

## Article

# Spatio-Temporal Differentiation and Driving Factors of Land Use and Habitat Quality in Lu'an City, China

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**Abstract:** The spatio-temporal evolution of land use/land cover (LULC) and habitat quality (HQ) is vital to maintaining ecological balance and realizing regional sustainable development. Using the InVEST and CA-Markov model, with the Kendall coefficient as the sensitivity value, LULC and HQ in Lu'an City from 2000 to 2030 are simulated and evaluated. Then, Spearman is used to analyze the correlation between HQ and driving factors. Finally, the influence of policy factors on HQ is discussed. The results show the following: (1) from 2000 to 2030, the LULC of Lu'an is mainly cropland (about 40%) and forest land (about 30%) which are transferred to construction land; (2) the kappa coefficient is 0.9097 (>0.75), indicating that the prediction results are valid; (3) the Spearman coefficient shows that DEM (0.706), SLOPE (0.600), TRI (0.681), and HFI (−0.687) are strongly correlated with HQ, while FVC (0.356) and GDP (−0.368) are weakly correlated with HQ; (4) the main reasons for the decrease in HQ are the increase in construction land area, the decrease in forest area, the vulnerability of artificial forests to threat factors, and their low biodiversity. This study outlines exploratory research from two perspectives of HQ factors and policy effects to provide policy suggestions for the sustainable development of Lu'an City.

**Keywords:** InVEST model; CA-Markov model; land use/land cover; habitat quality; sustainability; correlation analysis; driving factors



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## 1. Introduction

For thousands of years, scholars around the world have developed many ways to understand and relate to nature and its many values [1]. However, since the Industrial Revolution (and especially in the 2000s), significant changes have taken place in the global natural ecological environment. With the rapid development of the social economy, China's urbanization rate rose from 10.6% in 1949 to 63.89% in 2020 [2]. The rapid expansion of human-made land for urban construction has eroded the natural ecological surface and put increasing pressure on the natural ecological environment. HQ refers to the ability of an ecosystem to provide sustainable conditions for the survival and development of individuals and populations over a certain period of time and space [3–5]. HQ is a common index used to reflect the status of regional biodiversity [6] and evaluate ecosystem services [7]. HQ level is an important index to measure the habitat suitability, health, and sustainability of regional ecosystems [8]. The assessment of HQ and the study of its spatio-temporal changes are the prerequisite for solving the ecological environment problems caused by human's exploitation and utilization of ecosystems and are also of great significance for maximizing ecosystem service functions and maintaining the balance and sustainability of natural ecosystems [9].

Recently, the threat of HQ comes from large-scale deforestation, wetland reduction, overgrazing, alien species invasion [10,11], and land use/land cover change (LUCC) [12]. LUCC is a major cause of HQ degradation and loss [13]. Land use is a threat factor in HQ evaluation,

and its change will affect the improvement and decline in HQ [14]. Therefore, in the process of evaluating the dynamic evolution of HQ, considering the change in land use type, especially the analysis and simulation of its spatio-temporal dynamic evolution, may be beneficial for the conservation of HQ in the study area. In the field of land use change, most scholars used land prediction models to simulate and forecast land use, such as the FLUS model [15], PLUS model [16], etc. Among them, the CA-Markov model combines the characteristics of the CA (cellular automata) model in simulating spatial pattern evolutions [17] and the advantages of the Markov model in long-term quantitative estimation [18]. Therefore, the CA-Markov model can not only improve the prediction accuracy of land use type change but also effectively simulate the spatial change in land use pattern [19]. In this study, we use the CA-Markov model to predict the LUCC of Lu'an City in 2025 and 2030.

In addition, the evaluation of HQ is affected by many factors, such as research scale and data source, and there are many differences in the evaluation methods of different scholars [11]. At present, there are two main methods used to study the impact of land use change on HQ. The first is the index system method based on the landscape pattern, and the second is the quantitative research based on ecological assessment [20–23]. The former is to evaluate HQ through field investigation and the construction of the evaluation index system to obtain HQ parameters in the study area [24,25]. This method is suitable for small-scale, time-consuming, difficult-to-control dynamic characteristics of time and space and focuses on short-term changes [26–28]. The latter has the characteristics of easy data acquisition, lower costs, and a strong visualization effect. In the evaluation of HQ dynamic features in a large spatial range and long time series, the methods commonly used by scholars include the InVEST model [29], habitat suitability index model (HIS) [30], etc.

The InVEST model integrates remote sensing data, the mathematical elevation model, climate interpolation data, and other earth observation data, overcoming the shortcomings of the “point-to-surface” method and has the characteristics of relatively few operating parameters, easy access to basic data, large output data, quantitative evaluation results, and spatial visualization. This provides a possibility for the quantification, visualization, and refinement of large-medium scale regional HQ analysis and evaluation, which lacks measured data, and can also describe the spatial heterogeneity of regional HQ more directly [31]. At present, the InVEST model has been widely used in river basins [32,33], ecological reserves [34], wetlands [35], islands [13,36], the Greater Bay Area [37,38], and other geographical units [39], which proves that the InVEST model is effective in evaluating HQ in the study area. It is of great practical significance to conduct in-depth research on regional HQ by using the InVEST model.

In the process of calculating HQ with InVEST, the sensitivity of LULC to threat factors is a key parameter. At present, scholars mostly use the literature method [40], the expert opinion method [41], or a combination of both to set sensitivity values [2]. However, the sensitivity obtained based on this approach has certain limitations, which can lead to human error in the results. Only a few scholars use the correlation coefficient instead of manual experience [38], which enhances the objectivity of the results. But few scholars have studied the future evolution of HQ on this basis. So, focusing on the impact of threat factors on LULC in different periods, we used the Kendall rank correlation coefficient as the sensitivity value and explored the evolution of HQ in 2025 and 2030.

In addition, policy factors play an important role in the evolution of HQ. However, scholars have mostly explored the driving mechanism of HQ from terrain, climate, economy, population, and other factors or predicted regional LULC and HQ under different circumstances [37,42] and have rarely studied the impact of policies on HQ. Therefore, there are still the following problems in the current research on HQ and its driving mechanism, which need to be further explored: (1) How do we set parameters such as sensitivity in the HQ model to reduce subjectivity and increase the objectivity of the results? (2) What is the impact of policy factors on HQ, and how do we provide reasonable and effective policy recommendations?

In fact, about 30% of the area of Lu'an City is covered by forests, which is an important commercial grain base and water conservation area, bearing important ecological functions. Therefore, the scientific evaluation of HQ in this region and the exploration of its

relationship with policy factors are of great significance for the formulation of sustainable development policies and ecological protection. Over the past 20 years, the Lu'an City government has implemented numerous policies for regional development and protection, which provides an opportunity to explore the impact of policies in depth.

We carried out an in-depth investigation and research on Lu'an City, China. In our study, we integrated the InVEST, Kendall, Spearman, and CA-Markov models and established a research framework (Figure 1). The framework uses the Kendall rank correlation coefficient instead of human parameters to evaluate HQ. Then, it uses Spearman to analyze the correlation between HQ and driving factors and finally puts forward policy recommendations. This is of great value for decision makers to formulate scientific and reasonable policies to achieve the balance between HQ and economic development.

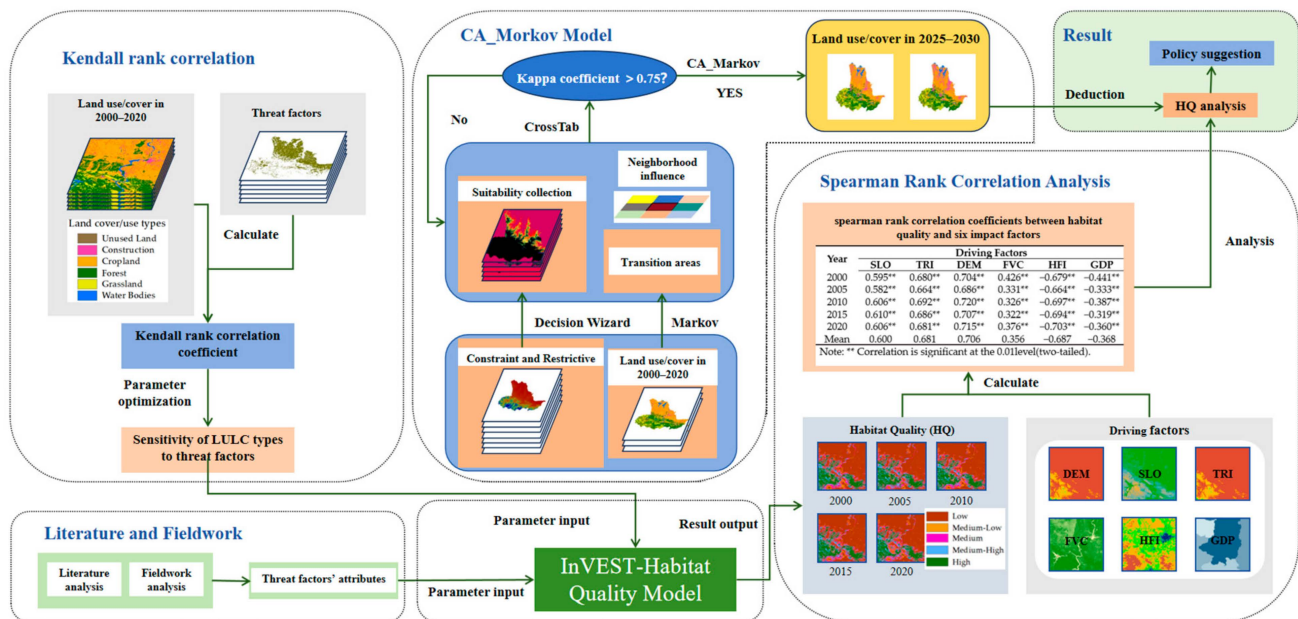
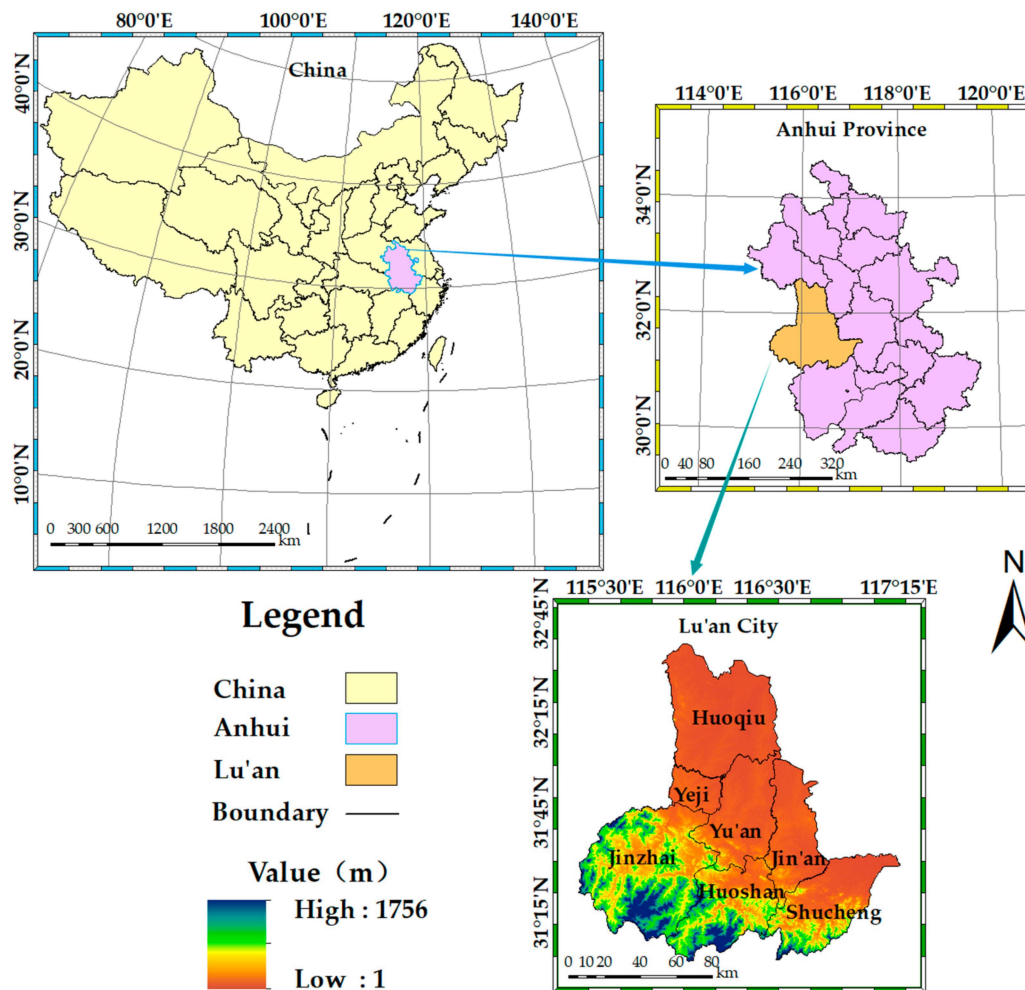


Figure 1. The research framework.

## 2. Materials and Methods

### 2.1. Study Area

The Lu'an City is located in the west of Anhui Province in China, at the northern foot of the Ta-pieh Mountains and the westernmost part of the Yangtze River delta. The area is located between 115°20'–117°14' E and 31°01'–32°40' N (Figure 2), east of Hefei (the capital of Anhui Province), with a total area of 15,451.2 km<sup>2</sup>. The region has a subtropical monsoon climate with good combination of rain, sunshine, and temperature. The landscape pattern of mountains, hills, valleys, and domains is distinct. The area is rich in natural resources and contains more than 2000 species of plants and animals, which have significant ecological value. In the past 20 years, the economy of Lu'an City has developed rapidly, while the ecological environment situation has become increasingly severe; the problems of water pollution, soil and water conservation, forest management, etc., have become prominent; and the ecological pressure has been increasing day by day. In response to these problems, the local government has implemented many policies and measures, which provides conditions for further exploring the impact of policies on HQ.



**Figure 2.** The administrative boundary and elevation of Lu'an City.

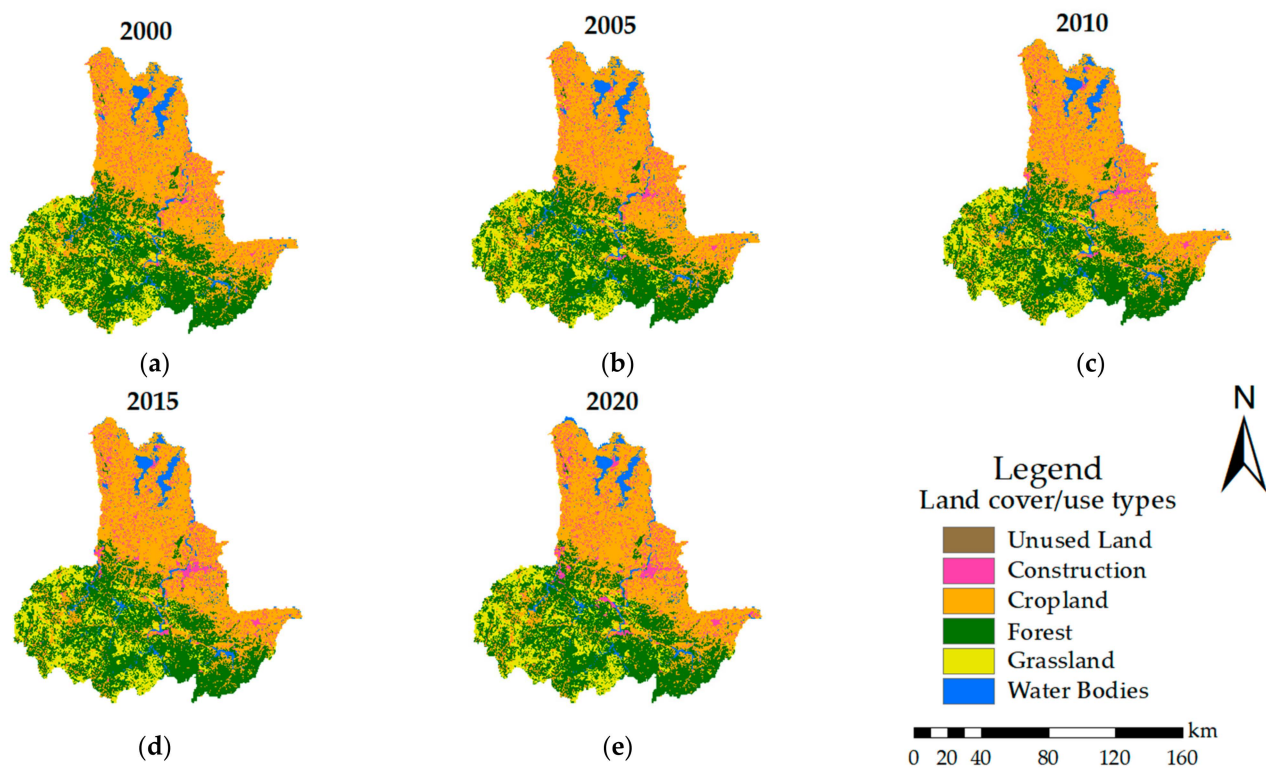
## 2.2. Data Source and Preprocessing

The land use data in this study are obtained from remote sensing data via the Resource and Environmental Science Data Platform of the Chinese Academy of Sciences (<http://www.resdc.cn/>, accessed on 15 April 2023). The social and economic data used in this study mainly include the spatial distribution data of government departments (<https://download.geofabrik.de/asia/china.html#>, accessed on 10 June 2023), national geopark (<https://zh.wikipedia.org>, accessed on 11 June 2023), national key cultural relics protection units (<https://geodata.pku.edu.cn/>, accessed on 11 June 2023), and nature reserves (<http://www.resdc.cn/>, accessed on 11 June 2023) of Lu'an City. HFI (human footprint index, [https://www.x-mol.com/groups/li\\_xuecao/news/48145](https://www.x-mol.com/groups/li_xuecao/news/48145), accessed on 5 January 2024) and GDP (gross domestic product, <http://tjj.ah.gov.cn/ssah/qwfbjd/tjnj/index.html>, accessed on 24 November 2023) are included. The natural environment data mainly include DEM (digital elevation model, <http://www.gscloud.cn/>, accessed on 9 June 2023), SLO (slope), TRI (terrain roughness index), and FVC (fractional vegetation cover). Based on DEM, SLO and TRI are extracted by using the slope and focus statistical tools of ArcGIS. Then, FVC is derived from NDVI (normalized difference vegetation index, <http://www.nesdc.org.cn/>, accessed on 2 January 2024) [43,44]. Finally, the economic–natural development data of Lu'an City is obtained through field investigation.

In this study, the land use data of five periods (2000, 2005, 2010, 2015, and 2020) in Lu'an City were selected to calculate and analyze the land use change in the study area in the past 20 years. The resolution of land use data is 30 m, which mainly involves the area calculation of LULC. After that, the reclass tool in ArcGIS was used to classify land



use into six categories: cropland, forest land, grassland, water bodies, construction land, and unused land (Figure 3). The specific resolution of the data used in this study can be found in Table S1 of the Supplementary Materials.



**Figure 3.** Spatial pattern of land use in Lu'an City from 2000 to 2020: (a) represents land use in 2000; (b) represents land use in 2005; (c) represents land use in 2010; (d) represents land use in 2015; (e) represents land use in 2020.

In addition, the survey results show that the planning period of land use in Lu'an City is generally 10 to 20 years, and the implementation cycle of economic and environmental protection policies is generally 5 to 10 years. Then, by referring to similar studies [45,46], we decided to forecast the land use and HQ of Lu'an City in 2025 and 2030.

### 2.3. Methods

The research method is divided into four key steps. Firstly, the Kendall correlation coefficient is used to replace the empirical value to calculate the initial parameter, that is, the sensitivity of various land use types to threat factors. Secondly, the optimized HQ model is used to evaluate the degree of habitat degradation and HQ in the Lu'an City area over the past 20 years. Third, the CA-Markov model is used to predict the land use change in the Lu'an City area in 2025 and 2030, and the habitat status in 2025 and 2030 is predicted. Fourth, Spearman rank correlation is used to analyze the correlation between drivers and HQ.

#### 2.3.1. Land Use Transfer

The land use transfer matrix is a quantitative description of land class change in different periods. Land change degree can be determined by calculating the area or percentage difference in the same type of land in different periods to reflect the area data of

each type of land in a specific region at a specific time, as well as the area transferred out of each type of land in the early stages and the area transferred in the later stages [47].

$$S_{ij} = \begin{pmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2n} \\ \vdots & \vdots & & \vdots \\ S_{n1} & S_{n2} & \cdots & S_{nn} \end{pmatrix} \quad (1)$$

where  $S_{ij}$  represents the area of class  $i$  land transformed into class  $j$  land from the beginning to the end of the study period, and  $n$  is the land use/land cover (LULC) type. In the study, we used ArcGIS to fuse and overlay the LULC maps of five periods in Lu'an City and derived the attribute table after calculating the area, thus completing the data extraction of the transfer matrix.

### 2.3.2. InVEST Model and HQ Model

The InVEST model is an evaluation model developed by Stanford University that can quantify multiple ecosystem services. The HQ module in this model uses a classification map to conduct the spatial quantitative evaluation of HQ in the study area based on the impact distance and spatial weight of threat factors, habitat suitability, and sensitivity to threat factors. It is characterized by a small amount of imported data and a large amount of output data [48].

We used the InVEST model, land use data (2000–2030), threat factors' attributes, sensitivity parameters, habitat suitability, half-saturation constant ( $k = 0.05$ ), and constant ( $z = 2.5$ ) to calculate the HQ of Lu'an City from 2000 to 2030. The land use data for 2025 and 2030 are the predicted results.

#### (1) Evaluation principle of habitat degradation degree

The degree of habitat degradation represents the impact level of threat factors on the habitat structure [49]. Its calculation is based on the assumption that the higher the sensitivity of a certain land use type in an ecosystem to threat factors, the greater the degree of degradation of the that type, and its magnitude is closely related to factors such as the number of local species and threat factors in the habitat [50]. When the LULC type is  $j$ , the habitat degradation degree ( $D_{xj}$ ) of grid cell  $x$  can be calculated as follows [40,49]:

$$D_{xj} = \sum_{r=1}^R \sum_{y=1}^{Y_r} \left( \frac{W_r}{\sum_{r=1}^R W_r} \right) r_y i_{xy} \beta_x K_{jr} \quad (2)$$

where  $r$  represents the threat factor;  $y$  is the grid number of the  $r$ -th threat factor;  $Y_r$  is the total grid number of threat factor  $r$ ;  $w_r$  is the weight of the threat factor, and its value ranges from 0 to 1.  $r_y$  represents grid cell  $y$  as a threat grid cell (0 or 1);  $i_{xy}$  is the threat level of the threat factor value of threat grid cell  $y$  to grid cell  $x$  in the region;  $\beta_x$  is the reach ability level of grid cell  $x$  (0–1);  $K_{jr}$  is the sensitivity of LULC type  $j$  to threat factor  $r$  (0–1).  $i_{xy}$  can be calculated by the following formula [40,49]:

$$i_{rxy} = 1 - \left( \frac{d_{xy}}{d_{rmax}} \right) \text{ if linear} \quad (3)$$

$$i_{rxy} = \exp \left[ - \left( \frac{2.99}{d_{rmax}} \right) d_{xy} \right] \text{ if exponential} \quad (4)$$

where Formula (3) is the linear distance decay function, and Formula (4) is the exponential distance decay function.  $d_{xy}$  is the linear distance between grid cells  $x$  and  $y$ ;  $d_{rmax}$  is the maximum effective distance of threat  $r$  reaching across space.

#### (2) The principle of HQ evaluation

HQ is the level of environment that the outside world provides for the survival of individual organisms and populations. This module shows how human behavior affects ecosystems. When the intensity of human activity increases, the levels of biodiversity and HQ decrease, putting more pressure on existing habitats [41].

In the HQ model, HQ is calculated based on the degree of habitat degradation, and the score decreases with the increase in the score of habitat degradation. The calculation formula is as follows [40,49]:

$$Q_{xj} = H_j \left[ \left( 1 - \frac{D_{xj}^z}{D_{xj}^z + k^z} \right) \right] \quad (5)$$

where  $Q_{xj}$  represents the HQ of grid cell  $x$  when the LULC type is  $j$ ;  $H_j$  represents the habitat suitability of the LULC type  $j$ .  $D_{xj}$  represents the degree of habitat degradation in grid cell  $x$  when the LULC type is  $j$ ;  $k$  and  $z$  are scaling parameters, the  $k$  constant is a half-saturation constant, usually equal to the  $D$  value, so it takes half of the maximum value of  $D_{xj}$ , and  $z$  is defined as the constant of 2.5.

Habitat suitability is an important parameter of the HQ model, and the score represents the numerical parameter of LULC type of suitable habitat, generally in the range of 0–1 [49]. In addition, the user's guide of the InVEST model applies the maximum threat factor impact range (MAX-DIST), threat factor weight (0–1), and decline index of threat factor impact on habitat in the model. This study referred to the recommended reference value of the model and other relevant studies [6,38,51–53] as the assigned habitat suitability values to cropland, forest land, grassland, water bodies, construction land, and unused land (Table 1).

**Table 1.** Habitat suitability of land use/land cover (LULC).

| LT | CRO  | FOR | GRA  | WB  | CON | UNL  |
|----|------|-----|------|-----|-----|------|
| HS | 0.35 | 1   | 0.75 | 0.9 | 0   | 0.15 |

Note: LT: LULC type; HS: habitat score; CRO: cropland; FOR: forest; GRA: grassland; WB: water bodies; CON: construction; UNL: unused land. (Other information such as sensitivity parameters can be found in Table S2 of the Supplementary Materials).

In addition, intense human activities and environmental changes have had a profound impact on the land system [54]. Thus, in this study, the LULC types with the most frequent human activities (paddy field, dryland, urban land, rural residential land, and other construction land) [13] and unused land [41] were selected as the threat factors, and the maximum impact distance, weight, and decline index of the impact of stress factors on habitat were assigned for each threat factor in Table 2.

**Table 2.** Threat factors' attributes.

| Threat | MD/km | Weight | DT          |
|--------|-------|--------|-------------|
| PF     | 0.5   | 0.3    | exponential |
| DL     | 0.5   | 0.3    | exponential |
| UL     | 8     | 0.9    | exponential |
| RSL    | 2     | 0.7    | exponential |
| OCL    | 1     | 0.5    | exponential |
| UNL    | 3     | 0.4    | linear      |

Note: MD: maximum distance; DT: decay type; PF: paddy field; DL: dryland; UL: urban land; RSL: rural residential land; OCL: other construction land; UNL: unused land (including bare land and bare rock land).

The maximum influence distance of paddy field, dryland, the rural residential area, and other construction land is defined as 0.5, 0.5, 2, and 1, respectively [55], and the weights of rural residential area and other construction land is defined as 0.7 and 0.5 [55,56].

The sensitivity parameters are calculated using the Kendall rank correlation analysis method and Python code and obtained by taking absolute values, and the sensitivity of

“nan” value is referred to the relevant literature [33,57,58] and is defined as 0. See Table S2 for specific parameters.

### 2.3.3. Kendall Rank Correlation Analysis Method

Kendall rank correlation analysis can be used to measure the degree of dependence between two categorical variables. In the HQ model, the original parameters of land use data in 5 periods were used to obtain the Kendall coefficient of each habitat threat factor for each land type. The absolute value of Kendall correlation coefficient was used as the sensitivity of habitat types to threat factors in the HQ model. In this study, all correlation coefficients were calculated using Python 3.11.5 software. (Supplementary Materials, Code S1) The calculation formula is as follows [38]:

$$T = |\tau| = \left| \frac{n_c - n_d}{\frac{n(n-1)}{2}} \right| \quad (6)$$

where  $T$  is the absolute value of Kendall correlation coefficient,  $\tau$  is the Kendall correlation coefficient,  $n_c$  is the number of consistent sample data pair,  $n_d$  is the number of inconsistent sample data pairs, and  $n$  is the total number of sample data pairs.

### 2.3.4. Analysis of Factors Affecting HQ

#### (1) Standardization

A variety of natural and socioeconomic data were involved in this study. In order to minimize the errors caused by the data dimension, the input data are uniformly normalized to ensure that the value of each variable is in the range of 0 to 1.

$$R_m = (R - R_{min}) / (R_{max} - R_{min}) \quad (7)$$

where  $R_m$  is the normalized value of the target parameter,  $R$  is the target value of the dataset,  $R_{min}$  is the minimum value of the dataset, and  $R_{max}$  is the maximum value of the dataset.

#### (2) Spearman Rank Correlation Analysis Method

Spearman rank correlation analysis is used to measure the strength of the relationship between variables and does not require normal distribution or a linear relationship between variables. If the two variables do not have low kurtosis (i.e., normal or platykurtic distributions) or outliers are likely to be present, Spearman rank correlation analysis is the preferred method because it has superior performance in terms of variability and robustness. In fact, the distribution of HQ and driving factors in Lu'an City is non-normal [59]. In principle, the Spearman rank correlation coefficient is the ranking of sample data pairs before correlation coefficient calculation, which is only a special case of the Pearson coefficient [60]. The simple expression of  $r_s$  based on the difference between two rank variables is as follows [59,61]:

$$r_s = 1 - \frac{6 \sum d_i^2}{N(N^2 - 1)} \quad (8)$$

where  $d_i = X'_i - Y'_i$  is the difference between each pair of sorting variables, and  $N$  is the total number of samples. It is a measure of a monotone relationship that can be used when the characteristics of the paired variables (such as frequency distribution and/or linear distribution) make Pearson's formula misleading or undesirable.

HQ is influenced by both natural and human factors. Fractional vegetation cover (FVC) [38] is an important ecological parameter for detecting ground vegetation cover and reflecting the vegetation growth status. The digital elevation model (DEM), slope (SLO), and terrain roughness index (TRI) [42] are important geographical parameters to measure the terrain and landform of the study area. The human footprint index (FHI) [62] and gross domestic product (GDP) [38] are important human factors used to reflect the intensity of



human activities. FHI reflects 8 variables of different aspects of human pressure, such as the built environment, population density, night light, cropland, pasture, road, railway, and navigable waterway. Therefore, we selected four natural factors, FVC, DEM, SLO, and TRI, and two human factors, HFI and GDP, and used Spearman to calculate all HQ datasets in 2000, 2005, 2010, 2015, and 2020 of Lu'an City and the Spearman correlation coefficients of all driving factors in the same period.

### 2.3.5. CA-Markov Model

The CA model has an excellent spatial computing ability and can simulate the changes in the system in space. However, its scope of action is limited to only between cells, and it cannot analyze the overall cellular state. The Markov model can be used to predict the quantity change in the LULC type in a certain period, but it lacks the ability to simulate the change in space. The CA-Markov model combines the advantages of both and uses the transition probability matrix to simulate future LULC mapping over time. The conversion rules, which are composed of land suitability, related policies, and socio-economic factors of LUCC, determine the possibility of LULC type conversion in each cell. When the probability exceeds the threshold, the LULC type is converted [63]. Using the local transformation of each cell, the complex simulation of LUCC in Lu'an City was realized, and the formula was as follows [64,65]:

$$S_{t+1} = f(S_t, N) \quad (9)$$

where  $S$  represents a finite, discrete set of states of the cell;  $t$  and  $t + 1$  denote different moments;  $N$  represents the neighborhood of the cell;  $f$  represents a transformation rule for a local space.

$$S_{t+1} = P_{ij} \times S_t \quad (10)$$

where  $S_t$  and  $S_{t+1}$ , respectively, represent the state of land use at  $t$  and  $t + 1$  time, and  $P_{ij}$  represent the transfer probability of the LULC type of  $i$  transforming into the LULC type of  $j$ , which can be expressed as follows:

$$P_{ij} = \begin{matrix} & P_{11} & \dots & P_{1n} \\ \vdots & \vdots & & \vdots \\ P_{n1} & \dots & & P_{nn} \end{matrix} \quad (11)$$

where  $n$  represents the LULC type and simultaneously meets  $0 \leq P_{ij} < 1$  and  $\sum_{i=1}^n P_{ij} = 1$ .

There are four key steps in the prediction process of this study: (1) The Markov module in IDRISI Selva 32.00 software is used to calculate the data of the training set and obtain the suitability map of the land use transfer matrix and the natural state. (2) Taking into account the distribution of government departments and the distribution of protected areas in the Lu'an City area and combining with the suitability atlas obtained, we re-compiled the suitability atlas in line with the actual situation of the study area. (3) The CA-Markov module is used to predict the LUCC situation of Lu'an City in 2020. If the kappa coefficient is greater than 0.75, the simulation result is good, and then the future LUCC situation can be predicted. (4) The CA-Markov simulation is used to predict the LUCC situation of Lu'an City in 2025 and 2030.

### 2.3.6. Fieldwork Method

The purpose of the field investigation is to avoid cognitive bias, eliminate the a priori interference, eliminate subjectivity, pursue the unity of subjective and objective, and obtain the right direction. In the past year, we have visited the government departments, communities, and rural households in Jin'an District, Yu'an District, and Huoshan County, Lu'an City, and carried out in-depth investigations. During the field investigation, we visited Pishihang Irrigation Area, Jiuligou Hydropower Station, Hengpaitou Pivotal Project, Yu'an Forestry Bureau, Huoshan Forestry Bureau, Shaochong Village, Longmen Chong Village, Danlongsi Town Forestry Station, Dongfengqiao Village, Guanyinyan Village,

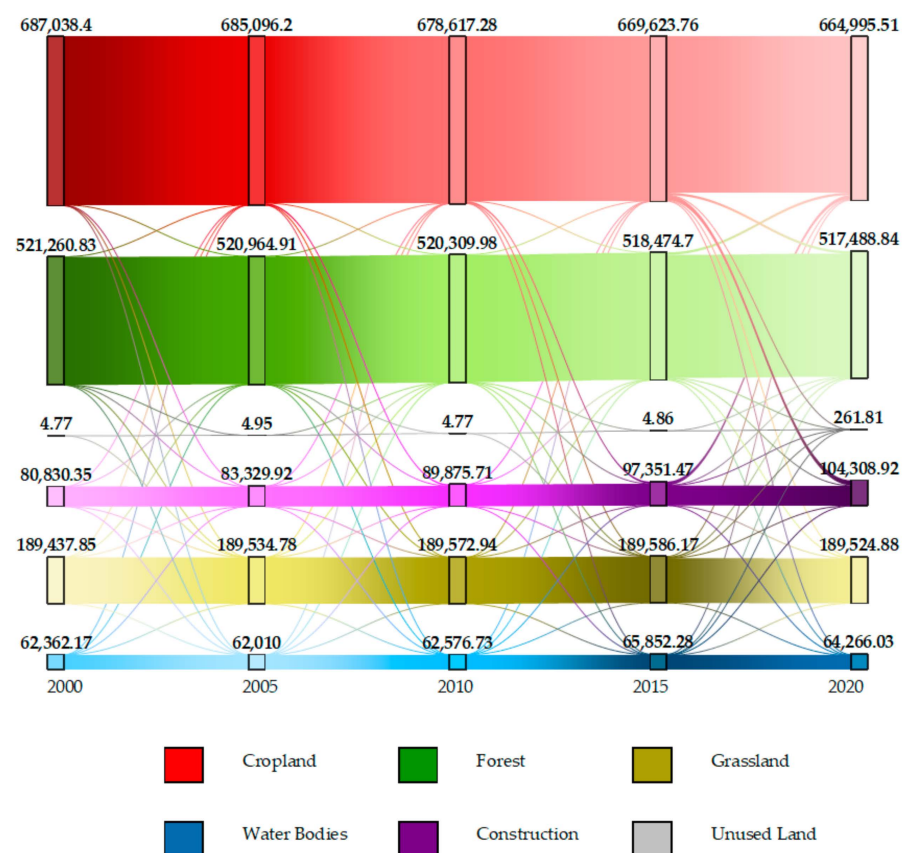
Fenghuang Chong Village, Dashanzhai Village, and Yanshan Forest Farm. During the investigation, we lived together with the local residents and established a good relationship, collected and analyzed the data in a targeted manner, and effectively understood the reality of the survey area from the policy, human, and economic perspectives.

### 3. Results

#### 3.1. Dynamic Evolution of LULC in Lu'an City

##### 3.1.1. Spatio-Temporal Dynamic Evolution of Land Use

Between 2000 and 2020, the GDP of Lu'an City increased from CNY 17.09 billion to CNY 167 billion (in 2020, due to the impact of the COVID-19 pandemic, the economic growth rate was only 2.99%, Supplementary Materials, Figure S1). With the rapid economic development and urban expansion, land resources are under greater pressure. During this period, the area of land used for construction increased significantly by about 29.05% compared to 2000. Although the unused land area fluctuates, the proportion is relatively small and can be ignored. At the same time, the area of grassland and water bodies increased slightly by 0.05% and 3.05%, respectively. In contrast, cropland and forest land areas decreased by 3.21% and 0.72%, respectively. In short, in the past 20 years, along with the economic development, the ecological environment has been damaged to a certain extent, and the land use type is generally manifested as the transformation of cropland and forest land into construction land (Figure 4). However, with the implementation of ecological protection policies and cropland protection policies, such as Returning Cropland to Forest and the Anhui Province 10 million mu Forest Growth Project, the decrease trend of the area of cropland and forest land in Lu'an City has been curbed from 2010 to 2020 (Supplementary Materials, Table S3).

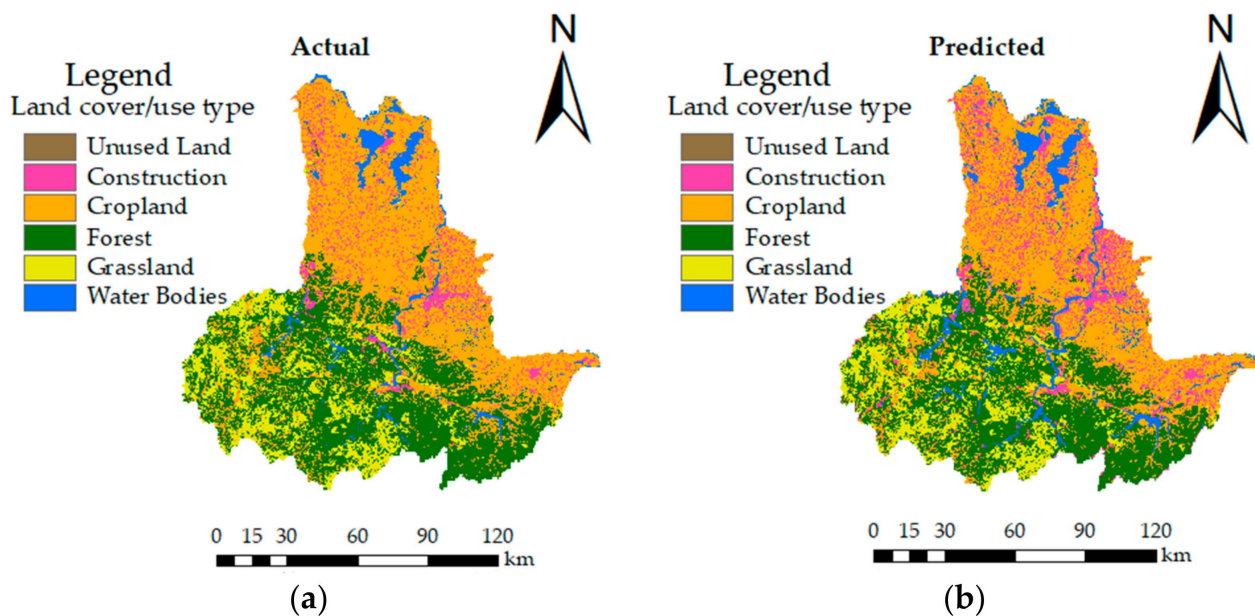


**Figure 4.** The land and use change in Lu'an City during the period from 2000 to 2020. Different colors in the figure represent different types of land. Darker colors indicate increase in area.

### 3.1.2. Prediction of Land Use/Land Cover Change (LUCC)

#### (1) Validation

In this study, the land use data of Lu'an City in 2010, 2015, and 2020; DEM, slope data, and administrative area data of 2015 and 2020; and spatial distribution data of national geoparks, key cultural relics protection units, and nature reserves were used as validation datasets to carry out research. The IDRISI Selva software was used to control constraints and restrictive factors to make a suitability map [64], the CA-Markov module was used to predict the land use situation of Lu'an City in 2020 (Figure 5b), and the CrossTab module was used to verify the actual value of 2020 (Figure 5a). Finally, the verified kappa coefficient is 0.9097, significantly higher than the standard of 0.75, which verifies the validity of the CA-Markov model to simulate the land use status in Lu'an City.



**Figure 5.** The comparison of actual and predicted land use change in Lu'an City in 2020: (a) represents actual results; (b) represents predicted results.

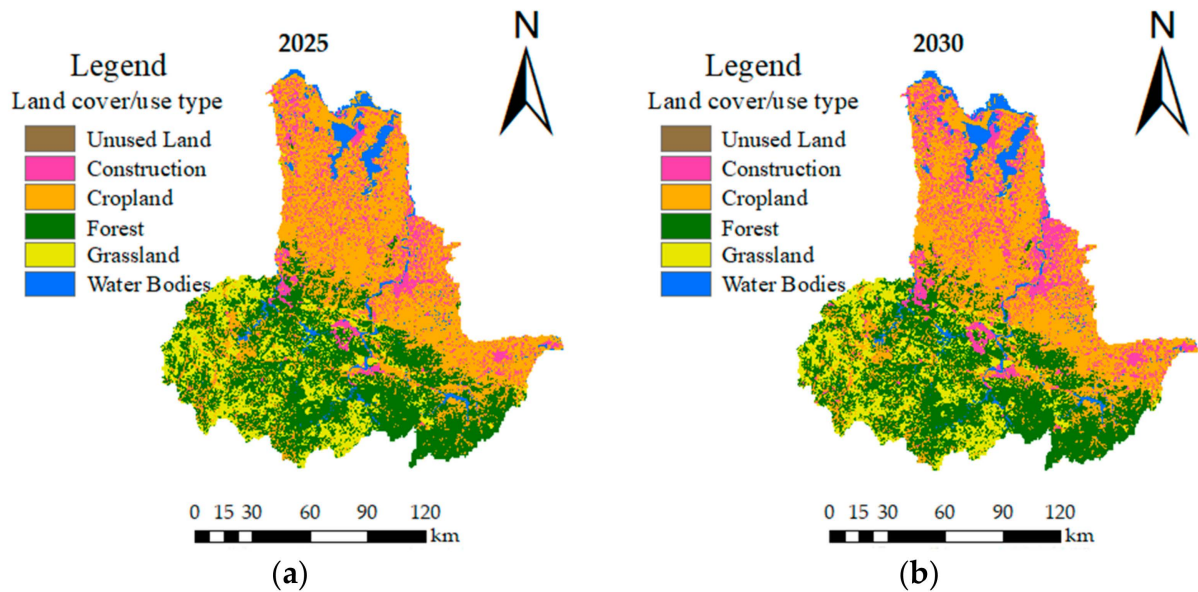
#### (2) Prediction

Using the CA-Markov model, we predicted the LUCC trend of Lu'an City in 2025 and 2030 under the natural development scenario (Figure 6). Data analysis shows (Table 3) a consistent trend in land change over the two years. The area of cropland, forest land, grassland, and unused land all show a decreasing trend, among which the area of cropland decreased by 5.41% and 5.72%, respectively. The area of water bodies and construction land will increase significantly by 7.51% and 54.69%, respectively, in 2025 and by 7.47% and 35.34% in 2030. These changes are mainly manifested in the conversion of cropland to water bodies and construction land and the conversion of forest land to cropland and construction land (Figure 7).

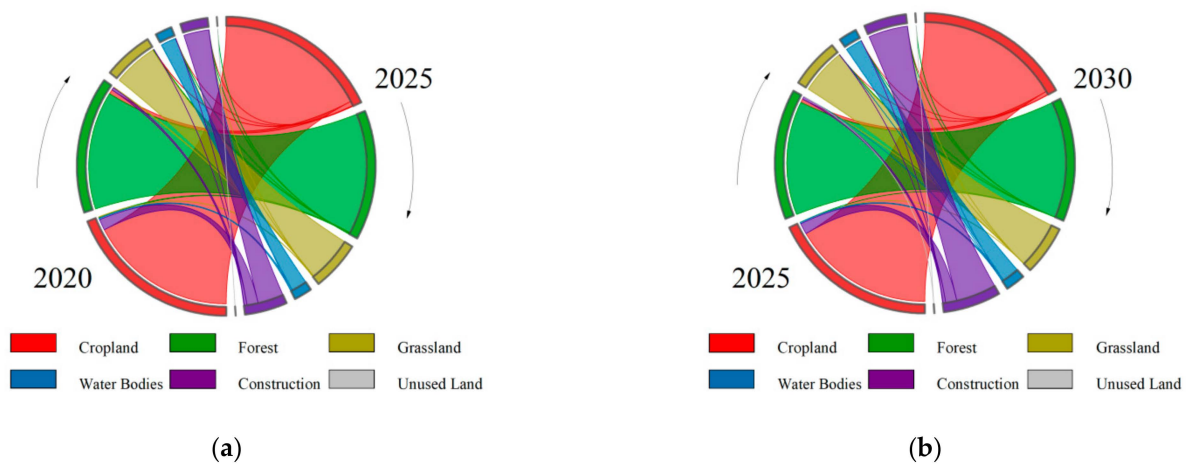
**Table 3.** The land use change rate of Lu'an City from 2025 to 2030.

| A | V         | LT       |        |           |              |              |             |
|---|-----------|----------|--------|-----------|--------------|--------------|-------------|
|   |           | Cropland | Forest | Grassland | Water Bodies | Construction | Unused Land |
|   | 2020–2025 | −5.41%   | −4.88% | −0.33%    | 7.51%        | 54.69%       | −3.23%      |
|   | 2025–2030 | −5.72%   | −5.18% | −0.36%    | 7.47%        | 35.34%       | 0.00        |

Note: A: age, V: variation, LT: land type.



**Figure 6.** The simulation of land use from 2025 to 2030 in Lu'an City: (a) represents land use in 2025; (b) represents land use in 2030.



**Figure 7.** The land use change from 2025 to 2030 in Lu'an City: (a) represents land use transfers that occurred between 2020 and 2025; (b) represents land use transfers that occurred between 2025 and 2030. The arrow represents the order of land use types over the same period.

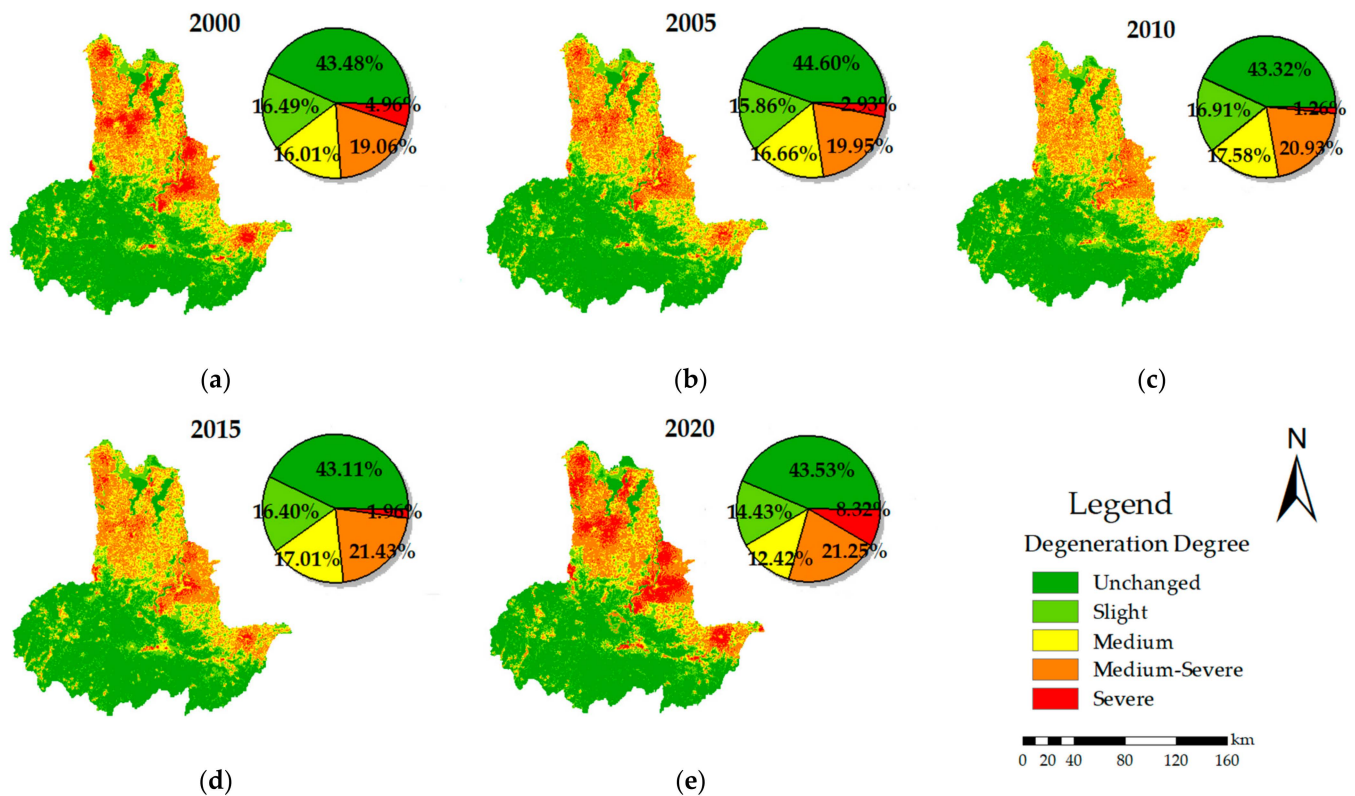
### 3.2. Spatio-Temporal Differentiation and Prediction of Habitat Degradation Degree and HQ

#### 3.2.1. Spatio-Temporal Differentiation

##### (1) Habitat Degradation Degree

We use natural breaks to classify the habitat degradation degree in 2000 into five levels (Supplementary Materials, Table S5), and based on this, we classify the habitat degradation degree in the other six periods [66]. Over the past two decades, approximately 70% of the study areas is at lower risk of degradation (Figure 8). In addition, the proportion of areas at serious risk of degradation increases from 1.96% in 2015 to 8.32% in 2020. During this period, Lu'an City undertakes the industrial transfer from Hefei. In the same period, the economic scale of Lu'an City reaches the largest, at CNY 167 billion (Figure S1), and the urbanization rate rises to 48.49%. Rapid economic growth inevitably leads to dramatic changes in land use and an increased risk of habitat degradation.





**Figure 8.** The distribution of habitat degradation degree at five levels in Lu'an City from 2000 to 2020. The pie chart shows the proportion of habitat degradation degree at five levels over different periods. (a) represents the habitat degradation degree of Lu'an City in 2000; (b) represents the habitat degradation degree of Lu'an City in 2005; (c) represents the habitat degradation degree of Lu'an City in 2010; (d) represents the habitat degradation degree of Lu'an City in 2015; (e) represents the habitat degradation degree of Lu'an City in 2020.

## (2) Habitat Quality (HQ)

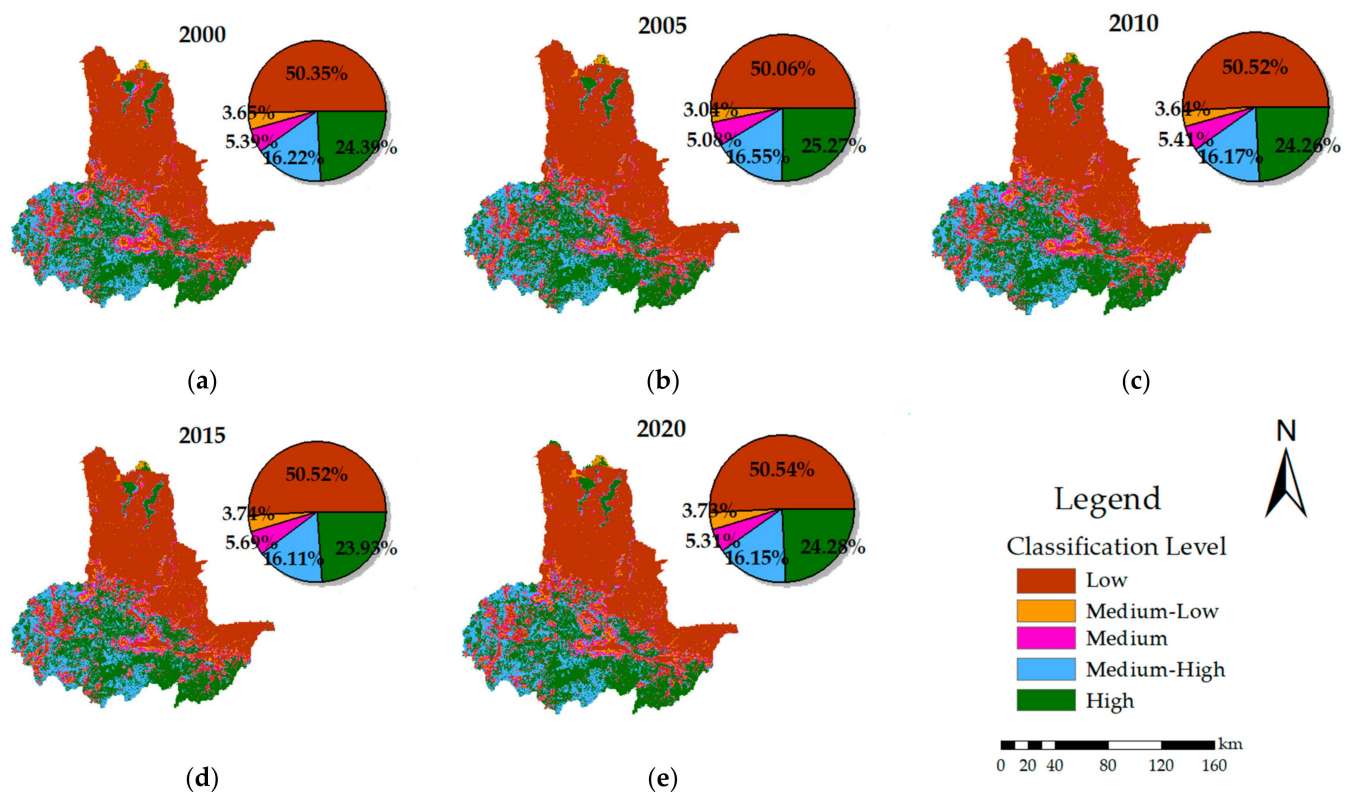
In this study, HQ is divided into five levels, 0–0.1, 0.1–0.3, 0.3–0.6, 0.6–0.8, and 0.8–1, namely low, medium-low, medium, medium-high, and high [29,42]. According to the statistical data (Supplementary Materials, Table S4), during the period from 2000 to 2020, the area with low ecological and environmental quality accounted for the largest proportion (Figure 9), mainly distributed in the central and northern part of the study area (mainly plain), covering a large number of croplands, urban areas, and residential settlements. The other section is at high altitudes in the south, covering cities and residential areas. It is worth noting that the degree of habitat degradation in these areas is above a relatively high level.

This study reveals the spatio-temporal evolution of HQ in Lu'an City over the past 20 years. (1) In terms of time, the area with medium or above HQ decreases and shows a worsening trend, while the cropland and forest land decrease significantly, and the construction land increases rapidly. (2) In terms of space, Lu'an City is mainly composed of cropland and forest land, while the vegetation types of the Ta-pieh Mountains in the southwest are forest land and grassland. This area is a water conservation functional area with high terrain and a high degree of fragmentation, so its HQ is high. The northern part of the Ta-pieh Mountains, below 100 m and above sea level, is flat terrain, affected by human activities, and is a functional area to provide agricultural products, so its HQ is low.

Around 2002, the policy of Returning Cropland to Forest was implemented in Lu'an City. In 2012, the 10 million mu Forest Growth Project and the Green Corridor Project were launched in Anhui Province. In 2017, ecological policies such as the Forest Chief Scheme and Forestry Double Increase (forest area and stock) were implemented in the



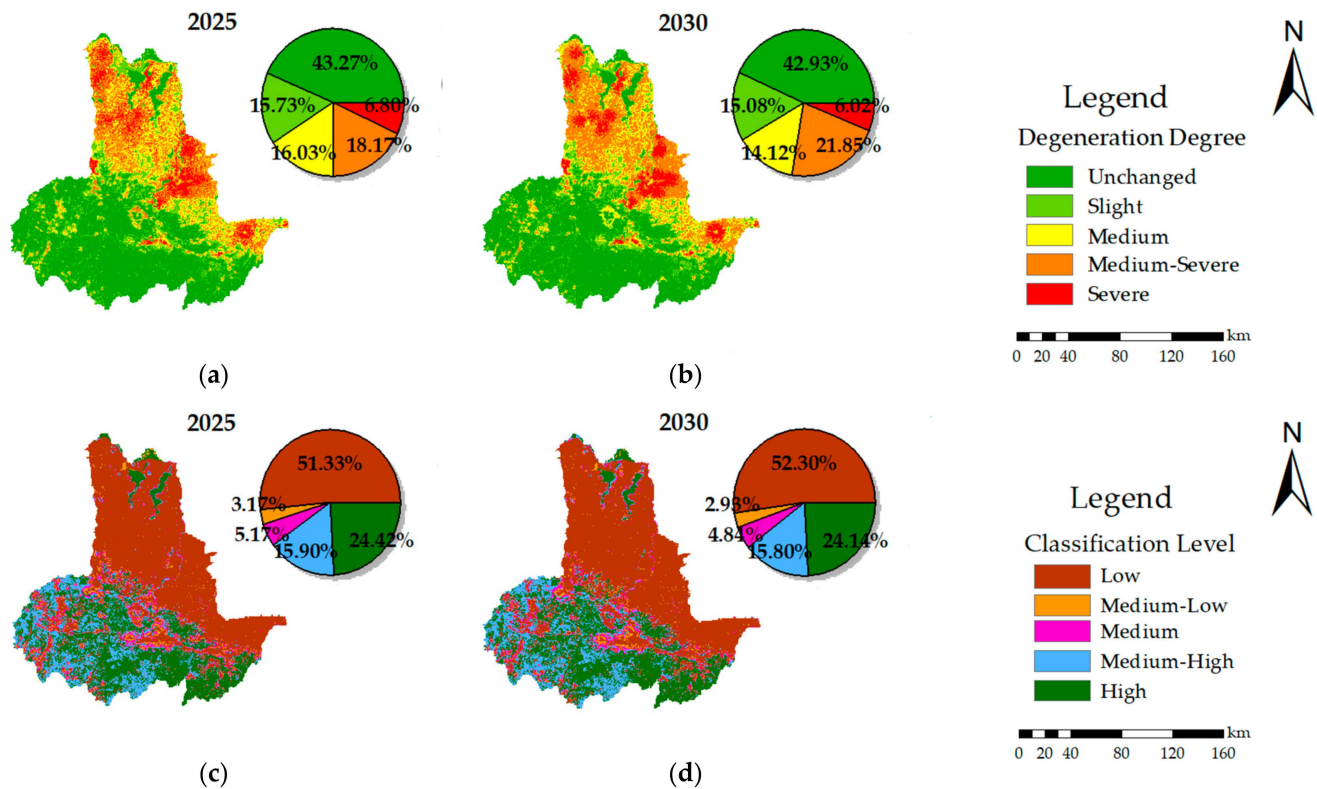
province. The afforestation rate of Lu'an City increased to 51.3% in 2018, and the forest coverage rate increased to 45.5% (2020). However, despite the growth in the forest area, the quality of the ecological environment is still significantly low, which is attributed to the intensification of human activities and the reduction in biodiversity and scarcity. According to field surveys, increased human activity (especially rapid urban expansion and increased cropland area) has resulted in increased ecological pressure on the forest, which have affected the distribution of species and may have led to the gradual decline and disappearance of some species such as wolves and coyotes over the past 20 years.



**Figure 9.** The pattern of HQ in Lu'an City from 2000 to 2020. The pie chart shows the proportion of HQ at five levels over different periods. (a) represents the HQ of Lu'an City in 2000; (b) represents the HQ of Lu'an City in 2005; (c) represents the HQ of Lu'an City in 2010; (d) represents the HQ of Lu'an City in 2015; (e) represents the HQ of Lu'an City in 2020.

### 3.2.2. Prediction

In the study, we use the LULC maps of Lu'an City in 2025 and 2030 to predict its HQ in 2025 and 2030. Because the threat factor data (PF, DL, UL, RSL, and OCL) is extracted from LULC's secondary classification map, it is difficult to obtain threat factor data for 2025 and 2030. Finally, we use the threat factor data in 2020, combined with the sensitivity tables in 2025 and 2030 (Supplementary Materials, Table S6), and finally obtain the distribution of the habitat degradation degree and HQ in the next decade (Figure 10). The results showed that the HQ in Lu'an City would continue to decline in the next 10 years (Supplementary Materials, Table S7). Habitat degradation will also increase (Supplementary Materials, Table S8) but mainly in urban and rural areas. Spatially, there is no obvious expansion in the degraded region.



**Figure 10.** The distribution of habitat degradation degree and HQ in Lu'an City from 2025 to 2030: (a) represents the habitat degradation degree of Lu'an City in 2025; (b) represents the habitat degradation degree of Lu'an City in 2030; (c) represents the HQ of Lu'an City in 2025; (d) represents the HQ of Lu'an City in 2030.

#### 4. Discussion

##### 4.1. Correlation Analysis of HQ and Driving Factors in Lu'an City

In this study, we created a point shapefile with ArcGIS and used the editor tool to select 270 random points. Since HQ is significantly affected by human activities, we selected HFI and GDP as the socio-economic driving factors. In addition, through the analysis of HQ in Lu'an City, we took DEM, SLO, TRI, and FVC as the natural driving factors. Then, we used the sample tool to sample the raster files of six drivers and HQ in different periods into the point shapefile, and then extracted the attributes of the points. Finally, we removed 28 outliers and normalized 242 points. After processing, we obtained the properties of 242 points.

We used SPSS to calculate the Spearman coefficient of HQ and the driving factors in different periods. The calculation results show that the Spearman correlation coefficient of HQ in different years is significantly correlated with the driving factors (Table 4). The average results show that the HQ of Lu'an City is strongly correlated with DEM, TRI, and SLO performance ( $r = 0.706$ ;  $r = 0.681$ ;  $R = 0.600$ ); In addition, it showed a strong negative correlation with HFI ( $r = -0.687$ ). The results show that with the increase in elevation, the terrain roughness index, and slope, human activities decrease, ecosystem damage decreases, and HQ increases. In addition, the correlation between HQ, GDP, and HVC is weak, which is  $-0.368$  and  $0.356$ , respectively, indicating that the growth in GDP and the reduction in vegetation will be accompanied by a certain degree of HQ decline.

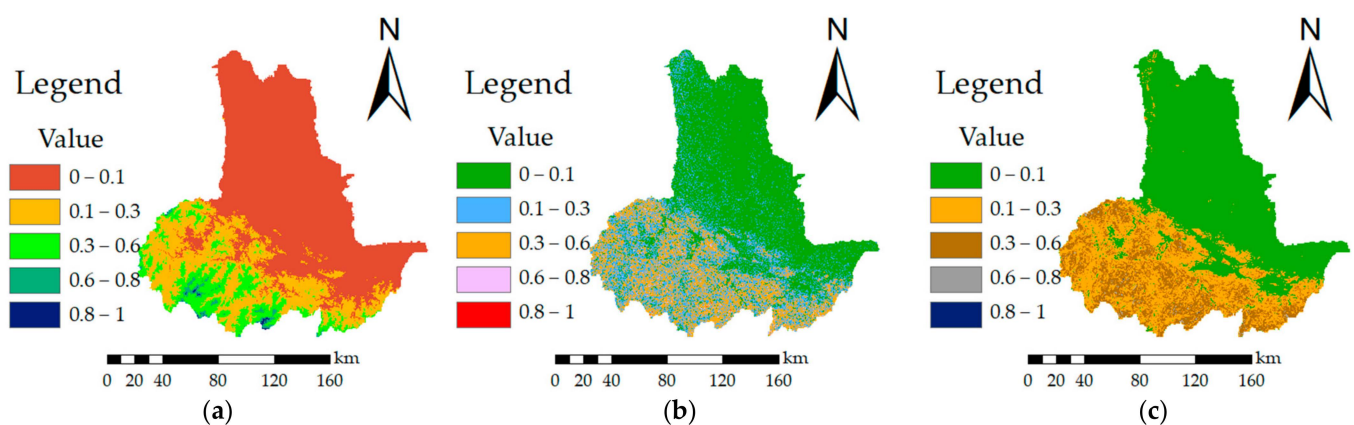
**Table 4.** The Spearman rank correlation coefficients between HQ and six driving factors in Lu'an City.

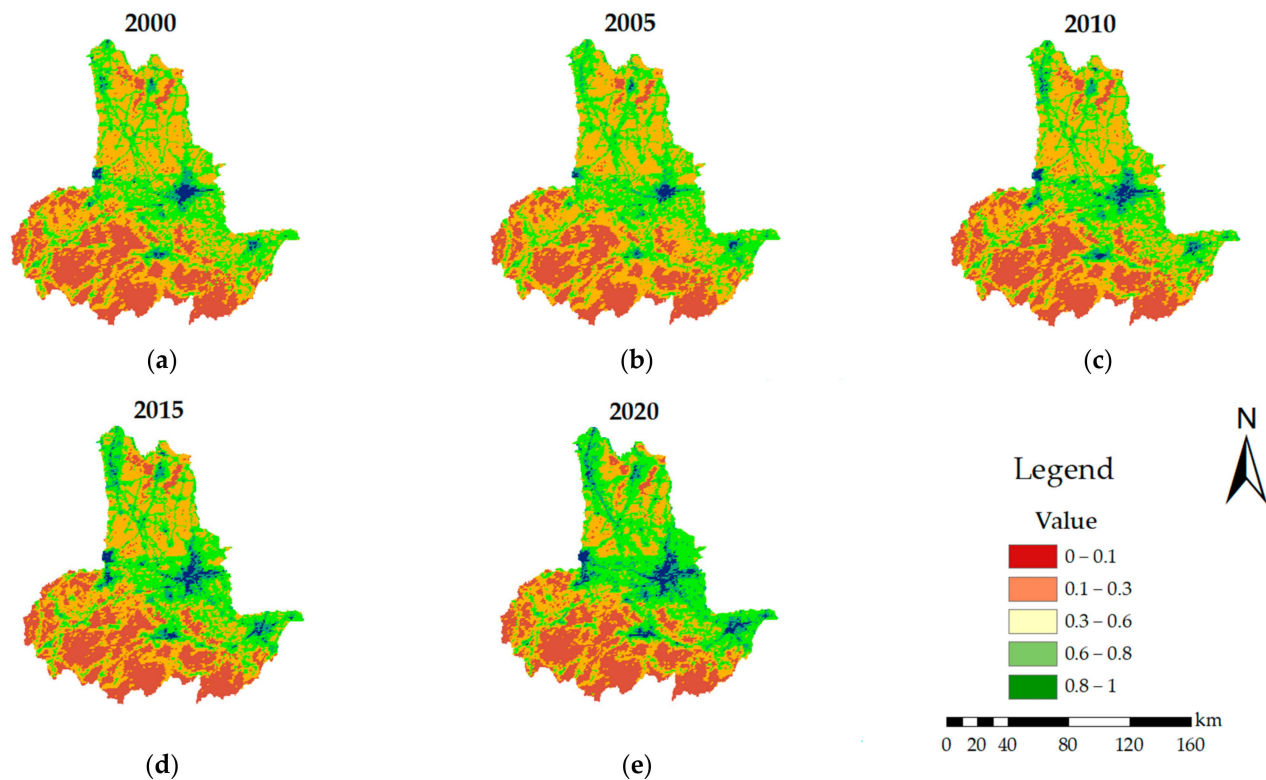
| Year | Driving Factors |          |          |          |           |           |
|------|-----------------|----------|----------|----------|-----------|-----------|
|      | SLO             | TRI      | DEM      | FVC      | HFI       | GDP       |
| 2000 | 0.595 **        | 0.680 ** | 0.704 ** | 0.426 ** | −0.679 ** | −0.441 ** |
| 2005 | 0.582 **        | 0.664 ** | 0.686 ** | 0.331 ** | −0.664 ** | −0.333 ** |
| 2010 | 0.606 **        | 0.692 ** | 0.720 ** | 0.326 ** | −0.697 ** | −0.387 ** |
| 2015 | 0.610 **        | 0.686 ** | 0.707 ** | 0.322 ** | −0.694 ** | −0.319 ** |
| 2020 | 0.606 **        | 0.681 ** | 0.715 ** | 0.376 ** | −0.703 ** | −0.360 ** |
| Mean | 0.600           | 0.681    | 0.706    | 0.356    | −0.687    | −0.368    |

Note: \*\* Correlation is significant at the 0.01 level (two-tailed); SLO—slope; TRI—terrain roughness index; DEM—digital elevation model; FVC—fractional vegetation cover; HFI—human footprint index; GDP—gross domestic product.

According to the environmental Kuznets curve [67,68], in the early stage of economic development, economic benefits are usually pursued at the expense of certain ecological benefits, but then they will gradually have a positive impact on the ecological environment. The economic development of Lu'an City may be in the process of this transformation, which may be one of the reasons for the weak correlation between GDP and HQ. Lu'an City is an important ecological function area, connected to the Huai River in the north and the Yangtze River in the south. The project to protect natural forests began in 1998, and the project to return cropland to forests, lakes, and grasslands began in 2002. The implementation of a series of major ecological projects has greatly improved the ecological environment of Lu'an City. These efforts have greatly reduced deforestation and improved vegetation destruction, resulting in a weak correlation between vegetation cover and HQ changes.

According to the data analysis, the level of HQ is not strongly correlated with GDP and FVC but significantly correlated with altitude, slope, the terrain roughness index, and human activities, and the high HQ areas are all located in the Ta-pieh Mountain areas with high altitude (Figure 11a), slope (Figure 11b), terrain roughness index (Figure 11c), and low human activities (Figure 12). Although the human footprint index in the region has increased over the past two decades, it remains low overall (Figure 12a–e). Under the influence of terrain factors and environmental protection policies, the ecological protection of the region is strong, and biodiversity and biological scarcity have been effectively maintained. The FVC index increased steadily from 2000 to 2010 (Figure 13a–c). Between 2010 and 2020 (Figure 13c–e), the FVC index increased significantly. This is one of the important reasons for the high HQ index in the region.

**Figure 11.** The geographical status of Lu'an City: (a) represents the DEM distribution of Lu'an City; (b) represents the slope distribution of Lu'an City; (c) represents the TRI distribution of Lu'an City.

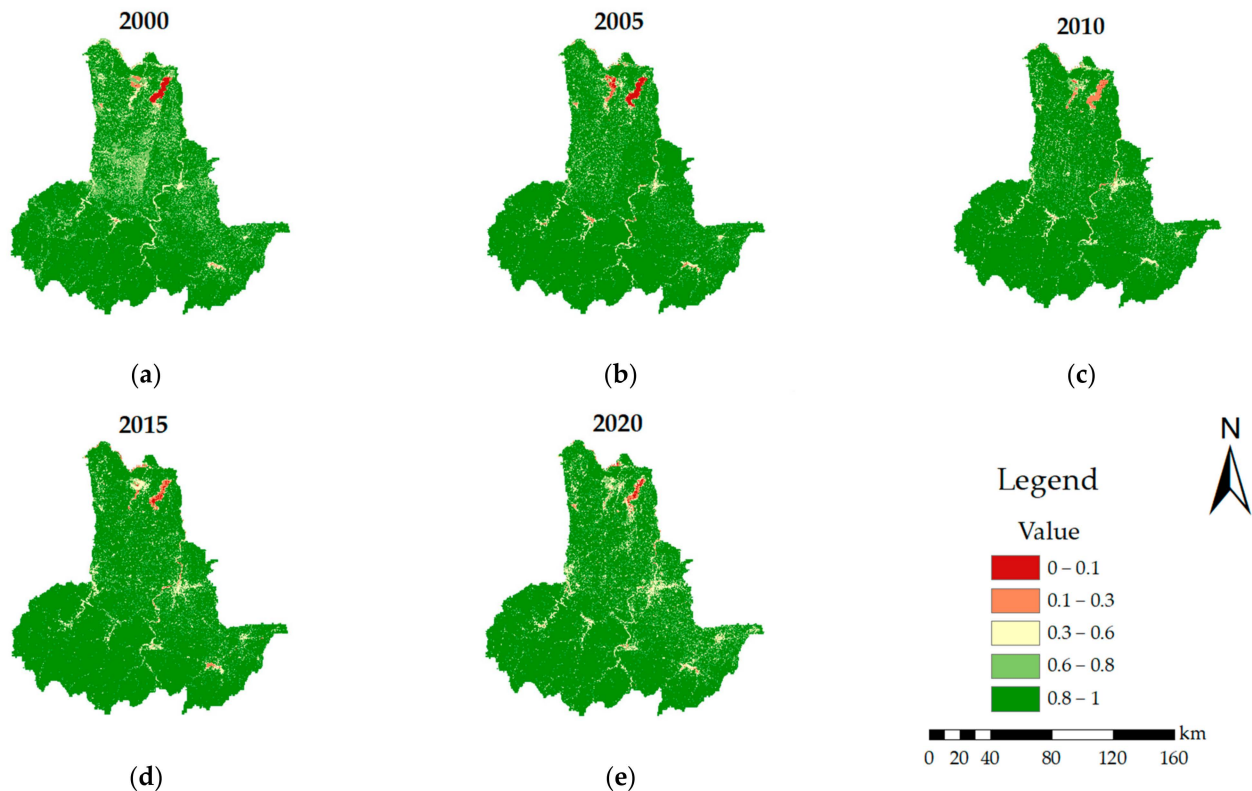


**Figure 12.** The distribution of human footprint index (HFI) of Lu'an City from 2000 to 2020: (a) represents the distribution of HFI in 2000; (b) represents the distribution of HFI in 2005; (c) represents the distribution of HFI in 2010; (d) represents the distribution of HFI in 2015; (e) represents the distribution of HFI in 2020.

However, the HFI in 2020 (Figure 12e) shows a significant change from the HFI in 2000 (Figure 12a), with the area of human activity expanding by two to three times. It is accompanied by species change. In fact, in 2023, we conducted field surveys in six villages, four towns, and three districts (counties) of Lu'an City and received some valuable feedback from local officials, residents, and farmers. The results show that in the surveyed area, large animals such as wolves and wild leopards disappeared, the *procapra gutturosa* population decreased, and the wild boar population recovered only around 2017 (Supplementary Materials, Table S9). Since the 1988 snow disaster, Yanshan Forest Farm now has more than 913 ha of natural secondary forest (mostly bamboo forest), so there is a certain decline in biodiversity and biological scarcity in the area.

In 2010, the Chinese government formulated the Wanjiang City Belt Industrial Transfer Demonstration Zone Plan. Lu'an City actively undertook the industrial transfer from Hefei City, forming industrial agglomeration and significantly increasing GDP. This helps explain why the areas of high habitat degradation degrees between 2010 and 2020 are in urban areas. In this period, the degradation did not expand spatially, which may be related to the ecological protection and scientific and reasonable policy implementation in recent years. It is due to the combined effect of human activities and species changes that have led to the decline of regional HQ. However, ecological protection and scientific and reasonable policies can guide social and economic development [69], thus ultimately easing the contradiction between economic development and HQ decline.





**Figure 13.** The distribution of fractional vegetation cover (FVC) in Lu'an City from 2000 to 2020: (a) represents the distribution of FVC in 2000; (b) represents the distribution of FVC in 2005; (c) represents the distribution of FVC in 2010; (d) represents the distribution of FVC in 2015; (e) represents the distribution of FVC in 2020.

#### 4.2. The Role of Policies in LULC and HQ Governance

Policy plays an important role in regional habitat development and land use [70,71] and can often promote the benign development of both [72]. Since 2000, governments at all levels have introduced many policies aimed at environmental protection and ecosystem restoration (Table 5). These policies had a great impact on the evolution of LUCC and HQ in Lu'an City. Table S9 shows that in the past 20 years, taking the policy of returning cropland to forest as an example, 8500 ha of cropland in Huoshan County alone has been converted into forest land, while 6167 ha of forest has been tended and restored. Therefore, the strong intervention of the policy can curb the rapid expansion of the scope of human activities and play an important role in the scientific use of land to curb the decline of HQ.

However, ecological protection policies cannot completely prevent the decline of HQ in Lu'an City. Taking the 10 million mu Forest Growth Project as an example, the Lu'an City government artificially increased 11,213 ha of forest land in 2015 but actually reduced 1835.28 ha of forest land that year, which was mainly transferred to construction land. After investigation, two main reasons for this situation have been found: (1) the decrease in forest area is not reflected in government documents; (2) some forest lands are commercial and other forest lands, which are not included in the ecological red line. In addition, the new artificial forest land has low biodiversity, and with the expansion of construction area, the habitat is vulnerable to urban land and other threat factors, resulting in an increased risk of habitat degradation. This is the main reason why HQ is still declining under the protection of various ecological policies.

**Table 5.** The main environmental and economic policies of Lu'an City from 2000 to 2024.

| Year | Policy                                                                                                                                                                          | Sources                                                                                                                                                                              |
|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2000 | Several opinions of the State Council on Further Improving the Pilot Work of Returning Cropland to Forests and Grasslands                                                       | <a href="https://www.gov.cn/gongbao/content/2000/content_60486.htm">https://www.gov.cn/gongbao/content/2000/content_60486.htm</a> , accessed on 30 March 2024.                       |
| 2001 | Natural forest protection project                                                                                                                                               | <a href="https://www.forestry.gov.cn/main/5925/20200414/090421585104600.html">https://www.forestry.gov.cn/main/5925/20200414/090421585104600.html</a> , accessed on 30 March 2024.   |
| 2002 | Several opinions of the State Council on Further improving the policy and measures for returning cropland to forest                                                             | <a href="https://www.gov.cn/gongbao/content/2002/content_61463.htm">https://www.gov.cn/gongbao/content/2002/content_61463.htm</a> , accessed on 30 March 2024.                       |
| 2002 | Regulations on returning cropland to forest                                                                                                                                     | <a href="https://www.gov.cn/gongbao/content/2003/content_62531.htm">https://www.gov.cn/gongbao/content/2003/content_62531.htm</a> , accessed on 30 March 2024.                       |
| 2010 | Notice on the issuance of Shucheng County to accelerate the Wanjiang City Belt to undertake industrial transfer Demonstration Zone Construction Planning                        | <a href="https://www.shucheng.gov.cn/public/6598641/34717434.html">https://www.shucheng.gov.cn/public/6598641/34717434.html</a> , accessed on 24 January 2024.                       |
| 2012 | Overall plan of Anhui Province's 10 million mu Forest Growth Project (2012–2016)                                                                                                | <a href="http://district.ce.cn/zt/zlk/bg/201210/23/t20121023_23780196.shtml">http://district.ce.cn/zt/zlk/bg/201210/23/t20121023_23780196.shtml</a> , accessed on 30 March 2024.     |
| 2012 | Opinions of the People's Government of Anhui Province on implementing the 10 million mu Forest Growth Project and promoting the construction of an ecologically strong province | <a href="https://www.ah.gov.cn/szf/zfgb/8118971.html">https://www.ah.gov.cn/szf/zfgb/8118971.html</a> , accessed on 30 March 2024.                                                   |
| 2012 | The Green Corridor Project                                                                                                                                                      | <a href="http://www.lazdgcc.cn/zdgc/gjjptsj/3043091.html">http://www.lazdgcc.cn/zdgc/gjjptsj/3043091.html</a> , accessed on 29 March 2024.                                           |
| 2017 | Opinions of the People's Government of Anhui Province on implementing the action of increasing forest area and stock in forestry (Forestry Double Increase)                     | <a href="https://www.ah.gov.cn/szf/zfgb/8118971.html">https://www.ah.gov.cn/szf/zfgb/8118971.html</a> , accessed on 23 January 2024.                                                 |
| 2020 | The Leading Group of Hefei Metropolitan Area Construction issued a notice on the Development Plan of the Hefei-Lu'an Economic Corridor (2020–2025)                              | <a href="https://www.ja.gov.cn/public/6599071/21729501.html">https://www.ja.gov.cn/public/6599071/21729501.html</a> , accessed on 8 February 2024.                                   |
| 2022 | Lu'an City "14th five-year plan" ecological environmental protection planning                                                                                                   | <a href="https://www.luan.gov.cn/public/6608171/9901072.html">https://www.luan.gov.cn/public/6608171/9901072.html</a> , accessed on 16 October 2023.                                 |
| 2022 | Notice on further improving policies and measures to consolidate the results of returning cropland to forest and grassland                                                      | <a href="https://www.gov.cn/zhengce/zhengceku/2022-11/11/content_5726119.htm">https://www.gov.cn/zhengce/zhengceku/2022-11/11/content_5726119.htm</a> , accessed on 10 October 2023. |
| 2022 | The three-year action plan to accelerate the development of Camellia Oleifera Abel industry                                                                                     | <a href="https://www.gov.cn/zhengce/zhengceku/2023-01/10/content_5736075.htm">https://www.gov.cn/zhengce/zhengceku/2023-01/10/content_5736075.htm</a> , accessed on 27 March 2024.   |
| 2023 | The Master Plan of Land Space of Lu'an City (2021–2035)                                                                                                                         | <a href="https://www.ja.gov.cn/public/6602111/24951309.html">https://www.ja.gov.cn/public/6602111/24951309.html</a> , accessed on 15 September 2023.                                 |

While policies cannot completely prevent the decline of HQ, they can control the extent and scope of decline. Firstly, the formulation and implementation of policies are the cornerstone of ecological governance and coordinated development [73]. The government should scientifically formulate urban and rural development plans, strengthen top-level designs, improve the efficiency of urban land use, and control the expansion of construction land to reduce the encroachment on grassland, forest land, and water bodies and the risk of habitat degradation. Moreover, construction land and cropland are the two major causes of the high habitat degradation degree in Lu'an City. So, the second step is that the government should manage cropland and forests to effectively protect biodiversity [74]. For example, in HQ areas above medium level, the government can centrally relocate remote villages [75] or establish nature reserves and ecological buffer zones to minimize the negative impact on the biodiversity of all biomes in the area [76]. Because the buffer zone has the lowest ecological risk, which is conducive to the recovery of HQ [77], protected areas are the cornerstones for the long-term conservation of biodiversity [78]. Finally, optimizing data collection methods and conducting regular field surveys will help improve the accuracy of data collection, correct errors, formulate government policies scientifically, establish effective

cross-departmental cooperation mechanisms, and promote the effective implementation of policies. Through the implementation of sound policies and land use planning, habitat decline can be limited to areas with intensive human activity, such as urban and rural areas. This is very significant for the protection of HQ in Lu'an City.

It is worth mentioning that GDP plays an important role in the HQ evolution of the Henan water source area [42], and in this study, GDP shows a weak correlation. Therefore, when other scholars refer to the research results of this study, they should adopt them dialectically according to their research objects.

## 5. Conclusions

Research on the sensitivity of LULC can effectively reduce human error in the research results, which is conducive to the accurate evaluation of HQ. Establishing a research framework to evaluate and simulate LUCC and HQ is helpful to explore their evolution in time and space and provide theoretical guidance for the improvement of regional ecosystem services and policy adjustment. Exploring the impact of driving factors and policy factors on HQ can provide a theoretical basis for effectively improving HQ, scientifically formulating policy planning, and providing conditions for achieving sustainable development. Taking Lu'an City as an example, in this study, we used ArcGIS, InVEST model, CA-Markov model, and other models and methods and took the Kendall coefficient as the sensitivity value to analyze the HQ of Lu'an City over the past 20 years. Subsequently, we effectively predicted the LULC of Lu'an City in 2025 and 2030 and predicted and evaluated the HQ of Lu'an City in the next ten years. Finally, we fully analyzed the correlation between HQ and driving factors and the effect of policy factors. The following conclusions are drawn: (1) From 2000 to 2020, the main LULC in Lu'an City is cropland (about 40%) and forest land (about 30%). During this period, the main LUCC of Lu'an City is the conversion of cropland and forest land to construction land. (2) As one of the threatening factors, cropland accounts for more than 40% of the area of Lu'an City, which is the main reason for the high degree of habitat degradation. (3) By exploring the correlation between the HQ and driving factors and analyzing the impact of policies on HQ, we found the main reasons leading to the decline of HQ in Lu'an City. The reasons are the increase in construction land, the decrease in forest land, the vulnerability of artificial forest to threat factors, and its low biodiversity. (4) In the study, we provide policy suggestions from three aspects: policy formulation and implementation, cropland and forest management, and data collection. In future research, based on current research, we can focus on building a framework to improve the accuracy of HQ evaluation and prediction. The framework includes setting LULC's habitat suitability scientifically, improving the accuracy of the CA-Markov model's suitability atlas and quantifying policy effects. The framework can provide a prerequisite for a more accurate and scientific assessment of HQ and the formulation of policies and help form a sustainable development model that meets the actual situation of the region.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/land13060789/s1>, Figure S1: The changes of GDP in Lu'an City during the period from 2000 to 2020; Table S1: Generalized description of data; Table S2: The sensitivity of LULC to threat factors; Table S3: Transition matrix of land use in Lu'an City in 2000–2020 (ha); Table S4: Proportion of changes in HQ in the Lu'an City from 2000 to 2020; Table S5: Proportion of changes in habitat degradation degree in the Lu'an City from 2000 to 2020; Table S6: Habitat suitability and its sensitivity to threat factors; Table S7: Proportion of changes in HQ in the Lu'an City from 2025 to 2030; Table S8: Proportion of changes in habitat degradation in Lu'an City from 2025 to 2030; Table S9: Basic Situation of Land Use and Ecological Development in Lu'an City in recent Decades (Survey data); Code S1: Sensitivity [38,47,66,79,80].

**Author Contributions:** Conceptualization, G.W. and Q.Z.; Methodology, G.W. and Q.Z.; Software, G.W.; Validation G.W.; Formal analysis, Q.Z. and W.J.; Investigation G.W., Q.Z. and W.J.; Resources, Q.Z. and W.J.; Data curation, G.W.; Writing—original draft preparation, G.W.; Writing—review and editing, G.W. and Q.Z.; Visualization, G.W.; Supervision, Q.Z. and W.J.; Project administration, Q.Z.; Funding acquisition, Q.Z. All authors have read and agreed to the published version of the manuscript.

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