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Assessing the Multifunctional Potential and Performance of Cultivated Land in Historical Irrigation Districts: A Case Study of the Mulanbei Irrigation District in China

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Abstract

Historical irrigation districts (HIDs) are integrated systems of natural and cultural assets, with cultivated land providing critical functions such as food security, environmental conservation, and cultural inheritance. This study presents a research framework for evaluating multifunctional potential, performance, and geographical matching along the "potential-performance" dimensions using analytical tools such as SPSS26.0, ArcGIS pro3.5.2, GeoDa1.22, InVEST3.13, and bivariate spatial autocorrelation. We use Mulanbei HID in China as a case study because of its thousand-year irrigation history and unique location at the intersection of coastal urban and rural communities. The results show the following: (1) In the Mulanbei HID, multifunctional cultivated land exhibits functions in the following order: producing functions, ecological functions, landscape–cultural functions, and social functions. The production function has a homogenous distribution characterized by high values. The ecological function, on the other hand, is distinguished by high-value clusters that decrease significantly as building land approaches its periphery. Social and landscape–cultural roles continue to be undervalued, with high-value places isolated on metropolitan margins. (2) In terms of matching multifunctional potential and performance, in the High-Potential–High-Performance cluster, production and ecological functions account for 19% and 20%, respectively, while in the High-Potential–Low-Performance cluster, social and landscape–cultural functions account for 33% and 27%. The Low-Potential–Low-Performance cluster has 4% production, 4% ecological, 10% social, and 13% landscape–cultural functions, but all four functions are less than 4% in the Low-Potential–High-Performance cluster. These findings provide a scientific foundation for improving cultivated land zoning and governance with a focus on heritage protection.

Keywords: cultivated land; multifunctionality; historical irrigation district; land use; potential and performance; spatial match

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1. Introduction

Historical irrigation districts (HIDs) are hydrological basin units that have been in continuous operation for more than 50–100 years [1,2]. They are distinguished by regulated water regimes, linked canal networks, and hydraulic infrastructure. Over generations, human–land interactions have developed resilient and efficient networks, sustained productive croplands, and supported agrarian towns, making HIDs key carriers of agricultural heritage and cultural landscapes [3]. However, pressure on land preservation has increased due to the reduction in both cultivated land area and agricultural investment brought about by global industrialization and urbanization [4]. The threats facing HIDs are particularly severe. On the one hand, the decrease in agricultural services has the potential to degrade the entire system, resulting in the irreversible loss of distinctive cultural landscapes and ecological value [5]. On the other hand, these areas' development paths have been regulated by their sole focus on grain production, increasing their industrial vulnerability [6,7].

Meanwhile, increasing urban and rural demand for ecological and cultural services [8] is driving a move away from single-purpose agriculture toward multifunctional cultivated land use [9,10]. Research on multifunctional farmed land can be traced back to scholarly discussions about agricultural multifunctionality. In the 1980s, the European Union pushed multifunctional agriculture to combat agricultural marginalization [11]. In 1992, the United Nations Conference on Environment and Development identified agricultural multifunctionality as crucial to sustainability. Agriculture, according to organizations such as the FAO [12], OECD [13], and World Bank [14], is developing from a simply production unit to a multifunctional system that integrates ecological, cultural, and political functions. This paradigm has since spread to ecosystem management [15], landscape planning [16], and land system science [17].

Cultivated land, as the fundamental land type in multifunctional agriculture, has undergone significant changes in its value perception and research paradigms. Compared to traditional cultivated land research, which focuses on productivity [18], quantitative changes [19], and utilization efficiency [20], multifunctionality studies have emphasized the study of its connotation [11], classification [21], spatiotemporal patterns [22–24], and driving factors [25]. Based on a variety of indicators, these studies developed assessment systems to measure and assess multifunctionality on farmed land across multiple spatiotemporal settings, as well as examine the spatiotemporal evolution characteristics of such multifunctionality [26]. Building on this basis, they used approaches like coupling coordination analysis [27] and spatial autocorrelation [28] to discover trade-offs and synergies between different functions [29,30], and offered zoning-based management and control mechanisms. These discoveries have had a positive impact on coordinating cultivated land governance and control, as well as increasing the cultivated land development orientation.

Nevertheless, certain limitations remain: (1) While these studies have assessed multifunctional performance through established indicators, they have often neglected the foundational role of cultivated land potential. In reality, this potential acts as a fundamental constraint on multifunctional development, and its variations directly limit the feasible models for cropland utilization. The use of variables such as slope, soil texture, and road density as direct proxies for multifunctionality exemplifies this oversight. (2) In functional assessment, the majority of existing studies have relied on a static analytical framework and failed to distinguished between the potential that supports multifunctional cultivated land and the dynamic process of its final performance. Such shortcomings may lead to overexploitation of specific functions and a mismatch between functional potential and realized outcomes in practice, thereby impeding the efficient allocation of limited resources [31,32]. Therefore, many recent studies have begun to examine potential and performance as separate strands of inquiry, while also highlighting the need for further integration into a

unified framework [33]. Given their superior resource endowment and agricultural history, HIDs offer a more suitable context for investigating potential–performance differentiation.

Recent study has increasingly viewed HIDs as eco-cultural complexes, particularly in the Netherlands and China. According to consensus, farmed land in HIDs offers significant multifunctional development potential in addition to its traditional agricultural production value [34,35]. From a cultural standpoint, the farming system in HIDs reflects local communities' extensive knowledge of natural processes [36]. Ecologically, the canals and cultivated land produce a semi-natural wetland with strong water-land edge effects, which promotes biodiversity [37] and helps to conserve soil-water [38]. Esthetically, the intertwined patterns of water and land, together with the rhythmic character of agricultural activities, provide unique landscape resources for experiencing rural natural scenery [39,40]. However, prior research has been concentrated on provincial and municipal scales, and its macro-level methodologies are not well matched to the micro-scale characteristics of farmed land in HIDs.

To address the aforementioned issues, this study established a "potential-performance" framework for multifunctional cultivated land, focusing on HIDs in China. The research aimed to answer two key questions: (1) How to assess the potential and performance of multifunctional cultivated land in HIDs? (2) What is the spatial correlation between the multifunctional potential and performance of cultivated land in these districts?

2. Materials and Methods

2.1. Research Framework

This study presented a "potential-performance" framework for multifunctional cultivated land (Figure 1). Potential encompasses natural resource endowments, environmental conditions, production characteristics, and regional development structure and level [41,42]. The multifunctional potential of cultivated land refers to the highest sustainable functional service capacity that cultivated land may supply within a specific spatial unit under the combined effect of natural-geographical factors and socioeconomic activity. In this study, the determinants of multifunctional cultivated land potential were divided into four categories: geographical, historical, infrastructure, and land management aspects. The performance of multifunctional cultivated land refers to the process by which humans transform the potential of cultivated land into actual functional services through agricultural production practices, policy interventions, and technological inputs [43], with its essence lying in the development and utilization of cultivated land space. The primary indicator of the production function's performance is food production (FP). The performance of the ecological function is demonstrated by essential ecosystem services such as water conservation (WC), habitat quality (HQ), soil conservation (SC), and carbon sequestration (CS). The performance of social functions is measured by residential carrying capacity (RC), agricultural product services (AS), and healthcare and wellness (HW). The performance of the landscape–cultural function is primarily represented by scientific research and education (SRE) and recreation-ecotourism. Finally, using a spatial correlation model, the spatial correlation between multifunctional potential and performance of multifunctional cultivated land can be classified into four categories [44]: high potential–low performance, low potential–low performance, high potential–high performance, and low potential–high performance.

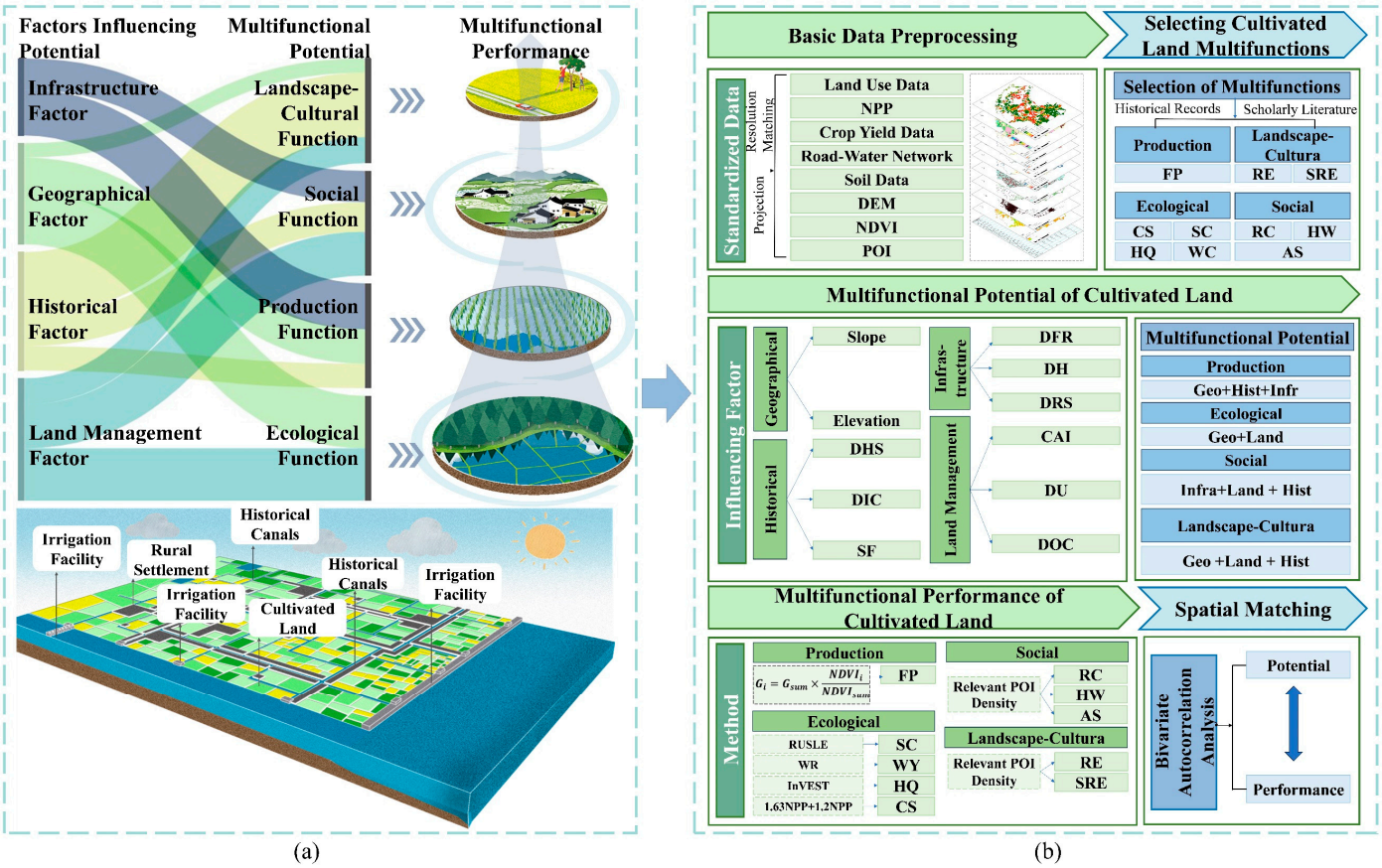


Figure 1. Research framework. (**a**) Research Framework; (**b**) Technical Route.

2.2. Identification of Multifunctionality in Cultivated Land Within HIDs

A number of local gazetteers and hydraulic engineering documents in China provide significant evidence for determining landscape uses of cultivated land during historical times. By extracting functional keywords directly associated with cultivated land from historical documents and integrating these with contemporary research on the multifunctionality of cultivated land, this study categorized the landscape functions of cultivated land in HIDs into four dimensions, production, ecology, society, and landscape–culture, along with ten representative functions.

Functions are identified using two essential principles: First, the application of historical textual materials is guided by clear principles of choice and complementarity. HIDs in China display key traits such as water resource reliance and historical continuity. Notably, the Yangtze River Basin and China's southern provinces have long been key grain production areas, with a large concentration of HIDs based on polder and water diversion irrigation. These areas have undergone complex land use transformations in modern development, making them focal zones for studying multifunctional utilization of cultivated land. Accordingly, this study retrieved historical documents using landscape function-related keywords associated with three HIDs: Taihu Longkou in Huzhou, Zhejiang, West Lake in Hangzhou, Zhejiang, and Mulanbei in Putian, Fujian [45,46]. Second, the framework adheres to the temporality and cognitive expansibility of functional connotations. To capture functions that were either underrecognized in historical records due to the contextual limitations or have emerged more prominently in contemporary society, supplementary literature on the multifunctionality of cultivated land is collected from academic databases such as CNKI and WOS. The detailed process and criteria for function selection are documented in Appendix A. (Table A1).

2.3. Assessing the Multifunctional Potential of Cultivated Land in HIDs

Among the four types of elements impacting farmed land's multifunctional potential, the geographical component serves as its natural base. Slope and elevation have a direct impact on agricultural production suitability [47], ecological sensitivity [48], and landscape distribution range [49] because they affect the efficiency of light, heat, water, and soil configuration. Historical causes influence the core characteristics and spatial distribution of cultivated land. Long-term cultivation in HIDs has preserved effective farming practices, positively contributing to soil fertility [50], and thus ensuring sustained agricultural productivity. Furthermore, the water channel networks in these districts not only secure irrigation water supply but also form distinctive water hydraulic landscapes [51], enhancing the esthetic value of the interdependence between fields and water. The integration of cultivated land landscapes with surrounding historical and cultural resources strengthens both the landscape character and cultural significance. This composite landscape not only improves the visual quality but also supports leisure, tourism, science popularization, and education activities [52], thereby effectively promoting the development of rural tourism and healthcare functions [53]. Infrastructure constitutes a critical enabling condition for the multifunctional development of cultivated land. Rural settlements, road networks, and other transportation facilities influence agricultural operation efficiency, transportation costs, commercialization rates [54], and the radiation capacity of cultivated land functions. Land management serves as a regulatory mechanism. Through spatial planning and land use control, it coordinates the trade-offs among the various competing functions of cultivated land and optimizes the overall benefits, while ensuring that its core functions are safeguarded. Higher degree of cultivated land aggregation facilitates the continuity of ecological processes and supports the formation of a large-scale agricultural landscape. Furthermore, the location of cultivated land and its adjacent land uses significantly affect its stability [54]. When cultivated land is located near urban areas, it offers convenient access for recreational use by residents, but it also faces greater pressure of urban encroachment, weakening its ecological barrier function. In contrast, when suited farther from urban areas, it experiences less ecological disturbance, yet limited accessibility constrains the development of social service functions such as leisure and education.

Among the four categories of influencing factors of potential, the Slope (SL) and Elevation (EL) of the terrain were extracted for each cultivated land grid value in ArcGIS pro3.5.2 using the Slope tool and raster calculator. The Density of Field Roads (DFR) and Irrigation Canals (DIC) were calculated for each grid through the Line Density tool combined with the Raster Calculator in ArcGIS. Five distance-based indicators: the Distance from Cultivated Land to Highways (DH), Distance from Cultivated Land to Rural Settlements (DRS), Distance from Cultivated Land to Historical Sites (DHS), Distance from Cultivated Land to the Central Urban Area (DU), and Distance from Cultivated Land to Other Construction Land (DOC), were derived for each cultivated land grid value using the proximity analysis tool and Raster Calculator in ArcGIS. Soil Fertility (SF) is evaluated based on the content of soil organic matter, total nitrogen, available phosphorus, available potassium, pH value, and cation exchange capacity. A modified Nemerow index method is employed to integrate these indicators and quantify the composite index [55,56]. The formula is as follows:

$$F = \sqrt{\frac{\left(\overline{F}_i\right)^2 + \left(F_{imin}\right)^2}{2}} \cdot \left(\frac{n-1}{n}\right)$$

where F is the comprehensive soil fertility index, $\overline{F}_i$ is the average value of each sub-fertility index, F_{imin} is the minimum value among each sub-fertility index, and n is the evaluated indicator number.

The cultivated land Aggregation Index (CAI) is calculated by Fragstats [57].

The weights of each indicator need to be determined according to their relative influence on the multifunctional potential and performance of cultivated land. In this study, the Analytic Hierarchy Process is employed to assign weights to each evaluation indices. Based on the pairwise comparisons of the importance between criteria and sub-indicators by 22 domain experts, a quantitative scoring method using the 1 to 9 scale and its reciprocals was adopted to derive the weight of each index. See Tables A2–A16 in Appendix B.1 for the complete process and detailed pairwise comparison matrices. In Table 1, a plus (+) indicates that a higher indicator value enhances the function, while a minus (−) denotes that a higher value weakens it. For all distance-based indicators, a larger value represents greater physical distance, so a "−" here means that a greater distance reduces the functional level (Table 1).

Table 1. Weight of Influencing Factors for the Multifunctional Potential of Cultivated Land.

Cultivated Land Multifunctionality	Criterion Layer	Criterion Weight	Indicator Layer	Global Weight	Indicator Nature
Production Function	Geographical Factor	0.3291	Slope	0.2468	−
			Elevation	0.0823	−
	Infrastructure Factor	0.4376	Density of Field Roads	0.0645	+
			Distance from Cultivated Land to Highways	0.1717	−
			Distance from Cultivated Land to Rural Settlements	0.2014	−
	Historical Factor	0.2333	Soil Fertility	0.1183	+
			Density of Irrigation Canals	0.0859	+
			Distance from Cultivated Land to Historical Sites	0.0291	−
Ecological Function	Geographical Factor	0.5000	Slope	0.3125	−
			Elevation	0.1875	−
	Land Management Factor	0.5000	Cultivated land Aggregation Index	0.2671	+
			Distance from Cultivated Land to the Central Urban Area	0.1290	−
			Distance from Cultivated Land to Other Construction Land	0.1038	−
Social Function	Infrastructure Factor	0.4182	Density of Field Roads	0.0244	+
			Distance from Cultivated Land to Highways	0.1201	−
			Distance from Cultivated Land to Rural Settlements	0.2737	−

Table 1. *Cont.*

Cultivated Land Multifunctionality	Criterion Layer	Criterion Weight	Indicator Layer	Global Weight	Indicator Nature
Social Function	Land Management Factor	0.2985	Cultivated land Aggregation Index	0.0879	+
			Distance from Cultivated Land to the Central Urban Area	0.1229	−
			Distance from Cultivated Land to Other Construction Land	0.0877	−
	Historical Factor	0.2833	Soil Fertility	0.0442	+
			Density of Irrigation Canals	0.0875	+
			Distance from Cultivated Land to Historical Sites	0.1516	−
Landscape–Cultural Function	Geographical Factor	0.1360	Slope	0.0850	−
			Elevation	0.0510	−
	Land Management Factor	0.2494	Cultivated land Aggregation Index	0.0921	+
			Distance from Cultivated Land to the Central Urban Area	0.0906	−
			Distance from Cultivated Land to Other Construction Land	0.0668	−
	Historical factor	0.6146	Soil Fertility	0.0299	+
			Density of Irrigation Canals	0.0977	+
			Distance from Cultivated Land to Historical Sites	0.4870	−

2.4. Assessment of Multifunctional Performance of Cultivated Land in HIDs

In the assessment of the multifunctional performance of cultivated land, well-established methods have been developed for evaluating production and ecological functions, particularly through quantifying ecosystem services [58,59]. In contrast, the evaluation of social and landscape–cultural functions has largely relied on participatory assessments and perceptual surveys, limiting their applicability to specific local contexts [60]. Point-of- Interest(POI) data offers obvious advantages in terms of spatial coverage, accuracy, and update frequency, and has been widely applied in studies on land multifunctionality [61]. In urban green space research, scholars have utilized POI data to characterize actual usage patterns within a 1 km buffer around green spaces [62,63]. Similarly, in cultivated land research, recent efforts have employed POI data to assess the current status of green infrastructure in suburban farmland [64]. Therefore, integrating multi-dimensional influencing factors with the comprehensive use of POI data can provide robust methodological support for evaluating the multifunctional performance of cultivated land.

1. Production Function

The research was based on the positive correlation between the annual crop yield in Putian and the normalized difference vegetation index (NDVI) to represent the performance of the food production [65]. The calculation formula is as follows:

$$G_i = G_{sum} \times \frac{NDVI_i}{NDVI_{sum}}$$

where G_i represents the grain output of the cultivated land grid i, G_{sum} represents the total crop output of the study area, $NDVI_i$ represents the normalized vegetation index of the

i-th cultivated land grid, and $NDVI_{sum}$ represents the sum of the normalized vegetation indices of the cultivated land in the study area.

2. Ecological Function

Habitat quality was obtained through the Habitat Quality module in InVEST3.13 [66].

The water conservation capacity represents the performance of cultivated land in conserving water sources. The oxygen content of water in cultivated land was calculated through the water conservation model [67], as shown in the following formula:

$$WR = NPP_{mean} \times F_{sic} \times F_{pre} \times [1 - F_{slo}]$$

where WR represents the water conservation service capacity index, NPP_{mean} represents the average value of the net primary productivity of vegetation over many years, F_{sic} represents the soil infiltration factor, F_{pre} represents the average annual precipitation factor, and F_{slo} represents the slope factor.

The amount of soil erosion characterizes the performance of soil conservation on cultivated land. The Revised Universal Soil Loss Equation [68] was adopted. The formula is as follows:

$$Q_s = R \times K \times L \times S \times C$$

where Q_s represents the actual soil erosion amount, R is the rainfall erosivity factor, K is the soil erodibility factor, L is the slope length factor, S is the slope gradient factor, and C is the vegetation cover factor.

The amount of carbon sequestration and oxygen release characterizes the performance of carbon sequestration. The calculation of the amount of carbon sequestration and oxygen release refers to the measurement methods of Porter et al. [69], Liu et al. [70]. The formula is as follows:

$$C_i = 1.63 \times NPP_i + 1.2 \times NPP_i$$

where C_i represents the carbon sequestration and oxygen release of pixel i, and NPP_i represents the net primary productivity of pixel i.

3. Social Function

The density of business and residential accommodation services, rural life services, shopping services, and public facility POIs within a one-kilometer buffer surrounding each cultivated land grid was used to represent the performance of the residential carrying capacity. The densities of catering service POIs within a one-kilometer buffer surrounding each cultivated land grid containing the keywords “farmhouse”, “agriculture”, and “rural”, as well as the density of shopping service POIs associated with the keywords “vegetable market”, “agricultural products”, and “farmers market”, were employed to reflect the performance of the agricultural product service. Similarly, the density of medical and health care POIs within a one-kilometer buffer around the cultivated land grid was used to represent the performance of healthcare and wellness.

4. Landscape and Cultural Function

The density of POIs such as farmhouses, parks, picking gardens, fishing ponds, resorts, campsites, tourist attractions, temples, and Taoist temples within a one-kilometer buffer surrounding each cultivated land grid was used to represent the performance of the recreation-ecotourism. The density of POIs such as memorial halls, science and education cultural venues, research institutions, colleges and universities, vocational and technical schools, primary and secondary schools, kindergartens, cultural palaces, art galleries, botanical gardens, museums, and exhibition halls within a one-kilometer buffer surrounding

each cultivated land grid was used to represent the performance of the scientific research and education.

The AHP weights of each indicator were obtained through the same steps to calculate the potential weights. See in Tables A17–A20 Appendix B.2 for the complete process and detailed pairwise comparison matrices. Given the different priorities among the various functions of cultivated land, the final indicator weights for assessing the multifunctional performance were determined by integrating findings from previous research [71]. In Table 2, a plus sign indicates that a higher value of the indicator positively contributes to the function (Table 2).

Table 2. Weight of Representative Functions in the Multifunctional Performance of Cultivated Land.

Cultivated Land Multifunctionality	Criterion Layer	AHP Weight	Function Weight	Global Weight	Indicator Nature
Production Function	Food production	1	0.4037	0.4037	+
Ecological Function	Habitat Quality	0.1513	0.3357	0.0508	+
	Water Conservation	0.3077		0.1033	+
	Soil Conservation	0.3669		0.1232	+
	Carbon Sequestration	0.1741		0.0584	+
Social Function	Residential Carrying Capacity	0.2728	0.1081	0.0295	+
	Agricultural Product Services	0.5455		0.0589	+
	Healthcare and wellness	0.1819		0.0197	+
Landscape–Cultural Function	Scientific Research and Education	0.7143	0.1525	0.1089	+
	Recreation and Ecotourism	0.2857		0.0436	+

2.5. Spatial Matching of Multifactional Potential and Performance of Cultivated Land in HIDs

This study adopted the spatial autocorrelation analysis method: univariate spatial autocorrelation analysis is used to explore the spatial clustering or dispersion patterns of a single variable; while bivariate spatial autocorrelation analysis is mainly used to assess the spatial matching situation between two variables [72,73]. The global Moran's I index is utilized to identify the overall spatial dependence patterns of multifunctional potential and performance of cultivated land. Building on this, bivariate autocorrelation analysis is conducted using GeoDa1.22 software to investigate the spatial correlation between multifactorial potential and performance across the study area.

2.6. Study Area

China, with its long agricultural history and diversified geography, has several historic irrigation projects. Over 400 ancient irrigation schemes are still active [2], making China the world's biggest concentration of irrigated crops [74]. The Mulanbei HID in Putian, Fujian, China, has approximately a thousand years of irrigation development. Mulanbei Dam, the basic structure, was built in 1064 AD and is located in the tidal region of the Mulanxi River. It prevents saltwater intrusion and regulates freshwater intake while also performing important tasks in flood control, water storage, and irrigation. The canal and river network system, centered on the Mulanbei Dam, was gradually modified over the last millennium, eventually forming the current Mulanbei HID. This district is an outstanding example of traditional Chinese water conservancy projects, with huge amounts of high-quality farmed land and serving as a vital grain production base for Fujian province. The Mulanbei Dam was named a national essential cultural relic conservation unit in the third batch in 1988, and the Mulanbei HID was included in the first batch of sites recognized by the World Heritage Irrigation Structures (WHIS) list in 2014.

The Mulanbei HID (Figure 2) in this study refers to the irrigation area formed by the Mulanbei Dam and its associated water diversion channel network. The study area adheres to the boundary of the Heritage Core Demonstration Zone as defined in the Mulan River Basin Systematic Management Plan (2021–2035) issued by the Putian Water Resources Bureau. This boundary was precisely delineated by integrating the natural landscape pattern, water network distribution, and ecological characteristics of the WHIS. The study area spans 16 towns in Putian City, covering a total area of approximately 373 km^2, of which about 197 km^2 consists of cultivated land.

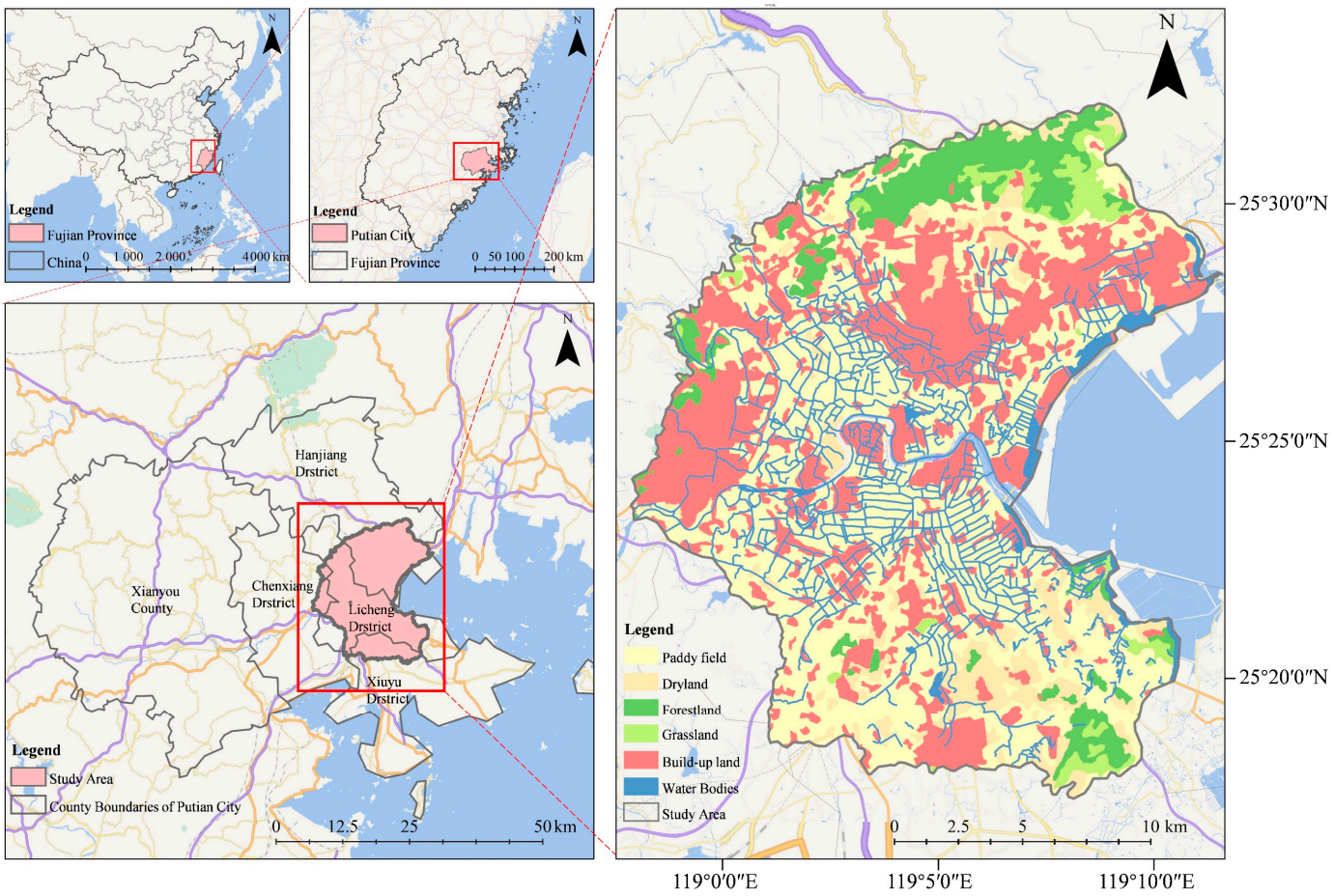


Figure 2. Study Area.

This study uses the Mulanbei Historical Irrigation District (HID) in Fujian Province as a case study, owing to its unique representativeness and typicality in clarifying the "potential-performance" relationship of multifunctional farmed land. The district is distinguished by a thick network of crisscrossed streams and fertile soil, which not only supports agricultural production but also defines a unique ecological and cultural landscape. This establishes a great ecological and cultural foundation for the multifunctional use of agricultural land. As a core zone in a rapidly urbanizing coastal region, it is at the epicenter of regular urban-rural interactions. As a result, it encounters acute and complex demands from both urban and rural populations for ecological services, leisure and recreation, and regional cultural experiences, making it an important location for studying the real-world performance pressures and conflicts of multifunctional farmed land. Most importantly, this distinct geographical position emphasizes the contrast between the traditional purpose of conserving agricultural production and rising diversified demands. Specific needs such as ecological conservation, rural development, and leisure activities all compete for limited cultivated land resources, posing direct challenges to the long-standing objective of pre-

serving agricultural functions. Therefore, the Mulanbei HID unites "superior foundational potential," "high-intensity diversified demand," and "pronounced functional competition" into a single micro-scale unit. This makes it an ideal and typical venue for empirically testing the "potential-performance" analytical paradigm suggested in this study and for finding the mechanisms of multifunctional differentiation.

2.7. Data Sources

The cultivated land in the study area was divided into 2614 square grids, each measuring 350 m × 350 m. The ArcGIS "Identify" tool was used to extract attribute values for each grid, and the data were aggregated by grid FID. Table 3 presents the dataset employed in this study.

Table 3. Data source.

Data	Data Description	Data Source
Land use (Landsat 8)	Land use data with resolution of 30 m in 2020	The Centre for Resource and Environmental Science and Data of the Chinese Academy of Sciences (https://www.resdc.cn/) (accessed on 24 July 2024)
DEM	DEM with resolution of 30 m in 2020	U.S. National Aeronautics and Space Administration (https://www.earthdata.nasa.gov/data/catalog/lpcloud-nasadem-hgt-001) (accessed on 24 July 2024)
Soil data	Soil depth data with resolution of 1 km in 2020	The World Soil Database (https://gaez.fao.org/pages/hwsd) (accessed on 25 July 2024)
Meteorological data	Daily observation data of meteorological station from January to December in 2020	National Tibetan Plateau Data Center (https://data.tpdc.ac.cn/zh-hans/data/71ab4677-b66c-4fd1-a004-b2a541c4d5bf) (accessed on 25 July 2024)
NPP (MODIS)	NPP with resolution of 500 m in 2020	NASA's Land Processes Distributed Active Archive Center (https://lpdaac.usgs.gov/products/mod17a3hgfv061/) (accessed on 24 July 2024)
NDVI (Landsat 5/7/8/9)	NDVI with resolution of 30 m in 2020	National Ecosystem Science Data Center (http://www.nesdc.org.cn) (accessed on 24 July 2024)
Grain production	Crop Yield in 2020	Putian Statistical Yearbook 2021 (https://www.putian.gov.cn/tjnj/pttjnj2021.htm) (accessed on 24 July 2024)
Road networks	Roads and waterways	OpenStreetMap (https://www.openstreetmap.org/) (accessed on 24 July 2024)
POI	1 km buffer surrounding each cultivated land grid	Gaode Maps (https://lbs.amap.com/) (accessed on 24 July 2024)

3. Results

3.1. Multifunctional Potential of Cultivated Land in the HIDs and Its Spatial Distribution Characteristics

3.1.1. Spatial Distribution of Multifunctional Potential of Cultivated Land

Figure 3a shows the regional distribution of multifunctional potential. The production function potential was typically high and concentrated in the middle plains, while low to

extremely low values were found in the northern and southern highlands, as well as the eastern coastline tidal flats.

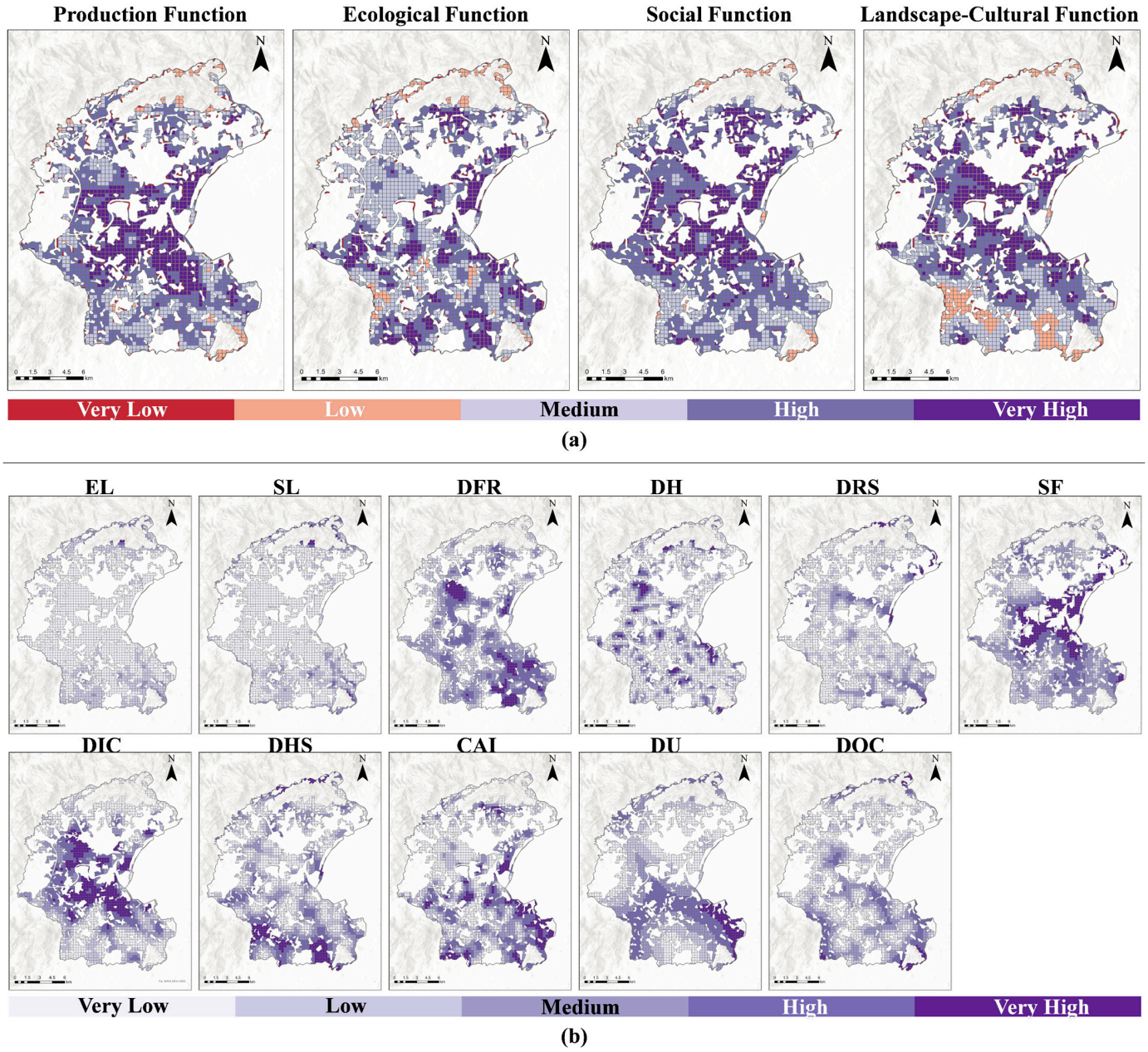


Figure 3. Spatial Distribution of Multifunctional Potential of Cultivated Land and Its Influencing Factors. (**a**) Multifunctional Potential of Cultivated Land; (**b**) Influencing Factors for the Multifunctional Potential of Cultivated Land.

The ecological function's potential was often lower than that of the production function. High and extremely high values were found in the transitional zones between the southern and northern mountains and agricultural area, forming discrete clusters. Medium values were found on cultivated ground along urban and rural settlement margins, particularly between the western and northern urban districts, next to industrial and mining territory. Low and very low values were most prevalent in the northern and southern mountain zones.

The social function potential was highest throughout the western and northern peripheries of metropolitan districts, primarily in cultivated land near to heavily populated rural villages. Medium values were found in southern dryland farming regions, but low

and extremely low values were few and found in remote mountainous cultivated land in the southwestern and northern regions near forested areas.

The landscape–cultural function potential followed a spatial pattern comparable to that of social function. High and extremely high values are concentrated in the central plains, which surround urban built-up areas and the center district. Medium values are found in the topographically diversified southern area. Low values were related with fragmented cultivated land in the southeastern and northern mountainous regions.

3.1.2. Spatial Distribution of Influencing Factors for the Multifunctional Potential of Cultivated Land

The influencing factors of the multifunctional potential of cultivated land are shown in Figure 3b. In terms of geographical factors, the medium, high and very high values of Slope and Elevation were scattered in the mountainous regions of the northern and southern parts of the study area, while the very low values were widely distributed across the central plains.

In terms of infrastructural factors, the study area had a reasonably high level of infrastructure. The high and extremely high values of The Density of Field Roads were concentrated in the southeastern region's drylands as well as the transitional zone between the two major urban regions. The closeness of farmed land to highways was usually positive, with high values dispersed evenly. Except for places near cities and mountains, the majority of farmed land was located near rural settlements.

In terms of historical variables, the central plains had the highest and very high values for both soil fertility and the density of irrigation canals. A spatial disparity was detected between the two major urban regions, with the density of irrigation canals remaining high but soil fertility being comparatively low. The spatial distribution of Historical Sites followed a pattern of "abundance in the north and scarcity in the south," with concentrations largely in the northeastern coastal area and the central plains.

In terms of land management variables, the Central Urban Area was located in the north of the research area, while Other Construction Land was spread in the south, resulting in a spatial pattern of "dense in the north and sparse in the south." Similarly, the Cultivated Land Aggregation Index was greater in the south and much lower in the areas around northern metropolitan centers.

3.2. Multifunctional Performance of Cultivated Land in the HIDs and Its Spatial Distribution Characteristics

3.2.1. Spatial Distribution of Multifunctional Performance of Cultivated Land

Figure 4a depicts the regional distribution of cultivated land's multifunctional performance, exhibiting significant variation across all four functions. Overall performance was graded as follows: productive functions, ecological functions, landscape–cultural functions, and social functions. High-performance zones for production and ecological functions were quite extensive, as opposed to the extremely dispersed pattern observed for social and landscape–cultural activities. There was some spatial overlap between the performance distributions of production and ecological functions. The bulk of cultivated land units in the research region had poor ratings for social and landscape–cultural functions.

The spatial variation in the performance of the production function showed that high and very high values were concentrated in the contiguous cultivated land in the central and southeastern regions, which were characterized by high overall crop yields. In contrast, low and very low values were less prevalent and were scattered along the fringes of the northern mountainous areas and in regions with fragmented cultivated land. Furthermore, a very limited number of low values were located on coastal tidal flats. The spatial variation in the performance of the ecological function was pronounced. High and very high values

were primarily located along both banks of the Mulan River, as well as in the southwestern and northeastern parts of the study area, where they adjoined to woodland and water bodies. Low values were concentrated near the edges of construction land. These zones were predominantly dryland farming areas. The spatial distribution of social function performance exhibited a general correlate positively with the intensity of human activities. High and very high values were predominantly located on cultivated land at the periphery of central urban districts. Conversely, cultivated land positioned distant from people agglomerations typically displayed very poor levels of social function performance. The overall level of spatial variance in the landscape–cultural function's performance was comparatively modest. Its high and very high values revealed a distribution pattern comparable to that of the social function, both located along the peripheries of urban construction land.

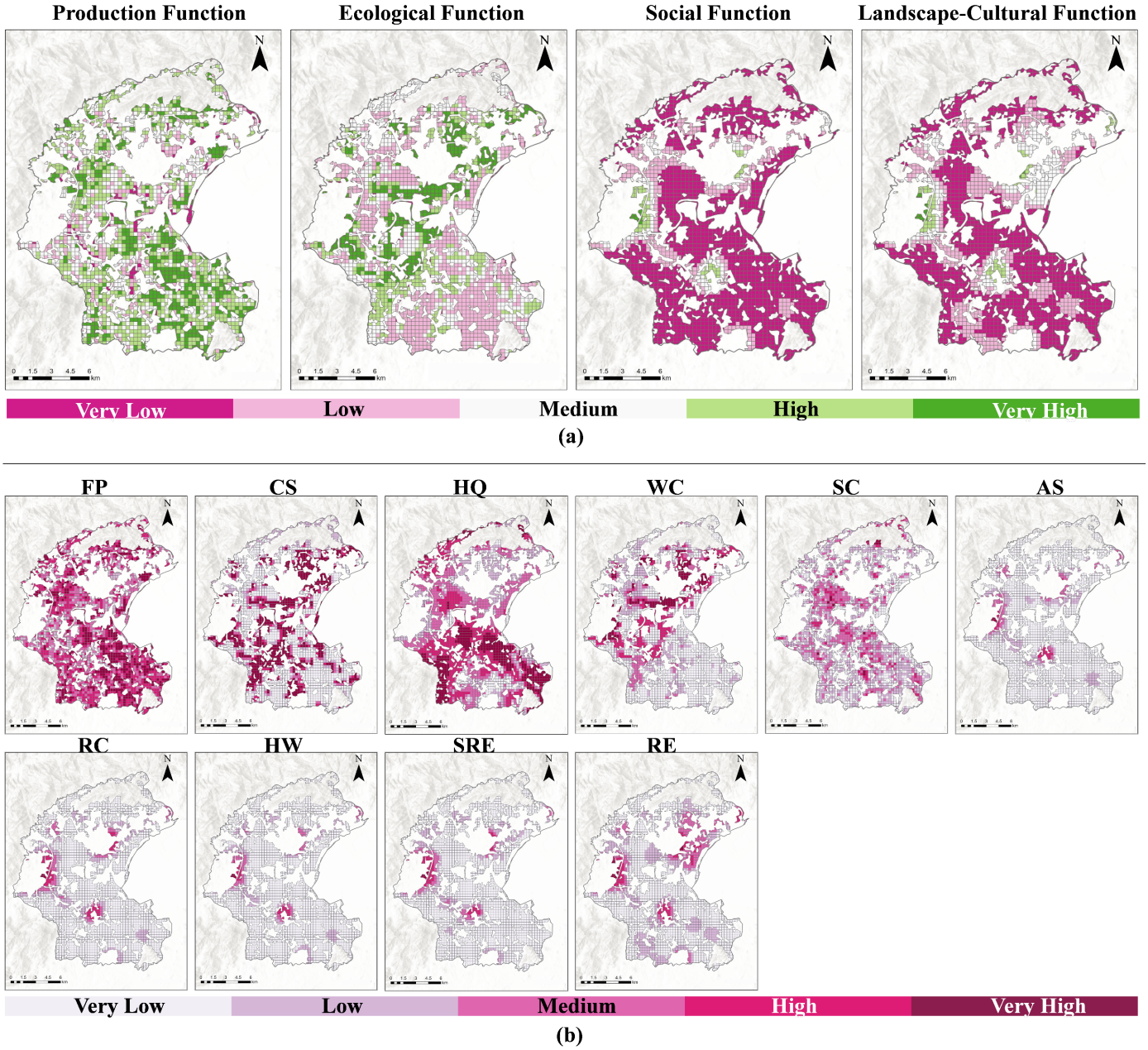


Figure 4. Spatial Distribution of the Multifunctional Performance of Cultivated Land and the Performance of Its Representative Functions. (**a**) Multifunctional Performance of Cultivated Land; (**b**) Representative Function for the Multifunctional Performance of Cultivated Land.

3.2.2. Spatial Distribution of Representative Function for the Multifunctional Performance of Cultivated Land

The representative functional performance of multifunctional cultivated land is shown in Figure 4b. Results for production and ecological functions are summarized as follows: Food Production (FP) showed uniformly high performance throughout the study area. Carbon Sequestration (CS) exhibited a fragmented spatial pattern, with high values occurring near the northern urban district and in central–southern paddy fields. Low values were found in northern mountainous areas, cultivated plots fragmented by construction land, and sparsely vegetated dryland farms in the southeast. Habitat Quality (HQ) displayed a clear north–south divergence, with higher performance in the south. High values were scattered near woodlands in the north and southwest, while medium to low values were concentrated in central and northern urban areas, southern dryland farms, and fragmented cultivated land. Water Conservation (WC) showed high values clustered along central river channels within irrigated zones. Moderate values appeared near southwestern woodlands, and low values were distributed across northern mountains, southwestern dryland farming areas, and peripheries of construction land. Soil Conservation (SC) was generally high across the region, particularly in areas with dense field ridges that enhance stability. Low values coincided with steep slopes and central zones with dense water networks, while some dryland farms with low vegetation cover exhibited medium to low performance.

The spatial characteristics of social and landscape–cultural functions are as follows: High values of Agricultural Product Services (AS) were predominantly concentrated in cultivated lands surrounding urban centers. Moderate-performance zones extended along major transportation corridors and suburban cultivated land, whereas low values were widely distributed in peripheral regions with limited infrastructure access. Residential Carrying Capacity (RC) exhibited high values in discrete patches located near rural settlements, while extensive farmland distant from settlements showed low performance. Healthcare and Wellness (HW) functions displayed sporadically distributed high values in central regions, reflecting a combination of medical facility accessibility and favorable ecological conditions. Most cultivated land demonstrated low performance due to insufficient medical services or limited ecological attractiveness. Recreation and Ecotourism (RE) and Scientific Research and Education (SRE) exhibited similar spatial patterns, with high values appearing as point-like clusters along urban peripheries and major transport routes. Moderate values were observed near suburban settlements but do not form continuous zones. Low values prevailed across most cultivated land, including historical villages. Notably, recreational performance exceeded that of research and education, particularly in central-eastern coastal areas, where cultural resources enhanced recreational potential without corresponding benefits for scientific research.

3.3. Spatial Matching Analysis Between Multifunctional Potential and Performance of Cultivated Land in HID

Bivariate Local Moran's I analysis was then used to uncover clustering patterns in the potential and performance of each cultivated land function. Quantitatively (Table 4), the "potential-performance" spatial correlation exhibited polarization: the production and ecological functions were primarily characterized by synergistic development, whereas the social and landscape–cultural functions demonstrated a clear contradiction of potential suppression. In High–High (HH) clusters, the production and ecological functions accounted for the highest proportions. In Low–Low (LL) clusters, all four functions had relatively small proportions, with production and ecological functions accounting for only 4%. Within the geographically mismatched High–Low (HL) clusters, the social and landscape–cultural functions were especially significant, accounting for more than a quarter of the cultivated land area. Conversely, in Low–High (LH) clusters, all four functions accounted for less than 4%.

Table 4. Spatial Matching Cluster Proportions of Multifunctional Potential and Performance of Cultivated Land.

Cultivated Land Multifunctionality	Production Function	Ecological Function	Social Function	Landscape–Cultural Function
H-H Cluster	19%	20%	10%	12%
L-L Cluster	4%	4%	10%	13%
H-L Cluster	6%	4%	33%	27%
L-H Cluster	4%	3%	2%	3%

3.3.1. Production Function

Cross-referencing with satellite imagery found that the HH clusters for the production function's potential and performance accounted for the biggest proportion among the four cluster types, with concentrations near the urban periphery in the central region and in the south's continuous paddy fields. LL clusters were sparse, primarily located on fragmented farmed ground in the northern mountains. Both HL and LH clusters occupied small proportions. Satellite imaging revealed features in some HL clusters, such as cleanly defined fields with chaotic vegetation cover, intersections with highways or expressways, spatial proximity to factories, and cultivated land surrounded by residential buildings, resulting in "urban farmland". Some LH clusters were positioned on terraced fields, adjacent to urban areas (Figure 5).

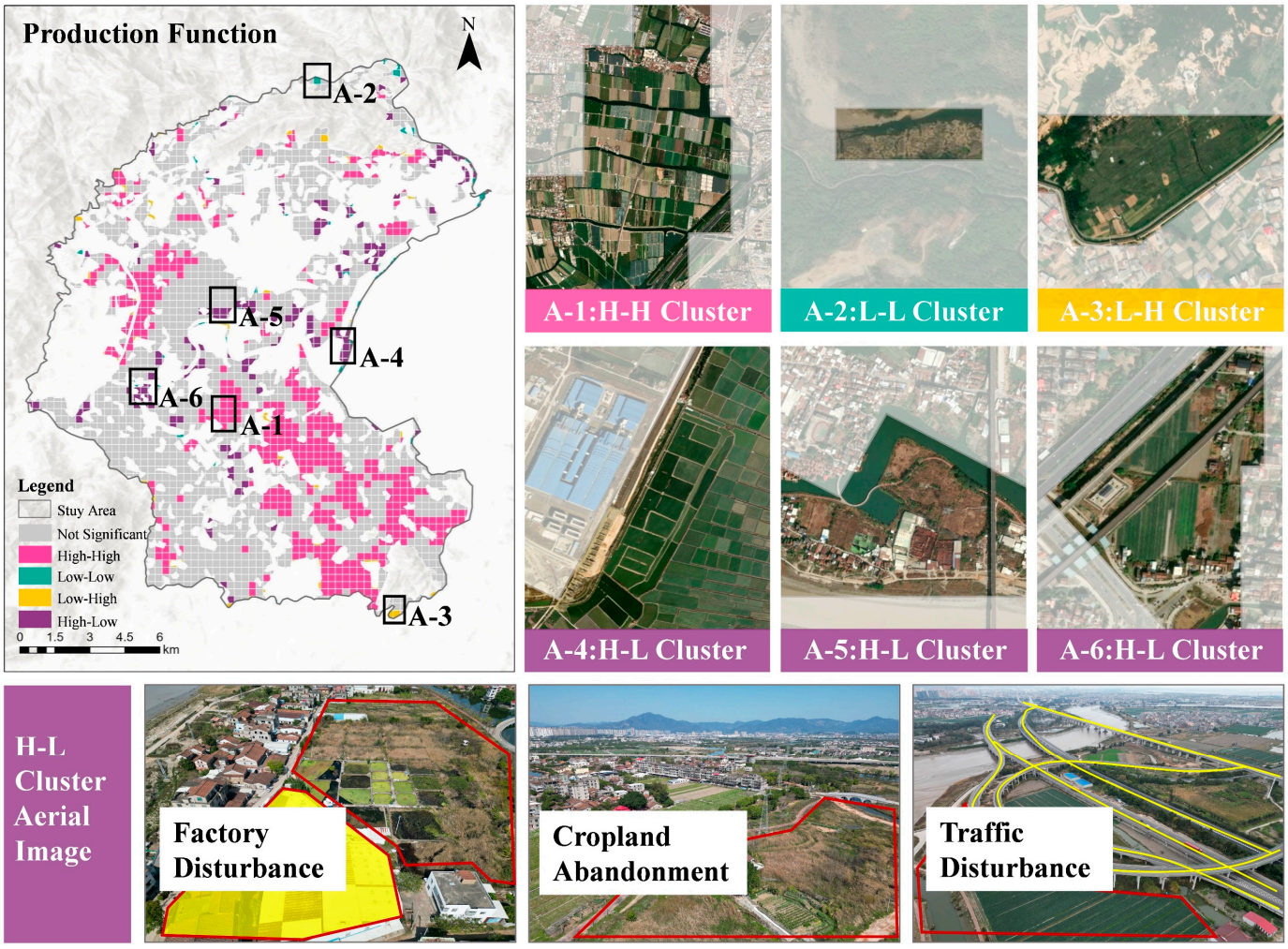


Figure 5. Bivariate Spatial Autocorrelations of the Production Function of Cultivated Land. Note: The red outlines demarcate cultivated land, while the yellow areas indicate disturbance factors affecting it.

3.3.2. Ecological Function

HH clusters for the potential and performance of the ecological function were distributed in areas near woodland and water bodies in the north and west, as well as in farmed land in the central area with a dense water network. LL clusters were randomly placed in the comparatively high-altitude mountainous parts of the north. HL and LH clusters are minor. Some HL clusters were located on both sides of the Mulan River estuary and on farmed land bordering building sites. A small number of LH clusters were found near construction land but had high surrounding plant cover or access to water sources (Figure 6).

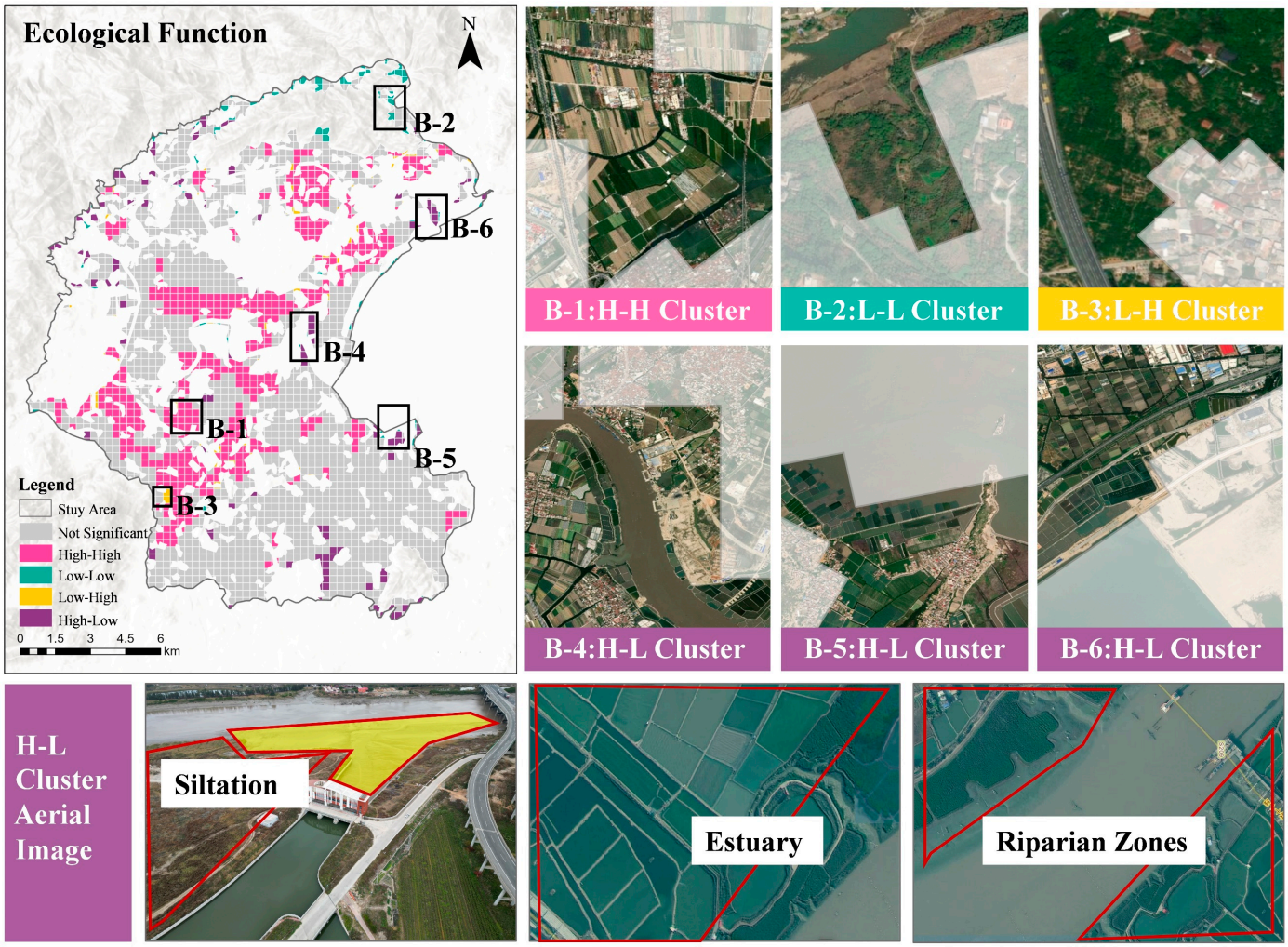


Figure 6. Bivariate Spatial Autocorrelations of the Ecological Function of Cultivated Land. Note: The red outlines demarcate cultivated land, while the yellow areas indicate disturbance factors affecting it.

3.3.3. Social Function

Within the urban–cultivated land transition zone, HH clusters for the potential and performance of the social function were dispersed. LL clusters were widely dispersed throughout coastal farmed land and surrounding highland regions. HL and LH clusters were rather common. HL clusters were abundantly scattered on both sides of the middle Mulan River and in the southeastern adjoining farmed land. There were few LH clusters, and those that did exist were close to cities (Figure 7).

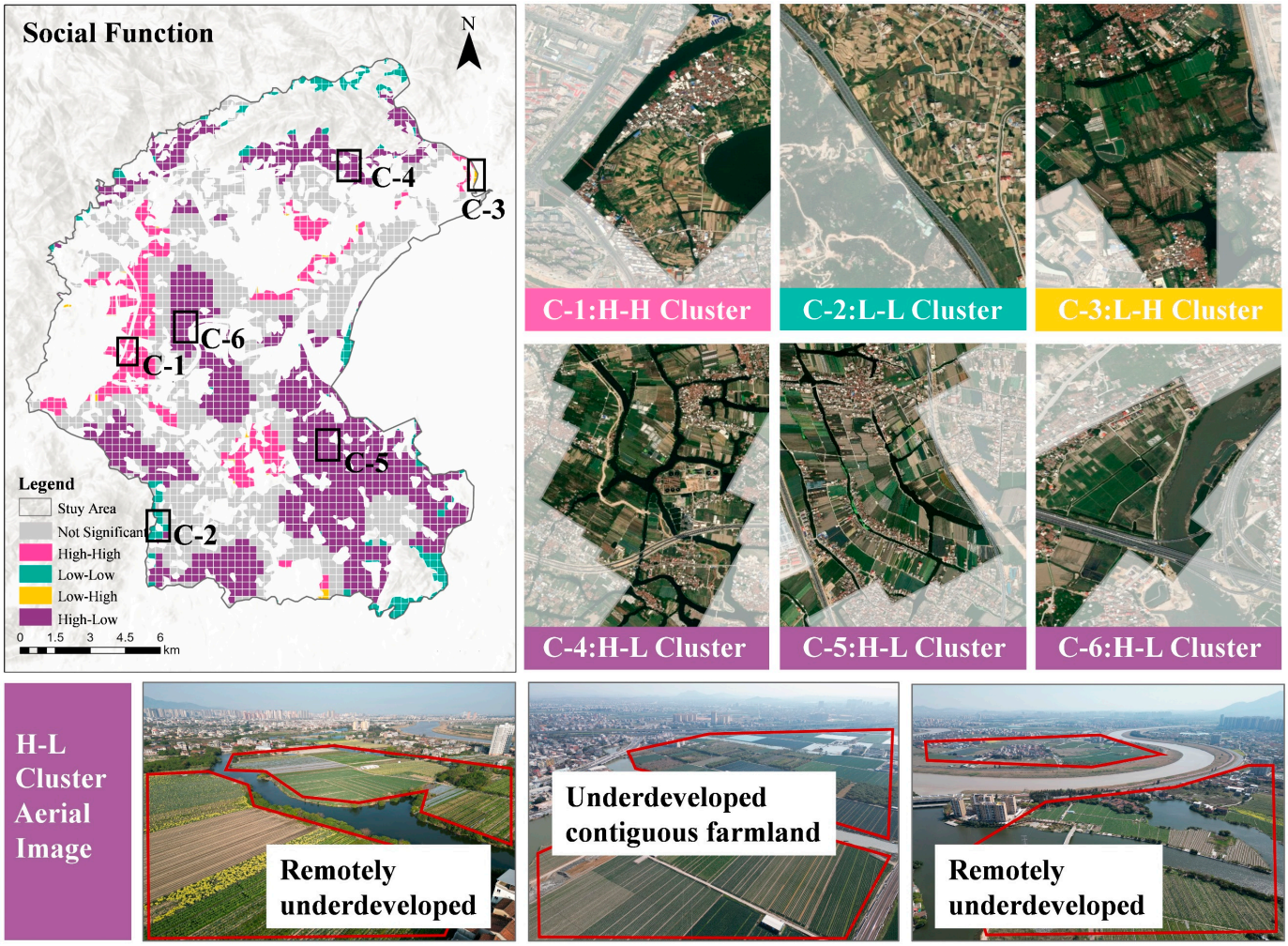


Figure 7. Bivariate Spatial Autocorrelations of the Social Function of Cultivated Land. Note: The red outlines demarcate cultivated land.

3.3.4. Landscape–Cultural Function

HH clusters for landscape and cultural function had a distribution pattern similar to social function clusters, but they were larger. Aside from being concentrated in the urban-cultivated land transition zone, coastal cultivated land in the northern area performed quite well. LL clusters were found in outer mountainous locations. Both HL and LH clusters are fairly numerous. HL clusters were seen on both sides of the central Mulan River, as well as on farmed terrain around the southeastern coast. Satellite photography revealed that these areas were made up of contiguous agricultural land connected by water systems. LH clusters were sparse, with a few scattered throughout the urban edge. The cultivated land in these locations had few water networks and was mostly dryland farming (Figure 8).

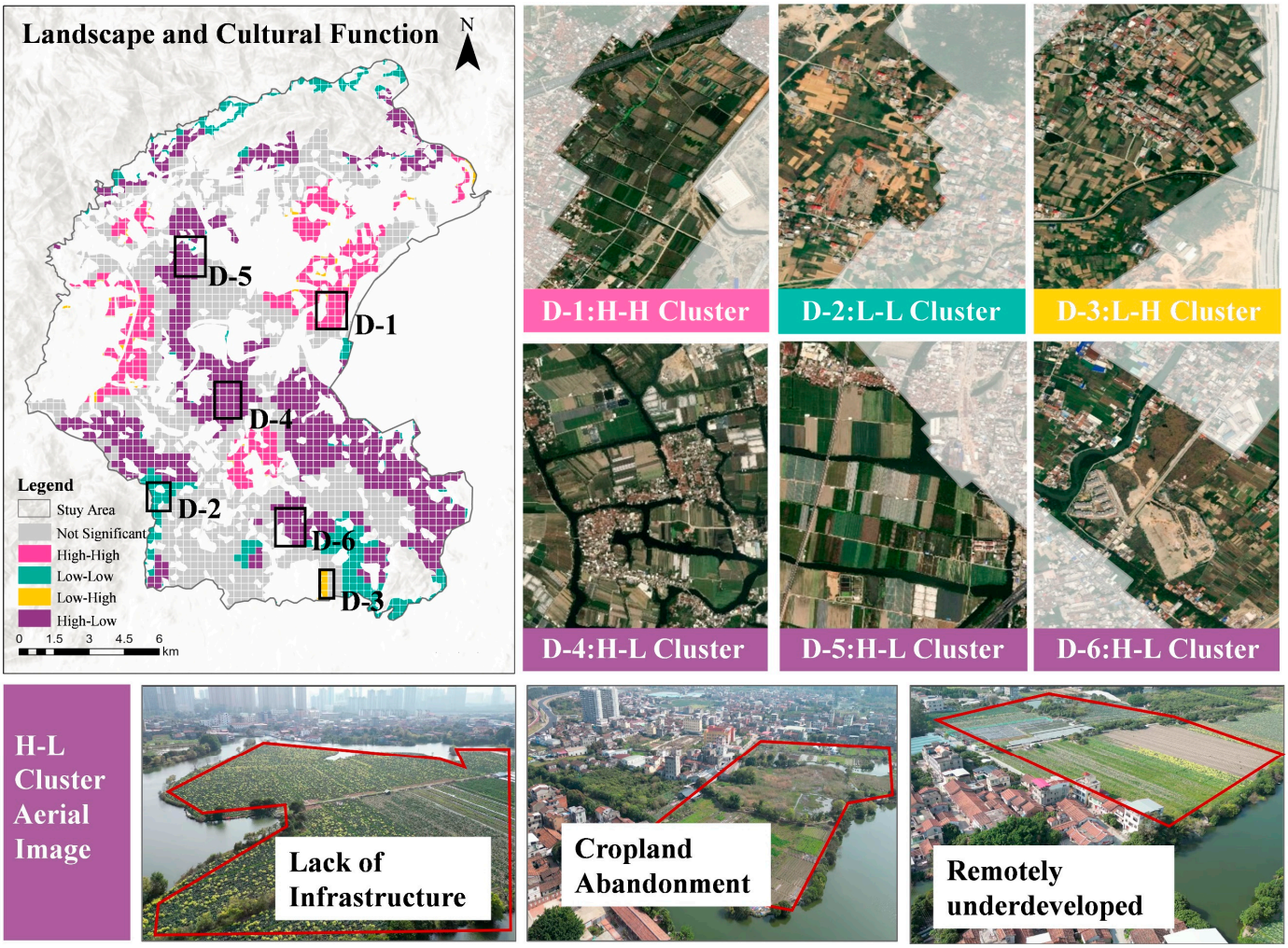


Figure 8. Bivariate Spatial Autocorrelations of the Landscape–Cultural Function of Cultivated Land. Note: The red outlines demarcate cultivated land.

4. Discussion

4.1. Driving Factors of Performance Differences in Cultivated Land Multifunction

The spatial differentiation of multifunctional performance in the Mulanbei HID is caused by numerous geographical and socioeconomic connections. While this is consistent with wider patterns identified in cultivated land studies, our use of the "potential-performance" approach provides a more detailed, diagnostic knowledge of the underlying processes. This method demonstrates that the observed patterns are more than just descriptive outcomes; they reflect variable degrees of congruence between inherent capability and realized benefit.

The high production performance in Mulanbei, consistent with findings from Zhejiang [75], Jiangsu [76], and Shaanxi [77], exemplifies a successful "high potential to high performance" transition. This success is underpinned by favorable geophysical conditions—notably the fer-tile plains that provide superior soil and terrain for large-scale production, coupled with an extensive water network of canals, wetlands, and polder systems that inherently supports agricultural output—along with sustained agricultural investment. Together, these form a coherent socio-ecological production system, one that remains oriented toward agricultural supply in line with national food security priorities. In contrast, Beijing's fragmented cultivated land lacks a similarly dense water network and suffers from water scarcity [78], while its megacity status drives strong demand

for leisure and cultural services, supported by a developed service economy and high urbanization. These distinct socioeconomic conditions, less conducive to intensive agricultural production, have prompted a functional transition toward alternatives such as leisure agriculture.

More importantly, the framework identifies major functional mismatches that indicate specific governance issues. A notable example is the landscape–cultural function. Despite Mulanbei's rich past as a historical irrigation region, which has significant intrinsic potential, its performance falls short of national agrotourism development targets. This "high potential-low performance" gap highlights micro-level obstacles, such as smallholder agricultural structures and poor market integration, that impede the translation of macro-level cultural assets into synergistic socioeconomic advantages. Identifying such gaps shifts the focus from "what is" to "what could be," revealing specific areas for policy intervention.

Furthermore, our analysis helps reconcile seemingly contradictory findings regarding urbanization's impact on cultivated land functions. The concentration of social and landscape–cultural functions near urban fringes in Mulanbei aligns with the "radiation effect" observed in Wuhan [79], This contrasts with the macro-regional "siphon effect" noted in the Huang-Huai-Hai Plain, where urbanization correlates negatively with social functions [80]. The "potential-performance" lens clarifies that urbanization exerts a dual, scale-dependent influence. In peri-urban systems like Mulanbei, proximity to urban consumers can positively enhance certain non-production functions, whereas at a broader regional scale, urbanization may deplete them. This nuanced understanding moves beyond a uniform negative assessment and emphasizes the importance of contextual and spatial scale in functional analysis.

In conclusion, by assessing cultivated land using the combined dimensions of potential and performance, this study develops a diagnostic paradigm for multifunctional evaluations. It illustrates that such a strategy is especially useful in historically significant cultural landscapes such as HIDs, where functions extend beyond agricultural output to incorporate ecological and socio-cultural features. The framework not only describes current spatial patterns but also identifies areas with the greatest potential for functional enhancement or remediation. For similar locations, this means that management techniques should be differentiated based on each function's distinct "potential-performance" relationship, promoting personalized governance for sustainable and heritage-sensitive land use.

4.2. Implications of the Potential–Performance Framework for Cultivated Land Multifunction

The analysis of spatial matches between potential and performance has identified two key regional types. While HL clusters indicate underutilized multifunctional potential and idle endowments, whereas LH clusters exhibit high performance unsupported by inherent potential, suggesting reliance on intensive external inputs that may be unsustainable in the long term [81].

Production function analysis reveals a clear potential–performance disparity. Spatially, areas north and south of the central Mulan River possess high potential yet underperform, while the southern region with medium potential achieves notably higher outputs. This observed mismatch is further underscored by the regional average rice yield of 6581 kg/ha, which falls below the provincial benchmark of 7050 kg/ha set in Fujian's High-Standard Farmland Construction Standards. Consequently, this calls for rigorously differentiated management strategies. HL clusters require a fundamental transition from extensive "exploitation" to systematic "quality enhancement," achievable through scaled farmland management and intensified agricultural practices. In contrast, LH clusters should shift from passive "maintenance" to active "transformation" by developing eco-circular

agriculture and establishing market-oriented, high-value production systems to ensure long-term viability.

Ecological function exhibits spatial homogeneity, characterized by the minimal presence of HL and LH clusters. This finding aligns with research by Zhu et al. [52] and Yu et al. [22], which observed a similar consistency in the spatial distribution of ecological functions and further documented its stable evolution over time. The success of the Putian Ecological Green Heart strategy has helped maintain this stability. Studies have indicated that the patch structure and corridor connectivity in polder landscapes are fundamental to sustaining ecological functions [82], which underscores the necessity of preserving the existing ecological structure. For LH clusters, enhanced sustainability monitoring is crucial to minimize dependence on external inputs. Meanwhile, HL clusters require investigation into anthropogenic degradation drivers, such as unsuitable cropping systems, and subsequent restoration through land consolidation and eco-friendly practices.

Social and landscape–cultural functions have similar distribution patterns, with fewer LH clusters but much more HL clusters than production and ecological functions. This reflects a significant reliance on external socioeconomic drivers and resource inputs, with existing mismatches indicating underinvestment and operational flaws. Priorities for social-function HL clusters include expanding public services, such as healthcare, to rural areas and improving functional synergy between cultivated land and residential services through spatial planning. For landscape-function HL clusters, high-potential unique nodes should be activated and linked to existing HH clusters via greenways and tourism routes to establish synergistic networks. Meanwhile, LH clusters should be reoriented toward production or ecological tasks to improve resource allocation.

4.3. Limitations and Future Research

This study creates a "potential-performance" framework for studying the multifunctionality of cultivated land in HIDs, offering fresh views and methodological support for developing varied cultivated land preservation measures. However, due to the intricacy of cultivated land systems, numerous areas require additional refining. In terms of functional identification, we broadened data sources by using historical irrigation documents, but the coverage of varied historical records such as local chronicles and folk traditions remained unsystematic, indicating that the classification approach requires further validation. In terms of mechanistic analysis, the use of satellite images has only begun to study the underlying causes of spatial potential–performance mismatches, and analytical precision requires improvement. In addition, the selection of indicators, particularly for land management, was constrained by data accessibility, which may affect the direct linkage to specific spatial policies.

Future study should focus on methodically integrating various historical records in order to create a more thorough functional classification system. Meanwhile, modern statistical and spatial tools like geographical detectors and structural equation modeling should be used to better quantify the contributions and interactions of different driving forces. Furthermore, future efforts could seek to incorporate more authoritative spatial governance data, such as the "three lines" in territorial spatial planning, where accessible, to strengthen the policy relevance of the indicator system. Finally, long-term monitoring will be essential to disclose the spatiotemporal evolution patterns of the potential–performance link, providing stronger theoretical and decision-making support for sustainable cultivated land management in HIDs.

5. Conclusions

This study assesses the potential and performance of cultivated land multifunctionality in HIDs using four dimensions: production, ecological, society, and landscape–culture. Using the Mulanbei HID as a case study, the regional differentiation and association between the functional potential and performance of cultivated land are thoroughly examined. The key findings are as follows: (1) Production and ecological functions outperformed social and landscape cultural functions. Spatially, the production function shows a rather even and high-performance distribution. Ecological function is more effective near woods and bodies of water, but it is less effective near development sites. Social and landscape–cultural functions are mainly underperforming throughout the area, with good performance limited to urban edges. (2) The Mulanbei HID exhibits a spatial mismatch between the potential and performance of multifunctional cultivated land. Production and ecological functions are primarily clustered in "high-high" areas, accounting for 19% and 20%, respectively; social and landscape cultural functions are prominently clustered in "high-low" areas, accounting for 33% and 27%, respectively; in "low-low" clusters, the proportion of production and ecological functions is 4%, while that of social and landscape–cultural functions is 10% and 13%, respectively; the proportion of "low-high" clusters is extremely low. This work stands out from previous research on HIDs due to its new analytical approach. While previous research has primarily used static and macro-scale assessments of multifunctional cultivated land, this study introduces a dynamic "potential-performance" framework that advances our theoretical understanding of multifunctional differentiation mechanisms and human–land system coupling in agricultural heritage landscapes. On a practical level, the Mulanbei HID's application of this framework provides not only site-specific insights for spatial optimization but also a transferable methodology that allows other HIDs to better balance food security, ecological protection, and cultural conservation, addressing key limitations in conventional assessment approaches.

Author Contributions: Conceptualization, T.L.; methodology, Y.Z. and X.Z.; formal analysis, Y.Z.; investigation, Y.Z.; resources, X.Z.; data curation, Y.Z.; writing—original draft preparation, Y.Z. and Z.Z.; writing—review and editing, X.Z. and T.L.; visualization, Y.Z. and Z.Z.; supervision, T.L.; project administration, T.L.; funding acquisition, X.Z. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The data presented in this study are fully listed in the 'Data Sources' section (Section 2.7) of this manuscript. All data are derived from publicly available sources as referenced therein.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Representative Functions of Cultivated Land Multifunctionality.

Cultivated Land Multifunctionality	Representative Function	Keyword	Relevant Sentence	Source
Production Function	Food Production	Farmland; Irrigation	Vast expanses of once barren, saline land were converted into highly productive farmland.	*The Water Conservancy Annals of Putian*, Volume 2
			The farmland outside the city relied completely on the water stored in this lake for irrigation.	*The Joint Petition by Gentry and Scholars including Chen Danchi in the Sixth Month of the Sixth Year of the Kangxi Reign*
Social Function	Residential Carrying Capacity	Family; Livelihood	Thanks to effective water management, the farmlands were protected from flooding and salinization, ensuring the livelihood and stability of numerous families, who thus praised the benevolent governance of the dynasty	*Rhapsody on Mulanbei*
			Families owning numerous fields near the canals	*Record of Repairing Lakes and Canals*
	Agricultural Product Services	Trade; Benefit	He then instructed his fellow villagers, based on his experience, to manage the Putian area—a former saline land—by having the people engage in excavation and trade	*Xinghua Prefecture Putian County Gazetteer*, Volume 2
			Planting mulberry, hemp, reeds, and similar species to check water flow, thereby benefiting the people who profited from these livelihoods	*Huzhou City Gazetteer*
	Healthcare and Wellness	Healthcare; Cultivation	Integrating agricultural production with healthcare services to serve health intervention functions	Luo et al. [71]
			Combining rice cultivation with care services to promote social participation among care recipients and optimize the quality of care	Ura et al. [72]

Table A1. *Cont.*

Cultivated Land Multifunctionality	Representative Function	Keyword	Relevant Sentence	Source
Ecological Function	Habitat Quality	Egret; Islets float	The stone embankments and sand dykes curb the sea's force, while teals and mandarin ducks dart amidst the vibrant spring scenery	*Mulanbei*
			Islets float upon the water's surface, gathering abundant wild ducks and egrets on solitary spits	*Memorial to Governor on Dredging the West Lake*
	Water Conservation	water	The Mulanbei irrigates ten thousand qing of farmland, and every year the people drink from its water	*Xinghua Prefecture Putian County Gazetteer*, Volume 2
			Water flows outside the polder dykes, while fertile fields are formed within them	*Chinese Historical Hydraulic Archives: Taihu Lake and Southeast China*, Volume 2
	Carbon Sequestration	Oxygen; Carbon	Its water systems circulate, oxygen converges, and it boosts local vitality while broadly benefiting the people and all living things.	*Letter to Lu Laizang on Irrigation Management*
			Farmland ecosystems play a significant role in the carbon cycle of terrestrial ecosystems	Sun et al. [73]
	Soil Conservation	Soil; Polder Dyke	At the ends of fields facing the ditches, soil was piled into mounds about a foot high for protection.	*Xinghua Prefecture Putian County Gazetteer*, Volume 2
			Consequently, polder dykes were built adjacent to the city, creating fertile farmland in the Wu region	*Guangxu Gaochun County Gazetteer*
Landscape and Cultural Function	Recreation and Ecotourism	Scenery	From then on, boats and ships connected the waterways, fields stretched far into the distance, and the scenery rivaled that of Jiangnan	*The Water Conservancy Annals of Putian*, Volume 1
			These channels connected like veins, distributed vertically and horizontally, resembling the scenery of the well-field system.	*Chronicles of Seawall Defense*
	Scientific Research and Education	Scientific; Education	Educational and scientific research services provided by farmland to humanity	*Ecological Product Catalog* (2024 Edition)
			As a result, governance and education were extensively implemented.	*Study on Water Conservancy of Fuzhou City Rivers*

Appendix B

Research on Indicator Weights for the Multifunctional Potential and Performance of Cultivated Land

The geometric mean was calculated from the scores provided by 22 experts.

Appendix B.1. The Multifunctional Potential of Cultivated Land

Appendix B.1.1. Production Function

Table A2. Criterion Layer: Production Function Potential of Cultivated Land.

Production Function	Geographical Factor	Infrastructure Factor	Historical Factor
Geographical Factor	1	-	-
Infrastructure Factor	11/7	1	-
Historical Factor	3/5	5/8	1

Table A3. Indicator Layer: Geographical Factor.

Geographical Factor	Slope	Elevation
Slope	1	-
Elevation	1/3	1

Table A4. Indicator Layer: Infrastructure Factor.

Infrastructure Factor	Density of Field Roads	Distance from Cultivated Land to Highways	Distance from Cultivated Land to Rural Settlements
Density of Field Roads	1	-	-
Distance from Cultivated Land to Highways	25/9	1	-
Distance from Cultivated Land to Rural Settlements	3	11/9	1

Table A5. Indicator Layer: Historical Factor.

Historical Factor	Soil Fertility	Density of Irrigation Canals	Distance from Cultivated Land to Historical Sites
Soil Fertility	1	-	-
Density of Irrigation Canals	25/9	1	-
Distance from Cultivated Land to Historical Sites	3	11/9	1

Appendix B.1.2. Ecological Function

Table A6. Criterion Layer: Ecological Function Potential of Cultivated Land.

Ecological Function	Geographical Factor	Land Management Factor
Geographical Factor	1	-
Land Management Factor	1	1

Table A7. Indicator Layer: Geographical Factor.

Geographical Factor	Slope	Elevation
Slope	1	-
Elevation	3/5	1

Table A8. Indicator Layer: Land Management Factor.

Land Management Factor	Cultivated Land Aggregation Index	Distance from Cultivated Land to the Central Urban Area	Distance from Cultivated Land to Other Construction Land
Cultivated land Aggregation Index	1	-	-
Distance from Cultivated Land to the Central Urban Area	1/2	1	-
Distance from Cultivated Land to Other Construction Land	3/8	5/6	1

Appendix B.1.3. Social Function

Table A9. Criterion Layer: Social Function Potential of Cultivated Land.

Social Function	Infrastructure Factor	Land Management Factor	Historical Factor
Infrastructure Factor	1	-	-
Land Management Factor	3/5	1	-
Historical Factor	4/5	4/5	1

Table A10. Indicator Layer: Infrastructure Factor.

Infrastructure Factor	Density of Field Roads	Distance from Cultivated Land to Highways	Distance from Cultivated Land to Rural Settlements
Density of Field Roads	1	-	-
Distance from Cultivated Land to Highways	31/6	1	-
Distance from Cultivated Land to Rural Settlements	32/3	12/5	1

Table A11. Indicator Layer: Land Management Factor.

Land Management Factor	Cultivated Land Aggregation Index	Distance from Cultivated Land to the Central Urban Area	Distance from Cultivated Land to Other Construction Land
Cultivated land Aggregation Index	1	-	-
Distance from Cultivated Land to the Central Urban Area	11/7	1	-
Distance from Cultivated Land to Other Construction Land	8/9	4/5	1

Table A12. Indicator Layer: Historical Factor.

Historical Factor	Soil Fertility	Density of Irrigation Canals	Distance from Cultivated Land to Historical Sites
Soil Fertility	1	-	-
Density of Irrigation Canals	13/7	1	-
Distance from Cultivated Land to Historical Sites	11/3	13/8	1

Appendix B.1.4. Landscape–Cultural Function

Table A13. Criterion Layer: Landscape–Cultural Function Potential of Cultivated Land.

Landscape–Cultural Function	Geographical Factor	Land Management Factor	Historical Factor
Geographical Factor	1	-	-
Land Management Factor	11/3	1	-
Historical Factor	25/9	23/4	1

Table A14. Indicator Layer: Geographical Factor.

Geographical Factor	Slope	Elevation
Slope	1	-
Elevation	3/5	1

Table A15. Indicator Layer: Land Management Factor.

Land Management Factor	Cultivated Land Aggregation Index	Distance from Cultivated Land to the Central Urban Area	Distance from Cultivated Land to Other Construction Land
Cultivated land Aggregation Index	1	-	-
Distance from Cultivated Land to the Central Urban Area	1	1	-
Distance from Cultivated Land to Other Construction Land	5/7	3/4	1

Table A16. Indicator Layer: Historical Factor.

Historical Factor	Soil Fertility	Density of Irrigation Canals	Distance from Cultivated Land to Historical Sites
Soil Fertility	1	-	-
Density of Irrigation Canals	24/7	1	-
Distance from Cultivated Land to Historical Sites	31/2	21/4	1

Appendix B.2. The Multifunctional Performance of Cultivated Land

Appendix B.2.1. Production Function Performance of Cultivated Land

Table A17. Production Function Performance of Cultivated Land.

Production Function	Food Production
Food production	31/2

Appendix B.2.2. Ecological Function Performance of Cultivated Land

Table A18. Ecological Function Performance of Cultivated Land.

Ecological Function	Habitat Quality	Water Conservation	Soil Conservation	Carbon Sequestration
Habitat Quality	1	-	-	-
Water Conservation	11/3	1	-	-
Soil Conservation	11/4	11/6	1	-
Carbon Sequestration	2/3	3/5	5/7	1

Appendix B.2.3. Social Function Performance of Cultivated Land

Table A19. Social Function Performance of Cultivated Land.

Social Function	Residential Carrying Capacity	Agricultural Produce Services	Healthcare and Wellness
Residential Carrying Capacity	1	-	-
Agricultural Product Services	1/2	1	-
Healthcare and wellness	1/3	2/3	1

Appendix B.2.4. Landscape–Cultural Function Performance of Cultivated Land

Table A20. Landscape—Cultural Function Performance of Cultivated Land.

Landscape-Cultural Function	Scientific Research and Education	Recreation and Ecotourism
Scientific Research and Education	1	-
Recreation and Ecotourism	2/5	1

References

1. UNESCO Bangkok. *UNESCO Asia-Pacific Awards for Cultural Heritage Conservation*; UNESCO Bangkok: Bangkok, Thailand, 2009.
2. Li, Y. World Heritage irrigation structure and its protection significance analysis. *China Water Resour.* **2020**, *2020*, 47–49+53.
3. Guo, W.; Sun, J.; Ji, W.; Hou, X. Landscape of the Irrigation Districts: Traditional Landscape Camping in the Perspective of Territorial Spatial Development. *J. Hum. Settl. West China* **2023**, *38*, 17–23. [CrossRef]
4. Li, S.; Li, X. Global understanding of farmland abandonment: A review and prospects. *J. Geogr. Sci.* **2017**, *27*, 1123–1150. [CrossRef]
5. Huan, Y.; Nijhuis, S.; Tillie, N. Optimizing urban agriculture for long-term ecosystem services: Integrating scenario-based suitability analysis and the landscape approach. *J. Clean. Prod.* **2025**, *536*, 147149. [CrossRef]
6. Mandal, U.K.; Karim, F.; Yu, Y.; Ghosh, A.; Zahan, T.; Mallick, S.; Kamruzzaman, M.; Paul, P.L.C.; Mainuddin, M. Assessing vulnerability and climate risk to agriculture for developing resilient farming strategies in the Ganges Delta. *Clim. Risk Manag.* **2025**, *47*, 100690. [CrossRef]
7. Tanir, T.; Yildirim, E.; Ferreira, C.M.; Demir, I. Social vulnerability and climate risk assessment for agricultural communities in the United States. *Sci. Total Environ.* **2024**, *908*, 168346. [CrossRef]
8. Long, H. Theorizing land use transitions: A human geography perspective. *Habitat Int.* **2022**, *128*, 102669. [CrossRef]
9. Song, X.; Huang, Y.; Wu, Z.; Ouyang, Z. Changes of cultivated land function in China since 1949. *J. Geogr. Sci.* **2015**, *25*, 817–835. [CrossRef]
10. Peng, H.; Zhang, X.; He, J.; Zhou, X.; Zou, Q.; Zhang, P. Spatial differentiation of cropland multifunctionality trade-offs and their drivers across urban-rural gradients: A case study of major grain-producing areas, China. *Habitat Int.* **2026**, *167*, 103661. [CrossRef]
11. Song, X.; Ouyang, Z. Connotation of multifunctional cultivated land and its implications for cultivated land protection. *Prog. Geogr.* **2012**, *31*, 859–868. [CrossRef]
12. FAO Natural Resources Management and Environment Department. Taking stock of the multifunctional character of agriculture and land. In Proceedings of the FAO/Netherlands Conference on the Multifunctional Character of Agriculture and Land, Maastricht, The Netherlands, 12–17 September 1999; pp. 33–36.
13. OECD Organisation for Economic Co-Operation and Development. *Multifunctionality: Towards an Analytical Framework*; OECD: Paris, France, 2001; pp. 1–157, ISBN 92-64-18625-5.
14. Bank, W. *International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD): Global Program Review*; World Bank: Washington, DC, USA, 2006.
15. Fu, B.; Zhang, L. Land-use change and ecosystem services: Concepts, methods and progress. *Prog. Geogr.* **2014**, *33*, 441–446. [CrossRef]
16. Liccari, F.; Boscutti, F.; Bacaro, G.; Sigura, M. Connectivity, landscape structure, and plant diversity across agricultural landscapes: Novel insight into effective ecological network planning. *J. Environ. Manag.* **2022**, *317*, 115358. [CrossRef]
17. Baldwin, C.; Hamerlinck, J.; McKinlay, A. Institutional support for building resilience within rural communities characterised by multifunctional land use. *Land Use Policy* **2023**, *132*, 106808. [CrossRef]
18. Singh, R.J.; Kumar, G.; Sharma, N.K.; Deshwal, J.S.; Mishra, M.; Roy, P.; Bhattacharyya, R.; Madhu, M. Conservation tillage-based Arundo donax agro-geotextiles enhance productivity and profitability of sloping croplands in the Indian Himalayas by reducing soil erosion and improving soil organic carbon. *J. Environ. Manag.* **2025**, *377*, 124728. [CrossRef]
19. Yang, G. The process and driving forces of change in arable-land area in the Yangtze River Delta during the past 50 years. *J. Nat. Resour.* **2001**, *16*, 121–127. [CrossRef]
20. Zhang, Z.; Du, J.; Shen, Z.; El Asraoui, H.; Song, M. Effects of modern agricultural demonstration zones on cropland utilization efficiency: An empirical study based on county pilot. *J. Environ. Manag.* **2024**, *349*, 119530. [CrossRef]
21. Jiang, G.; Zhang, F.; Kong, X.; Qin, L.; Zhang, J.; Wang, X. The different levels and the protection of multi-functions of cultivated land. *China Land Sci.* **2011**, *25*, 42–47. [CrossRef]
22. Yu, S.; Ma, E.; Ji, Y. Multifunctional spatiotemporal evolution and its inter-regional coupling of cultivated land in a typical transect in Northern China. *J. Nat. Resour.* **2025**, *40*, 314–329. [CrossRef]
23. Lobert, F.; Schwieder, M.; Hostert, P.; Gocht, A.; Erasmi, S. Characterizing spatio-temporal patterns of winter cropland cover in Germany based on Landsat and Sentinel-2 time series. *Int. J. Appl. Earth Obs. Geoinf.* **2025**, *142*, 104728. [CrossRef]
24. Lotfi, P.; Ahmadi Nadoushan, M.; Besalatpour, A. Cropland abandonment in a shrinking agricultural landscape: Patch-level measurement of different cropland fragmentation patterns in Central Iran. *Appl. Geogr.* **2023**, *158*, 103023. [CrossRef]
25. Liao, Y.; Huang, J.; Luo, C.; Fang, M.; Xu, X.; Qiao, Z.; Liu, L. Deciphering supply-demand mismatch and influencing mechanisms of cropland multifunction in China: Toward targeted spatial governance. *J. Clean. Prod.* **2025**, *527*, 146719. [CrossRef]
26. Tao, J.; Zhang, J.; Dong, P.; Lu, Y.; Wang, T.; Qian, Z.; Ma, X.; Sun, F. Spatial heterogeneity in cropland multifunctionality trade-offs and their drivers: A case study of the Huaihai Economic Zone, China. *Environ. Impact Assess. Rev.* **2024**, *107*, 107569. [CrossRef]

27. Ma, R.; Huang, Y.; Zhou, W.; Ren, J.; Wang, H.; Shi, Z.; Wang, J. How to transform cultivated land protection on the Northeast Tibetan Plateau ? A multifunctional path exploration. *Ecol. Indic.* **2025**, *170*, 112988. [CrossRef]
28. Wang, X.; Wang, D.; Wu, S.; Yan, Z.; Han, J. Cultivated land multifunctionality in undeveloped peri-urban agriculture areas in China: Implications for sustainable land management. *J. Environ. Manag.* **2023**, *325*, 116500. [CrossRef]
29. Wang, M.; Huang, X. Inhibit or promote: Spatial impacts of multifunctional farmland use transition on grain production from the perspective of major function-oriented zoning. *Habitat Int.* **2024**, *152*, 103172. [CrossRef]
30. Bonato, M.; Burian, A.; Equihua, J.A.; Cord, A.F.; Bartkowski, B.; Strauch, M. Minimizing trade-offs in agricultural landscapes through optimal spatial allocation of agri-environmental practices. *J. Environ. Manag.* **2025**, *393*, 126939. [CrossRef]
31. Chen, R.; Ye, C.; Cai, Y.; Xing, X.; Chen, Q. The impact of rural out-migration on land use transition in China: Past, present and trend. *Land Use Policy* **2014**, *40*, 101–110. [CrossRef]
32. Liu, Y.; Fang, F.; Li, Y. Key issues of land use in China and implications for policy making. *Land Use Policy* **2014**, *40*, 6–12. [CrossRef]
33. Wang, S.; Jin, X.; Qu, Y.; Zhu, J.; Fan, Y.; Liu, J.; Zhou, Y. How to achieve adaptive optimization of cultivated land multifunctionality? Insights from coupled supply-utilization-demand interactions. *Habitat Int.* **2025**, *164*, 103524. [CrossRef]
34. Sun, J.; Wang, Q.; Guo, W. Genesis and characteristics of the traditional human settlement system of polder fields in the Xitiaoxi River Basin. *Landsc. Archit.* **2024**, *31*, 64–70. [CrossRef]
35. Nijhuis, S. The Noordoostpolder: A Landscape Planning Perspective on the Preservation and Development of Twentieth-Century Polder Landscapes in the Netherlands. In *Adaptive Strategies for Water Heritage: Past, Present and Future*; Hein, C., Ed.; Springer: Cham, Switzerland, 2020; pp. 212–229.
36. da-Silva-Branco, C.; de Brito, A.G.; Seixas, P.C. A comprehensive review of traditional irrigation systems: Sustainability and future prospects. *Agric. Syst.* **2026**, *231*, 104481. [CrossRef]
37. Coelho, C.R.V.; Börjesson, P.; Smith, H.G. Understanding land use impacts of croplands on biodiversity through UNEP's Global Guidance for Life Cycle Impact Assessment. *Resour. Conserv. Recycl.* **2025**, *222*, 108420. [CrossRef]
38. Luo, Z.; Li, Y.; Xu, X.; Zhang, W.; Gu, H. Ecological restoration effect of paddy fields after rice planting pattern transformation in the rural wetlands of Chenhaiwei, Jiangsu Province. *J. East China Norm. Univ. (Nat. Sci.)* **2020**, *2020*, 164–171. [CrossRef]
39. Hermansen, N.; Petersen, R.J.; Hoffmann, C.C.; Kjeldgaard, A.; Thodsen, H.; Zak, D.H.; Kronvang, B.; Larsen, S.E.; Audet, J. Long-term evidence of nitrogen removal from four decades of wetland restoration in agricultural landscapes in Denmark. *Agric. Ecosyst. Environ.* **2026**, *395*, 109924. [CrossRef]
40. Hou, X.; Guo, W. Polder landscape study: Discussion on form, function and impact. *Landsc. Archit.* **2015**, *22*, 123–128. [CrossRef]
41. Heckscher, E.F.; Ohlin, B.G. *Heckscher-Ohlin Trade Theory*; MIT Press: Cambridge, MA, USA, 1991.
42. Ohlin, B.G. *Interregional and International Trade*; Harvard University Press: Cambridge, MA, USA, 1933.
43. Zhen, L.; Cao, S.; Wei, Y.; Xie, G.; Li, F.; Li, Y. Land use functions: Conceptual framework and application for China. *Resour. Sci.* **2009**, *31*, 544–551.
44. He, H.; Guo, J.; Chen, Z.; Liu, Y.; Luo, W. Ecological product zoning method and governance path based on "potentiality--suitability" coupling. *J. Arid Land Resour. Environ.* **2024**, *38*, 1–12. [CrossRef]
45. Li, S.; Cheng, Y.; Cai, J.; Zhang, X. Influence of livelihood capitals on landscape service cognition and behavioral intentions in rural heritage sites. *Land* **2024**, *13*, 1770. [CrossRef]
46. Zhang, X.; Lin, C.; Ren, W.; Wang, X. Study on the landscape multifunctionality and multi-subject game in the Fuzhou West Lake water heritage. *Chin. Landsc. Archit.* **2023**, *39*, 36–42. [CrossRef]
47. Zou, L.; Li, Y.; Liu, Y.; Cheng, Y. Theory building and empirical research of production-living-ecological function of cultivated land based on the elements. *Geogr. Res.* **2021**, *40*, 839–855. [CrossRef]
48. Li, H.; Shi, D. Spatio-temporal variation in soil erosion on sloping farmland based on the integrated valuation of ecosystem services and trade-offs model: A case study of Chongqing, southwest China. *CATENA* **2024**, *236*, 107693. [CrossRef]
49. Hou, L.; Liu, T. Study on the landscape pattern of southwest transition zone from mountainous to hilly areas under the influence of multi-dimensional terrain factors: A case study of the middle and upper reaches of Fujiang River Basin. *J. Ecol. Rural Environ.* **2020**, *36*, 741–751. [CrossRef]
50. Wang, X.; Zhang, X.; Hu, Y.; Mu, W.; Luo, W. Soil fertility and influencing factors of cultivated land based on the Geodetector. *Environ. Sci.* **2024**, *45*, 7378–7389. [CrossRef]
51. Wang, X.; Lin, Q. Traditional Chinese mountain-water-field-city system from the perspective of territorial landscape. *Landsc. Archit.* **2018**, *25*, 10–20. [CrossRef]
52. Zhu, Q.; Hu, W.; Zhao, Z. Dynamic analysis on spatial-temporal pattern of trade-offs and synergies of multifunctional cultivated land---Evidence from Hubei Province. *Econ. Geogr.* **2018**, *38*, 143–153. [CrossRef]
53. Heringa, P.W.; van der Heide, C.M.; Heijman, W.J.M. The economic impact of multifunctional agriculture in Dutch regions: An input-output model. *NJAS—Wagening. J. Life Sci.* **2013**, *64–65*, 59–66. [CrossRef]
54. Qian, F.; Wang, Q.; Bian, Z.; Yang, Z.; Kang, M. Site condition assessment during prime farmland demarcating. *J. Nat. Resour.* **2016**, *31*, 447–456. [CrossRef]

55. Zhou, W.; Wang, W.; Zhang, B.; Xiao, L.; Lü, H.; He, X. Soil fertility evaluation for urban forests and green spaces in Changchun City. *Acta Ecol. Sin.* **2017**, *37*, 1211–1220. [CrossRef]
56. Yang, S.; Aftab, A.; Xie, J.; Han, L. Development of a simplified health assessment method for saline cultivated land using soil and crop indicators. *Geoderma* **2025**, *463*, 117557. [CrossRef]
57. Zakharova, K.; Rodela, R.; Lehtilä, K. Indicators of visual and ecological complexity of urban wetlands and lakes in Stockholm. *Ecol. Indic.* **2025**, *181*, 114362. [CrossRef]
58. Wang, Z.; Yang, H.; Hu, Y.; Peng, Y.; Liu, L.; Su, S.; Wang, W.; Wu, J. Multifunctional trade-off/synergy relationship of cultivated land in Guangdong: A long time series analysis from 2010 to 2030. *Ecol. Indic.* **2023**, *154*, 110700. [CrossRef]
59. Ehrlich, P.R.; Ehrlich, A.H. The causes and consequences of the disappearance of species. *Q. Rev. Biol.* **1981**, *56*, 82–85.
60. van Zanten, B.T.; Verburg, P.H.; Espinosa, M.; Gomez-y-Paloma, S.; Galimberti, G.; Kantelhardt, J.; Kapfer, M.; Lefebvre, M.; Manrique, R.; Piorr, A.; et al. European agricultural landscapes, common agricultural policy and ecosystem services: A review. *Agron. Sustain. Dev.* **2014**, *34*, 309–325. [CrossRef]
61. Yin, J.; Cao, X.J.; Huang, X.; Cao, X. Applying the IPA--Kano model to examine environmental correlates of residential satisfaction: A case study of Xi'an. *Habitat Int.* **2016**, *53*, 461–472. [CrossRef]
62. Huang, Y.Y.; Lin, T.; Zhang, G.Q.; Jones, L.; Xue, X.Z.; Ye, H.; Liu, Y.Q. Spatiotemporal patterns and inequity of urban green space accessibility and its relationship with urban spatial expansion in China during rapid urbanization period. *Sci. Total Environ.* **2022**, *809*, 151123. [CrossRef]
63. Huang, Y.Y.; Lin, T.; Zhang, G.Q.; Zhu, Y.G.; Zeng, Z.W.; Ye, H. Spatial patterns of urban green space and its actual utilization status in China based on big data analysis. *Big Earth Data* **2021**, *5*, 391–409. [CrossRef]
64. Cai, J.; Zhang, X.; Lin, T.; Zeng, Z.; Geng, H. Green infrastructuration and characteristics of suburban cropland from a zonal perspective. *Acta Ecol. Sin.* **2024**, *44*, 1–12. [CrossRef]
65. Wu, W.; Peng, J.; Liu, Y.; Hu, Y. Tradeoffs and synergies between ecosystem services in Ordos City. *Prog. Geogr.* **2017**, *36*, 1571–1581. [CrossRef]
66. Moreira, M.; Fonseca, C.; Vergílio, M.; Calado, H.; Gil, A. Spatial assessment of habitat conservation status in a Macaronesian island based on the InVEST model: A case study of Pico Island (Azores, Portugal). *Land Use Policy* **2018**, *78*, 637–649. [CrossRef]
67. Sun, D.; Wu, X.; Wen, H.; Ma, X.; Zhang, F.; Ji, Q.; Zhang, J. Ecological security pattern based on XGBoost-MCR model: A case study of the Three Gorges Reservoir Region. *J. Clean. Prod.* **2024**, *470*, 143252. [CrossRef]
68. Renard, K.G. *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)*; U.S. Department of Agriculture, Agricultural Research Service: Washington, DC, USA, 1997; Volume Agricultural Handbook No. 703.
69. Porter, J.; Costanza, R.; Sandhu, H.; Sigsgaard, L.; Wratten, S. The value of producing food, energy, and ecosystem services within an agro-ecosystem. *MBIO A J. Hum. Environ.* **2009**, *38*, 186–193. [CrossRef]
70. Liu, Y.; Wan, C.; Xu, G.; Chen, L.; Yang, C. Exploring the relationship and influencing factors of cultivated land multifunction in China from the perspective of trade-off/synergy. *Ecol. Indic.* **2023**, *149*, 110171. [CrossRef]
71. Zhang, Y.; Cai, H.; Zhang, X.; Chen, L.; He, Q. Multi-functional spatiotemporal evolution of cultivated land and its driving mechanisms in Poyang Lake Plain. *Bull. Soil Water Conserv.* **2023**, *43*, 245–253. [CrossRef]
72. Moran, P.A.P. The interpretation of statistical maps. *J. R. Stat. Society. Ser. B (Methodol.)* **1948**, *10*, 243–251. [CrossRef]
73. Al-Sabbagh, T.A.; Mohamadi, B.; Abu Ghazala, M.O.; Younes, A. Land use as a target for terrorism: A geospatial and temporal framework of terrorist preferences analysis in Egypt. *Land Use Policy* **2026**, *160*, 107822. [CrossRef]
74. FAO. AQUASTAT – Global Maps: Irrigated Areas. Available online: https://www.fao.org/aquastat/zh/geospatial-information/global-maps-irrigated-areas/irrigation-by-country/ (accessed on 24 July 2025).
75. Zhu, C.; Li, W.; Du, Y.; Zhang, X.; Chen, S. Spatial-temporal change, trade-off and synergy relationships of cropland multifunctional value in Zhejiang Province, China. *Trans. Chin. Soc. Agric. Eng.* **2020**, *36*, 263–272. [CrossRef]
76. Fan, Y.; Jin, X.; Xiang, X.; Yang, X.; Liu, J.; Zhou, Y. Evaluation and spatial characteristics of arable land multifunction in southern Jiangsu. *Resour. Sci.* **2018**, *40*, 980–992. [CrossRef]
77. Wei, X.; Lin, L.; Luo, P.; Wang, S.; Yang, J.; Guan, J. Spatiotemporal pattern and driving force analysis of multi-functional coupling coordinated development of cultivated land. *Trans. Chin. Soc. Agric. Eng.* **2022**, *38*, 260–269. [CrossRef]
78. Shi, Y.; Zhao, H.; Yun, W.; Tang, H.; Xu, Y. Analysis on spatial differentiation of arable land multifunction and socio-economic coordination model in Beijing. *Resour. Sci.* **2015**, *37*, 247–257.
79. Huang, D.; Lu, Y.; Liu, Y.; Liu, Y.; Tong, Z.; Xing, L.; Dou, C. Multifunctional evaluation and multiscenario regulation of non-grain farmlands from the grain security perspective: Evidence from the Wuhan Metropolitan Area, China. *Land Use Policy* **2024**, *146*, 107322. [CrossRef]
80. Zhang, Y.; Long, H.; Ma, L.; Ge, D.; Tu, S.; Qu, Y. Farmland function evolution in the Huang-Huai-Hai Plain: Processes, patterns and mechanisms. *J. Geogr. Sci.* **2018**, *28*, 759–777. [CrossRef]

81. Yang, H.; Zou, R.; Hu, Y.; Wang, L.; Xie, Y.; Tan, Z.; Zhu, Z.; Zhu, A.-X.; Gong, J.; Mao, X. Sustainable utilization of cultivated land resources based on "element coupling-function synergy" analytical framework: A case study of Guangdong, China. *Land Use Policy* **2024**, *146*, 107316. [CrossRef]
82. Wang, J.; Tang, C.; Yan, W. Mechanism and pattern of polders in the Yangtze River Delta: Effective physical form for ecosystem services provision. *Landsc. Archit.* **2018**, *25*, 38–44.

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