

Article

Identification of Potential Land Use Conflicts in Shandong Province: A New Framework

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Abstract: Land use conflicts (LUCs) have become a significant global issue. Accurately identifying potential LUCs is crucial for mediating these conflicts, optimizing land use structure, and enhancing land use function. The necessary conditions of LUCs are land use multi-suitability (LUMS), land resource scarcity (LRS), and diversity of demands (DD). However, few studies have approached LUC identification from these three dimensions simultaneously. In addition, when assessing the diversity of demand, only human needs are considered and wildlife needs are ignored. In order to address this gap in the research, this paper constructs a novel framework for LUC identification and proposes an induction-oriented governance path. LUMS was evaluated from three aspects: construction suitability, cultivation suitability, and ecological suitability. LRS is measured from three dimensions: construction land, cultivated land, and ecological land scarcity. The DD is expanded into human and wildlife demand diversity. By analyzing the combination of LUMS, LRS, and DD, LUCs are classified using the potential LUC identification Rubik's cube model, and corresponding governance paths are suggested. In Shandong Province, potential LUCs are relatively high, with strong, medium, and weak conflicts accounting for 27.39%, 57.10%, and 13.06%, respectively. Potential strong conflicts are mainly distributed in the metropolitan suburbs and in the western plain of Shandong Province. Cultivated land is the main potential land use conflict space. The new framework of LUC identification proposed in this paper can effectively identify potential LUCs. Our research provides scientific reference for sustainable land use.

Keywords: land use conflicts; land suitability; urban expansion; cultivated land; Shandong



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1. Introduction

Land serves as the spatial foundation for human production and living, as well as a crucial resource and asset for human survival [1]. With the accelerated transformation and development of the social economy and the rapid advancement of urbanization, industrialization, and information technology, the production and lifestyle patterns, consumption structure, and diet of humans have undergone great changes. In addition, urban, rural, and inter-regional populations flow frequently and demonstrate characteristics of agglomeration to big cities. This has resulted in significant changes in land use structure, function, and layout [2–5]. In this process, humans' demand for limited land resources is increasingly diversified [6–8], resulting in land use conflict (LUC) becoming a global issue [9–12].

While the term LUC is not clearly defined, LUCs arise when stakeholders are not compatible with the interests of a particular parcel [6,13]. There are various reasons for LUC, including inter-departmental competition, water resources shortage, land expropriation, and war, and LUCs also show different types, such as spatial conflict among production space, living space, and ecological space, agricultural land use conflict, and environmental conflict [6,14,15]. Competition among different land use types is one of the common manifestations. For example, construction land occupies cultivated land and further

results in land degradation, the decline of ecosystem services and biodiversity, and food security [6,16].

Since the reform and opening up, China has experienced an unprecedented process of urbanization that could be considered the greatest resettlement experiment in human history [17]. This also makes China the country with the most severe LUC [7,18]. There are various forms of LUC in China [7,18,19], including urban expansion occupying cultivated land [9,20,21], mixed production and living space [22,23], and crowding of ecological space [24]. Serious LUCs not only reduce the quality of living environment but also lead to contradictions and conflicts between individuals and departments that threaten food security, reduce biodiversity, and are detrimental to social harmony and sustainable development [25–28].

In recent years, with the transformation of social and economic development and the proposal of carbon neutrality and carbon peak initiatives, LUC has garnered increasing attention. Relevant scholars have conducted a large number of studies on the identification [29,30], driving factors [7,31], simulation, and mediation of LUC [25,32–34]. LUC identification, in particular, is a leading topic in LUC research, as well as the premise and guarantee of LUC mediation. For instance, Brown and Raymond [35] used participatory mapping to quantitatively identify LUC. Karimi and Brown [15] further compared the advantages and disadvantages of LUC identification methods such as land use preference and location importance. Although these methods can accurately identify LUC in small areas, they are often subjective and challenging to apply on a larger research range.

In recent years, quantitative analysis methods have increasingly been applied to LUC identification [25], including landscape index analysis [7,32], ecological security pattern construction [9], and multi-criteria evaluation [6,8,30,36]. The advantage of using landscape pattern analysis to identify LUC is that it can quantitatively identify the intensity of LUC at grid scale and facilitate the analysis of LUC change. However, this method primarily relies on land use data and focuses on natural pattern analysis, with insufficient consideration of social and economic factors. Ecological security pattern construction law follows the basic principle of prioritizing ecological protection, and can identify the conflicts between construction land and ecological land, or cultivated land and ecological land. However, this method cannot identify other types of conflicts such as that between construction land and cultivated land. The multi-criteria evaluation method is a kind of quantitative evaluation method that considers the factors of natural and social economic development comprehensively and can be carried out at the grid and administrative levels.

Previous studies have provided a variety of alternative methods for LUC identification and accumulated valuable experience. However, although scholars generally believe that land use multi-suitability (LUMS), land resource scarcity (LRS), and diversity of demands (DD) are the necessary conditions of LUC [7,9,36], few consider these three factors comprehensively when identifying LUC [30]. Dong, Ge, Jia, Sun, and Pan [30] pointed out that LUMS, LRS, and diversity of human needs were the necessary conditions for LUC and constructed a corresponding evaluation index system to quantitatively identify LUC in Jinan city. However, the DD is often limited to human needs, overlooking the diverse needs of wildlife. This is inconsistent with sustainable development and harmonious coexistence between humans and nature [16] and is not conducive to biodiversity conservation. Wildlife plays an important role in maintaining biodiversity and ecosystem balance, as well as improving ecosystem services. Neglect of the needs of wildlife has resulted in the loss of wildlife habitat, species extinction, biodiversity decline, frequent weather extremes, and other adverse effects.

In light of these research gaps, this paper attempts to expand the DD to include both human and wildlife needs. It also constructs a new framework for LUC identification based on LUMS, LRS, and DD and further explores the induction-oriented LUC governance path. Shandong Province, where urbanization and industrialization are advancing rapidly and LUCs have been severe in recent years [37], was selected as the research area, and the types and intensity of LUC in Shandong Province were quantitatively identified based on

the land use conflict identification Rubik's cube model [6,8,30]. This research ultimately provides a scientific reference for alleviating LUC and rational use of territorial space.

2. Study Area and Data Sources

2.1. Study Area

Shandong Province is located on the east coast of China (Figure 1). The overall landscape shows a pattern of high elevations in the central areas and lower elevations around the periphery, with mountains in the middle, plains in the west, and hills in the east. Shandong is a populous and economically robust province in China, with a permanent population of 102 million and a GDP of 7312.90 billion CNY in 2020. In recent years, the pace of social and economic transformation has accelerated. The state has promulgated the new urbanization strategy [17], the rural revitalization strategy [38], the replacement of old with new driving forces, the goal of “carbon neutrality and carbon peak” [39], and the strategy of high-quality development and ecological protection in the Yellow River Basin, all of which have brought new opportunities and challenges to Shandong Province. However, rapid urban expansion inevitably encroaches on cultivated land and ecological land, and LUCs are significant.

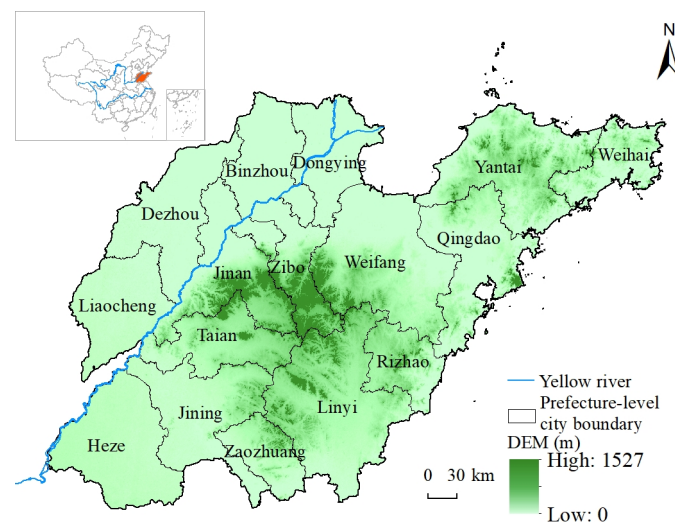


Figure 1. Location of Shandong Province, China.

2.2. Data Sources

The data used in this work mainly include social and economic statistics and geospatial data (Table 1). Social and economic data mainly encompass total population, urban population, rural population, GDP, per capita disposable income of urban residents, and that of rural residents of 137 counties of Shandong Province in 2020, which are derived from the statistical yearbook of each city in 2021 and primarily used for the evaluation of LRS and DD. The geospatial data mainly include DEM, a geological hazard susceptibility map, a land use map, rainfall, surface soil texture, soil thickness, NDVI, and NPP, which are primarily used for the evaluation of LUMS and DD. Other geospatial data are developed based on the above geographic data with the help of the spatial analysis function of ArcGIS. For example, slope can be extracted from DEM using the slope tool of ArcGIS. Distance data were collected using the Euclidean distance function of ArcGIS, and DEM data were download from the Geospatial Data Cloud (<http://www.gscloud.cn>, accessed on 9 April 2022). The map of geological hazard susceptibility is derived from the research group's data accumulation. Land use data, rainfall, surface soil texture, NDVI, and NPP were downloaded from Resources and Environmental Science and Data Center (<https://www.resdc.cn>, accessed on 2 May 2022). Soil thickness data were downloaded from the National Earth System Science Data Center (<http://www.geodata.cn/index.html>, accessed on 3 May 2022). In this paper, DEM has the highest spatial resolution of raster data,

with a resolution of 90 m. The lowest is that of soil data, with a resolution of 1 km; To enable accurate overlay analysis in GIS, we unify the spatial resolution of raster data to 1 km.

Table 1. Data sources.

Category	Datasets	Resolution	Data Sources
Geospatial data	DEM	90 × 90 m	Geospatial data Cloud (http://www.gscloud.cn , accessed on 9 April 2022)
	Geological hazard susceptibility map	Vector	Shandong provincial geological environment monitoring station
	Land use data of 2020	1000 × 1000 m	Resources and Environmental Science and Data Center (https://www.resdc.cn , accessed on 2 May 2022)
	Rainfall of 2020	1000 × 1000 m	Resources and Environmental Science and Data Center (https://www.resdc.cn , accessed on 2 May 2022)
	Surface soil texture	1000 × 1000 m	Resources and Environmental Science and Data Center (https://www.resdc.cn , accessed on 2 May 2022)
	Soil thickness	1000 × 1000 m	National Earth System Science Data Center (http://www.geodata.cn/index.html , accessed on 3 May 2022)
	NDVI of 2020	100 × 100 m	Resources and Environmental Science and Data Center (https://www.resdc.cn , accessed on 2 May 2022)
	NPP of 2020	1000 × 1000 m	Resources and Environmental Science and Data Center (https://www.resdc.cn , accessed on 2 May 2022)
Social and economic statistics	Total population, urban population, rural population, GDP, per capita disposable income of urban residents, and that of rural residents of each district and county in 2020	County level	Statistical yearbook of prefecture-level cities of Shandong Province in 2021

3. Research Process and Methods

3.1. Conceptual Framework

The essence of LUC is human–land contradiction caused by an imbalance between the supply and demand of land resources and the game of interests of different stakeholders behind the spatial competition of different land use types [6,8,10,12,13]. Based on the inherent properties of land resources (i.e., LUMS and land resources limitation), this paper establishes a theoretical framework for the identification and governance of LUC by combining resource scarcity theory, Maslow’s hierarchy-of-needs theory, supply–demand balance theory, and human–land coordination theory (Figure 2). Resource scarcity theory is used to explain the finiteness and scarcity of land resources. Maslow’s hierarchy-of-needs theory is used to explain DD. The supply–demand balance theory is used to analyze the mechanism of LUC. Human–land coordination theory is used to formulate LUC governance strategies.

LUMS is an inherent attribute of land resources; it means that the same land can be used for different land use types [30]. In practice, humans determine land use types based on production and living needs and then form a land use spatial pattern composed of cultivated land, garden land, forest land, rural residential land, industrial and mining land, and commercial and service land. When different stakeholders with varying functional needs, rights, and interests have control over a land parcel, it can lead to inconsistent expected land use types and LUC risk. LUMS is thus the premise and foundation of LUC.

Resource scarcity theory refers to the condition in which resources can only be obtained and used through economic competition due to their natural limitations. As the spatial carrier of human production and life [16,32], land itself is limited, and land resources with

advantages of resource endowment and location become the object of competition for stakeholders, which aggravates LRS. LRS is an important cause of LUC.

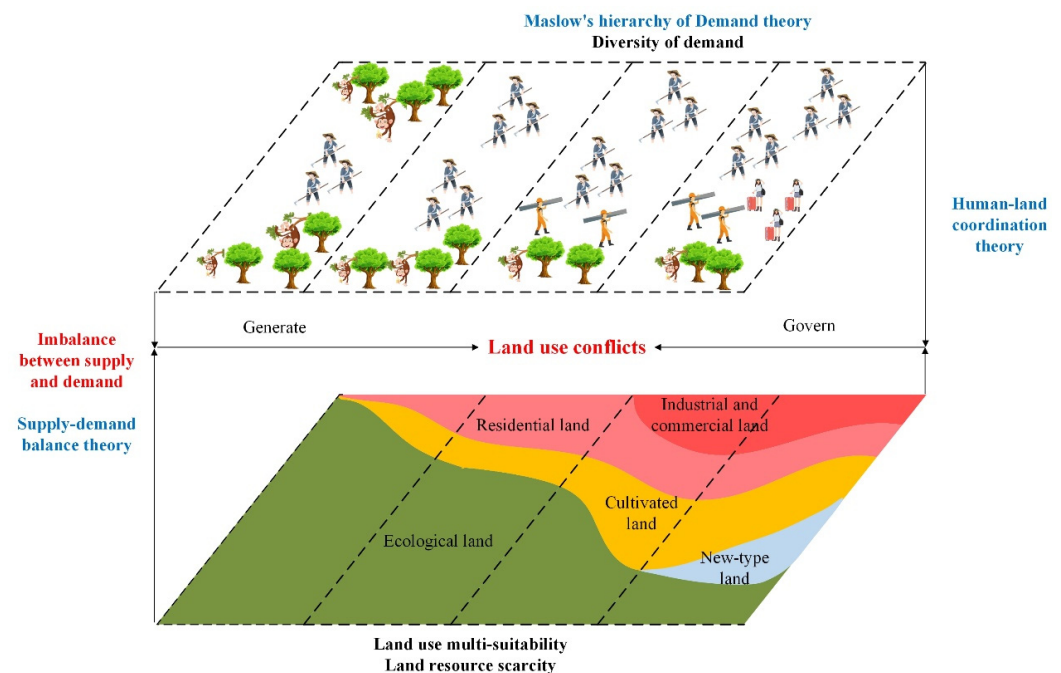


Figure 2. Conceptual framework for LUC identification and governance.

According to Maslow's hierarchy-of-needs theory [40], human needs are structured in a pyramid with five levels. Among them, physiological needs and safety needs are low-level needs, while social needs, respect needs, and self-actualization needs are high-level needs. When the lower-level needs are satisfied to a certain extent, the higher-level needs can arise. These demands are constantly changing with social and economic development, population growth, social division of labor, and peasant household livelihood shifts. For the demand of land use, meeting the demand of food production is the most basic need. With the change from nomadism and hunting to settled life, there is a corresponding demand for fixed residence. With further socio-economic development, human needs gradually diversify, and agricultural land, residential land, industrial and mining land, commercial land, and tourism open space come into being [5,22,30]. Therefore, DD is the key to LUC.

According to supply–demand balance theory, as land resources are limited, the increasing and diversifying demands make LRS more prominent. The quantity supply of land resources is less than the demand [6], and the supply and demand are dislocated in space [41], which makes different stakeholders compete for limited land resources and leads to LUC.

The theory of human–land coordination advocates for the harmonious coexistence between humans and nature. Human exploitation and utilization of land resources should be based on the premise of sustainable utilization of land resources to realize the coordinated development of human–land relationships (<https://sdgs.un.org/goals>, accessed on 2 August 2024). The governance of LUC is an effective way to meet this goal. LUC governance should be based on the level of social and economic development, comprehensively consider DD and LRS, promote the transformation of land use and spatial reconstruction through the adjustment of land use structure and optimization of land distribution, improve the efficiency of land use, resolve LUC, and ultimately realize the coordinated development of human–land relationships.

3.2. Identification of Potential LUC

According to the constructed conceptual framework, this paper adopts a multi-objective comprehensive evaluation method to evaluate land use multi-suitability, land

resource scarcity, and demand diversity. Following this assessment, the Rubik's cube model is used to quantitatively identify potential land use conflicts in Shandong Province.

3.2.1. Developing Multi-Criteria Evaluation System

Different evaluation objectives require the construction of a targeted evaluation index system. This paper evaluates land use multi-suitability from three aspects: construction suitability, cultivation suitability, and ecological land suitability. Similarly, land resource scarcity considers the scarcity of construction land, cultivated land, and ecological land. The evaluation of demand diversity (DD) not only takes into account human needs but also emphasizes the needs of wildlife.

Evaluation of LUMS

LUMS refers to the suitability of the same land for multiple utilization modes. In relevant studies, there are two main ways to classify LUMS. One is to divide LUMS into production suitability, living suitability, and ecological suitability according to the function of land carrying [23,29,36]. The other is to divide LUMS into construction suitability, cultivation suitability, and ecological suitability according to land use patterns [6,8,30]. In the first method, it is necessary to establish the corresponding relationship between various land use types and production, living, and ecology functions and then merge land use types accordingly. However, the attribution of some land use types is a bit ambiguous. For example, construction land serves both productive and living functions. In contrast, the second division is more intuitive. The boundary between the three types of land use suitability is more explicit, and it is more convenient to select evaluation indexes and evaluate land use suitability according to the specific land use type. Therefore, this paper divides LUMS into construction suitability, cultivation suitability, and ecological suitability.

(1) Construction suitability

Construction land is an artificial surface. It is the main settlement area of human beings and carries the function of production and living. Relevant studies show that natural conditions, such as DEM, slope, and geological disaster, are the basic determinants of construction suitability [7,16,30,42,43]. The expansion of construction land is primarily influenced by social and economic factors, exhibiting clear tendencies towards urban areas and along road networks [44–46]. Therefore, construction land suitability is comprehensively evaluated from the aspects of natural conditions and location conditions, including DEM, slope, geological disaster, distance to town, and distance to road (Table 2). The higher the elevation, the greater the slope, the higher the geological-disaster-prone rate, the greater the cost, difficulty, and risk of construction, and the lower the construction suitability. The closer the distance to the town and road, the higher the construction suitability. This paper uses an analytic hierarchy process to determine weight within the evaluation index. Raster layers with uniform spatial reference and resolution were generated for each evaluation index, and then the raster calculator of ArcGIS software (version 10.5) was used to evaluate the suitability of construction land.

Table 2. The evaluation indicator system of construction suitability.

Factor (Weights)	Indicator	Weights	Indicator Classification and Score				
			100	80	60	40	20
Natural conditions (0.6)	DEM (m)	0.40	<50	50–70	70–163	163–291	>291
	Slope (°)	0.15	<2	2–6	6–15	15–25	>25
	Susceptibility to geological hazards	0.45	None	—	Low	Medium	High
Location conditions (0.4)	Distance to town (km)	0.75	<1.5	1.5–3.0	3.0–5.0	5.0–8.0	>8.0
	Distance to main road (km)	0.25	<1	1–2	2–4	4–6	>6

(2) Evaluation of cultivation suitability

Cultivation land refers to the land used to grow crops. The suitability of cultivation land is influenced by natural endowments, which are characterized by flat terrain, fertile soil, and reliable irrigation [47,48]. High DEM increases the difficulty and cost of farming, discouraging farming activities. Farming on sloped land easily causes soil erosion, which is not conducive to the stability of farming or soil and water conservation. Adequate rainfall is an important guarantee of irrigation water. Surface soil texture and soil thickness are important indicators of soil fertility. In addition, cultivation convenience is also one of the important factors that affect cultivation suitability. ‘Work with sunrise and rest with sunset’ is a vivid depiction of Chinese traditional farming activities that highlights the fact that the distance of farming should not be too great. Field research has shown that the main way for farmers to travel in agricultural production is by tractor, motorcycle, and foot, and a reasonable farming radius is considered to be within 4 km. Therefore, cultivation suitability was evaluated from the two aspects of natural endowment and cultivation convenience (Table 3). Natural endowment is quantitatively characterized by DEM, slope, rainfall, surface soil texture, and soil thickness. The convenience of cultivation is represented by the distance to rural settlements and roads in towns and villages. The higher the elevation and slope, the worse the natural endowment of land, and the higher the value of rainfall, surface soil texture, and soil thickness, the better the natural endowment of land. The closer the distance to rural settlements and roads, the higher the convenience of farming.

Table 3. The evaluation index system of cultivation suitability.

Factor (Weight)	Indicator	Weight	Indicator Classification and Score				
			100	80	60	40	20
Natural endowment (0.75)	DME (m)	0.3473	<50	50–70	70–163	163–291	>291
	Slope (°)	0.1213	<2	2–6	6–15	15–25	>25
	Rainfall	0.1285	>679.89	609.75–679.89	535.35–609.75	454.57–535.35	<454.57
	Surface soil texture	0.2427	Silt loam	Loam	Silty clay loam	Clay loam; sandy loam	Silt
	Soil thickness	0.1601	>162	140–162	115–140	90–115	<90
Cultivation convenience (0.25)	Distance to rural settlement (km)	0.6667	<1	1–2	2–3	3–4	>4
	Distance to road of town and village	0.3333	<1	1–2	2–3	3–4	>4

(3) Evaluation of ecological suitability

Ecological land refers to land with a good natural environment and functions, such as maintenance of biodiversity and conservation of water and soil, and can include forest land, grassland, and water areas. Ecological suitability is mainly affected by natural endowment and human disturbance (Table 4). NDVI and rainfall can be used to represent the natural endowment of ecological land. The higher the value of NDVI and rainfall, the higher the suitability of ecological land.

Human disturbance is an important factor affecting ecological suitability. Urban and rural residential areas are the primary sites of human production and life, and the intensity of human activities is high. Roads are passageways for communication within and between regions. With the advancement of globalization, urbanization, and industrialization, the social economy is undergoing rapid transformation and development, science and technology are advancing, factors of production are flowing more and more frequently, and the types and quantity of transportation modes are increasing. The intensity of human activity on the roads should not be underestimated. In addition, the intensity of human activities varies significantly among different land use types. Therefore, distance to town, distance to

rural settlement, and distance to road and land use types were selected as the evaluation indexes of human disturbance degree. The shorter the distance to towns, rural settlements, and roads, the higher the degree of human interference. The intensity of human activity in construction land was higher than it was in cultivated land, and the intensity of human activity in water areas, forest land, grassland, and wetlands was the lowest. The higher the intensity of human activities, the lower the ecological suitability.

Table 4. Evaluation index system of ecological suitability.

Factor (Weight)	Indicator	Weight	Indicator Classification and Score				
			100	80	60	40	20
Natural endowment (0.3)	NDVI	0.6667	>0.76	0.65–0.76	0.49–0.65	0.23–0.49	<0.23
	Rainfall (mm)	0.3333	>679.89	609.75–679.89	535.35–609.75	454.57–535.35	<454.57
Human disturbance (0.7)	Distance to town	0.2761	>10	8–10	5–8	3–5	<3
	Distance to rural settlement	0.1953	>4	3–4	2–3	1–2	<1
	Distance to road	0.1381	>5	3–5	2–3	1–2	<1
	Land use type	0.3905	Water; forest; grassland; wetland			Cultivated land; unused land	Construction land

Evaluation of LRS

LRS is relative to human needs in a particular area. The smallest statistical unit of China’s social and economic statistical data that can be publicly obtained is county. Therefore, at the county level, this paper employs a per capita land use index from the three aspects of construction scarcity, cultivated scarcity, and ecological scarcity to quantitatively evaluate LRS (Table 5). Specifically, construction land scarcity is quantitatively depicted by selecting per capita urban land area and per capita rural residential land area. Cultivated land scarcity is characterized by per capita cultivated land area. Ecological land scarcity is quantitatively evaluated based on per capita forest area, per capita grassland area, and per capita water area. The higher the per capita land use index value, the lower the LRS.

Table 5. Evaluation index system of LRS.

Factor	Indicator	Indicator Classification and Score				
		100	80	60	40	20
Construction land scarcity (0.2)	Per capita urban land area (0.6667)	<90.06	90.06–151.82	151.82–245.12	245.12–383.20	>383.20
	Per capita rural settlement area (0.3333)	<125.5	125.5–234.9	234.9–347.4	234.9–520	>520
Cultivated land scarcity (0.4)	Per capita cultivated land area	<333.95	333.95–930.24	930.24–1468.03	1468.03–2845.16	>2845.16
Ecological land scarcity (0.4)	Per capita forest land area (0.3333)	<45.52	45.52–172.11	172.11–320.42	320.42–533.27	>533.27
	Per capita grassland area (0.3333)	<38.15	38.15–119.48	119.48–249.06	249.06–419.51	>419.51
	Per capita water area (0.3333)	<41.52	41.52–110.19	110.19–296.19	296.19–625.94	>625.94

Evaluation of DD

The earth is the common home of humans and wildlife. Harmonious coexistence between humans and nature is an inevitable requirement of sustainable development [16]. Therefore, the DD not only includes the diversity of human demands, but also the diversity of wildlife demands (Table 6). With the improvement of social and economic development levels and the increase in urban and rural residents' income, the production and lifestyle, diet structure, and consumption structure of human beings will also change and affect the DD. In addition, diversity of human demands should also be discussed within a certain region. Therefore, combined with the availability of data, this paper selects the total population, GDP, per capita disposable income of urban residents, and that of farmers at county level to quantitatively evaluate the diversity of human demands.

Table 6. Evaluation index system of DD.

Factor	Indicator	Indicator Classification and Score				
		100	80	60	40	20
Human demands (0.5)	Total population (0.2310)	>111.2	74.00–111.2	58.50–74.00	40.40–58.50	<40.40
	GDP (0.4901)	>1100.89	640.17–1100.89	432.70–640.17	268.96–432.70	<268.96
	Per capita disposable income of urban residents (0.1634)	>37,118	32,032–37,118	26,529–32,032	21,920–26,529	<21,920
	Per capita disposable income of farmers (0.1155)	>16,447	14,297–16,447	12,209–14,297	10,721–12,209	<10,721
Wildlife demands (0.5)	Biodiversity index					

The demand of wildlife for land resources is mainly reflected in the demand for habitat, which is affected by such factors as species and quantity of wildlife, but these characteristics are dynamic and often difficult to determine accurately. Therefore, referring to relevant studies [24], this paper adopts the biodiversity index to reflect the demands of wildlife. On the landscape scale, high-quality biodiversity is primarily characterized by the following aspects. Firstly, the land needs to provide sufficient food, and secondly, it needs to have high habitat quality. Promoting a strong ecological environment is not only a human desire for a better life, but also an important guarantee for the protection and maintenance of wildlife habitats and biodiversity. Finally, the connectivity between habitat patches must be strong. Accordingly, the following formula is used to calculate the biodiversity index:

$$B = NPP + HQ + CON \quad (1)$$

where B is the biodiversity index, NPP is net primary productivity, HQ is habitat quality, and CON is connectivity.

3.2.2. Indicator Grading Assignment, Weight Determination, and Multi-Objective Evaluation Model

According to the attributes of the evaluation indicator, this paper uses reclassification and the natural breakpoint method to assign evaluation indexes. Specifically, for qualitative indicators, such as land use type, the reclassification method is adopted. For quantitative indicators, such as total population, GDP, per capita disposable income, and biodiversity index, the natural breakpoint method is used to classify.

An analytic hierarchy process is used to determine the weights of evaluation indicators based on yaahp software (version 0.6.0), which integrates the advantages of expert experience and objectivity. The key to this method is to construct the hierarchical structure

model and determine the weight of evaluation indicators by a pairwise comparison of the relative degrees of importance. The multi-objective evaluation model is used to evaluate the LUMS, LRS, and DD.

$$S = \sum w_{factor} \times w_{indicator} \times s_j \quad (2)$$

where S is the comprehensive evaluation score, w_{factor} and $w_{indicator}$ are the weights of factors and evaluation indicators, respectively, and s_j is the score of the j th evaluation indicator.

3.2.3. Classification of Potential LUC

First, the evaluation results of LUMS, LRS, and DD are divided into three grades: high, medium, and low. Then, 27 combinations can be theoretically obtained through spatial overlay of these layers (Figure 3). These combinations can be further classified into four categories: high, medium, low, and none. When at least two of the LUMS, LRS, and DD of a certain land parcel are high, the potential LUC of the land parcel is high. When at least two of the LUMS, LRS, and DD of a certain land parcel are medium or above, the potential LUC of the land parcel is medium. The potential LUC of a certain land parcel is low when two of the factors (i.e., LUMS, LRS, and DD) are low. When the LUMS, LRS, and DD of a certain land parcel are low, there is no potential LUC in the land parcel.

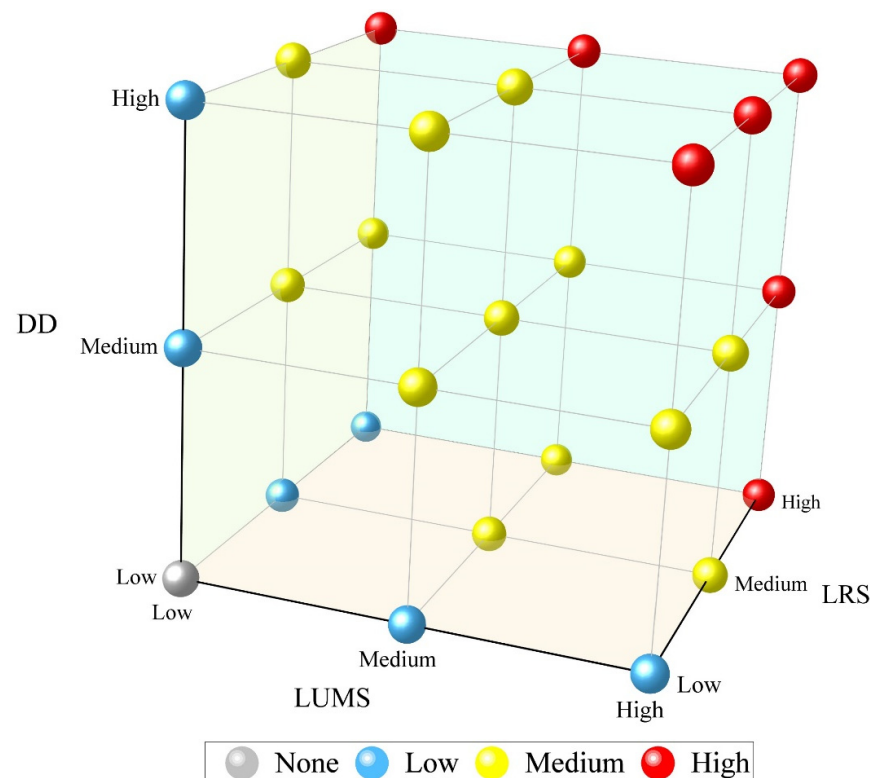


Figure 3. Potential land use conflict identification Rubik's cube model.

4. Results

4.1. Spatial Distribution Characteristics of LUMS

4.1.1. Construction Suitability

Under the comprehensive influence of natural geographical conditions and social and economic development levels, the construction suitability of Shandong Province presents a spatial distribution pattern of low values in the middle and high in the surrounding areas (Figure 4a). The proportion of land with high construction suitability was 25.56% and primarily distributed in towns and surrounding areas that are close to urban areas with perfect infrastructure, convenient transportation, and high levels of social and economic

development. The proportion of land with moderate construction suitability was as high as 51.19% and widely distributed, especially in the western plain area, where the terrain is flat and a potential space for the layout of urban and rural residential areas. The proportion of land with low construction suitability was the lowest (23.25%) and mainly distributed in the mountainous and hilly areas of central and southern Shandong and the Jiaodong hills.

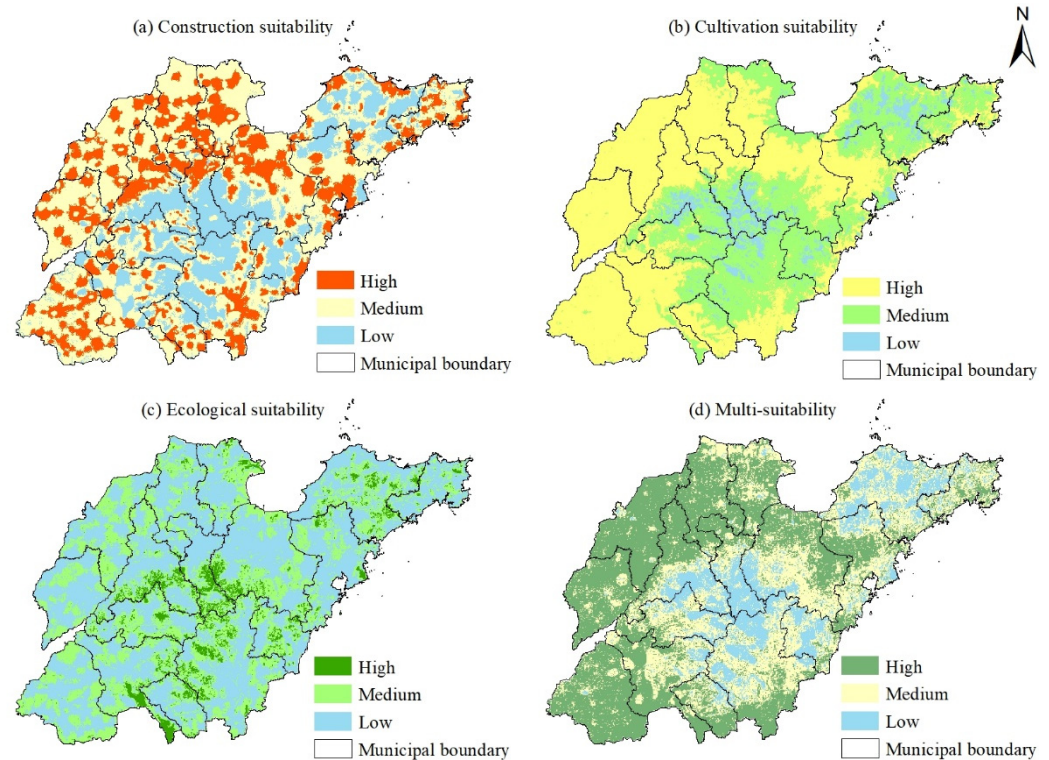


Figure 4. Spatial distribution of land use suitability.

4.1.2. Cultivation Suitability

Flat and fertile areas are often suitable for both farming and construction. Therefore, the spatial distribution of cultivation suitability and construction suitability is similar and presents a spatial distribution pattern of low values in the middle and high in the surrounding areas (Figure 4b). The cultivation suitability of Shandong Province is high. The proportion of land with high cultivation suitability is 56.10%, primarily distributed in the West Shandong Plain, which belongs to the North China Plain, has flat terrain and fertile soil, and is an important grain production base. The proportion of land with medium cultivation suitability is 37.01% and mainly distributed in the mountainous and hilly areas of central and southern Shandong, Jiaodong's hilly area, the Laizhou Bay area, and the coastal areas of northern Dongying and northern Binzhou. The cultivation suitability in mountainous and hilly areas in central and southern Shandong Province, as well as in the Jiaodong hilly area, is mainly limited by natural conditions such as topography, while the cultivation suitability in Laizhou Bay and the coastal areas of Dongying and northern Binzhou is affected by soil salinization. The proportion of land with low cultivation suitability is the lowest (only 7.16%) and is distributed sporadically in the mountainous area of central and southern Shandong and the hilly area of Jiaodong.

4.1.3. Ecological Suitability

Shandong Province is dominated by low ecological suitability because of the high degree of exploitation and utilization of land resources and the wide-range, high-intensity influence of human activities (Figure 4c). The amount of land with high ecological suitability is very small (only accounting for 6.43%), and it is relatively concentrated in the southern mountainous area of Jinan, Mountain Lu, Mountain Meng, Nansi Lake, and the Yellow

River Delta. These areas possess good natural endowments and are mostly mountainous or watersheds, far from towns and cities, and relatively unaffected by human activities. In addition, to protect biodiversity, the country has established some nature reserves in these areas, such as the Yellow River Delta Nature Reserve, which has enhanced the ecological suitability of the region. The proportions of middle- and low-ecological-suitability land are 37.07% and 56.11%, respectively, and widely distributed in Shandong Province.

4.1.4. LUMS

The LUMS in Shandong Province is relatively high, displaying a clear spatial differentiation pattern of a circle layer structure (Figure 4d). The amount of land with low LUMS is relatively small (17.45%) and concentrated in mountainous and hilly areas in central and southern Shandong, forming the innermost circle layer of the circle layer structure. In addition, there is a large amount of land with low LUMS in Yantai. The proportion of land with high LUMS is the highest (46.65%) and widely distributed in the plain area of Shandong Province, forming a “C” shape, which is the outermost layer of the circle layer structure. The proportion of medium LUMS is 35.90%, and it is distributed in the transition zone between high and low LUMS, forming the middle layer of the circle layer structure.

4.2. Spatial Distribution Characteristics of LRS

4.2.1. Construction Land Scarcity

The per capita construction land area in Shandong Province is small, and the construction land scarcity is high (Figure 5a). There are only 29 counties with high construction land scarcity, and they are mainly located in Qingdao, Linyi, Dezhou, and Liaocheng. There are 65 counties with moderate construction land scarcity, distributed primarily in Heze, Jining, and Tai'an. The counties with low construction land scarcity are primarily distributed in the northern part of Shandong Province, especially Binzhou, Dongying, Weifang, Weihai, Yantai, and Jinan.

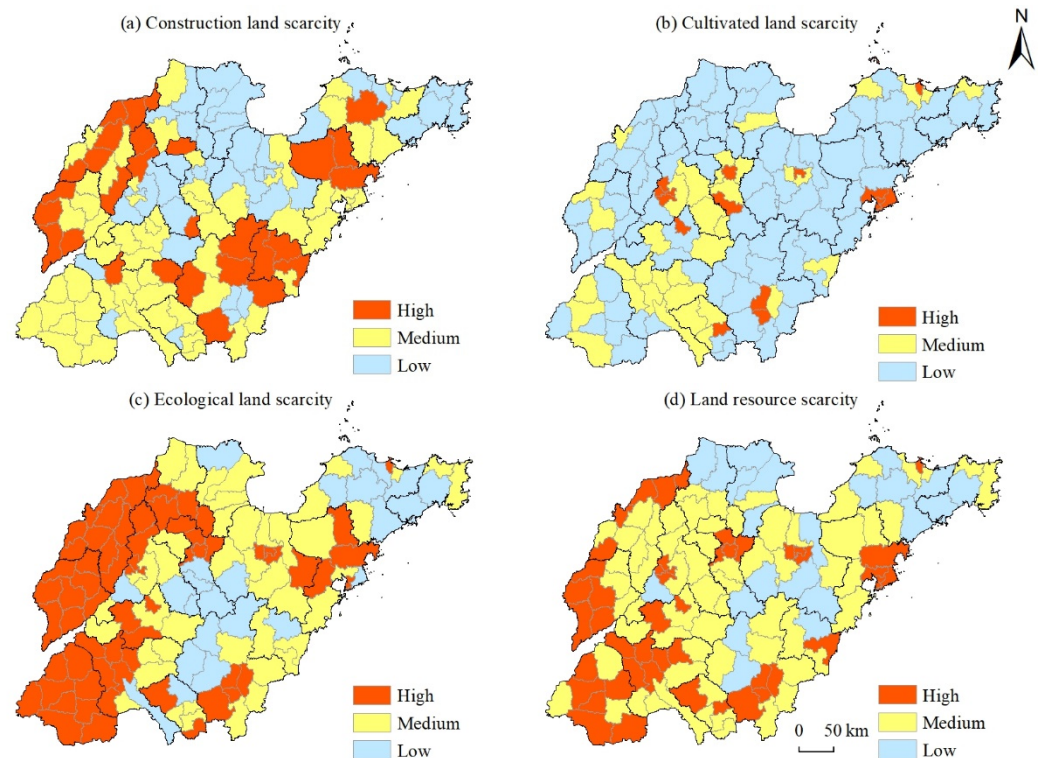


Figure 5. Spatial distribution of LRS.

4.2.2. Cultivated Land Scarcity

The cultivated land scarcity in Shandong Province is not high, and the low cultivated land scarcity is the dominant type (Figure 5b). Among the 137 counties in Shandong Province, 83 counties have low cultivated land scarcity. The number of counties with high cultivated land scarcity is 18, which includes the municipal districts of Jinan, Qingdao, Zibo, and Linyi, where the land urbanization level is relatively high, resulting in high cultivated land scarcity. The number of counties with medium cultivated land scarcity is 36, and these areas were concentrated in the southeast of Jinan, the middle of Zibo, the north of Zaozhuang, and Jining.

4.2.3. Ecological Land Scarcity

The ecological land scarcity in Shandong Province is relatively high, and the regional difference is obvious (Figure 5c). The number of counties with high ecological land scarcity reached 68, accounting for 49.64% of the total number of counties. These counties are primarily distributed in the Western Shandong Plain area, which is dominated by agricultural production space and small ecological space. The number of counties with low ecological scarcity was the lowest (only 25). These areas were mainly distributed in Mount Tai, Mount Yimeng, Mount Kunyu, and Nansi Lake, which are rich in ecological resources such as forest or water. The other 44 counties have medium ecological land scarcity.

4.2.4. LRS

Shandong Province is densely populated and has a high level of economic development, which leads to a high LRS (Figure 5d). Forty-nine counties have high LRS, and for the most part, they are located in municipal districts or plain areas. The scarcity of ecological and construction land is the main reason for high LRS in plain areas. Only 17 counties had low land scarcity (17), and these areas were mainly distributed in the coastal plain of Northern Shandong Province, the Jiaodong hilly area, and Mount Yimeng. The number of counties with moderate LRS was the largest (up to 71), and these areas were widely distributed.

4.3. Spatial Distribution Characteristics of DD

4.3.1. Diversity of Human Demands

The city scale is too rough, whereas the township scale is fine enough; however, it is often difficult to collect data for the latter scale. The county is an ideal unit to study the diversity of human demands, as it has both towns and villages at the spatial scale between cities and towns. In view of this, this paper evaluates the diversity of human demands at the county scale.

Affected by natural endowment and regional conditions, Shandong Province's population distribution is uneven, and regional development is unbalanced. Consequently, there are obvious regional differences in the spatial distribution of the diversity of human demands (Figure 6a). The counties with medium or high diversity of human demands are mainly distributed along the line between Rongcheng in Weihai and Dongming in Heze in a northeast–southwest direction. Among them, the counties with a high diversity of human demands are mainly distributed in Jinan, Qingdao, and the junction of Dongying, Zibo, and Weifang. The counties with low diversity of human demands are mainly distributed on both sides of the Rongcheng–Dongming line.

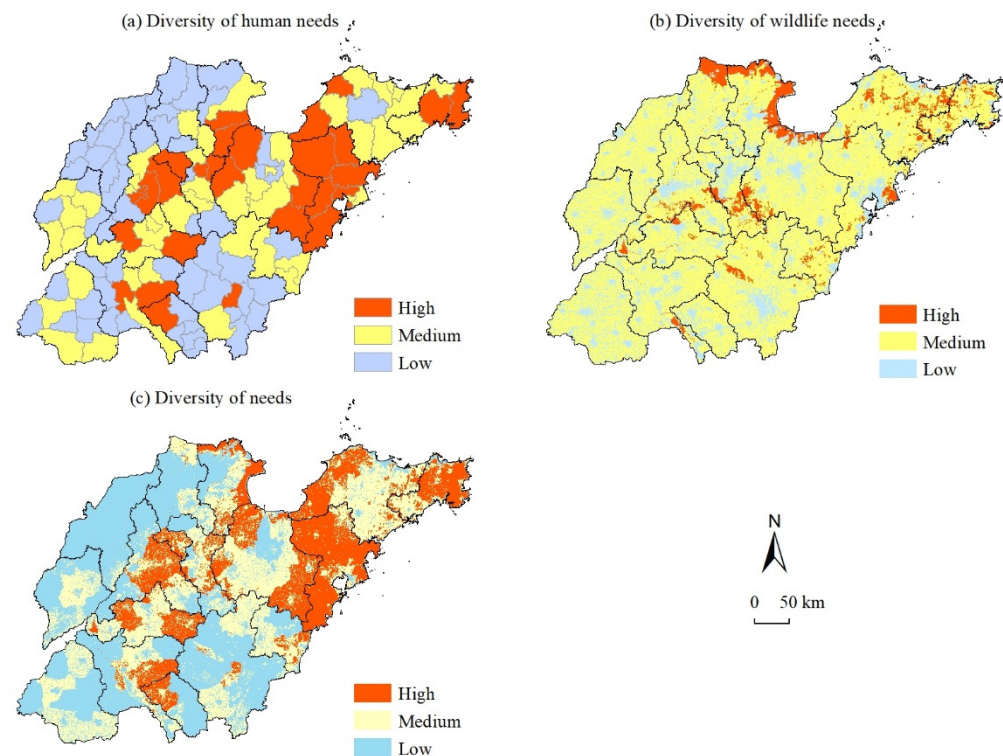


Figure 6. Spatial distribution of DD.

4.3.2. Diversity of Wildlife Demands

The degree and intensity of land use and development in Shandong Province are high, and the growth space of wildlife is relatively limited (Figure 6b). The amount of land with high diversity of wildlife demands is relatively small, only accounting for 6.34%, and the distribution is scattered, but relatively concentrated in Laizhou Bay, northern Binzhou and northern Dongying coastal areas, Nansi Lake, Mountain Tai, Mountain Meng, Mountain Lu, and Mountain Lao. The areas with low diversity of wildlife demands are mainly urban and rural residential areas with intensive human activities and account for 19.64% of the total. The land with medium diversity of wildlife demands is large in quantity and widely distributed, accounting for as much as 74.02% of the total, and consists of agricultural production space dominated by cultivated land.

4.3.3. DD

The DD in Shandong Province is obviously different from east to west, showing a spatial pattern of high values in the east and low in the west (Figure 6c). The areas with high DD accounted for 23.46% and were mainly concentrated in Qingdao, Weihai, western Yantai, eastern Weifang, eastern Dongying, and eastern Jinan. The proportion of the area with medium DD was 34.74%, and the distribution was more concentrated in Yantai, Weifang, and Tai'an. The areas with low DD accounted for the highest proportion (41.80%) and were concentrated in the central and western parts of Shandong Province.

4.4. Results of Potential LUC Identification

4.4.1. Spatial Distribution of Potential LUC

Potential LUCs in Shandong Province include strong conflict, medium conflict, weak conflict, and no conflict, and medium conflict is the main type (Figure 7). Among them, strong LUC accounted for 27.39% of the total cases and were mainly distributed around large cities, such as Jinan and Qingdao, and in plain areas, such as Heze, Liaocheng, Dezhou, and Jining. Due to high levels of urbanization, large cities attract a large amount of population inflow, which increases the demand for construction land. Under the influence

of the spillover effect, LUC and changes around big cities are intense. Heze, Liaocheng, and Jining are located in plain areas with high LUMS. In addition, a large population leads to more construction land and less ecological land, which results in high LRS. Therefore, the region has potential for strong LUC. The proportion of medium LUC is 57.10%, which is widely distributed. The proportion of weak LUC is 13.06% and is mainly distributed in mountainous and hilly areas in central and southern Shandong, Jiaodong Peninsula, and some areas of Binzhou and Dongying. Among them, the mountainous and hilly areas in central and southern Shandong and Jiaodong Peninsula are not suitable for construction and cultivation and have low LUMS. This further leads to a sparse population, relatively backward economic development, low LRS, and low DD in the region. Although Binzhou and Dongying are plain areas, due to the historical influence of Yellow River flooding and salinization, they have sparse populations, low levels of economic development, low LRS, and low DD.

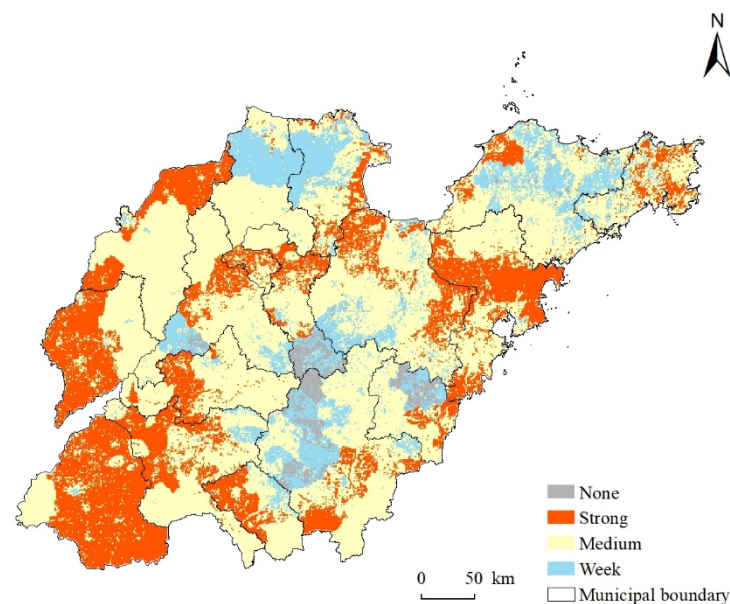


Figure 7. Spatial distribution of potential LUC.

4.4.2. Current Land Use Types under Different Potential LUC Intensities

In order to analyze the rationality of land use in Shandong Province and explore effective measures to mediate LUC, the layers of potential LUC and current land use were superimposed. The differences between current land use types under different intensification of LUC were compared and analyzed.

The dominant land use types of potential LUC at different levels are all cultivated land. The proportion of cultivated land in potential LUC space increases with the change of LUC level from weak to strong. Specifically, the proportion of cultivated land under weak LUC is 53.73%. The proportion of cultivated land in medium LUC is 67.35%. The proportion of cultivated land under strong LUC is the highest, reaching 74.60%. In addition, the proportion of ecological land, such as forest land, grassland, and water area in the weak LUC, is the highest (26.82%). The proportion of ecological land in the space with strong and medium LUC is 9.80% and 13.20%, respectively. The proportion of unused land in LUC is the smallest, all less than 1%, which is mainly due to the high intensity of land use development in Shandong Province and the small amount of unused land.

4.5. Governance Strategy of LUC Based on Inducement

The higher the intensity of LUC, the more likely it is that land use change occurs [6]. Therefore, strong LUC is the focus of LUC governance. This part focuses on the gover-

nance path of strong LUC. Similar approaches can be adopted to formulate corresponding strategies for medium and weak LUC.

According to the combination of LUMS, LRS, and DD, strong LUC can be further divided into four subtypes. For subtype A, LUMS, LRS, and DD are all high, which leads to strong LUC. For subtype B, the grades of LUMS and LRS are high, while the grades of DD are medium or low. Therefore, this type of LUC is dominated by LUMS and LRS. For subtype C, LUMS and DD are high, while LRS is medium or low. In subtype D, LRS and DD grades are high, and LUMS grades are medium or low.

LUC governance should be tailored to the case. LUC is caused by LUMS, LRS, and DD. Therefore, the corresponding governance of LUC should be guided by multi-function theory, supply–demand balance theory, Maslow’s hierarchy-of-needs theory, and human–land relationship theory so as to achieve harmonious and sustainable development of human–land relationships.

Subtype A, which has good land resource endowment, high LRS, and large DD, faces difficulty in governing strong LUC. The land use in this region should implement the new urbanization strategy, adhere to the priority of ecological protection, protect cultivated land as strictly as the protection of giant pandas, and ensure the space needed for urban and rural development using the scientific demarcations of “three zones” and “three lines” (http://www.sz.gov.cn/hdjl/ywzsk/ghj/csghl/content/post_9136291.html, accessed on 15 September 2022) to improve the efficiency of land resource use and achieve high-quality development. “Three zones” refers to three types of territorial space: urban space, agricultural space, and ecological space. “Three lines” refers to three control lines (urban development boundary, permanent basic farmland, and the ecological protection red line), which correspond to urban space, agricultural space, and ecological space, respectively.

Subtype B, which has high grades of LUMS and LRS, is a potential region for LUC. The level of social and economic development in this region is relatively backward, so the land use control system should be strictly implemented to prevent urban expansion from occupying cultivated land. We should also actively explore the separation of the three rights of agricultural land, prevent abandonment of cultivated land, and promote large-scale management through land circulation. In addition, it is necessary to establish an overall regional planning system with economically developed areas and implement the balance of farmland occupation and compensation, ecological compensation, and transfer payment.

For subtype C, LUMS and DD are the main causes of strong LUC. Land use in this region is extensive, so land consolidation should be strengthened, inefficient land use management should be carried out, land use transformation and development should be realized, and the level of economical and intensive use should be improved. At the same time, the land use control system will be strictly implemented to protect cultivated land and ecological land.

For subtype D, LRS and DD are the main causes of LUC. The imbalance of supply and demand is the essential cause of LUC in this region. These areas should be the key areas for LUC mediation. Unreasonable land use is likely to cause ecological environmental problems such as construction occupation of cultivated land, farmland occupation of ecological land, ecological space shrinkage, and quality decline. In this region, measures should be taken according to local conditions, the LRS and the DD should be fully considered, the land use scale should be reasonably calculated, and the land use structure and layout should be optimized based on the evaluation results of land use suitability.

5. Discussion

5.1. Land Use Implications

- (1) Pay attention to tapping potential reserves and improve the efficiency of construction land

Flat and fertile areas are often suitable for both farming and construction. Therefore, cultivation suitability and construction suitability have similar spatial distributions. In reality, the spatial distributions of cultivated land and construction land are also close to

each other, which is the main reason that urban expansion occupies a large amount of cultivated land [20,21]. In view of this, we should take advantage of the opportunity to compile territorial space planning, reasonably delimit the boundary of urban development, reasonably set the blank space, strictly control the increment, tap the potential stock, improve the efficiency of construction land, and prevent the expansion of construction land at will.

(2) Strengthen cultivated land “quantity, quality, and ecology” trinity protection

On the one hand, the current use mode of potential LUC space is mainly cultivated land, indicating that LUC is more likely to occur on cultivated land. For example, the expansion of urban and rural settlements occupies cultivated land, especially high-quality cultivated land [20]. On the other hand, from the perspective of LRS, the ecological land scarcity in western Shandong Province is relatively high. These areas mainly consist of cultivated land, and their primary function is agricultural production; however, they also play a more important ecological role [49–51]. Therefore, Shandong Province should strengthen the protection of cultivated land “quantity, quality, and ecology”, clarify the responsibilities for cultivated land protection, resolutely prevent the “non-agricultural” and “non-grain” cultivated land, and strictly implement the protection of cultivated land.

(3) Adhere to “bottom line” thinking and protect ecological land

It can be seen from the spatial distribution of ecological suitability and diversity of wildlife demands that the mountainous and hilly areas in central and eastern Shandong, the Yellow River Delta, and Nansi Lake are important ecological spaces in Shandong Province, and their spatial distribution varies greatly. Among them, the mountainous and hilly areas in central and eastern Shandong have large terrain fluctuations, and unreasonable land use causes ecological environment problems such as soil erosion. The Yellow River Delta is an important biodiversity conservation area. In addition, the region also has other problems such as soil salinization. For these important ecological spaces, we should adhere to a “bottom line” way of thinking, minimize the interference of human activities, and carry out reasonable protection and utilization.

5.2. Advantages, Application Scope, and Limitations of the Proposed New Framework and Future Work

Different from the previous studies which only focused on the LUMS, the new framework of land use conflict identification proposed in this paper also considers LRS and DD. For DD, not only the diversity of human demands is considered, but also the diversity of wildlife demands, which is more in line with the current urgent needs of harmonious and sustainable development of human and nature. In short, the advantages of the new framework of land use conflict identification proposed in this paper include at least two aspects: its more sufficient theoretical basis and its consideration of the needs of humans and wildlife. In addition, the new framework proposed in this paper has obvious advantages in accurately identifying potential LUC. According to the identification results of this paper, the urban–rural integration zone is the key area of potential LUC, which is consistent with the results of previous studies [6,8]. However, there are some new findings in this paper. The plain of west Shandong Province is also a key area of potential land use conflicts. This result seems unexpected, but, in fact, it is reasonable and in line with the current developmental reality of China. The plain of west Shandong Province, which belongs to the North China Plain, is an important grain production base in Shandong Province. Because of the flat terrain and fertile soil, the land use multi-suitability in this area is high. Because most of the area is cultivated land, the scarcity of ecological land in this area, such as forest land, grassland, and water area, is high. Due to the good quality of the ecological environment and high connectivity, the demand for diversity of wildlife in this region is high. The combined effects of the above three aspects lead to serious potential land use conflicts in the plain of west Shandong Province. This is in line with China’s current development situation. China is still in the process of rapid urbanization, and despite the implementation of the strictest farmland protection system, China still

faces serious farmland non-agricultural, non-grain problems, threatening national food security [52,53]. Thus, the plain area is also a potential land use conflict area. If the strictest farmland protection system is not adopted, a large amount of farmland will be occupied by construction land or converted into forest land and cash crops through agricultural restructuring. To sum up, the plain of west Shandong Province is also a key area of potential land use conflicts, and the cultivated land protection policy should be strictly implemented, and effective measures should be taken to prevent the non-agricultural and non-grain conversion of cultivated land.

In the new framework of land use conflict identification constructed in this paper, the evaluation of each dimension is achieved by using the multi-objective comprehensive evaluation method on the basis of the evaluation index system, with clear concepts and simple and mature methods. It is not only applicable to Shandong Province but also can be extended to other regions of China and even other countries and regions for application.

The evaluation scales of LUMS, LRS, and DD are inconsistent. The evaluation unit of LUMS is grid, the evaluation unit of LRS is administrative region, and the evaluation unit of DD is grid and administrative region. On the one hand, the discussion of LRS and DD is often aimed at a specific region; on the other hand, socio-economic statistics such as the total population of the county are used in the evaluation, and these data are obtained at the administrative scale. Therefore, administrative districts are used in the above evaluation units. In the future, further studies should be conducted on how to evaluate LRS and DD on more refined scales such as grids.

Construction, cultivation, and ecology are the three dominant types of land use in Shandong Province. Therefore, construction land suitability, cultivation land suitability, and ecological land suitability were selected to evaluate land use multi-suitability. However, along with ongoing social and economic development, land use patterns are also undergoing a significant transformation and gradually showing multi-functionality and diversity [5,54,55]. When focusing on smaller research scales, LUMS evaluation should be carried out according to the actual situation. For example, the Yellow River Delta is mainly used for ecological protection and tourism. Therefore, game theory can be used to discuss the protection and utilization of the Yellow River Delta region [56–58]. In addition, it should be noted that socio-economic development and technological progress will also affect land use suitability, but the relevant data scale is too coarse, so it is not included in the evaluation index system of land use suitability in this paper.

6. Conclusions

This paper constructs a new framework for the identification of LUC including LUMS, LRS, and DD. The diversity of wildlife demands and human demands are included in the DD at the same time, which expands its connotation and scope. Based on this framework, potential LUC can be accurately identified. In Shandong Province, LUC was mainly of medium size, accounting for 57.10%. Strong conflicts accounted for 27.39%. Among them, the potential strong conflicts around big cities are mainly caused by urban expansion, while the potential strong conflicts in plain areas are mainly caused by the scarcity of ecological land. The main land type of potential LUC is cultivated land. Shandong Province should pay attention to tapping potential stock and improve construction land efficiency, strengthen the protection of “quantity, quality, and ecology” of cultivated land, and adhere to “bottom line” thinking to protect ecological land.

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