Evaluation of Ecological Environmental Quality Based on Multi-temporal Remote Sensing Data

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***Abstract*—The quality of ecological environment is closely related to human life and the method of the evaluating the ecological environmental quality is the main factors for the accuracy of the models. We proposed a novel Ecological Environmental Quality Evaluation (EEQE) model which is constructed by combining the Decision Making Trial and Evaluation Laboratory (DEMATEL) and the Principal Component Analysis method (PCA) etc. The natural factors, meteorological factors, topographical factors and anthropogenic activities factors are also considered in the EEQE model which can be utilized to effectively assess the quality of the ecological environment. The results showed that the ecological environmental quality of five cities with good level and excellent level is most about 80%. Besides, we also analyzed the correlations between ecological environmental quality and the impact factors. The results indicate that the dominant factors of the ecological environment quality in Huai'an, Lianyungang, Suqian, Xuzhou and Yancheng are precipitation, land surface temperature, net primary productivity, wetness and slope respectively.**

Keywords—ecological environmental quality evaluation, DEMATEL, PCA, multi-temporal remote sensing, impact factors

I. Introduction

The rapid development of urbanization and anthropogenic activities have brought significant influence on the ecological environment, such as global climate change, land degradation, resource shortage, environmental pollution and ecological environment deterioration[1, 2]. It is vital important to construct a thorough research on ecological environmental quality evaluation for solving the ecological environment quality problems.

In 1980s, China's ecological environment quality evaluation was developed. With the development of research work, the evaluation of ecological environment quality has gradually become institutionalized and standardized. It has made a lot of achievements based on the remote sensing technology to evaluate the quality of regional ecological environment. Wang et al proposed an eco-environmental quality index (EQI) model to evaluate China's ecological environment quality[3]. Wang used pressure-state-response (PSR) model and analytic hierarchy process (AHP) to construct an ecological vulnerability evaluation index system[4]. He combined analytic hierarchy process and Geographic Information System (GIS) to evaluate Longkou’s geological and ecological environment[5]. Chai utilized dynamic co-word network and the statistical data to build the ecological environmental quality model[6].

However, most research has only focused on natural factors, meteorological factors and topographical factors, without consideration on anthropogenic activities factors. Besides, some studies only uses the statistical data for modeling, which is lacking of spatial analysis. And the evaluation method is relatively simple and deficiency.

Hence, this paper addresses the following specific objectives: 1) a novel evaluation model is constructed by using the remote sensing data, meteorological data, topographical data and GIS technology, which includes natural factors and anthropogenic activities factors; 2) PCA-DEMATEL-LS method is proposed to determine the weight of the indicators in the model; 3) analyze spatio-temporal changes of the study areas; 4)identify the major factors that have driven the ecological environmental quality changes in the five cities.

II. Data and Method

A. Study Region

The Huaihai Economic Zone (32.39 °-36.54 °N,113.85 °-121.01 °E), with an area of 178,000 km^2, has warm temperate continental monsoon climate. The Huaihai Economic Zone is composed of Shandong Province, Jiangsu Province, Henan Province and Anhui Province. Due to the wide coverage of the Huaihai Economic Zone, five prefecture-level cities in Jiangsu Province (including Xuzhou, Suqian, Huai'an, Yancheng, Lianyungang) are selected as the main research area in this paper, which was showed in Fig. 1.

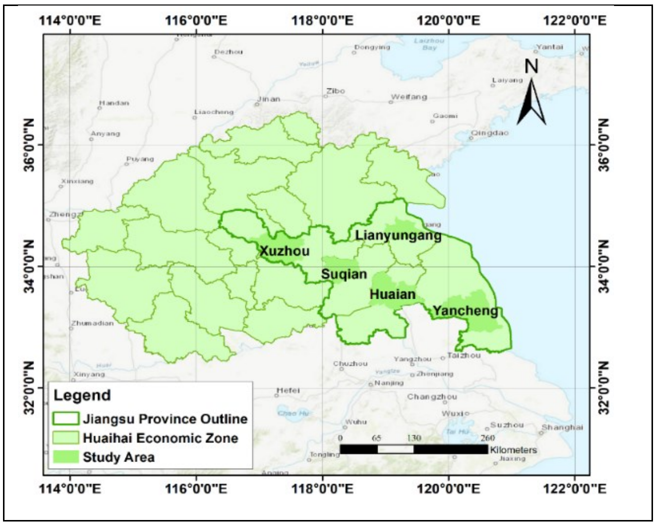

Fig. 1. The study area in Huaihai Economic Zone

B. Datasets

Orthorectified standard level 1 Terrain-corrected (L1T) Landsat images between 2000 and 2015, which have been archived in the Google Earth Engine(GEE) platform as the

This research is supported in part by Shan’xi Key Research and Development Program (2018ZDXM-GY-023), National Natural Science Foundation of China (No. 41871337, 41471356), Priority Academic Program Development of Jiangsu Higher Education Institutions.

image collection of United States Geological Survey (USGS) Landsat 5/8 Top of Atmosphere (TOA) Reflectance, were utilized in this paper. All the Landsat data was processed by cloud computing technology in the GEE platform.

Other dataset includes: (1) the meteorological data is provided by the National Meteorological Information Center; (2) the vector layers are downloaded from the Omap software, using the WGS84 geographic coordinate system; (3) the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) is derived from the National Aeronautics and Space Administration (NASA) at a spatial resolution of 30m.

C. Research Methods

The ecological environmental quality are affected by many indicators. In this paper, remote sensing data, meteorological data and topographic data are mainly data sources, and these data are easy to collect and update. All the indicators in this paper can be directly obtained by using Landsat data, DEM data and meteorological data. Additionally, both human and natural factors which have the scientific foundation are selected (Table I). We proposed the PCA-DEMATEL-LS method to determine the weight of the indicators. The least square (LS) method is to optimize the combination weight, as shown in (1)(2)[7]:

$$minH(W) = \sum_{i=1}^{7}\{[(u_i - W_i)z_{1i}]^2 + [(v_i - W_i)z_{1i}]^2\} \quad (1)$$

$$st\sum_{i=1}^{7} W_i = 1(W_i > 0, \ i = 1,2 \ldots, \ 7) \quad (2)$$

Where u_i is the ith subjective weight, v_i is the ith objective weight and W_i is the ith combination weight. The $minH(W)$ represents the least square model.

The ecological environmental quality evaluation (EEQE) model was structured in (3):

$$EEQE = \sum_{i=1}^{7} W_i * P_i \quad (3)$$

Where the $EEQE$ model is the ecological environmental quality evaluation model, W_i is the ith combination weight and P_i is the ith indicator.

TABLE I. ECOLOGICAL ENVIRONMENTAL QUALITY EVALUATION MODEL

Target Layer	Criteria Layer	Indicator Layer
Eco-environmental Quality Evaluation Model	Natural factors	Vegetation coverage
		Net Primary Productivity
		Wetness
	Meteorological factors	Land surface temperature
		Precipitation
	Topographical factors	Slope
	Anthropogenic activities factors	Impervious surface

III. RESULT AND ANALYSIS

A. Spatial and Temporal Patterns of Ecological Environmental Quality

To analyze the ecological environmental quality patterns, the results were divided into five classes: worst (0-0.2), poor (0.2-0.4), moderate (0.4-0.6), good (0.6-0.8) and excellent (0.8-1.0). Analyzing the ecological environmental quality, most of study areas are at good level and excellent level (Fig. 2). From 2000-2015, the ecological environmental quality of five cities with good level and excellent level is almost about 80% (Fig. 3). The percentage of worst level and poor level are quite low, with a maximum of 13.62%, and these areas are mainly concentrated in waters and human settlements.

B. Impacts Factors Analysis

To analyze the correlations between ecological environmental quality and the impact factors (NDVI, NPP, Wetness, LST, IS, PRE, Slope), the Gray Relational Analysis (GRA) method was utilized. Table II shows that the main driving factors affecting the ecological environment quality of Huai'an, Lianyungang, Suqian, Xuzhou and Yancheng are PRE, LST, NPP, Wetness and Slope respectively. Due to the monsoon climate and the abundant precipitation, which effectively promote the material circulation and energy conversion of ecological environment, it shows the greatest impact on ecological environmental quality in Huai'an City. During the period of 2000-2015, the built-up area in Lianyungang City has expanded from 87 km^2 to 289 km^2. With the rapid development of urbanization, the urban climate regulation is destroyed and the urban heat island effect has sharply increased, so that the surface temperature makes the main contribution to the ecological environmental quality of the Lianyungang City. Compared with other cities, the correlation between several influencing factors and the quality of ecological environment is similarity in Suqian City. Wetness has a strong influence on surface energy balance and plays an important role in the exchange of surface and atmosphere, which has an extremely impact on agricultural production. Xuzhou has a large area of crop cultivation, and the wetness promotes the ecological environment quality in this region. The Yancheng City is a plain landform with flat terrain and smaller change in slope, which effectively promotes the development of biodiversity in the region and thus has high relevance with the ecological environment quality of the region. The correlation between all the impact factors and the quality of the ecological environment is higher than 0.5.

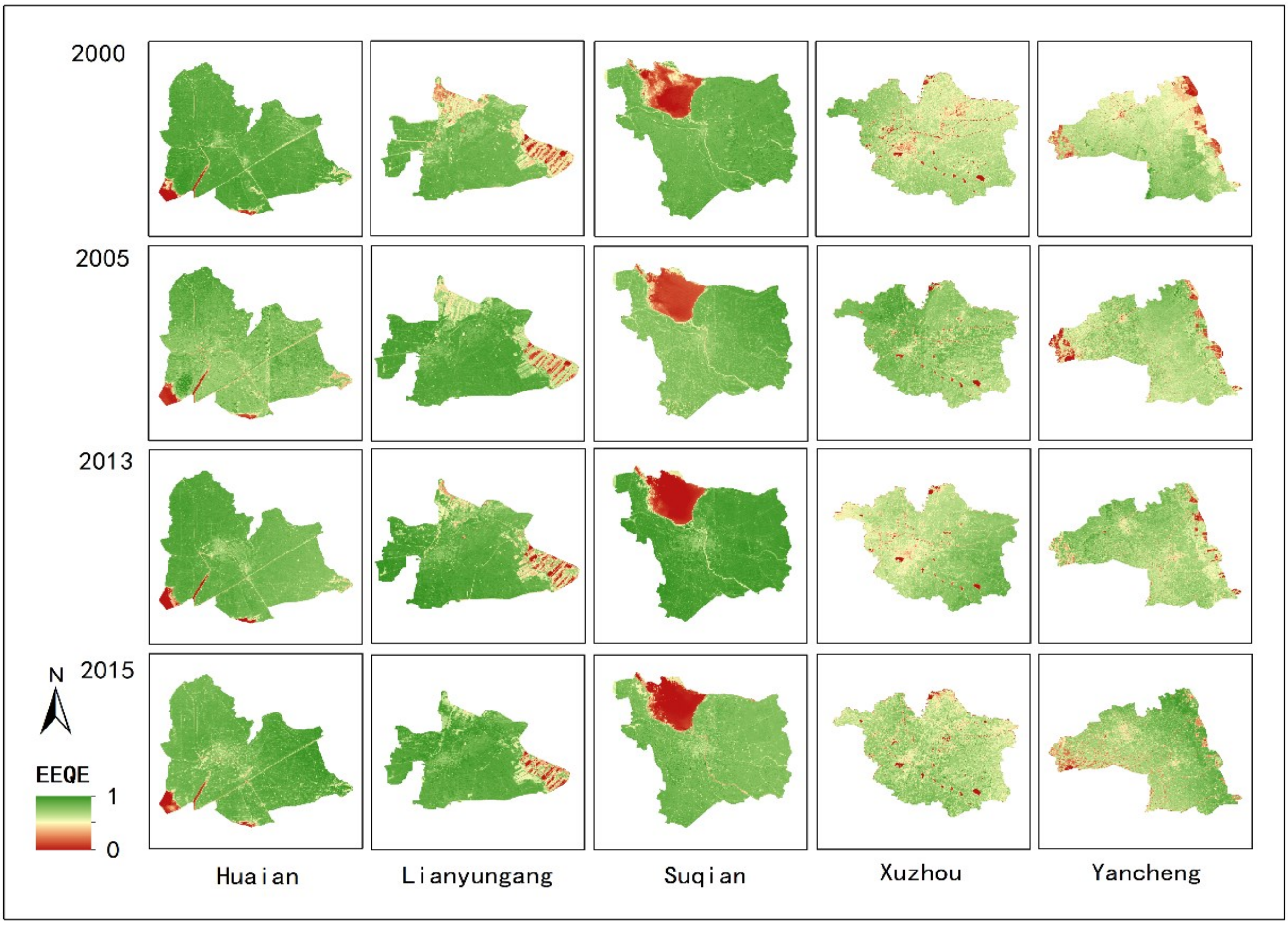

Fig. 2. Model result of five prefecture-level cities study area in Jiangsu Province from 2000-2015

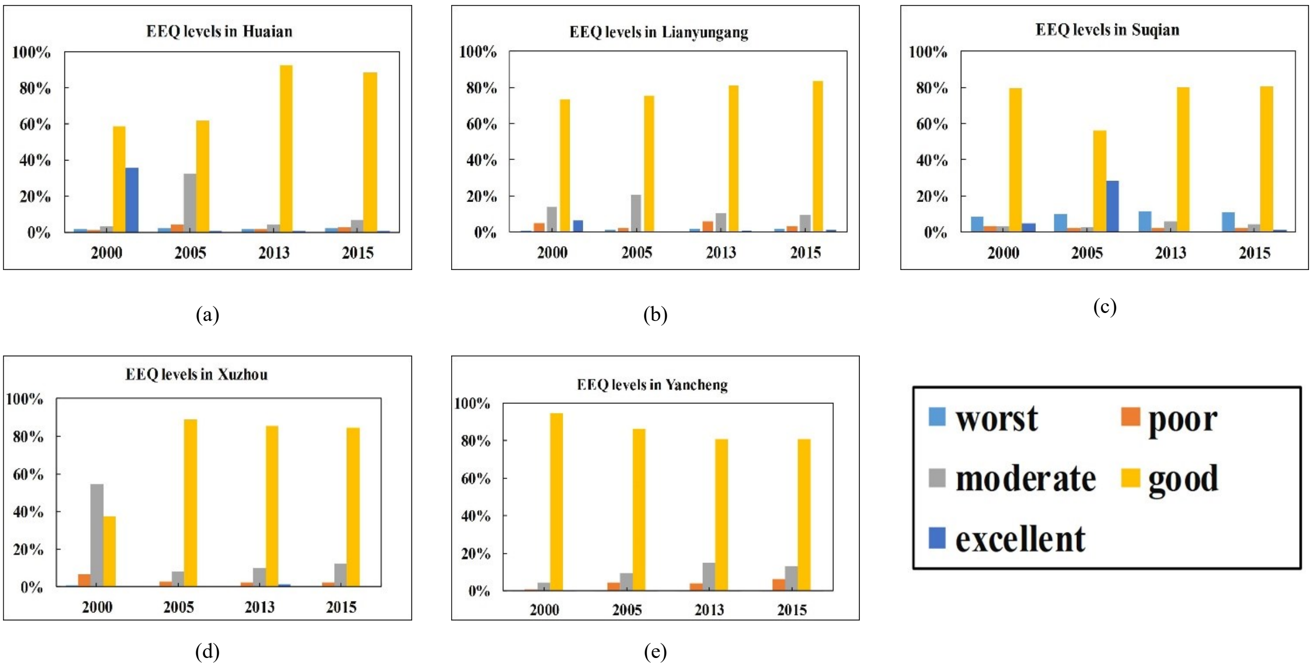

Fig. 3. Ecological environmental quality levels of five prefecture-level cities from 2000-2015 in Jiangsu Province.(a) Huaian City, (b) Lianyungang City, (c) Suqian City, (d) Xuzhou City, (e) Yancheng City.

TABLE II. THE CORRELATION BETWEEN ECOLOGICAL ENVIRONMENTAL QUALITY AND THE IMPACT FACTORS

	NDVI	NPP	Wetness	LST	IS	PRE	Slope
Huaian	0.718119	0.765879	0.595418	0.781667	0.685581	**0.940385**	0.773944
Lianyungang	0.716670	0.780888	0.591357	**0.801295**	0.700377	0.639304	0.794015
Suqian	0.749914	**0.764351**	0.619348	0.752695	0.624154	0.661294	0.754802
Xuzhou	0.653182	0.608893	**0.885560**	0.746380	0.536958	0.577659	0.752398
Yancheng	0.644707	0.791224	0.675705	0.928510	0.575390	0.813387	**0.931553**

IV. CONCLUSION

In this study, PCA-DEMATEL-LS method is proposed to obtain the combination weight and construct the ecological environmental quality evaluation (EEQE) model, which can estimate the ecological environmental quality in five prefecture-level cities located in Jiangsu Province from 2000-2015. The EEQE model consists of natural factors, meteorological factors, topographical factors and anthropogenic activities factors etc. The ecological environmental quality of five cities most is good level and excellent level by analyzing the spatial and temporal patterns of ecological environmental quality. Through quantificational evaluating, the relationship between impact factors and ecological environment quality by grey correlation analysis performs different responses in different areas, which means that the main factors are different in this study area.

ACKNOWLEDGMENT

This research is supported in part by Shan'xi Key Research and Development Program (2018ZDXM-GY-023), National Natural Science Foundation of China (No. 41871337, 41471356), Priority Academic Program Development of Jiangsu Higher Education Institutions.

REFERENCES

[1] LIN Y, CHEN J, JIN Z, et al. Impacts of human activities on coastal ecological environment during the rapid urbanization process in Shenzhen, China [J]. Ocean & coastal management, 2018, 154: 121-132.

[2] XU G, LIU Q, CHEN L, et al. Remote sensing for China's sustainable development: opportunities and challenges [J]. Journal of Remote Sensing, 2016, 20(5): 679-688.

[3] SHI-XIN W, YAO Y, YI Z. Analysis of ecological quality of the environment and influencing factors in China during 2005-2010 [J]. International journal of environmental research and public health, 2014, 11(2): 1673-93.

[4] YONG W, QIAN D, ZHUANG D. An eco-city evaluation method based on spatial analysis technology: A case study of Jiangsu Province, China [J]. Ecological Indicators, 2015, 58(58): 37-46.

[5] HE F, GU L, TAO W, et al. The synthetic geo-ecological environmental evaluation of a coastal coal-mining city using spatiotemporal big data: A case study in Longkou, China [J]. Journal of Cleaner Production, 2017, 142: 854-866.

[6] CHAI L H, LHA D. A new approach of deriving indicators and comprehensive measure for ecological environmental quality assessment [J]. Ecological indicators, 2018, 85: 716-728.

[7] WEI C, HAO X. An Optimal Combination Weights Method Considering Both Subjective and Objective Weight Information in Power Quality Evaluation [J]. Advanced Electrical and Electronics Engineering, 2011, 2: 97.