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The identification of potential land use conflicts based on land use competitiveness in Guangdong Province, China

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Accelerating urbanization and industrialization in China has intensified land use conflicts (LUCs), requiring the identification of potential LUCs and their reconciliation to support the sustainable utilization of land resources. In this study, we established a hierarchical multi-criteria evaluation system for land use competitiveness from the perspective of land suitability and potential driving forces of land-use conversion. Based on this system, we measured the competitiveness intensity for construction, agricultural, and ecological land. Finally, a conflict identification matrix was used to determine the types and intensity of LUCs. We took Guangdong Province as the case study because it is one of the most economically dynamic regions in China and is experiencing severe LUCs. The results were as follows: the potential LUCs were more acute in the non-core areas of the Pearl River Delta, the Eastern Coastal Economic Zone, and the Western Coastal Economic Zone, but weak in agricultural advantage areas, economically developed metropolitan, and ecologically sensitive areas. The primary types of these conflicts were notably between agricultural and ecological land, between agricultural and construction land, and among three land use types, which accounted for 34.00, 10.40, and 10.51% of the provincial area, respectively. The conflict between agricultural land and ecological land mainly occurred in the interface between agricultural and forest ecosystems. Based on the scope, intensity, and spatial patterns of LUCs in each zone, we finally proposed targeted land use strategies and recommendations for different administrative regions. Our findings provide scientific evidence for sustainable land use planning and management in rapidly developing regions.

KEYWORDS

China, Guangdong, land use competitiveness, land use conflict, multi-criteria evaluation

1 Introduction

As a cornerstone for human survival and development, land provides the essential physical space, natural resources, and ecosystem services (Elden, 2010; Zhou et al., 2020; Qu et al., 2024). With the population growth, urbanization, economic development, and consumption changes, land is caught in a tightening bind between its immutable physical limitations and the increasing demands from human society (Scoones et al., 2018; Wang et al., 2025). Intensifying competition among diverse stakeholders for scarce land resources has positioned land use conflicts (LUCs) as a critical and widespread global problem. For example, agricultural

modernization and the expansion of the agricultural frontier have perpetuated and deepened long-standing conflicts over land in the Brazilian Amazon (Sauer, 2018); the expropriation of traditional pastures for industrial plantations in Ethiopia exacerbate land conflict in agro-pastoral areas (Bekele et al., 2022); the large-scale transportation and logistics infrastructure development in Germany's Jade Bay has triggered a direct conflict between transportation logistics demands and ecological conservation goals (Susman and Weith, 2025); China confronts intense LUC during the rapid urbanization and industrialization processes, characterized by construction land encroaching on substantial high-quality agricultural land and ecological land (Fan et al., 2022; Wen et al., 2024; Qi et al., 2025), as well as agricultural land expansion compressing ecological space (Han et al., 2023; Peng et al., 2023; Qin et al., 2024). These conflicts have negative impacts on economic development, ecological security, food security, and social stability, thereby impeding the achievement of sustainable development goals (Zou et al., 2021; Xiong et al., 2025). Therefore, identifying potential LUCs and reconciling LUCs are essential for the sustainable utilization of land resources (Zou et al., 2019; Jiang et al., 2020; Han et al., 2023).

Over the past few decades, extensive research of LUCs has been conducted on the concept (Brown and Raymond, 2014; Steinhäußer et al., 2015), basic theories (Dietz and Engels, 2020), identification (Liu et al., 2014; Qu et al., 2023; Xiao et al., 2024; Wang C. et al., 2023), temporal and spatial dynamics (Yang et al., 2018; Feng et al., 2021; Jiang et al., 2020; Wang et al., 2025), driving mechanisms (Han et al., 2023; Zong et al., 2025; Zheng et al., 2025), and management (Bao et al., 2021; Gao et al., 2021). Among these research topics, the identification of LUCs is vital for conflict prevention and resolution, and has become a growing focus of the academic community, yielding considerable research outcomes. The common methods include participatory survey (Brown and Raymond, 2014; Yuan et al., 2023), composite index evaluation method (Zhou et al., 2017; Meng et al., 2023), ecological risk assessment (Zong et al., 2021; Jiang et al., 2021; Wang C. et al., 2023), multi-criteria evaluation (Iojă et al., 2014; Jiang et al., 2020; Zou et al., 2021; Wang et al., 2025). Participatory survey aims to reveal the interests of stakeholders by collecting conflict data from the public, but it is constrained by high workload, strong subjectivity, low quantifiability, and limited suitability to small-scale studies. Composite index evaluation method relies heavily on socio-economic statistics and is limited by the administrative scale of the data, making it difficult to identify the geographic locations of LUCs. Ecological risk assessment applies landscape ecological risk concepts to quantify LUCs, but its comprehensiveness is constrained by the neglect of socio-economic dimensions. In comparison, multi-criteria evaluation can overcome the limitations of the above method, and thus serves as a better candidate for identifying potential LUCs and analyzing their future trends (Jiang et al., 2020).

Commonly, multi-criteria evaluation method attempts to integrate multiple attributes in a given geographic unit or pixel (Brown and Raymond, 2014), and employs land use suitability (Xiao et al., 2024; Zong et al., 2025), competitiveness (Liu et al., 2014; Jiang et al., 2020), and functions (Iojă et al., 2014; Zou et al., 2021) as primary criteria. After establishing an indicator system for each criterion, it determines the type and intensity of LUCs by constructing a conflict identification matrix. Liu et al. (2014) identified potential LUCs in Daxing district of Beijing through evaluation of competitiveness for construction, agricultural, and ecological land. From the perspective of the constraints of local water resources, Jiang et al. (2020) derived the spatiotemporal patterns of potential LUCs by comparing the competitiveness of cultivated, construction, and ecological land. Based on the "ecological-production-living" perspective of sustainable development, Zou et al. (2021) constructed the spatial identification and intensity diagnosis model of potential LUCs, and selected a typical coastal city in southeast China as an empirical analysis. By integrating the "ecological-agricultural-urban" function with a four-tier classification of conflict intensity, Wang et al. (2025) classified 12 distinct conflict patterns into nine archetypes based on competing land use attributes within each 250-meter grid cell in China. Regarding study areas, scholars have mainly focused on relatively small-scale urban units (Liu et al., 2014; Zou et al., 2021), river basin subsystems (Jiang et al., 2020) and large-scale national level (Wang et al., 2025; Zong et al., 2025). However, the exploration of the meso-scale of provincial regions is relatively insufficient, resulting in the conflict patterns within provincial administrative units at different scales not being fully revealed. This is mainly because LUCs are not only constrained by natural conditions but also significantly influenced by administrative units at different levels (Zong et al., 2021). Therefore, it is necessary to systematically carry out research on the identification of LUCs at the provincial scale and within its internal administrative units using multi-criteria evaluation.

China is widely recognized as a country experiencing intense LUCs, due to its massive population and rapid economic growth (Zou et al., 2019; Han et al., 2023; Fang et al., 2024). Since the "Reform and Opening Up" activities in the 1980s, the socio-economic conditions of China have developed rapidly, accompanied by the most intense urbanization and industrialization processes in the world (Lu et al., 2019; Ma et al., 2020; Yang et al., 2020; Han et al., 2023). As the forefront of "Reform and Opening Up," Guangdong province is one of the most dynamic and influential regions with complex LUCs in China. In particular, urban construction and agricultural production in Guangdong are gradually expanding at the expense of ecological land (Li et al., 2025; Zou et al., 2019; Wu et al., 2024), and the imbalance of land use structure is particularly prominent (Feng et al., 2021; Wen et al., 2024). This phenomenon makes Guangdong an ideal subject for researching LUCs in the context of rapid economic growth.

Taking Guangdong Province as an example, this study aims to assess land use competitiveness and derive spatial characteristics of potential LUCs among different land use types. To achieve this goal, we (1) constructed a hierarchical multi-criteria evaluation system for land use competitiveness, (2) compared the spatial patterns of the competitiveness of construction, agricultural, and ecological land, (3) analyzed the scope, intensity and spatial distribution characteristics of potential LUCs in 2023, and (4) proposed management policy suggestions for governance to coordinate land use. These analyses may aid in preventing and reducing LUCs, and achieving sustainable use of land resources.

2 Materials and methods

2.1 Study area

Guangdong Province (Figure 1) is located in the southernmost part of mainland China (20°09′–25°31′N, 109°45′-117°20′E), spanning approximately 17.98×10^4 km^2. Under the "One Core, One

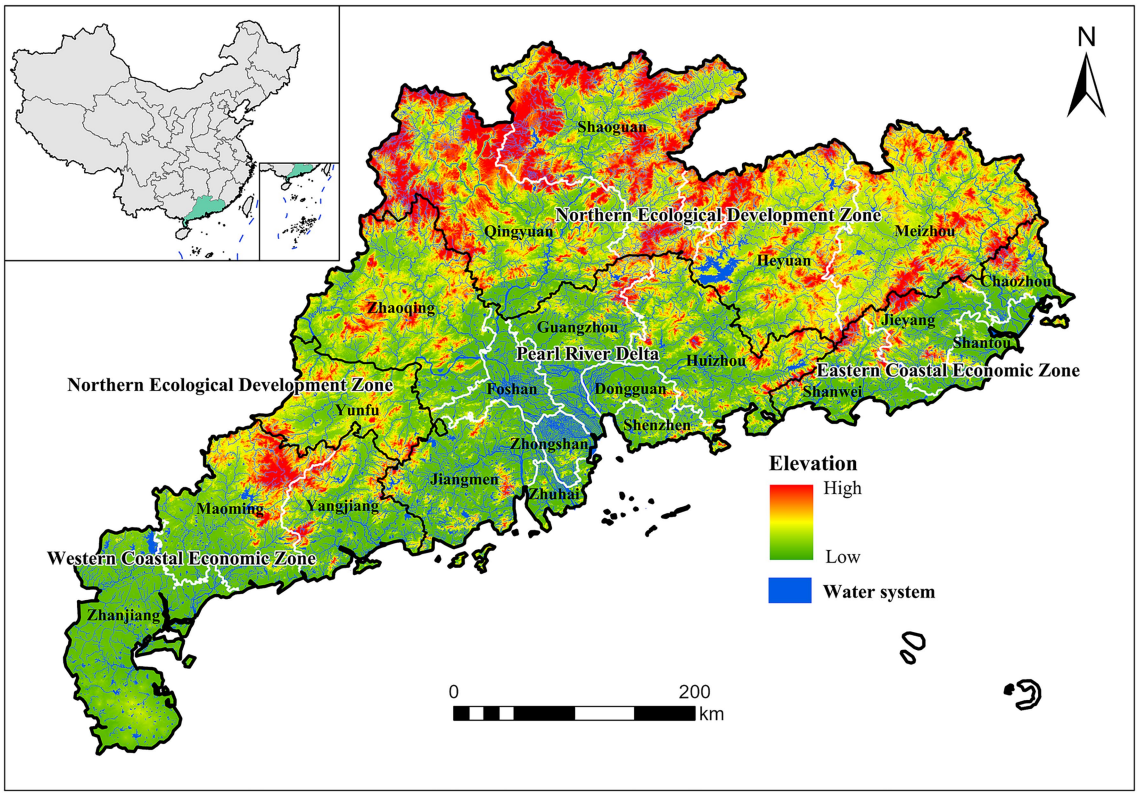

FIGURE 1
The location map of Guangdong Province. The map is for illustrative purposes only. The base map was derived from a standard map with official approval (Approval Number: GS (2024)0650) to ensure compliance with Chinese cartographic regulations.

Belt, One Zone" spatial development framework in Guangdong Province, it is divided into four regions (Chen et al., 2023), including the Pearl River Delta (PRD), the Eastern Coastal Economic Zone (ECEZ), the Western Coastal Economic Zone (WCEZ), and the Northern Ecological Development Zone (NEDZ). The PRD is the core area and main engine leading development, including nine cities: Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen, and Zhaoqing. The ECEZ and WCEZ are the key fronts for development, with the ECEZ comprising Shantou, Shanwei, Jieyang, and Chaozhou, and the WCEZ comprising Zhanjiang, Maoming, and Yangjiang. The NEDZ acts as an important ecological security barrier, including five cities: Shaoguan, Meizhou, Qingyuan, Heyuan, and Yunfu. Situated within the East Asian Monsoon Zone, Guangdong is characterized by abundant insolation, thermal resources, and precipitation. The elevation decreases from north to south, with the north dominated by mountains and hills and the south mainly consisting of plains and tablelands. This combination of favorable climatic conditions and heterogeneous landscapes fosters favorable conditions for plant growth. Moreover, it is one of the most economically dynamic regions in China. By the end of 2023, the permanent resident population of Guangdong Province was 127 million, and the regional GDP reached 13.57 trillion yuan, ranking first in China for over 35 consecutive years. In recent years, land development intensity in the core of PRD has reached exceptionally high levels, substantially exceeding the international warning threshold. Land resources in the PRD are approaching saturation and commanding prohibitive costs (Yang et al., 2020). Meanwhile, a clear trend shows that land demand is shifting toward the ECEZ, WCEZ and NEDZ. Yet these peripheral areas also confront stringent requirements for ecological conservation and agricultural land protection, leading to increasingly intense LUCs. Owing to its rapid development pressure, ecological sensitivity, and agricultural significance, Guangdong Province offers an exemplar for investigating land use competition and potential LUCs. The analytical method and empirical findings have great implications for other rapidly developing regions.

2.2 Data sources

The data used in this study mainly including land use data, the "Three Zones and Three Lines" planning boundaries, high-standard farmland, grain production functional areas and important agricultural product production protection areas, natural conservation area data, road network data, the digital elevation model (DEM) data, elevation and slope data, soil quality data, points of interest (POIs) data, NPP/VIIRS nighttime light data, and population distribution data. The specific sources, temporal coverage, spatial resolutions, and preprocessing steps for each dataset are detailed below:

(1) Land use data were generated through manual visual interpretation of sub-meter-resolution satellite imagery (e.g., Gaofen-1 and Gaofen-2). Interpretation and vectorization followed the Chinese national standard classification of Land

Use Status (GB/T 21010–2017), based on diagnostic visual characteristics such as tone, texture, shape, size, spatial context, and seasonal phenological signatures. The result dataset was validated by overlaying the vector layer on the original imagery and inspecting each polygon manually for positional and thematic accuracy.

(2) The "Three Zones and Three Lines" planning boundaries (Three Lines refer to the urban development boundary, the permanent basic farmland protection line, and the ecological conservation redline), grain-production functional areas and important agricultural-product production protection areas, and high-standard farmland were extracted from the official Guangdong Provincial Territorial Spatial Plan (2021–2035). These boundaries were digitized through manual tracing high-resolution remote sensing imagery to ensure spatial accuracy.

(3) Natural conservation area data originated from the Guangdong Provincial Protected Area Plan (2021–2035) and were derived through vectorization by overlaying high-resolution remote sensing imagery.

(4) Road network data were sourced from the open geographic database OpenStreetMap (OSM). The road network for China was downloaded from the Geofabrik website.[1]

(5) The DEM data used in this study were the ASTER Global Digital Elevation Model (ASTER GDEM) Version 3, with a spatial resolution of 30 meters. This product was downloaded via the Geospatial Data Cloud platform.[2] Terrain slope was derived by calculating from the DEM data using standard GIS algorithms.

(6) Soil quality data were derived by applying the natural quality index formula from Natural Quality Index Calculation Reference (GB/T 33469–2016) to input datasets, including the Second National Soil Survey, long-term average precipitation, accumulated temperature, and other variables, all obtained from the National Earth System Science Data Center,[3] followed by spatial interpolation.

(7) The POIs data for Guangdong Province in 2023 were obtained via the Amap Open Platform,[4] encompassing public service facilities including transportation, healthcare, elderly care, education, sports, and entertainment facilities.

(8) NPP/VIIRS nighttime light data used in this study were obtained from the 2023 annual composite product, provided by the Earth Observation Group (EOG) at the Colorado School of Mines. This dataset has a nominal spatial resolution of approximately 500 meters and has been filtered to remove transient light sources such as wildfires and auroras.

(9) Population distribution data were sourced from the LandScan™ Global Population Database (2023 edition), developed by Oak Ridge National Laboratory (ORNL), USA. The LandScan global population dataset integrates census data with ancillary geospatial layers to model ambient population distribution at an approximate resolution of 1 km.

The evaluation units in this study are vector patches from the land use data. According to the "Land Change Survey Technical Regulations" and relevant literature, construction land here includes urban areas, designated towns, villages, transportation land, and other construction-related uses. Agricultural land primarily encompasses cropland, orchards, aquaculture ponds. Ecological land comprises wetlands, forested land, grassland, water bodies, and unused land.

2.3 Study framework and methods

2.3.1 Study framework

This study analyzed LUCs from the perspective of land use competitiveness. The occurrence and degree of LUCs depend on the intensity of land use competitiveness. If a parcel is exclusively suitable for a single land use, no LUCs occur. However, if a parcel exhibits multi-purpose suitability (e.g., construction development, agricultural production, ecological conservation), divergent stakeholder demands will instigate competition among different land use types (Steinhäußer et al., 2015), and potential LUCs will arise. In this context, this study first quantified land use competitiveness of construction, agricultural and ecological land using the multi-criteria evaluation method. Then, competitiveness levels for each category were classified as strong, medium and weak, and their combinations were systematically arranged to characterize LUCs types and diagnose the conflict intensity. On this basis, the spatial patterns of potential LUCs across Guangdong Province are examined through spatial analysis. Finally, different governance strategies were proposed based on the spatial distribution, manifestation and conflict degree of potential LUCs zones.

2.3.2 Construction of land use competitiveness evaluation models

Land use competitiveness is jointly influenced by the multi-suitability of land resources and the driving forces of land-use conversion (Liu et al., 2014; Jiang et al., 2020). The multi-suitability of land resources is a critical prerequisite for the occurrence of land use competition, and the strength of driving forces of land-use conversions determines the likelihood of the potential conflicts escalating into actual conflicts. For the land suitability, we selected specific and representative indicators reflecting natural and location factors. For the potential driving forces of land-use conversion, we identified key indicators derived from social and policy factors. The multi-criteria evaluation system for construction, agricultural, ecological land competitiveness is shown in Tables 1–3, respectively.

(1) Natural factors determine the inherent productivity of land and dictate its optimal utilization modalities, which are mainly measured the elevation, slope, patch area, natural quality of agricultural land index. (2) Location factors are important reasons or conditions that influence the formation and changes of land use type, including proximity effect, the distance from roads, water sources, residential areas, government agency, the urban development boundary and the ecological conservation redline. The distance from roads is divided into distance from roads above county level and distance from roads at county and township level in construction and ecological land competitiveness assessment. The water sources indicate distance from rivers and lakes in construction and ecological land competitiveness assessment, and distance from rivers, lakes and irrigation ditch in agricultural land competitiveness assessment. (3) Social factors

1 https://download.geofabrik.de
2 http://www.gscloud.cn
3 https://www.geodata.cn
4 https://lbs.amap.com

TABLE 1 Evaluation indexes and grading assignment for construction land competitiveness.

Criteria layer (weights)	Sub-criteria layer (weights)	Factor layer (weights)	Factor grading and score				
			100	80	60	40	20
Suitability (0.67)	Natural factors (0.25)	Elevation (m) (0.38)	≤50	50–100	100–200	200–500	>500
		Slope (0.62)	0–5°	5–10°	10–15°	15–25°	>25°
	Location factors (0.75)	Proximity effect (0.27)	≥80%	60–80%	40–60%	20–40%	<20%
		Distance from rivers and lakes (m) (0.14)	≥100	70–100	50–70	30–50	<30
		Distance from government agency above township level (m) (0.18)	≤500	500–1,000	1,000–1,500	1,500–2,500	>2,500
		Distance from roads at county and township level (m) (0.11)	≤500	500–1,000	1,000–1,500	1,500–2,500	>2,500
		Distance from roads above county level (m) (0.13)	≤500	500–1,000	1,000–2000	2000–5,000	>5,000
		Distance from the urban development boundary (m) (0.17)	≤500	500–1,000	1,000–2000	2000–5,000	>5,000
Driving forces (0.33)	Social factors (0.62)	Population density (0.29)	Equation 1				
		Nighttime light intensity (0.33)	Equation 1				
		Density of public service facilities (0.38)	Equation 1				
	Policy factors (0.38)	Land use types (0.41)	Construction land		Agricultural land and ecological land		
		The scope of the urban development boundary (0.59)	Within the boundary				Outside the boundary

represent the socioeconomic driving force of land use, which mainly select indicators that are directly related to land use function or reflect functional status, including population density, nighttime light intensity and density of public service facilities. As construction land is more directly driven by social factors compared to agricultural and ecological land, this study established a specific sub-criterion layer of social factors exclusively for construction land competitiveness. (4) Policy factors indicate the priority direction of land use. This study selected land use type and the scope of the urban development boundary as evaluation indicators of construction land competitiveness, chooses current land use type, the scope of the permanent basic farmland, the scope of high-standard farmland, and the scope of grain production functional areas and important agricultural product production protection areas as evaluation indicators of agricultural land competitiveness, and selects current land use type, the scope of the ecological conservation redline, the scope of natural conservation area as evaluation indicators of ecological land competitiveness.

2.3.3 Scoring and weighting indicators

Considering the diversity of data types, we employed multiple methods to grade the indicators, including assignment method, the equivalent method, and standardization method. For quantitative factors (e.g., elevation, slope, patch area, and the natural quality index of agricultural land) and qualitative factors (e.g., the scope of the urban development boundary, permanent basic farmland, and the ecological conservation redline), the scores or ranks for each class were determined by referring to previous research (Liu et al., 2014; Jiang et al., 2020). For proximity effect, it describes the spatial dependence of land use, meaning that the land use type of a certain patch is not independent but is significantly influenced by the adjacent patches (Zou et al., 2021). Therefore, the proximity effect was quantified using the area proportions of construction, agricultural, and ecological land within a 100-meter buffer around each patch, which were then assigned scores by the equivalent method. For population density, nighttime light intensity and density of POIs, the standardization method was applied using the equation below:

$$f_i = 100\left(X_i - X_{\min}\right) / \left(X_{\max} - X_{\min}\right) \quad (1)$$

In Equation 1, X_i reprents the value of the index for patch i, X_{max} is the maximum value of the index, and X_{min} is the minimum value of the index.

We adopted the Analytic Hierarchy Process to determine the index weights (Zou et al., 2021). The core of this method is to construct pairwise judgment matrices based on the importance of evaluation indicators, determine the relative importance of each level of indicators to the target at the previous level, and ultimately yield the weight values of each level of indicators relative to the overall target.

2.3.4 Comprehensive evaluation of land use competitiveness

Land use competitiveness can be calculated using the formula:

$$F_i = \sum_{i=1}^{n} W_{i1} \cdot W_{i2} \cdot W_{i3} \cdot V_i \quad (2)$$

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TABLE 2 Evaluation indexes and grading assignment for agricultural land competitiveness.

Criteria layer (weights)	Sub-criteria layer (weights)	Factor layer (weights)	Factor grading and score				
			100	80	60	40	20
Suitability (0.44)	Natural factors (0.70)	Slope (0.23)	0–2°	2–6°	6–15°	15–25°	>25°
		Patch area (hm^2) (0.23)	≥30	20–30	10–20	5–10	<5
		Natural quality of agricultural land index (0.54)	≥4,800	3,600–4,800	2,400–3,600	1,200–2,400	<1,200
	Location factors (0.30)	Proximity effect (0.31)	≥80%	60–80%	40–60%	20–40%	<20%
		Distance from roads (m) (0.2)	≤100	100–200	200–500	500–1,000	>1,000
		Distance from residential areas (m) (0.24)	≤500	500–1,000	1,000–2000	2000–3,000	>3,000
		Distance from rivers, lakes and irrigation ditch (m) (0.25)	≤50	50–150	150–350	350–500	>500
Driving forces (0.56)	Policy factors (1.00)	Land use types (0.15)	Agricultural land		Ecological land		Construction land
		The scope of the permanent basic farmland (0.39)	Within the scope				Outside the scope
		The scope of high-standard farmland (0.27)	Within the scope				Outside the scope
		The scope of grain-production functional areas and important agricultural-product production protection areas (0.19)	Within the scope				Outside the scope

In Equation 2, *Fi* represents land use competitiveness of evaluation unit *i*, and W_{i1},W_{i1},W_{i1} are the weight of criterion, factor, and indicator levels, respectively. *Vi* is the actual score of the indicator *i*.

The competitiveness scores of construction, agricultural, and ecological land are divided into three ranks: strong, medium and weak. This method can group similar values based on data distribution so as to avoid subjectivity in classification process.

2.3.5 Identification of potential LUCs

We mainly adopted a conflict identification matrix from Jiang et al. (2020) to identify potential LUCs. According to Jiang et al. (2020), conflict intensity is assigned to a patch based on the following criteria: "intense" for two or three land use types with strong competitiveness; "medium" for two or three land use types exhibiting a mixture of strong and medium competitiveness; "weak" for three land use types with weak competitiveness; and "no conflict" for two land use types with weak competitiveness. The construction, agricultural, and ecological land competitiveness ranks were divided into 27 combinations, and categorized into 4 first-level categories and 12 s-level categories. The specific LUCs identification matrix is presented in Table 4.

3 Results

3.1 Spatial distribution of land use competitiveness

Based on land use competitiveness evaluation models, this study quantified the spatial patterns and areal proportions of land use competitiveness among construction, agricultural, and ecological land in Guangdong Province (Figure 2; Table 5). As indicated in Table 5, construction land in Guangdong Province exhibits predominantly low competitiveness. 63.91% of its area is classified as weak, 25.18% is categorized as medium, and only 10.91% of construction land is classified as strong. This pattern varies markedly across the province's "One Core, One Belt, One Zone" spatial development framework. The PRD accounts for the highest proportion of strong competitiveness (5.78%), substantially exceeding that of the ECEZ (1.23%), WCEZ (1.64%), and NEDZ (2.26%). Within the PRD, cities such as Shenzhen and Dongguan display particularly high proportions of land with strong competitiveness, with more 40% of their total land area is classified as this category. This pattern is closely associated with the exceptional economic density (e.g., with GDP per km^2 exceeding RMB 400 million in both Shenzhen and Dongguan), coupled with strategic land demands driven by the Guangdong-Hong Kong-Macao Greater Bay Area initiative, which emphasizes advanced manufacturing clustering and innovation infrastructure development, thereby intensifying land use competition for developable land. In contrast, cities in the NEDZ like Shaoguan, Meizhou, and Heyuan exhibit less than 5% strong competitiveness in construction land, indicating that land use pressures in these areas primarily arise from interactions among agricultural and ecological functions rather than urban expansion. As illustrated in Figure 2A, the spatial distribution of construction land competitiveness in Guangdong Province follows a distinct "one major core with two minor cores" agglomeration pattern. The primary core is centered on the PRD, while the secondary cores correspond to the Chaoshan-Jieyang metropolitan area in the ECEZ and the Zhanjiang-Maoming metropolitan area in the WCEZ. Areas with strong competitiveness are concentrated in the urban cores of

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TABLE 3 Evaluation indexes and grading assignment for ecological land competitiveness.

Criteria layer (weights)	Sub-criteria layer (weights)	Factor layer (weights)	Factor grading and score				
			100	80	60	40	20
Suitability (0.24)	Natural factors (0.20)	Elevation (m) (0.55)	>500	200–500	100–200	50–100	≤50
		Slope (0.45)	>25°	15–25°	10–15°	5–10°	0–5°
	Location factors (0.80)	Proximity effect (0.25)	≥80%	60–80%	40–60%	20–40%	<20%
		Distance from rivers and lakes (m) (0.21)	≤50	50–100	100–150	150–500	>500
		Distance from roads at county and township level (m) (0.19)	>500	300–500	200–300	100–200	≤100
		Distance from roads above county level (m) (0.16)	>1,000	500–1,000	300–500	200–300	≤200
		Distance from the ecological conservation redline (m) (0.19)	≤500	500–1,000	1,000–2000	2000–3,000	>3,000
Driving forces (0.76)	Policy factors (1.00)	Land use types (0.14)	Ecological land		Agricultural land		Construction land
		The scope of the ecological conservation redline (0.43)	Within the scope				Outside the scope
		The scope of natural conservation area (0.43)	Within the scope				Outside the scope

these three regions, whereas surrounding areas exhibit markedly weaker competitiveness. Although the NEDZ is largely characterized by weak competitiveness, its central urban districts such as those in Shaoguan and Meizhou display localized hotspots of strong competitiveness. This pattern reflects significant internal heterogeneity. On the one hand, vast rural and mountainous areas experience low development pressure, constrained by ecological conservation redline and permanent basic farmland protection. On the other hand, county-level urban centers such as Shaoguan and Meizhou have become localized hotspots of strong competitiveness. Their moderate expansion is permitted under Guangdong's policy framework of "ecological priority with controlled urbanization." Overall, construction land competitiveness is consistently stronger in city centers across Guangdong, reflecting a close spatial correspondence with gradients in socioeconomic development and urbanization intensity. This pattern underscores a strong coupling between land use competitiveness and regional development dynamics.

In contrast, agricultural land in Guangdong Province exhibits a markedly different spatial pattern of land use competitiveness. Strong competitiveness areas account for 49.75% of the total land, substantially exceeding the proportions classified as medium (28.03%) and weak (22.23%) (Table 5). The NEDZ hosts the largest proportion of strong grade competitiveness land (24.94%), followed by the PRD (12.05%). Conversely, areas with weak competitiveness are mainly concentrated in the PRD (7.92%) and NEDZ (7.39%), reflecting differences in regional land endowments and administrative extents. At the region level, the WCEZ and NEDZ both exhibit over 50% of their land classified as strong competitiveness for agriculture. Notably, Zhaoqing (PRD), Maoming and Yangjiang (WCEZ), and Meizhou, Heyuan, and Qingyuan (NEDZ), each have more than half of their territory falling into this category. Spatially, agricultural land competitiveness (Figure 2B) is relatively weak in the urban cores of the PRD but stronger in the surrounding peri-urban belts. A similar pattern is observed in other zones, including the ECEZ, where suburban and peri-urban areas display stronger agricultural competitiveness than central urban districts. Intriguingly, certain peri-urban interfaces, particularly those surrounding major cities, simultaneously exhibit strong competitiveness for both construction and agricultural land. This spatial overlap signals intense functional competition and identifies these zones as potential hotspots of LUCs, where ongoing urban expansion directly threatens high-quality agricultural land.

Figure 2C shows that ecological land use competitiveness in Guangdong Province lacks significant spatial agglomeration, exhibiting fragmented distribution and limited connectivity across intensity classes, patterns that are strongly shaped by anthropogenic pressures. Areas with strong competitiveness are predominantly concentrated within and adjacent to legally designated nature conservation areas, including nature reserves and drinking water source protection zones, which represent ecologically sensitive hotspots. As presented in Table 5, the competitiveness levels of ecological land are relatively balanced: strong, medium, and weak categories accounting for 35.80, 40.91, and 23.29% of the provincial land area. Notably, nearly 20% of all strong-competitiveness ecological land is located in the NEDZ. This reflects the strategic role of the NEDZ as the core of the Nanling Mountain ecological barrier in northern Guangdong, which provides a vital "green shield" of forested mountains and watersheds encircling the northern periphery of the Greater Bay Area. All cities in the study area contain both strong and medium ecological competitiveness zones. In the mountainous and hilly municipalities of the NEDZ, including Shaoguan, Meizhou, Qingyuan, and Heyuan, strong-competitiveness ecological land exceeds 40% of their total area. As Guangdong's primary ecological conservation zone, the NEDZ prioritizes ecosystem

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TABLE 4 Composition relationships and conflict types of LUCs.

Primary types		Second level types		Composition relationships of land competitiveness		
Code	Definition	Number	Definition	CL	AL	EL
A	Intense conflict	A1	Intense conflict among three land use types	S	S	S
		A2	Intense conflict between CL and AL	S	S	M
				S	S	W
		A3	Intense conflict between CL and EL	S	M	S
				S	W	S
		A4	Intense conflict between AL and EL	W	S	S
				M	S	S
B	Medium conflict	B1	Medium conflict among three land use types	M	M	M
				S	M	M
				M	S	M
				M	M	S
		B2	Medium conflict between CL and AL	S	M	W
				M	S	W
				M	M	W
		B3	Medium conflict between CL and EL	S	W	M
				M	W	S
				M	W	M
		B4	Medium conflict between AL and EL	W	S	M
				W	M	S
				W	M	M
C	Weak conflict	C1	Weak conflict among three land use types	W	W	W
D	No conflict	D1	CL dominance	S	W	W
				M	W	W
		D2	AL dominance	W	S	W
				W	M	W
		D3	EL dominance	W	W	S
				W	W	M

CL, AL, and EL, respectively, represent construction land, agricultural land, and ecological land. S, M, and W, respectively, represent strong, medium, and weak.

protection, restoration, and the sustained provision of regulating services such as water conservation and biodiversity support. Consequently, the zone hosts numerous protected areas subject to stringent land use restrictions, which underpin the extensive spatial footprint of strong-competitiveness ecological land. In contrast, zones of weak competitiveness are largely confined to the urban cores, especially within the PRD, where intensive development and high levels of economic activity have substantially eroded ecological functionality.

3.2 Spatial patterns of potential land use conflicts zones

Based on an analysis of the relative competitiveness of construction, agricultural, and ecological land uses in Guangdong Province, and by applying a potential LUCs classification matrix, this study identified four primary conflict types (Figure 3) and twelve secondary potential conflict zones (Figure 4).

Further analysis of the spatial distribution of these conflict types reveals distinct regional patterns that reflect Guangdong's functional zoning and development pressures. On the whole, the potential LUCs were more acute in the peripheral areas of the PRD, ECEZ, and WCEZ. Figure 3 and Table 6 show that the predominant potential LUCs types in Guangdong Province are no conflict zones (i.e., areas dominated by a single land use type) and medium conflict zones, which together account for 40.66 and 38.38% of the provincial land area. Among no-conflict zones, agricultural land dominance zones represent the largest category, covering 19.16% of the total area. Approximately 60% of Guangdong's territory experiences potential land use conflict (classified as intense, medium, and weak). Intense conflict zones constitute 20.22% of the total area, while weak conflict zones are only 0.74%. Notably, intense potential conflicts are concentrated in the NEDZ, where 30% of the land in Meizhou and Heyuan falls into this category. Medium potential LUCs are primarily located in the NEDZ (14.95%) and PRD (12.08%). Statistical analysis further reveals that seven cities exhibit medium potential LUCs

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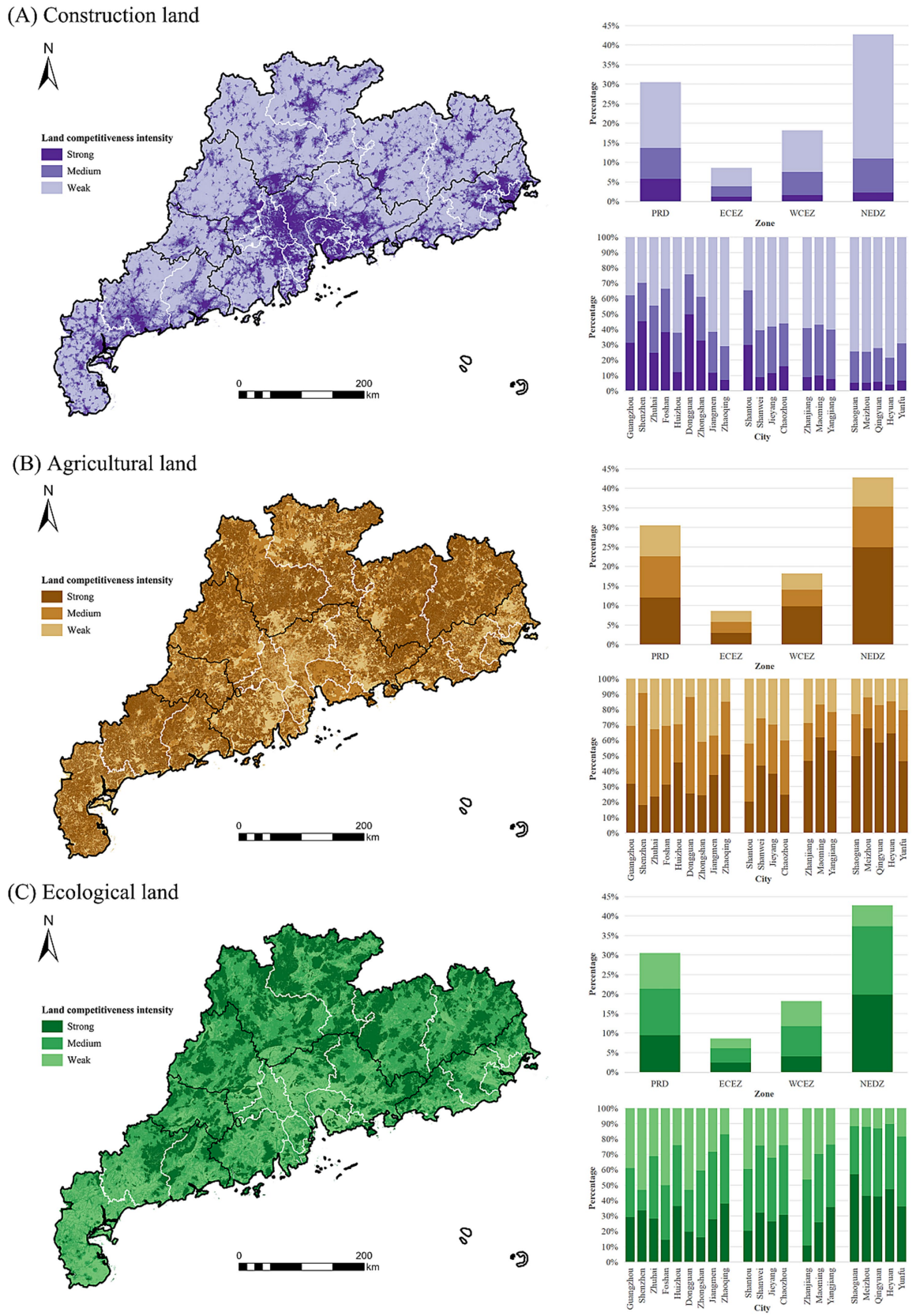


FIGURE 2
Spatial distribution of land use competitiveness for **(A)** construction land, **(B)** agricultural land, and **(C)** ecological land.

TABLE 5 Percentages of different competitiveness ranks for land use types.

Land use type	Construction land			Agricultural land			Ecological land		
	Strong	Medium	Weak	Strong	Medium	Weak	Strong	Medium	Weak
PRD	5.78%	7.91%	16.79%	12.05%	10.51%	7.92%	9.49%	11.94%	9.05%
ECEZ	1.23%	2.64%	4.76%	3.00%	2.84%	2.79%	2.43%	3.69%	2.50%
WCEZ	1.64%	5.88%	10.67%	9.76%	4.30%	4.13%	4.02%	7.80%	6.37%
NEDZ	2.26%	8.76%	31.70%	24.94%	10.38%	7.39%	19.86%	17.49%	5.36%
Total	10.91%	25.18%	63.91%	49.75%	28.03%	22.23%	35.80%	40.91%	23.29%

coverage exceeding or approaching 45% of their administrative area: Zhuhai (PRD); Shantou, Shanwei, Chaozhou, and Jieyang (ECEZ); Yangjiang (WCEZ); and Yunfu (NEDZ).

In terms of conflict composition, the dominant types of intense and medium conflicts were those between agricultural and ecological land, between construction and agricultural land, and among three land use types, accounting for 34.00, 10.40 and 10.51% of the provincial area, respectively (Table 6). The most extensive individual categories include: intense conflict zones between agricultural land and ecological land (18.18%), medium conflict zones between agricultural land and ecological land (15.82%), medium conflict among three land use types (10.45%), and medium conflict between agricultural land and construction land (8.80%). This pattern aligns closely with Guangdong Province's land use characteristics and reflects fundamental tensions inherent in land resource endowments. Favorable natural endowments, such as fertile soils, abundant water resources, and diverse topography, confer dual advantages: ecologically sensitive areas that provide critical ecosystem services often coincide spatially with lands highly suitable for agriculture. This overlap between "green mountains and clear waters" (i.e., high-value ecological zones) and productive agricultural landscapes ("grain baskets and orchards") creates inherent functional conflicts over land designation and use. Compounding this tension, rapid economic development has driven extensive expansion of built-up areas, resulting in persistent encroachment on both agricultural and ecological spaces. Consequently, transitional zones where construction, agricultural, and ecological land uses intersect have become hotspots of intense and recurrent land use pressure.

According to area statistics by conflict intensity, the matching level of spatial compatibility between agricultural and ecological land in Guangdong Province is low. Intense and medium conflict zones together account for up to 34.00% of the provincial area, with the intense conflict zones alone comprising 18.18%. In terms of spatial distribution, the conflict zones between agricultural and ecological land are predominantly located adjacent to ecologically sensitive areas such as the Nanling Mountains and the Fengjiang Reservoir. Intense conflicts are concentrated in the NEDZ, particularly in Meizhou, Heyuan, and Shaoguan. Medium conflict zones largely cluster around these intense conflict hotspots. Beyond the NEDZ, medium conflict zones are also widespread in the ECEZ and PRD, notably in Zhaoqing and Huizhou (PRD), as well as Maoming and Yangjiang (ECEZ).

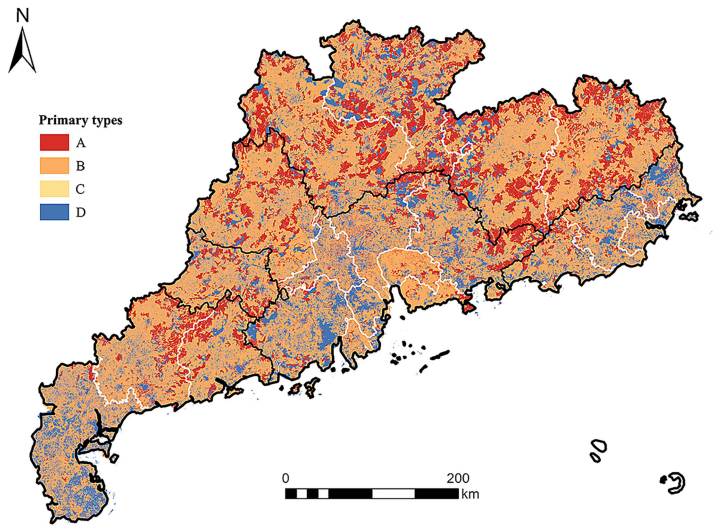
From Figure 4, over 40% of the land area in Shaoguan, Meizhou, Heyuan, Zhaoqing, Qingyuan, and Yunfu is subject to potential conflicts between agricultural land and ecological land. Among these cities, Shaoguan, Qingyuan, Heyuan, Zhaoqing, and Yunfu are located in northern Guangdong within the Nanling Mountain region, which is characterized by a predominantly hilly and mountainous landscape and functions as a critical water source conservation area and a nationally designated key ecological function zone. Similarly, Meizhou shares comparable topographic characteristics, and lies within the Hanjiang River Basin, which provides the region's primary freshwater resources for domestic and agricultural use. In these cities, conflict-prone areas are spatially concentrated along mountain ridges and in proximity to major river systems, reflecting the overlapping demands for agricultural production, ecological protection, and water resource security in ecologically sensitive upland landscapes.

Table 6 indicates that conflicts among three land use types and between agricultural and construction land in Guangdong Province are also prominent. Conflict zones among three land use types account for 10.51% of the provincial area, with medium conflict zones comprising the vast majority (10.45%). In contrast to the spatial pattern of conflict zones between agricultural land and ecological land, conflict zones among three land use types are predominantly located in the PRD and ECEZ. This pattern aligns with the current development trajectory in Guangdong Province, characterized by rapid urbanization, intensive peri-urban agriculture, and increasingly fragmented ecological spaces. Remarkably, intense conflict among three land use types zones is nearly across the province; instead, medium conflict zones cluster in cities such as Zhuhai, Guangzhou, Zhongshan, Dongguan, and Shantou. Spatially, conflict zones among three land use types exhibit a dispersed yet transitional pattern, typically situated at the interfaces among construction land dominance zones, agricultural land dominance zones, and ecologically significant regions. Such zones commonly arise at the expanding fringes of urban built-up areas, where construction land encroaches upon adjacent agricultural lands, forming dynamic peri-urban interfaces marked by heightened competition over land allocation.

Similarly, potential conflict zones between agricultural and construction land cover 10.39% of Guangdong's land area, of which 8.80% is classified as medium conflict zones. These conflict zones are primarily concentrated in the ECEZ and WCEZ, with Maoming, Jieyang, and Zhanjiang emerging as key hotspots. Such zones commonly arise at the expanding fringes of construction land dominance zones, where construction land encroaches upon adjacent agricultural lands, forming a peri-urban interface marked by heightened competition over land allocation.

3.3 Spatial relationship of potential land use conflict zones

To identify spatial clusters of potential LUCs, a hot spot analysis was conducted. As shown in Figure 5, statistically significant hot spots of potential land use conflicts are predominantly concentrated in the



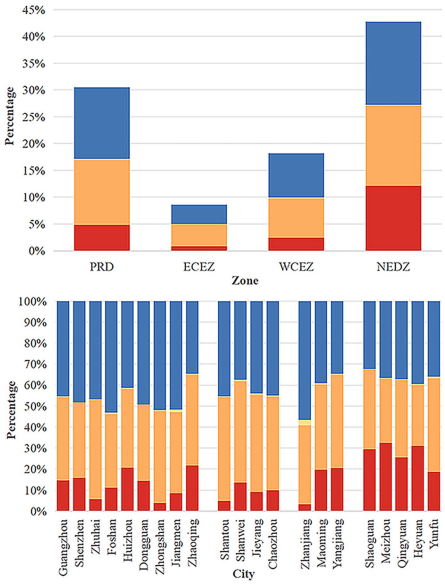
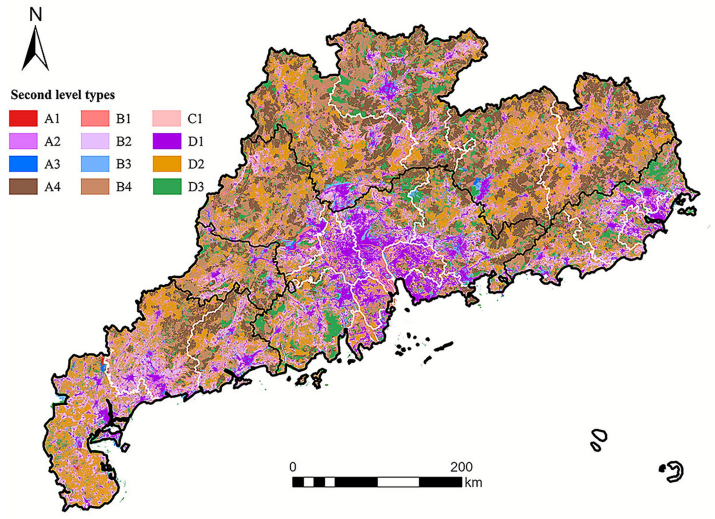


FIGURE 3
Spatial distribution of primary types of potential land use conflicts zones.



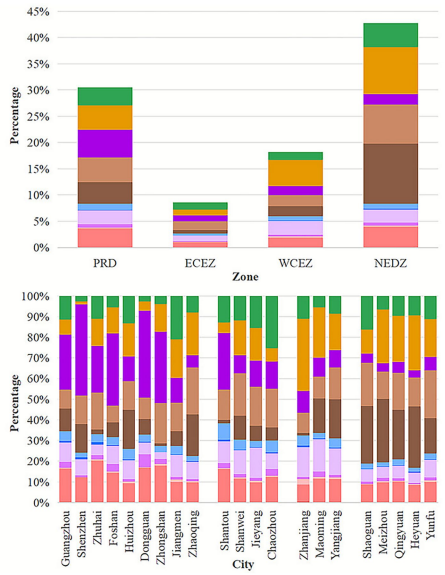


FIGURE 4
Spatial distribution of second level types of potential land use conflicts zones.

NEDZ and Zhaoqing (PRD), with limited clustering observed in the core urban area of the PRD, ECEZ, and WCEZ. The dominant type of potential LUCs zone in these areas is between agricultural and ecological land. In addition, the PRD exhibits medium conflict zones between three land use types, whereas medium conflict zones between construction and agricultural land characterize in the ECEZ and WCEZ. These hot spots consistently emerge in transitional zones, particularly at urban–rural fringes and along the interfaces between agricultural areas and forest ecosystems, suggesting intensifying competition among land use demands. The clustering of high-value conflicts is likely driven by active socio-economic dynamics, which promote land use diversification and function overlap in these economically sensitive zones.

Statistically significant cold spots of potential land use conflict are primarily located in the PRD, the central urban districts of the ECEZ and NEDZ, as well as in Zhanjiang within WCEZ, but are notably absent from transitional or mixed-use zones. These areas are predominantly characterized by construction land dominance zones or agricultural land dominance zones, suggesting that functional homogeneity and explicit land use specialization can effectively suppress spatial competition and mitigate conflict emergence. In the PRD and central urban districts of the ECEZ and NEDZ, land

TABLE 6 The percentages of different types of potential land use conflicts.

Primary types	Secondary types	Area percentage
A Intense conflict	A1 Intense conflict among three land use types	0.06%
	A2 Intense conflict between construction land and agricultural land	1.60%
	A3 Intense conflict between construction land and ecological land	0.38%
	A4 Intense conflict between agricultural land and ecological land	18.18%
	Total	20.22%
B Medium conflict	B1 Medium conflict among three land use types	10.45%
	B2 Medium conflict between construction land and agricultural land	8.80%
	B3 Medium conflict between construction land and ecological land	3.31%
	B4 Medium conflict between agricultural land and ecological land	15.82%
	Total	38.38%
C Weak conflict	C1 Weak conflict among three land use types	0.74%
	Total	0.74%
D No conflict	D1 Construction land dominance	10.16%
	D2 Agricultural land dominance	19.61%
	D3 Ecological land dominance	10.89%
	Total	40.66%

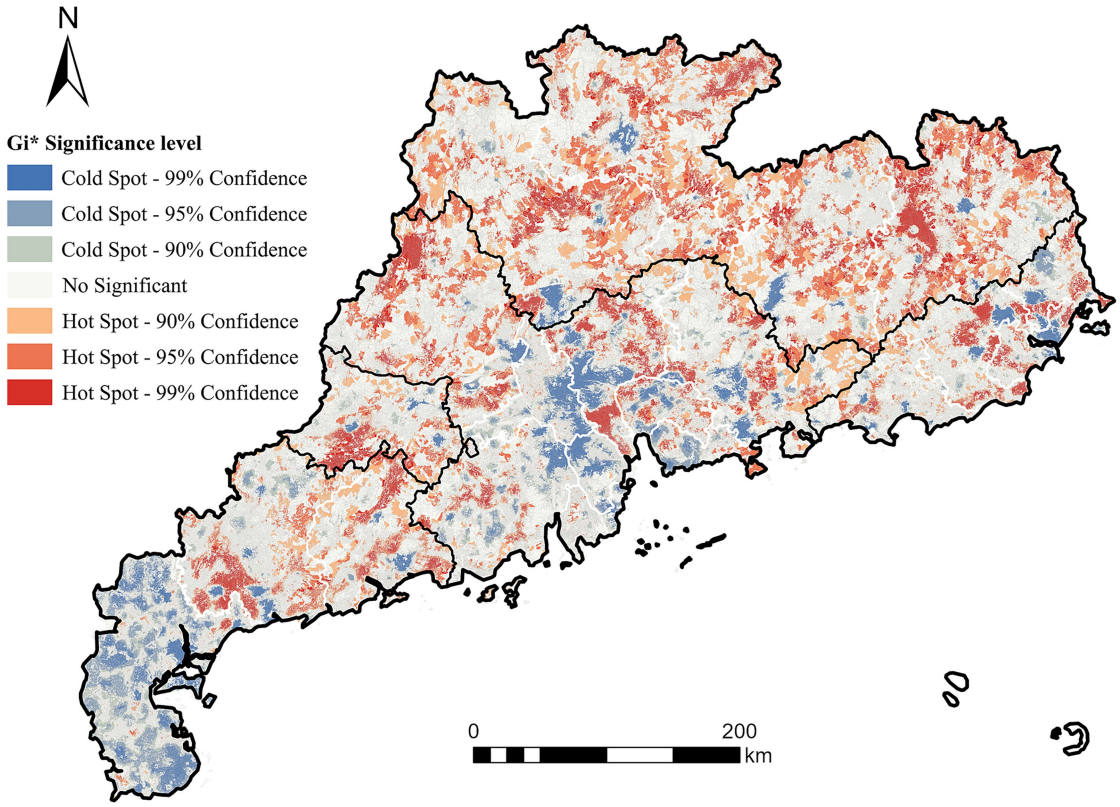


FIGURE 5
Hot spots of potential land use conflicts.

allocation is overwhelmingly oriented toward urban development, with minimal encroachment on high-value agricultural land or ecologically sensitive areas. Conversely, in intensive agricultural belts such as Zhanjiang, stringent farmland protection measures (e.g., permanent basic farmland designation) have substantially curtailed conversion pressure from urban expansion. However, this apparent "low-conflict" status may conceal underlying vulnerabilities. In construction land dominance zones, the absence of LUCs could reflect

saturated development capacity, potentially limiting the adaptive reallocation of land uses in response to evolving socio-ecological demands. In agricultural land dominance zones, low conflict intensity may stem not from a sustainable equilibrium but from rigid institutional constraints that suppress competing land use demands, particularly when the ecological potential of these lands remains underutilized. Therefore, policy interventions aimed at managing potential LUCs should guard against complacency toward cold spots. Rather than interpreting them as "problem-free," they should be reconceptualized as areas of latent risk or functional imbalance. Such a perspective is essential for proactive, forward-looking land governance that anticipates future pressures and fosters multifunctional landscape resilience.

4 Discussion

Since 2019, to promote coordinated regional development and reduce inter-regional disparities, the Guangdong Provincial Committee of the CPC and the provincial government have implemented the "One Core, One Belt, One Zone" regional development strategy. This framework delineates four functional zones with distinct developmental mandates: the Pearl River Delta (PRD) as the "One Core," serving as the primary growth engine and leading pole for provincial growth; the Eastern and Western Coastal Economic Zone (ECEZ and WCEZ), collectively forming the "One Belt," designated as the main arena for high-quality development in the new era; and the Northern Ecological Development Zone (NEDZ) as the "One Zone," functioning as a critical ecological barrier for the entire province. Within this policy context, it is imperative to identify and diagnose the types and spatial patterns of potential LUCs across Guangdong's diverse regions. This study evaluated the land use competitiveness of construction, agricultural, and ecological land and identified the spatial characteristics of their potential LUCs types. To better inform the effective implementation of the regional strategy, we further identify distinct spatial configurations of these potential LUCs zones across the four functional zones. Our findings provide critical evidence for evidence-based land governance, supporting targeted policy design and adaptive management in alignment with each zone's developmental and ecological mandates. Nevertheless, certain limitations of the methodological approach should be acknowledged and addressed in future research to enhance the robustness and applicability of conflict identification frameworks.

4.1 Divergent conflict landscapes across Guangdong's territorial zoning

Due to divergent regional development mandates and socioeconomic trajectories, the primary potential LUCs types across four major regions exhibit systematic spatial differentiation. As the core of Guangdong Province, the PRD is primarily characterized by intense and medium conflict zones between agricultural and ecological land, as well as medium conflict zones among three land use types. Cities characterized predominantly by agricultural or ecological land dominance zones, such as Huizhou, Zhaoqing, and Jiangmen, primarily experience potential conflicts between agricultural and ecological land. In contrast, highly urbanized and economically advanced cities like Shenzhen, Foshan, and Dongguan face not only this dyadic tension but also significant tripartite conflicts among all three land use types. This divergence stems from contrasting development contexts. Huizhou, Zhaoqing, and Jiangmen host ecologically sensitive areas of high conservation value and possess favorable conditions for agriculture; however, their relatively low levels of urbanization and economic intensity limit competing land demands. Conversely, in cities like Shenzhen and Foshan, the co-occurrence of natural endowments (e.g., flat terrain and abundant water resources), strong population agglomeration effects, rapid economic growth, and environmental pressures intensify land use competition. The dense river network and transportation in the PRD infrastructure further facilitate both agricultural productivity and urban expansion, reinforcing population concentration and economic activity (Liu et al., 2016). Yet, excessive development intensity, particularly along the Pearl River estuary, has accelerated the fragmentation of ecological and agricultural patches (Xie et al., 2017; Yi et al., 2024), exacerbating pressure on local resource and environmental systems (Yang et al., 2018; Chen and Zhang, 2024). Without proactive spatial planning and integrated land governance, these dynamics risk deepening inter-city disparities in both economic opportunity and environmental quality, potentially escalating tripartite land use conflicts to medium or even high intensity.

As the two wings of the Coastal Economic Belt, the WCEZ and ECEZ exhibit both commonalities and distinct spatial patterns of LUCs. In the ECEZ, exemplified by Shantou, urbanization dynamics increasingly mirror those of highly developed cities in the PRD. No-conflict zones here are mainly dominated by either construction or agricultural land. The primary potential conflict zones include medium conflict zones between agricultural and ecological land, between agricultural and construction land, and among the three land use types. In contrast, the WCEZ represented by Zhanjiang, is characterized by high agricultural land competitiveness across its three constituent cities. Dominant potential LUCs types comprise intense and medium conflict zones between agricultural and ecological land, as well as medium conflict zones between agricultural and construction land. Both wings stretch along Guangdong's southern coastline, featuring extensive maritime territories, high-quality bays, expensive tidal flats, and numerous islands, endowing that confer significant potential for ecological conservation and blue economy development. Geographically adjacent to the PRD, China's most economically advanced metropolitan region, they benefit from strong spillover effects. At the same time, as designated priority development zones, they are assigned a dual, and often competing, mandate: to safeguard arable land while simultaneously serving as key nodes for urban expansion and major hubs for agricultural production. This institutional tension renders the region especially vulnerable to multiple, overlapping forms of latent LUCs (Jin et al., 2025; Zhang et al., 2025). In particular, the WCEZ functions as a core grain-producing area, where agricultural land continues to yield higher comparative economic returns than ecological land. This disparity intensifies competition between agricultural and ecological functions, resulting in intense conflicts between agricultural and ecological land. Conversely, in the ECEZ, construction land generates greater comparative benefits than agricultural land, leading to simultaneous pressures from all three land use types and triggering complex, multi-dimensional spatial competition among them.

As a critical ecological barrier, the NEDZ is primarily characterized by intense and medium conflicts between agricultural and ecological land. Statistically, the zone holds 32.76% of the province's permanent basic farmland and contains 57.63% of the province's terrestrial ecological protection red line. This spatial co-occurrence imposes a dual, and often competing, mandate: to ensure food security through the strict protection of high-priority cropland while simultaneously preserving vital ecosystem services via stringent ecological conservation measures. The resulting spatial mismatch, where high-intensity agricultural production and rigorous ecological regulation are concentrated within the same geographic units, results in high-intensity agricultural production and strict ecological conservation being assigned to the same spatial unit, exacerbating LUCs and hampering sustainable management efforts. Consequently, the NEDZ is particularly vulnerable to persistent and escalating conflicts that jeopardize both agricultural productivity and ecological integrity, posing significant challenges to long-term sustainability.

4.2 Policy implications for mitigating land use conflicts

Based on the regional conflict patterns identified in Section 4.1, there is an urgent need for spatially differentiated governance approaches that align with Guangdong's "One Core, One Belt, One Zone" development strategy. Our analysis reveals distinct spatial configurations of potential LUCs across these functional zones: the PRD faces multi-functional competition, grappling with the tension between economic development and ecological conservation; conflicts between agricultural and construction land, and among three land uses concentrate in the ECEZ, suggesting potential risks posed by rapid urbanization and land use change; conflicts between agricultural and ecological land, as well as between agricultural land and construction land occur in the WCEZ; frictions between agricultural and ecological land are observed in the NEDZ. The potential LUCs originate from the spatial overlap, competition, and mismatch of different land use suitability and driving forces (Fienitz and Siebert, 2023; Zou et al., 2023). This pattern shows how provincial spatial planning frameworks interact with local conditions and development pressures to shape land use competition, underscoring the importance of tailored interventions. The following section will propose targeted strategies and recommendations for adaptive territorial spatial governance in conjunction with the Guangdong Provincial Territorial Spatial Plan.

The PRD has experienced intense competition among multifunctional land uses, driven by the expansion of construction land, favorable agricultural suitability, and the fragmentation of ecological patches. In the absence of strengthened regulatory oversight, future urban expansion may extend into adjacent zones of medium potential conflict, thereby encroaching upon high-quality farmland and ecological space, and severely compressing the spatial base required for both agricultural production and ecological security (Liu et al., 2016). To mitigate these risks, it is necessary to delineate the growth boundary of urban areas in accordance with the overall land-use plan and to promote urban development under the condition that regional natural and farmland ecosystems are not degraded or destroyed (Can et al., 2025). The rational reallocation of land functions is therefore of paramount importance. Regional planning and management efforts should prioritize the scientific allocation of land use types and enhance spatial coherence to reduce potential LUCs and foster functional synergies through function-oriented planning approaches (Tian et al., 2020; Yang et al., 2023). Furthermore, within the region, strategic interventions should be implemented to guide the optimization of land use structure, promote intensive and efficient land utilization, and encourage land use transformation that aligns with long-term development objectives. Such measures can support sustainable development through the spatial reorganization of agricultural, construction, and ecological zones (Wang et al., 2025). Concurrently, ecological protection and environmental governance must be reinforced to prevent ecosystem degradation and declines in environmental quality, ensuring that functional development remains consistent with sustainability goals.

The functional positioning and development requirements of the ECEZ encompass metropolitan area development, coordinated urban–rural growth, coastal ecological barrier conservation, and stable grain production. These objectives inherently entail overlapping demands on construction, agricultural, and ecological land functions. Without an effective coordination mechanism, this spatial arrangement is highly susceptible to moderate conflicts among the three land use types, particularly between agricultural and construction land. To address these challenges, ecological space should prioritize conservation-oriented utilization. Where ecologically appropriate, low-impact ecotourism may be developed in open or semi-open forms that leverage the region's rich ecological resources without compromising ecosystem integrity (Qu et al., 2023). The favorable conditions for agricultural development in the region should be fully harnessed. Obstacles to agricultural productivity can be mitigated through land consolidation and soil quality improvement, thereby facilitating transition toward intensive, efficient modern agriculture and enhancing overall agricultural output (Xiong et al., 2025). Construction land serves as a critical foundation for rapid socioeconomic development. As a rapidly urbanizing region, the ECEZ must enhance the intensity and efficiency of construction land, avoid inefficient urban sprawl, and promote the coordinated development of existing and newly added construction land. Such efforts would strengthen the radiating and driving capacity of Shantou as a regional urban center (Chen and Zhang, 2024). Moreover, in response to pressing challenges, including ecological fragility, population growth, and food security concerns, the land demand pressures may be partially alleviated through the strategic allocation of land resources within flexible or contingent spatial reserves. Areas meeting specific planning and ecological criteria may be conditionally developed in accordance with regulatory controls, while those failing to satisfy such conditions should be maintained as reserved space for future adaptive use (Fan and Wei, 2024).

As a major grain-producing region, the WECZ frequently experiences conflicts between agricultural and construction land, with agricultural land vulnerable to encroachment by urban expansion. To address this, highly suitable arable land within agricultural dominance zones should be formally designated as permanent basic farmland to prevent conversion to construction purposes. In medium conflict between construction and agricultural land zones, stringent controls on urban sprawl are essential (Jiang et al., 2020; Wang M. et al., 2023). Complementary measures, such as farmland protection subsidies and agricultural land consolidation, should be implemented to optimize

cropping systems and promote high-efficiency, modern peri-urban agriculture. In transitional zones where both ecological and agricultural functions are important, such as peri-urban wetland farmland or cropland designated for water conservation, the establishment of multifunctional coordination zones warrants consideration. Such an approach supports a transition toward multifunctional agriculture by replacing the traditional binary land use paradigm, which rigidly classified land as either agricultural or ecological. Instead, it encourages compatible management practices, including ecological farming and near-natural cultivation. This integrated strategy helps reconcile the perceived trade-off between "protecting grain" (i.e., ensuring food security) and "protecting green" (i.e., safeguarding ecological functions) (Xiong et al., 2025).

In the NEDZ, significant potential LUCs exist between agricultural expansion and ecological conservation, with ecological land particularly susceptible to conversion into farmland. To safeguard critical ecological function, spatial control boundaries, including those for permanent basic farmland, cultivated land protection, ecological protection, and urban development, should be rigorously delineated in accordance with the national regulatory frameworks. Concurrently, illegal land use activities must be subject to stringent enforcement measures (Zou et al., 2019; Wang C. et al., 2023). In transition zones between agricultural and ecological land dominance zones, land use management should adhere strictly to the principle of "agriculture where suitable for farming, ecology where suitable for conservation." Within agriculturally suitable areas, it is recommended to optimize agricultural production patterns and enhance the sustainable use of agricultural resources. Conversely, on marginal or low-suitability cropland, afforestation or ecological restoration should be incentivized through enhanced ecological compensation mechanisms. Existing ecological land must prioritize ecological integrity and green development, thereby addressing the underlying tension of "competing for land" between agricultural and ecological functions. Expansion of new construction land should be strictly constrained. Instead, integrated land use models, such as agroforestry (i.e., under-forest economy) and ecotourism, should be actively promoted to enhance the economic viability and functional competitiveness of ecological land (Zong et al., 2025).

4.3 Rationality, limitations, and prospects of the study

This study developed a hierarchical multi-criteria evaluation system to assess land use competitiveness by integrating natural, location, and policy factors. It calculated and analyzed the competitiveness intensity and spatial distribution characteristics of agricultural, construction, and ecological land in Guangdong Province in 2023. On this basis, our study identified and diagnosed potential LUCs using an identification matrix and proposed policy recommendations to mitigate potential LUCs. These findings contribute to advancing sustainable land resource utilization. Based on the previous research, this study further integrates factors of territorial spatial planning, particularly the regulatory boundaries of the "Three Zones and Three Lines," into the land use competitiveness evaluation models. This enhancement helps to more accurately reflect the role of the "Three Zones and Three Lines" in mediating LUCs within territorial spaces, thereby providing scientific guidance for their future optimization and adjustment.

Nevertheless, several limitations warrant acknowledgment. First, the assessment of land use competitiveness is inherently complex and systemic. The selection of indicators inevitably involves regional specificity and subjective judgment, and is further constrained by data availability and other conditions. Consequently, it is difficult for any indicator system to comprehensively capture all relevant influencing factors, which may introduce uncertainties into the competitiveness assessment and subsequent identification of potential LUCs. Second, LUCs are dynamic and evolving. This study provides only a static spatial assessment of potential conflicts in Guangdong Province for 2023. Long-term and multi-scale investigations would be necessary to help us to understand and analyze the temporal dynamic and evolving development of land use conflicts. Moreover, conflicts in practice commonly occur among specific sub-types of land use. Identifying potential conflicts between dominant sub-types within agricultural, ecological, and construction land could provide targeted insights for refined planning and management. Third, LUCs arise from the complex interaction of natural factors and human activities. Combinations of strong and weak competitiveness between agricultural and ecological land would also result in actual conflicts, as illustrated by the spatial mismatch between forest land located in plains and cultivated land distributed on steep slopes. Therefore, further exploration is warranted to identify the latent and typical LUCs in practical scenarios. Finally, a deeper understanding of potential LUCs is required. On the one hand, different land uses possess multifunctionality, meaning that high competitiveness does not necessarily lead to actual land use disputes. On the other hand, land serves both tangible and intangible functions, and how to quantify the value of intangible functions, such as cultural, aesthetic, or ecological services, remains a significant challenge. Furthermore, future research should use more diverse, high-resolution data sources and incorporate spatial optimization and scenario-based simulation models. Such approaches would strengthen both theoretical frameworks and empirical analysis, thereby supporting more scientifically territorial spatial planning and management practices.

5 Conclusion

This study integrated a set of indicators reflecting fundamental land use conditions, underlying drivers, and policy orientations, including natural, geographic, social, and policy elements, to construct a land use competitiveness evaluation model for construction, agricultural, and ecological land. The model was applied to assess the competitiveness intensity of these three land types across Guangdong Province. Subsequently, a LUCs identification matrix was employed to diagnose potential LUCs types and their spatial distribution characteristics. The results reveal that the potential LUCs were more acute in the non-core areas of the PRD, ECEZ, and WCEZ, but weak in agricultural advantage zones, economically developed metropolitan regions, and ecologically sensitive areas. Specifically, the PRD exhibited conflicts among all three land use types and between agricultural and ecological land; the ECEZ was characterized by potential LUCs among three land use types and between agricultural and construction land; In the WECZ, dominant conflicts occurred between agricultural and ecological lands, as well as between agricultural and construction land; the NEDZ primarily experienced conflicts between agricultural and ecological land. Based on these spatially differentiated conflict patterns, the study proposes

region-specific policy recommendations tailored to the prevailing types of potential LUCs in each region. These insights aim to provide both theoretical support and practical guidance for advancing sustainable land use planning in Guangdong Province.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: the data generated in this study are not publicly available due to institutional and national data security policies. Aggregated findings are reported in the manuscript. Reasonable requests for access to processed data can be directed to the corresponding author, subject to approval by the data custodians. Requests to access these datasets should be directed to Ziling Tan, zltan02@163.com.

Author contributions

XP: Writing – review & editing, Formal analysis, Data curation, Conceptualization. ZT: Visualization, Writing – review & editing, Investigation, Project administration, Supervision, Writing – original draft. XL: Writing – review & editing, Methodology. YC: Writing – review & editing, Data curation, Formal analysis. DC: Funding acquisition, Writing – review & editing, Formal analysis, Data curation.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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