sustainability

Article

Long-Term Ecological Environment Quality Evaluation and Its Driving Mechanism in Luoyang City

Hui Li, Haitao Jing *, Geding Yan, Huanchao Guo and Wenfei Luan

College Surveying and Land Information Engineering, Henan Polytechnic University, Jiaozuo 454000, China; 212104010008@home.hpu.edu.cn (H.L.); 212104010020@home.hpu.edu.cn (G.Y.); 212104010006@home.hpu.edu.cn (H.G.); luanwf@hpu.edu.cn (W.L.)
* Correspondence: jht@hpu.edu.cn; Tel.: +86-135-0391-9065

Abstract: The quality of the ecological environment determines human well-being, and the degree of ecological environment quality has a significant impact on regional sustainable development. Currently, the assessment content of ecological environment quality in Luoyang is relatively single-indicator-based and is insufficient to comprehensively reflect the changes in the ecological environment quality of Luoyang city. Therefore, the study aims to use the Remote Sensing Ecological Index (RSEI), a comprehensive evaluation model, with Landsat remote sensing images and statistical yearbooks as the data sources, to evaluate the spatiotemporal dynamic changes in the ecological environment quality of Luoyang city from 2002 to 2022 through trend analysis and mutation testing; the study employs geographical detectors to analyze the driving factors about the changes in ecological environment quality. The study found that: (1) the average RSEI value in Luoyang city has increased by 0.102 in the past 20 years, indicating an overall improvement in the ecological environment quality of Luoyang city. (2) The northern region of the study area has lower RSEI values, while the southern region has better ecological environment quality, which corresponds to the fact that the northern part of Luoyang city has intensive human activities, while the southern part is characterized by higher vegetation coverage in mountainous areas. (3) The proportion of areas with medium and above ecological environment quality grades have increased from 47.2% to 67.5%, indicating a positive trend in future ecological environment quality changes. (4) The population change was the strongest single factor influencing the ecological environment quality change in Luoyang city. The interaction between temperature and GDP was relatively the strongest. The current ecological environment status in the study area is the result of the combined effects of natural and anthropogenic factors. The research conclusions contribute to improving regional ecological environment quality and are of great significance for the regional ecological environment planning and the achievement of sustainable development goals.

Keywords: RSEI; ecological environment quality; Luoyang city; trend analysis; geodetector

Citation: Li, H.; Jing, H.; Yan, G.; Guo, H.; Luan, W. Long-Term Ecological Environment Quality Evaluation and Its Driving Mechanism in Luoyang City. *Sustainability* **2023**, *15*, 11866. https://doi.org/10.3390/su151511866

Academic Editor: Antonio Boggia

Received: 17 July 2023
Revised: 27 July 2023
Accepted: 31 July 2023
Published: 2 August 2023

1. Introduction

The ecological environment is a complex system comprising society, economy, and nature; a high-quality ecological environment is crucial for the survival of humans and the sustainable development of society and economy [1]. With the rapid economic development in China and the ongoing process of urbanization, the environmental quality in some regions has been seriously affected [2]; this conforms with the ecological marketing phenomenon proposed by Popescu et al. [3,4]. People often become aware of the environmental issues that arise, yet they fail to take actions to protect the ecosystem. The changes in the ecological environment affect various aspects, bringing a series of challenges. Knowing how to respond to these challenges is crucial, and accurate monitoring and analysis of environmental quality can provide a reliable scientific basis for green development in the region.

As the global ecosystem continues to suffer from severe human activities of varying scales, significant population growth and rapid social and economic development have led to a series of serious ecological environment problems [5]. Wang et al. [6] proposed that the issue of carbon emissions caused by economic growth is becoming increasingly prominent. The intensification of urbanization has significant impacts on both economic growth and environmental quality [7,8]. Urbanization is a global issue, and its impact on the ecological environment requires extensive technological and methodological detection and assessment [9,10]. Remote sensing technology, as an effective means of quantitative monitoring of environmental quality, has been widely applied [11]. With the worldwide development of remote sensing technology, the spatial–temporal resolution of remote sensing images continues to improve. Some scholars have attempted to estimate ecological environment quality entirely based on remote sensing images. However, a single index, such as the Normalized Difference Vegetation Index (NDVI), has difficulty representing the quality of the ecological environment. Whether it is evaluating wetland ecology with a water index [12] or inferring vegetation growth status with the Leaf Area Index [13], they ignore the joint effects of other natural factors on the ecological environment. Therefore, there are a series of problems such as one-sided evaluation results and difficulties in convincingly justifying the evaluation results.

In 2013, Xu et al. [14] proposed a comprehensive ecological evaluation method called Remote Sensing-based Ecological Index (RSEI). The method uses four indicators to comprehensively evaluate the ecological condition of a region, effectively solving the one-sidedness problem of the conventional single-indicator evaluation method. RSEI has been widely applied in areas with different ecological conditions. The RSEI index supports the efficient display of regional ecological quality images using remote sensing data, allowing researchers to more intuitively evaluate the ecological status of continuous land cover. Yang et al. [15] studied the spatiotemporal changes and driving factors of the ecological environment quality in the Yangtze River Basin based on RSEI and obtained the overall characteristics of the ecological quality in the region. RSEI is a comprehensive evaluation index, which is based on widely covered and long-term remote sensing data, that allows for a quick and effective evaluation of the ecological environment. Chen et al. [16] created an improved Remote Sensing Ecological Index, using an entropy-weighted method that considers the temporal and seasonal characteristics of urban environmental changes. They quantified the impact of human activities on the urban ecological environment quality through a geographically weighted regression model. The objectivity and rationality of the evaluation results are guaranteed, as this index is not affected by ground survey data or factor weighting, and thus has strong promotion value in ecological evaluation and monitoring applications.

There are many factors that influence the quality of the ecological environment, including social, economic and terrain factors. The city of Luoyang in the province of Henan has significant differences in terrain distribution, with the south being mostly mountainous and the north being densely populated urban areas, making it a typical integrated plain-mountain city. Presently, research on Luoyang's ecology mainly focuses on analyzing the changes in ecosystem service value [17] caused by land use changes or using water ecological energy values [18] to analyze water ecological system issues, while ignoring the interaction of multiple economic and social factors as well as the spatial heterogeneity of changes within Luoyang. Ecological quality monitoring has a double spatial–temporal feature, and the factors affecting changes in ecological quality are divided into single-factor and dual-factor effects. Therefore, this paper mainly focuses on the following aspects for Luoyang: (1) What are the spatial–temporal distribution characteristics of RSEI in Luoyang in the past 20 years? (2) What is the trend of future changes in ecological environment quality in Luoyang? Which areas will improve, and which areas will decline? (3) What are the causes and influencing factors of the temporal–spatial characteristics that have led to changes in ecological environment quality in Luoyang? A comprehensive analysis of

Luoyang's ecological environment quality was conducted, which is of great significance to the local green living and sustainable economic development.

2. Materials and Data

2.1. Study Area

Luoyang city in the province of Henan is located between longitude 112°16′–112°37′ E and latitude 34°32′–34°45′ N. It is situated in the middle and lower stages of the Yellow River, and it is an ecologically important site in the Yellow River Basin, where three major watersheds and five major rivers converge. Luoyang is also a key node and regulatory city for high-quality development in the region [19]. The city features a warm temperate continental monsoon climate and is characterized by concentrated urban areas in the north, while the south is mostly mountainous (as shown in Figure 1). Overall, the terrain of Luoyang presents high terrain in the west and south, while low terrain in the east and north with complex high and low undulating topography, which is the starting point of the ancient overland Silk Road.

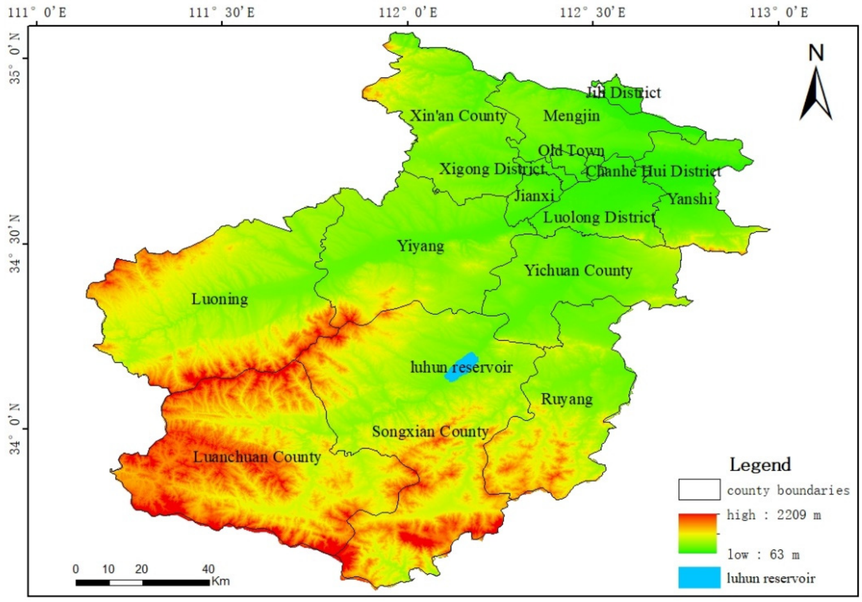

Figure 1. Location and elevation information of Luoyang city.

2.2. Data Sources and Preprocessing

This study selected 21 Landsat5 TM images data and Landsat8 OIL/TIRS data from 2002 to 2022 from the Google Earth Engine (GEE) platform database of remote sensing data. Different seasons have different surface dry/wet conditions and vegetation growth states. To reduce the differences caused by seasons during remote sensing data monitoring, summer Landsat images from June to September of each year were selected. The images were preprocessed through atmospheric and geometric correction, and then the average images for the target months of the year were composited using a cloud removal method. Some images showed missing data after cloud removal. This study used adjacent year images from the same time period to fill in these gaps. In addition, there were no Landsat5 or Landsat8 data from June to September 2012. These days used the Landsat7 dataset, and for images with band noise, the filling method was used to supplement the data. Because water bodies have a certain impact on the calculation of humidity indicators, an improved modified normalized difference water index (MNDWI [20]) was used to mask out image data that includes water bodies. According to the research objectives, land cover data were divided into seven categories: cultivated land, grassland, forest, artificial surfaces, water body, wetlands, and bare land (as shown in Figure 2). This was completed in preparation for accurately identifying their spatial dynamic changes in subsequent analyses. Population data and GDP, which were factors that influenced the ecological environment quality, were obtained from the Statistical Yearbook of Henan Province https://tjj.henan.gov.cn/tjfw/tjcbw/tjnj/ (6 May 2023). The temperature and precipitation data were obtained from the "ECMWF/ERA5/MONTHLY" dataset provided by the GEE platform. The land cover data were downloaded from the Global Land Cover Dataset (GlobleLand30), a publicly available global geospatial information product http://www.globallandcover.com/ (1 February 2023). The digital elevation model (DEM) data were acquired from the official website of Geospatial Remote Sensing Data Hub https://www.gisrsdata.com/data-gis/ (1 February 2023).

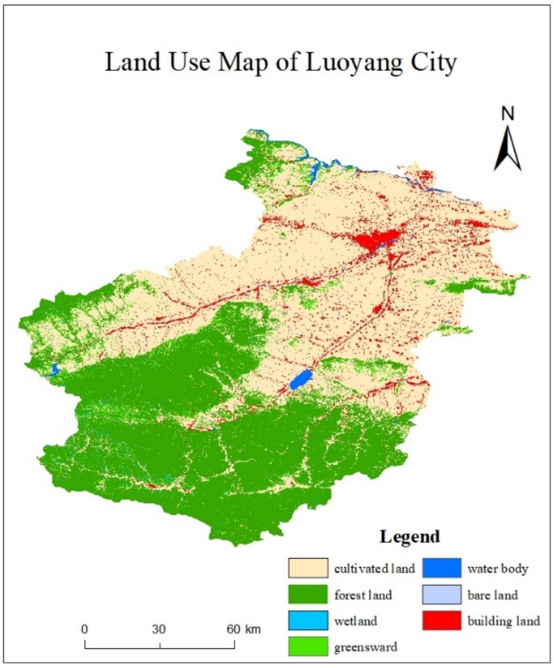

Figure 2. Land use map of Luoyang city.

3. Methodology

Remote Sensing Ecological Index (RSEI) is a comprehensive evaluation system, which is based on natural factors unaffected by human activities, and directly related to the quality of the ecological environment, including humidity, greenness, dryness, and thermal indicators, which are combined with remote sensing technology to objectively assess the ecological environment. Relevant research [21] indicates that greenness, humidity, thermal, and dryness are crucial components of an ecosystem and also the most important indicators for human perception of ecological conditions. Therefore, they are frequently used to assess ecological quality. Using RSEI as the evaluation index, this study investigated the ecological environment status of Luoyang city from 2002 to 2022. The four indicators of greenness, humidity, thermal, and dryness were represented by the Normalized Difference Vegetation Index (NDVI), Wet component, Land Surface Temperature (LST), and Normalized Difference Soil Index (NDSI), respectively. RSEI index was constructed by normalization and Principal Component Analysis (PCA [22]) to dynamically monitor the changes in the ecological environment quality in Luoyang. Furthermore, a univariate linear regression model was used to predict the future trend of ecological environment quality based on remote sensing image data, while the Mann–Kendall mutation test was employed to explore mutation anomalies. Lastly, social and economic indicators are selected and incorporated into a geographic detector to investigate the dominant factors influencing the changes in ecological environment quality in Luoyang city (the overall flowchart is shown in Figure 3).

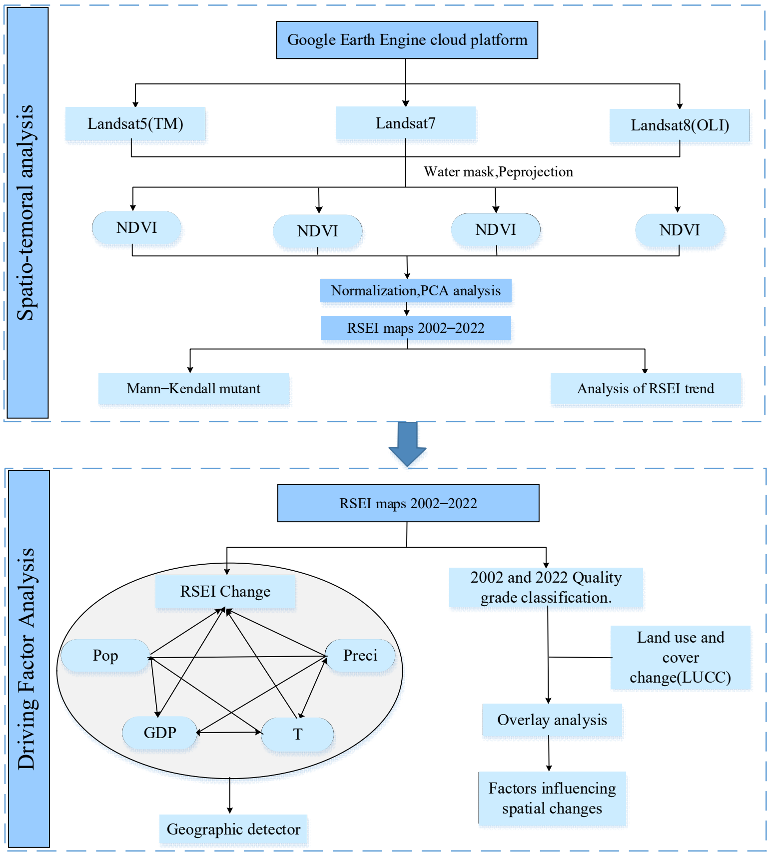

Figure 3. Overall framework of driving factors of ecological environment change.

3.1. The Calculation of Remote Sensing Ecological Index Component Indicators

(1) Greenness indicator is represented by the Normalized Difference Vegetation Index [23] (NDVI), which can reflect intuitively and effectively the growth status of plants and the distribution of vegetation density. The extraction formula is

$$NDVI = (\rho_{nir} - \rho_{red})/(\rho_{nir} + \rho_{red}) \tag{1}$$

where ρ_{nir} represents the reflectance of the near-infrared band in the TM and OLI image data, and ρ_{red} represents the reflectance of the red band in the TM and OLI image data.

(2) Humidity indicator. Humidity influences the growth of vegetation, and low humidity indicates insufficient soil moisture, poor plant growth status, low vegetation coverage on the ground, and hence reflects a poor ecological environment quality. On the other hand, high humidity indicates sufficient soil moisture, good plant growth status, and hence, this indicates a higher quality of the ecological environment. Therefore, one of the selected indicators is the humidity indicator represented by the Wet component. The extraction formulas for humidity indicators in Landsat 5 and Landsat 8 images differ due to the different sensors used, and their formulas are as follows.

Landsat5 TM data [24]:

$$WET = 0.0315\rho_{blue} + 0.2021\rho_{green} + 0.3102\rho_{red} + 0.1594\rho_{nir} - 0.6806\rho_{swir1} - 0.6109\rho_{swir2} \tag{2}$$

Landsat8 OLI data [25]:

$$WET = 0.1511\rho_{blue} + 0.1973\rho_{green} + 0.3283\rho_{red} + 0.3407\rho_{nir} - 0.7171\rho_{swir1} - 0.4559\rho_{swir2} \tag{3}$$

where ρ_{blue}, ρ_{green}, ρ_{red}, ρ_{nir}, ρ_{swir1} and ρ_{swir2} represent the reflectance values in the blue, green, red, near-infrared, shortwave infrared 1, and shortwave infrared 2 bands of TM and OLI images, respectively.

(3) Thermal indicator. The atmospheric correction method that can retrieve surface temperature is used for extraction. The specific extraction formula is

$$L_\lambda = Gain \times DN + Bias \tag{4}$$

$$B(T_s) = \left[L_\lambda - L_\downarrow - \tau(1-\varepsilon)L_\uparrow\right]/\tau\varepsilon \tag{5}$$

where Gain and Bias, respectively, refer to the meanings of the gain and bias, L_λ represents the radiance of the sensor, and $B(T_S)$ represents the brightness exhibited by the blackbody thermal radiation. τ is the atmospheric transmission in the thermal infrared band, $L_\uparrow$ and $L_\downarrow$, respectively, represent the measurements of upward and downward atmospheric radiations. Finally, the surface temperature, T_s can be obtained by solving the equation.

(4) Dryness indicator. The dryness metric is expressed in terms of the Normalized Difference Built-up Index (NDBSI), which is a normalized index. It is represented by fitting two indices, namely Soil Index (SI [26]) and Building Index (IBI [27]), into a single composite index. The extraction of the relevant area of each index is achieved by setting appropriate threshold values. The weighted average of the area ratio is computed and used as the dryness metric. The formula for calculating the NDBSI is given below.

Soil Index:

$$SI = [(\rho_{swir1} + \rho_{red}) - (\rho_{blue} + \rho_{nir})]/[(\rho_{swir1} + \rho_{red}) + (\rho_{blue} + \rho_{nir})] \tag{6}$$

Built-up Index:

$$IBI = \frac{2\rho_{swir2}/(\rho_{swir1} + \rho_{nir}) - \left[\rho_{nir}/(\rho_{red} + \rho_{nir}) + \rho_{green}/\left(\rho_{swir1} + \rho_{green}\right)\right]}{2\rho_{swir2}/(\rho_{swir1} + \rho_{nir}) + \left[\rho_{nir}/(\rho_{red} + \rho_{nir}) + \rho_{green}/\left(\rho_{swir1} + \rho_{green}\right)\right]} \tag{7}$$

Dryness indicator (NDBSI):

$$NDBSI = \alpha \cdot SI + \beta \cdot IBI \tag{8}$$

where ρ_{green}, ρ_{blue}, ρ_{red}, ρ_{nir}, ρ_{swir1}andρ_{swir2} represent the reflectance values for the green, blue, red, near-infrared, mid-infrared 1, and mid-infrared 2 bands of the TM and OLI images, respectively. α and β denote the weighting coefficients for SI and IBI, respectively.

3.2. Construction of Remote Sensing Ecological Index Evaluation Model

The article, departing from the traditional weighted sum method, employs principal component analysis to establish a remote sensing ecological index. The first principal component (PC1 [27]) of the four indicators largely captures the majority of the important information in the indicators. Since the four component indicators of RSEI have different units, normalization is carried out on each component using the following formula:

$$NI_i = \frac{I_i - I_{min}}{I_{max} - I_{min}} \tag{9}$$

where NI_i represents the normalized value of a certain indicator, I_i is the indicator value, and I_{min} and I_{max} represent the minimum and maximum values of that indicator, respectively.

The function for calculating the initial $RSEI_0$ represented by four component indicators is as follows:

$$RSEI_0 = 1 - \{PC1[f(WET, NDVI, LST, NDBSI)]\} \tag{10}$$

where PC1 represents the first principal component, WET refers to the soil moisture index, "NDVI" represents the Normalized Difference Vegetation Index, "LST" stands for Land

Surface Temperature, and "NDBSI" represents the Normalized Difference Built-up and Bare Soil Index.

Finally, normalization is carried out again on $RSEI_0$ as follows:

$$RSEI = \frac{RSEI_0 - RSEI_{0-min}}{RSEI_{0-max} - RSEI_{0-min}} \tag{11}$$

The RSEI value is normalized to be between 0 and 1. The smaller RSEI value between the intervals indicates a poorer ecological quality, whereas a larger value indicates a better ecological environment quality in the study area. Based on the ecological and environmental classification criteria using RSEI in the "Technical Specification for Ecological and Environmental Assessment," RSEI is classified into five levels: poor (0–0.2), relatively poor (0.2–0.4), moderate (0.4–0.6), good (0.6–0.8) and excellent (0.8–1).

3.3. Analysis of Dynamic Changes in Ecological Index

3.3.1. Trend Analysis

We conducted a significance test (slope trend analysis [28]) using the principle of least squares and employed linear fitting to examine the changing trend of the ecological environment quality in the study area of Luoyang city. The slope function can represent the trend of changes in each pixel value in the remote sensing image, based on which change trend of RSEI from 2002 to 2022 in the study area for 21 years was obtained.

If *Slope* > 0, it indicates that the pixel value shows a growing trend over the decades, and a larger value indicates a faster growth in the mean RSEI value, indicating a better improvement in the ecological environment quality in Luoyang city. If *Slope* < 0, it indicates that the pixel value shows a decreasing trend over the decades, and a smaller value indicates a greater reduction in the mean RSEI value, indicating the degradation of the ecological environment in the study area is more severe.

3.3.2. Mutation Analysis

The Mann–Kendall change point detection method is a non-parametric statistical method that is not affected by change outliers. It was initially proposed and further developed by Mann (H.B. Mann) and Kendall (M.G. Kendall). In this study, it is used to analyze the change point of the RSEI time series, which can objectively reflect the trend of the time series. The main formula for the Mann–Kendall change point detection method is

$$S_k = \sum\nolimits_{i-1}^{k} \sum\nolimits_{j}^{i-1} a_{ij}, k = 2, 3, \ldots, n \tag{12}$$

where:

$$a_{ij} = \begin{cases} 1, x_i > x_j, 1 \le i \le j \\ 0, x_i \le x_j, 1 \le i \le j \end{cases} \tag{13}$$

Additionally, the assumption is that the time series is random, and the statistical parameter is defined as:

$$UF_k = \frac{S_k - E(S_k)}{\sqrt{Var(S_k)}}, k = 1, 2, \ldots, n \tag{14}$$

$$E(S_k) = \frac{k(k+1)}{4} \tag{15}$$

$$Var(S_k) = \frac{k(k-1)(2k+5)}{72} \tag{16}$$

The UF_k statistical sequence is calculated from the time series $x_1, x_2, \ldots, x_n$, and it follows a standard normal distribution. Similarly, the UB_k sequence is calculated by reversing the order of the time series $-(x_n, x_{n-1}, \ldots, x_1)$. The UF_k and UB_k curves are plotted separately, and if *UF* > 0, it indicates an upward trend in the time series. On the other hand, if UF < 0, it suggests a downward trend in the time series [29]. The critical confidence interval line is shown beyond the curves, where for testing confidence level $\alpha = 0.05$, the confidence interval line is ± 1.96; for $\alpha = 0.01$, it is ± 2.32; and for $\alpha = 0.10$, it is ± 1.28. If the curves lie outside the confidence interval lines, it indicates the magnitude of the upward or downward trend is extremely steep, and if the curves intersect within the confidence interval lines, it indicates a change point in the time series and the corresponding point in time is identified as the beginning of the change [30].

3.3.3. Analysis of Impact Factors on Geographic Detectors

Geographic detectors [31] are tools used to study spatial relationships, primarily to detect the spatial heterogeneity of phenomena, which is used to explore a certain similarity relationship between independent variables and dependent variables. Wang et al. pointed out that the geographic detector includes four detectors: differentiation and factor detector, interaction detector, risk area detector and ecological detector. In the article, we primarily employed the differentiation and factor detector to explore the driving factors (X) affecting the ecological environment quality of Luoyang city, and explore their relationship with the interannual remote sensing ecological index (Y); the q value within the range of [0, 1] is used as a measure in this context, with the expression:

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} \tag{17}$$

where h represents the factor influencing stratification and q indicates the driving force of the independent variable on the dependent variable, with a higher q-value indicating stronger influence power of the independent variable X on the dependent variable Y, while a lower q-value suggests a weaker influence. N_h and N represent the number of units in layer h and the entire study area, respectively; σ_h^2 and σ^2 represent the variances of Y values in layer h and the study area, respectively [32].

4. Results and Analysis

4.1. Changes in the Ecological Environment Quality in Luoyang City

4.1.1. Analysis of Spatiotemporal Changes in Remote Sensing Ecological Index

From 2002 to 2022, according to the mean values of RSEI (as shown in Figure 4), the average annual RSEI values in Luoyang city exhibited a very limited number of periods showing a degradation state. The overall trend has been fluctuating with a continuous upward trajectory, indicating a positive development in ecological environmental quality [33]. The mean value has increased from 0.445 in 2002 to 0.529 in 2022, with the lowest value occurring in the initial year of 2002 and the highest value of 0.588 in 2020. The p value of the coefficients is 0.0014, the mean value has shown an overall fluctuation with slow growth, and the overall trend is that the change in ecosystem quality was significant before 2014 and has been smaller since 2014 [34]. This indicates that the study area of Luoyang city has increasingly focused on environmental improvement over the past 21 years, and the quality of the living environment is continuously improving.

The following figure displays the distribution map of ecological environment quality grades in the study area over a period of five years, which are the years 2002, 2007, 2012, 2017 and 2022, with the mean values of RSEI being 0.445, 0.481, 0.557, 0.541 and 0.529, respectively. The RSEI mean falls within the range of [0, 1], and is divided equally into five intervals [35] of poor (I), relatively poor (II), moderate (III), good (IV) and excellent (V) according to the ranges of 0.0–0.2, 0.2–0.4, 0.4–0.6, 0.6–0.8 and 0.8–1.0 (as shown in Figure 5). From the maps, the image shows that the areas with lower environmental quality levels in Luoyang city are mainly concentrated in the northeast, and were particularly severe in 2002. However, on the southwest side, the area with the highest environmental quality level has been continuously increasing, indicating an overall improvement in the ecological conditions of Luoyang city. More specific numerical values can be seen in Figure 6.

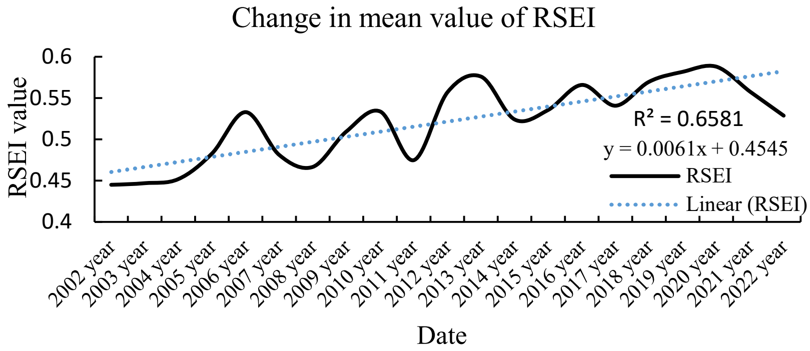

Figure 4. Timing curve of RSEI changes in Luoyang city.

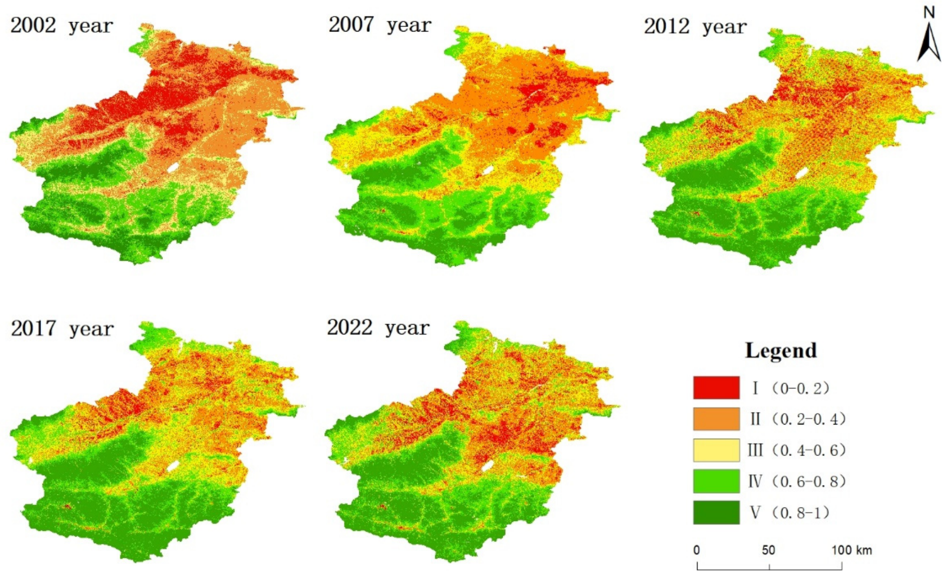

Figure 5. Distribution map of ecological environment quality level in Luoyang city.

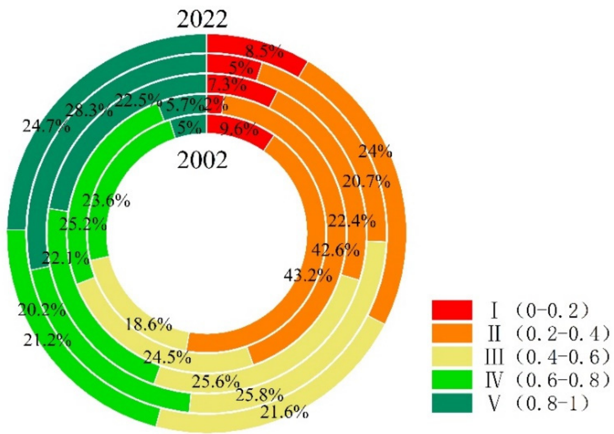

Figure 6. The proportion of graded area of ecological quality in Luoyang city from 2002 to 2022.

The following figure displays the proportions of different ecological environment quality grades within Luoyang city. Compared with 2002, the area occupied by the ecological quality grade "excellent" in 2022 accounts for 24.7% of the total area, an increase of 19.7%, while the area occupied by the ecological quality grade with a lower rating accounts for 24% of the total area, a decrease of 19.2%. There has been significant improvement in the ecological quality. But in 2017, the overall ecological quality of Luoyang city was at its best, with the region evaluated as excellent in ecological environment quality accounting for 28.3%, while the region with poor ratings accounted for only 5%. From 2002 to 2022, the average RSEI value has consistently increased, indicating a fluctuating upward trend in ecological environment quality, with a decrease in the area of grades I and II and an increase in the area of grades IV and V. From the perspective of the proportion of each grade in a single year, the area with a relatively poor-quality grade had the highest proportion in 2002; however, by 2022, the area with the highest ecological environment quality rating (excellent) has the highest proportion.

4.1.2. Mutation Analysis of Remote Sensing Ecological Index

According to the mean RSEI data from 2002 to 2022, the M–K abrupt change test was performed, and the test results (shown in Figure 7) indicate that the statistical curves of UF and UB intersect within the critical value (α = 0.01 significant level line $\pm$2.32). Therefore, the data exhibit mutability. The intersection point of the two curves determines the time of RSEI mean values undergoing an abrupt change in 2009. The UF curve exceeded the critical upper value of +2.32 before 2012, indicating a significant upward trend beyond the 0.01 significant level. Moreover, the entire RSEI sequence presents an upward trend, as indicated by the fact that the UF curve is always greater than 0; thus, the overall ecology of the study area is improving.

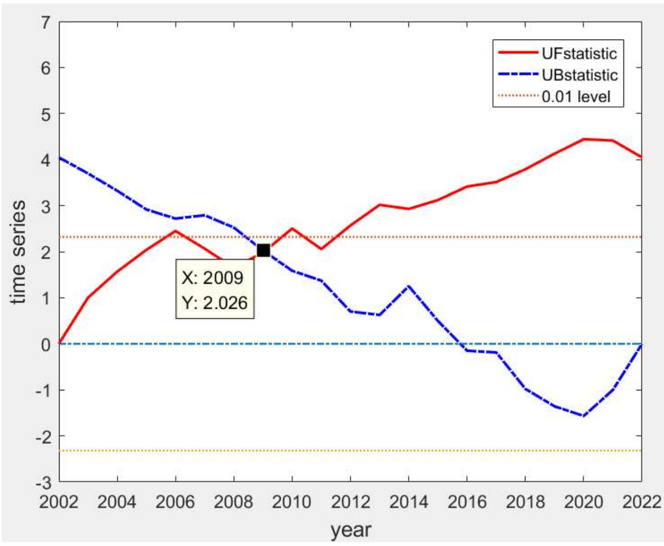

Figure 7. RSEI mean M−K mutation test curve.

4.2. Trend Analysis of Ecological Environment Quality in Luoyang City

This study conducts a trend analysis on the basis of 21 RSEI datasets to clarify the quality change trends and spatial distribution patterns of the ecological environment in Luoyang city from 2002 to 2022. As shown in the figure below, the spatial trends of ecological quality are classified into three states: significantly reduced, no significant trend, and significantly increased (as shown in Figure 8) [36]. The result indicates that the overall improvement of the ecological environment quality in the study area is expected in the future [37], with only a small portion exhibiting stable trends, and the area showing worsened trends being the least. The specific proportions of these areas are detailed in Table 1.

Table 1. Statistics of RSEI spatial variation area in Luoyang city.

Status	Area/km^2	Percentage
Significantly reduced	125.08	0.82%
No significant trend	5350.06	35.21%
Significantly increased	9721.51	63.97%

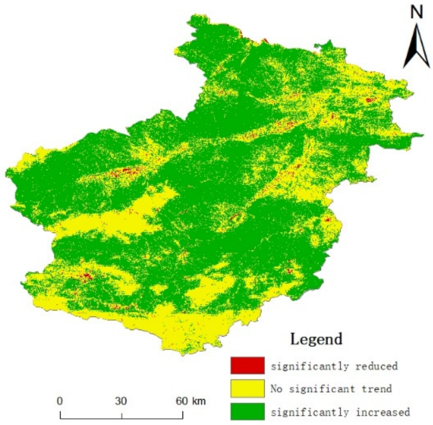

Figure 8. Spatial distribution map of RSEI spatial change trends in Luoyang city.

According to Table 1, the area with an improved ecological quality trend accounts for 63.97% of the study area, which accounts for more than half of the total area. The proportion of areas with a stable ecological quality trend is relatively low, accounting for only 35.21%. In contrast, the proportion of areas exhibiting significantly increased ecological quality is the smallest, representing only 0.82% of the total area [38]. This indicates that in the future, there are very few areas where ecological quality will worsen in the study area, and the majority of the region's ecological quality is likely to continue to improve. From Figure 5, it can be observed that the spatial distribution of areas with improved ecological environment quality is relatively uniform, and the low-value ecological quality areas have gradually aggregated towards the city's inner regions, with only the southernmost area remaining stable. This indicates that both the mountainous southwestern region and the residential northeastern region are focusing on environmental protection and management, promoting an overall trend towards ecological improvement. This trend is closely related to local policies and governance plans. Since the northeastern area is located in a densely populated urban area, the changes in ecological quality are affected by various anthropogenic factors, indicating that human activities may be the leading factor driving ecological improvement.

4.3. Driving Factors of Ecological Environment Quality in Luoyang

4.3.1. Factors Affecting Temporal Changes in Ecological Environment Quality

As a comprehensive evaluation index for terrestrial ecological environments [39], RSEI is closely related to multiple economic and social factors. For this study, we selected the economic factor gross domestic product (GDP), the social factor average annual population of various Chinese cities (Population), and the average annual temperature (temperature) and average annual precipitation (precipitation) as environmental factors that are less impacted by anthropogenic factors. We obtained the annual mean values of these four factors from 2002 to 2022, as shown in the figure below (as shown in Figure 9) [15].

Using the factor detection tool in the geographical detector, we can explore the influence of different factors on the ecological environment quality in Luoyang city. The statistical item q can be employed to assess the impact strength of these factors. The independent variables selected were average annual temperature, average annual precipitation, population, and regional gross domestic product (GDP), and the impact of these independent variables on the dependent variable (ecological environment quality) was explored. The detection of influence was divided into single-factor detection and dual-factor detection, and the definition of interactive detection effects indicated that when the interactive detection value of the two factors was greater than the sum of the single-factor detection values, it was considered to be non-linear enhancement. When the interactive detection value of both factors exceeded that of each single-factor detection, it was determined to be dual-factor enhancement. The driving factors affecting the ecological environment quality in Luoyang city, according to the results of single-factor detection, are as follows: population > gross domestic product (GDP) > Temperature > Precipitation, indicating that the ecological environment quality of Luoyang city was most affected by population growth under single-factor conditions. According to the detection results in the Figure 10 below, it can be concluded that the interactive detection values of dual factors are greater than those of each single factor, and the response of any dual-factor interaction is stronger than dual-factor interaction. Therefore, the results of exploring the driving factors affecting the changes in the ecological environment quality of Luoyang city are determined to be dual-factor enhancement [40], and the interactive effect of temperature and GDP has the greatest impact on the RSEI of the study area.

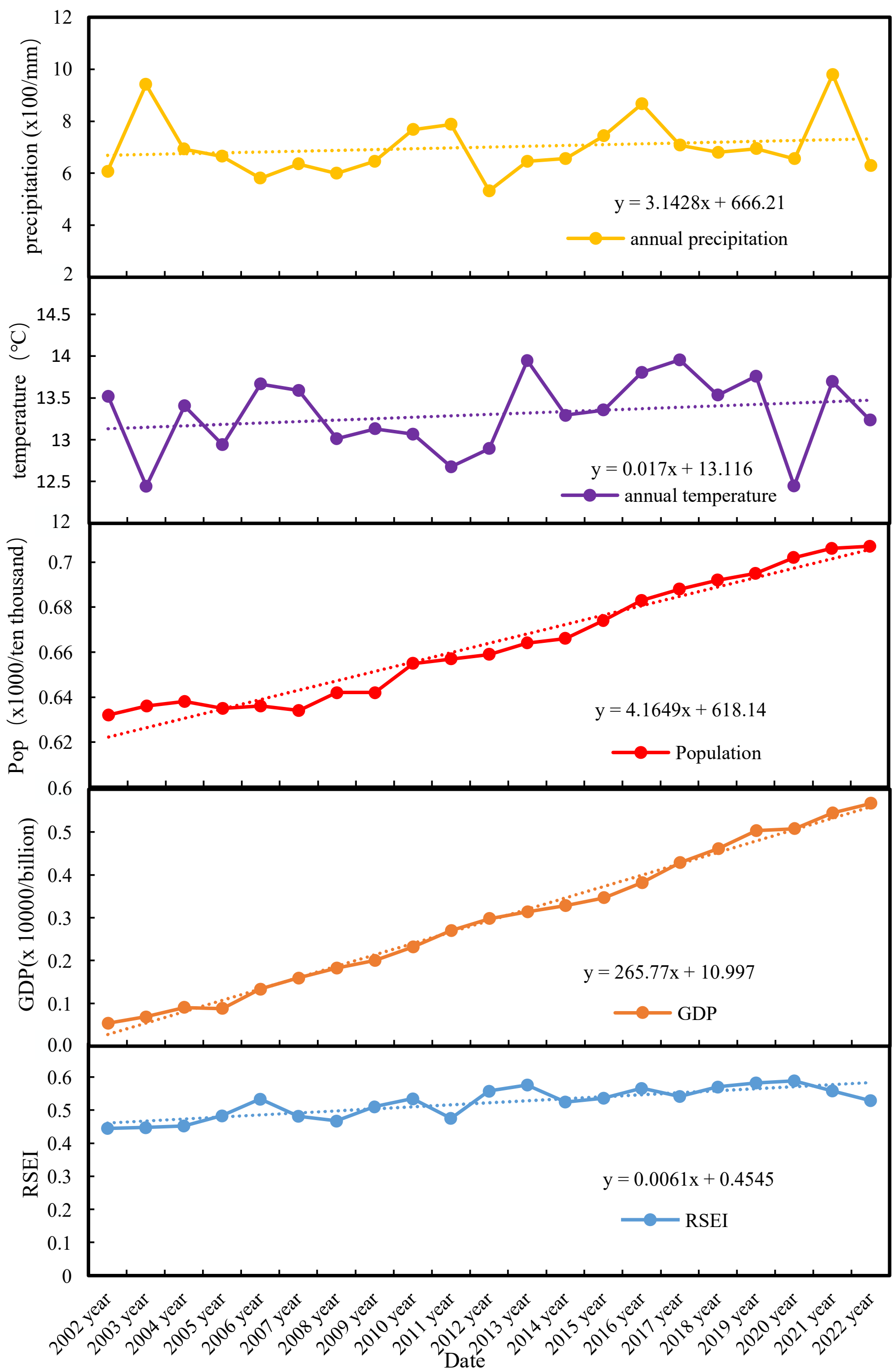

Figure 9. Annual average of temperature, precipitation, population, and GDP from 2002 to 2022.

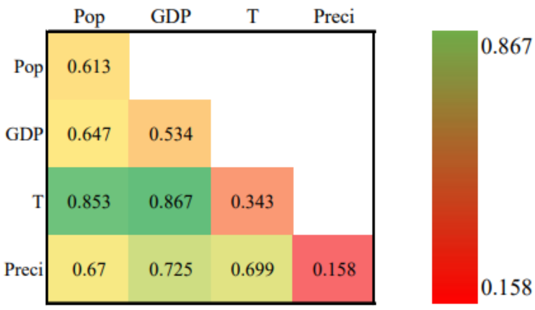

Figure 10. Detection results of the driving factors of ecological environment quality change in Luoyang city.

4.3.2. Factors Affecting Spatial Changes in Ecological Environment Quality

The significant difference in terrain, with higher elevation in the southern part and lower elevation in the northern part of Luoyang city, has led to a spatial clustering pattern of RSEI grades, whereby the southern part of the city has a relatively higher elevation, while the northern part has a relatively lower elevation, and the differences in land cover types between the north and south have a strong impact on RSEI. According to the land use type change data from 2002 to 2020 in the study area (the land cover data of 2020 were used instead of 2022), the Sankey diagram below (as shown in Figure 11) clearly shows that over the past 20 years, there have been noticeable areas of conversion between different land use types in the study area; here are the numerical values of the area conversions. The overall area of cultivated land and forest land accounts for the largest shares, and the potential for "green" development is constantly being released, leading to a continuous improvement in air quality. Luoyang has ultimately maintained its "green waters and lush mountains". Furthermore, based on the RSEI level distribution data obtained from the above research, high-level RSEI grid images were screened out based on the three levels of medium, good, and excellent (referred to as high levels) of RSEI distribution. These were then overlaid and analyzed with land cover data to ultimately derive the total area of high-level RSEI included in the conversions of different land cover types [41]. Thus, it can be known that different land use conversion types have led to changes in the total high-level remote sensing ecological index area in the study area.

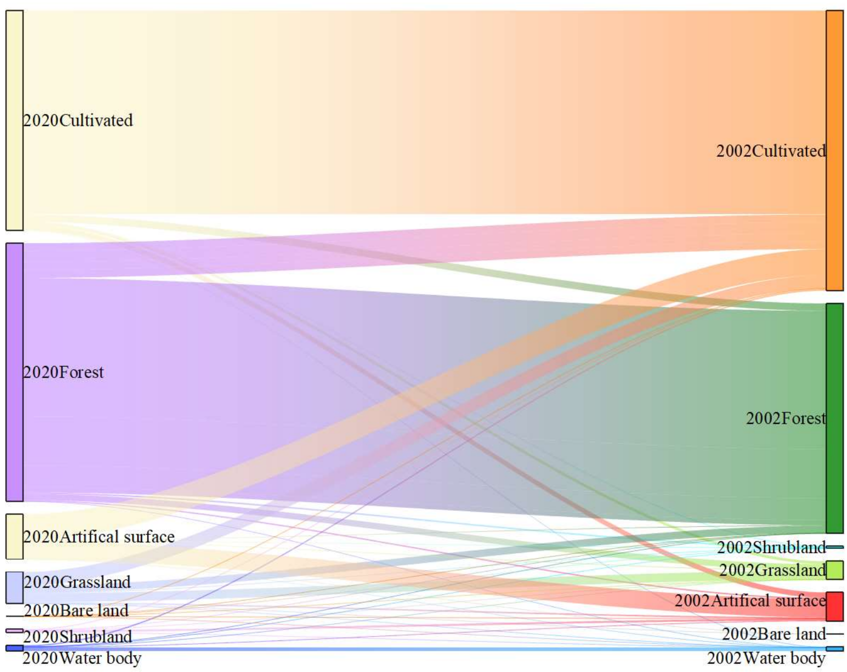

Figure 11. Statistics of land use type conversion in Luoyang city.

The information presented in the Table 2 represents the conversion of high-level RSEI total area values for land use types during two time periods. It is evident that forested and cultivated land areas contributed the most to the changes in high-level RSEI regions in Luoyang. Additionally, the artificial surface type showed some changes, indicating that despite rapid developments in construction and industry, the city remains committed to protecting its ecological environment. This might be attributed to notable achievements in the past decades of the southern ecological protection and restoration project of Luoyang. Moreover, the increase in cultivated and forested land, as well as improvements in water conservancy infrastructure and the promotion of economic and cultivated forests, played a significant role in shaping the results of the city's land use type changes. As a result, the increase in cultivated and forested land areas has led to a steady improvement in Luoyang's overall ecological environment quality.

Table 2. High-grade RSEI total value change matrix of different land use conversion types in Luoyang city.

2020 \ 2002	Grass Land	Cultivated Land	Forest Land	Bare Land	Artificial Surface	Wetland	Waterbody	Sum/km^2
Grass land	43.086	9.557	64.943	0.027	0.609	-	0.118	118.339
Cultivated land	0.042	0.110	0.088	-	0.027	*	0.016	0.286
Forest land	83.240	84.694	5026.902	1.107	5.219	0.098	1.710	5202.969
artificial surface	0.149	0.325	0.258	-	0.146	0.040	0.037	0.955
Wetland	10.085	1.046	33.503	0.082	0.036	-	0.008	44.760
Waterbody	*	0.125	0.017	-	-	-	0.126	0.267
Sum/km^2	136.602	95.856	5125.711	1.216	6.036	0.141	2.015	5367.576

Note: "-" represents that no changes were made to the land use type where high-level RSEI was identified, and "*" represents very small converted areas.

The changes in the ecological environment quality of Luoyang city have been significantly influenced by changes in land cover types [42], as well as being benefited by soil conservation. However, the increasing soil conservation services are also due to the vegetation and water conservation factors, which in turn contribute to the improvement of ecological environment quality. The increase in the built-up area in the northern region and the expansion of cultivated land caused an increase in surface runoff and a decrease in infiltration, resulting in higher water yields in the area. Therefore, Luoyang's regional ecological quality is subject to strong natural disturbances, with consistently higher RSEI values in the southwest and more significant fluctuations in RSEI values near the artificial surface areas in the northeast region, requiring coordinated and comprehensive regulation efforts.

5. Discussion and Conclusions

5.1. Discussion

5.1.1. The Spatiotemporal Variation Characteristics of RSEI

A systematic analysis was conducted on the spatiotemporal variations of the ecological environment quality in Luoyang city. The results showed that the mean RSEI value fluctuated with a wave-like trend of "continuous decline and then rise" on the temporal scale, showing an overall improving direction, which is in line with previous research results [43]. In the study focusing on the ecological environment quality of the Henan segment of the Yellow River Basin, Zhang et al. observed a progressive increase in the proportion of regions exhibiting an excellent ecological environment index. The regions with poor ecological environment index on the spatial scale are relatively small in the entire Henan segment; the primary distribution areas of these regions include cities such as Zhengzhou and Luoyang. In this research study's findings, the spatial distribution of ecological environment quality in Luoyang city also showed low RSEI values in the northern urban areas and better ecological environment quality in southern mountainous areas; these research findings align with the fact that the northern part of Luoyang city is characterized by intensive human activities, while the southern part consists of mountainous areas with higher vegetation coverage. The research findings indicate that in the ecological environment assessment of 2002, the highest proportion was occupied by areas categorized as poor quality, but by 2022, the area with the highest proportion of ecological environment rating of "excellent" had increased, indicating an overall improvement in the RSEI rating of Luoyang city. Particularly in the northwest of Luoyang city, it was an area with poor ecological quality in 2002, but gradually dispersed and spread towards the northeast over time. Around 2007, there was almost no distribution of higher-level RSEI in the northern part of Luoyang. However, after more than a decade of development, the lower-level RSEI became uniformly distributed in the northern half of Luoyang city by 2022, with only high-quality levels existing in the peripheral areas. Overall, it presented a pattern of low in the central area and high in the surrounding areas. Furthermore, the trend analysis based on the RSEI data for the 21 periods showed that 63.97% of the area exhibited a upward trend in the future ecological environment quality of Luoyang city, aligning with previous research findings [44].

5.1.2. The Influence of Different Factors on RSEI Changes

Ecological security is closely related to human survival security, given that human activities consistently influence the spatiotemporal patterns of cities. Many experiments have shown that ecological environment quality is significantly affected by various driving factors. This study has shown that the RSEI of Luoyang city is influenced by the interaction of natural and anthropogenic factors. To explore the influencing factors on the interannual variation of RSEI, we used a geodetector based on the optimal parameters to be investigating the singular and combined interactions between natural factors and anthropogenic factors that affect the interannual variation of RSEI [45]. The natural factors studied were the annual average temperature and precipitation, while the anthropogenic factors studied were population and regional GDP. Analysis of the impact of single factors indicates that population and GDP are key factors driving the quality of the ecological environment within the study area [46]. Furthermore, the correlation between these two factors and the ecological environment quality in the study area aligns with the findings of prior research, as they serve as direct indicators of population density and economic development level. The interaction analysis of the dual factors indicates that the interplay between temperature and GDP has the greatest impact on the variations in RSEI within the scope of the study. Moreover, the co-monitoring detection values were greater than the single-factor detection values, and the results indicated that the driving factors of ecological environment quality change in Luoyang city are predominantly enhanced by dual factors.

In addition, regarding the spatial dynamics of RSEI, we selected land use as the control factor with the strongest driving force, including both anthropogenic and natural factors. Superimposing the spatial changes in ecological quality with alterations in land cover patterns, we analyzed the driving effect of land cover type changes on ecological quality changes. The significant influence between the two is consistent with existing research findings. Gao et al. [47] pointed out in their simulation of urban expansion in Henan province that the increase in urban land use is mostly accompanied by a decrease in farmland due to the saturation of building area. Therefore, our study found that the cultivated land area sharply decreased from 2002 to 2020, while the artificial land area increased significantly, resulting in poor ecological environment quality in the northern building area of Luoyang city. This is the same as the relevant research results [48], which showed that the main driving factor behind ecological environment deterioration was land use/cover change (LUCC), primarily resulting from urban expansion. In addition to objective factors, human subjective activities are also important factors contributing to the changes in ecological environment quality. Relevant studies have shown that government activities play a crucial role in addressing issues such as environmental degradation and socio-economic insecurity for sustainable urban development [49]. The government of Luoyang city, in collaboration with the market, is actively promoting the process of new urbanization, leading to a rapid increase in the urbanization rate. As a result, the northeastern urban area of Luoyang city has expanded rapidly, causing significant land use type conversions and further impacting the changes in the ecological environment. Therefore, human activities indirectly influence the fluctuations of the ecosystem, and areas with concentrated human activities are sensitive zones for ecological changes.

5.1.3. Application and Future Recommendations

The study suggests that RSEI is affected directly or indirectly by various factors. Therefore, in future urban construction and development, it is recommended to place a greater emphasis on the dissemination of ecological principles. The impact of changes in GDP, population, temperature, precipitation, and land use on the ecological environment quality of Luoyang city indicates that Luoyang city can formulate and implement sustainable development strategies, to ensure a balance between economic development and ecological environment protection. This can be achieved by implementing population control policies and planning urban development rationally to avoid uncontrolled urban expansion. Moreover, it can also be achieved by promoting the transformation of Luoyang city towards a low-carbon economy and reducing greenhouse gas emissions, thereby alleviating the pressure of temperature on the environment. Strengthening water resource management and protection, improving water use efficiency, and ensuring the sustainable utilization of water resources are also important aspects. These measures aim to provide theoretical support for the improvement of Luoyang city's ecological environment.

The RSEI comprehensive evaluation method used in this study fills the void in assessing the qualitative and quantitative aspects of ecological quality in Luoyang city. Compared to previous studies, this research no longer relies on a single indicator to evaluate ecological environment quality. Instead, it incorporates the RSEI index to simultaneously monitor ecological changes in both urban and mountainous areas. By studying two different terrains, the research aims to explore the factors that influence the variation in ecological quality and identify potential differences between them. However, this method mainly focuses on greenness, humidity, thermal, and dryness and may not fully reflect all the influences on the quality of the ecological environment. Moreover, while examining the factors that exert influence, the study has not further investigated the positive or negative effects of each factor on RSEI, and the obtained results exclusively capture the magnitude of the factors' impact on the response variable [50]. Therefore, further research should explore which factors contribute positively to ecological changes and which factors contribute negatively to ecological changes, to make the research results more comprehensive. The key issue in future research on changes in ecological quality is to construct a more comprehensive, systematic, and fully covered framework of assessment metrics for evaluating ecological environment quality and to improve the overall ecological quality.

5.2. Conclusions

In this study, a comprehensive ecological environmental quality evaluation system was efficiently extracted using the GEE platform. It explored the spatiotemporal characteristics of ecological changes in Luoyang city over the past 20 years. Additionally, it investigated the driving factors influencing the changes in the RSEI of Luoyang city between spatial and temporal factors. The following results were obtained:

(1) Utilizing the RSEI model to analyze the dynamics of ecological environment quality in the research of Luoyang city. From a temporal perspective, the RSEI mean value showed a consistent rising trend from 2002 to 2022. The environmental conditions of Luoyang city are progressively enhancing over time.
(2) From a spatial perspective, regions with the poor RSEI values are concentrated in the densely populated urban areas in the north of Luoyang city, while regions with the high elevation and vegetation cover in the southern mountainous areas generally have a better ecological environment quality. The area with ecological environment quality grade at a

moderate level or above increased from 47.2% to 67.5%. Moreover, 63.97% of the regions in Luoyang city show an improving trajectory in ecological environment quality.

(3) From the perspective of influencing factors on RSEI changes, population and GDP are key factors driving the temporal changes in the ecological environmental quality of the study area, as indicated by the results of the single-factor analysis. The analysis conducted in the study area reveals that the interaction between temperature and GDP has the highest impact on the fluctuations observed in RSEI; these results highlight the crucial role played by the combined influence of temperature and GDP in shaping the changes in RSEI within the study area. The spatial changes in land use type changes have a close relationship with the spatial changes in high-level RSEI; the existing ecological environment condition in the study area is an outcome shaped by the interplay of both natural and anthropogenic factors.

As a consequence, we should place greater emphasis on the importance of ecological conservation while focusing on economic development, to ensure the continuous improvement of ecological quality, coordinate and restore areas with the poor ecological quality, and reasonably arrange the rate of urban expansion to provide better geospatial foundations for ecological governance.

Author Contributions: Methodology, G.Y. and W.L.; Resources, W.L.; Writing—original draft, H.L.; Writing—review & editing, H.J., G.Y., H.G. and W.L.; Supervision, H.J. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Natural Science Foundation of China (Grant No. 42201328).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data used in this study can be obtained from the first author at 212104010008@home.hpu.edu.cn with a reasonable request.

Acknowledgments: The Landsat images and DEM data were from Google Earth Engine (GEE) platform, which provides an open database. The authors would like to thank the above institutions for their help and support.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Cao, J.; Wu, E.; Wu, S.; Fan, R.; Xu, L.; Ning, K.; Li, Y.; Lu, R.; Xu, X.; Zhang, J.; et al. Spatiotemporal Dynamics of Ecological Condition in Qinghai-Tibet Plateau Based on Remotely Sensed Ecological Index. *Remote Sens.* **2022**, *14*, 4234. [CrossRef]
2. Huang, H.; Chen, W.; Zhang, Y.; Qiao, L.; Du, Y. Analysis of ecological quality in Lhasa Metropolitan Area during 1990–2017 based on remote sensing and Google Earth Engine platform. *J. Geogr. Sci.* **2021**, *31*, 265–280. [CrossRef]
3. Popescu, R.; Corboş, R.; Bunea, O. Study on the perception of young Romanians on the eco-marketing and promotion efficiency in increasing the environmental NGOs competitiveness. *Calitatea* **2018**, *19*, 417–422.
4. Popescu, R.; Corbos, R.; Comănescu, M.; Bunea, O. Ecological Marketing-Strategic Option for Business Development in Bucharest. *Econ. Comput. Econ. Cybern. Stud. Res.* **2017**, *51*, 67–83.
5. Sha, Z.; Bofu, Y.; Yao, Z. Global concurrent climate extremes exacerbated by anthropogenic climate change. *Sci. Adv.* **2023**, *9*, eabo1638.
6. Wang, Q.; Li, L. The effects of population aging, life expectancy, unemployment rate, population density, per capita GDP, urbanization on per capita carbon emissions. *Sustain. Prod. Consum.* **2021**, *28*, 760–774. [CrossRef]
7. Wang, Q.; Su, M.; Li, R. Toward to economic growth without emission growth: The role of urbanization and industrialization in China and India. *J. Clean. Prod.* **2018**, *205*, 499–511. [CrossRef]
8. Wang, Q.; Hu, S.; Li, L.; Li, R. Accelerating urbanization serves to reduce income inequality without sacrificing energy efficiency—Evidence from the 78 countries. *Sustain. Cities Soc.* **2023**, *92*, 104477. [CrossRef]
9. Wang, Q.; Wang, X.; Li, R. Does urbanization redefine the environmental Kuznets curve? An empirical analysis of 134 Countries. *Sustain. Cities Soc.* **2022**, *76*, 103382. [CrossRef]
10. Wang, Q.; Su, M.; Li, R.; Ponce, P. The effects of energy prices, urbanization and economic growth on energy consumption per capita in 186 countries. *J. Clean. Prod.* **2019**, *225*, 1017–1032. [CrossRef]

11. Jiang, F.; Zhang, Y.; Li, J.; Sun, Z. Research on remote sensing ecological environmental assessment method optimized by regional scale. *Environ. Sci. Pollut. Res.* **2021**, *28*, 68174–68187. [CrossRef]
12. Zhang, Y.; Liu, L.; Zhao, P. WZ5 water index and validation of its effectiveness in a coastal wetland water extraction. *J. Zhejiang A F Univ.* **2018**, *35*, 735–742.
13. Liang, L.; Huang, T.; Di, L.; Geng, D.; Yan, J.; Wang, S.; Wang, L.; Li, L.; Chen, B.; Kang, J. Influence of Different Bandwidths on LAI Estimation Using Vegetation Indices. *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.* **2020**, *13*, 1494–1502. [CrossRef]
14. Xu, H.Q. A remote sensing urban ecological index and its application. *Acta Ecol. Sin.* **2013**, *33*, 7853–7862.
15. Yang, X.; Meng, F.; Fu, P.; Zhang, Y.; Liu, Y. Spatiotemporal change and driving factors of the Eco-Environment quality in the Yangtze River Basin from 2001 to 2019. *Ecol. Indic.* **2021**, *131*, 108214. [CrossRef]
16. Chen, N.; Cheng, G.; Yang, J.; Ding, H.; He, S. Evaluation of Urban Ecological Environment Quality Based on Improved RSEI and Driving Factors Analysis. *Sustainability* **2023**, *15*, 8464. [CrossRef]
17. Junru, Y.; Xuan, L.; Hua, W.; Wei, H.; Enxiang, C. Spatio-temporal variations of ecosystem service values in response to land use/cover change in Luoyang city. *Front. Environ. Sci.* **2022**, *10*, 984888.
18. Xinjian, G.; Yuwen, F.; Yu, M.; Denghua, Y. Water ecology emergy analytic system construction and health diagnosis. *Energy Convers. Manag.* **2022**, *270*, 116254.
19. Kaili, Z.; Rongrong, F.; Zhicheng, Z.; Chun, D.; Hongjuan, Z.; Kang, L. Exploring the Driving Factors of Remote Sensing Ecological Index Changes from the Perspective of Geospatial Differentiation: A Case Study of the Weihe River Basin, China. *Int. J. Environ. Res. Public Health* **2022**, *19*, 10930.
20. Xu, H. Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. *Int. J. Remote Sens.* **2006**, *27*, 3025–3033. [CrossRef]
21. Helili, P.; Zan, M. Coupling Coordination Development of Urbanization and Ecological Environment in the Urban Agglomeration on the Northern Slope of the Tianshan Mountains, China. *Sustainability* **2023**, *15*, 4099. [CrossRef]
22. Jing, Y.; Zhang, F.; He, Y.; Johnson, V.C.; Arikena, M. Assessment of spatial and temporal variation of ecological environment quality in Ebinur Lake Wetland National Nature Reserve, Xinjiang, China. *Ecol. Indic.* **2020**, *110*, 105874. [CrossRef]
23. Song, C.; Huang, B.; You, S. Comparison of three time-series NDVI reconstruction methods based on TIMESAT. In Proceedings of the 2012 IEEE International Geoscience and Remote Sensing Symposium, Munich, Germany, 22–27 July 2012.
24. Crist, E.P. A TM Tasseled Cap equivalent transformation for reflectance factor data. *Remote Sens. Environ.* **1985**, *17*, 301–306. [CrossRef]
25. Baig, M.H.A.; Zhang, L.; Shuai, T.; Tong, Q. Derivation of a tasselled cap transformation based on Landsat 8 at-satellite reflectance. *Remote Sens. Lett.* **2014**, *5*, 423–431. [CrossRef]
26. Rikimaru, A.; Roy, P.S.; Miyatake, S. Tropical forest cover density mapping. *Trop. Ecol.* **2002**, *43*, 39–47.
27. Yun, Z.; Liangjun, Z.; Kai, N.; Asiya, M. Environmental Monitoring in Northern Aksu, China Based on Remote Sensing Ecological Index Model. *Open J. Appl. Sci.* **2022**, *12*, 757–768.
28. Enjun, G.; Fangxin, S.; Zhihui, W.; Qingfeng, H.; Jing, Z.; Hongxin, H. Evaluating Environmental Quality and Its Driving Force in Northeastern China Using the Remote Sensing Ecological Index. *Sustainability* **2022**, *14*, 16304.
29. Wu, Z.; Chen, S.; de Boeck, H.J.; Stenseth, N.C.; Tang, J.; Vitasse, Y.; Wang, S.; Zohner, C.; Fu, Y.H. Atmospheric brightening counteracts warming-induced delays in autumn phenology of temperate trees in Europe. *Glob. Ecol. Biogeogr.* **2021**, *30*, 2477–2487. [CrossRef]
30. Hadad, Y.; Keren, B.; Gurevich, G. Improving demand forecasting using change point analysis. *Int. J. Bus. Forecast. Mark. Intell.* **2017**, *3*, 130–151. [CrossRef]
31. Wang, J.F.; Li, X.H.; Christakos, G.; Liao, Y.L.; Zhang, T.; Gu, X.; Zheng, X.Y. Geographical detectors-based health risk assessment and its application in the neural tube defects study of the Heshun Region, China. *Int. J. Geogr. Inf. Sci.* **2010**, *24*, 107–127. [CrossRef]
32. Wenbo, Y.; Jun, Y.; Feng, W.; Baojie, H.; Bing, X.; Shaohua, W.; Huisheng, Y.; Xiangming, X.; Cecilia, X.J. Realistic characteristics and driving mechanisms of pseudo-human settlements in Chinese cities. *Humanit. Soc. Sci. Commun.* **2023**, *10*, 50.
33. Xiong, Y.; Xu, W.; Lu, N.; Huang, S.; Wu, C.; Wang, L.; Dai, F.; Kou, W. Assessment of spatial–temporal changes of ecological environment quality based on RSEI and GEE: A case study in Erhai Lake Basin, Yunnan province, China. *Ecol. Indic.* **2021**, *125*, 107518. [CrossRef]
34. Gao, W.; Zhang, S.; Rao, X.; Lin, X.; Li, R. Landsat TM/OLI-Based Ecological and Environmental Quality Survey of Yellow River Basin, Inner Mongolia Section. *Remote Sens.* **2021**, *13*, 4477. [CrossRef]
35. Bai, L.; Yang, Y.; Zhang, K.; Liu, S.; Liu, G. Monitoring and Analysis of the Driving Forces of Changes in the Ecological Environment of a Mining Area of Western China from 1986 to 2022. *Processes* **2023**, *11*, 1721. [CrossRef]
36. Jinjie, W.; Jianli, D.; Xiangyu, G.E.; Shaofeng, Q.; Zhe, Z. Assessment of ecological quality in Northwest China (2000–2020) using the Google Earth Engine platform: Climate factors and land use/land cover contribute to ecological quality. *J. Arid Land* **2022**, *14*, 1196–1211.
37. Cui, J.; Zhu, M.; Mi, H.; Liu, Y. Evaluation of Eco-Environmental Quality and Analysis on Spatio-Temporal Variation in Jinan, China. *Pol. J. Environ. Stud.* **2022**, *31*, 1061–1072. [CrossRef]
38. Wu, S.P.; Gao, X.; Lei, J.Q.; Zhou, N.; Guo, Z.K.; Shang, B.J. Ecological environment quality evaluation of the Sahel region in Africa based on remote sensing ecological index. *J. Arid Land* **2022**, *14*, 14–33. [CrossRef]

39. Ma, D.; Huang, Q.; Liu, B.; Zhang, Q. Analysis and Dynamic Evaluation of Eco-Environmental Quality in the Yellow River Delta from 2000 to 2020. *Sustainability* **2023**, *15*, 7835. [CrossRef]
40. Xinran, N.; Zhenqi, H.; Qi, Z.; Mengying, R. Research on Temporal and Spatial Resolution and the Driving Forces of Ecological Environment Quality in Coal Mining Areas Considering Topographic Correction. *Remote Sens.* **2021**, *13*, 2815.
41. Ahmed, G.; Zan, M.; Kasimu, A. Spatial–Temporal Changes and Influencing Factors of Surface Temperature in Urumqi City Based on Multi-Source Data. *Environ. Eng. Sci.* **2022**, *39*, 928–937. [CrossRef]
42. Yang, L.; Shi, L.; Wei, J.; Wang, Y. Spatiotemporal evolution of ecological environment quality in arid areas based on the remote sensing ecological distance index: A case study of Yuyang district in Yulin city, China. *Open Geosci.* **2021**, *13*, 1701–1710. [CrossRef]
43. Zhang, S.; Wang, X. Spatial-temporal variation and driving factors of eco-environmental quality in Henan section of the Yellow River Basin. In Proceedings of the 2022 29th International Conference on Geoinformatics, Beijing, China, 15–18 August 2022.
44. Wang, S.; Si, J.; Wang, Y. Study on Evaluation of Ecological Environment Quality and Temporal-Spatial Evolution of Danjiang River Basin (Henan Section). *Pol. J. Environ. Stud.* **2021**, *30*, 2353–2367. [CrossRef]
45. Yuanyuan, Z.; Liwen, Y.; Binggeng, X.; Junhan, L.; Jianyong, X.; Jing, X.; Zhixing, L. Analysis of ecological quality changes and influencing factors in Xiangjiang River Basin. *Sci. Rep.* **2023**, *13*, 4375.
46. Xiaoyun, R.; Mingkong, Z.; Juncheng, Q.; Shuangquan, L.; Jingxu, W.; Jun, D. Analyzing Spatio-Temporal Change in Ecosystem Quality and Its Driving Mechanism in Henan Province, China, from 2010 to 2020. *Sustainability* **2022**, *14*, 11742.
47. Gao, C.; Wang, J.; Wang, M.; Zhang, Y. Simulating Urban Agglomeration Expansion in Henan Province, China: An Analysis of Driving Mechanisms Using the FLUS Model with Considerations for Urban Interactions and Ecological Constraints. *Land* **2023**, *12*, 1189. [CrossRef]
48. Dongyu, Z.; Tao, C.; Na, Z.; Ruiqing, N. Monitoring the effects of open-pit mining on the eco-environment using a moving window-based remote sensing ecological index. *Environ. Sci. Pollut. Res. Int.* **2020**, *27*, 15716–15728.
49. Rana, M.M.P. Urbanization and sustainability: Challenges and strategies for sustainable urban development in Bangladesh. *Environ. Dev. Sustain.* **2011**, *13*, 237–256. [CrossRef]
50. Yibo, Y.; Ziyuan, C.; Simayi, Z.; Shengtian, Y. The temporal and spatial changes of the ecological environment quality of the urban agglomeration on the northern slope of Tianshan Mountain and the influencing factors. *Ecol. Indic.* **2021**, *133*, 108380. [CrossRef]