Environment, Resource and Ecology Journal (2022)
Clausius Scientific Press, Canada

DOI: 10.23977/erej.2022.060508
ISSN 2616-3756 Vol. 6 Num. 5

Spatial and Temporal Change Assessment and Driving Force Analysis of Urumqi Ecological Environment Based on RSEI

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Keywords: Remote sensing and environmental data, Remote sensing ecological environment index, Urumqi, Temporal and spatial changes, Urban expansion

Abstract: This paper studied and analyzed the characteristics and internal driving forces of the ecological environment quality change in Urumqi from 2013 to 2021. The remote sensing ecological index RSEI was constructed using the principal component analysis method, Dynamic control and assessment of Urumqi's ecological environment quality based on RSEI can be realized. The experimental results show that the ecological environment in the study area has experienced both improvement and deterioration from 2013 to 2021, but the overall trend is to improve. From 2015 to 2017, the degree of deterioration was relatively serious. In the process of urban expansion in the study area, the ecological environment of the area was slightly improved. It provides a scientific basis for improving the ecological environment quality of the region.

1. Introduction

Due to the rapid development of China in recent years, the process of urbanization is accelerating, and the energy mining industry has also emerged in succession, which has also created many serious environmental problems in the process of China's economic and social prosperity [1-3]. For the changes in the ecological environment quality, we can observe the changes in the regional environment accurately, efficiently and in a large range through remote sensing technology and study the reasons [4-6]. Scientific research using remote sensing technology can not only conduct in-depth research on the evolution of ecological environment at various time scales, but also objectively analyze the changes of ecological environment quality from an all-round perspective.

With the comprehensive development of remote sensing technology, the analysis and evaluation of remote sensing ecological index (RSEI) has become an important means of regional ecological environment monitoring. In 2013, Xu Hanqiu and other scholars put forward that the remote sensing ecological index is composed of four environmental indexes, namely, greenness, humidity, heat and dryness [4]. This index not only achieves the effect of quantitative evaluation of regional ecological environment quality, but also can make a visual expression of the evaluation conclusion in terms of space size [7]. The RSEI model has been successfully used to control and evaluate the ecological environment of mines [8], hydropower development zones [9], grasslands [10], wetlands [11], river basins [12] and cities [13]. Urumqi urban area is located in the middle of Xinjiang, with a typical temperate continental climate. The construction temperature is high and relatively hot. The winter is cold, the air is relatively poor, and the annual average rainfall is small. All the above reasons have resulted in the fragile ecological environment of Urumqi City, which will inevitably lead to the change of the ecological environment in its urbanization process [14], and the change of the ecological environment will also affect the economic development of the region. Therefore, it is crucial to understand the characteristics of the space-time dynamic change of the ecological environment in the context of the rapid development of urbanization. At present, a lot of research has been done to discuss the relationship between the urbanization development level and the regional natural environment quality [15], but there are few studies on the use of remote sensing ecological index to build the study area to evaluate the spatial and temporal changes of regional ecological environment quality, and on the use of regional impervious water [16] and night light [17] and other data to quantitatively analyze the relationship between the urbanization process and the change of ecological environment quality.

In this paper, Urumqi, which is located in the northwest, is selected as the experimental area. Through the establishment of the RSEI model, the principal component analysis method and relevant software are used to study the spatial and temporal dynamic changes of the ecological environment in this area; The driving force of environmental change in the study area is analyzed by extracting the impervious surface data [16] of the study area and the remote sensing ecological index established by combining the night light data of the study area. Thus, the situation and main driving factors of eco-environment quality in northwest arid region are determined, which provides a reference for later research on related regions.

2. Study Area and Data

2.1. Overview of the Study Area

The study area is located in the north of Xinjiang Uygur Autonomous Region, the north of the middle Tianshan Mountains and the south of Junggar Basin. The total area is 14195.8584 km2 and the total population is 3.504 million. It is located between 42 45 '- 44 08'N and 86 37' - 88 58'E. The overall terrain varies greatly, and the mountainous area is vast. It belongs to the continental arid climate of the middle temperate zone. The spring and autumn are shorter, the winter and summer are longer, and the temperature difference between day and night is large. The whole Urumqi City includes Tianshan District, Shaibak District, Xinshi District, Shuimogou District, Toutunhe District, Dabancheng District, Midong District and Urumqi County. Seven districts and one county are shown in Figure 1.

2.2. Remote Sensing Data

The remote sensing data obtained in this study are mainly from the national geospatial data cloud. The cloud cover in the selected study area is less than 10%, and the time is the Landat8 OLI remote sensing image data of the same period in the summer of 2013, 2015, 2017, 2019, and 2021 respectively. The process of ecological transformation in the study area is monitored and evaluated, and the monthly luminous image (NPPVIRS) in China is also obtained as an important part of the driving force analysis. At the same time, the image of impervious water surface in the study area was extracted from the remote sensing image map. After weighting the impervious water surface and the luminous image in the study area, the driving force of the change of ecological environment quality was analyzed using the results obtained.

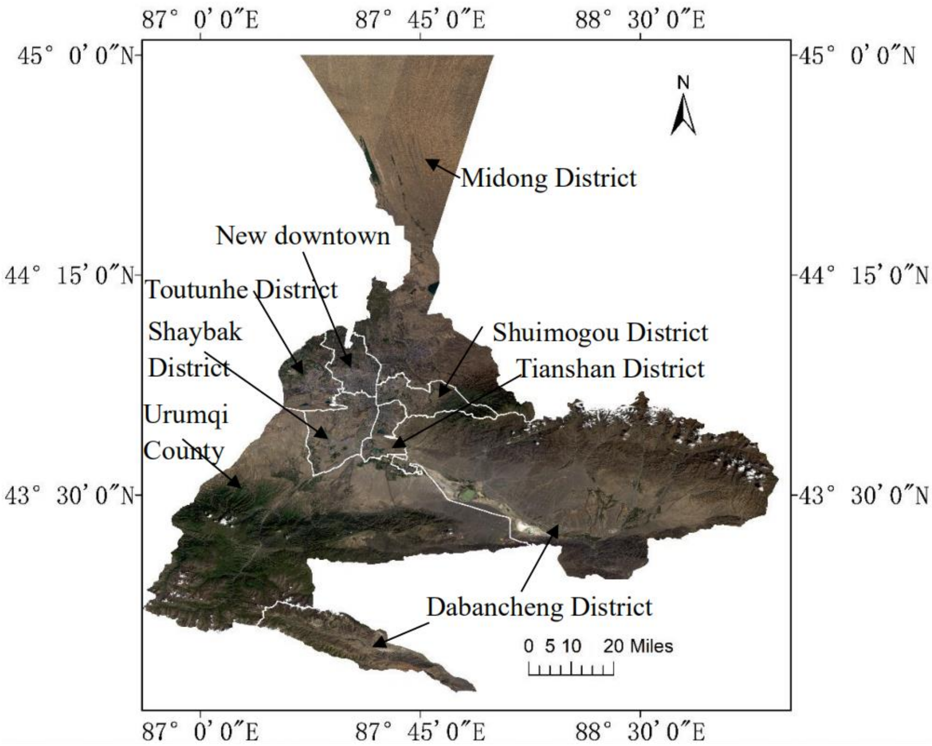

Figure 1: Location of the Study Area

3. Methods

3.1. Overall Idea of Experiment

This experiment first processes five remote sensing images from 2013 to 2021 to obtain four natural factors of greenness, humidity, heat and dryness (Greenness, Wetness, Dryness and Heat) in each year of the study area. This experiment uses four normalized indexes, NDVI, WET, NDBSI and LST, respectively. The calculation formula of normalization is

$$x_i = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}} \tag{1}$$

In the formula, $x_i$is the normalized indicator,$X_i$is the original metric,$X_{min}$is the minimum value in the original metric, $X_{max}$is the maximum value in the original metric.

Then the four indexes were processed by principal component analysis (PCA), and the corresponding remote sensing ecological index (RSEI) of each year in the study area was constructed. Remote sensing ecological index covers four natural environmental factors, such as plant coverage, humidity, heat and dryness, which are key factors to directly judge the quality of natural ecological environment. Therefore, RSEI index can be comprehensively used to evaluate and detect the quality of natural ecological environment in the scientific research area [18]. Therefore, the RSEI analysis in this paper will reflect the environmental level of the study area. Construct the RSEI remote sensing ecological index function, namely

$$RSEI = f\ (NDVI,\ WET,\ LST,\ NDBSI) \tag{2}$$

In the formula,NDVIis an indicator of greenness;WETis humidity indicator;LSTis a heat indicator;

NDBSIis an indicator of construction and bare soil.

For simple comparison, the RSEI index obtained is normalized with Formula (1) to make its value range around [0,1], and the closer the RSEI value range is to 1, the better the ecological environmental quality is. Thus, the ecological environmental quality of each year in the study area can be evaluated. After that, the RSEI values of the adjacent years are subtracted, and the ecological environment quality in the study area can be evaluated by the value of the difference.

In terms of driving force analysis of environmental change, firstly, extract the impervious surface of the study area through remote sensing images, and then conduct weighted synthesis with the night light remote sensing data images of the study area, observe the correlation between the results obtained and the corresponding RSEI index, analyze its internal causes, so as to achieve the purpose of driving force analysis of environmental change in the study area. The overall idea of the experiment is shown in Figure 2.

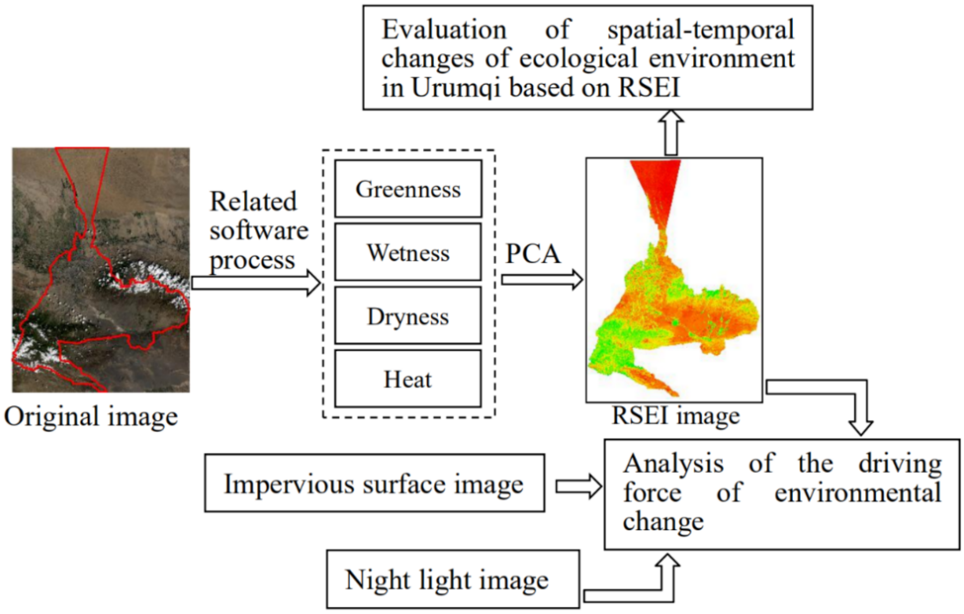

Figure 2: The overall idea of the experiment

3.2. Calculation of RSEI Parameters

The RSEI remote sensing ecological index model is constructed by green degree index (NDVI), humidity index (WET), heat index (LST) and dryness index (NDBSI). The calculation of each index is as follows

(1)Greenness

Greenness index is related to vegetation cover biomass, leaf area index and plant coverage in the studied area, and NDVI is also the most commonly used plant index. The calculation formula of NDVI is

$$NDVI = (B_4 - B_3) / (B_4 + B_3) \tag{3}$$

In the formula, B3 and B4represent the reflectance of the infrared and near-infrared bands of remote sensing data, respectively.

(2)Wetness

The brightness, greenness, moisture content and other components obtained from the remote sensing tassel cap have been widely used in ecological and environmental monitoring. The temperature and humidity index studied in this paper is represented by this temperature and humidity component, which reflects the temperature and humidity relationship between water, soil and plants, and is related to the natural environment.Thecalculation formula of WET is

$$WET = 0.1511 \times B_2 + 0.1973 \times B_3 + 0.3283 \times B_4 \\ +0.3407 \times B_5 - 0.7117 \times B_6 - 0.4559 \times B_7 \tag{4}$$

In the formula, B2~B7represents the reflectance of the blue, green, red, near-infrared, short-wave red outer1and short-wave redouter2bands of remote sensing data, respectively.

(3) Dryness

The dryness index is an indicator reflecting the degree of "drying" in the study area. The "drying" of urban areas is mostly caused by the expansion of construction land and large-scale bare land. Therefore, in this study, the construction bare soil index (NDBSI) synthesized by the building index (IBI) and bare land index (SI) is used to represent the dryness index of the study area. NDBSI is calculated by

$$SI = (B_6 + B_4 - B_5 - B_2) / (B_6 + B_4 + B_5 + B_2) \tag{5}$$

$$IBI = (2 \times B_6 / (B_6 + B_5) - (B_5 / (B_5 + B_4) + B_3 / (B_3 + B_6))) \\ /(2 \times B_6 / (B_6 + B_5) + (B_5 / (B_5 + B_4) + B_3 / (B_3 + B_6))) \tag{6}$$

$$NDBSI = (IBI + SI) / 2 \tag{7}$$

Where B2, B3, B4, B5, and B6 refer to the corresponding bands of landsat8, respectively.

(4) Heat

In this paper, the surface temperature (LST) is used to express the heat index, and the surface temperature is also an important part of judging the quality of the ecological environment. The calculation formula of LST is

$$pv = (NDVI - 0.05) / (0.7 - 0.05) \tag{8}$$

$$\mathrm{e} = 0.04 \times pv + 0.986 \tag{9}$$

$$L_{10} = gain * TIRS1 + bias \tag{10}$$

$$T = K_2 / ln\left(K_1 / L_{10} + 1\right) \tag{11}$$

$$LST = T / \left(1 + \left(lamda * T / p\right) * ln\left(e\right)\right) \tag{12}$$

Where, *e* is the surface emissivity; gain=(L_{max}-L_{min})/255, bias=L_{min}, where $L_{m/ax}$ and L_{min} are the maximum and minimum spectral radiance values respectively, which can be obtained from the MTL file of Landsat8. TIRS1 is the thermal infrared band of Landsat8. K1 and K2 values can be obtained from MLT documents of Landsat8. The central wavelength of TIRS1 band is 1.0895micron, lamda=1.0895; p=0.01438.

3.3. Principal Component Analysis

Principal component analysis [19] (PCA) transforms multiple indexes into a few multiple comprehensive indexes (i.e. principal components) by using the idea of dimension reduction. Each major factor can express the main content of each factor, and the required data do not overlap. With this method, complex factors are attributed to multiple main factors while introducing more factors, which makes the problem simpler, and the results are also reasonable data quality. This is exactly the way adopted in this project to realize the ecological environment assessment by selecting key and relatively independent comprehensive indexes among these indexes. After passing the principal component analysis, the first principal component PC1 is the RSEI0 of the initial remote sensing environmental indicators. In some cases, the lower the RSEI0 value of an area with good ecology, the 1-RSEI0 formula can be used to calculate, so that the place with high RSEI value indicates the better the ecology. The obtained RSEI value has been normalized so that its range is between [0,1]. The higher the value, sayit is clear that the natural environment in this area is good.

4. Experiment Result

4.1. Principal Component Analysis of Ecological Environment Indicators

Table 1: Principal component analysis of remote sensing ecological index

year	Statistical values	PC1	PC2	PC3	PC4
2013	eigenvalue	0.1468	0.0401	0.0117	0.0001
	Contribution Rate%	73.91	20.18	5.87	0.04
2015	eigenvalue	0.0410	0.0089	0.0010	0.0001
	Contribution Rate%	80.26	17.49	1.98	0.27
2017	eigenvalue	0.1304	0.0379	0.0118	0.0001
	Contribution Rate%	72.39	21.03	6.55	0.03
2019	eigenvalue	0.0289	0.0067	0.0006	0.0001
	Contribution Rate%	79.63	18.60	1.70	0.07
2021	eigenvalue	0.1561	0.0608	0.0150	0.0002
	Contribution Rate%	67.24	26.18	6.48	0.10

Table 2: Normalized mean statistics of ecological indicators and RSEI in different years

year	Statistical values	NDVI	WET	LST	NDBSI	RSEI
2013	minimum	-0.374	-1.000	-0.264	-0.627	0.004
	maximum	0.642	1.000	-0.027	0.644	1.000
	mean	0.128	0.718	-0.050	-0.004	0.243
	standard deviation	0.101	0.520	0.041	0.079	0.222
2015	minimum	-0.345	-1.000	-0.264	-0.629	0.004
	maximum	0.629	1.000	-0.027	0.573	1.000
	mean	0.112	0.700	-0.056	-0.009	0.361
	standard deviation	0.091	0.542	0.056	0.105	0.239
2017	minimum	-0.489	-1.000	-0.264	-0.621	0.004
	maximum	0.648	1.000	-0.027	0.561	1.000
	mean	0.118	0.678	-0.048	0.012	0.241
	standard deviation	0.100	0.562	0.040	0.074	0.222
2019	minimum	-0.457	-1.000	-0.264	-0.636	0.004
	maximum	0.611	1.000	-0.037	0.557	1.000
	mean	0.097	0.662	-0.048	0.015	0.382
	standard deviation	0.080	0.576	0.046	0.067	0.231
2021	minimum	-0.433	-1.000	-0.264	-0.629	0.004
	maximum	0.678	1.000	-0.027	0.677	1.000
	mean	0.127	0.648	-0.052	-0.011	0.396
	standard deviation	0.112	0.506	0.044	0.109	0.275

It can be seen from Table 1 that in the time area of this experimental study, the characteristic values of the first major element of the ecological environment indicators in 2013, 2015, 2017, 2019 and 2021 are 0.1468, 0.0410, 0.1304, 0.0289 and 0.1561 respectively, and their average contribution rates to the corresponding characteristic values are more than 70%, which indicates that PC1 has covered the main characteristics of the four indicators.

It can be seen from Table 2 that in 2013, the average value of the RSEI index in the study area in 2017 was relatively close and lower than that in other years, being 0.243 and 0.241 respectively, while in 2015, 2019 and 2021, the average value of the RSEI index in the study area was relatively close, being 0.361, 0.382 and 0.396 respectively. The average value of the RSEI index in these five years is on the rise as a whole. According to the change trend of four ecological indicators every year, the average value of greenness indicators will decrease slightly from 2013 to 2019, and increase in 2021. The mean value of humidity index has been decreasing slightly from 2013 to 2021. The mean values of heat index and dryness index both show a downward trend from 2013 to 2015, and an upward trend from 2017, and basically remain unchanged from 2017 to 2019, and will decline again in 2021. From the average changes of the above indexes, the average values of greenness index and dryness index have a large range of changes, indicating that the important factors affecting the changes of the ecological environment in Urumqi are greenness and dryness. According to the results of RSEI mean change in the past five years, Urumqi's natural and ecological environment has improved from 2013 to 2021.

4.2. Classification of Ecological Environment Quality in Urumqi

After obtaining the remote sensing image of PC1 after the principal component analysis by using the relevant software operation and referring to the environmental classification specifications in the National Technical Specifications for Ecological Environment Assessment [20], the remote sensing ecological indicators are divided into five levels according to the interval of 0.2, namely, ecological poor (0~0.2), ecological poor (0.2~0.4), ecological general (0.4~0.6), ecological good (0.6~0.8) and ecological excellent (0.8~1.0), The classification grade map of ecological environment quality is as shown in Figure 3, and after classification calculation, Figure 4 is obtained.

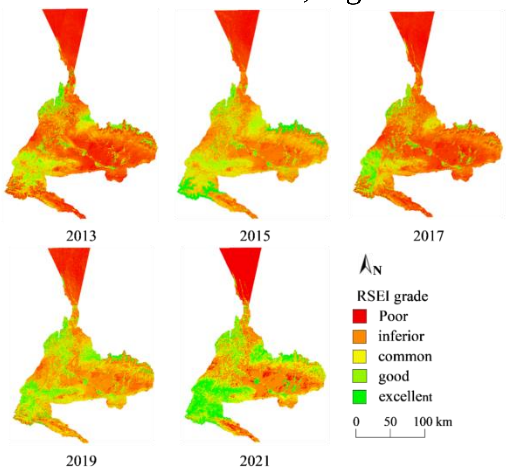

Figure 3: Rank distribution of RSEI in Urumqi

From the spatial distribution of remote sensing ecological index (Fig. 3), it can be seen that the regions with low ecological environment quality are concentrated in the desert area in the north of Urumqi (Midong District), and the regions with high altitude in the southwest (Urumqi County) and southeast (Dabancheng District). The ecological environment quality improved significantly from 2013 to 2015, but decreased significantly from 2015 to 2017. The ecological environment quality increased year by year in the following three years from 2017 to 2021.

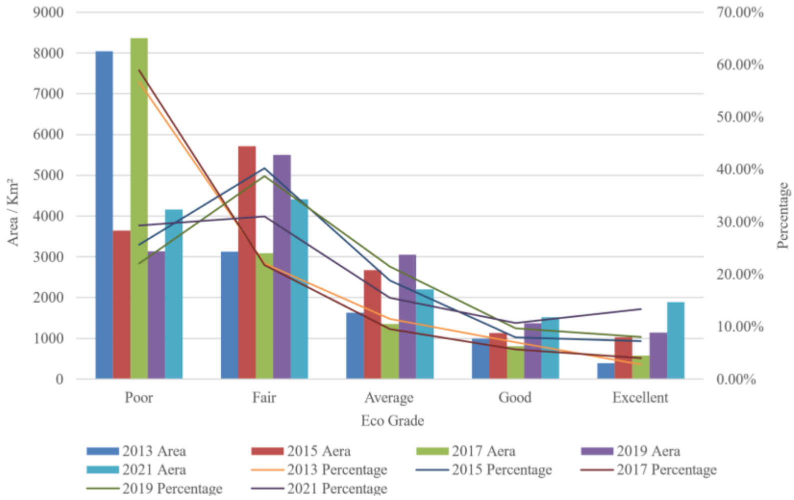

Figure 4: Classification of remote sensing ecological index and area of each grade in Urumqi from 2013 to 2021

It can be seen from Figure 4 that the area occupied by different years under the same level is obviously different, and 2013 and 2017 are significantly higher than other years in the two levels of poor and poor, which also shows that the ecological environment quality is poor in 2013 and 2017, and the corresponding RSEI indicators are low. In 2013, the area with poor grade accounted for 56.69% of the total area, while in 2015, the area with poor grade accounted for 25.67%. In 2017, it rose to 58.95%, and in 2019 and 2021, the proportion of the area with poor grade decreased significantly to 22.08% and 29.32%. The proportion of areas with poor ecological environment has increased from 22.03% in 2013 to 40.25% in 2015, indicating that the situation of areas with poor ecological environment has improved since 2013, but the proportion of areas with poor ecological environment in 2017 has decreased to 21.08%, indicating that the ecological environment is poor from 2015 to 2017, and the proportion of areas with poor ecological environment in 2019 and 2021 has increased to 38.76% and 31.08%. The change trend of the proportion of the area of regions with general ecological level is roughly the same as that of regions with poor ecological level. It can also be seen that the ecological environment improved from 2013 to 2015 and deteriorated from 2015 to 2017. In addition to a slight decline in the area proportion in 2017, the rest of the regions with a good ecological level show an upward trend. The areas with a good ecological level account for 7.01%, 7.99%, 5.68%, 9.66% and 10.72% of the total area, respectively. The change trend of the area of the region with excellent ecological level is the same as that of the region with good ecological level. In 2017, the area decreased, and the percentage of each year was 2.77%, 7.24%, 4.05%, 8.02% and 13.34% respectively. It can be seen from the above analysis that the ecological environment quality has experienced a fluctuating state of both improvement and deterioration in the eight years from 2013 to 2021. The overall trend is that the ecological environment quality of Urumqi has improved over time, and the deterioration of the ecological environment quality in 2017 is the most serious.

4.3. Assessment on Spatial-Temporal Changes of Ecological Environment

In order to further study the ecological environment change of Urumqi from 2013 to 2021, this experiment monitored the changes of RSEI index values in each year. The specific method is to subtract the RSEI index values of the adjacent years and divide the differences into five grades: significantly deteriorated (≤ - 0.6), slightly deteriorated (- 0.6~- 0.3), unchanged (- 0.3~0), slightly improved (0~0.3), significantly improved (≥ 0.3). The corresponding spatial distribution map is shown in Figure 5 and the ecological environment change grade is shown in Table 3. It can be seen from Table 3 that from 2013 to 2015, the area with significant and slight deterioration of the ecological environment in Urumqi accounted for 3.28% of the total area, while the percentage of slight and significant improvement was 79.43%. Therefore, from 2013 to 2015, the quality of the ecological environment in Urumqi has been greatly improved. From 2015 to 2017, the area of significantly deteriorated and slightly deteriorated ecological environment accounted for 7.32% of the total area, the area of slightly improved and significantly improved accounted for 15.54% of the total area, while the percentage of unchanged area was 77.23%, and the difference range of unchanged RSEI index was - 0.3~0. Therefore, in general, the ecological environment quality showed a deteriorating trend from 2015 to 2017. From 2017 to 2019, the area percentage of deterioration accounted for only 1.35%, while the area percentage of improvement was 85.77%, so the ecological environment quality improved significantly from 2017 to 2019. The area deteriorated from 2019 to 2021 accounted for 2.13%, and the area improved accounted for 37.97%, so the ecological environment quality improved from 2019 to 2021. According to the spatial location analysis, the areas where the ecological environment quality has deteriorated are concentrated in the northwest of Urumqi (Toutunhe District, Xinshi District and the southwest of Midong District) and the southwest of Urumqi (Shaibak District, Urumqi County). However, in general, from 2013 to 2021, the ecological environment quality of Urumqi was gradually improved, and only a few urban construction expansion areas were deteriorating, which also shows that the environmental governance of Urumqi urban area has achieved remarkable results in recent years, and the ecological environment has changed well.

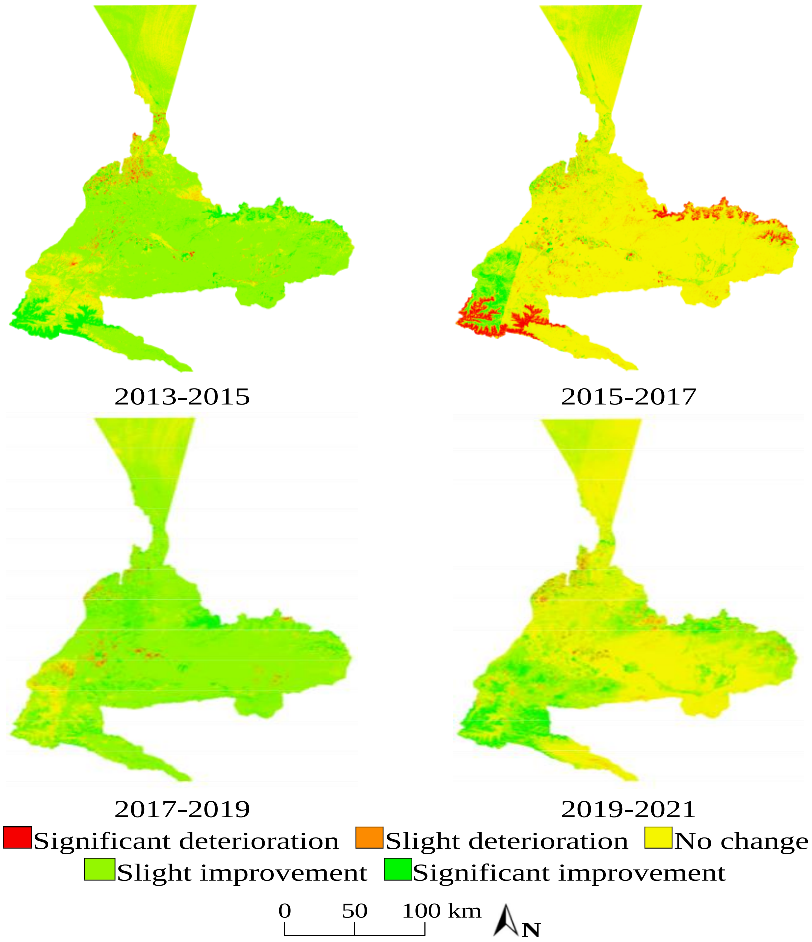

Figure 5: Monitoring of RSEI changes in Urumqi City in 2013-2021 years

Table 3: Ecological environment change hierarchy based on RSEI from 2013 to 2021

year	Change statistics	Significant deterioration	Slight deterioration	No change	Slight improvement	Significant improvement
2013-2015	Change area(km$^{2)}$	47.53	181.29	2691.68	10303.15	972.22
	Percentage (%)	0.33	1.28	18.96	72.58	6.85
2015-2017	Change area(km^{2})	525.38	513.87	10963.98	1820.16	372.48
	Percentage (%)	3.70	3.62	77.23	12.82	2.62
2017-2019	Change area(km^{2})	41.60	150.10	1828.64	11096.44	1079.08
	Percentage (%)	0.29	1.06	12.88	78.17	7.60
2019-2021	Change area(km^{2})	38.61	264.04	8502.57	4267.43	1123.21
	Percentage (%)	0.27	1.86	59.89	30.06	7.91

5. Discuss and Analyze

In order to explore the impact of human activities and other factors on the ecological environment quality of the study area, this experiment deeply discusses the impact of urban expansion on the ecological environment quality based on the impervious water surface image extracted from remote sensing images (as shown in Figure 6, left) and the luminous image of the study area (as shown in Figure 6, right). After normalizing the pixel values of the impervious water surface image and the luminous image respectively, the weighted synthesis is carried out. This experiment uses the weighted synthesis image to analyze the changes of the artificial ground in each county and district of Urumqi from 2013 to 2021, which is taken as the urban expansion of Urumqi from 2013 to 2021. And compare it with the average value of RSEI of each county in the study area, so as to obtain the internal relationship between urban expansion and ecological environment change in the study area.

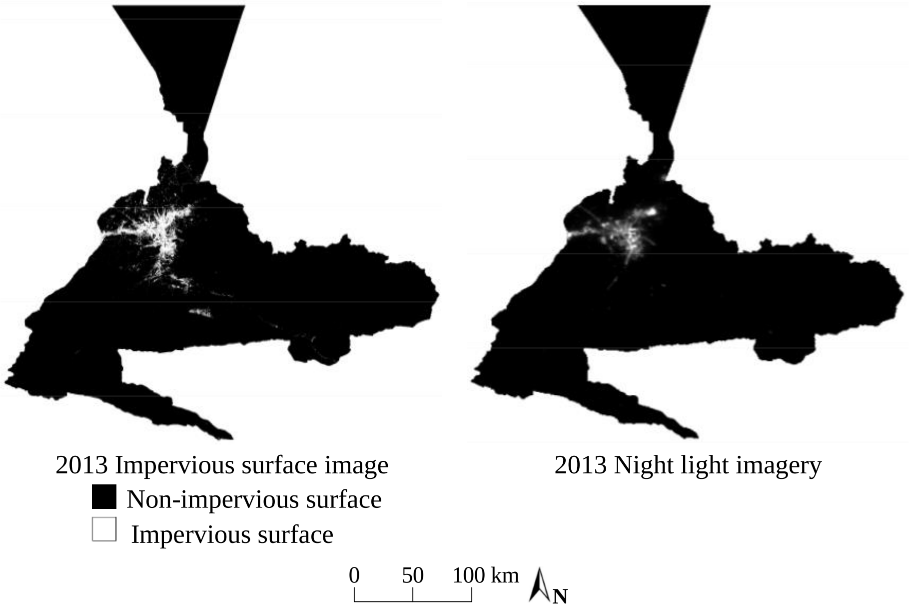

Figure 6: Impervious surface and night light image of Urumqi city in 2013

This experiment will analyze each county (7 districts and 1 county) in the study area one by one, and statistically analyze the proportion of artificial surface in each county (the ratio of artificial surface area in each county to the total area of the study area) and the average RSEI in the corresponding period. The analysis results are shown in Figure 7. From the analysis results, it can be seen that the proportion of artificial ground area in each county is positively correlated with the average RSEI of each county. The correlation of the four curves in 2013, 2015, 2017 and 2021 is similar, and the relevant change trend of the curve in 2019 is slightly different from that in other years. Considering the spatial correlation between regional urbanization and expansion development, as well as the threat to the regional ecological environment quality, it can be seen from the fitting function of the average RSEI value of each county and its corresponding artificial surface proportion that the deepening of urbanization has different impacts on the ecological environment quality of each county in the study area, From the change of the function curve between 2017 and 2019 in Figure 7, it can be concluded that the rapid expansion of artificial surface area in each county and district in the study area during 2017 and 2019 has a relatively strong impact on its ecological environment quality, while the impact on other years is relatively weak. To sum up, in the development process of urban expansion in the study area from 2013 to 2021, the rapid expansion of human activities had a strong impact on the regional ecology, and also showed a significant positive correlation with the proportion of artificial land surface in each county and the average RSEI of each county. In particular, the rapid expansion of the urbanization process in each county in the study area from 2017 to 2019 had a good impact on the ecological environment quality. The above experimental results have much to do with the geographical location and unique climate of Urumqi. It belongs to the temperate continental climate, with dry weather, hot summer and cold winter. Therefore, there are large areas of bare land in the southeast (Dabancheng District) of Urumqi and large areas of desert in the north, which also results in the low average RSEI. Although the expansion of the human activity area will bring some damage to the ecological environment of the area, with the continuous improvement of human's ability to protect and repair the ecological environment in recent years, urban expansion will also bring vegetation and water to the area, which also makes the average RSEI of the area increase rather than decrease. Therefore, the ecological environment quality of Urumqi will be improved in the process of urban expansion. At the same time, it also shows that in the process of urban construction, human beings are paying more and more attention to the protection of the ecological environment.

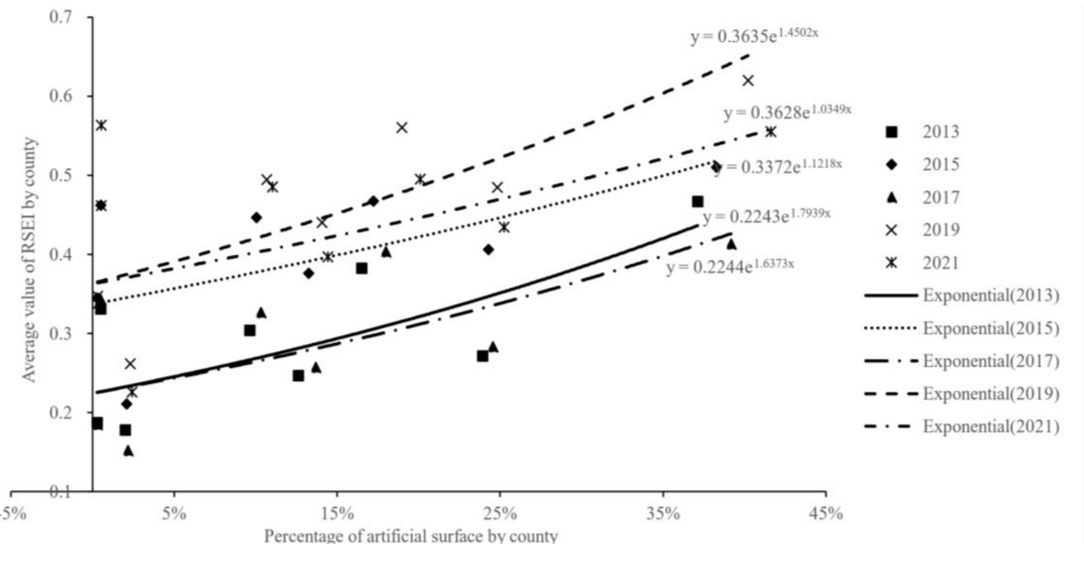

Figure 7: Statistical relationship between the proportion of artificial ground area and RSEI value in different counties and districts

6. Conclusion

In this paper, the principal component analysis (PCA) method is used to build the RSEI index of Urumqi in 2013, 2015, 2017, 2019 and 2021. On the basis of this index, the change and development trend of the ecological environment quality of Urumqi are studied. At the same time, the single factor analysis of the land use change in Urumqi in recent years is carried out to explore its relationship with the ecological environment quality. The main conclusions are as follows:

(1) It can be seen from the principal component analysis that the ecological environment quality in the study area has been improved in general from 2013 to 2021, and the NDVI and NDBSI have changed greatly, indicating that the main factors affecting the ecological environment change in Urumqi are greenness and dryness.

(2) From 2013 to 2021, the ecological environment quality of Urumqi has experienced both improvement and deterioration. The overall trend is that the ecological environment quality of Urumqi has been improved over time, and the ecological environment quality in 2017 is the worst.

(3) By monitoring the changes of RSEI index values in each year in the study area, it is concluded that the ecological environment quality in the study area has been greatly improved from 2013 to 2015, 2017 to 2019 and 2019 to 2021. The area of significant and slight deterioration of the ecological environment and the area of unchanged area in the study area from 2015 to 2017 accounted for 84.55% of the total area, and the area of slight and significant improvement accounted for only 15.54% of the total area, It can be concluded that the ecological environment quality in the study area has deteriorated to a large extent from 2015 to 2017.

(4) Through the discussion and analysis of the relationship between urban expansion and ecological environment quality in the study area, the proportion of artificial land surface in each county from 2013 to 2021 is positively correlated with the average RSEI value of each county, that is, during the process of urban expansion in Urumqi, the ecological environment quality in this region will be improved to some extent.

Acknowledgement

This study was supported by project of the Autonomous Region level Innovation Training Plan for College Students in 2021 "Analysis of the Impact of Urban Expansion on the Atmospheric Humidity of the Urban Agglomeration on the Northern Slope of Tianshan Mountains" (Grant No.S202110755118)

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