological policy of the THM contributed to the improvement of HQ, the development of the scenic spots still poses a threat to the environmental security.

The results of our study show a spatial gradient effect of land use types and ESs changes around the scenic spots, with a 10-km buffer zone outside the scenic spots generally acting as an “influence zone” for land-use (Fig. S4) and ESs (Figs. S6, S7). Specifically, the results show that the area within 6–7 km of the scenic spots experienced a shift in land use type. For instance, the proportion of farmland within this range was lower than the average proportion within the buffer zone, while the proportions of forest and constructed land were higher (Fig. S4). Similarly, we observed a spatial gradient effect in the changes of ESs provision. Our analysis shows that the supply of FP, CS, and HQ reached its highest levels at 8–9 km from scenic spots and then decreased with further increasing distance from scenic spots (Fig. S6). Moreover, the trade-off and synergistic relationship for the ESs reached its maximum and minimum values within a 10-km range (Fig. S7). Previous studies have provided insight into the “tourism island effect,” whereby one or more environmental or socioeconomic indicators of a tourism destination notably differ from those of nearby non-tourist districts (Li et al., 2014), leading to regional development dilemmas (e.g. spatial isolation, power imbalances). However, previous studies mostly explained this phenomenon in theoretical terms. By analyzing the changes in land use and ESs at the spatial scale, we found that the “influence zone” within a 10-km radius around the scenic spots in the THM may be a critical area for addressing potential issues caused by the island effect. The scope of influence of each scenic spot may also vary owing to differences among the various scenic spots within the study area. We therefore investigated the differences between the median and average ESs values of these provinces (Table S4), finding differences in the mean and median ESs but the overall trends were consistent.

Scenic spot development profoundly affected the trade-offs and synergies between some ESs in the THM via direct and indirect pathways. In 2010, land encroachment driven by rapid tourism development significantly contributed to the trade-off between SR and other ESs throughout the THMs. The increase in tourism revenue stimulated local residents to engage in the tourism industry, which led to an expansion of constructed land, while also occupying some vegetation (Liu et al., 2021b). The trade-off between FP and SR also weakened owing to the reduced area of farmland and vegetation. Farmland and constructed land were found to negatively influence SR and HQ (Yohannes et al., 2021). Although the contributions of tourism to the economy and road construction negatively impacted vegetation in 2010, the positive effects of vegetation on the synergistic relationships among HQ, CS, and SR still dominated, which reflects the positive ecological effects of NCFP and GFGP. Furthermore, as the scenic spot revenue increases, the associated increased investment in ecological restoration efforts can improve the CS and SR (Wang and Dai, 2020). However, the scenic spot level became a significant factor in the ESs trade-offs or synergistic relationships in 2020, likely owing to better environmental protection measures and increased national and local government investment in the high-level scenic spots (Lin et al., 2020; Ma and Zou, 2022). For example, the ecological quality of the scenic spots is considered when rating scenic spots in China, in which higher ratings are associated with better ecological environments (e.g., air and water quality) around the scenic spots (Ma and Zou, 2022). Higher-level scenic spots therefore typically have more ecological space than lower-level spots (Cao et al., 2021), which will increase the HQ-CS synergy. Moreover, most of the constructed land in the THM came from the conversion of farmland, which made it much less efficient for reducing CS than increasing WY, ultimately leading to weaker trade-offs between CS and WY (Ma et al., 2022). Tourism normally increases the trade-off between FP and CS (Chai et al., 2021), while the results in Fig. 5b show a different outcome, which can mostly be attributed to agritourism in the THM (Zhang et al., 2022) and an increase in both food output and revenue, ultimately reducing the trade-off between FP and CS.

### 4.2. Management implications

In terms of the direct impact of scenic spots (Fig. 6), ecological environmental protection should be coordinated early when planning the development of scenic spots to minimize unfavorable trade-offs between ESs owing to tourism growth. For example, the revenue from scenic spots can be used to fund environmental improvements, while increasing the use of water- and energy-saving materials in and around scenic spots (Mendoza et al., 2022). Communities are a crucial component for establishing sustainable tourism growth (Lee and Jan 2019) and are the key to avoiding and reducing the island effect (He et al., 2018). In this regard, the interests of those residing in communities near scenic spots should be taken into consideration (Dou et al., 2021). For example, tourism development can be reconciled with the livelihoods of local people by increasing eco-investment (e.g. establishing eco-industrial chains). Furthermore, residents should be encouraged to participate in public affairs in their communities and instill a sustainable understanding and approach to tourism development (Kanwal et al., 2020; Ren et al., 2021).

In terms of indirect impact pathways, scenic spots also profoundly affect ecosystems by driving socio-economic development (Wang et al., 2022). For instance, scenic development stimulates population concentration, which results in increased income from related industries and the expansion of land for construction (Li et al., 2020; Wang et al., 2022). The needs of local residents for amenities will also increase, ultimately exacerbating the trade-offs between ESs (Liu et al., 2021a). To reduce such negative impacts, it is recommended that ecological “red line zones” be delineated as restricted development boundaries (Bai et al., 2018). For example, all development could be prohibited within the red line zone to prevent the destruction of the natural environment (Bai et al., 2018); while outside the red line zone, construction and development areas could be designated to reduce pollution and damage to the environment caused by uncontrolled spatial layout (Li et al., 2020).

Vegetation cover is a major factor affecting many ESs in terms of impact pathways for land system transformation. Abundant vegetation cover enhances the availability of CS, SR, and HQ. Degraded ecological space around scenic spots can be restored by increasing the vegetation cover and selecting water-saving plants, thus effectively reducing the trade-offs between WY and CS, SR, and HQ. A strict threshold should be set by conducting a comprehensive evaluation in terms of ecological safety, environmental pollution emissions, and the maximization of resource utilization (Bai et al., 2016). Additionally, an effective system of rewards and penalties could be implemented to encourage compliance with environmental regulations and promote sustainability (Pope et al., 2019). The multifunctionality of land use should also be considered in landscape management, and land remediation of abandoned land should be carried out from a supply-side perspective to achieve the simultaneous promotion of tourism and environmental restoration (Huber et al., 2020; Liu et al., 2021a).

## 5. Conclusion

This paper provides a temporal and spatial analysis of change concerning land-use and ESs around scenic spots in the THM, and examines the relationships between tourism development and ESs trade-offs and

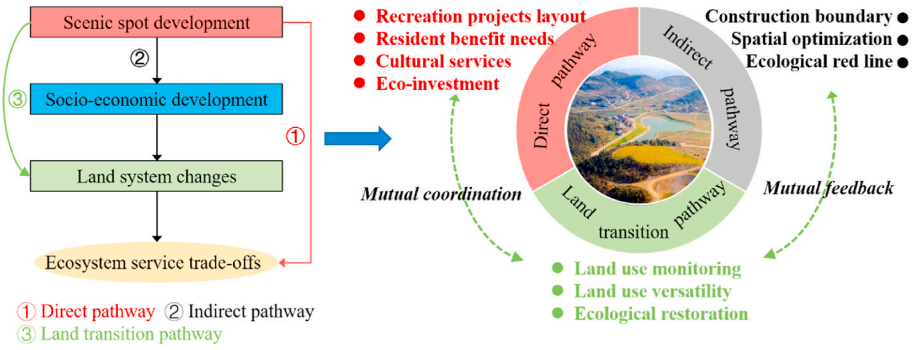

**Fig. 6.** Social–ecological pathways showing how scenic spot development impacts ecosystem services trade-offs and policy implications.

synergies. These findings provide valuable insights into the necessity of including ecological services in decision-making. Our results show that the constructed land area around scenic spots in the THM continued to increase from 2000 to 2020 at the expense of agriculture, grassland, and forests, which led to a decline in WY and HQ and an increase of FP, CS, and SR. Tourism development was also found to significantly affect the trade-offs between important ecological functions of the study area via indirect means such as promoting population growth, industrial restructuring, and infrastructure development. To achieve sustainable development in the EFZ, it is essential to ensure that the negative impacts of tourism development on the environment and ESs are maintained within acceptable limits, as determined through a comprehensive and scientific assessment.

To further advance our knowledge in this field, future research must address the study's two key limitations. First, while our technique provides a straightforward and flexible method to evaluate numerous ESs, model evaluation uncertainties are unavoidable. We make the assumption that the eight types of land use are homogeneous, which may neglect certain information (e.g., types of crops, forests) and hence reduce the classification accuracy. Additionally, the model evaluation's input parameters are based on earlier studies, which could possibly contribute to some errors in the evaluation findings. To improve our understanding of the ESs dynamics, future research could seek for more high resolution data or narrow down to areas with available spatial data on key factors. Secondly, despite the examination of the direct and indirect effects of tourism on trade-offs and synergies between ESs, this study does not further analyze the spatial variability or effects of various scenic spots types on nearby land use and ESs. Meanwhile, we did not analyze the driving mechanisms of dramatic changes in land use/cover and ESs within 10 km of scenic spots. One way to advance our knowledge of the interactions between tourism activities and ESs is to concentrate future studies on analyzing the spatial distribution of trade-offs and synergies among ESs at different scales and different types of scenic spot and tourism activities. To ensure the relevance and applicability of the research, it is crucial to engage stakeholders in interpreting the results and considering trade-offs in ecosystem management decisions that impact local well-being.

## Credit author statement

Li Li: Conceptualization, Methodology, Software, Data curation, Visualization, Formal analysis, Writing- Original draft preparation. Rundong Feng: Methodology, Formal analysis, Data curation, Visualization, Writing-Reviewing, Supervision, Editing.Jianchao Xi: Project Administration, Writing-Reviewing, Validation, Supervision.Edward H. Huijbens: Writing-Reviewing, Supervision.Yiran Gao: Validation, Editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2023.118183.

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