Pol. J. Environ. Stud. Vol. 32, No. 1 (2023), 387-397
DOI: 10.15244/pjoes/152830 ONLINE PUBLICATION DATE: 2022-11-03

Original Research

Study on Comprehensive Assessment of Air Quality of Energy Consumption in Industrial Parks: Take Nanjing HX Industrial Park in China as an Example

Lingjuan Xu[1]*, Yijiang Liu[2], Xiaoyu Zhang[1]

[1]College of Economics and Management, Nanjing University of Aeronautics and Astronautics, Nanjing 211106, China
[2]Lille College, Hohai University, Nanjing 213022, China

Received: 24 June 2022
Accepted: 17 August 2022

Abstract

In order to explore the comprehensive assessment method of air quality of pollutant emission of energy consumption in China's urban internal industrial parks, based on the full consideration of the actual situation of air pollution control in Nanjing HX Industry Park, this paper selects 15 air quality assessment indicators. According to the national air quality standard, the air quality standard of Nanjing and the air quality standard of Nanjing HX Industry Park, the air quality assessment standard is determined about pollutant emission of energy consumption in Nanjing HX Industry Park. Through the technical treatment of the selected assessment indicators, the niche suitability model is introduced, and based on this, the spatial niche suitability model is reconstructed to comprehensively assess the air quality of pollutant emission of energy consumption in Nanjing HX Industry Park. The study found that the air quality of Nanjing HX Industry Park has been improved from level III in 2012 to level I in 2020. According to the assessment results, the differences of assessment results of different niche suitability models are discussed, which fully reflects the advantages of spatial niche assessment methods. The change law and influencing factors of the assessment results are further discussed.

Keywords: air quality assessment, spatial niche assessment model, energy consumption, pollutant discharge, air pollution treatment

Introduction

The low carbonization process of China's economy and society under the goals of carbon peaking and carbon neutrality depends on the efficiency of energy utilization and the level of control of major pollutant emissions. With the rapid development of Chinese economy, industrial parks have gradually become the main force promoting China's economic growth and a demonstration area for environmental protection [1, 2]. Since China's industrial parks are concentrated areas of energy consumption, the Chinese government

*e-mail: nuaaxulj@163.com

formulated the “Air Quality Standard (GB3095-1996)” as early as the 1990s. After several revisions, the “Air Quality Standard (GB3095-2012)” is now implemented. The exhaust emissions generated by energy consumption contains a large amount of toxic and harmful substances [3]. Although these undesired outputs have been scientifically treated through the treatment of exhaust emissions, the air quality of the industrial park cannot reach the state of an ecological area without exhaust emissions due to various reasons [4]. In order to strengthen the effective treatment of the impact of exhaust emissions of energy consumption on the air quality of industrial parks, industrial parks have generally implemented quality treatment monitoring and assessment systems [5]. In the process of air quality treatment in industrial parks, due to the complexity of environmental conditions and the diversity of influencing factors, the air quality in industrial parks has not reached the ideal state [6, 7]. During the investigation in the Nanjing HX Industrial Park (HX is the trade name), we found that behind the ecological environment of the park, there is still slight or mild atmospheric environmental pollution. What’s more, partial or short-term pollution will also be moderate or severe, which poses a significant threat to the flora, fauna and related people in the park. Many reasons account for this phenomenon. The comprehensive analysis found that the main reasons are reasonable use of test data, singular selection of assessment indicators, qualitative assessment methods, simplification of assessment models, static assessment process, and other issues. Therefore, under this circumstance, it is essential and urgent to study the comprehensive assessment models and their applications of air quality for environmental pollution treatment of exhaust emissions of energy consumption in industrial parks.

Air quality assessment studies were first developed in western developed countries. In the early 1930s, the North Pacific winter air quality conditions were analyzed, with a focus on the convergence phenomena of the unbalanced weather system and atmospheric instability due to rising ground temperatures [7]. In the early 1980s, American scholars studied the method and application of air quality assessment when American industrial waste was placed on the land for waste disposal [8]. The research on air quality assessment in China began in the mid-1980s; Chinese scholar Lu et al. first studied the air quality pollution caused by open-pit mining in Chinese metal mines and studied methods and applications of air quality indicator and hygienic indicator analysis [9]. China accelerated economic development after the 1990s, air quality problems were gradually raised, and the achievements of air quality assessment research were becoming more and more important [10]. However, most of the early studies on air quality assessment in China used international theories and methods for references, and there was no in-depth research. In the 21st century, air quality assessment has gradually become a significant issue of global importance [11].

For a long time, academic research on air quality assessment has focused on assessment model research. International scholars have paid more attention to technical methods and pollution indicators. The technical staff of the Australian Meteorological Agency has constructed a photochemical model of air quality assessment in the process of studying atmospheric environmental quality, which has achieved effective assessment results in urban air quality assessment [12]. The staff of Kruger Life Science Company in Germany adopted the method of pollution index detection in the process of assessing the air quality of the aircraft cockpit, using chemical and particulate matter indicators to assess the air quality of the cockpit [13]. Chinese scholars attach importance to qualitative assessment methods and mathematical assessment methods in air quality assessment research [14, 15]. As the international community pays more and more attention to air quality issues, the research on air quality assessment has gradually shifted to the direction of specialization and multi-method comprehensive assessment [16]. Korean scholars use various methods such as chemical index analysis, pollution index analysis, and comparative analysis to study children’s health care and indoor air quality assessment of medical facilities, and explore the impact of indoor air quality on children’s health [17]. Scholars comprehensively used a combination of pollution index method, analytic hierarchy process, and fuzzy mathematics to study the comprehensive assessment of air quality in India, and combined environmental data in Indian to conduct an application study [18]; Italian scholars used indicator analysis, environmental pollution index and IAM and other methods to study regional air quality assessment issues and constructed a decision-making framework for local-scale air quality assessment [19]; German scholars use indicator analysis, pollution index and logistic regression models to study the air pollution caused by German urban traffic. The exploration of the results of comprehensive air quality assessment is an effective measure for traffic-reduction [20]; American scholars use a combination of normative and empirical research to explore the relationship between economic development and air quality in the process of American economic development, especially the impact of deforestation, pollution discharge and carbon emissions on environmental quality. China’s research on air quality started relatively late. China started relatively late in air quality, but its development speed is very fast. The research ideas and methods are also very different from those of developed countries. Domestic research on quality control assessment pays attention to the impact of energy consumption and pollutant discharge on air quality and attaches importance to the selection of assessment method [21]. Bo et al. used the method of combining normative research and empirical research to study the impact of thermal power enterprises’ emissions of energy consumption on regional air pollution in Beijing-Tianjin-Hebei region of China [22]; Tan et al. used fuzzy matter-element analysis to study the air quality assessment in the industrial park area, conducted a preliminary exploration for the air quality assessment of the general industrial parks in China [23]; Yan et al. used the combination of Logit model and pollution indicators to study the public preference and policy assessment issues of air pollution treatment in Xi'an, China, and explored effective methods to improve the air quality of large cities in China [6]; Song et al. studied the assessment method of the air pollution treatment effect of the Chinese government, and explored the effective ways for China to build a "low-carbon city"[24]; Li et al. studied the impact of urban industrial agglomeration on haze pollution and conducted regression test using empirical research methods [25].

The above literature review shows that air quality assessment is an important research subject and has formed an international research environment. However, there is no effective method in the research of this subject so far. In the existing research results, experts and scholars have expressed their opinions, but there is no evaluation method that has been agreed. This subject's research direction is moving towards the complexity of the assessment content and the combination of multiple assessment methods. Summarizing the existing research results, the deficiencies of the research in this topic are mainly manifested in the poor rationality of the selection of assessment indicators, the insufficient applicability of the assessment methods, and the need to improve the authenticity of the application data. Therefore, this paper chooses to take Nanjing HX Industrial Park as an example, fully considers that the study area has obvious characteristics of heavy metal air pollution, and learns from the latest research results at home and abroad. In addition, this paper uses real research data, selects to build a spatial niche suitability model to study the comprehensive assessment method and its application of quality treatment of Nanjing HX Industrial Park energy consumption's pollution treatment to promote the rapid development of China's eco-industrial park construction.

Materials and Methods

Study Area and Data Source

Located in Jiangbei new area, Nanjing, Jiangsu Province, Nanjing HX Industrial Park is a National HX Industrial Park and the second key petrochemical base in China after Shanghai and the planned area of the park is 100 square kilometers. A total of 300 billion yuan has been invested in the industrial zone of the park, and more than 150 enterprises have been completed and put into operation. There is a specific agency in industrial park which is responsible for regularly testing the air quality and submitting it to the relevant government departments. According to the requirements of China air quality standard (GB3095-2012), 15 assessment indicators are selected to assess the air quality of Nanjing HX Industrial Park, the basic data of the assessment indicators are from the air

Table 1. Basic Data of Air Quality Indicators of Nanjing HX Industrial Park.

Indicators	2012	2013	2014	2015	2016	2017	2018	2019	2020
SO_2 (μg/m^3)	30.95	30.35	26.27	22.27	20.54	19.67	19.06	18.89	17.86
NO_2 (μg/m^3)	61.06	60.54	56.58	50.47	48.32	43.68	41.49	40.68	39.76
CO (μg/m^3)	6.17	6.05	5.94	5.72	5.32	4.89	4.18	3.98	3.86
O_3 (μg/m^3)	162.05	161.45	155.48	148.89	142.56	137.47	120.47	110.27	106.38
PM_{10} (μg/m^3)	71.89	71.36	66.72	60.89	60.38	56.28	51.49	46.28	41.38
$PM_{2.5}$ (μg/m^3)	37.03	36.84	31.46	26.42	21.36	18.68	16.86	16.32	15.86
TSP (μg/m^3)	201.27	200.35	185.38	171.28	165.27	156.28	126.27	95.37	82.26
NO_X (μg/m^3)	62.87	62.37	59.58	58.28	57.32	56.83	53.28	50.32	49.25
P_b (μg/m^3)	1.1636	1.1126	1.0831	0.9628	0.8528	0.7429	0.6528	0.5965	0.5532
BaP (μg/m^3)	3.1027	3.0261	2.8527	2.5237	2.1827	1.8027	1.6428	1.3427	0.9627
C_d (μg/m^3)	0.0185	0.0127	0.0105	0.0091	0.0084	0.0068	0.0059	0.0052	0.0048
H_g (μg/m^3)	0.1302	0.1287	0.1262	0.1146	0.0964	0.0852	0.0627	0.0515	0.0495
A_s (μg/m^3)	0.0081	0.0078	0.0068	0.0064	0.0057	0.0046	0.0038	0.0032	0.0022
C_r (μg/m^3)	1.68E-4	1.32E-4	1.18E-4	6.26E-5	5.86E-5	5.52E-5	4.88E-5	4.22E-5	2.85E-5
F (μg/m^3)	10.96	10.87	10.02	9.75	8.77	8.15	7.85	7.46	7.08

quality inspection institutions in the industrial park. This study adopts the principle of uniform distribution of detection points in the park, collects the air quality data detected in Nanjing HX Industry Park, analyzes the data information of each detection point in the detection data, deletes some abnormal detection data, and selects the average value of annual detection data as the basic data of air quality in that year. According to the actual situation of the development of Nanjing HX Industrial Park and the statistical results of air quality testing, the statistical data of the annual average value of air quality assessment indicators of waste gas emission of energy consumption in the park from 2012 to 2020 are shown in Table 1.

Determination of Air Quality Assessment Standard in Industrial Park

In order to use the spatial niche suitability model to assess the air quality of industrial parks, the assessment criteria for determining the assessment indicators and items of the industrial park are based on the "Chinese Ambient Air Quality Standards" (GB3095-1982) and two revised versions of (GB3095-1996) and (GB3095-2012). In early China's national air quality standards, the three-level standard system was used, which is different from the current five-level standard. In this study, the early air quality standards will be refined without changing the standard values. It is refined to a five-level standard, making it consistent with the current five-level air quality standard [26]. This paper refers to national standards and the assessment indicator standards for air pollution treatment of industrial park exhaust emissions of energy consumption based on comprehensive analysis are detailed in Table 2.

Using the criteria of the above assessment indicators, the spatial niche suitability model and the relative weights of the assessment indicators can be used to calculate the degree of membership of the assessment indicators and the assessment results determined by the membership degrees and relative weights of all assessment indicators can be finally calculated [27]. The value range of the assessment result is within the interval [0, 1]. The assessment results and the assessment degree standards can be used to determine the air quality of the industrial park. Since the assessment indicator's standard is affected by the determination of the maximum and minimum values of the parameters in the process of standardization and degree of membership function calculation of criteria for assessing indicators, the final assessment result tends to be narrowed. Therefore, when formulating the overall assessment standards for air quality treatment in industrial parks, appropriate adjustment level standards should be carried out. Similarly, the air quality assessment standards of industrial parks are divided into five quality degrees according to the national "Air Quality Standards". The specific standards are: assessment results [0.90-1.00], level I, no pollution; assessment results [0.80-0.90), level II, slightly polluted; assessment results [0.60-0.80), level III, light pollution; assessment results [0.40-0.60), level IV, moderate pollution; assessment results [0-0.40), level V, high pollution.

Table 2. Assessment standard of air quality assessment indicators.

Indicators	Level I	Level II	Level III	Level IV	Level V
SO_2	<20	20-60	60-100	100-200	>200
NO_2	<40	40-60	60-80	80-100	>100
CO	<4	4-6	6-8	8-10	>10
O_3	<100	100-160	160-200	200-250	>250
PM_{10}	<40	40-70	70-100	100-150	>150
$PM_{2.5}$	<15	15-35	35-50	50-65	>65
TSP	<80	80-200	200-250	250-300	>300
NO_X	<50	50-60	60-70	70-80	>80
P_b	<0.5	0.5-1	1-5	5-10	>10
BaP	<1	1-3	3-5	5-10	>10
Cd	<0.005	0.005-0.1	0.1-0.3	0.3-0.5	>0.5
Hg	<0.05	0.05-0.1	0.1-0.2	0.2-0.3	>0.3
As	<0.006	0.006-0.001	0.001-0.005	0.005-0.01	>0.01
Cr	<2.5E-05	2.5E-05-5.0 E-05	5.0 E-05- E-04	E-04-5.0E-04	>5.0E-04
F	<7	7-10	10-20	20-30	>30

The Basic Research Ideas of this Paper

The enterprises in Nanjing HX Park emit a large number of harmful gases in the production process, resulting in a certain degree of air pollution. Because there are a large number of heavy metals in the harmful gases discharged by energy consuming enterprises, it is easy to cause the health analysis of exposed people, especially the risk of cancer caused by carcinogenic heavy metals. According to the actual situation of air pollution in Nanjing HX Industrial Park, in order to effectively assess the air quality of the industrial park, referring to the research experience of experts and scholars at all the world, this paper selects the spatial niche suitability model. After comprehensive consideration and analysis, the specific ideas of research method selection and application in this paper are shown in Fig. 1.

Construction of Spatial Niche Suitability Model

According to the theory of ecological economics, niche refers to the position of a population in an ecosystem in time and space and its functional relationship and function with the related population [28]. It represents the minimum threshold of habitat necessary for the survival of every organism in the ecosystem. Niche modeling refers to a mathematical model that uses the niche theory and method to determine the level of ecological compensation effect by calculating the niche suitability of assessment indicators [29]. If there are n ecological factors in a region, the quantized values of these ecological factors are expressed by X_i means, the ecological factors matrix can be expressed as: X = $\{X_1, X_2, \dots, X_n\}$, then the ecological factors of m regions can form ($n \times m$) dimensional quantized values matrix of ecological factors, the matrix is represented by EFM, and the specific expression is as follows:

$$EFM = \begin{pmatrix} x_{1(t_1)} & x_{2(t_1)} & \cdots & x_{n(t_1)} \\ x_{1(t_2)} & x_{2(t_2)} & \cdots & x_{n(t_2)} \\ \vdots & \vdots & \vdots & \vdots \\ x_{1(t_m)} & x_{2(t_m)} & \cdots & x_n(t_m) \end{pmatrix} \quad (1)$$

In the above formula: i = 1, 2, ..., n; j = 1, 2, ..., m. $x_i(t_j)$ is a subset of n-dimensional ecological factor space E^n at time t_j, then $f(x_1(t_j), x_2(t_j), \dots, x_n(t_j))$ is called the niche of ecosystem. If the actual value of ecological factor is $X_t = (x_1(t_j), x_2(t_j), \dots, x_n(t_j))$, the most suitable value is $X_\alpha = (x_1(\alpha), x_2(\alpha), \dots, x_n(\alpha))$, the approach degree between the two is the niche suitability of ecological factors, expressed in NS_t, then: $NS_t = \tau(X_i, X_\alpha)$, the niche suitability model can be determined by using the distance formula as follows:

$$NS_t = \sum_{i=1}^{n} \frac{W_i(\delta_{min} + \lambda\delta_{max})}{\delta_{it} + \lambda\delta_{max}} = \sum_{i=1}^{n} \frac{W_i\left\{min\left[\left|x_i(t_j) - x_i(\alpha)\right|\right] + max\,\lambda\left[\left|x_i(t_j) - x_i(\alpha)\right|\right]\right\}}{\left|x_i(t_j) - x_i(\alpha)\right| + max\,\lambda\left\{\left|x_i(t_j) - x_i(\alpha)\right|\right\}} \quad (2)$$

In the formula: $\delta_{it} = \left|x_i(t_j) - x_i(\alpha)\right|$, $\delta_{\max} = \max\{\delta_{it}\} = \{\left|x_i'(t) - x_i'(\alpha)\right|\}$, $\delta_{\min} = \min\{\delta_{it}\} = \{\left|x_i'(t) - x_i'(\alpha)\right|\}$, i = 1, 2, ..., m; t = 1, 2, ..., n; λ is the model parameter ($0 \le \lambda \le 1$), in the average case $\lambda = 0.5$. In order to improve the effectiveness of niche suitability model assessment, this paper reconstructs the niche model based on the traditional niche suitability model, and tries to build a

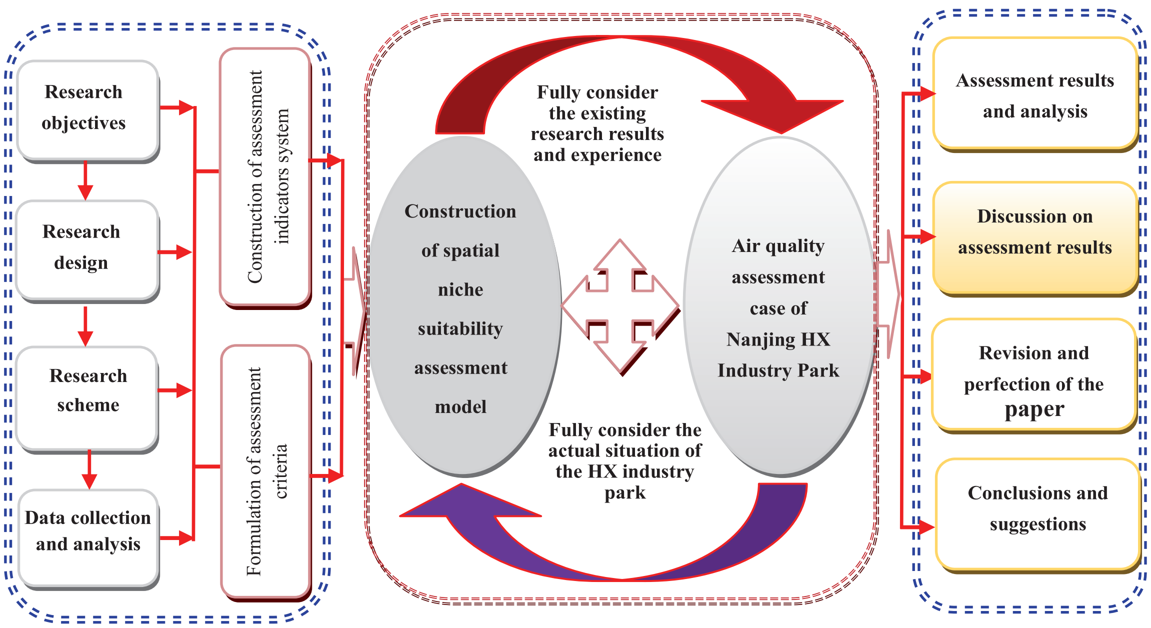

Fig. 1. Research idea of this paper.

comprehensive assessment model of spatial niche suitability. Taking the concentration value of the air quality assessment indicators as the niche value, $X_i(t_j)$ represents the concentration value of air quality assessment indicator at the i_{th} assessment object, the j_{th} assessment indicator. In order to construct the comprehensive assessment model of niche suitability, the generalized correlation degree in grey theory is introduced to calculate the niche of ecological factors. Since the data of air quality assessment indicators of industrial parks come from government statistics, this paper does not adopt the method of Weakening buffer processing the assessment indicators. In order to facilitate the calculation of niche suitability, the assessment indicators need to be normalized processing, the data after normalization processing has no dimension and its value range is between [0,1]. The specific calculation formula is as follows:

$$\begin{cases} X_i'(t_j) = X_i(t_j)\cdot\left[max\,X_i(t_j)\right]^{-1} & (forward\ pointer) \\ X_i'(t_j) = 1\text{-}X_i(t_j)\cdot\left[max\,X_i(t_j)\right]^{-1} & (contrary\ indicator) \end{cases} \tag{3}$$

If $X_i(\alpha)$ is the most appropriate value in the assessment indicators in line i, $X'_{i\alpha}$ is the most appropriate value of the normalized processing assessment indicators, then there are:

$$\begin{cases} X_i'(\alpha) = X_i(\alpha)\cdot\left[max\,X_i(t_j)\right]^{-1} & (forward\ pointer) \\ X_i'(\alpha) = 1\text{-}X_i(\alpha)\cdot\left[max\,X_i(t_j)\right]^{-1} & (contrary\ indicator) \end{cases} \tag{4}$$

In the actual construction process of the assessment model, according to the specific requirements of comprehensive assessment, the determination method and application of the relative weighted value of the absolute and relative niche suitability model can be studied. In order to build a comprehensive assessment model of spatial niche suitability, firstly, an absolute niche suitability measurement model is constructed. First, according to the dimensionless processing results, use the following formula to calculate the absolute zero conversion:

$$\begin{cases} X_{it}'(0) = \left(x_{1t}'(0),\ x_{2t}'(0),\ldots,\ x_{mt}'(0)\right) = x_i'(t_j) - x_1'(t_j) \\ X_{i\alpha}'(0) = \left(x_{1\alpha}'(0),\ x_{2\alpha}'(0),\ldots,\ x_{m\alpha}'(0)\right) = x_i'(t_j) - x_1'(0) \end{cases} \tag{5}$$

Then, according to the results of absolute zero conversion and referring to the niche suitability model, the absolute niche suitability model is constructed. The model is as follows:

$$ANS_{t\alpha} = \frac{1+|S_\alpha|+|S_t|}{1+|S_\alpha|+|S_t|+|S_\alpha - S_t|} \tag{6}$$

In the formula:

$|S_t| = \left|\int_1^n \left(x_{it}'(0) - x_{i1}'(0)\right)\mathrm{d}t\right| = \left|\sum_{k=2}^{n-1} x_{kt}'(0) + \frac{1}{2}x_{mt}'(0)\right|$,

$|S_\alpha| = \left|\int_1^n \left(x_{i\alpha}'(0) - x_{i1}'(0)\right)\mathrm{d}t\right| = \left|\sum_{k=2}^{n-1} x_{k\alpha}'(0) + \frac{1}{2}x_{mt}'(0)\right|$,

$|S_t - S_\alpha| = \left|\sum_{k=2}^{n-1}\left(x_{i\alpha}'(0) - x_{it}'(0)\right) + \frac{1}{2}\left(x_{m\alpha}'(0) - x_{kt}'(0)\right)\right|$.

On this basis, the relative niche suitability model is constructed by using the same method above. First, the relative zero conversion and the calculation formula is as follows:

$$\begin{cases} X_{it}''(0) = \left(x_{1t}''(0),\ x_{2t}''(0),\ldots,\ x_{nt}''(0)\right) = x_i''(t_j)\times\left[x_1''(t_j)\right]^{-1} \\ X_{i\alpha}''(0) = \left(x_{1\alpha}''(0),\ x_{2\alpha}''(0),\ldots,\ x_{n\alpha}''(0)\right) = x_i''(\alpha)\times\left[x_1''(t_j)\right]^{-1} \end{cases} \tag{7}$$

Then, the relative niche suitability assessment model is constructed by using the above relative zero conversion: calculation results, the specific assessment model of relative niche suitability is as follows:

$$RNS_{t\alpha} = \frac{1+|S_\alpha''|+|S_t''|}{1+|S_\alpha''|+|S_t''|+|S_\alpha'' - S_t''|} \tag{8}$$

In the formula:

$|S_t''| = \left|\sum_{k=2}^{m-1} x_{kt}''(0) + \frac{1}{2}x_{mt}''(0)\right|$, $|S_\alpha''| = \left|\sum_{k=2}^{m-1} x_{k\alpha}''(0) + \frac{1}{2}x_{m\alpha}''(0)\right|$,

$|S_t'' - S_\alpha''| = \left|\sum_{k=2}^{n-1}\left(x_{k\alpha}''(0) - x_{kt}''(0)\right) + \frac{1}{2}\left(x_{m\alpha}''(0) - x_{kt}''(0)\right)\right|$.

The comprehensive assessment model of spatial niche suitability is the weighted average value of absolute niche suitability model and relative niche suitability model, if W is a relative weight, the specific expression is as follows:

$$SNS_{t\alpha} = W\cdot ANS_{t\alpha} + (1-W)RNS_{t\alpha} \tag{9}$$

In the formula: W ($0\leq W\leq 1$) is the weighting coefficient. When considering the equal importance of absolute niche suitability and relative niche suitability, according to the principle of neutrality, the value of W is taken as 0.5. When the value of is less than 0.5 and tends to 0, the spatial niche suitability value tends to the relative niche suitability value. When the value of W is greater than 0.5 and tends to 1, the spatial niche suitability value tends to the absolute niche suitability value [30].

Results and Discussions

The Assessment Results of Spatial Niche Suitability Model

According to the above assessment principle of the spatial niche suitability model, the formula (4) and (5) are used to perform the dimensionless calculation for the assessment indicator value in Table 1. In this paper, dimensionless calculation adopts the method of normalization processing. The maximum value is 2 times of the lower boundary value of level V in the assessment indicators standard (Han et al., 2021), the specific calculation results are shown in Table 3.

In order to effectively assess the air quality of the industrial park, it is necessary to use formula (5) to conduct absolute zero conversion on the normalized assessment indicators, so as to prepare for the assessment using the absolute niche suitability model. The specific relative zero conversion results are shown in Table 4.

Then use formula (7) to conduct relative zero conversion on the normalized assessment indicators, so as to prepare for the assessment using the absolute niche suitability model. The specific relative zero conversion results are shown in Table 5.

According to the above calculation results, formulas (6), (8) and (9) can be used to calculate the absolute niche suitability, relative niche suitability and spatial niche suitability of the assessment object respectively. The specific calculation results are shown in Table 6.

According to the above assessment results, in the nine years from 2012 to 2020, the air quality assessment results of Nanjing HX Industry Park increased from 0.7919 to 0.9125, and the corresponding air quality level increased from level III to level I.

Discussion on the Difference of Niche Suitability Model Assessment Results

According to the above assessment results, there is a great difference between the assessment results of absolute niche suitability model and relative niche suitability model in the comprehensive assessment results of air quality of energy consumption and waste gas emission of Nanjing HX Industry Park. The assessment results of spatial niche suitability model are in between and have the characteristics of relative stability. According to the assessment results of the spatial niche suitability assessment model, the degree of environmental pollution caused by energy consumption and pollution discharge in Nanjing HX Industry Park has increased from level 3 in 2012 to level 1 in 2020, but it is still at the lower boundary of level 1. In order to reflect the differences between the assessment results of the above three niche suitability models, we use a cone chart to draw the composition and trend of the assessment results of the three models, the detailed results are shown in Fig. 2.

Discussion on the Main Factors Affecting the Assessment Results

The overall impact of the assessment indicators on the assessment objects can be shown by analyzing these indicators. From 2012 to 2020, the values and trends of the air quality assessment indicators for the environmental pollution treatment of exhaust emissions of energy consumption in Nanjing HX Industrial Park are shown in Fig. 3.

From Fig. 3, the concentrations of NO_2, O_3, TSP, PM_{10}, $PM_{2.5}$ in the Nanjing HX Industrial Park are relatively high, and the impact of these indicators on the air quality depends on the magnitude of the impact.

Table 3. Normalized results of air quality assessment indicators in industrial parks.

Indicators	2012	2013	2014	2015	2016	2017	2018	2019	2020
SO_2 (μg/m^3)	0.9226	0.9241	0.9343	0.9443	0.9487	0.9508	0.9524	0.9528	0.9554
NO_2 (μg/m^3)	0.6947	0.6973	0.7171	0.7477	0.7584	0.7816	0.7926	0.7966	0.8012
CO (μg/m^3)	0.6915	0.6975	0.7030	0.7140	0.7340	0.7555	0.7910	0.8010	0.8070
O_3 (μg/m^3)	0.6759	0.6771	0.6890	0.7022	0.7149	0.7251	0.7591	0.7795	0.7872
PM_{10} (μg/m^3)	0.7604	0.7621	0.7776	0.7970	0.7987	0.8124	0.8284	0.8457	0.8621
$PM_{2.5}$ (μg/m^3)	0.7152	0.7166	0.7580	0.7968	0.8357	0.8563	0.8703	0.8745	0.8780
TSP (μg/m^3)	0.6646	0.6661	0.6910	0.7145	0.7246	0.7395	0.7896	0.8411	0.8629
NO_X (μg/m^3)	0.6071	0.6102	0.6276	0.6358	0.6418	0.6448	0.6670	0.6855	0.6922
P_b (μg/m^3)	0.9418	0.9444	0.9458	0.9519	0.9574	0.9629	0.9674	0.9702	0.9723
BaP (μg/m^3)	0.8449	0.8487	0.8574	0.8738	0.8909	0.9099	0.9179	0.9329	0.9519
C_d (μg/m^3)	0.9815	0.9873	0.9895	0.9909	0.9916	0.9932	0.9941	0.9948	0.9952
H_g (μg/m^3)	0.7830	0.7855	0.7897	0.8090	0.8393	0.8580	0.8955	0.9142	0.9175
A_s (μg/m^3)	0.5950	0.6100	0.6600	0.6800	0.7150	0.7700	0.8100	0.8400	0.8900
C_r (μg/m^3)	0.8320	0.8680	0.8820	0.9374	0.9414	0.9448	0.9512	0.9578	0.9715
F (μg/m^3)	0.8173	0.8188	0.8330	0.8375	0.8538	0.8642	0.8692	0.8757	0.8820

Table 4. Absolute zero conversion result of air quality assessment indicators standard in Industrial Park.

Indicators	2012	2013	2014	2015	2016	2017	2018	2019	2020
SO_2 ($\mu g/m^3$)	0	0	0	0	0	0	0	0	0
NO_2 ($\mu g/m^3$)	-0.2279	-0.2268	-0.2172	-0.1966	-0.1903	-0.1692	-0.1598	-0.1562	-0.1542
CO ($\mu g/m^3$)	-0.2311	-0.2266	-0.2313	-0.2303	-0.2147	-0.1953	-0.1614	-0.1518	-0.1484
O_3 ($\mu g/m^3$)	-0.2467	-0.2470	-0.2453	-0.2421	-0.2338	-0.2257	-0.1933	-0.1733	-0.1682
PM_{10} ($\mu g/m^3$)	-0.1622	-0.1620	-0.1567	-0.1473	-0.1500	-0.1384	-0.1240	-0.1071	-0.0933
$PM_{2.5}$ ($\mu g/m^3$)	-0.2074	-0.2075	-0.1763	-0.1475	-0.1130	-0.0945	-0.0821	-0.0783	-0.0774
TSP ($\mu g/m^3$)	-0.2580	-0.2580	-0.2433	-0.2298	-0.2241	-0.2113	-0.1628	-0.1117	-0.0925
NO_X ($\mu g/m^3$)	-0.3155	-0.3139	-0.3067	-0.3085	-0.3069	-0.3060	-0.2854	-0.2673	-0.2632
P_b ($\mu g/m^3$)	0.0192	0.0203	0.0115	0.0076	0.0087	0.0121	0.0150	0.0174	0.0169
BaP ($\mu g/m^3$)	-0.0777	-0.0754	-0.0769	-0.0705	-0.0578	-0.0409	-0.0345	-0.0199	-0.0035
C_d ($\mu g/m^3$)	0.0589	0.0632	0.0552	0.0466	0.0429	0.0424	0.0417	0.0420	0.0398
H_g ($\mu g/m^3$)	-0.1396	-0.1386	-0.1446	-0.1353	-0.1094	-0.0928	-0.0569	-0.0386	-0.0379
A_s ($\mu g/m^3$)	-0.3276	-0.3141	-0.2743	-0.2643	-0.2337	-0.1808	-0.1424	-0.1128	-0.0654
C_r ($\mu g/m^3$)	-0.0906	-0.0561	-0.0523	-0.0069	-0.0073	-0.0060	-0.0012	0.0050	0.0161
F ($\mu g/m^3$)	-0.1053	-0.1053	-0.1013	-0.1068	-0.0949	-0.0866	-0.0832	-0.0771	-0.0734

Table 5. Absolute zero conversion result of air quality assessment indicators standard in Industrial Park.

Indicators	2012	2013	2014	2015	2016	2017	2018	2019	2020
SO_2 ($\mu g/m^3$)	0	0	0	0	0	0	0	0	0
NO_2 ($\mu g/m^3$)	-0.2279	-0.2268	-0.2172	-0.1966	-0.1903	-0.1692	-0.1598	-0.1562	-0.1542
CO ($\mu g/m^3$)	-0.2311	-0.2266	-0.2313	-0.2303	-0.2147	-0.1953	-0.1614	-0.1518	-0.1484
O_3 ($\mu g/m^3$)	-0.2467	-0.2470	-0.2453	-0.2421	-0.2338	-0.2257	-0.1933	-0.1733	-0.1682
PM_{10} ($\mu g/m^3$)	-0.1622	-0.1620	-0.1567	-0.1473	-0.1500	-0.1384	-0.1240	-0.1071	-0.0933
$PM_{2.5}$ ($\mu g/m^3$)	-0.2074	-0.2075	-0.1763	-0.1475	-0.1130	-0.0945	-0.0821	-0.0783	-0.0774
TSP ($\mu g/m^3$)	-0.2580	-0.2580	-0.2433	-0.2298	-0.2241	-0.2113	-0.1628	-0.1117	-0.0925
NO_X ($\mu g/m^3$)	-0.3155	-0.3139	-0.3067	-0.3085	-0.3069	-0.3060	-0.2854	-0.2673	-0.2632
P_b ($\mu g/m^3$)	0.0192	0.0203	0.0115	0.0076	0.0087	0.0121	0.0150	0.0174	0.0169
BaP ($\mu g/m^3$)	-0.0777	-0.0754	-0.0769	-0.0705	-0.0578	-0.0409	-0.0345	-0.0199	-0.0035
C_d ($\mu g/m^3$)	0.0589	0.0632	0.0552	0.0466	0.0429	0.0424	0.0417	0.0420	0.0398
H_g ($\mu g/m^3$)	-0.1396	-0.1386	-0.1446	-0.1353	-0.1094	-0.0928	-0.0569	-0.0386	-0.0379
A_s ($\mu g/m^3$)	-0.3276	-0.3141	-0.2743	-0.2643	-0.2337	-0.1808	-0.1424	-0.1128	-0.0654
C_r ($\mu g/m^3$)	-0.0906	-0.0561	-0.0523	-0.0069	-0.0073	-0.0060	-0.0012	0.0050	0.0161
F ($\mu g/m^3$)	-0.1053	-0.1053	-0.1013	-0.1068	-0.0949	-0.0866	-0.0832	-0.0771	-0.0734

Table 6. Assessment results of niche suitability models in Nanjing HX Industry Park.

Indicators	2012	2013	2014	2015	2016	2017	2018	2019	2020
	0.8047	0.8025	0.8314	0.8553	0.8746	0.8903	0.9086	0.9262	0.9345
Level	II	II	II	II	II	II	I	I	I
	0.7791	0.7711	0.7982	0.8149	0.8306	0.8523	0.8898	0.8918	0.9015
Level	III	III	III	II	II	II	II	II	I
	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	0.7919	0.7868	0.8148	0.8351	0.8526	0.8713	0.8957	0.9035	0.9125
Level	III	III	II	II	II	II	II	I	I

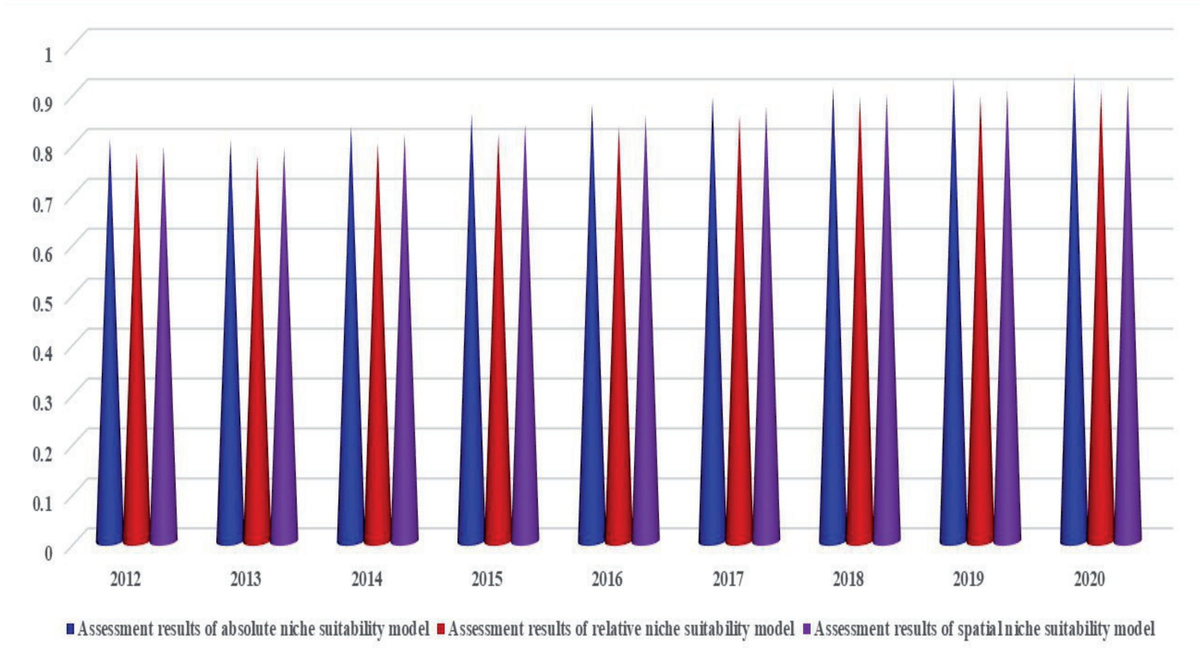

Fig. 2. Composition and change trend of assessment results of three niche suitability models.

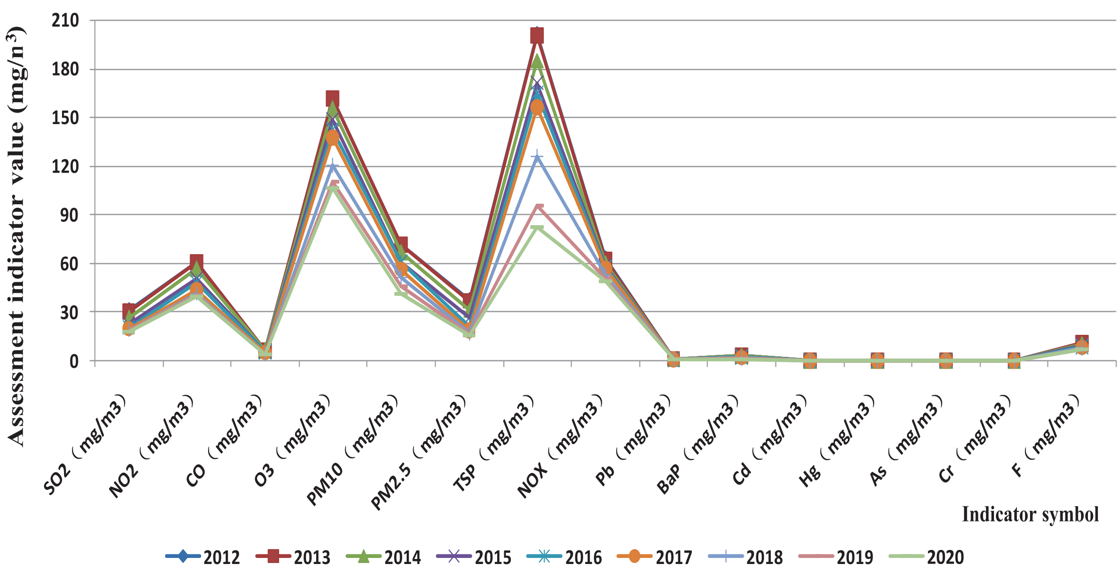

Fig. 3. Composition and trend of influencing factors of air quality in Nanjing HX Industry Park.

Conclusions

Under the carbon peaking and carbon neutrality goals, urban industrial parks have gradually become the main force and environmental protection demonstration area to promote the green development of China's economy. Air quality assessment of heavy energy consumption Industrial Park has become a very important research topic. In order to explore an effective method to solve this research topic, based on the research background analysis and literature review, 15 air quality standards identified in China's "Air Quality Standards" (GB3095-2012) were selected. The spatial niche suitability model was constructed, taking the air quality assessment of Nanjing HX Industry Park as an example. The study found that the air quality degree of environmental pollution treatment of exhaust emissions of energy consumption in industrial parks showed an upward trend. The assessment result of the absolute niche suitability assessment model is that the air quality of the target industrial park increase from level II in 2012 to level I in 2020.

In addition, the study finds that the assessment method has a significant impact on the assessment results and the study should attach great importance to the selection and construction of the assessment model, and continuously improve the assessment model according to the requirements of the air quality assessment of the industrial park to promote the continuous improvement of the effectiveness of the comprehensive assessment results of air quality for the environmental pollution treatment of exhaust emissions of energy consumption in industrial parks.

The air weight comprehensive assessment of environmental pollution treatment in high energy consumption Industrial Park is an important subject that needs long-term research. There are many factors affecting the improvement of energy consumption and air quality in industrial parks, such as the improvement of environmental regulations, the support of green financial policies, the promotion and utilization of clean energy, the dynamic adjustment of air quality standards for energy consumption and the innovation of energy efficiency improvement technologies. Taking Nanjing HX Industry Park in China as an example, this paper selects three niche suitability model methods to conduct a preliminary study on this subject and has achieved effective results. This study aims to start a discussion to promote in-depth research on this topic in academia for achieving the sustainable development of China's industrial parks.

Acknowledgments

This paper is supported by the humanities and Social Sciences Foundation of the Ministry of education, the project name is "Research on China's systemic financial risk prevention and control based on three-dimensional structural analysis" (Approval number: 19YJA790098). The author thanks the humanities and Social Sciences Foundation of the Ministry of education of China for providing research funds for this research. At the same time, we would like to thank the Management Committee of Nanjing HX industry park for providing relevant data required for this study.

Conflict of Interest

The authors declare no conflict of interest.

References

1. HUAN Q.Z., XU Y. Construction of the Ecological Civilization Demonstration Area from the Three-dimensional Perspective and Prospect. Journal of China University of Geosciences (Social Sciences Edition) **17** (3), 54, **2017**.
2. HUANG Z. H., YU Q., MA W.C., CHEN L.M. Surveillance efficiency of air quality monitoring networks for air pollution episodes in industrial parks: Pollution detection and source identification. Atmospheric Environment **215**:116874, **2019**.
3. HAN X.Y., CAO T.Y. Study on ecological environment quality of the energy consumption pollution treatment in industrial parks. Environmental Science and Pollution Research **28**, 28038, **2021**.
4. JI J.L., MA Y.L, WANG S.S., LONG W.Q., WANG K., ZHANG R.Q. Analysis of energy saving and emission reduction benefits of energy cascade utilization in an industrial park and its impact on urban air quality. Act a Scientiae Circumstantiate **40** (5), 1884, **2020**.
5. ZHENG B.W., LIU W.H., XU H., LI J.F., JIANG X.W. Occurrence and distribution of antimicrobial resistance genes in the soil of an industrial park in China: A metagenomics survey. Environmental Pollution **273**:116467, **2021**.
6. YAN Y., YAO L.Y., XU T., ZHAO M.J. Public preferences and policy of air pollution control: Taking the haze governance in Xi'an as an example. Journal of Arid Land Resources and Environment **32** (4), 19, **2018**.
7. HAN L., ZHAO J.Y., GU Z.L. Assessing air quality changes in heavily polluted cities during the COVID-19 pandemic: A case study in Xi'an, China. Sustainable Cities and Society **70**: 102934, **2021**.
8. SHEN T.T. Air quality assessment for land disposal of industrial wastes. Environmental Management **6** (4), 297, **1982**.
9. LU G.R., TANG Z.P., CAI J.Y., MA D.W., LIU B.H. Study on the method of air quality in the production environment of deep open pit mine. Metal Mine (1): 11-15+23, **1986**.
10. ZHANG N.N., MA F., GUAN Y., LI Y.F. Spatial assessment of air resources in China from 2013 to 2017. Science of The Total Environment **658**, 294, **2019**.
11. GUO J.M., ZHAO M.J., XUE P., LIANG X., FAN G.G., DING B.H., LIU J.J., LIU J.P. New indicators for air quality and distribution characteristics of pollutants in China. Building and Environment **172**, 106723,**2020**.
12. HESS G.D. A photochemical model for air quality assessment: Model description and verification. Atmospheric Environment **23** (3), 643, **1989**.

13. MATNEY M.L., BOYD J.F., COVINGTON P.A., LEANO H.J., LIMERO T.F., JAMES J.T. Air quality assessments for two recent Space Shuttle flights. Aviation, space, and environmental medicine. **64** (11), 992, **1993**.
14. BAI N.B., DU M., YAO G.A., YUAN J.W., SHEN B.L. An Expert system for Regional Air Quality Assessment. China Environmental Science **14** (2), 95, **1994**.
15. DING J.B., HE Q., CHENG Y.P. Grey Comprehensive Judgement Method and Air Quality. Sichuan Environment **12** (3), 46, **1993**.
16. GUTTIKUNDA S.K., NISHADH K.A., GOTA S., SINGH P., CHANDA A., JAWAHAR P., ASUNDI J. Air quality, emissions, and source contributions analysis for the Greater Bengaluru region of India. Atmospheric Pollution Research **10** (3), 941, **2019**.
17. EHSANUL K., KIM K.H., RYEYL S.J., YOUN K.B., HYUN S.J. Indoor air quality assessment in child care and medical facilities in Korea. Environmental monitoring and assessment **6**, 395, **2012**.
18. GORAI A.K., UPADHYAY K.A., GOYAL P. Design of fuzzy synthetic model for air quality assessment. Environment Systems and Decision **34** (3), 456, **2014**.
19. GUARISO G., MAIONE M., VOLTA M. A decision framework for Integrated Assessment Modeling of air quality at regional and local scale. Environmental Science & Policy **65**, 3, **2016**.
20. SCHMITZ S., WEIAND L., BECKER S., NIEHOFF N., SCHWARTZBACH F., SCHNEIDEMESSER F.V. An assessment of perceptions of air quality surrounding the implementation of a traffic-reduction measure in a local urban environment**.** Sustainable Cities and Society **41**: 525, **2018**.
21. HAN X.Y., SUN T., CAO T.Y. Study on environmental pollution loss measurement method of waste gas emits in Nanjing MV Industrial Park. Environmental Science and Pollution Research **27**, 16539, **2020**.
22. BO X., WANG G., WEN R., HE Y.J., DING F., WU C.Z., MENG F. The impact of thermal power enterprises on the air pollution in Beijing-Tianjin-Hebei region. Chinese Environmental Science **35** (2), 364, **2015**.
23. TAN Q., ZHUANG H., TIE Z.X., DING C.F., WU Q. An air quality model for the industrial park based on the fuzzy matter element analysis. Journal of Safety and Environment **17** (5), 2019, **2017**.
24. SONG H., SUN Y.J., CHEN D.K. Assessment for the Effect of Government Air Pollution Control Policy: Empirical Evidence from "Low-carbon City" Construction in China. Management World (6), 95, **2019**.
25. LI X.H., XU Y.Y., YAO X. Effects of industrial agglomeration on haze pollution: A Chinese city-level study. Energy Policy **148**, 111928, **2021**.
26. YOU W.J., XU Z.S., LIU D.L. On the fire risk assessment for the ancient buildings based on the matter element analysis. Journal of Safety and Environment **17** (3), 873, **2017**.
27. ZHANG J.Y., LIU X.D., PANG X.D., YU Y.C. Pollution Assessment of Heavy Metals in Urban Green Land Soils in Nanjing City based on the Matter-Element Extension Model. Research of Environmental Sciences **31** (9), 1572, **2018**.
28. XIAO S.C., OU M.H. Study on Delineation of Ecological Protection Red Line on the Terrestrial Parts of Jiangsu Province Based on Niche-fitness Model. Resources and Environment in the Yangtze Basin **31** (2), 366, **2022**.
29. KRTOCOS D.J., IRELAND K.B., MORIN L., KUMARAN N., RAFTER M.A., OTA N., RAGHU S. Integrating ecoclimatic niche modelling methods into classical biological control programmes. Biological Control. **160**, 104667, **2021**.
30. HAN X.Y., CAO T.Y. Study on the evaluation of ecological compensation effect for environmental pollution loss from energy consumption: Taking Nanjing MV Industrial Park as an example. Environmental Technology & Innovation. **27**, 102473, **2022**.