Land Use Transformation Based on Production–Living–Ecological Space and Associated Eco-Environment Effects: A Case Study in the Yangtze River Delta Urban Agglomeration

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Abstract: We investigate the eco-environmental effects and the driving factors of transforming the production–living–ecological space (PLES) land use function and offer a scientific foundation for developing regional territorial area and environmental preservation. Eco-environment quality index and ecological contribution ratio are used to analyze the spatial–temporal evolution characteristics and eco-environment effects of land use transformation in the Yangtze River Delta Urban Agglomeration (YRDUA) over the three time periods of 2000, 2010, and 2020, and the geographic detectors are used to analyze the factors that influence the spatial difference of eco-environment quality (EEQ). The findings indicate the following: (1) The land use transformation of YRDUA is primarily shown in the shrinkage of the production land area, the stability of ecological land, and the rapid increase of living land. The area of ecological land, such as water, forest, and pasture, has remained relatively steady from the perspective of secondary land types. In contrast, the area of urban and rural living land has significantly increased. (2) Most land use environment comprises the lower-value zone, accounting for about 50%. The area of the low-value zone has continued to rise owing to the rapid urban and rural living land development, tending to continuous growth. (3) Both the ecological improvement and degradation trends are present simultaneously, although the ecological improvement trend is less prominent than the environmental degradation trend. The primary factor is improving the eco-environment by transforming agricultural production land into forest, water, and ecological pasture land. The degradation of the regional EEQ is mostly due to the occupation of agricultural production land by urban and rural living land. (4) Considering natural elements such as altitude, precipitation, and slope, the extent of land use impacts the EEQ. The combination of several factors has changed the EEQ of the YRDUA. The effect of any two elements is stronger than that of a single factor.

Keywords: land use transformation; production–living–ecological space; eco-environment effects; geographical detector; the Yangtze River Delta Urban Agglomeration

1. Introduction

Rapid industrialization has accelerated social and economic growth and created dramatic changes in land use and spatial reconstruction that has had an enormous influence on the regional eco-environment [1–3]. It involves changing regional land use function and structure, corresponding to changing the social development stage during social change and innovation. This unique method of land use comprehensive study is known as “land use transformation” [4–6]. Grainger [5] first proposed the land use transformation, then numerous scholars performed in-depth research on land use, involving regional land use transformation [7], cultivated land transformation [8,9], driving mechanism [10,11], eco-environment effects [12,13], and so on. The transformation of the dominant function of land use, or the balance between the three primary land use functions, production, ecology, and life, illustrates how land use is transforming [14,15]. Linking production–living–ecological
land use transformation is an essential starting point for exploring the eco-environment effects of regional land use transformation [16,17].

Land use transformation is one of the variables that contribute to eco-environment change, affecting aspects such as regional climate, water quality, and soil quality, as well as the structure and function of the ecosystem [18–21]. Studies on how land use affects the environment have been performed. One method is to use biomass to characterize the level of regional EEQ, such as by using single indicators such as vegetation net primary productivity [22], normalized vegetation index [23], and other single indicators, or by using the ecological status index [24], remote sensing ecological index [25], and other comprehensive indicators. The second is a complete quantitative measurement method based on land use data, such as landscape ecological risk index [26], eco-environment quality index [27], etc. Few advancements have been achieved in the PLES perspective of analyzing regional land use change and its impact on the environment. Meanwhile, regression analysis [28] and partial least squares [29] are commonly used to study the driving factors of EEQ evolution. Based on the comprehensive consideration of natural and social factors, this paper attempts to use factor and interaction detectors in geographic detectors to explore the influencing mechanism of the evolution of EEQ in the YRDUA.

YRDUA is a crucial platform for China to participate in the global market and a key engine for economic and social development as it acts between the nations of the “Belt and Road” [30,31]. With the fast development of industrialization and urbanization, the pace of urban land expansion and development intensity has steadily increased, resulting in the invasion of green ecological land and the low degree of land use caused by the land use transformation process, culminating in several eco-environmental issues [32,33]. To summarize, this paper uses three-phase land use data as the basic data to quantify and study the land use function transformation, spatial–temporal evolution characteristics, and EEQ of the YRDUA from 2000 to 2020, based on the perspective of PLES. In addition, with the support of a geographic detector, the dynamic change trend of the eco-environment is analyzed. A reference for the development and use of regional land resources and eco-environment protection, the driving mechanism of the evolution of EEQ is investigated to reveal the effects of land use function transformation on the eco-environment.

2. Materials and Methods

2.1. Study Area

YRDUA is situated in the southeast coastal regions of China (115°46′ E–123°25′ E, 27°14′ N–33°41′ N) (Figure 1), with an area of roughly 215,000 km², accounting for 2.2% of the total national land area, including 26 cities in Jiangsu, Shanghai, Zhejiang, and Anhui provinces, according to the boundaries of the 2016 State Council-approved “YRDUA Development Plan”. With an average altitude of 88 m, the geographical type is primarily plain. The climate is mainly subtropical monsoon with an average annual temperature of 15 to 17 °C and average annual precipitation of 1000 to 1800 mm [34,35].

2.2. Data Sources and Processing

The Resource and Environmental Science and Data Center (http://www.resdc.cn, accessed on 8 May 2022) is the source of all the land use and driving factor data for the YRDUA in 2000, 2010, and 2020. Land use data mainly use Landsat-MSS, Landsat-TM/ETM, Landsat8 remote sensing image data, after-image fusion, geometric correction, image enhancement, and splicing processing, combined with human–computer interaction visual interpretation method and use field survey data to check and correct. The data in 2000 and 2010 mainly used Landsat-TM/ETM remote sensing image data, and the data in 2020 mainly used Landsat 8 remote sensing image data. The spatial resolution is 30 m, and its original data includes six first-level land use types and 25 second-level land use types.

DEM spatial distribution data are derived from SRTM (Shuttle Radar Topography Mission) based on the latest SRTM V4.1 data splicing, collation, and generation. The spatial interpolation dataset of annual average temperature and annual precipitation in China
is generated by calculation and spatial interpolation based on the daily observation data of more than 2400 meteorological stations in China. The dataset of GDP and the spatial population distribution is of grid type. Each grid of GDP data represents the GDP output value within the grid range (1 km\(^2\)), and the unit is ten thousand CNY per square kilometer. Each grid of population data represents the population within the grid range (1 km\(^2\)), and the unit is the population per square kilometer.

To cover various land use types, this study employs the three-division method based on production, ecological, and living land and uses economic production, eco-environment, and living life to reflect the multiple dimensions of regional economic and social growth [36] by the GB/T21010-2017 “Land Use Status Categorization” standard and concerning Yang et al. [37], based on the perspective of PLES and the primary function of land use. At the same time, the EEQ values of different second-level land types were formulated. PLES land classification’s EEQ was assigned using the area weighting method, based on the research results of Li et al. [38] and Cui et al. [39] (Table 1).

Table 1. Eco-environmental quality assignment for PLES.

| Primary Land Type | Secondary Land Type           | Ecological Environment Index |
|-------------------|-------------------------------|------------------------------|
| Production land   | Agriculture production land   | 0.29                         |
|                   | Industrial and mining land    | 0.15                         |
| Ecological land   | Forest ecological land        | 0.87                         |
|                   | Pasture ecological land       | 0.80                         |
|                   | Water ecological land         | 0.57                         |
|                   | Other ecological land         | 0.03                         |
| Living land       | Urban living land             | 0.20                         |
|                   | Rural living land             | 0.20                         |

2.3. Research Methods

The workflow is as follows to study the land use transformation and eco-environment effect of PLES in the YRDUA (Figure 2). First, land use data for 2000, 2010, and 2020 are reclassified according to the PLES division method. Then, the spatial and temporal variation characteristics of EEQ and ecological contribution rate are analyzed. Finally, the geographical detector is used to explore the driving factors of EEQ change.
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2.3.1. Land Use Transformation Matrix

The land use transformation matrix represents the transfer area of each land use type from the beginning to the end of the research period in a matrix form [40]. The calculation formula is

\[ S_{ij} = \begin{bmatrix} S_{11} & \cdots & S_{1n} \\ \vdots & \ddots & \vdots \\ S_{n1} & \cdots & S_{nn} \end{bmatrix} \]  

(1)

where \( S \) represents the land area; \( n \) represents the number of land use types; \( i \) represents the land use type at the start of the study; \( j \) represents the land use type at the end of the research period.

2.3.2. Eco-Environment Quality Index

The EEQ index reflects the ecological quality and area share of the PLES in the study area. It is used to quantitatively characterize the overall condition of EEQ [37,41]. The calculation formula is

\[ EV_t = \sum_{i=1}^{N} \frac{A_{ki}}{A_k} R_i \]

(2)

where \( EV_t \) is the EEQ index in the region \( t \) period; \( R_i \) is the EEQ index of the \( i \)-th land use type; \( A_{ki} \) is the area of the \( i \)-th type of land use in the region \( t \) period; \( A_k \) is the total area of the region; \( N \) is the number of land use types.
2.3.3. Ecological Contribution Rate

The change in regional EEQ caused by a change in a specific land use type is referred to as the ecological contribution rate of land use transformation. This index assesses the effect of the change in land use function on the EEQ index, which helps detect the main driving forces behind the regional eco-environmental change [37]. A positive value indicates that this transformation improves the quality of the regional eco-environment, while a negative value suggests that it degrades the quality. The calculation formula is

\[ CLEI = \left( LE_{t+1} - LE_t \right) \times \frac{LA}{TA} \]  

where \(CLEI\) is the rate of land use transformation that contributes ecologically; \(LE_{t+1}\) and \(LE_t\) are EEQ indexes for land use change at the end and start periods, respectively; \(LA\) is the area of the change type; \(TA\) is the total area of the area.

2.3.4. Geographical Detector

The geographical detector is a new statistical method for detecting spatial heterogeneity and revealing the driving mechanism, which has been widely used in driving mechanism analysis [42]. In this study, the geographic detector’s factor and interaction detector are used to investigate the driving mechanism.

The factor detector detects the spatial heterogeneity of the dependent variable \(Y\), as well as the influence of the driving factor \(X\) on the dependent variable \(Y\), measured by the \(q\) value, and the expression is

\[ q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma^2_h}{N \sigma^2} = 1 - \frac{SSW}{SST} \]  

\[ SSW = \sum_{h=1}^{L} N_h \sigma^2_h, \quad SST = N \sigma^2 \]  

where \(h = 1, ..., L\) is the stratification of the variable \(Y\) or \(X\) factor; \(N_h\) and \(N\) is the number of units in the layer \(h\) and the whole area, respectively; \(\sigma^2_h\) and \(\sigma^2\) are the variances of the \(Y\) values of the layer \(h\) and the whole area, respectively. The value range of \(q\) is \([0,1]\).

To ascertain if factors \(X1\) and \(X2\) will increase or decrease the ability of the dependent variable \(Y\) to explain variation, or whether these variables impact \(Y\) independently; the interaction detector is employed to find the interaction between various driving factors.

Due to the similarity in the impact of driving factors on EEQ in different periods, 2010 was used as the target year for the analysis. Combined with the study area’s characteristics and data availability, the driving factors were selected from both natural and socioeconomic aspects. Referencing related articles [43,44], altitude (\(X1\)), slope (\(X2\)), temperature (\(X3\)), and precipitation (\(X4\)) are among the selected natural environment factors, while land use degree (\(X5\)), population density (\(X6\)), and GDP (\(X7\)) are among the socioeconomic factors. When using the geographical detector to analyze the driving factor, it is necessary to combine the actual situation of the study area and appropriately discrete the continuous variables of the driving factor. Referring to the research of Cao et al. [45] on the discretization classification of driving factors, combining regional characteristics, and using ArcGIS 10.8 to discretize seven social and natural factors. By constructing a 5 km \(\times\) 5 km grid, the driving factors corresponding to the center point of each grid are extracted as the independent variable \(X\), and the EEQ index is the dependent variable \(Y\). \(X\) and \(Y\) are input into the geographic detector for matching, and then the detection results are obtained.

3. Results

3.1. Land Use Transformation Analysis

3.1.1. Basic Situation of Land Use

Using the PLES land use classification system, the geographic distribution and structural evolution aspects of land use in the YRDUA were examined (Table 2 and Figure 3).
According to the area and spatial distribution of the first-level land types in the YRDUA from 2000 to 2020, production land was primarily spread in Anhui and Jiangsu provinces in the north, with a total decline of 10,531.63 km² throughout the study period. The ecological land mainly distributed in southern Zhejiang Province also showed a decreasing trend, but the overall change was small, with a decrease of 2.61 km². The living land was mainly distributed near the Yangtze River and Taihu Lake and showed an expansion trend, with an increase of 10,534.23 km².

Table 2. Area of land use types in the YRDUA during 2000–2020 (km²).

| Year    | APL    | IML    | FEL    | PEL    | WEL    | OEL    | ULL    | RLL    |
|---------|--------|--------|--------|--------|--------|--------|--------|--------|
| 2000    | 110,508.46 | 1337.96 | 57,473.73 | 7876.06 | 18,319.20 | 34.87  | 4255.00 | 10,743.41 |
| 2010    | 101,652.75 | 2665.69 | 57,005.51 | 7355.57 | 19,385.53 | 235.04 | 9769.88 | 12,478.70 |
| 2020    | 97,698.68 | 1337.96 | 56,957.90 | 7521.16 | 18,916.27 | 305.93 | 11,791.50 | 13,741.14 |

Table 2. Area of land use types in the YRDUA during 2000–2020 (km²).

From the spatial distribution of secondary land types, agricultural production land and forest ecological land are widely distributed. Agricultural production land is concentrated in the central plains of Jiangsu Province and the Taihu Lake Basin, and forest ecological land is mainly located in the hilly and mountainous areas of northern Zhejiang Province. The river and lake water networks in the Yangtze River Delta region are densely distributed, and the water ecological land occupies a relatively high proportion, mainly allocated along the Yangtze River and Taihu Lake basins. Urban residential land is primarily concentrated near the Yangtze River, while rural residential land is scattered. From the change of secondary land type’s structure, the agricultural production land, forest ecological land, and pasture ecological land decreased by 12,809.78 km², 515.83 km², and 354.90 km², respectively. At the same time, the reductions in three types of land use mainly occurred during 2000–2010 and were relatively small during 2010–2020. Industrial and mining production land and urban and rural living land increased by 2278.15 km², 7536.50 km², and 2997.73 km²,

Figure 3. PLES land use of the YRDUA during 2000–2020.
respectively. The increase in the three types of land mainly occurred in 2000–2010 and was relatively small in 2010–2020. Water ecological land first increased and then decreased, showing an overall increasing trend. Other ecological land in the two stages is a rising trend, but the overall change is minimal. It shows that when the degree of urbanization increases, the YRDUA faces an increase in demand for urban living space, and the land availability gap widens.

3.1.2. Land Use Transformation

To investigate the characteristics of land use function transformation, a transformation matrix (Table 3) based on the PLES secondary land use type was constructed, and the trend and magnitude of mutual transformation of land use function types were clarified. The results indicate that between 2000 and 2020, agricultural production land in the YRDUA was mainly converted to urban and rural living land, with a total transfer area of 6185.21 km$^2$ and 4142.73 km$^2$, respectively. Forest ecological land was mostly transformed into agricultural production land, as well as industrial and mining production land, with a total transfer area of 594.94 km$^2$ and 423.03 km$^2$, respectively. Water ecological land was mostly turned into agricultural production land, industrial, and mining production land, and 196.93 km$^2$ of urban living land was converted into rural living land. With a transfer area of 478.01 km$^2$ and 1030.67 km$^2$, rural living land was mostly changed into agricultural production land and urban living land; conversion between other types of land is not obvious. The dynamic mutual transformation between agricultural production land, urban, and rural living land is how the land use function of the YRDUA changes from 2000 to 2020, and the three land use functions land of production land, ecological land, and living land maintain dynamic stability.

| Year | APL | IML | FEL | PEL | WEL | OEL | ULL | RLL |
|------|-----|-----|-----|-----|-----|-----|-----|-----|
| 2000 | 95,540.77 | 2171.98 | 910.94 | 93.30 | 1426.96 | 33.81 | 6185.21 | 4142.73 |
| 2010 | 153.11 | 417.02 | 8.46 | 16.71 | 504.50 | 9.13 | 186.91 | 41.93 |
| 2020 | 594.94 | 423.03 | 55,834.21 | 165.63 | 83.40 | 7.56 | 30.42 | 33.20 |
| 2001 | 202.12 | 101.15 | 130.72 | 6889.46 | 480.13 | 181.62 | 149.19 |
| 2011 | 688.39 | 432.92 | 34.97 | 348.80 | 16,347.91 | 188.49 | 181.32 | 92.44 |
| 2021 | 0.90 | 0.82 | 2.33 | 0.06 | 1.10 | 25.77 | 3.07 | 0.81 |
| 2002 | 38.64 | 11.87 | 7.92 | 0.35 | 7.16 | 0.13 | 3991.97 | 196.93 |
| 2022 | 478.01 | 56.30 | 23.45 | 5.40 | 61.91 | 3.81 | 1030.67 | 9083.67 |

3.2. Eco-Environmental Effects

3.2.1. Spatial–Temporal Evolution of Eco-Environment Quality

According to Formula (2), the EEQ index of the YRDUA in 2000, 2010, and 2020 were 0.4844, 0.4791, and 0.4766, respectively, and the overall EEQ level decreased (Table 4). According to the EEQ index of various land use types, agricultural production land, forest ecological land, and pasture ecological land are the land use types with deteriorating EEQ. Urban and rural living areas, water ecological areas, and land used for industrial and mining production are some of the land use with improved EEQ; the EEQ of other ecological areas usually remains steady.

| Year | APL | IML | FEL | PEL | WEL | OEL | ULL | RLL |
|------|-----|-----|-----|-----|-----|-----|-----|-----|
| 2000 | 0.1522 | 0.0010 | 0.2375 | 0.0299 | 0.0496 | 0.0001 | 0.0040 | 0.0102 | 0.4844 |
| 2010 | 0.1400 | 0.0019 | 0.2356 | 0.0279 | 0.0525 | 0.0001 | 0.0093 | 0.0119 | 0.4791 |
| 2020 | 0.1346 | 0.0026 | 0.2354 | 0.0286 | 0.0521 | 0.0001 | 0.0112 | 0.0131 | 0.4766 |
The research area’s EEQ was calculated using the sampling grid technique, and the EEQ of the YRDUA from 2000 to 2020 was further evaluated using the Kriging interpolation method for spatial interpolation. The EEQ index of the YRDUA is divided into five grades: low-value zone \((EV \leq 0.2627)\), lower-value zone \((0.2627 < EV \leq 0.4304)\), moderate-value zone \((0.4304 < EV \leq 0.5602)\), higher-value zone \((0.5602 < EV \leq 0.6967)\), and high-value zone \((EV > 0.6967)\). The following differences were found in the EEQ values at all levels (Table 5): low-value zone, lower-value zone, higher-value zone, and high-value zone all increased in proportion from 2000 to 2020, with the proportion of higher-value zone increasing the greatest, by approximately 3.47%. The low-value zone climbed by 1.04%, while the moderate and higher-value zone remained unchanged. With a total decline of 5.96%, the fraction of the lower-value zone exhibited a downward trend. Overall, the low-level EEQ area is increasing, a major contributor to the decline in overall regional quality.

| Types             | 2000          | 2010          | 2020          |
|-------------------|---------------|---------------|---------------|
|                   | Area (km²)    | Rate (%)      | Area (km²)    | Rate (%)      | Area (km²)    | Rate (%)      |
| Low-value zone    | 12,476.59     | 5.93          | 12,304.47     | 5.85          | 14,657.70     | 6.97          |
| Lower-value zone  | 115,768.84    | 55.03         | 104,872.68    | 49.85         | 103,230.40    | 49.07         |
| Moderate-value zone| 26,056.46   | 12.39         | 27,883.76     | 13.11         | 27,386.51     | 13.02         |
| Higher-value zone | 27,069.96     | 12.87         | 28,817.48     | 13.70         | 28,803.81     | 13.69         |
| High-value zone   | 29,010.47     | 13.79         | 36,803.93     | 17.49         | 36,303.91     | 17.26         |

The EEQ index of the YRDUA displayed notable regional disparities in 2000, 2010, and 2020, with the general geographic layout being high in the south and low in the north (Figure 4). High-value zone and higher-value zone are mostly located in the hilly and mountainous regions of Taihu Lake and northern Zhejiang and are affected by topography and landforms; the functional types are mainly forest land and pasture ecological land, which restricts the development of industry and mining and the agglomeration of cities and towns, making EEQ high. The moderate-value zone and the lower-value zone are concentrated in the central and northern part of the YRDUA, and the proportion in the area along the Yangtze River in Jiangsu is decreasing. The scope of the low-value zone is gradually expanding, mainly distributed around big cities, and growing rapidly. In 2000, it was only scattered around central cities such as Shanghai and Suzhou, and the scope was small, accounting for about 5.93%; by 2020, the area of low-value zone will expand to 14,657.70 km², accounting for 6.97% of the total. There is a trend toward concentrated and continuous distribution, mostly consistent with the regional focus of urban economic growth and industrial expansion.

3.2.2. Ecological Contribution Rate

It shows that the overall change in the YRDUA's EEQ from 2000 to 2020 is quite minimal in Table 4. This is the outcome of two opposing tendencies in regional EEQ improvement and degradation, which partially balance one another. The ecological contribution rate of land use transformation was evaluated to demonstrate the effects of each functional land transformation on the regional EEQ (Table 6). The transformation of agricultural production land into the forest, water ecological land, and industrial and mining production land into water ecological land is the most important aspect of improving the eco-environment between 2000 and 2020. The land functions that enhance the eco-environment are relatively concentrated, and the first eight categories of transformed land functions account for 95.11% of the improvement in EEQ. The conversion of agricultural production land to urban and rural living land, industrial and mining production land, and forest land ecological land to agricultural, industrial, and mining production land are all key elements in the degradation of EEQ. The first 13 types of land function transformation accounted for 91.29% of the decline in EEQ. In general, there are two ecological tendencies...
in the YRDUA: progress and degradation. The rate of improvement in the eco-environment is slower than the rate of degradation, and the rate of degradation is increasing.

Figure 4. Distribution of EEQ in the YRDUA.

Table 6. Transformation and contribution rate of major land use function types in the YRDUA during 2000–2020.
3.3. Driving Factors Analysis of Eco-Environment Quality

3.3.1. Single Factor Detection Analysis

From greatest to smallest, each factor’s explanatory power on the EEQ index of the YRDUA is X5 (0.698) > X1 (0.656) > X4 (0.653) > X2 (0.462) > X6 (0.293) > X7 (0.178) > X3 (0.133) (Figure 5). Among them, the degree of land use (X5) has the most effect on the EEQ, followed by natural factors such as altitude (X1), precipitation (X4), and slope (X2). The degree of land use indicates the extent to which human activities have disrupted the land ecosystem. The transformation of regional land use is driven by the continuous intensification of human activity, which also affects the local EEQ. The distribution of regional vegetation types influences changes in the regional EEQ, and factors including altitude, precipitation, and slope are important driving factors behind these changes.

3.3.2. Interaction Detection Analysis

EEQ is affected by a variety of elements. There are many interrelated aspects, and as a result, there will be variations in the size, intensity, and direction of the driving factors. The influence on the EEQ may be raised or lowered by the interaction between factors. Interaction detectors are used to detect whether interactions between factors increase or decrease the explanatory power of the dependent variable relative to a single factor. Based on the interaction detection results (Figure 6), the interaction of any two factors is greater than that of a single factor, indicating that the impact factor’s impact on the EEQ does not occur alone but shows a synergistic effect. The change in the EEQ of the YRDUA results from the joint action of multiple factors. Among them, the interaction between land use degree (X5) and altitude (X1), land use degree (X5) and precipitation (X4) were the strongest, reaching 0.852 and 0.839, respectively, which are higher than the effect of a single factor. The interaction between different driving forces significantly enhanced the spatial differentiation effect of the EEQ of the YRDUA. The synergistic enhancement effect formed by the complex coupling between different factors jointly affects the spatial differentiation effect of the EEQ of the YRDUA.

Figure 5. Driving factors contribution rate.
4. Discussion

Statistical assessment and evaluation of spatial–temporal changes in land use and associated EEQ are essential for regional ecological security and sustainable development [46–48]. This paper explores the spatial and temporal changes of land use change and its EEQ in the YRDUA from 2000 to 2020, as well as the effect that changing land use has on EEQ. It analyzes the driving factors of EEQ change by combining with geographic probes to provide a scientific basis for eco-environmental protection, sustainable development, and regional territorial spatial planning in the YRDUA.

The study shows that the overall EEQ index of the YRDUA has slightly decreased in the past 20 years. The pattern of geographical dispersion reveals the characteristics of higher hills in the south and lower plains at low altitude in the north. The degradation of EEQ is mainly related to construction land development, industrial and mining activities, and vegetation degradation, indicating that land use transformation is closely related to the ecological quality index [49,50]. Since the 21st century, the pressure of population growth and economic development on resources and the environment has been increasing, and the conflict between people and land is increasing. The coupling coordination of the land use function focuses on alleviating land use conflicts and land resource management. PLES is the basic carrier of human social development and economic activities, and its collaborative development is an effective way to alleviate land use conflicts and realize regional coordinated development [51,52]. The impact of future land use changes on the EEQ should be considered in land use management and planning, and ecological restoration techniques should be undertaken in compliance with existing conditions to enhance the ecosystem function of ecological land. Avoid excessive expansion of construction land and reduce the negative impact on the eco-environment in the process of land use transformation to realize the sustainable development of social economy and eco-environment [50,53].

The eco-environment effect is not only related to the EEQ index corresponding to each land use function type but also has a close relationship with the area of each land use function type [54]. The research results show that the high-value zone is mainly woodland, and the low-value zone is mainly urban land. Therefore, in future land use planning, we should rationally develop urban land, adhere to the bottom line of basic farmland, and protect ecological land. The data used in this paper come from remote sensing data and
are obtained by manual visual interpretation. There is an inevitable error in accuracy. Therefore, more accurate remote sensing image data can ensure the reliability of land use data so that the research results are more precise and credible. This study solely refers to the effects of different factors on the EEQ from natural and social perspectives, and it ignores micro-factors such as management techniques and policy backgrounds in its selection of influencing factors [36]. In the future, exploring the driving mechanism of EEQ change is necessary.

YRDUA is in a period of transformation between urban and rural development. It is critical to strengthen the impact mechanism of urbanization-driven land use transformation and the resulting eco-environment effects, analyze and simulate the evolution situation, discuss the connectivity principles and approaches, and propose land use promotion. Then, it puts forward the safeguard measures to promote the optimal allocation of land use and the optimization of environmental effects in order to support the direction and path of the healthy development of cities in the future [55,56].

5. Conclusions

The above study evaluates the land use function transfer matrix, eco-environment quality index, and ecological contribution rate of land use function transformation using three periods of land use in 2000, 2010, and 2020 to reveal the spatial–temporal changes in land use function and EEQ in the YRDUA. The following are the main results of the analysis:

1. The transformation of land use is mostly shown in the decrease of production land, stabilization of ecological land, and rapid expansion of living land. The dramatic drop in agricultural production land, the relative stability of ecological land types, including water, forest, and pasture, and the sharp rise in urban and rural living land are secondary land types.

2. The overall EEQ index has deteriorated from 0.4844 in 2000 to 0.4766 in 2020. Most of the environmental condition of land use comprises regions of the low-value zone, which make up around 50% of the total area. Rapid urban and rural land development has resulted in an ongoing trend of growth and a rise in the area of the low-value zone.

3. There are both ecological improvement and degradation in the study area, and the tendency for ecological improvement is more minor than environmental degradation. The conversion of agricultural production land into ecological land is the leading factor in ecological improvement. The occupation of agricultural production land by urban and rural living land is an important factor in the degradation of regional EEQ.

4. The results of factor detection show that natural factors such as altitude, precipitation, and slope have less impact on the EEQ than on the degree of land use. The results of interaction detection demonstrate that the effect of any two variables working together is higher than any one component working alone and that the change in the EEQ is the consequence of the combined activity of several factors.

This study analyzes the spatial–temporal evolution of land use transformation and the eco-environment effect of the YRDUA from 2000 to 2020 and discusses the driving factors of ecological environment quality change, which has specific reference significance for regional land use development and utilization. However, the evaluation index data selected in the analysis of driving factors are fewer, and there is a specific deviation in the evaluation results. At the same time, how to adjust the land use types in PLES and coordinate various land use types need further study. In the future, relevant policies and planning should promote the rational distribution of PLES, steadily improve the EEQ, and continuously promote the construction of ecological civilization in the YRDUA.

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