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Concept and Method of Land Use Conflict Identification and Territorial Spatial Zoning Control

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Abstract: With the intensification of socioeconomic activities and climate change, land use conflicts are becoming more and more serious, posing major obstacles to the sustainable use of territorial space. This study conducted research on land use conflict and zoning control with a view to contributing new ideas for the prevention and resolution of land use risks. By analyzing the positioning and drawing upon fundamental theories, a novel research paradigm was proposed. An empirical study was conducted in the Gan River Basin in Jiangxi Province by applying the comprehensive evaluation method and geographical detector, and the basin was divided into six types of zones according to the intensity of land use conflict and the hierarchy of ecosystem service values. The results of the empirical study showed that the areas of intense conflict, low conflict and weak conflict accounted for 1.57%, 29.16% and 69.26% of the basin area, respectively. Of the intense conflict areas, 4.42% of the areas in the lower Gan River Basin were in intense conflict, while only 0.37% of the right bank of the middle reaches was in intense conflict. The driving factor analysis showed that precipitation, the population density and policy planning had a greater influence on land use conflict and that land use conflict was more likely to occur with the interaction of precipitation and the nighttime light index, population density and NDVI. The superimposed image analysis revealed that the land use conflict was intense at the junctions of urban areas and cropland and at the junctions of cropland and forests in the middle and upper reaches of the basin, which were mainly caused by the demand for urban expansion and the spread of agricultural production areas. The results of this empirical study are in agreement with the actual situation in the Gan River Basin, proving that the research paradigm proposed in this study is scientific and applicable. Moreover, we emphasize that this paradigm can be adapted in its application according to different research objects and continuously improved in response to the evolution of the territorial spatial management system. This study is of positive significance for the implementation of territorial spatial planning and provides a scientific basis for the further enhancement of the system of territorial spatial governance.

Keywords: land use conflict; territorial spatial zoning; control strategy; Gan River Basin

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1. Introduction

In the prolonged process of urbanization and industrialization, urban expansion has exerted prominent impacts on agricultural and ecological space due to the lack of effective assessment methods and control mechanisms [1–3]; thus, these spaces have been shrinking in size and declining in quality [4]. Reconciling the conflict between development and protection has become a significant task for territorial spatial management in the new era [5]. The 20th National Congress of the Communist Party of China explicitly emphasized the need to vigorously promote ecological civilization construction [6]; accelerate the implementation of major projects for the protection and restoration of essential ecosystems [7–9];

solidify the foundation of grain security [10]; deeply implement the major function-oriented zone strategy and the new urbanization strategy [11,12]; and construct a complementary, high-quality regional economic layout and territorial spatial management system [13]. The new development philosophy sets forth new goals and requirements for ecological protection and restoration, agricultural production development and urban development in the new era [14]. Conducting research on land use conflict (LUC) identification and territorial spatial zoning control can provide new perspectives and methods for the rational formulation of territorial spatial planning and the promotion of the coordinated development of production, living and ecology. Furthermore, it can promote the realization of efficient agricultural production, optimized ecological patterns and orderly urban development, which are of great significance for the rational and efficient utilization of resources, food security, the maintenance of biodiversity and responses to global challenges such as climate change. The research results can contribute to the realization of the United Nations' sustainable development goals, such as hunger eradication and forest protection.

At present, numerous studies focus on the causes, types, characteristics [15], assessment and driving factors of LUC [16]. Peng et al. argue that urbanization in Shenzhen City has brought about a serious conflict between socioeconomic development and ecological protection. Through a case study using logistic regression and transfer probability methods, they found that the slope and distance from construction land are important factors contributing to changes in urban ecological land [17]. Wang et al. carried out LUC zoning in China based on a multi-level spatial assessment methodology and concluded that the prevalence of LUC in China is mainly due to the aggressive expansion of construction land [18]. Existing studies have considerably enriched the research framework for LUC and zoning control. However, existing studies lack an analysis of the effects of interactions among driving factors, the use of imagery to validate the findings and the consideration of current policy planning [19]. With the rapid advancement and widespread application of the "3S+" spatial information technology [20], there has been a gradual tendency for research to be quantitative, spatial and visual. In this process, a series of effective research methods for the identification of LUC have emerged, which can be broadly classified into four types. (1) Qualitative methods such as public participation surveys and game theory [21] often require extensive questionnaire surveys, resulting in significant workloads and difficulties in quantitatively reflecting the intensity characteristics of LUC. (2) The Pressure–State–Response (PSR) model and its extensions [22], which are primarily based on a large volume of socioeconomic data, make it challenging to determine the specific spatial locations of conflicts. (3) The Landscape Pattern Index (LPI) method, which adopts landscape pattern indices from ecological risk models to measure the sources, receptors and effects of risks [23], comprehensively reflects the intensity of LUC and can accurately locate conflict occurrences but cannot specify the exact types. (4) The Multi-Criteria Evaluation Method [19,24], which evaluates and compares various attributes at the same spatial location, has proven to be an effective means of identifying LUC. It has become a new research hotspot in the field of land science to identify the specific locations, types, intensities and spatial characteristics of LUC and accordingly propose control strategies tailored to the local conditions to aid in territorial spatial management [25].

This study proposes a complete and flexible research paradigm for LUC identification and territorial spatial zoning control, and it is verified with a case study of the Gan River Basin. This study considers the construction of an evaluation system from the perspectives of natural resources, socioeconomics, policy and location conditions around the three dominant functions of agricultural production, urban construction and ecological protection. It also emphasizes the consideration of the influence of existing policies and plans to make the evaluation results more comprehensive and the identification of LUC more accurate. However, due to the lack of accumulation of some historical data, a scenario simulation cannot be completed yet. We put forward the concept and outlook for an LUC simulation, which is achievable in the future after accumulating the existing observation data. Overall, this study could provide an open-ended idea for subsequent research.

2. Concepts and Connotations

LUC has long impacted the sustainable utilization of land resources and sustainable socioeconomic development [26]. Since the reform and opening up, China has introduced various major types of function-oriented zoning or dominant functional zoning within the territorial spatial planning and management system [27]. These efforts have included evaluations of the resources and environmental carrying capacities and suitability assessments for territorial spatial development and utilization [28], providing a theoretical foundation for the identification of LUC and territorial spatial zoning control. As territorial spatial planning efforts are comprehensively advanced, there is an urgent need to prevent and mitigate LUC [29], scientifically plan the development and protection patterns of territorial space, effectively regulate the spatial development order and improve the mechanisms for spatial control [30].

2.1. Connotations and Characteristics of LUC

Due to the continual changes in natural, social and economic attributes throughout different eras, the corresponding positioning and characteristics of LUC vary, as shown in Table 1. As the material foundation upon which human society survives [31], land resources have always possessed various functional attributes, such as agricultural production, urban construction and ecological protection. Territorial spatial planning emphasizes the necessity of analyzing regional resource endowments and environmental conditions to delineate appropriate spaces for agricultural production, urban construction and ecological protection [32]. However, the multi-functionality and multi-suitability of land resources lead to competition among different utilization methods and benefit forms [33], intensifying the phenomenon of LUC. For instance, the competition for land between traditional agricultural production zones and the establishment of nature reserves has become increasingly pronounced [34], as has the destruction of biological habitats due to rapid urbanization and biodiversity loss caused by excessive land development [35]. On this basis, LUC can be defined as the state of mismatch and disharmony displayed between the natural resource attributes and socioeconomic attributes of land resources in the allocation of different utilization methods and the balance of different benefit forms [36–38]. Therefore, LUC mainly manifest as intrinsic contradictions among land use functions and extrinsic struggles among land stakeholders. From the perspective of territorial spatial control, LUC particularly highlights the multi-functionality and multi-suitability conflicts that arise during land utilization.

2.2. Connotations and Characteristics of Dominant Functional Zoning

The concept of "major function-oriented zones" was introduced in the "Outline of the Eleventh Five-Year Plan for National Economic and Social Development of the People's Republic of China", which initiated a novel strategy for regional coordinated development. Subsequently, research on geographical partitioning and dominant functional zones has advanced to a new phase [11]. The "Opinions of the Central Committee of the Communist Party of China and the State Council on Establishing and Supervising the Implementation of a Territorial Spatial Planning System" advocate for the establishment and supervision of a territorial spatial planning system, integrating dominant functional zone planning, land use planning and urban–rural planning, which intends to improve the modernization of territorial spatial governance [13,39]. Progress in terms of novel ideas, technology and approaches has resulted in the advancement of complex interdisciplinary, multi-scale and multi-objective studies on territorial space. Consequently, there is a growing body of research on the type classification, spatial structure pattern recognition and optimization of dominant functions [40]. Territorial space is a cohesive entity composed of several spatial units that are consistently spread out in time and space. Various spatial units display different functional types with variable intensities due to changes in the composition, structure and working mechanisms of internal resources, society, the economy and ecology. The function that exhibits the greatest external impact and the most apparent advantage and plays a decisive role in regional development is the dominant function of the territorial spatial unit [41,42]. Dominant functional zoning identifies the leading functional types within specific spatial units from the perspective of the overall positioning of the territorial space development, while adhering to the principles of coordination. For a certain territorial space, its dominant function can be the supply of agricultural products, ecological products or socioeconomic construction [43], without excluding other ancillary functions within the region. At specific spatial scales, there is no overlap between different dominant functional zones, but, at varying spatial scales, the types of dominant functions may change. These characteristics lay the foundation for the clarification of the positioning of territorial spatial planning and management.

Table 1. Comparative analysis of the positioning and coordination methods for LUC.

Conflict Type	Conflict Positioning	Analysis Method	Indicators	Manifestations and Coordination Methods
Conflicts between usage and suitability	Unreasonable engineering layout of land use, resulting in a mismatch between the way in which the territorial space is utilized and its appropriateness for use	Overlay analysis based on historical and current land use data and the results of the assessment of the suitability of territorial spatial utilization [44]	Indicators for the evaluation of the suitability of various types of territorial spatial and utilization, such as topography, soil, climate and engineering conditions	Manifested as an imbalance in land use patterns and difficulty in realizing the maximum value of the land. Coordination methods include game theory and multi-objective planning.
Conflicts over the functionality or suitability of territorial space	Territorial space excels in multiple functions or multiple types of suitability, with multiple possibilities for utilization, leading to potential conflicts	Assessing the suitability of various utilization methods for territorial space and identifying the optimal use strategy through a trade-off analysis [45]	Factors affecting the development, utilization and functional strength of territorial space, such as natural resources, socioeconomic conditions and policies	Manifested as the competition between multiple functions or multiple types of suitability of the territorial space. Coordination methods include the coupling coordination model, multi-objective planning and zoning utilization.
Conflicts between territorial space development and ecological protection	Fragmentation and loss of ecological space caused by the high-intensity development and utilization of territorial space, such as urban construction, mining and agricultural development [46]	Analyzing the area and intensity of conflict based on an ecological risk assessment and its extended model and validating it through remote sensing [47]	External pressure indicators, such as the landscape fractional dimension index; vulnerability indicators, such as the landscape vulnerability index; stability indicators, such as the patch density index [48]	Manifested as the destruction of the landscape structure, the degradation of ecological functions and a decline in wildlife living space. The coordination methods include ecological protection and the restoration of territorial space and zoning control.
Conflicts between land use methods and economic efficiency	Conflicts in the choice of land use modes between land use stakeholders arising from the pursuit of their own interests [49]	Conducting public participatory surveys or PSR modeling analysis for LUC cases to examine the intensity of conflict among various interest groups	Survey and collection of socioeconomic, environmental and other information to assess the benefits of different land use modes and their environmental impacts	Manifested as competition for land or space by stakeholders. The main coordination methods are non-cooperative gaming methods.
Conflicts between personal and social benefits in land use processes	Conflicts between public perception and government planning in the process of territorial spatial management	Conducting participatory surveys to systematically understand the public's willingness to use land and analyzing the causes of conflicts [50]	Collecting information on public aspirations and perceptions as well as government planning for comparative analysis [51]	Manifested as obstacles in the implementation of territorial spatial planning [52]. The main coordination methods are government macro-control [53], public participatory planning and game theory [4].

3. Theories of LUC Identification and Territorial Spatial Zoning Control

LUC identification contributes to the construction of land use risk early warning mechanisms. Zoning control is a crucial step in the comprehensive protection, systematic restoration and integrated governance of territorial space. By determining the dominant functions of a land space, scientifically identifying LUC areas and delineating control zones, support can be provided for the usage regulation of territorial space [54]. This approach holds substantial theoretical significance and practical value.

3.1. Basic Principles

(1) Goal-oriented. The identification of LUC is based on a multi-objective evaluation system, which serves the goals of achieving the harmonization of "production–life–ecology" and the efficient management of territorial space. The zoning control of territorial space should be tailored to the development realities and orientation of the region and implement upper-level planning [55], so as to achieve sustainable resource management, sustainable land use, sustainable ecological security and a sustainable regional economy.

(2) Function-oriented. The essence of territorial spatial zoning control is to identify and optimize the dominant functions. LUC represents a real contradiction between the natural and socioeconomic attributes of land resources, as well as the external manifestation of an incomplete understanding or inadequate performance of the dominant functions of territorial space. Only by clarifying the dominant functions of territorial space can we better identify LUC and implement effective management measures for territorial space [56].

(3) Problem-oriented. Under the combined influence of natural and human factors, LUC exhibits different external characteristics over time and space. Territorial spatial zoning control aims to optimize areas with potential or existing LUC [57] and guide land use behavior to facilitate the mitigation of conflicts. Effective zoning control must focus on the primary issues and respect objective realities, which means developing different remediation strategies based on the type, intensity and spatial characteristics of LUC.

(4) Demand-oriented. LUC identification and territorial spatial zoning control must address the resolution of LUC issues while also satisfying the need to build a better territorial space. Therefore, territorial spatial zoning control should be based on the regional territorial governance demands, clearly identifying the main tasks and key areas, specifying the layout of major projects and ensuring comprehensive planning and deployment.

3.2. Basic Ideas

LUC identification and territorial spatial zoning control must embrace the concepts of a "great system", "great ecology" and "great pattern", with the objectives of optimizing the spatial structure, efficient resource utilization and upgrading ecological functions [58]. These tasks should be integrated with the formulation and implementation of territorial spatial planning. Efforts should be made to establish an ecological space with a complete structure and functions, an agricultural space with green safety and obvious characteristics and an urban space with high quality and synergistic complementation [59], so as to ultimately build a territorial spatial management pattern with territory-wide coverage, classified measures and systematic control. Taking into account the goals of alleviating LUC and achieving effective territorial spatial management, the present research mainly comprises three parts. The first is conducting the identification of LUC. The second is delineating the territorial spatial control zones. The third is formulating mitigation schemes for LUC. The basic framework is illustrated in Figure 1.

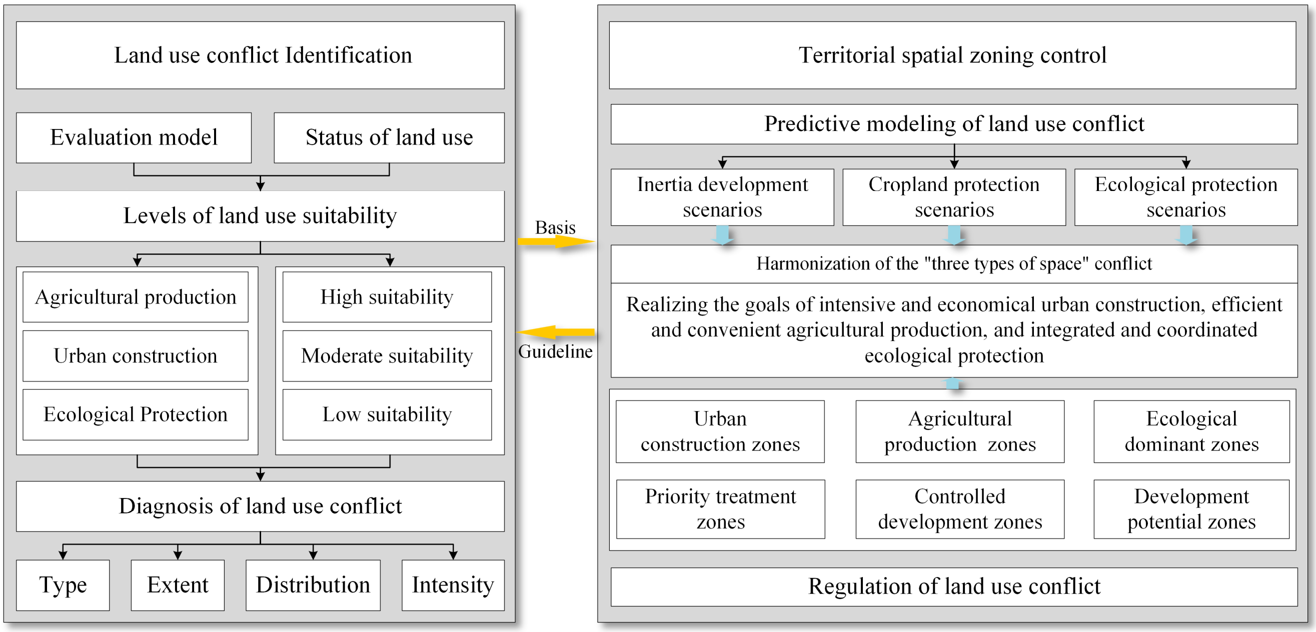

Figure 1. Research framework for LUC identification and territorial spatial zoning control.

4. Technical Route

In the context of the current development strategy of ecological prioritization and grain security, land use is tending towards agricultural and ecological purposes, inevitably leading to overlaps and intersections among land use demands [38]. Balancing land use modes under the three major objectives of agricultural development, urban construction and ecological protection, as well as coordinating land use layouts to alleviate LUC, thereby determining the direction of territorial spatial development, has become an urgent issue to address. Territorial spatial zoning control, with land use regulation as the guiding principle, can serve as an important means to coordinate LUC by organizing regional issues. This study conducts a case study of the LUC in the Gan River Basin, utilizing suitability evaluation methods, spatial overlay methods and comprehensive analysis methods to explore the methods and technical routes of LUC identification and territorial spatial zoning control.

Based on the analysis of the current status of the regional territorial space, a land use suitability evaluation index system was constructed to classify the suitability levels for agricultural production, urban construction and ecological protection [60]. Utilizing a conflict identification matrix [61], the types and intensities of LUC were diagnosed. Through spatial analysis, conflict hotspot areas were identified, and the intrinsic mechanisms of conflict evolution were explored. Subsequently, territorial spatial control zones were delineated, and conflict mitigation and management strategies for each zone were proposed. This study formed a research paradigm consisting of fundamental investigation, suitability evaluation, conflict identification, problem diagnosis, driving factor analysis, scenario simulation, control zoning, and the application of the results, providing technical support for territorial spatial planning and governance This is a complete paradigm that can be adapted to suit the research needs in a specific study.

(1) Foundational Investigation: Conducting a comprehensive survey of the region and collect basic data on the natural resources, ecology, socioeconomics and policy planning [62]. This survey comprehensively analyzes and organizes the elements within the region that affect agricultural production, urban construction and ecological protection. It can provide data support for the evaluation of the territorial spatial suitability and zoning control.

(2) Suitability Evaluation: Separate suitability evaluation systems are constructed for territorial spatial development and utilization under the three major development

goals of agricultural production, urban construction and ecological protection [63]. The strength of suitability of these functions can be characterized spatially. This approach provides the guiding direction for the development and utilization of territorial space.

(3) Conflict Identification: Based on the results of the suitability evaluation, suitability levels (high suitability, moderate suitability and low suitability) can be determined. According to game theory, the suitability levels are arranged and combined to construct a conflict judgment matrix [64] to identify the types and intensities of the conflicts. Applying spatial analysis methods, the spatial distribution patterns of the LUC can be explored.

(4) Problem Diagnosis: Investigations of the different types and intensities of LUC are carried out to clarify the practical issues in conflict areas and provide a basis for subsequent analysis.

(5) Driving Factor Analysis: Exploring the mechanisms and the spatiotemporal patterns of the LUC in terms of natural factors, such as climate change, and anthropogenic factors, such as policy planning. The findings can contribute to the construction of a conflict early warning system and provide a basis for the simulation of LUC.

(6) Scenario Simulation: Identifying the change trends of various conflict areas under different development scenarios, such as inertia development, arable land protection and ecological protection. By incorporating policy constraints, driving factors and conversion rules, the changes in LUC patterns under different future scenarios can be simulated.

(7) Control Zoning: Based on the dominant functional types, the spatial differentiation characteristics of LUC and the grades of the ecosystem service value, the entire region can be divided into six types of zones, which are ecologically dominant zones, urban construction zones, agricultural production zones, priority treatment zones, controlled development zones and potential development zones.

(8) Application of Results: Based on control zoning and the objectives of territorial spatial management, strategies are formulated for the protection, restoration and utilization of the territorial space. In ecologically dominant zones, the core task is the construction of an ecological civilization, with the implementation of policies that restrict construction and enforce ecological protection control lines.

5. Empirical Analysis

5.1. Study Area

The Gan River is a primary tributary of the Yangtze River and one of the five major rivers in the Poyang Lake Basin, which is distributed between 113°46′ E–116°37′ E and 24°29′ N–29°4′ N (Figure 2). The Gan River Basin has average annual precipitation of 1600.1 mm and an average annual temperature of 18.2 °C [65]. It covers a total area of approximately 80,000 square kilometers and is characterized by a significant topographical gradient, rich mineral resources, favorable hydrothermal conditions and abundant biological resources [66]. According to statistics, the Gan River Basin had a population of 24.50 million and a GDP of CNY 1433.88 billion in 2022, both of which accounted for more than 40% of those of Jiangxi Province. The Gan River Basin is home to two large cities, Nanchang and Ganzhou, as well as a large number of important functional areas for food production. It also includes a large number of nature reserves, which provide important ecosystem services, such as soil conservation, water retention and biodiversity protection. The land in the Gan River Basin has varied utilization suitability and is spatially cross-distributed. In recent years, the rapid expansion of cities, the continuous enhancement of agricultural development activities and the continuous promotion of ecological restoration in the basin have increased the demand for various types of land use, which has led to LUC. Therefore, it is appropriate to choose the Gan River Basin as the case study object. The technical charts of the empirical study are shown in Figure 3.

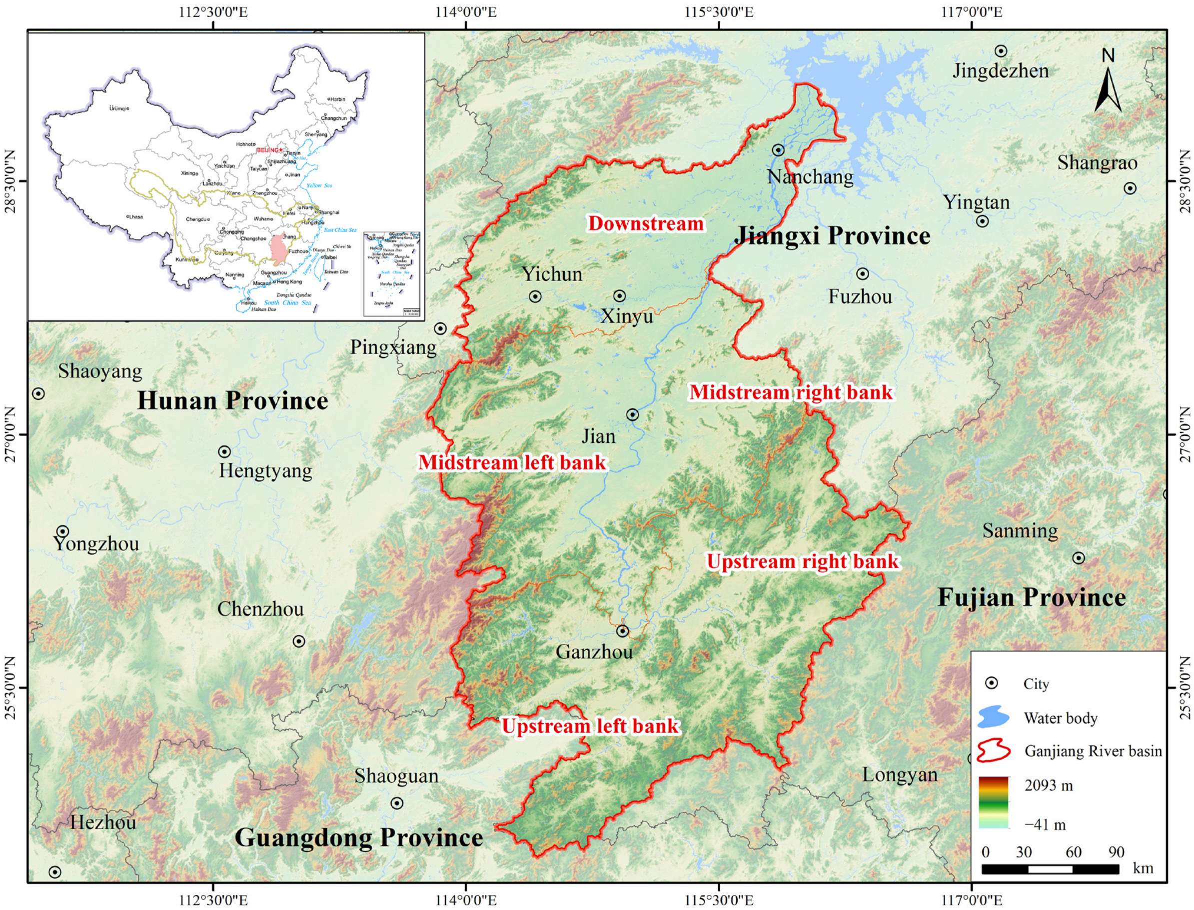

Figure 2. Location of the Gan River Basin.

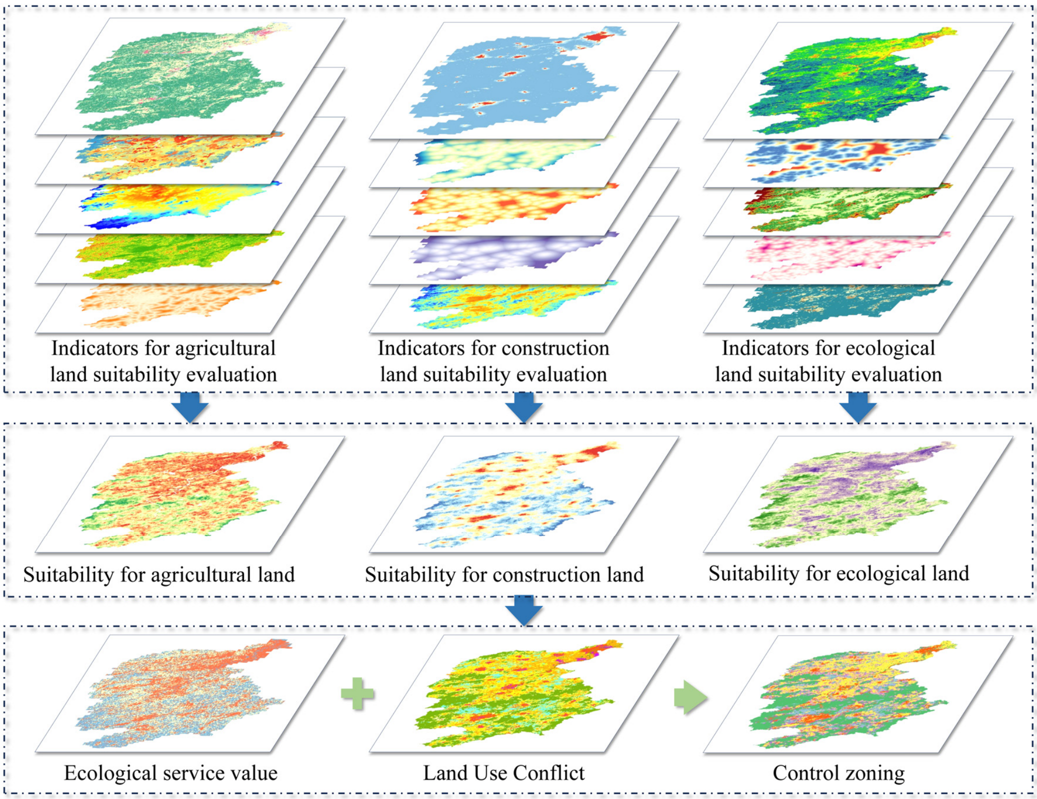

Figure 3. Technical charts for empirical study.

5.2. Methods

5.2.1. Multi-Objective Land Use Suitability Evaluation Method

Suitability Evaluation Indicator System

The essence of LUC lies in the spatial competition between different land use suitability levels, which are influenced by a combination of natural and anthropogenic factors. The multi-objective evaluation method provides a comprehensive evaluation of the land use suitability from multiple dimensions. Drawing on relevant studies [60,61,67], this study selects indicators from various perspectives, including natural factors, social and economic factors, ecological factors, engineering factors and policy factors, to construct suitability evaluation systems for agricultural land, construction land and ecological land, respectively (Tables 2–4). The control lines are delineated by government departments according to the needs of development and ecological protection, representing the current land use policies of government departments, and they are the focus of attention of government departments in land management. However, the urban development boundary control line will inevitably lead to the occupation of arable land and forests by construction land, which is a direct manifestation of LUC. Therefore, the inclusion of the control lines in the evaluation system can effectively reflect the areas and intensity of possible conflicts under the influence of the current policies, and it can further provide a more detailed basis for policy departments to address these risks.

Table 2. Agricultural land suitability evaluation indicator system.

Target	Factor	Index	Weight	Data Source
Suitability of land for agriculture	Natural factors	Slope	0.0703	https://www.gscloud.cn/ (accessed on 12 March 2024)
		Average multi-year precipitation	0.0312	https://data.tpdc.ac.cn/home (accessed on 22 April 2024)
		Effective soil thickness	0.1354	Soil characteristics dataset of China [68] (accessed on 19 April 2024)
		Soil organic matter content	0.0942	Soil characteristics dataset [68] (accessed on 20 April 2024)
		Top soil texture	0.0425	https://www.fao.org/home/en/ (accessed on 20 April 2024)
	Engineering factors	Fragmentation of cropland	0.0530	https://www.resdc.cn/ (accessed on 15 April 2024)
		Distance to water sources	0.1098	https://www.resdc.cn/ (accessed on 15 April 2024)
		Distance from road	0.1329	https://www.openstreetmap.org/ (accessed on 10 April 2024)
		Distance to villages	0.1561	https://www.resdc.cn/ (accessed on 15 April 2024)
	Policy factors	Permanent basic farmland protection red line	0.1746	Natural Resources Bureau

Table 3. Construction land suitability evaluation indicator system.

Target	Factor	Index	Weight	Data Source
Suitability of land for construction	Natural factors	Terrain index	0.1096	https://www.gscloud.cn/ (accessed on 12 March 2024)
		Distance to rivers and lakes	0.0550	https://www.resdc.cn/ (accessed on 15 April 2024)
	Social and economic factors	Nighttime lighting index	0.1862	https://www.resdc.cn/ (accessed on 15 April 2024)
		Population density	0.0930	https://hub.worldpop.org/ (accessed on 19 April 2024)
	Location factors	Distance to road	0.1076	https://www.openstreetmap.org/ (accessed on 10 April 2024)
		Distance to town	0.1517	https://www.resdc.cn/ (accessed on 10 April 2024)
		Distance to educational facilities	0.0548	https://www.openstreetmap.org/ (accessed on 10 April 2024)
		Distance to medical facilities	0.0775	https://www.openstreetmap.org/ (accessed on 10 April 2024)
	Policy factors	Urban development boundary	0.1646	Natural Resources Bureau

Table 4. Ecological land suitability evaluation index system.

Target	Factor	Index	Weight	Data Source
Suitability of land for ecology	Natural factors	DEM	0.0515	https://www.gscloud.cn/ (accessed on 12 March 2024)
		Land cover type	0.1021	http://irsip.whu.edu.cn/resources/CLCD.php [69] (accessed on 25 May 2024)
		NDVI	0.0823	http://www.nasa.gov (accessed on 17 March 2024)
		Soil erosion intensity	0.0656	RUSLE model
		Landscape fragmentation	0.1269	Fragstats (v4.2.1) software
		Biodiversity conservation capacity	0.1605	INVEST model
	Location factors	Distance from construction land	0.0840	https://www.resdc.cn/ (accessed on 15 April 2024)
		Distance from ecological source	0.1679	Natural Resources Bureau
	Policy factors	Ecological protection red line	0.1592	Natural Resources Bureau

Comprehensive Evaluation Method

According to the evaluation system, a comprehensive evaluation method was used to calculate the suitability score with the following formula. The weights of the indicators were determined through the Analytic Hierarchy Process (AHP), and the Weighted Sum tool in the ArcGIS (10.8) software was employed to overlay the indicator layers to obtain land suitability evaluation maps. The formula is expressed as [19,70]

$$S_{ij} = \sum_{j=1}^{n} (w_j s_j) \tag{1}$$

where S_{ij} is the comprehensive score for land suitability. i denotes the code number of the spatial unit; j denotes the type of land, such as agricultural land, construction land or ecological land; n denotes the number of indicators; w_j denotes the weight of the indicator; and s_j denotes the score of the indicator.

5.2.2. Driving Factors Analysis Based on Geographical Detector (GD)

(1) Factor detector

The GD measures the strength of the driving factor's influence on the spatial differentiation of LUC by outputting q values. Higher q values indicate the stronger explanatory power of the driving factor for the characteristics of the spatial differentiation of LUC. The q value can be expressed as [71,72]

$$q = 1 - \frac{1}{N\sigma^2} \sum_{i=1}^{L} N_i \sigma_i^2 \tag{2}$$

where q is the explanatory power of each driving factor for the spatial variability in LUC, with values in the range of [0, 1]. N_i and N are the number of units in stratum i and the whole area, respectively. σ_i and σ are the variance in the LUC for stratum h and the whole region, respectively.

(2) Interaction detector

The interaction detector identifies the interactions between different driving factors, i.e., whether the interactions among driving factors (e.g., X_1 and X_2) increase or decrease the explanatory power for LUC or whether the impacts of these factors on LUC are independent of each other. The evaluation method involves first calculating the q values of the two driving factors X_1 and X_2 (separately: $q(X_1)$ and $q(X_2)$) and then calculating the q values when they interact (separately: $q(X_1 \cap X_2)$), followed by comparing $q(X_1)$, $q(X_2)$ with $q(X_1 \cap X_2)$. The comparative relationships between the three q values and their interpretations are shown in Table 5 [71].

Table 5. Types of interactions and the basis for judgment.

Basis of Judgment	Type of Interaction
$q(X_1 \cap X_2) < Min(q(X_1), q(X_2))$	Weakened nonlinear: the impacts of single driving factors are attenuated nonlinearly by the interaction of two driving factors.
$Min(q(X_1), q(X_2)) < q(X_1 \cap X_2) < Max(q(X_1), q(X_2))$	Weakened univariate: the effects of single driving factors are weakened by interaction.
$q(X_1 \cap X_2) > Max(q(X_1), q(X_2))$	Enhanced bivariate: the effects of single driving factors are enhanced by interaction.
$q(X_1 \cap X_2) = q(X_1) + q(X_2)$	Independence: the effects of driving factors on LUC are independent of each other.
$q(X_1 \cap X_2) > q(X_1) + q(X_2)$	Nonlinear enhanced: the impacts of single driving factors are nonlinearly enhanced by interaction.

5.2.3. LUC Discriminant Matrix and Zoning Control Methodology

Building on the results of the land use suitability evaluation, a discrimination matrix was constructed to identify the types and intensities of LUC. Since existing research has yet to establish a unified coordination plan for conflicts among the suitability for agricultural production, urban construction and ecological protection, this study integrated the spatial matching characteristics of the ecosystem service values with the conflict types and intensities [73]. The ecosystem service value layers were obtained from the Chinese Academy of Sciences, and the layer overlay analysis was completed in the ArcGIS software. Consequently, the territorial space of the Gan River Basin was divided into six control zones (Figure 4). For example, E_1-A_1-C_1-S_1-Q_4 means that the area has high ecological land suitability (E_1), high agricultural land suitability (A_1) and high construction land suitability (C_1); there is an intense LUC; and the area has strong ecosystem services (S_1), so the area should be designated as a priority management zone (Q_4). Furthermore, corresponding development strategies were then proposed for each zone, tailored to their specific characteristics.

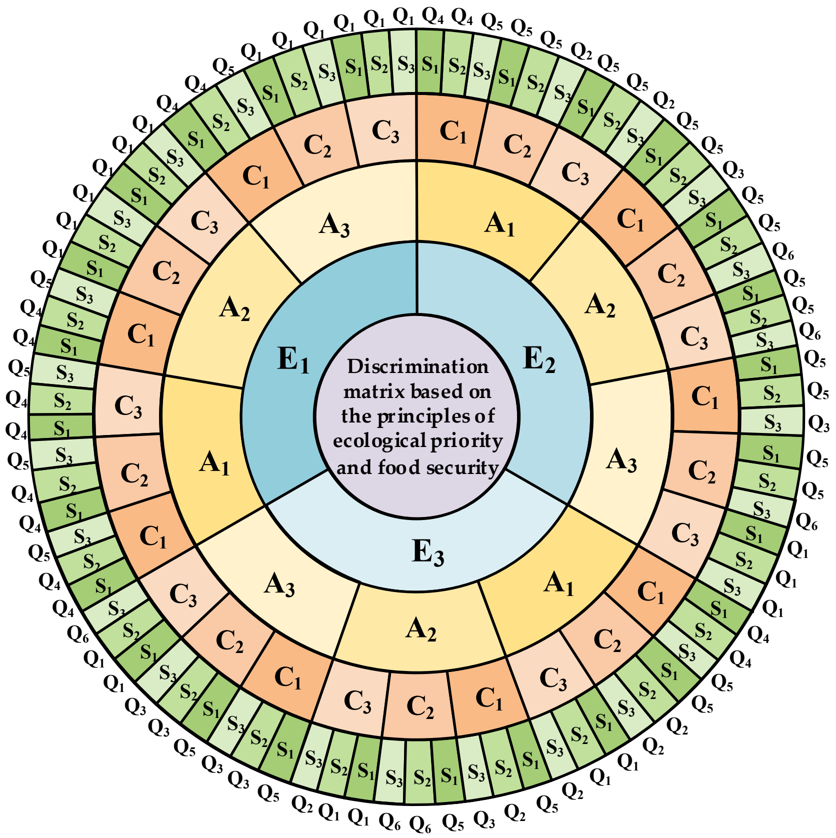

Figure 4. Schematic of the discrimination matrix for LUC identification and control zoning. Notes: E, A, C represent the suitability of ecological land, agricultural land and construction land; S represents the ecosystem service value; 1, 2, 3 represent high, moderate and low levels. For example, E_1 indicates a high suitability level for ecological land, A_2 indicates moderate suitability for agricultural land and C_3 indicates low suitability for construction land. Q_1, Q_2, Q_3, Q_4, Q_5 and Q_6 represent ecologically oriented zones, agricultural production zones, urban construction zones, priority treatment zones, restricted development zones and development potential zones.

5.3. Results

Under the combined influences of the natural background, human activities and climate change, the land use in the Gan River Basin has undergone significant changes, with different land use types competing with each other and prominent conflicts arising. Driven by the comprehensive requirements of maintaining ecological security, ensuring grain security and sustaining economic growth, the LUC in the Gan River Basin has become increasingly intense. Consequently, LUC has emerged as an unavoidable issue in the management of the Gan River Basin.

5.3.1. Land Use Suitability

The areas of land suitability in each sub-basin were tabulated through the zoning statistics tool of the ArcGIS software (Table 6 and Figure 5), and the suitability for territorial spatial development and utilization was mapped out (Figure 6). The results showed that the areas with high suitability for agricultural land were mainly concentrated in the downstream region of the Gan River and the left bank of the middle reaches, with an area of 6738.64 km^2 and 2769.04 km^2, respectively, accounting for 45.76% and 18.80% of the high-suitability area for agricultural land in the whole basin, due to the fact that there were more plains and basins here. The areas with high suitability for construction land were mainly distributed in the downstream region and the left bank of the upper reaches of the Gan River Basin, with an area of 2224.27 km^2 and 906.23 km^2, accounting for 50.75% and 20.68% of the high-suitability area for construction land in the whole basin, respectively, due to the obvious transportation and location advantages of these areas. Areas with high ecological land suitability were mainly located in the upper and middle reaches of the Gan River Basin, characterized by high forest cover and abundant hydrothermal resources, providing habitats for the survival and reproduction of wildlife.

Table 6. Area of land suitability distribution by sub-basin (km^2).

Suitability		UL	UR	ML	MR	DS	Total
A	A_1	1447.13	1399.37	2769.04	2372.72	6738.64	14,726.90
	A_2	7005.86	4549.23	6261.00	4904.23	6810.93	29,531.26
	A_3	12,280.59	6024.76	8095.41	5283.77	3867.62	35,552.15
C	C_1	906.23	256.89	610.61	384.70	2224.27	4382.70
	C_2	6224.85	3435.16	6770.92	5101.75	9431.52	30,964.19
	C_3	13,602.50	8281.30	9743.92	7074.28	5761.41	44,463.42
E	E_1	5432.22	1873.14	3400.30	2399.83	1762.12	14,867.61
	E_2	8725.38	5388.33	5884.05	4173.57	3099.52	27,270.85
	E_3	6575.99	4711.89	7841.09	5987.32	12,555.56	37,671.85
Total		20,733.59	11,973.35	17,125.45	12,560.73	17,417.20	79,810.31

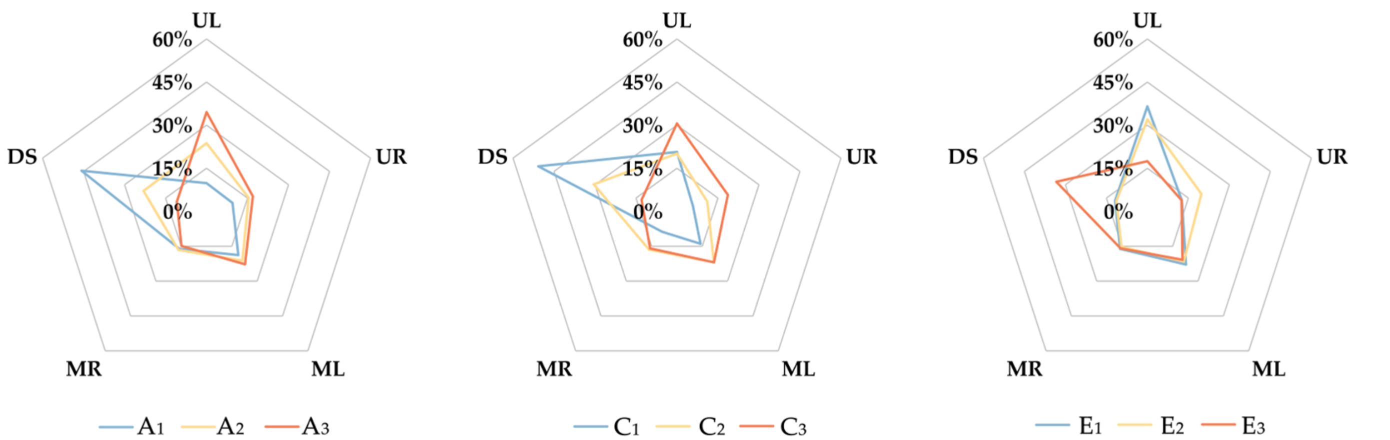

Figure 5. Statistical plot of land suitability distribution by sub-basin area. Notes: UL, UR, ML, MR and DS represent the upstream left bank, upstream right bank, midstream left bank, midstream right bank and downstream region of the Gan River Basin.

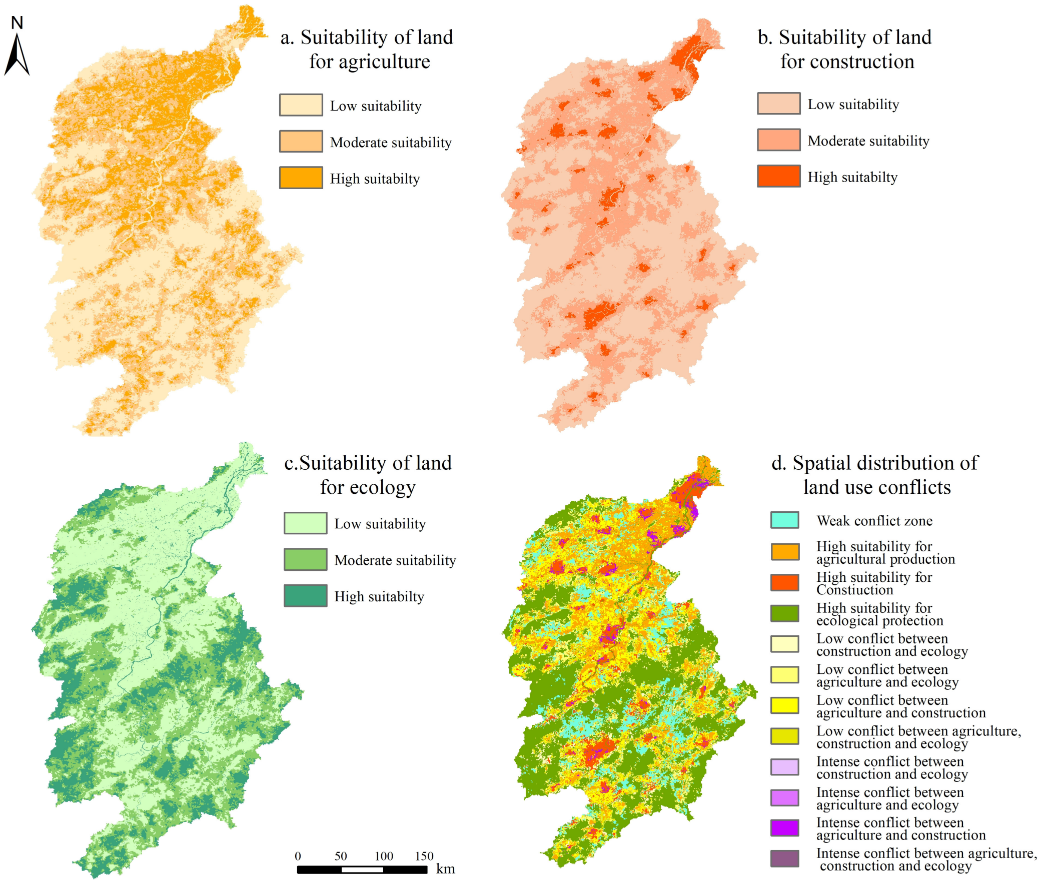

Figure 6. Results of land suitability and LUC identification in the Gan River Basin.

5.3.2. Land Use Conflict

LUC areas were tabulated for each sub-basin with the zoning statistics tool of the ArcGIS software (Table 7). The intense conflict zones were mainly located in the downstream region, with an area of about 770.68 km^2, accounting for 4.42% of the total area of the downstream region (Figure 7). The downstream region is spread over a vast plain, where Nanchang, the capital of Jiangxi Province, and the most important agricultural production areas of Jiangxi Province are located, resulting in a large area of overlap between the high-suitability zones for agricultural land and construction land. The zones of intense conflict are least distributed on the right bank of the upper reaches of the Gan River, with an area of about 43.89 km^2, accounting for 0.37% of the right bank of the upper reaches. The right bank of the upper reaches of the Gan River is characterized by a complex topography, the distribution of a large number of nature reserves and low economic development, where the ecology has been better protected for a long time and resource differentiation is obvious; this resulted in reduced spatial intersection among the highly suitable zones for different types of land utilization and relatively less LUC.

Table 7. Area of LUC type distribution by sub-basin (km^2).

Conflict Type	UL	UR	ML	MR	DS	Total
Intense conflict	176.86	43.89	175.57	89.07	770.68	1256.07
Low conflict	5921.48	3404.18	5203.73	3923.13	4821.61	23,274.13
Weak conflict	14,635.25	8525.29	11,746.15	8548.52	11,824.90	55,280.10
Total	20,733.59	11,973.35	17,125.45	12,560.73	17,417.20	79,810.31

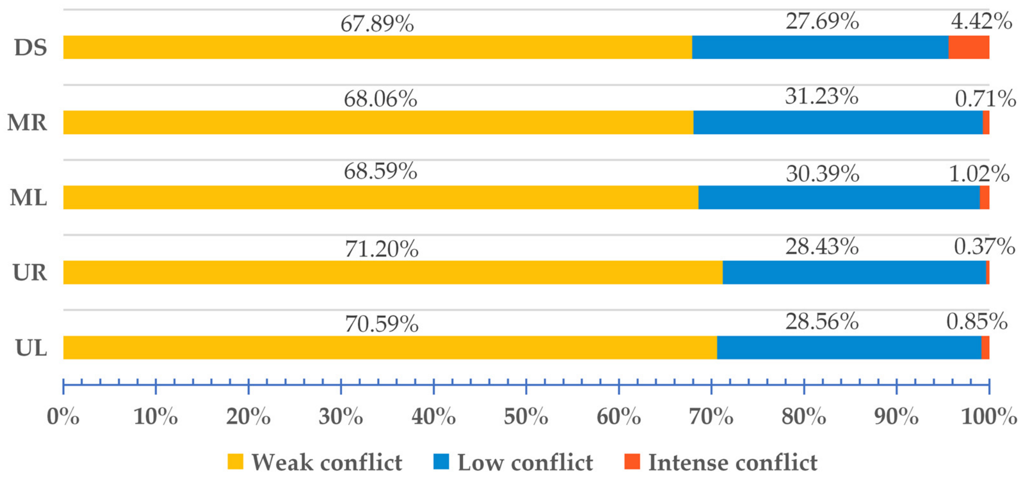

Figure 7. Statistical plot of LUC intensity distribution by sub-basin area.

Intense conflict zones are more likely to occur at the junction of urban and agricultural land, where the terrain is flat, the advantages of transportation and the location conditions are obvious, the educational and medical resources are favorable and the potential for economic development is greater, so that agricultural land in these areas is more likely to be encroached upon by construction land. As shown in Figure 8, the transportation routes cross a large area of agricultural land during the building process, and the villages and towns render the agricultural land fragmented; the agricultural land on both sides of the road was transformed into construction land from 1990 to 2020.

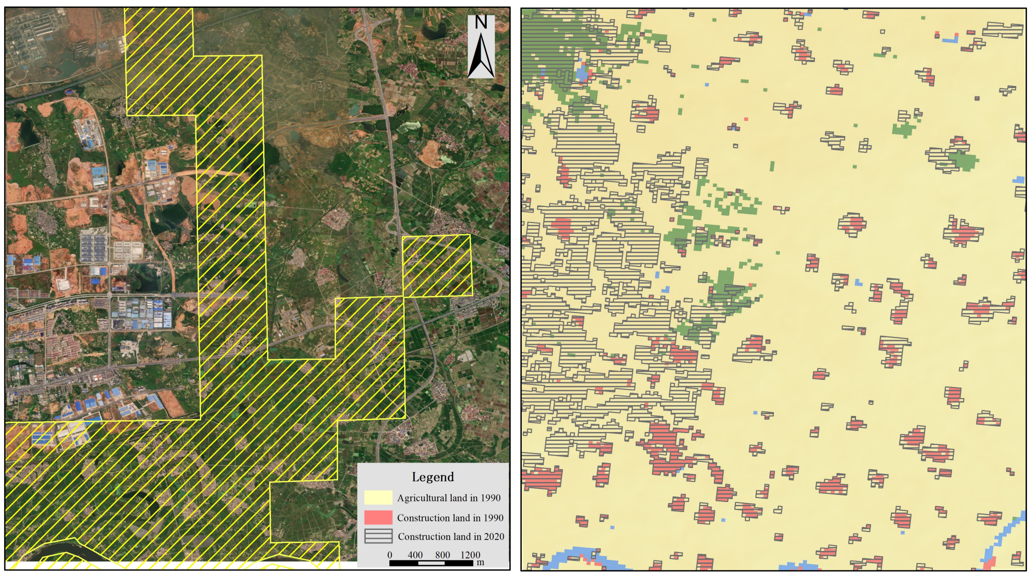

Figure 8. Images of areas with intense conflict between construction and agricultural land.

The conflicts between agricultural and ecological land mainly occur in the transition zone from traditional agricultural areas to hilly areas in the middle and upper reaches of the Gan River, because there are fewer plains in these areas and there is a tendency for agriculture to spread from the valleys to the hilly areas. However, due to the limitations of the topography and the difficulties of agricultural development, these zones are moderately suitable zones for agricultural and ecological land use, and thus the degree of conflict is low. As shown in Figure 9, from 1990 to 2020, the agricultural land expanded in strips into forested areas at a slower rate.

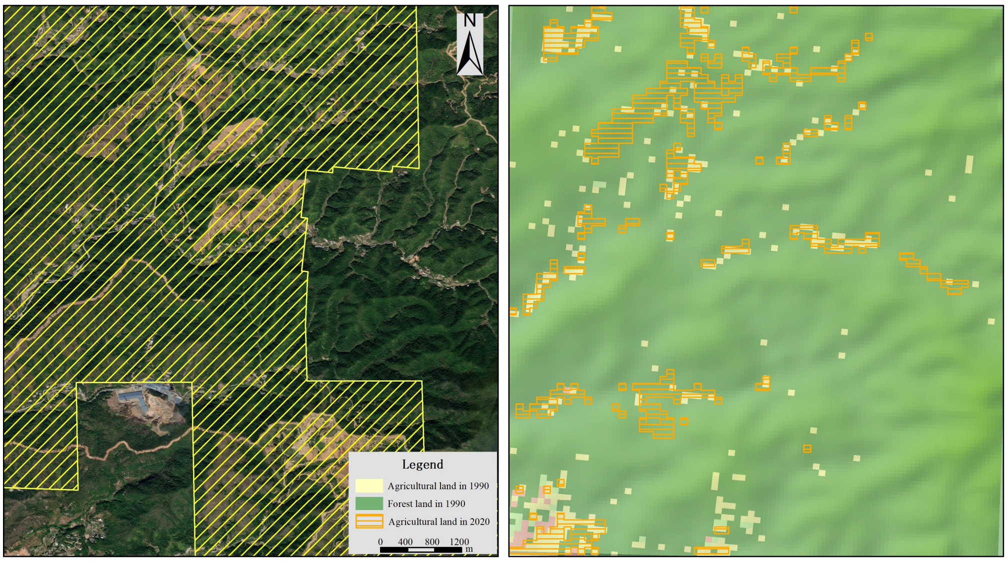

Figure 9. Images of areas with conflict between ecological and agricultural land.

5.3.3. Driving Factors

The influence of the driving factors on LUC was analyzed by applying the geographical detectors. As shown in Figure 10, precipitation, the population density and the delineation of ecological control lines in the current policy were important factors in the generation of moderate conflicts in the single-factor analysis, with q values of 0.436, 0.427 and 0.318, respectively. According to the dual-factor interaction detection analysis, fewer LUC areas are likely to occur under the interaction among the terrain index and population density, the population density and NDVI, precipitation and the NDVI and the population density and distance from water bodies. For intense LUC, the results of the single-factor analysis show (Figure 10) that the nighttime lighting index and the delineation of urban development boundaries under the current policy are important factors regarding the emergence of intense LUC, with q-values of 0.474 and 0.422, respectively. The results of the dual-factor interaction detection show that intense LUC areas are more likely to appear under the interactions of nighttime lighting and precipitation, nighttime lighting and the population density and nighttime lighting and the delineation of the ecological protection red line under the current policy. The results show that LUC is intensified by the interaction among climate change and human activities.

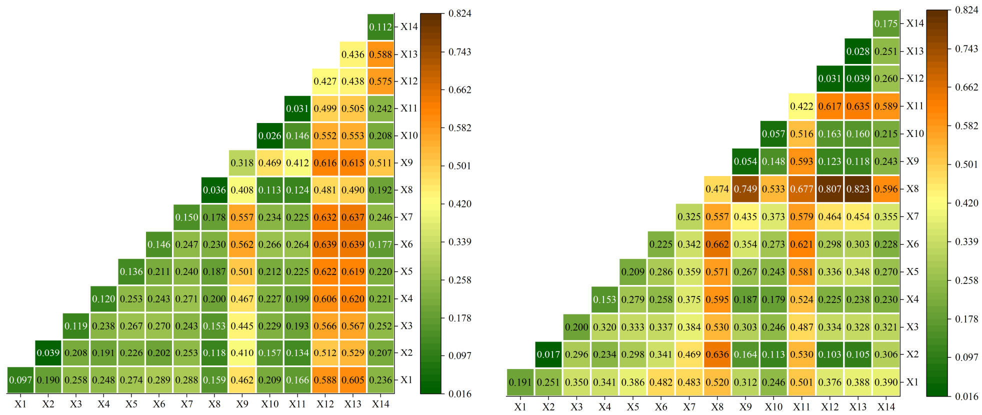

Figure 10. Geographical detection q values for driving factors of low LUC and intense LUC. Notes: X1 to X14 represent the distance from the city, distance from the ecological core, distance from roads, distance from rural areas, distance from water bodies, topographic index, NDVI, night light index, ecological control line planning, permanent basic farmland planning, urban development boundary planning, population density, precipitation and slope, respectively.

5.3.4. Control Zoning

Based on the spatial distribution and characteristics of the LUC in the Gan River Basin, six control zones were delineated (Figure 11), and strategies for their development and management are proposed. (1) The urban construction zones focus on socioeconomic development, with the main task being the creation of efficient urban spaces. (2) The ecological protection zone is led by the construction of an ecological civilization, and the occupation of agricultural and construction land in this area is strictly controlled to ensure ecological land and ecological quality. (3) In agricultural production zones, strict adherence to the grain security strategy is required to prevent encroachment on the permanent basic farmland protection control lines. This involves stringent control over the conversion of arable land to non-agricultural uses, along with intensified efforts regarding pollution control. (4) The priority treatment zones are targeted for comprehensive land consolidation and ecological restoration, aligned with the regional development goals. (5) In controlled development zones, strategies are implemented to slow down the pace of exploitation and prioritize ecological and grain security. (6) The potential development zones provide flexible spaces for future regional growth, with an emphasis on meeting future development demands.

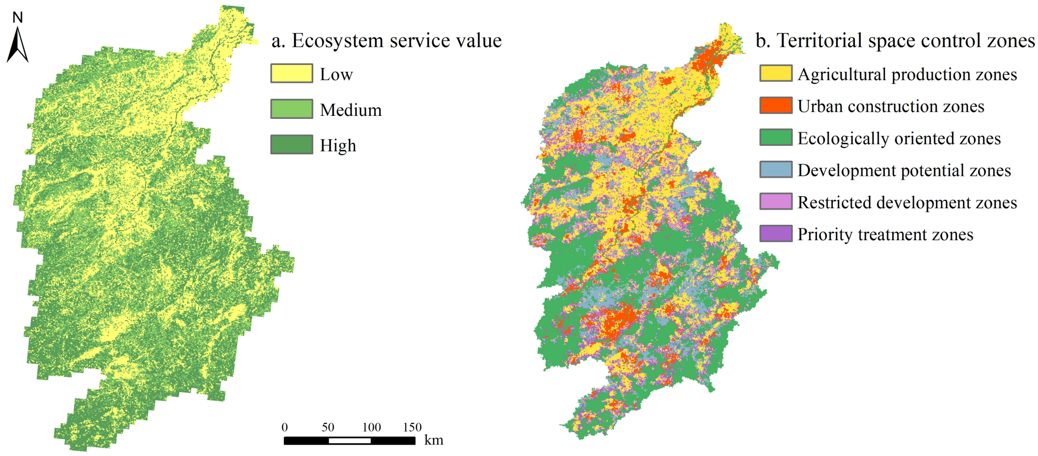

Figure 11. Ecosystem service value levels and territorial space control zoning in the Gan River Basin.

6. Discussion

Under the framework and development trends of territorial space management in the new period, through a detailed analysis of the concepts and characteristics related to LUC and zoning control, this study proposes a research paradigm for LUC identification and territorial spatial zoning control. Compared with traditional research, the paradigm proposed in this study is complete, flexible and open-ended, as it can be adjusted according to the actual situation or different research targets and continuously supplemented and improved according to the practical needs of territorial spatial management in the process of development, so it has wider application scope. Although adjustments for different regions are necessary, in this paradigm, we emphasize that the data can be spatialized to reflect the LUC and zoning control in more detail. When the accumulation of historical data is insufficient, it is possible to consider disregarding the scenario simulation stage and performing a fuller investigation of the current situation. For instance, in the suitability evaluation stage, the selection of indicators should aid in reflecting the actual background of the region, and it may vary for different study areas [74]. In summary, this method must be continuously adapted to the dynamics of LUC research and evolving territorial spatial management policies and be refined through ongoing practice.

The results of the land suitability evaluation in the Gan River Basin are characterized by obvious spatial differentiation. The highly suitable areas for agricultural land are mainly concentrated in the basin and plains in the middle and downstream regions of the Gan

River Basin. The highly suitable areas for construction land are mainly in the buffer zones of large cities such as Nanchang and Ganzhou. This is confirmed by the findings of Jing et al., indicating that the spatial distribution pattern of production suitability is similar to that of living suitability, with highly suitable areas mainly located in river valleys with a low topography [75]. The highly suitable areas for ecological land are mainly distributed in mountainous areas with a complex topography, such as the Luoxiao Mountains and Julian Mountains, as well as in the buffer zones of important rivers and lakes, such as the Gan River. Overall, the dominant functions of the Gan River Basin present obvious gradient characteristics. The ecological protection function is more significant in the middle and upper reaches, and the agricultural production function is more important in the middle and lower reaches, while the areas with strong urban construction functions are more concentrated in the lower reaches. Wang et al.'s study showed that the most important ecological regions include mainly river headwater areas, as well as areas with concentrated forest cover, which is consistent with the findings obtained in this study [18]. Furthermore, Zhang et al. found that the ecological function showed a clear inverse distribution in general compared with the other functions, and the areas with high ecological function values were mainly distributed in the western mountainous areas; these were influenced by both the physical conditions and human activities [41]. This finding is similar to those of this study, which found that the high-suitability zones for agricultural and construction land were mainly concentrated in the downstream region with flat terrain, while the high-suitability zones for ecological land were mainly distributed in the upstream mountainous areas.

To better understand and mitigate LUC, the driving factors should be considered. The study by Wang et al. concluded that the ecological intertwining zones between cropland, watersheds and unutilized land show intensified conflicts. Moderate conflicts are concentrated in the intersections between cropland and rural settlements and between forests and grassland. The intensification of LUC is mainly driven by competition arising from land use fragmentation [22]. The views of Wang et al. are similar to those in this study, as the satellite overlay analysis in the empirical study showed that the fragmentation of arable land around towns has led to the gradual erosion of such land. Moreover, LUC tends to occur at the urban–rural interface and the junctions of agricultural land and ecological land. A study conducted in China by Zong et al. concluded that land reclamation has a significant effect on LUC and that larger slopes reduce the possibility of LUC due to their weaker suitability for development. The population density and secondary and tertiary industries are also important factors that contribute to LUC [76]. The conclusions of Zong et al. are consistent with this study, as the driving factor analysis showed that LUC areas are more likely to occur when the slope interacts with the population density and nighttime lighting index. The higher the nighttime lighting index, the more developed the secondary and tertiary industries; coupled with the effect of population agglomeration, the land demand is expanding, leading to more intense LUC. The study by Peng et al. showed that water bodies and grassland near city centers have a higher probability of transitioning to construction land, which suggests that densely populated areas with a high intensity of economic construction and covered by vegetation are more prone to LUC; therefore, these areas should be focused on and controlled [17]. This view is similar to the findings of this study. LUC areas are more likely to occur as a result of the interaction between climate change and human activities, and it is therefore necessary to develop responses to global climate change in order to achieve the mitigation of LUC [77].

As the results of the territorial spatial control zoning showed, the priority treatment zones are mainly the areas around small and medium-sized towns and cities that are developing rapidly, because these areas need more space for development to grow their urban areas and industries. In addition, the junctions of agricultural and ecological land in the middle and upper reaches of the basin also need to be focused on. Because there are fewer plains and more dense mines, agricultural development frequently extends towards the low hills and gentle slopes, and the mining activities are intensive, so that areas with high ecological value are vulnerable to damage [78]. This study is of great significance in promoting the effective management of territorial space and the efficient utilization of land resources. The six types of zoning cover the protection, utilization and restoration of territorial space, taking into account both ecological protection and socioeconomic development, which are essential for the comprehensive, balanced and sustainable development of the region [79]. The management strategies are formulated based on the actual characteristics of the LUC in each zone, with general applicability at a macro level, but the specific implementation process should be improved by taking into account the actual situation in the region.

Currently, more traditional studies identify LUC based on the suitability of the land in terms of production, living and ecology, while this study focuses on a suitability evaluation in terms of agricultural production, urban construction and ecological protection and emphasizes the dominant functions, enabling us to better define the boundaries of the functions. For example, arable land has both production and ecological functions, such as carbon sequestration and landscape esthetics, so it may be difficult to define the production, living and ecological functions of this land use. In this study, the dominant function of arable land was clearly defined as agricultural production, and the problem of functional ambiguity has been solved; thus, we avoid the influence of the evaluation method's limitations on the results of LUC identification. In addition, the graded classification of the different functions makes them comparable to each other, which lays the foundation for the accurate identification of conflict areas and their intensity [56].

7. Conclusions

The purpose of LUC identification and territorial spatial zoning control is to achieve efficient resource utilization and orderly territorial spatial development. This method synthesizes various factors affecting agricultural production, urban construction and ecological protection; highlights differences in land use suitability under different goal orientations; and identifies potential conflict areas. In response to differences in the conflict types and intensities, territorial spatial control zoning is divided. The zoning results emphasize both systematic and holistic approaches, as well as localized and unitary aspects, ensuring scientific rigor and feasibility. Through the empirical study of the Gan River Basin, the suitability characteristics of territorial spatial utilization were elucidated, the intensities of the LUC and its spatial patterns were examined, and the key areas for control were identified. The six regions delineated in the empirical study are designed to meet the needs of food production, urban development and ecological protection in the Gan River Basin. The zoning results are in accordance with the actual situation in the Gan River Basin. This work provides a scientific foundation for the promotion of the coordination, stability and sustainability of territorial space. It demonstrates the practicality of the principles and methods used for LUC identification and territorial spatial zoning control. The main conclusions of this study can be drawn as follows.

(1) The research paradigm proposed in this study has applicability. This is verified in the driving factor analysis and satellite overlay analysis, where the LUC in the Gan River Basin is mainly caused by urban expansion and cultivated land resettlement under the dual effects of climate change and human activities.

(2) The land suitability evaluation in the empirical study showed that the land suitability in the Gan River Basin exhibited an obvious distribution characteristic by sub-basin. The suitability regarding agricultural land and construction land shows a trend of being low in the upper reaches and high in the downstream region, with 45.76% of the highly suitable areas for agricultural land and 50.75% of the highly suitable areas for construction land distributed in the downstream region of the Gan River Basin. The suitability of ecological land shows a trend of being high in the upper reaches and low in the downstream region, and 36.54% of the high-suitability areas for ecological land are distributed in the left bank of the upper reaches.

(3) The results of the LUC identification in the empirical study showed that the areas of intense conflict, low conflict and weak conflict accounted for 1.57%, 29.16% and

69.26% of the basin area, respectively. Of the intense conflict areas, 4.42% of the areas in the lower Gan River Basin are in intense conflict, while only 0.37% of the right bank of the middle reaches is in intense conflict, which aligns with the results of the land suitability evaluation, as the suitability of both agricultural land and construction land is high in the downstream region. The main types of intense conflict are between construction land and agricultural land, followed by conflicts between agricultural land and ecological land.

(4) The results of the driving factor analysis in the empirical study showed that, among the driving factors of intense conflict, the interaction detection q values of precipitation with the nighttime lighting index, precipitation with the population density and precipitation with the ecological protection control line were 0.823, 0.807 and 0.749, respectively. This indicates that the combination of human activities and climate change is an important factor in the emergence of LUC. Climate warming and the unbalanced spatial distribution of precipitation, as well as increasing space for human activities and the increased food demand, have led to the continuous expansion of development and construction into agricultural areas and the spread of agricultural production activities into gently sloping areas with ecological functions. This conclusion was also verified in the satellite overlay analysis.

By applying LUC identification and zoning control, the efficiency and functionality of territorial spatial governance can be comprehensively enhanced, and a coordinated and rationally structured territorial spatial framework can be constructed. This provides a decision-making basis for regional territorial spatial planning and territorial spatial governance. Additionally, it offers an effective pathway for the achievement of sustainable territorial spatial development.

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