Research Article

Eco-Economic Environment Coupling Based on Urban RSEI Theory

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Introduction. Ecological environment is the foundation of social and economic development, and the coordinated development of social economy and ecological environment is one of the hotspots in urban sustainable development research. Traditional ecological economic measurement methods usually have problems such as difficulty in data acquisition and difficulty in pasteurization. In recent years, with the rise of global remote sensing technology, remote sensing has also been used to observe human social and economic activities. Remote sensing data have been created for the limitations of traditional statistical data with the advantages of being independent in the field of ecological and economic measurement. Methodology. This paper uses luminous remote sensing technique to obtain the visible-near-infrared electromagnetic wave information emitted from the surface at night under cloudless conditions and MODIS data combined with urban RSEI theory to quantitatively invert the ecological environment quality of the study area in 2019 based on a remote sensing perspective, taking a certain urban agglomeration in China as the research area. And it is continuous in time and space. Therefore, the coordination degree of remote sensing data should be fully explored in quantitative research. For proper analysis, regression was used. Research Content and Results. 2019 MODIS data were used to retrieve the six vegetation-related ecological environment factors in the study area and combine the urban RSEI theory to construct the remote sensing ecological comprehensive index of the study area, and the vegetation ecological environment quality and spatial agglomeration characteristics were evaluated. The results showed that vegetation coverage, leaf area index, total primary productivity, and surface moisture make positive contributions to the ecosystem of the study area. Based on the theoretical basis of coupling coordination theory, ecological economic theory, and sustainable development, we measured the degree of coordinated development between the social economic system and the ecological environment system in the study area from 2018 to the future period and combined the research results with the study area. The actual situation explores the practice path of benign coupling of the ecological economy. Conclusion. This paper is completely based on the research ideas of remote sensing data to measure the socioeconomic level and ecological environment quality and proves that remote sensing data and urban RSEI theory are efficient and reliable new tools for the coordinated development of ecological economics. The research results can provide a development plan for urban agglomeration.

1. Introduction

Since the 1930s, with the continuous expansion of cities and rapid population growth, people’s excessive consumption of natural resources has led to increasingly prominent global ecological problems, such as vegetation degradation, reduction of biodiversity, falling groundwater levels, and rising global temperatures [1–3]. Unfavorable factors restricted the development of economy, and then appeared the incoordination between human beings and nature, economy, and ecology. Traditional ecology and economics are difficult to solve these problems. In this context, ecological economics, an interdisciplinary subject that combines ecology and economics, has emerged. The core theory of ecological economics is the coordinated development of ecology and economy, as shown in Figure 1 and the coordinated development of ecological
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environment and social economy has become one of the key areas of research by scholars at home and abroad [4–7]. Traditional ecological economic research databases are mostly based on various statistical data. This type of data is generally at the provincial and municipal levels. It is difficult to obtain smaller-scale data such as county-level or even grids. Moreover, statistical data in various regions have different statistical standards and some indicators. Phenomena such as missing data have restricted the research on related issues. With the rapid development of remote sensing (RS) technology, geographic information system (GIS), global navigation satellite system (GNSS), computer software and hardware, and other technologies, remote sensing technology provides all-weather data sources for quickly obtaining surface information [8, 9]. Among them, daylight remote sensing can observe the natural environment, and luminous remote sensing can observe human social and economic activities; GIS provides a powerful data processing and storage, spatial analysis, and results from display platform; GNSS provides high accuracy positioning which helps to verify and update data. Especially with the development of remote sensing technology, its independent, objective, and continuous advantages in time and space can make up for the lack of statistical data and the difficulty of rasterization. It has gradually become a new data foundation for research in ecological economy-related fields. Sustainable development and the construction of ecological civilization are the theoretical basis for the coordinated development of ecological economy [10]. At present, related researches are generally based on census statistics, and there are very few related researches based entirely on remote sensing images. The research in this paper has the following scientific significance:

(1) The remote sensing data has the characteristics of wide coverage, a large amount of information, continuous time and space, and objective accuracy. Moreover, the “Luojia No. 1” 01-star luminous remote sensing data used in this paper is relative to the traditional luminous remote sensing data with higher spatial resolution, which is of great practical significance to promote the development of data foundation and research methods of ecological economic research.

(2) The current research on urban Risk Screening Environmental Indicator (RSEI theory) scores is based on Landsat data, and there is no large-scale inversion based on MODIS data (the Moderate Resolution Imaging Spectroradiometer design to monitor the Earth’s atmosphere). Regional ecological environment quality, exploring the application potential of MODIS data in retrieving ecological environment quality, is of great scientific significance for improving the urban RSEI theory.

(3) To grasp the level of socioeconomic development, ecological environment quality, and ecological economic coordinated development of the Yangtze River Delta urban agglomeration and based on the research results, we explore the development of the research area’s social and economic development and the ecological environment protection practice path of the good coupling, which can provide a scientific basis for the relevant government departments to scientifically and rationally formulate regional macrodevelopment strategy decisions, to quickly promote the Yangtze River Delta urban agglomeration city area county area integrated and coordinated development.

2. Related Work

2.1. Research Progress of Socioeconomic Measurement. The comprehensive social and economic measurement system plays an important role in evaluating social progress and policymaking. In terms of research theoretical basis, before the twentieth century, the social economic development measurement and evaluation mainly focused on the quantitative growth of the economic aggregate; after the twentieth century, the socioeconomic development measurement focused on the evaluation of both economic efficiency and social equity; since the twenty-first century, the socioeconomic development measurement and evaluation pay more attention to the sustainability of economic and social development. Reference [11] selected 12 indicators from 6 dimensions of income, consumption, education, population urbanization, transportation, and living facilities, established a polyhedral method for comprehensive regional multidimensional development measurement methods and models, and reconstructed them for comprehensive regional multidimensional development. The quantitative model of polygon method and vector sum method of measurement, together with the widely used weighted sum method, conducts comprehensive empirical research on the multidimensional development status of China’s regions by county, prefecture, and provincial units. Based on the new concept of “balanced, open, inclusive, and common development” in the sustainable development theory, a system of evaluation indicators for economic and social development of the “Belt and Road” countries has been constructed in three aspects of sustainable development, competitiveness, and openness. The economic and social development level of 64 countries along the route was measured and evaluated. In terms of research data foundation, the above-mentioned researches are all based on traditional statistical data. With the rapid development of luminous remote sensing technology, the observation of nature by remote sensing has been transferred to the observation of human social activities. The brightness of the light recorded by the luminous image represents the prosperity of the region. Its temporal and spatial continuity and independent and objective advantages can make up for the lack of statistical data in the region’s limitations on the estimation of social and economic parameters, and it has been gradually applied to the simulation of regional social and economic parameters. Elevidge et al. [12] used DMSP/OLS luminous data to perform regression analysis with 21 countries’ socioeconomic indicators, found that the night-time light index is highly correlated with GDP and energy consumption, and
initially confirmed that the use of luminous data is helpful to understand the economy of a country or region level. Yu et al. [13] found that NPP/VIIRS luminous data and provincial GRP and county GRP modeling capabilities are stronger than DMSP/OLS data. NPP/VIIRS luminous data improves the predictive ability of regional economic development. Zhang et al. [14] used NPP/VIIRS data to mine the correlation between the night light index and the county socioeconomic index to identify multidimensional poverty in China’s counties. In June 2018, China’s first professional luminous remote sensing satellite was also the first low-orbit satellite "Luojia-1” 01 (LJ1-01) with enhanced functions of Earth observation and satellite navigation. It was successfully launched with high-sensitivity luminous image and the camera’s imaging resolution is up to 130 m. Compared with DMSP/OLS data and NPP/VIIRS data, LJ1-01 data has a higher spatial resolution, allowing us to observe the spatial details of artificial lighting at night more clearly, which can fill the medium- and high-resolution luminous remote sensing data to a certain extent. For the gaps in the simulation study of socioeconomic parameters, the comparison of data parameters is shown in Table 1 [15].

2.2 Progress in Eco-Economic Coupling Research. At present, the researches on ecological economy mainly focus on the evaluation of ecological economic value and the research on the relationship of an ecological economic system. Eco-economic value assessment methods are usually based on biophysical measurements, such as ecological footprint, energy analysis, and ecosystem value services. Huang draws on the ecological index of economic growth and the conceptual basis of ecological efficiency and uses the analytic hierarchy process and expert consultation method to construct five modules including social development, economic growth, ecological construction, resource utilization, and environmental protection [17]. Apply eco-economic index evaluation index system and model to the Poyang Lake Eco-economic Zone. Eco-economic relationship research scholars mainly focus on the coupling relationship between the ecosystem and the economic system and the mechanism of system interaction. Eco-economic coupling relationship is usually based on coupling models, such as coupling degree model and coupling coordination degree model. Li et al. [18] analyzed the coupling law of the interaction between economic development and ecological environment in the study area through the regression model of the quadratic equation and cubic equation based on the environmental quality, pollutant emission, and economic development data of Liangyungang City from 1983 to 2000. Wang et al. [19] constructed a comprehensive evaluation index system for urbanization and ecological environment systems, constructed a dynamic coupling coordination degree model for urbanization and ecological environment with the aid of a physics coupling model, and quantitatively analyzed the Beijing-Tianjin-Hebei region from 1980 to 2011. The coupling process and evolution trend of urbanization and ecological environment is an important research. The research on the interaction mechanism of the ecological economic system is usually based on the environmental Kuznets curve (EKC). The EKC hypothesis [20] is used to describe the inverted U-shaped curve relationship between environmental pollution and per capita GDP. Yu et al. [21] took the eco-economic system around Dongting Lake as the research object. By constructing an evaluation index system, they used the neural network model to analyze the factor contribution of the system to achieve the best coupling and coordination state based on the coupling degree and coordination degree model and explore the coordination of system factors to the social economy and ecological environment. Ma and Huang [22] used the entropy-TOPSIS method, the technique for order of preference by similarity to ideal solution, which is a multicriteria decision analysis method to measure the green development index of 31 cities in the middle reach of the Yangtze River urban agglomeration, analyzed the causes of the differentiation pattern with the help of EKC theory, and further introduced the GWR model to deeply explore the spatial spillover effects of influencing factors. Zhang et al. [23] used analytic hierarchy process and PSR model to construct comprehensive indicators of urbanization level and ecological quality and used EKC to explore the interaction between rapid urbanization and ecological environment in Changzhou from 1986 to 2007 [24].

The rest of the paper is organized according to the following pattern. In Section 3, materials and methods are discussed followed by results in Section 4, in Section 4, the discussion is given, and the paper is concluded in Section 5.

3. Method

3.1 Data Sources

3.1.1 “Luojia-1” 01 Star Data. Luminous remote sensing is to obtain the visible-near-infrared electromagnetic wave information emitted from the surface at night under
cloudless conditions. Most of this information is related to human activities on the surface, the most important of which is human lighting at night. Therefore, luminous remote sensing images can effectively characterize the social economy of the surface. The research data of the socio-economic measurement in this paper is based on the 01 starry night light remote sensing image of Wuhan University “Luojia No.1,” with a spatial resolution of 130 m, which can identify roads and blocks. The data comes from the high-resolution Earth observation system Hubei data and application. The night lights on the Internet are different every night, with a certain degree of randomness. To reduce the impact of this accidental error on the measurement results, this paper selects two phases of LJ1-01 night light images in the study area and calculates the average night light of the two phases of images to participate in the construction of the final evaluation model. The images of each phase are mosaics of images from multiple scenes. Due to factors such as clouds, fog, and aerosols, the image quality will be affected, and the LJ1-01 image revisits cycle is 15 days. It is difficult to guarantee the same imaging time for each scene. The imaging time of scene images is not the same. The imaging time of the two phases of LJ1-01 in this paper is between July 16, 2019, and October 30, 2019, and the image quality is good. Although the LJ1-01 data product has undergone relative radiation correction and system geometric correction, the image still has a displacement of 2 to 3 pixels. To ensure the accuracy of the data, a certain number of well-recognized ground control points are selected on each image. It is evenly distributed on the image to perform geometric precision correction on each image. To keep the image pixel area constant and ensure the accuracy of the statistical results, the projection system in this paper adopts the WGS-84 geographic coordinate system and the Albers projection coordinate system. Finally, the scope of the study area is cut out according to the administrative boundary vector file of the study area. The radiance conversion formula is as follows:

\[ L = DN^{3/2} \cdot 10^{-10}, \]  

where \( L \) is the radiance value after absolute radiation correction, the unit is \( \text{W/(m}^2\text{.sr.\mu m)} \), and \( DN \) is the gray value of the image.

### Table 1: Comparison of mainstream remote sensing data source parameters.

| Parameter       | DMSP/OLS         | NPP/VIIRS        | Luojia 1-01    |
|-----------------|------------------|------------------|---------------|
| Sharing data time | 1992–2013        | Since 2011       | 2018–2019     |
| Country         | America          | America          | China         |
| Spatial resolution | 2.7 km          | 740 m            | 130 m         |
| Imaging amplitude | 3000 km         | 3000 km          | 250 km        |
| Spectral range  | 0.5–0.9 \( \mu \text{m} \) | 0.5–0.9 \( \mu \text{m} \) | 0.46–0.98 \( \mu \text{m} \) |
| Spectral resolution | 6 bits          | 14 bits          | 14 bits       |

3.2. Selection of Socioeconomic Indicators. To comprehensively measure the status quo of the social and economic development of the urban agglomerations in the Yangtze River Delta, this paper combines the previous research results on urban socioeconomic measurement and selects 26 indicators including per capita Gross Domestic Product (GDP) from four dimensions of the economic scale, economic structure, social benefits, and residents’ lives. The selection of indicators follows the principles of scientificity, rationality, pertinence, comprehensiveness, and availability. Among them, in terms of the economic scale, GDP per capita reflects the overall economic development of the
region; general public budget revenue per capita reflects the level of government financial resources; total retail sales of consumer goods per capita reflect the purchasing power of social goods; per capita investment in fixed assets refers to the construction and purchase fixed in currency. The workload of asset activities reflects a comprehensive indicator of the scale, speed, proportional relationship and uses the direction of fixed asset investment; the per capita deposit balance of financial institutions reflects the region’s ability to absorb funds. In terms of economic structure, the proportion of primary industry’s added value in GDP represents the natural resource endowment. The primary industry is agriculture. The lower the proportion, the better the economic structure, and vice versa. The tertiary industry’s added value in GDP is the third-largest proportion of GDP. The industry is a service industry. The higher the proportion, the better the economic structure, and vice versa; the proportion of general public budget revenue in GDP reflects the degree of government’s concentration of financial resources; the proportion of fixed asset investment in GDP reflects the degree of dependence on the government for economic development. Dependence refers to the proportion of total import and export in GDP, reflecting the degree of economic opening up. In terms of social benefits, population density reflects the degree of regional population density; the proportion of built-up area to administrative area reflects the level of regional urbanization; highway network density refers to the ratio of the total mileage of roads at all levels to the administrative area, reflecting the conditions of transportation infrastructure. The birth ratio reflects the educational conditions; the number of beds in health institutions per 1,000 people reflects the medical conditions; the number of patent applications granted per 10,000 people reflects the level of technological innovation; the per capita collection of public libraries reflects the level of cultural development. In terms of social benefits, the per capita disposable income of urban residents refers to the sum of the final consumption expenditures and other compulsory expenditures and savings that urban residents can obtain, that is, the income that urban residents can use for their free disposal; the per capita net income of rural residents refers to the average rural residents’ income level; Engel coefficient refers to the proportion of residents’ food expenditure to total personal consumption expenditure. It is an indicator of the equality of residents’ income distribution. The larger the Engel coefficient, the poorer the life, and vice versa. The number of cars per 10,000 people reflects the residents’ travel conditions; per capita housing area of urban residents reflects the living conditions of residents; per capita post and telecommunications services consumed per capita, reflecting the degree of residents’ foreign exchange; per capita electricity consumption indirectly reflects the status of residents’ possession of durable consumer goods. To ensure the scientificity and rationality of the index selection, the index evaluation system has been filtered through the coefficient of variation method to remove indicators with a coefficient of variation of less than 10% (weak variation) such as GDP growth rate, tertiary industry’s share of GDP, and Engel’s coefficient. The coefficient is a statistic used to measure the degree of dispersion between observations in a set of data. The calculation formula of the coefficient of variation of each index is as follows:

\[
V_i = \frac{S_i}{\overline{x}_i}
\]

where \(V_i\) is the coefficient of variation of the \(i\)-th index, \(\overline{x}_i\) is the average value of the \(i\)-th index, and \(S_i\) is the standard deviation of the \(i\)-th index, \(i = (1, 2, 3 \ldots n)\). In the standard deviation calculation, use \(n\) for data with more than 30 samples and \(n−1\) for data within 30 samples. When the coefficient of variation > 100% belongs to strong variation, 10% to 100% belongs to medium variation, and <10% belongs to weak variation.

### 3.3. Determination of Indicator Weights

#### 3.3.1. Dimensionless Indicators

To eliminate the dimensional difference between the indicators, the indicators need to be dimensionless first, and the calculation formula is as follows:

\[
x_i = \frac{x_i - x_{i\text{min}}}{x_{i\text{max}} - x_{i\text{min}}}, \quad (x_i \text{ Indicator attribute is positive}),
\]

\[
x'_i = \frac{x_{i\text{max}} - x_i}{x_{i\text{max}} - x_{i\text{min}}}, \quad (x_i \text{ Indicator attribute is negative}),
\]

where \(x_i\) is the \(i\)-th index, \(x_{i\text{max}}\) is the maximum value of index \(i\), and \(x_{i\text{min}}\) is the minimum value of index \(i\).

#### 3.3.2. Index Weight Determination

This paper adopts the subjective and objective comprehensive weighting evaluation method that combines the analytic hierarchy process (AHP) and entropy method, that is, using entropy to modify AHP to determine the weight of each indicator in the indicator system and calculate the social economy of districts and counties in Jiangsu Province. Socioeconomic Index (SEI) and entropy correction AHP calculation steps are detailed in formulas (4)

### Table 2: Research index and its data products.

| Index                  | Product | Time resolution | Spatial resolution | Level |
|------------------------|---------|-----------------|--------------------|-------|
| NDVI                   | MOD13A2 | 16              | 1000               | L3    |
| LAI                    | MOD15A2H| 8               | 500                | L4    |
| GPP                    | MOD17A2H| 8               | 500                | L4    |
| Surface temperature    | MOD11A2 | 8               | 1000               | L3    |
| Humidity/dryness       | MOD09A1 | 8               | 500                | L3    |
to (7), and we finally get the evaluation system of social and economic development index of the Yangtze River Delta urban agglomeration counties.

(1) Calculate the AHP indicator weight: construct AHP judgment matrix $A$.

$$A = (a_{ij})_{n \times n}$$  \hfill (4)

where $a_{ij}$ represents the relative importance scale of index $i$ and index $j$. The $1–9$ scale method is commonly used. Scale 1 means that the two indexes are equally important, scale 2–5 means that the importance of index $i$ relative to index $j$ is gradually increasing, and scale 6–9 means that the importance of index $i$ is gradually increasing relative to index $j$; $a_{ij} > 0$, $a_{ij} = (1/a_{ji})$, and when $i = j$, $a_{ij} = 1$.

Normalize judgment matrix $A$, and get the normalized judgment matrix $S_{ij}$:

$$S_{ij} = \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}}$$  \hfill (5)

Add the normalized judgment matrix $S_{ij}$ by row to get the vector $\omega_{i}$:

$$\omega_{i} = \sum_{j=1}^{n} S_{ij}.$$  \hfill (6)

Normalize the $\omega_{i}$ vector to obtain the AHP weight value $b_{i}$ of each indicator:

$$b_{i} = \frac{\omega_{i}}{\sum_{i=1}^{n} \omega_{i}}.$$  \hfill (7)

3.4. Remote Sensing Economic Measurement Model

3.4.1. Night Light Index. The theoretical basis of this chapter is based on the fact that luminous images can directly reflect the regional socioeconomic development status, and the corresponding socioeconomic measurement model is established by mining the correlation between the socioeconomic index and the night light index to measure the socioeconomic development status of the study area. Since all the indicators involved in the construction of the socioeconomic index are per capita, the SEI value obtained represents the average level of regional socioeconomic development. Therefore, it is necessary to improve the estimation accuracy of the socioeconomic development level of the study area. The construction of the night light index is the same to represent the meaning of “average.” Based on the LJ1-01 image DN value and image radiance value, this paper constructs the night light index per unit land area (ANLI), the night light index per unit of construction land (CANLI), and the night light index per population (PANLI) to represent the average level of the area. The intensity index is calculated as follows:

$$NLI_{\text{avg}} = \frac{NLI_{\text{total}}}{S},$$  \hfill (8)

where $NLI_{\text{avg}}$ represents the average light intensity of the area, $NLI_{\text{total}}$ represents the total light intensity of the area, and $S$ represents the total area of the regional land/area of construction land/total population.

3.4.2. Construction of Remote Sensing Economic Measurement Model. Due to the strong correlation between the SEI value and the night light index, to further describe the correlation quantitatively and construct the corresponding socioeconomic measurement model, this paper is based on the linear regression model theory and uses the SEI value of typical districts and counties to be compared with the unit land area. Luminous DN value, luminous DN value per unit land area, luminous DN value per unit of construction land area, luminous DN value per unit of construction land area, luminous DN value per population, and luminous radiation value per population are used to fit the first-order linear model and the second-order linear model. And the accuracy of the fitting model is evaluated by the model determination coefficient $R^2$, root mean square error (RMSE), and significance $F$ test to select the optimal model. Among them, $R^2$ indicates that the model can explain the total variation ratio of the response variable; RMSE is used to measure the deviation between the predicted value and the true value; $F$ value is the variance test quantity, which is the overall test of the model. The calculation formula for each accuracy evaluation index of the model is

$$R^2 = 1 - \frac{\text{SSE}}{\text{SST}} = 1 - \frac{\sum_{i=1}^{n} (y_i - \bar{y})^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2},$$

$$\text{RMSE} = \sqrt{\frac{\text{SSE}}{n-r-1}} = \sqrt{\frac{\sum_{i=1}^{n} (y_i - \bar{y})^2}{n-r-1}},$$

where $\text{SSE}$ is the residual sum of squares (the sum of squares of the difference between the predicted value and the measured value); $\text{SST}$ is the sum of squares of the total deviation (the sum of squares of the difference between the measured value and the measured mean); $\text{SSR}$ is the regression sum of squares (the predicted value of the sum of squares of the difference between the measured value and the predicted value); $y_i$ is the measured value; $\bar{y}$ is the average of the measured value; $\bar{y}$ is the predicted value; $n$ is the number of typical counties entered, $n = 36$; $r$ is the degree of freedom.

4. Experiments and Discussions

4.1. Linear Regression Model of Night Light Index and SEI Value. The fitting results of linear regression models for the 6 kinds of night lighting indices and SEI values are shown in Figures 2 to 4. All models have a good determination coefficient $R^2$ and have passed the 1‰ extremely significant test ($P < 0.001$). After comparison, it is found that (1) SEI has the highest correlation with ANLI, followed by PANLI, and has the lowest correlation with CANLI. (2) The fitting effect of the second-order linear equation is significantly better
The fitting effect based on the luminous radiance value is slightly better than that of the first-order linear equation. (3) The fitting effect based on the luminous radiance value is slightly better than the fitting effect based on the luminous DN value. In the SEI and ANLI linear regression models, the fitting effect of the second-order model based on the DN value and the second-order model based on the radiance value is relatively best.

To further verify the advantages of ANLI in measuring social and economic development, a linear regression model between ANLI in typical districts and counties, electricity consumption per capita, and Gross Domestic Product (GDP) per capita was established. From the linear regression results in Figures 5 and 6, we can see that the linear regression $R^2$ between ANLI and per capita electricity consumption and per capita GDP is 0.42 and 0.67, respectively, which are significantly lower than the linear regression $R^2$ between ANLI and SEI. To sum up, compared with the single per capita GDP and per capita electricity consumption indicators to measure the level of regional social and economic development, ANLI extracted based on LJ1-01 can measure the level of regional social and economic development more comprehensively and reliably.

4.2. Validation of Remote Sensing Economic Model in the Study Area. The verification results of the remote sensing economic model in the study area are shown in Table 3. After the 10-fold cross-validation of all models, the decrease in $R^2$ is small, indicating that the constructed model has high robustness. After comparing the degree of $R^2$ change, it is found that the second-order model $R^2$ of SEI and ANLI gray values and SEI and ANLI radiance values has the smallest change, reduced by 0.025 and 0.013, respectively, combined with model $R^2$ and RMSE accuracy evaluation results and model 10-fold cross validation. As a result, the second-order models of SEI and ANLI gray values and SEI and ANLI radiance values have higher estimation accuracy than other models for measuring the socioeconomic development of
the study area. The sample area of the remote sensing economic measurement model constructed in this paper is Jiangsu Province. From the perspective of brightness and density of luminous images, its socioeconomic development should theoretically be more prosperous in most of Anhui Province and the southwestern part of Zhejiang Province. Considering that the second-order equations of SEI and ANLI gray values estimate the lowest SEI value of 0.021, the second-order equations of SEI and ANLI radiance values estimate the lowest SEI value of 0.102, so the former model is more effective than the latter for estimating SEI. Low-value districts and counties (SEI < 0.102) have obvious advantages.

To sum up, this paper chooses the second-order linear regression model of SEI and ANLI gray values as the measurement model of the social and economic development level of the Yangtze River Delta urban agglomeration counties.

4.3. Research on Ecological Environment Based on Urban RSEI Theory. In 2013, based on remote sensing technology, Professor Xu proposed a remote sensing ecological index (RSEI) based entirely on remote sensing technology and mainly based on natural factors to quickly monitor and evaluate the ecological status of the city. RSEI uses principal component analysis technology to integrate the vegetation index, surface dryness, humidity component of tasseled cap transformation retrieved from Landsat data, and surface dryness represented by the building and bare soil index, which represent the vegetation ecological environment. The four major ecological elements, such as greenness, humidity, heat, and dryness, were later expanded into six indicators. The six normalized indicators were aggregated and based on the principal component transformation calculation process, the covariance matrix and variance contribution rate were calculated. Table 4 shows the results of the principal component transformation of the six indicators. Usually, the principal components are selected with the cumulative contribution rate reaching 75% as the threshold. It can be seen from the table that the eigenvalue contribution rate corresponding to the eigenvalue of the first principal component is greater than 75%, indicating that PC1 has concentrated most of the features of the 6 indicators, and the six indicators have a certain degree of contribution to PC1. In PC1, the FVC, GPP, and LAI indicators representing greenness and the wet indicator representing humidity are positive, indicating that these factors make a positive contribution to the ecosystem and represent the LST indicator of heat and the NDBSI indicator of dryness which are negative, indicating that they hurt the ecosystem, and the result is consistent with the actual situation. Among the characteristic components of PC2~PC6, these indicators fluctuate positively and negatively, which is difficult to explain. Therefore, compared with the characteristic components of PC2~PC6, PC1 can integrate 6 index information well. In this paper, PC1 is selected as the main component of the comprehensive quality evaluation of the ecological environment of the study area. To make the larger the RSEI value obtained by PC1, the better the ecological environment quality is, the reverse processing of PC1 is performed to obtain the initial remote sensing ecological index $RSEI_{0}$. At the same time, to facilitate the measurement and comparison with the SEI value below, $RSEI_{0}$ is further standardized. Its calculation formula is as follows:

$$RSEI_{0} = 1 - \left[ PC1 \left( FVC, LAI, GPP, Wet, LST, NDBSI \right) \right],$$

$$RSEI = \frac{(RSEI_{0} - RSEI_{0\min})}{(RSEI_{0\max} - RSEI_{0\min})} \tag{10}$$

where $RSEI$ is the standardized remote sensing ecological index, $RSEI_{0}$ is the initial remote sensing ecological index, $RSEI_{0\max}$ is the maximum value of the initial remote sensing ecological index, and $RSEI_{0\min}$ is the minimum value of the initial remote sensing ecological index.

Through the above comparison, it is found that the linear regression model $R^2$ constructed in this paper is significantly better than the previous research results. On the one hand, because the luminous remote sensing image reflects the
comprehensive development of the region, GDP is the only part of the development. The index is more comprehensive and to a certain extent can better reflect the real development level of the study area. On the other hand, because LJ1-01 data has higher spatial resolution and richer spatial details than DMSP/OLS data and NPP/VIIRS data, its applications to county-level
The results of the remote sensing economic measurement model of the study area and counties constructed by the Luojia 1-01 night light index and the socioeconomic index show that the correlation between the light index per unit land area and the socioeconomic index is the highest. The determination coefficient \( R^2 \) of the second-order linear regression model is as high as 0.92, \( RMSE \) is 0.05, and \( R^2 \) of the model after cross-validation is 0.91, which means that the model has high reliability. The recognition result of the remote sensing economic measurement model is 80.5% consistent with that of the top 100 counties in the study area recognized by the government. Therefore, the Luojia 1-01 data has a good estimation performance for the socioeconomic measurement. Luojia 1-01 data, as a new generation of high-resolution open-source luminous remote sensing data source, has higher spatial resolution and richer spatial details than mainstream DMSP/OLS data and NPP/VIIRS data and is applied to counties or even smaller scales. The socioeconomic measurement research can achieve more accurate identification results.

(2) Based on the urban RSEI theory and the 6 ecological indicators retrieved from MODIS data to evaluate the ecological environment quality of the study area, the research results show that vegetation coverage, leaf area index, total primary productivity, and surface humidity are positive for the study area’s ecosystem. The land surface temperature and surface dryness harm the ecosystem; the vegetation ecological environment quality of the Yangtze River Delta urban agglomeration has two levels of differentiation; and the overall spatial distribution pattern is better in the southwest and poor in the northeast. Among them, the area of fragile vegetation ecological environment accounts for 22.7%, and the area of high-quality vegetation ecological environment accounts for 32.3%, indicating that the overall vegetation ecological environment quality of the study area is inclined to a better direction. The ecological environment quality of vegetation in the study area is mainly affected by natural factors such as terrain and altitude, as well as human activities.

### Data Availability

The datasets used are available from the corresponding author upon reasonable request.

### Conflicts of Interest

The authors declare that they have no conflicts of interest.
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