Research Paper

Evaluation of ecological environment quality in Harbin based on Remote Sensing Based Ecological Index

Rong GUO, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Shuo LYU, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Chang LIU, Shijiazhuang College of Applied Technology, China

Abstract

Urban ecological environment is the basis of human survival and development, but with the continuous increase of urbanization process, it will inevitably have an impact on ecological environment. In this paper, ecological factors such as greenness, humidity, dryness and temperature were used to build the RSEI model. With Harbin as the research area, Landsat remote sensing data of 2000, 2005, 2010, 2015 and 2020 were selected as the data source to conduct a comprehensive evaluation of the eco-environmental status of Harbin. The results show that: (1) From 2000 to 2020, the mean RSEI in Harbin increased from 0.64 to 0.70, with an increase of 9.38%. (2) From the perspective of spatial distribution, the area of poor and poor RSEI decreased, the area of moderate RSEI increased, and the area of excellent and good RSEI expanded significantly, showing a concentrated contiguity distribution. (3) The northeastern part of Harbin always maintained a high RSEI value, the western part gradually changed to a high RSEI value, and the central part fluctuated greatly. According to the requirements of ecological civilization construction, this paper puts forward countermeasures and suggestions for the improvement of the eco-environmental quality in Harbin.

Keywords

Urban ecology, RSEI, Harbin

1. Introduction

The rapid urbanization of the world has provided various benefits to human society, greatly improving the convenience of life and job opportunities for urban residents. However, the process of urbanization is accompanied by the encroachment of construction land on ecological space, which intensifies the pollution of air, water and soil. These problems affect the ecological quality of the city, and bring potential threats to the health of the residents and the stable development of the social economy. Under the background of rapid urbanization, urban ecological quality has become the focus of people's attention (Folke et al.,2016). In order to better cope with these challenges, quantitative and spatial eco-environmental quality assessment is particularly important. It can help to formulate targeted ecological protection and restoration strategies, and provide theoretical support and practical guidance for urban planning and management.

The evaluation of ecological quality is an important means to measure the health status of eco-environmental system in a region (Shan et al.,2019). Through this evaluation, we can understand the stability, integrity and function of the ecosystem itself. However, the eco-environmental covers many elements of the natural ecosystem, such as the water, vegetation, and biodiversity. These elements are interrelated and interact with each other to form a complex ecosystem network. Therefore, its quality is difficult to be measured directly, and the eco-environmental quality is obtained indirectly in most studies. At present, most studies evaluate eco-environmental quality by selecting different evaluation index systems, such as index evaluation method and fuzzy discrimination method, to investigate the status quo and change trend of urban ecosystem from multiple dimensions (Bai et al.,2016; Asif 2016; Wu *et al,* 2022).

Some scholars have proposed the Remote Sensing Based Ecological Index (RSEI) (Xu ,2013) based on remote sensing information, which integrates four factors of greenness, humidity, heat and dryness through principal component analysis technology to comprehensively assess the overall status of regional ecological environment. Based on ecosystem classification and extraction of ecological parameters, the model can directly reflect the basic dynamics of ecological environment by evaluating the overall state of regional environment (Yue et al.,2019). RSEI can couple multiple single index comprehensive index evaluation, and can remove redundant information between indexes (Xu et al., 2018). RSEI can reduce the influence of subjective factors caused by artificial weight setting, and has the characteristics of simplicity, fast and objective. Initially, RSEI was mainly used for local or regional scales, and scholars built improved RSEI models according to the characteristics of different regional scales. At present, RSEI model has been widely used in the evaluation of regional ecological environment quality and the exploration of driving factors at different scales such as mining areas, nature reserves, wetlands, cities, regions and river basins (Yuan et al., 2021). For example, Maity (Maity et al.,2022) used RSEI to assess the ecological environment status of Kolkata urban agglomeration from 1990 to 2020, and the results showed that the impact of urbanization on the ecological environment in some areas was mitigated through the implementation of ecological management measures.

Rapid and timely evaluation of the change of ecological environment quality is the premise of realizing the coordinated and sustainable development of ecological environment and economy. In this study, the eco-environmental quality of Harbin was studied in five years: 2000, 2005, 2010, 2015 and 2020. The chosen time span includes the critical periods of urbanization, industrial growth, and the implementation of ecological policies in Harbin. Consequently, it offers robust data support for assessing the long-term trends in ecological quality and lays the foundation for future ecological management and decision-making processes.

2. Method

2.1. The study area

Harbin is located in Heilongjiang Province. It’s temperature shows obvious seasonal changes, the spatio-temporal distribution of precipitation is uneven, and the rain and heat are in the same season. The urban area of Harbin is flat and low-lying, with mountains and hills in the east, branches of Zhangguangcai Mountains in the southeast, and Small Xingan Mountains in the north. The rivers are vertical and horizontal, and the large and small rivers in the territory belong to the Songhua River system, and the change of water volume has obvious seasonal characteristics, with spring and summer two flood seasons. The total land area of Harbin is 53076.4km2, and the black soil is the most widely distributed and the most abundant soil type. At the end of 2020, Harbin consisted of 9 districts and 9 counties, with a total population amounting to 9.485 million and annual GDP of 518.38 billion yuan. Over the past few years, Harbin's ecosystem has become more susceptible to threats, and there is a risk of continuous degradation of ecological environment quality. Therefore, the eco-environmental quality evaluation can provide strong support for local government and environmental policy formulation and adjustment.

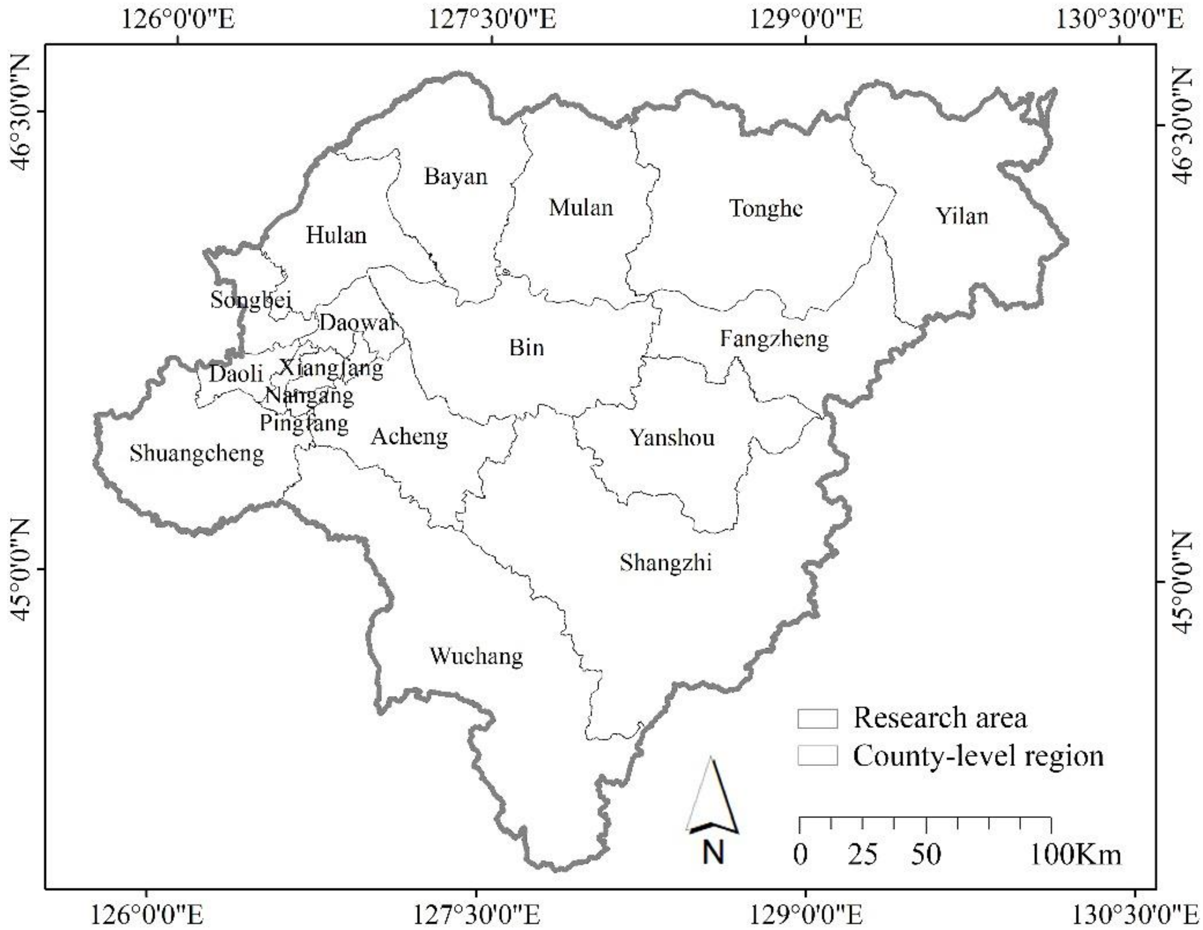

Figure 1. The study area. Source: Author self-painted.

2.2. Data Sources

The remote sensing satellite images were taken from Landsat series images with a resolution of 30m. In addition, to more comprehensively eliminate the seasons and weather as much as possible, the image with the smallest cloud cover in June to September when the plant growth is better was selected as the data.

2.3. Research Methods

RSEI takes into account the plants and the influence of the water, light and heat, which is simple and can comprehensively evaluate the quality of ecosystems by integrating multiple factors. Furthermore, PCA optimizes the evaluation index and summarize it into a comprehensive index that can characterize the ecosystem quality.

Table 1. Index summary table of remote sensing ecological index. Source: Compiled by the author.

Index	Description	Formula
Greenness	NDVI is adopted as the greenness index.	$NDVI = \frac{(\rho_{NIR} - \rho_R)}{(\rho_{NIR} - \rho_R)}$
Wetness	The Wetness Index (WET) derived from remote sensing data through fringe capacity transformation was utilized as a measure of wetness.	$WET = C_1\rho_B + C_2\rho_G + C_3\rho_R + C_4\rho_{NIR} + C_5\rho_{SWIR1} + C_6\rho_{SWIR2}$
Dryness	The surface temperature is calculated by combining brightness temperature and surface specific emissivity correction.	$LST = \frac{T_b}{\left[1 + \left(\frac{\lambda T_b}{\rho}\right)\right]}$
Heat	The IBI and the SI are utilized to quantify heat.	$NDSI = \frac{IBI + SI}{2}$

3. Results

The indexes and RSEI standardized mean values of Harbin in the five periods of 2000, 2005, 2010, 2015 and 2020 are listed in Table 2. From the perspective of time scale, from 2000 to 2020, the average RSEI in Harbin showed a continuous growth trend, from 0.64 to 0.70, with an increase rate of 9.38%. Harbin showed a significant upward trend in the past 20 years.

Greenness has gradually increased from 0.74 in 2000 to 0.82 in 2020. This is due to the development of urban green construction, ecological restoration, vegetation protection and other measures. Humidity fluctuated widely between 2000 and 2020, peaking at 0.83 in 2005, after which it declined slightly. The rise of moisture index indicates that soil moisture content or surface water area has increased, which is closely related to a series of strengthening measures taken by Harbin City in water resources management. The heat also showed a continuous upward trend, rising from 0.33 to 0.43. This reflects the enhanced urban heat island effect, which is related to urban expansion, increased building density, energy consumption and other factors. Dryness also showed an overall upward trend, but the increase was relatively small, from 0.54 to 0.60, indicating a relatively stable dryness in the region. The RSEI value increased steadily from 0.64 in 2000 to 0.70 in 2020, indicating that the ecological environment of Harbin has improved on the whole.

Table 2. Four indicators and RSEI mean value of Harbin from 2000 to 2020. Source: Compiled by the author.

Year	Greenness	Wetness	Dryness	Heat	RSEI
2000	0.74	0.70	0.33	0.54	0.64
2005	0.75	0.83	0.35	0.61	0.66
2010	0.78	0.74	0.38	0.52	0.67
2015	0.81	0.84	0.42	0.59	0.69
2020	0.82	0.78	0.43	0.60	0.70

To more comprehensively evaluate the eco-environmental quality of Harbin, we divided the RSEI value of each year into 5 grades, which successively represented 5 grades of poor, poor, medium, good and excellent quality.

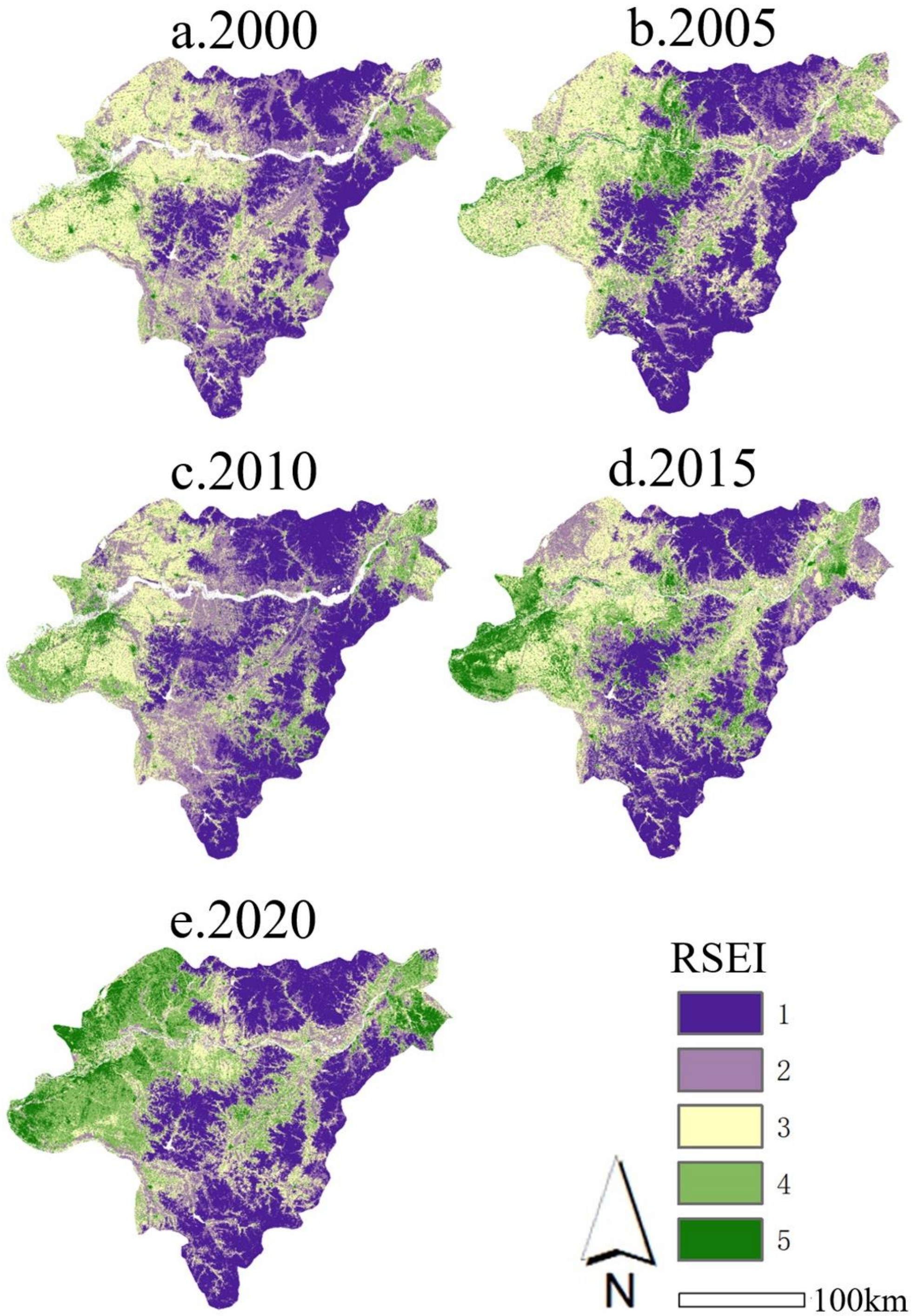

Figure 2. Spatial pattern of RSEI in Harbin from 2000 to 2020. Source: Author self-painted.

From the perspective of spatial distribution, the area of low RSEI value in 2000 was large, concentrated in tonghe, shangzhi and wuchang. The region with medium RSEI is the second, and the area with excellent RSEI and good RSEI is small. On the whole, RSEI in Harbin in 2000 was general and showed obvious spatial differentiation. Among them, the development of resources such as sand and gravel in Tonghe may lead to ecological degradation, while the expansion of agricultural activities in Shangzhi and Wuchang may cause pressure on the ecosystem. Compared with 2000, the area of low RSEI decreased in 2005, while the area of middle RSEI increased and became more concentrated. The area of RSEI good also increased, but the area of RSEI good changed relatively little. This may be because the best areas are usually located in nature reserves or ecological core areas with less variability. In 2010 and 2015, the area of low-value RSEI decreased significantly, while the area of high-value RSEI expanded significantly. There were fewer RSEI medium regions in 2015 compared to 2010. In 2020, the high-value RSEI area expands significantly and presents a concentrated contiguity of distribution characteristics, while the low-value and medium-value RSEI areas further shrink, indicating that the ecological quality continues to improve and the health and stability of the ecosystem has been significantly improved.

During 2000-2020, the overall trend of RSEI in Harbin is good, but the spatial differentiation was still obvious. The northeast always maintained a high RSEI value, the western region gradually changed to a high RSEI value, and the central region fluctuated greatly, and the overall spatial pattern changed significantly. The RSEI level showed an obvious upward trend, the low and medium RSEI areas gradually decreased, while the high RSEI areas gradually expanded. This indicates that the ecological environment indicators such as vegetation cover and humidity in Harbin have been improved, which is related to the implementation of local environmental management measures.

Table 3 lists the areas and proportions of each level of ecological quality in Harbin. The area of RSEI of different grades in Harbin changed significantly from 2000 to 2020, and the area proportion of low-value areas continued to decline from 2000 to 2010, but the decline narrowed from 2010, and even rebounded in 2015. The area shared of the middle class declined between 2000 and 2010, but rebounded after 2010. The proportion of high-value areas continues to rise, which reflects that Harbin has achieved remarkable results in improving the ecological environment.

Table 3. Statistical table of the percentage of RSEI value of each grade in Harbin from 2000 to 2020.

Source: Compiled by the author.

RSEI	2000		2005		2010		2015		2020	
	area/ km^2	percent /%	area /km^2	percent /%	area /km^2	percent /%	area /km^2	percent /%	area /km^2	percen t /%
very poor	14657	28	17885	34	17638	33	15976	30	17340	33
poor	14559	27	13761	26	10087	19	11301	21	9261	17
medium	16378	31	12462	23	15713	30	13586	26	9576	18
good	4681	9	5772	11	7131	13	8234	16	11871	22
excellent	1714	3	2109	4	2531	5	4002	8	5052	10

4. Conclusion

Taking 2000-2020 as the research period, this study quantified key ecological indicators through the construction of RSEI model, systematically analyzed the characteristics of Harbin's eco-environmental quality, and drew the following conclusions.

(1) From 2000 to 2020, the average RSEI in Harbin showed a continuous increasing trend, rising from 0.64 to 0.70, with an increase of 9.38%. This shows that the ecological quality of Harbin has improved.

(2) From 2000 to 2020, the greenness gradually increased from 0.74 to 0.82, indicating that the vegetation cover of Harbin has shown a significant improvement trend in the past 20 years. Humidity peaked at 0.83 in 2005. The increase of moisture index indicates that the soil moisture content or surface water area has increased. The heat increased from 0.33 to 0.43, reflecting the enhanced urban heat island effect. The dryness increased from 0.54 to 0.60, indicating a relatively stable dryness in the region.

(3) From 2000 to 2020, the area of coastal RSEI with low value is larger, followed by the area with medium value, and the area with high value is smaller. On the whole, the area of low-value RSEI decreased, the area of medium-value RSEI increased, and the area of high-value RSEI expanded significantly, showing the characteristics of centralized and contiguity distribution.

(4) From 2000 to 2020, the overall spatial differentiation of RSEI in Harbin is obvious. The northeast always maintains a high RSEI value, and the ecological quality is good and stable. The western region gradually changes to a high RSEI value, and the central region fluctuates greatly.

5. Countermeasures and suggestions

In the past 20 years, Harbin has made progress in actively implementing green development, ecological protection and restoration. Combined with the status quo of eco-environmental quality in Harbin, efforts should still be made in ecological protection and environmental governance.

(1) We will control new construction land, and avoid blind expansion. Priority should be given to the development of green Spaces such as parks, ecological corridors and wetlands to form a coherent ecological network. This can not only effectively improve the ecological environment of Harbin, but also improve the overall landscape quality of the city and the living comfort of residents.

(2) Increase vegetation coverage and improve ecological service functions. Actively expand urban green areas and improve vegetation coverage. Different types of vegetation have different contributions to air quality, soil and water conservation, biodiversity and so on. According to the natural conditions of different regions, suitable vegetation types should be selected, and the conservation and management of existing green space should be strengthened to improve its ecological service function.

(3) Improve the green land rate of built-up areas, create a comfortable environment, improve the environment of community public areas. This can not only beautify the urban landscape, but also improve the urban microclimate.

(4) While accelerating economic development, we ought to focus on ecological protection and strengthen the positive interaction between resource development and environmental protection in Harbin. We will strengthen the protection of forest lands, cultivated land and water areas, protect forest vegetation and biodiversity, and reduce soil erosion.

(5) The seasonal variation of annual precipitation in Harbin city is large, which is easy to cause regional urban flood disasters, protect the surface ecological environment and alleviate flood disasters, purify

harmful substances in the environment, conserve water sources, and provide conditions for the development of biodiversity.

6. References

Asif M. (2016) 'Growth and Sustainability Trends in the Buildings Sector in the GCC Region with Particular Reference to the KSA and UAE', *Renewable and Sustainable Energy Reviews,* 55, pp.1267-1273.

Bai Y., Jiang B., Wang M., et al. (2016) 'New Ecological Redline Policy (ERP) to Secure Ecosystem Services in China', *Land Use Policy,* 55, pp.348-351.

Boori M.S., Choudhary K., Paringer R., et al. (2021) 'Spatiotemporal ecological vulnerability analysis with statistical correlation based on satellite remote sensing in Samara, Russia'. *Journal Environmental Management,* 285, pp.112138.

Folke C., Biggs R., Norström A.V., et al. (2016) 'Social-Ecological Resilience and Biosphere-Based Sustainability Science', *Ecology and Society,* 21(3), p.41.

Karimi F. M., Fathololoumi S., Kiavarz M., et al. (2021) 'Land Surface Ecological Status Composition Index (LSESCI): A novel remote sensing-based technique for modeling land surface ecological status'. *Ecological Indicators,* 123, pp.107375.

Liu H., Jiang Y., Misa R., et al. (2021) 'Ecological environment changes of mining areas around Nansi lake with remote sensing monitoring', *Environmental Science and Pollution research*, 28(32), pp.44152-44164

Maity S., Das S., Pattanayak J.M., et al. (2022) 'Assessment of ecological environment quality in Kolkata urban agglomeration, India', *Urban Ecosystems*, 25(4), pp.1137-1154.

Shan W., Jin X., Ren J., et al. (2019) 'Ecological environment quality assessment based on remote sensing data for land consolidation', *Journal of Cleaner Production,* 239, pp.118126.

Wen X., Ming Y., Gao Y., et al. (2020) 'Dynamic monitoring and analysis of ecological quality of pingtan comprehensive experimental zone, a new type of sea island city, based on RSEI'. *Sustainability,* 12(1), p.21.

Wu S., Gao X., Lei, J. et al. (2022) 'Ecological environment quality evaluation of the Sahel region in Africa based on remote sensing ecological index'. *Journal of Arid Land,* 14(1), pp.14-33.

Xiong Y., Xu W., Lu N., et al. (2021) 'Assessment of Spatial–Temporal Changes of Ecological Environment Quality Based on RSEI and GEE: A Case Study in Erhai Lake Basin, Yunnan Province, China'. *Ecological Indicators*, 125, p.107518.

Xu H. (2013) 'A remote sensing index for assessment of regional ecological changes', *China Environmental Science,* 33(5), pp.889-897.

Xu H., Wang M., Shi T., et al. (2018) 'Prediction of ecological effects of potential population and impervious surface increases using a remote sensing based ecological index (RSEI)', *Ecological Indicators,* 93, pp.730–740.

Yang X.Y., Meng F., Fu P.J., et al. (2021) 'Spatiotemporal change and driving factors of the Eco-Environment quality in the Yangtze River Basin from 2001 to 2019', *Ecological Indicators*, 131, p.108214

Yuan B.D., Fu L.N., Zou Y., et al. (2021) 'Spatiotemporal change detection of ecological quality and the associated affecting factors in Dongting Lake Basin, based on RSEI', *Journal of Cleaner Production*, 302, p.126995

Yue H., Liu Y., Li Y., et al. (2019) 'Eco-Environmental Quality Assessment in China's 35 Major Cities Based on Remote Sensing Ecological Index', *IEEE Access,* 7, pp.51295-51311.

Zhang X., Fan H., Zhou C., et al. (2023) 'Spatiotemporal Change in Ecological Quality and Its Influencing Factors in the Dongjiangyuan Region, China'. *Environmental Science and Pollution research,* 30(26), pp.69533–69549.

Zheng Z.H., Wu Z.F., Chen Y.B., et al. (2020) 'Marinello Exploration of eco-environment and urbanization changes in coastal zones: A case study in China over the past 20 years', *Ecological Indicators*, 119, p.106847

Zhou Z., Du J., Liu Y. (2020) 'Evolution development and evaluation of eco-transportation in Guangdong-Hong Kong-Macao Greater Bay Area'. *Systems Science & Control Engineering*, 8(1), pp.97-107.

Zhu D.Y., Chen T., Niu R.Q., et al. (2021) 'Analyzing the Ecological Environment of Mining Area by Using Moving Window Remote Sensing Ecological Index'. *Geomatics and Information Science of Wuhan University*, 46(3), pp.341-347.