

Remote Sensing Monitoring of Ecological Environment Change in Jinchuan Mining Area, China

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Abstract

The mining activity in Jinchuan has a history of many years. Copper and nickel mining not only plays a supporting role in the local social and economic development, but also has a significant impact on the ecological environment of the region. Based on Landsat series remote sensing data from 1994 to 2024, the impacts of copper and nickel mining on ecological environment in Jinchuan region were studied. Then, the characteristics of ecological environment and temporal and spatial changes were analyzed by using remote sensing Ecological index (RSEI). The results show that the environmental change is related to mining exploitation and annual precipitation. From 1994 to 2024, the overall ecological quality of the study area has improved. Areas with improved ecological quality are mainly distributed in the northeast. In a few areas in the south where mining activities are concentrated, the ecological quality has declined. This change is mainly due to large-scale underground mining, and necessary measures should be taken to improve the environmental quality.

Keywords

Jinchuan Area, Copper-Nickel Mining, Ecological Environment, Remote Sensing Ecological Index, Spatiotemporal Variation, Ecological Quality, Mining Impact, Environmental Management

1. Introduction

The exploitation of mineral resources plays a vital role in driving economic development, especially in resource-rich regions. However, mining activities are often accompanied by serious ecological and environmental problems, especially in the

case of long-term, large-scale development [1]. Located in northwest China, Jinchuan area is an important copper and nickel mineral base in the country, and its mining has a history of decades. These mining activities have not only made important contributions to the local socio-economic development, but also had a significant negative impact on the ecological environment of the region [2].

In recent years, with the increasing awareness of ecological environment protection, more and more studies have begun to pay attention to the ecological changes and sustainable development of mining areas [3]. Due to its special geographical location and intensive mining of mineral resources, the local ecosystem in Jinchuan region is faced with a series of challenges such as vegetation degradation, soil erosion and soil pollution. In order to better understand the impact of mining activities on the environment and provide scientific basis for ecological restoration, remote sensing technology has been widely used in the monitoring and assessment of ecological environment due to its advantages of wide coverage and long time span [4].

Based on Landsat series remote sensing data from 1994 to 2024, this paper studied the temporal and spatial effects of copper and nickel mining on ecological environment in Jinchuan region. Based on the Remote Sensing Ecological Index (RSEI), the changes of the ecological environment were systematically analyzed to reveal the spatio-temporal evolution trend of the environmental quality in the mining area. RSEI has been proven to be an effective tool for assessing eco-environmental quality over large areas [5].

From 1994 to 2024, the overall ecological quality of the study area has improved. Areas with improved ecological quality are mainly distributed in the northeast. In a few areas in the south where mining activities are concentrated, the ecological quality has declined. This change is closely related to large-scale underground mining activities and the change of annual precipitation [6]. In order to mitigate the negative impact of mining on the ecological environment, it is necessary to take effective environmental management and restoration measures to improve the environmental quality of the region [7].

The research in this paper not only provides a scientific basis for understanding the environmental impact of mining activities in Jinchuan area, but also provides an important reference for formulating environmental protection policies and sustainable development strategies of mining areas. This research method, which combines remote sensing data with ecological assessment indicators, has wide application value for ecological environment monitoring and assessment in similar areas [8].

2. Overview of the Study Area

Jinchuan District of Jinchang City is located in the central part of Gansu Province, at the junction of Qilian Mountains and Loess Plateau. Its geographical coordinates are about 38°10' to 38°40' north latitude and 102°30' to 103°00' east longitude. The terrain of Jinchuan District is high in the west and low in the east, show-

ing a typical combination of mountain, hill and plain landform. The west is dominated by Qilian Mountains, which are high in height and rich in forest resources. In the east is the flat Loess Plateau, where the soil is fertile and suitable for agricultural production. In terms of climate, Jinchuan District belongs to the temperate continental climate, four distinct seasons, short and hot summer, cold and dry winter, the average annual temperature of about 7°C, less precipitation, annual precipitation of about 200 mm. Due to the influence of terrain and climate, the natural ecological environment of Jinchuan District is quite different. The mountain area is rich in vegetation coverage, with alternating distribution of forest, grassland and desert, while the plain area is mainly agricultural land, mainly planting wheat, corn and other crops. The ecological environment of Jinchuan District is facing certain pressure, especially the shortage of water resources and the expansion of desertified land. Therefore, in recent years, Jinchuan District has strengthened the work of ecological restoration and soil and water conservation, and strived to achieve the coordination and win-win of economic development and ecological protection. The remote sensing map of the study area is shown in **Figure 1**.

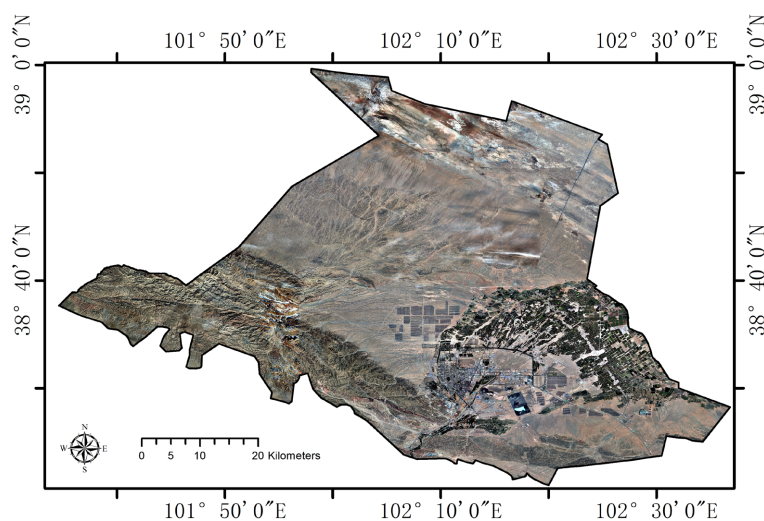


Figure 1. The remote sensing map of the study area.

3. Research Methods

1) Acquisition and processing of remote sensing data

In this study, Landsat series remote sensing image data from 1994 to 2024 were used to analyze the impact of copper and nickel mining on ecological environment in Jinchuan area. Landsat satellite data has the advantage of long time series, which can provide reliable data support for the study of spatio-temporal dynamics of ecological environment changes [9]. Data processing mainly includes image pre-processing and correction, with specific steps including radiation correction, atmospheric correction and geometric correction to ensure image accuracy and consistency.

2) Calculation of remote sensing Ecological index (RSEI)

In order to evaluate the change characteristics of ecological environment in Jinchuan area, this study introduced RSEI to analyze. RSEI is a comprehensive index based on various ecological factors, including greenness index, humidity index, heat index and dryness index. These factors are integrated into a comprehensive index through principal component analysis (PCA), which is used to evaluate the ecological quality of a region [10]. The calculation process of RSEI includes the following steps: First, the main factors of ecological environment are obtained through the extraction of remote sensing indicators such as NDVI, WET, LST and NDSI; Then, these factors are comprehensively analyzed by PCA to obtain the ecological quality index.

The RSEI (Remote Sensing Ecological Index) is chosen to evaluate the environment of the study area due to its numerous advantages. The RSEI is a comprehensive assessment tool. It is integrated through principal component analysis based on multiple factors such as greenness, humidity, heat, and dryness, enabling it to comprehensively reflect ecological quality, which is difficult to achieve with a single indicator or method. The remote sensing data it relies on, such as Landsat series data, is characterized by long-time series and wide coverage. This provides reliable data for the study of the temporal and spatial changes of the ecosystem. Moreover, the data processing methods are mature. Steps like radiometric correction, atmospheric correction, and geometric correction can ensure the accuracy and consistency of the images.

The RSEI can conduct time-series analysis. By comparing the values of different years, it can clearly reveal the changing trends and spatio-temporal characteristics of the ecosystem. It can also perform correlation analysis with other environmental factors to uncover the driving factors of ecological changes. Using software such as ArcGIS, the RSEI can carry out spatial interpolation and change detection, identify the areas where the ecological quality has changed, and quantify the spatial characteristics. It can also analyze the differences in ecological quality among different regions.

In addition, the RSEI has been widely applied and proven effective in multiple regions and ecosystems. It is highly efficient and accurate in data acquisition, processing, and analysis, showing obvious advantages compared with traditional ecological assessment methods. Therefore, in this study, the RSEI is adopted to evaluate the environment of the study area.

3) Temporal and spatial change analysis

After obtaining the RSEI value, this study analyzed the temporal and spatial changes of ecological environment in Jinchuan area. ArcGIS software was used to carry out spatial interpolation and change trend analysis on RSEI images of different periods, identify the changing regions of ecological environment quality, and quantify the spatial-temporal characteristics of the increase in the area of poor ecological quality and the decrease in the area of good and excellent ecological quality through change detection method [11]. Based on the time series analysis

of RSEI values from 1994 to 2024, the changing trend of ecological environment and its relationship with mining in Jinchuan region were revealed.

4) Correlation analysis of environmental factors

In order to further understand the driving factors of ecological environment change, this study combined mining activity data and annual precipitation data to analyze the relationship between these factors and ecological environment change. The correlation analysis method was used to evaluate the impact of factors such as mining intensity and precipitation on the change of ecological environment quality [12]. The results showed that there was a significant positive correlation between the increase of mining intensity and the decline of ecological quality, and the change of precipitation also had an important impact on regional ecological environment.

4. Results

1) The change of ecological environment quality

Through the analysis of Landsat remote sensing data from 1994 to 2024, the ecological environment quality of Jinchuan mining area has changed significantly. From 1994 to 2024, the overall ecological quality of the study area has improved. Areas with improved ecological quality are mainly distributed in the northeast. In a few areas in the south where mining activities are concentrated, the ecological quality has declined. The results indicate that the ecosystem quality of the mining area and its surrounding areas has generally shown a worsening trend over the past 30 years. The index maps of LST, NDBSI, NDVI, WET, and RSEI are shown in **Figures 2-6**.

2) Characteristics analysis of spatio-temporal changes

In terms of spatial distribution, the areas with poor ecological quality are mainly concentrated in the mining core and the areas with large mining influence, while the areas with good ecological quality or excellent ecological quality are gradually away from the mining core and distributed in the relative edge zone. In terms of time, the ecological degradation was mainly concentrated in the 1990s and early 2000s, which were the peak period of large-scale mining activities in Jinchuan Mining area.

3) Driving factors of environmental change

The study found that environmental change is closely related to mining activities and annual precipitation. Large-scale underground mining activities in mining areas are the main reason for the deterioration of ecological quality, resulting in land subsidence, vegetation destruction and soil pollution. In addition, the annual precipitation of Jinchuan area also has a significant impact on the change of ecological environment. The lack of precipitation further limits the recovery ability of regional vegetation, resulting in a more fragile ecological environment.

4) Regional differences of ecological degradation

There are significant differences in the degree of ecological degradation in different regions. The core area of mining area is affected by long-term large-scale mining activities, the ecological degradation is particularly obvious. In the areas

far away from the mining area, the impact of mining activities is small, and the degree of ecological degradation is relatively light, and the vegetation in some

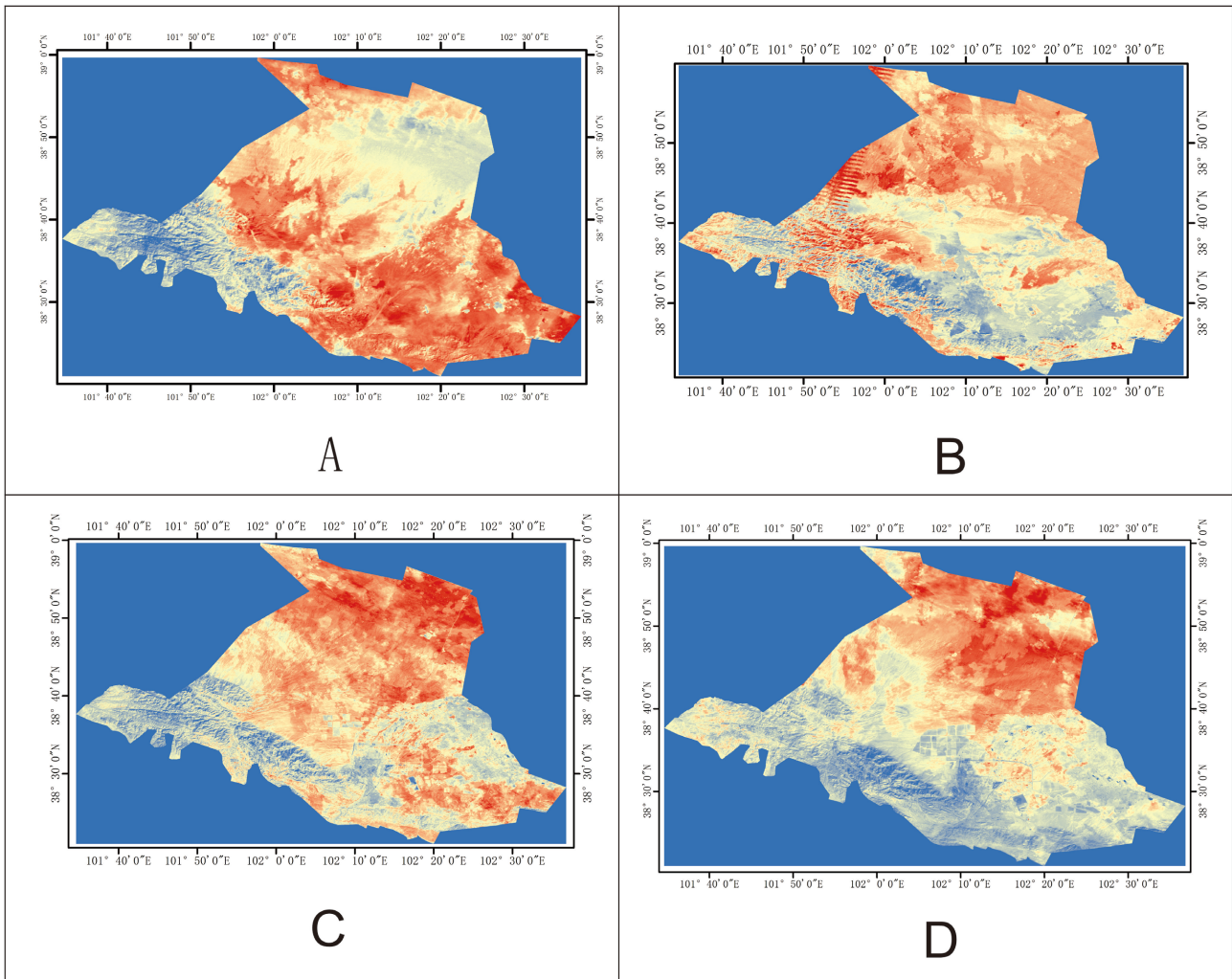
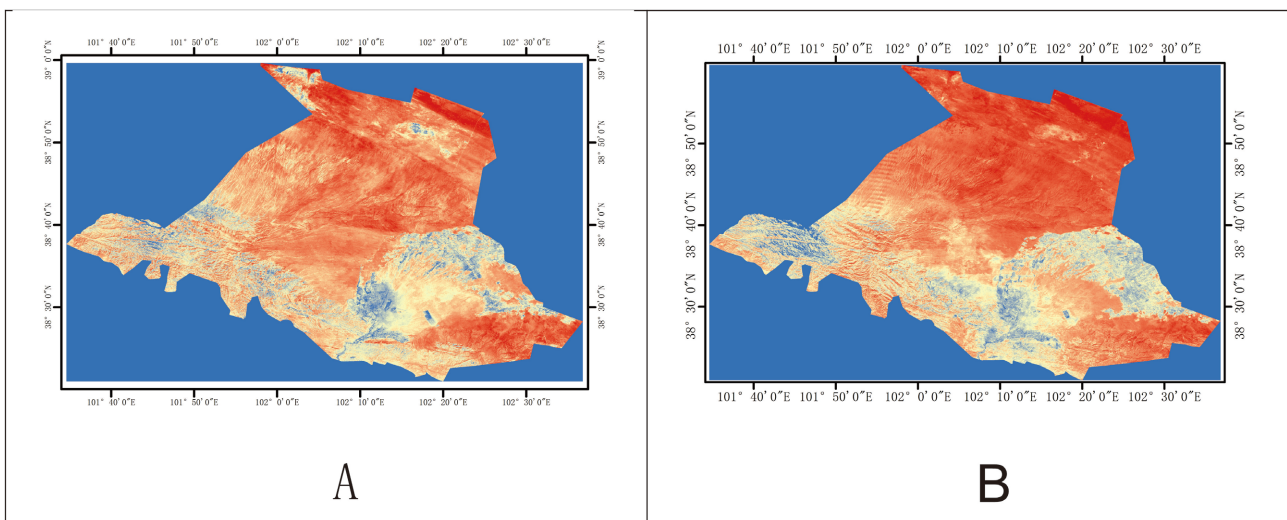


Figure 2. The index map of LST (1994, 2004, 2014, 2024).



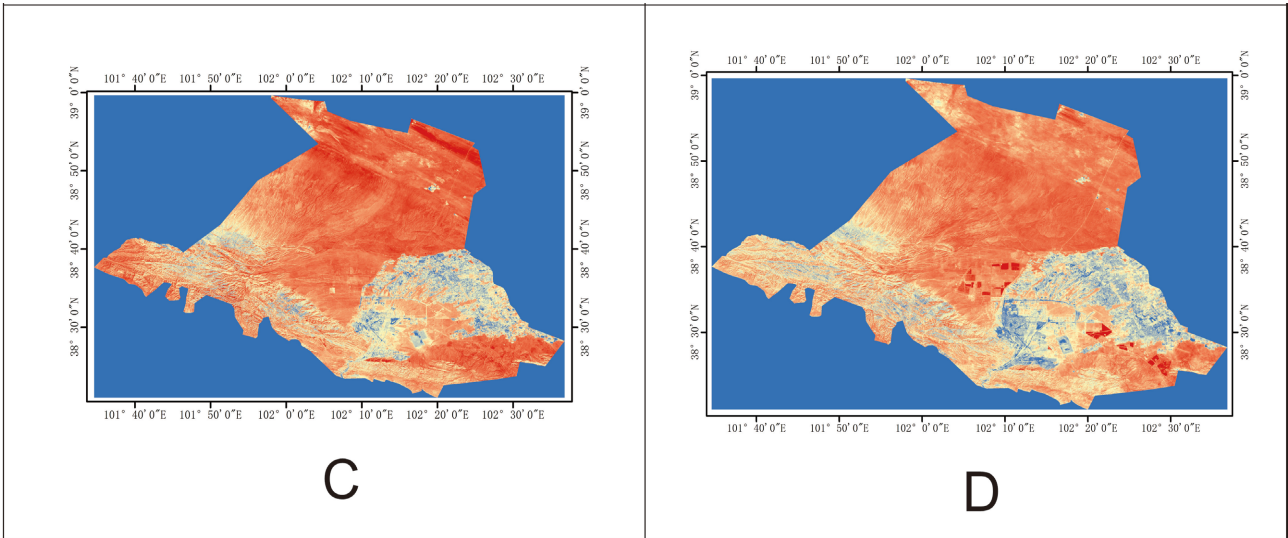


Figure 3. The index map of NDBSI (1994, 2004, 2014, 2024).

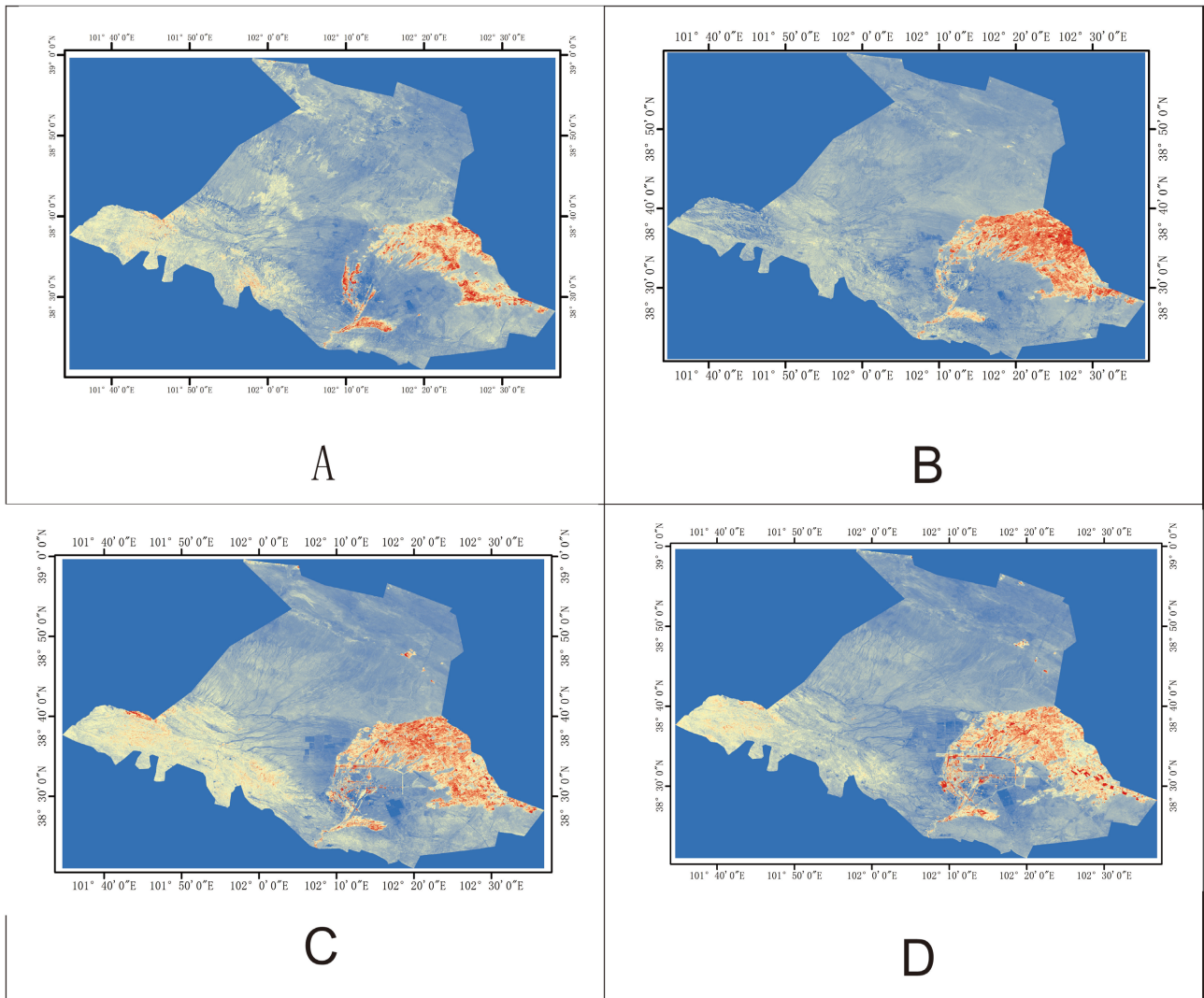


Figure 4. The index map of NDVI (1994, 2004, 2014, 2024).

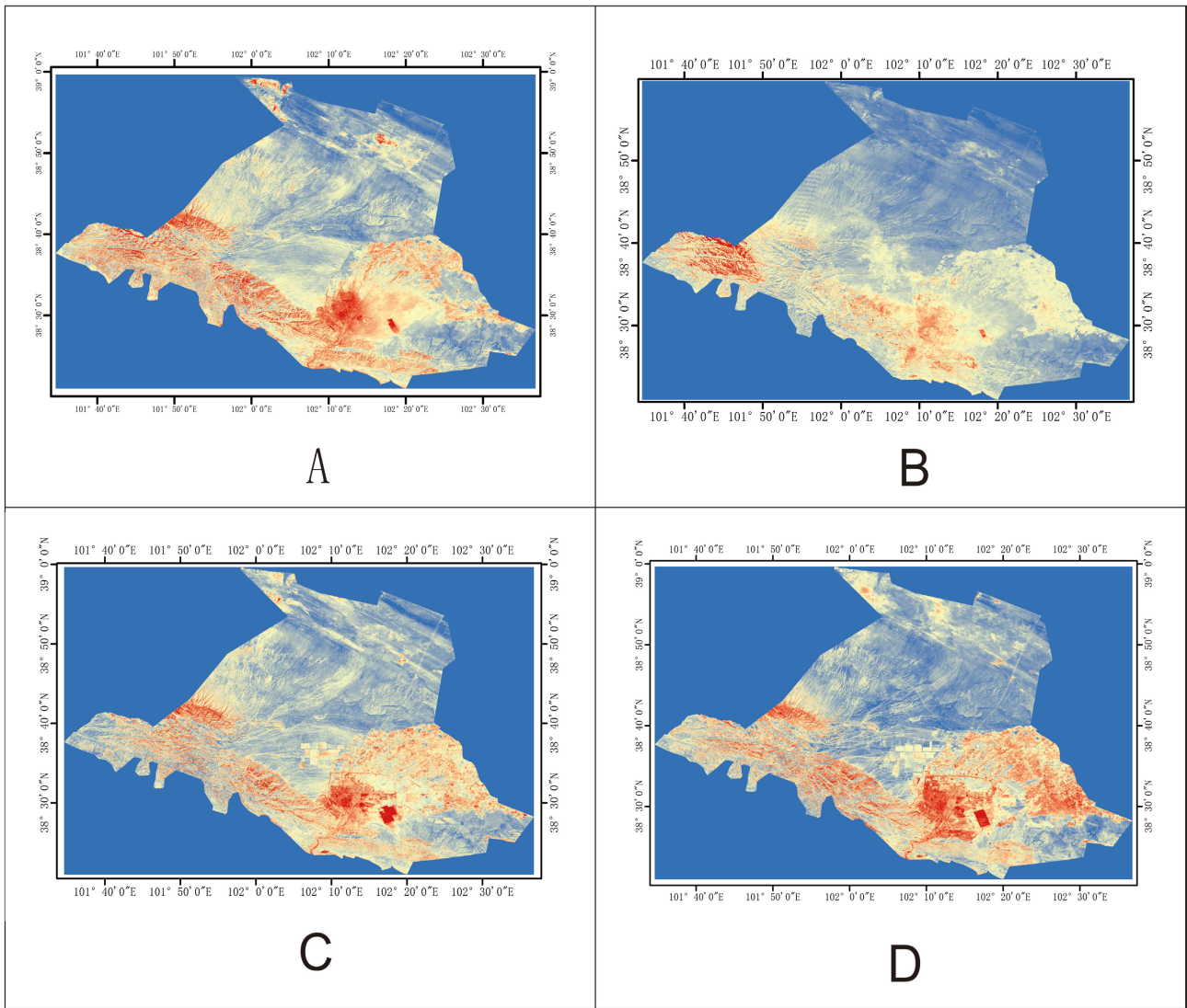
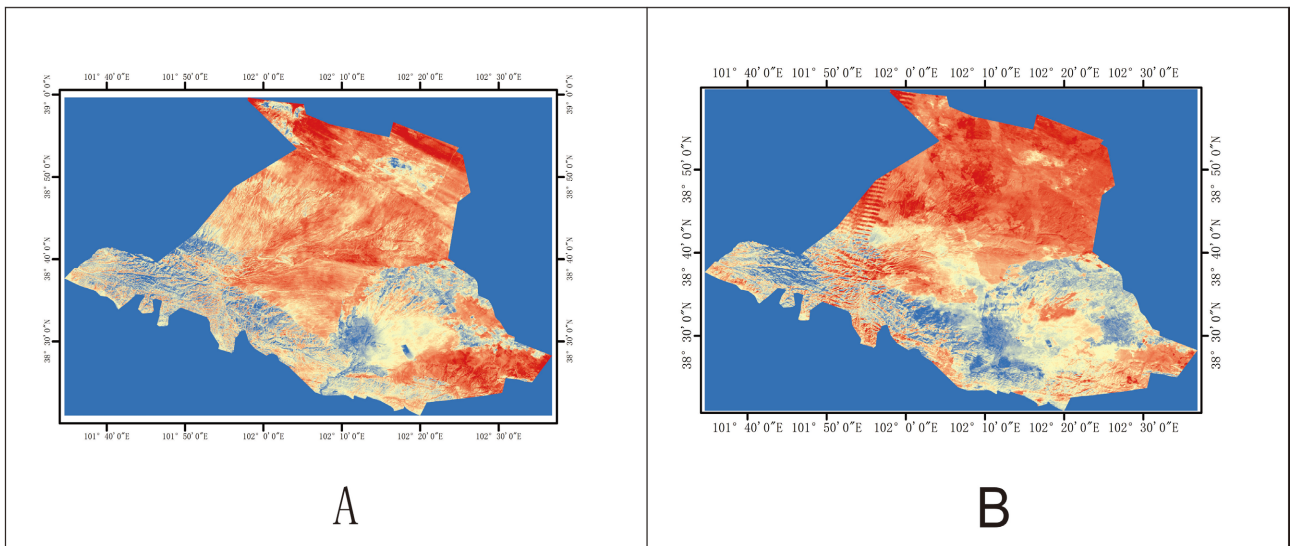


Figure 5. The index map of WET (1994, 2004, 2014, 2024).



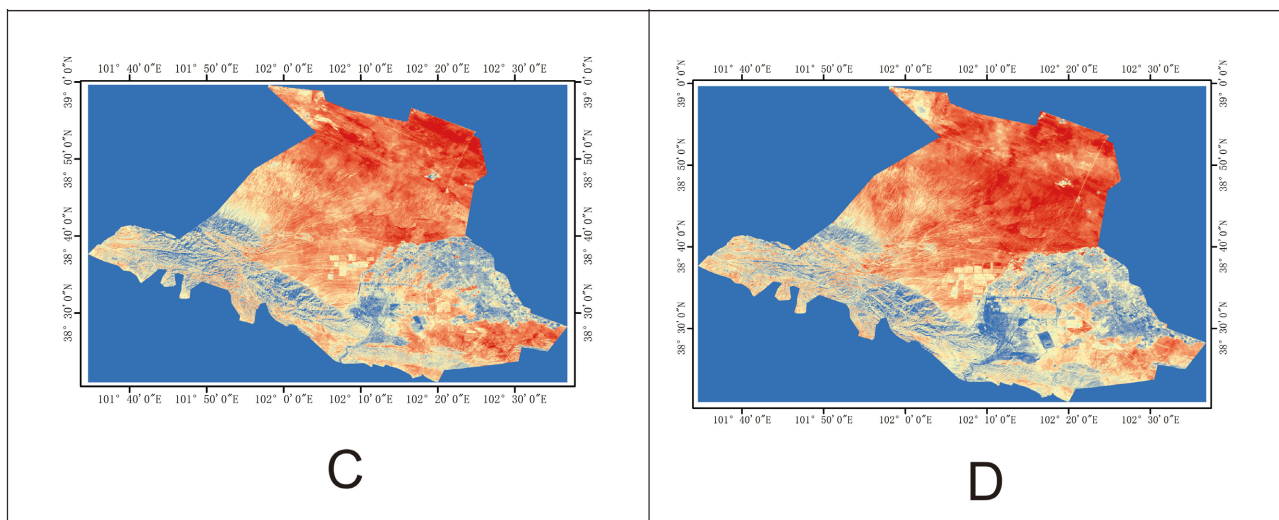


Figure 6. The index map of RESI (1994, 2004, 2014, 2024).

areas even has a certain ability to recover. This indicates that there is a significant correlation between the degree of ecosystem degradation in mining area and the spatial distribution of mining.

5) Suggestions for improving the quality of ecological environment

In order to reduce the negative impact of mining on the ecological environment, necessary ecological restoration and protection measures should be taken. For example, the disposal of waste should be strengthened to reduce the discharge of pollutants; Vegetation restoration projects should be carried out to increase green coverage; And reasonable management of groundwater resources to mitigate the impact of mining activities on the water table. Through the implementation of these measures, it is expected to improve the ecological environment quality of Jinchuan mining area and promote the sustainable development of the area. The change curves of LST, NDBSI, NDVI, WET and RSEI indices in 1994, 2004, 2014 and 2024 are shown in **Figures 7-11** as follows.

5. Discussion

1) The impact of copper-nickel mining on ecological environment

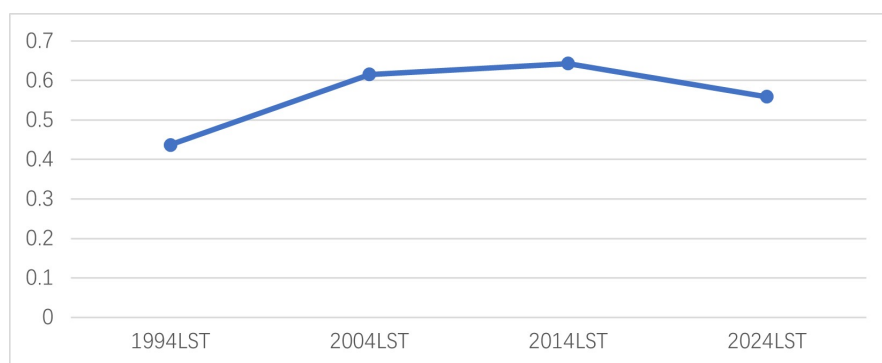


Figure 7. The change curve of the LST index.

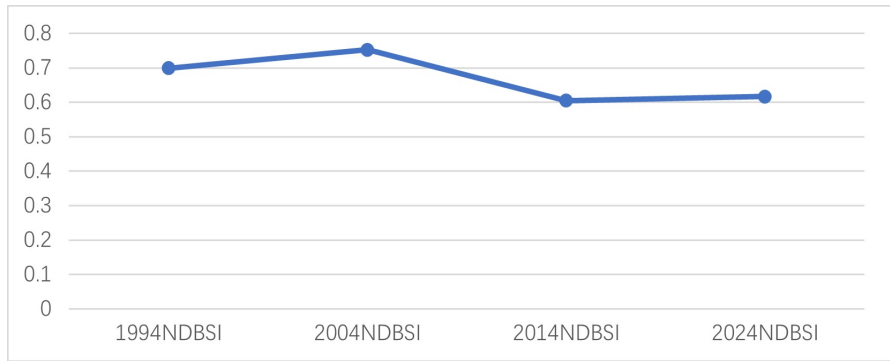


Figure 8. The change curve of the NDBSI index.

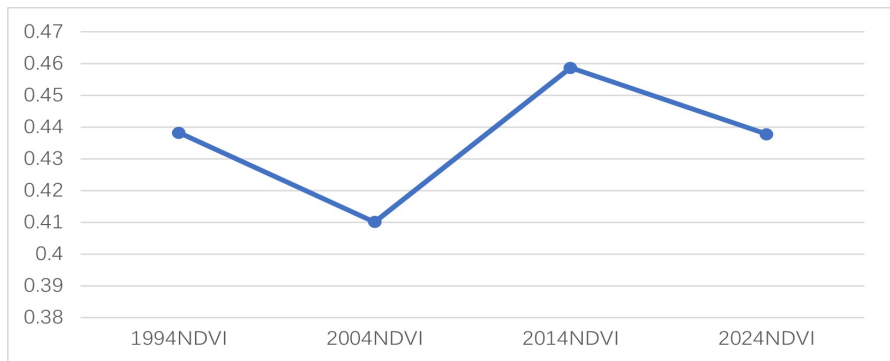


Figure 9. The change curve of the NDVI index.

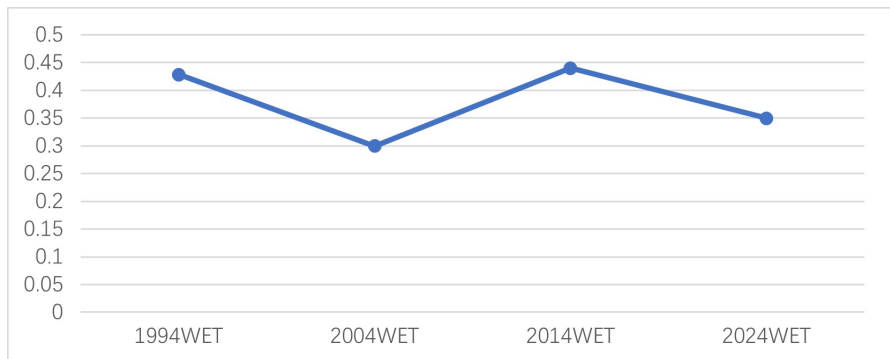


Figure 10. The change curve of the WET index.

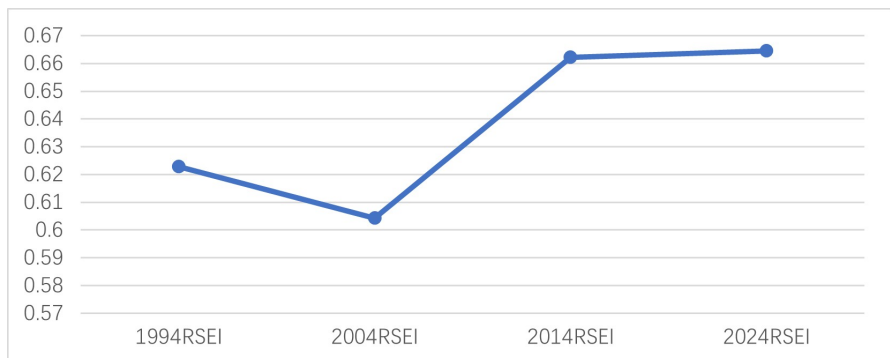


Figure 11. The change curve of the RSEI index.

This study reveals the significant impact of 30 years of copper-nickel mining on ecological environment in Jinchuan area. In the mining area, the area of poor ecological quality increased significantly, while the area of good and excellent ecological quality decreased gradually, which indicates that the pressure of mining on the regional ecosystem is increasing day by day. This change is mainly attributed to surface subsidence, soil pollution and vegetation destruction caused by large-scale underground mining activities. Waste and heavy metal pollution from mining activities have had a serious impact on soil and water bodies, further aggravating the decline in ecological quality in the region.

2) The contradiction between mining development and ecological protection

Mining in Jinchuan mining area has played an important role in promoting regional economic development, but it has also been accompanied by serious ecological and environmental degradation. This phenomenon reveals the contradiction between mining development and ecological protection. On the one hand, the mining of mineral resources has brought huge benefits to the local society and economy, providing support for infrastructure construction and the improvement of residents' lives. On the other hand, the vulnerability of the mining ecosystem continues to emerge under large-scale mining activities, and the ecological degradation seriously threatens the biodiversity of the region and the quality of life of the residents.

3) The influence of climate factors

In addition to mining activities, climatic factors, especially the fluctuation of annual precipitation, also have a significant impact on the change of ecological environment. The annual precipitation itself is low in Jinchuan area, and there are significant inter-annual fluctuations, which limits the resilience of the ecosystem to environmental disturbances. In dry years, vegetation recovery is difficult, and the vulnerability of the ecosystem is more prominent. Therefore, the superimposed effect of climatic conditions and mining activities further aggravated the deterioration of ecological environment in Jinchuan region.

4) Challenges and coping strategies of ecological restoration

In view of the ecological degradation in Jinchuan area, a series of ecological restoration suggestions were put forward. However, due to the particularity of mining environment, ecological restoration faces many challenges. First of all, long-term mining leads to the destruction of soil structure and heavy metal pollution, making vegetation restoration difficult. Secondly, due to the arid climate in the region, the shortage of water resources limits the growth and recovery of vegetation. To address these issues, it is recommended to implement ecosystem-based restoration strategies, such as strengthening waste management and reducing emissions of pollution sources; Vegetation restoration using drought-resistant native plants; And reasonable management of groundwater resources to support ecological restoration needs (Zhao et al., 2024).

5) The necessity of sustainable development in mining area

The results of this study emphasize the necessity of sustainable development of mining areas. In order to realize the sustainable development of Jinchuan mining area, it is necessary to find a balance between economic interests and ecological protection. The government and mining enterprises should jointly assume the responsibility of environmental protection, strengthen the ecological restoration of the mining area, and reduce the negative impact of mining on the environment. In addition, it is also necessary to enhance the public's awareness of environmental protection and actively participate in ecological restoration and protection, with a view to realizing the coordinated development of economic, social and environmental benefits.

6) Limitations of RSEI index

The Remote Sensing Ecological Index (RSEI) has certain limitations in evaluating the quality of the ecological environment. Firstly, RSEI is sensitive to atmospheric conditions. Clouds, aerosols, water vapor, etc. in the atmosphere can scatter and absorb electromagnetic waves, reducing the clarity and accuracy of remote-sensing data and affecting the calculation results of RSEI. For example, in areas with heavy cloud cover, it is more difficult to acquire and process remote-sensing data, resulting in deviations in the calculation of RSEI. Secondly, RSEI is also quite sensitive to the selection of data pre-processing. Different data pre-processing methods, such as radiometric correction, atmospheric correction, and geometric correction, can significantly affect the quality of remote-sensing data, and thus influence the accuracy and reliability of RSEI. For instance, insufficient radiometric correction may lead to inaccurate radiance values of remote-sensing data, affecting the calculation of RSEI.

7) Impact of the complex interactions among the RSEI index, mining, precipitation, and other environmental factors on the environment

There are complex interactions among the RSEI index, mining activities, precipitation, and other environmental factors, which have a significant impact on the ecological environment. Firstly, the damage of mining activities to the ecological environment is obvious. Large-scale underground mining activities can cause surface subsidence, vegetation damage, and soil pollution, thus reducing the RSEI value. For example, in the Jinchuan area, in the southern region where mining activities are concentrated, the ecological quality has declined significantly, and the RSEI value has decreased. Secondly, as an important climatic factor, precipitation plays a crucial role in the restoration and maintenance of the ecological environment. The annual precipitation in the Jinchuan area is low and has large inter-annual fluctuations, which limits the vegetation restoration ability and further exacerbates the vulnerability of the ecosystem. In years with less precipitation, the vegetation coverage decreases, and the RSEI value drops. In addition, other environmental factors such as land-use types, topography, and human activities also affect the RSEI. For example, changes in land-use types, especially the transformation from natural vegetation cover to construction land, can significantly reduce the RSEI value. The interactions of these factors make the changes

in the RSEI value more complex, and it is necessary to consider multiple factors comprehensively to accurately assess the changes in the quality of the ecological environment.

8) The impact of mining methods on the environment

Both open-pit mining and underground mining have significantly impacted the environment of the Jinchuan study area. Open-pit mining mainly causes problems such as soil erosion, ground subsidence, and dust pollution by altering the surface landforms, damaging vegetation and soil structure, thus affecting the regional ecological balance. Underground mining, on the other hand, mainly leads to surface subsidence, vegetation damage, and soil pollution. These activities not only reduce the regional ecological quality but also further exacerbate the degradation of the ecosystem by changing the land-use types and topography.

6. Conclusions

Based on Landsat remote sensing data from 1994 to 2024 and remote sensing Ecological Index (RSEI), this study analyzed the temporal and spatial changes of the impact of copper and nickel mining on ecological environment in Jinchuan area. The results show that the ecological environment of the mining area has undergone significant degradation in the past 30 years, especially in the area where mining activities are concentrated. From 1994 to 2024, the overall ecological quality of the study area has improved. Areas with improved ecological quality are mainly distributed in the northeast. In a few areas in the south where mining activities are concentrated, the ecological quality has declined. These changes are mainly attributed to large-scale underground mineral mining activities as well as fluctuations in annual precipitation within the regions.

Although mining activities have played an important role in supporting the local social and economic development, they have also caused a negative impact on the ecosystem of Jinchuan that cannot be ignored. The degradation of the ecosystem not only weakens the carrying capacity of the regional environment, but also poses a threat to the quality of life of residents and the sustainable development of the region.

Therefore, in order to realize the sustainable development of Jinchuan mining area, it is necessary to take effective ecological restoration and environmental protection measures in the future. This includes reducing the ecological damage caused by mining, strengthening waste management, implementing vegetation restoration projects and rational use of water resources. Through the implementation of these comprehensive measures, the ecological environment quality of Jinchuan mining area can be effectively improved and the long-term sustainable development of the mining area can be promoted.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

- [1] Chen, Y., Suo, Z., Lu, H., Cheng, H. and Li, Q. (2023) Active-Passive Remote Sensing Evaluation of Ecological Environment Quality in Juye Mining Area, China. *Remote Sensing*, **15**, Article 5750. <https://doi.org/10.3390/rs15245750>
- [2] Cai, Z., Fan, C., Chen, F. and Li, X. (2021) Pseudo-Invariant Feature-Based Linear Regression Model (PIF-LRM): An Effective Normalization Method to Evaluate Urbanization Impacts on Land Surface Temperature Changes. *Atmosphere*, **12**, Article 1540. <https://doi.org/10.3390/atmos12111540>
- [3] Dai, Q., Cui, C. and Wang, S. (2022) Spatiotemporal Variation and Sustainability of NDVI in the Yellow River Basin. *Irrigation and Drainage*, **71**, 1304-1318. <https://doi.org/10.1002/ird.2740>
- [4] Geng, J., Yu, K., Xie, Z., Zhao, G., Ai, J., Yang, L., *et al.* (2022) Analysis of Spatiotemporal Variation and Drivers of Ecological Quality in Fuzhou Based on RSEI. *Remote Sensing*, **14**, Article 4900. <https://doi.org/10.3390/rs14194900>
- [5] Hou, X., Liu, L., Li, X., Wang, Z., Zhang, C., Gao, M., *et al.* (2023) Changes of Ecological Vegetation in Major Coal Bases in North China. *Environmental Earth Sciences*, **82**, Article No. 522. <https://doi.org/10.1007/s12665-023-11187-5>
- [6] Hu, X. and Xu, H. (2018) A New Remote Sensing Index for Assessing the Spatial Heterogeneity in Urban Ecological Quality: A Case from Fuzhou City, China. *Ecological Indicators*, **89**, 11-21. <https://doi.org/10.1016/j.ecolind.2018.02.006>
- [7] McKenna, P.B., Lechner, A.M., Phinn, S. and Erskine, P.D. (2020) Remote Sensing of Mine Site Rehabilitation for Ecological Outcomes: A Global Systematic Review. *Remote Sensing*, **12**, Article 3535. <https://doi.org/10.3390/rs12213535>
- [8] Nie, X., Hu, Z., Ruan, M., Zhu, Q. and Sun, H. (2022) Remote-Sensing Evaluation and Temporal and Spatial Change Detection of Ecological Environment Quality in Coal-Mining Areas. *Remote Sensing*, **14**, Article 345. <https://doi.org/10.3390/rs14020345>
- [9] Zhang, P., Chen, X., Ren, Y., Lu, S., Song, D. and Wang, Y. (2023) A Novel Mine-Specific Eco-Environment Index (MSEEI) for Mine Ecological Environment Monitoring Using Landsat Imagery. *Remote Sensing*, **15**, Article 933. <https://doi.org/10.3390/rs15040933>
- [10] Liao, W. and Jiang, W. (2020) Evaluation of the Spatiotemporal Variations in the Eco-Environmental Quality in China Based on the Remote Sensing Ecological Index. *Remote Sensing*, **12**, Article 2462. <https://doi.org/10.3390/rs12152462>
- [11] Xu, H., Wang, M., Shi, T., Guan, H., Fang, C. and Lin, Z. (2018) Prediction of Ecological Effects of Potential Population and Impervious Surface Increases Using a Remote Sensing Based Ecological Index (RSEI). *Ecological Indicators*, **93**, 730-740. <https://doi.org/10.1016/j.ecolind.2018.05.055>
- [12] Zheng, Z., Wu, Z., Chen, Y., Guo, C. and Marinello, F. (2022) Instability of Remote Sensing Based Ecological Index (RSEI) and Its Improvement for Time Series Analysis. *Science of the Total Environment*, **814**, Article ID: 152595. <https://doi.org/10.1016/j.scitotenv.2021.152595>