

Postprint: Development Suitability Zoning of Unused Land in Huanghua City

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Date: 2018-01-05T00:00:00+00:00

Abstract

Unused land constitutes an important land reserve resource, and investigating its development suitability and development models represents a critical initiative for achieving sustainable land use, which is of great significance for ensuring national food security, realizing economic development, and promoting ecological civilization construction. Meanwhile, scientifically guiding land development and utilization, conducting suitability evaluations for potential development directions of unused land, and researching and determining development zones are also key priorities for promoting innovation in territorial science and technology. In this context, this paper takes Huanghua City, Hebei Province as an example, conducts a threefold evaluation of unused land for agricultural suitability, construction suitability, and ecological risk, and combines trade-off models and genetic algorithms to perform a coupled analysis of the above three evaluations to determine development zones, thereby solving the trade-off problems among multiple development directions and serving as a demonstration for unused land development nationwide. The research shows: 1) The agricultural development suitability of unused land in Huanghua City can be divided into 4 grades, mainly consisting of Grade N (unsuitable) agriculturally suitable unused land concentrated in the eastern coastal areas of the city; 2) The construction development suitability can be divided into 3 grades, mainly consisting of Grade J3 (low suitability) construction-suitable unused land concentrated in the central and western parts of the city; 3) Ecological risk zones can be divided into 5 levels, showing a spatial pattern of high risk in the east and low risk in the west, mainly consisting of unused land with medium-low and medium-high ecological risk; 4) Unused land resources in Huanghua City can be divided into three key development zones: cultivated land, construction land, and ecological land. Among them, key development zones for cultivated land are mainly distributed in the central and western parts, key development zones for construction land are mainly distributed around Huanghua Town, and key development zones for ecological land are mainly located in the eastern coastal areas. The research re-

sults can provide scientific and technological support for resolving the dilemma between land supply and demand.

Full Text

Preamble

Regionalization of Suitable Development on Unutilized Land in Huanghua City

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Abstract: As an important reserve land resource, studying the development suitability and patterns of unutilized land constitutes a crucial measure for achieving sustainable land use, with significant implications for safeguarding national food security, promoting economic development, and advancing ecological civilization. Scientifically guiding land development and utilization through suitability evaluation and zoning determination represents a key focus of territorial science and technology innovation. This paper takes Huanghua City in Hebei Province as a case study, conducting triple evaluations of unutilized land for cultivation suitability, construction suitability, and ecological risk. By integrating a trade-off model with genetic algorithms to couple these three evaluations, we determine development zones to resolve trade-offs among multiple development orientations, providing a demonstration for unutilized land development nationwide. The results indicate: (1) Cultivation suitability of unutilized land in Huanghua can be divided into four grades, predominantly Grade N (unsuitable) concentrated in the eastern coastal area; (2) Construction suitability can be divided into three grades, mainly Grade J3 (low suitability) concentrated in the central and western parts of the city; (3) Ecological risk zones can be classified into five levels, showing a spatial pattern of high risk in the east and low risk in the west, primarily comprising medium-low and medium-high risk areas; (4) Unutilized land resources in Huanghua can be divided into three key development zones: cultivated land, construction land, and ecological land. The cultivated land development zone is mainly distributed in the central and western regions, the construction land development zone is concentrated around Huanghua Town, and the ecological land development zone is primarily located in the eastern coastal area. These results provide scientific support for resolving the dilemma between land supply and demand.

Keywords: unutilized land; suitability evaluation; ecological risk evaluation;

development zoning; Huanghua City

1 Introduction

China is currently in a critical period of transformation and development. With the rapid advancement of industrialization and urbanization, the rational development of land resources and their sustainable utilization have gradually become hot-button issues. On one hand, the demand for construction land continues to increase, creating unprecedented tension between supply and demand. On the other hand, the protection of cultivated land and prime farmland faces an exceptionally severe situation, with the goals of cultivated land requisition-compensation balance and total quantity balance facing serious challenges [1-4]. To resolve this “dilemma” in land and resources management between safeguarding development and protecting resources, unutilized land development has been rapidly promoted across various regions under the organization and guidance of land and resources departments. As an important reserve land resource, evaluating the development suitability of unutilized land and determining development zones plays a positive role in alleviating land supply-demand contradictions and ensuring economic and social development. It also represents an important approach to breaking through index constraints and resource bottlenecks in land use planning revisions. In 2013, the Ministry of Land and Resources explicitly stated in the *National Territorial Planning Outline (2011-2030)* that “promoting the development and utilization of unutilized land is an inevitable choice for coordinating economic development with cultivated land protection and resolving the land supply-demand dilemma, as well as an important way to mitigate land acquisition conflicts and promote social harmony and stability.”

In recent years, academic circles both domestically and internationally have gradually attached greater importance to research on unutilized land resources. Some scholars have approached the issue from practical work perspectives, analyzing development models and existing problems in unutilized land development across China under the guidance of land and resources departments. Common issues include the widespread phenomenon of “occupying good land and compensating with inferior land” [5-7], as well as ecological problems caused by unreasonable development, such as land desertification, soil erosion, and soil salinization [8-10]. Other scholars have conducted in-depth research to seek solutions to these problems. For instance, researchers including Pereira [11], Fitzsimons [12], Mehrnoush [13], Tang Changchun [14], and Jin Gui [15] have continuously enriched and improved land evaluation indicator systems, conducting suitability evaluations from different perspectives to guide land use zoning. Zhang Fengrong [16], Shu Bangrong [17], Wu Dafang [18], and Guan Xiaoke [19] have enhanced the proportion of ecological indicators in evaluation systems from the perspectives of ecological security and ecological suitability. Liao Heping [20], Liu Yaolin [21], and Ouyang Zhiyun [22] have introduced fuzzy evaluation methods, computational intelligence theory, and ecological niche suitability methods into land evaluation, expanding the methodological system of this

field. However, overall, existing literature has primarily focused on unutilized land as a whole, with fewer studies conducting suitability evaluations for more detailed unutilized land categories. Furthermore, multi-objective analysis and multi-purpose coupling decision-making methods for more detailed unutilized land categories remain to be explored.

Against this background, this paper takes Huanghua City in Hebei Province as a case study. By establishing evaluation indicator systems for common unutilized land uses (suitable for cultivation and construction), we employ an interdisciplinary approach using the comprehensive index method, trade-off model, and genetic algorithm to assess land development utilization and its risks, thereby determining land use development zones through coupling analysis. First, we conduct triple evaluations of unutilized land for cultivation suitability, construction suitability, and ecological risk. Second, we couple these three evaluations using a trade-off model and genetic algorithm to determine land use development zones, aiming to provide new methods and research demonstrations for unutilized land development and land use planning in China.

2.1 Study Area Overview

Huanghua City is located in the southeastern part of Hebei Province, between 38°09' -38°39' N and 117°05' -117°49' E. The terrain is low-lying and flat, with elevations ranging from 1 to 7 meters. The city has an average annual temperature of approximately 13°C, annual evaporation of 1,500-2,000 mm, and precipitation of 500-600 mm. The soil is generally poor and severely salinized, with salt content above 0.3% and reaching up to 3.29% at maximum. Soil organic matter content is relatively low, averaging 9.5 g · kg⁻¹. The city has 66,590.53 hectares of unutilized land, accounting for 29.46% of the total land area, primarily comprising saline-alkali land, other grassland, inland beaches, and coastal beaches, with areas of 34,075.65 ha, 2,706.32 ha, 6,811.13 ha, and 22,997.43 ha, respectively. Saline-alkali land accounts for the largest proportion at 51.17% of the city's unutilized land, followed by coastal beaches at 34.54%, while other grassland has the smallest distribution area at 4.06%.

2.2 Data Sources

The suitability evaluation and development zoning of unutilized land resources involve numerous indicators across ecological, social, and economic dimensions, requiring extensive data. Our research data were obtained from two sources: primary data from field surveys of 303 valid sample points, and secondary data from Hebei provincial departments of land and resources, construction, water conservancy, and environmental protection. Specifically: (1) From the Land and Resources Bureau: 1:10,000 latest land use change survey results, 1:10,000 remote sensing imagery, new round of municipal and township-level land use master plans, land consolidation and prime farmland plans, geological disaster prevention plans, and cultivated land reserve resources survey data. (2) From

the Construction Planning Bureau: urban master plans, urban system plans, and technical regulations for building foundation bearing capacity. (3) From the Water Conservancy Bureau: water conservancy records, current status and comprehensive evaluation of water resources development and utilization, and documents related to groundwater extraction. (4) From the Environmental Protection Bureau: relevant materials for ecological and environmental planning.

2.3.1 Unutilized Land Suitability Evaluation Method

1) Suitability Evaluation Steps

The premise of unutilized land evaluation is the rational division of evaluation units. Common division methods include overlay, parcel, and grid methods, with different methods yielding different evaluation results. The parcel method requires familiarity with land conditions throughout the study area, avoids breaking parcel boundaries during unit division, produces operationally convenient results, and clarifies development directions for specific parcels.

The specific operational steps are as follows: First, establish an indicator system based on unutilized land characteristics and topographic constraints on cultivation or construction uses. The Delphi method is used to determine indicator selection, scoring, and weighting through back-to-back communication to solicit expert opinions, which are refined through multiple rounds to achieve consensus. Second, quantitatively process relevant data for each evaluation indicator, determine suitability attribute values, input them into the attribute database, and generate vector-format suitability base maps. Third, process the base maps through buffering and rasterization to generate raster-format single-factor evaluation maps. Fourth, calculate unutilized land development suitability using the comprehensive index method. Fifth, classify suitability grades using ArcGIS natural breaks method.

2) Suitability Evaluation Method—Comprehensive Index Method

The comprehensive index method is employed for suitability evaluation, conducting weighted overlay analysis based on each indicator's score and weight to calculate a comprehensive score [15,23]:

$$H = \sum_{j=1}^n w_j f_j$$

where H is the comprehensive score; w_j is the weight of the j th evaluation factor; f_j is the quality score of the j th evaluation factor; and n is the total number of evaluation factors. The total weight sums to 1, with comprehensive scores ranging from 0-100. ArcGIS natural breaks method is used to reclassify the comprehensive scores according to the evaluation system, dividing them into suitability grade intervals to obtain final comprehensive results.

2.3.2 Ecological Risk Evaluation for Unutilized Land Development

Ecological risk evaluation for unutilized land development employs integrated knowledge from land science, environmental science, ecology, geography, and biology, using quantitative analysis techniques to predict, analyze, and evaluate potential damage to ecosystems and their components from proposed unutilized land development. Therefore, when determining evaluation indicators, both unutilized land characteristics and surrounding environmental conditions must be considered. The Delphi method is used for indicator selection, scoring, and weighting, with the comprehensive index method applied in the evaluation process.

2.3.3 Land Use Development Zoning Method

The decision-making process for rational unutilized land development patterns requires comprehensive consideration of multiple social, economic, and ecological factors [24-25]. Conflicts may exist among the suitability objectives pursued by different decision-makers. To achieve relative balance among final objectives and coordinate different stakeholder interests, equilibrium points must be sought among conflicting goals. Based on the existing triple evaluations of cultivation suitability, construction suitability, and ecological risk, this study combines a trade-off model with genetic algorithms for coupling analysis to determine land use development zones.

(1) Construction of the Trade-off Model

Genetic algorithms are a class of stochastic optimization algorithms that effectively utilize existing information to guide searches and improve optimization quality through continuous evaluation of chromosomes and action on genes within chromosomes. This study employs genetic algorithms with unutilized land use types (cultivation-suitable, construction-suitable, and ecology-suitable—all undeveloped land that can be used as forestland, pasture, or maintained in its current state according to actual conditions, collectively referred to as ecology-suitable uses in this paper) as chromosomes. Constrained by total unutilized land area and socio-economic development conditions, the model simulates this process through repeated iterations to obtain non-inferior solution combinations for zoning development areas.

1) Setting Coupling Elements. Coupling elements are model variables. Considering data availability and variable operability, three unutilized land development methods are set as variables: cultivation-suitable unutilized land (x_1), construction-suitable unutilized land (x_2), and ecology-suitable unutilized land (x_3).

2) Determining Coupling Objectives. Coupling objectives consist of two or more sub-objectives to achieve an integrated objective. For example, unutilized land suitability objectives include economic, social, and ecological benefit

objectives. The integrated objective is to achieve multi-objective optimization. The original model is:

$$X = \max\{f_1(x), f_2(x), \dots, f_p(x)\}$$

where X is the comprehensive benefit (yuan); $f_i(x)$ is the sub-objective benefit (yuan); and p is the number of coupling objectives.

Suitability Objective. Extract suitability evaluation grade results for each evaluation unit, sum them to obtain the overall unutilized land development suitability evaluation result for the study area, with the ultimate goal of maximizing this value. The specific formula is:

$$f_1(x) = \sum_{i=1}^m \sum_{j=1}^n s_{ij}x_{ij}$$

where $f_1(x)$ is the sub-objective benefit (yuan); m is the number of unutilized land development types ($m = 1, 2, 3$); n is the number of evaluation units; x_{ij} is the area of evaluation unit j as land use type i (m^2); and s_{ij} is the suitability score of evaluation unit j for land use type i obtained through the comprehensive index method.

Economic, Social, and Ecological Benefit Objectives. The economic, social, and ecological sub-benefit objectives are initially determined through relevant literature [24-25] and refined using the Delphi method based on actual conditions in Huanghua City. The refined results are calculated using the following formulas:

$$f_2(x) = \sum_{i=1}^m \sum_{j=1}^n a_{ij}x_{ij}$$

$$f_3(x) = \sum_{i=1}^m \sum_{j=1}^n b_{ij}x_{ij}$$

$$f_4(x) = \sum_{i=1}^m \sum_{j=1}^n c_{ij}x_{ij}$$

where $f_2(x)$, $f_3(x)$, and $f_4(x)$ represent the economic, social, and ecological benefits of unutilized land resource development in the study area (yuan), respectively; a_{ij} , b_{ij} , and c_{ij} are the relative economic, social, and ecological benefit coefficients for evaluation unit j as land use type i (Table 1), respectively; other symbols have the same meanings as above.

3) Setting Constraints. This paper primarily considers two aspects: land use condition constraints in the study area and model operation constraints. For example, land use condition constraints include total land area, while model operation constraints include non-negative system variables. If variables in the trade-off model represent land type areas, they must be positive. Additionally, each evaluation unit representing a land parcel must have one and only one corresponding land use type, without gaps or overlaps.

Total Unutilized Land Area Constraint. The sum of the three land use types (cultivation-suitable, construction-suitable, and ecology-suitable) equals the total unutilized land area in the study area:

$$\sum_{i=1}^m \sum_{j=1}^n x_{ij} = A$$

where A is the total area of unutilized land resources in the study area (m^2); other symbols have the same meanings as above.

Model Operation Constraints. Non-negative system variable constraint: variables representing land type areas in the trade-off model must be positive:

$$x_1 > 0, x_2 > 0, x_3 > 0$$

(2) Solving the Trade-off Model with Genetic Algorithm

The trade-off model is solved using genetic algorithms with Matlab software assistance. First, the Random function is used to determine the initial population, which serves as the parent generation for offspring genetic variation and evolution. The Random function randomly selects parent individuals in areas with high suitability to generate the model's initial solution set. Second, according to the unit numbering sequence in the database, neighborhood analysis is conducted sequentially from left to right and bottom to top, selecting individuals with high adaptability for offspring inheritance. Third, during normal genetic operations, some individuals are randomly selected for crossover and mutation to generate new individuals, after which fitness values are recalculated and superior individuals are selected for evolution. Fourth, under model constraint conditions, qualified evolutionary results are generated and input into the GIS database to determine the final quantity and spatial location [26-27]. During model operation, the number of genetic generations is set to 100, and the proportion of excellent offspring individuals to parent individuals is set to 1/3. Through gradual evolution following these steps, the non-inferior solution set gradually approaches optimality.

3.1.1 Arable Suitability Evaluation Index System for Unutilized Land

The arable suitability evaluation is conducted separately for other grassland, saline-alkali land, coastal beaches, and inland beaches. For saline-alkali land and other grassland, seven indicators are selected: topsoil texture, land structure, groundwater depth, groundwater extraction limits, groundwater mineralization, soil salt content, and vegetation coverage (Table 2). For inland and coastal beaches, five indicators are selected: topsoil texture, groundwater depth, land structure, surrounding soil source type, and soil source distance (Table 3).

3.1.2 Construction Suitability Evaluation Index System for Unutilized Land

Construction suitability evaluation assesses the constraints of natural attributes, surface morphology, and engineering geological conditions on construction land development. Six indicators are selected for overall unutilized land evaluation: geological disasters, foundation bearing capacity, freshwater source guarantee, groundwater depth, transportation conditions, and flood degree (Table 4). The newly released *13th Five-Year Plan Outline for Land and Resources* explicitly proposes controlling the total amount of construction land. Therefore, this paper strictly controls each indicator, stipulating that any indicator scoring below 30 points is unsuitable for construction land development.

3.1.3 Ecological Risk Evaluation Index System for Unutilized Land Development

Based on the characteristics of ecological risk evaluation for unutilized land development, an indicator system is constructed from four aspects: salinity degree, vegetation coverage, soil thickness, and waterlogging degree (Table 5).

3.2.1 Arable Suitability Evaluation Results

Based on calculation results, the arable suitability of unutilized land in Huanghua City can be divided into four grades: S1 (highly suitable) for H1 values ≥ 84 , S2 (moderately suitable) for 76-84, S3 (low suitable) for 60-76, and N (unsuitable) for values <60 . Inland beaches are primarily S1-grade arable unutilized land, other grassland is mainly S2-grade, coastal beaches are entirely N-grade, and saline-alkali land is primarily S1 and S2-grade (Table 6).

Spatially (Figure 1 [Figure 1: see original paper]), S1-grade arable unutilized land resources cover 22,552.34 ha, accounting for 33.87% of the city's total unutilized land resources. These are mainly distributed in the north-central and southern regions of Huanghua City, involving towns such as Lüqiao Town, Yang'erzhuang Hui Town, State-owned Zhongjie Farm, and Yangsanmu Hui Town. S2-grade resources cover 12,955.43 ha (19.46%), mainly in central and

western Huanghua. S3-grade resources cover 5,801.81 ha (8.71%), primarily around Huanghua Town. N-grade resources cover 25,280.95 ha (37.96%), mainly distributed along the eastern coast.

3.2.2 Construction Suitability Evaluation Results

Based on calculation results, the construction suitability of unutilized land in Huanghua City can be divided into three grades (Table 7): J1 (highly suitable) for H2 values 70, J2 (moderately suitable) for 58-70, and J3 (low suitable) for values <58. J3-grade construction-suitable unutilized land has the largest area, while J2-grade has the smallest.

Specifically, J3-grade construction-suitable unutilized land covers 48,106.41 ha, representing 72.24% of the city's unutilized land. Spatially (Figure 2 [Figure 2: see original paper]), J3-grade land is concentrated in coastal beaches and central areas, involving towns such as Nanpaihe Town, Xincun Hui Town, Nandagang Management District, and State-owned Zhongjie Friendship Farm. By land type, J3-grade land mainly comprises coastal beaches and saline-alkali land, accounting for 47.80% and 32.81% of J3-grade land, respectively. All inland beaches are J3-grade. J1-grade construction-suitable unutilized land covers 17,996.17 ha (27.03%), distributed mainly in central and western areas including Huanghua Town, Yangsanmu Hui Town, and Jiucheng Town. By land type, J1-grade land is entirely saline-alkali land. J2-grade construction-suitable unutilized land has a very small area, primarily involving some saline-alkali land and other grassland.

3.3 Ecological Risk Evaluation Results

Based on ecological risk calculations, unutilized land in Huanghua City is classified into high, medium-high, medium, medium-low, and low ecological risk zones. High ecological risk zones are unsuitable for cultivation or construction development, while other risk zones participate in coupling calculations to determine development orientation.

The results (Table 8) show that medium-low and medium-high ecological risk zones are most extensive in Huanghua's unutilized land resources, covering 20,432.73 ha (30.68%) and 18,597.37 ha (27.93%), respectively. High ecological risk zones have the smallest area, accounting for 1.90% of unutilized land. Low and medium ecological risk zones account for 20.28% and 19.21% of the city's unutilized land, respectively.

Spatially (Figure 3 [Figure 3: see original paper]), ecological risk shows a pattern of high risk in the east and low risk in the west. High and medium-high risk zones are mainly distributed in the eastern coastal and central areas. By land type, high and medium-high risk zones primarily comprise inland and coastal beaches, while low and medium-low risk zones are mainly saline-alkali land. In terms of suitability evaluation results, high and medium-high risk zones mainly involve

N-grade arable and J3-grade construction-suitable unutilized land, which are unsuitable for first-priority development. Human development activities would exacerbate regional ecological damage, so these areas could be developed into land types with relatively high ecosystem service values such as forestland or reserved for final development sequences. Medium risk zones are widely distributed across various unutilized land types, with suitability results mainly involving S2-grade arable and J1/J2-grade construction-suitable land. Development activities would impact the regional ecological environment, so these areas should avoid first-priority development. Low and medium-low risk zones are mainly distributed in the central-western parts of the county, primarily saline-alkali land, with suitability results mainly involving S1/S2-grade arable and J1/J2-grade construction-suitable land. These areas have favorable development conditions and can be used as preferred development land.

3.4 Unutilized Land Development Zoning

Based on the above analysis and calculations using the trade-off model zoning method, Huanghua' s unutilized land resources are divided into three types: cultivated land development zone, construction land development zone, and ecological land development zone (Table 9). As shown in Figure 4 [Figure 4: see original paper], ecological land protection zones have the largest area, mainly distributed in eastern and central areas; cultivated land development zones rank second, primarily in central and western regions; and construction land development zones have the smallest area, concentrated around Huanghua Town.

The cultivated land development zone covers 19,105.58 ha (28.69% of the city' s unutilized land), mainly distributed in Yang' erzhuang Town, Zhongjie Farm, and Tengzhuangzi Town. This zone primarily comprises S1/S2-grade arable unutilized land and low/medium-low ecological risk zones. With relatively flat terrain, available water sources, and soil sources, engineering measures such as saline-alkali land improvement and land consolidation should be implemented to increase cultivated land reserves and improve land quality.

The construction land development zone covers 3,578.97 ha (5.37% of unutilized land), with concentrated spatial distribution mainly in Huanghua Town. This zone primarily involves J1/J2-grade construction-suitable unutilized land and low/medium-low ecological risk zones. Based on favorable site conditions, convenient transportation, and available water sources, and within the scope of conditional and permitted construction zones identified in the land use master plan, projects for people' s livelihood, infrastructure, and key construction projects should be encouraged and guided.

The ecological land development zone has the largest area at 43,905.98 ha (65.94% of unutilized land), located mainly in the eastern and central parts of the city, including Nanpaihe Town, Xincun Hui Town, and Zhongjie Farm. Suitability evaluation results mainly involve N-grade and S3-grade arable unutilized

land, J3-grade construction-suitable land, and high/medium-high ecological risk zones. Given poor topsoil texture in this zone, human development activities should be minimized to maintain the original ecological conditions.

4 Conclusions

Land resources serve as the carrier for all human socio-economic activities, and rational land use development zoning should be formed through site-appropriate land utilization [16]. Taking Huanghua City in Hebei Province as a case study and based on survey data from 303 valid sample points, this paper analyzes suitability evaluation methods and development zoning for unutilized land, aiming to provide effective methods for land and resources departments to alleviate land supply-demand contradictions and ensure economic and social development.

The results show that: (1) The arable development of unutilized land in Huanghua can be divided into four grades, with N-grade having the largest area and mainly distributed in the eastern part of the city; S3-grade has the smallest area; S1-grade is mainly distributed in the north-central and southern regions; and S2-grade is primarily in central and western areas. (2) Construction suitability can be divided into three grades, with J3-grade having the largest area and concentrated in coastal beaches and central areas; J1-grade is mainly distributed in central and western regions; and J2-grade is widely distributed, primarily involving some saline-alkali land and other grassland. (3) Ecological risk zones can be classified into five levels, showing a spatial pattern of high risk in the east and low risk in the west. High and medium-high risk zones are mainly distributed in the eastern coastal and central areas, while low and medium-low risk zones are primarily in the western and central parts, dominated by saline-alkali land. (4) Huanghua's unutilized land can be divided into three key development zones: cultivated land, construction land, and ecological land. The cultivated land development zone is mainly distributed in central and western areas, where saline-alkali land improvement and land consolidation can increase cultivated land reserves. The construction land development zone is concentrated around central Huanghua Town and should be prioritized for people's livelihood projects, infrastructure, and key construction projects. The ecological land development zone is located in the eastern part of the city, where human development activities should be minimized to prioritize ecological protection.

5 Discussion

This study's suitability evaluation and development zoning focus on each evaluation unit in Huanghua City without considering land parcel contiguity. Future research will incorporate contiguity constraints into the trade-off model to better align with actual land use conditions in China.

During the suitability evaluation process, only cultivation and construction uses were selected. Although Huanghua also has unutilized land suitable for pasture,

wetland, and forestland development, such areas are very small. Moreover, grassland and wetland uses can be considered ecological uses, and this paper includes ecological land zones (treating forestland, orchard land, grassland, wetland, and water areas uniformly as ecological land). Therefore, separate evaluations for grassland and wetland development were not conducted. To improve zoning precision, multiple-use suitability evaluations will be conducted in future research.

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