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Analysis of Spatiotemporal Changes in Ecological Quality of County-Level Land Consolidation Areas based on GEE

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Abstract: The connotation of county-level land consolidation is centered around human beings, based on ecological protection and restoration, with coordinated development of multiple elements and dimensions, promoting urban-rural integration and high-quality development of county-level space. This study started from the perspective of territorial spatial integration and analyzes the concept and connotation of urban fringe areas based on comprehensive land consolidation, revealing the important significance of land consolidation for the high-quality development of urban-rural transition areas. Explored the goals and priorities of land consolidation from two aspects: functional supplementation and urban-rural integration, and clearly proposed that ecological governance and restoration should be the core; Based on Google Earth Engine (GEE) and Geographic Information System (GIS), quantitative analysis was conducted on the spatiotemporal changes in ecological quality before and after land consolidation in the project area, clarifying the impact of comprehensive land consolidation on ecological quality. From 2010 to 2020, the RSEI of the comprehensive land improvement project in Shichuan River Basin showed a continuous upward trend, increasing from 0.475 to 0.592, an increase of 24.63%. The area with poor ecological level decreased by 95.07%, and the ecological environment quality in the eastern part of the study area was significantly higher than that in the western part, achieving significant results in ecological construction.

Keywords: Comprehensive land improvement; Ecological quality; Environmental protection; GEE.

1. Introduction

Shichuan River Basin is a representative area of the middle reaches of the Yellow River, with significant issues such as land degradation, soil pollution, and soil erosion, and a fragile regional ecosystem. With the implementation of ecological protection and high-quality development strategies in the Yellow River Basin, land improvement in the middle reaches of the Yellow River should prioritize the improvement of ecological quality, and comprehensively improve production, living conditions, and ecological environment. The Shichuan River land improvement area is located on the outskirts of urban areas, in the transitional area between urban and rural areas. It is a large-scale county-level land comprehensive development and ecological restoration project. The development of this project is dependent on the city, while also sharing the pressure for the city, forming an economic function driven and complementary relationship between the two.

In the rapid urbanization and industrialization process in our country, a series of resource, environmental, and land use problems have emerged, including a decrease in the quality and quantity of arable land, deterioration of the ecological environment, increasingly prominent structural contradictions in land supply, and increasingly tense human land relations, which have seriously constrained the sustainable development of the social economy . Since the rise of land consolidation in the 1990s, it has been widely promoted in China and has undergone nearly 30 years of development. It is of great significance in promoting farmland protection, improving land use patterns, improving land use efficiency, regulating land and ecosystems, and alleviating conflicts between humans and land . Land consolidation is gradually shifting from a single field infrastructure project to a comprehensive rural system project, and from regional practical exploration to a national strategy and important policy tool. It is an important lever and support platform for implementing food security strategies, promoting rural revitalization, and ecological civilization construction [3-4].

For a long period of time in the past, due to the influence of land consolidation strategy positioning, land ecological issues have not been given sufficient attention in the consolidation process. However, from the perspective of international advanced experience and recent practice in China, land consolidation is seen as an important means of protecting and improving the ecological environment, and the restoration and management of land resources such as pollution and degradation are necessary for land consolidation. The land consolidation in the new era should be a key platform for ecological civilization construction, following the concept of a community of human and natural life, systematically implementing comprehensive improvement and ecological restoration of mountains, rivers, forests, fields, lakes, and grasslands, coupling multiple elements to build a regional ecological security pattern, and ensuring the bottom line of ecological security.

2. Research Areas

Fuping County is located in a warm temperate continental semi humid and semi-arid climate zone, with a large temperature difference between day and night, mild climate, moderate precipitation, and distinct four seasons. According to the rainfall data from Fuping Meteorological Station from 1960 to 2008, the average annual rainfall in Fuping County is 528 mm; The distribution of precipitation within the year is uneven, with significant interannual variations. The precipitation from July to September accounts for about 50% of the annual precipitation. The average annual water surface evaporation is 1229 mm. The average annual temperature is 13.1 ℃, with an extreme maximum temperature of 40.9 ℃ and an extreme minimum temperature of -15.7 ℃. The average frost free period is 226 days, with an average annual relative humidity of 65%. The average annual wind speed is 3.4 m/s, and the maximum wind speed is 20 m/s. The maximum permafrost is 32 cm, and the maximum snow cover is 14 cm. The annual average sunshine hours are 2352.3 hours, and the annual average total solar radiation is 123.9 kcal/cm2.

Fuping County is located on the northern edge of the middle section of the Weihe Basin, which is a transitional zone of the Loess Plateau in northern Shaanxi. The terrain is generally high in the northwest, low in the southeast, and uneven in the central part, with an altitude of 375.8-1439 m. The northern part is a part of the Qiao Mountain Range, commonly known as the "North Mountain" in Guanzhong, with a general altitude of 800-1200 m. The terrain south of the North Mountain is gently inclined towards the southeast, with an altitude of 400-800 m. The low mountains in limestone face south and connect with the alluvial fan in front of the mountain. The depression at the front edge of the alluvial fan is connected to the steep slope of the Loess Plateau. The Shichuan River cuts through the county from west to southeast, forming a three-level terrace.

The research area is located in the Shichuan River Basin (Fuping area), at the junction of urban and rural areas (Figure 1), forming an open urban waterfront space that integrates multiple functions and diversities such as water conservancy, flood control, ecology, leisure, commerce, landscape, and sightseeing, becoming a landmark urban network ecological axis in Fuping.

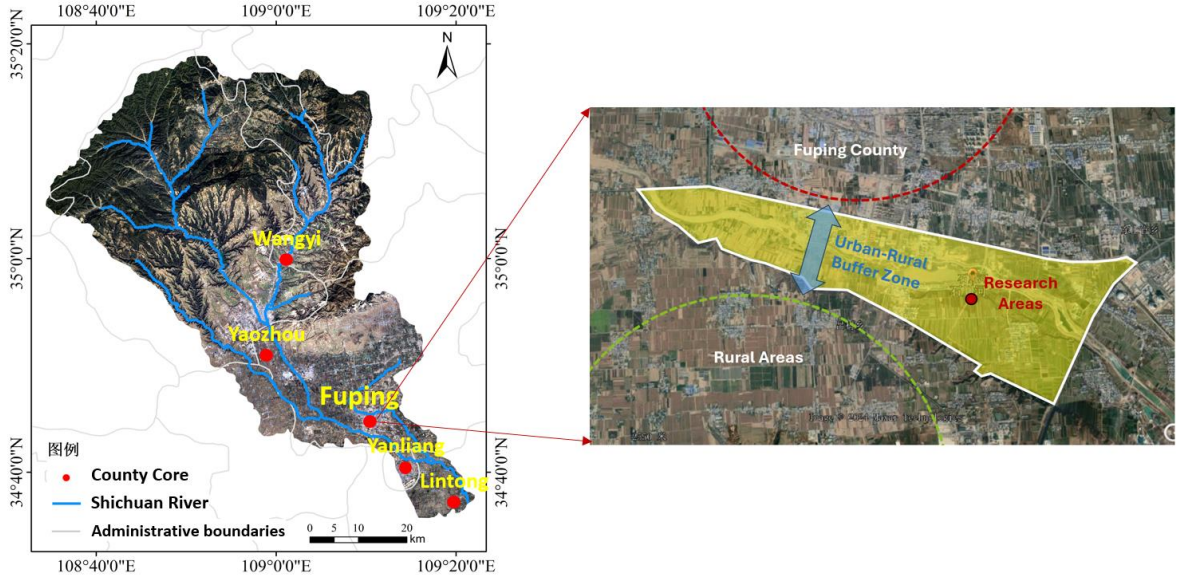

Figure 1. Research areas location

3. Data and Methodology

Considering various factors such as vegetation growth, crop harvest season, and cloud cover in different months, this study was based on the Google Earth Engine (GEE) platform and selected Landsat images from July to September 2010, 2015, and 2020 for cloud removal, median synthesis, and cropping processing. We are using the surface reflectance dataset on the GEE platform, which has undergone preprocessing such as radiometric calibration and atmospheric correction and can be directly used after cloud removal. The name of the Landsat8 dataset is LANDSAT/LC08/C01/T1-SR, and specifically the Landsat5 dataset is LANDSAT/LT05/C01/T1-SR.

Before calculating the Remote Sensing Ecological Index (RSEI), water masking is required. The water data selected for this study is the Joint Research Centre (JRC) dataset, named JRC/GSW1_4/YearlyHistory. This dataset contains maps of the location and time distribution of surface water from 1984 to 2021, and provides statistical data on the range and changes of these water surfaces. Its spatial resolution is 30 m.

This study adopted the RSEI method [6-7], which effectively integrated the four ecological elements of regional ecological environment. Normalized Difference Vegetation Index (NDVI) was used to evaluate greenness, Wet index was used to assess humidity, Land Surface Temperature (LST) index was used to calculate heat degree, and Normalized Difference Built-up and Bareness Index (NDBSI) presents dryness. Using principal component analysis (PCA) technology and RSEI method to evaluate the quality of regional ecological environment. This method is relatively easy to obtain data and is suitable for ecological quality assessment in this study area.

4. Results and Discussion

4.1. Applicability Evaluation

To determine whether the RSEI model is suitable for the study area, two aspects can be evaluated. Firstly, after principal component analysis, the contribution rate of the first principal component PC1 and the load value of each indicator

on the first principal component. The higher the contribution rate of PC1, the more features of the four component indicators are included in PC1, which can be used to characterize the ecological environment quality of the region. The second is to compare the correlation coefficients between various component indicators and RSEI. The larger the correlation coefficient value, the closer the connection between component indicators and RSEI.

Table 1 presents the analysis results of the first principal component PC1, which characterizes the loading capacity of each indicator on the first principal component. The positive and negative values correspond to the positive and negative effects of each indicator on the PC1 results. From Table 1, it can be seen that the contribution rates of PC1 in 2010, 2015, and 2020 were all above 70%, indicating in these three periods has concentrated most of the characteristics of the four indicators, proving that selecting PC1 as RSEI is reasonable. The contribution of the four component indicators to PC1 is different, among which the greenness index (NDVI) and humidity index (WET) have a positive contribution. The maximum load of greenness indicates the greatest impact of greenness, while the dryness index (NDBSI) and heat index (LST) have a negative contribution to PC1, which is also in line with the general principles of ecological environment quality evaluation.

Table 1. PC1 results

Year	NDVI	WET	NDBSI	LST	Eig.	Contribution Rate (%)
2010	0.624	0.461	-0.025	-0.631	0.060	72.22
2015	0.683	0.240	-0.608	-0.326	0.065	75.71
2020	0.627	0.337	-0.643	-0.281	0.051	72.87

Correlation coefficient is a statistical measure used to measure the degree of correlation between two variables. It represents the strength and direction of the linear relationship between two variables. Table 2 shows the correlation coefficients between RSEI and four component indicators for the three periods of 2010, 2015 and 2020. The higher the correlation value, the closer the connection between component indicators and RSEI. From Table 2, it can be seen that the relationship between greenness, humidity, and RSEI is positively correlated, while the relationship between dryness, heat, and RSEI is negatively correlated, which also meets the general criteria for judging ecological environment quality. The majority of the correlation coefficient values are greater than 0.5, indicating a good correlation between RSEI and various indicators.

In summary, it can be concluded that the RSEI model can concentrate most of the information of the four indicators, and the positive and negative correlation with the four indicators also meets the general principles of ecological environment quality evaluation. Therefore, it is appropriate to use the RSEI model to evaluate the ecological environment quality of the study area.

Table 2. Correlation coefficients of various component indicators and RESI（2010, 2015, 2020）

Year	NDVI	WET	NDBSI	LST
2010	0.901	0.891	-0.968	-0.053
2015	0.942	0.678	-0.951	-0.639
2020	0.897	0.784	-0.968	-0.555

4.2. RSEI Valuse

From 2010 to 2020, the overall ecological quality of Fuping County continued to improve, especially the green ecological barrier located in the southern part of Jingshan mountain, with most areas transitioning from poor to excellent (Figure 2). From the perspective of project area scale, Table 3 shows the mean statistics of RSEI and four component indicators in the remediation area in 2010, 2015 and 2020. It can be seen that the green index (NDVI) of the study area was continuously increasing in 2010, 2015 and 2020, and the humidity index (WET) was also on the rise overall. The dryness index (NDBSI) and heat index (LST) negatively correlated with RSEI are continuously decreasing. The remote sensing ecological index RSEI has gradually increased from 0.475 in 2010 to 0.592 in 2020, indicating a gradual improvement in the ecological environment quality of the study area.

Table 3. Average value changes of component indicators (2010, 2015, 2020)

Year	RSEI	NDVI	WET	NDBSI	LST
2010	0.475	0.493	0.496	0.564	0.443
2015	0.541	0.580	0.690	0.544	0.402
2020	0.592	0.675	0.662	0.443	0.353

4.3. RSEI Classification

In order to better analyze the ecological environment quality of the research area, referring to HJ192-2015 "Technical Specification for Ecological Environment Evaluation", RSEI is divided into five levels: poor, inferior, moderate, good and excellent based on 0-0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8 and 0.8-1. The land use and RSEI classification maps for 2010, 2015 and 2020 are shown in Figure 2. The results indicate that the quality of the ecological environment in the eastern part of the study area is significantly higher than that in the western region. From 2010 to 2020, the ecological environment quality of the study area has significantly improved, with a significant reduction in areas with inferior and poor ecological environment quality, and a significant increase in areas with excellent and good ecological environment quality. In 2010, most areas with poor ecological environment quality were concentrated in the central and southern parts of the study area. By 2015, the ecological environment quality in the region had significantly improved, with the level jumping to intermediate. By 2020, the ecological environment quality in the region had improved to a moderate level, indicating a significant effect of ecological environment governance. This is also one of the important reasons for the increase in the RSEI index in the study area.

To quantitatively describe the RSEI classification of the study area in 2010, 2015 and 2020, this study calculated the area of the research area at five levels: excellent, good, moderate, inferior, and poor, as shown in Table 4.

Between 2010, 2015 and 2020, the area of regions with excellent ecological environment quality has significantly increased, especially in areas with excellent ecological level, which has increased from 0.261 km2 in 2010 to 0.967 km2 in

2020. The areas with poor ecological environment quality has significantly decreased, which has decreased from 0.670 km2 in 2010 to 0.033 km2 in 2020 (Figure 3). This indicates that the ecological restoration work in the study area has achieved excellent results.

Table 4. Different RESI classification areas (Km2)

Year	Excellent	Good	Moderate	Inferior	Poor
2010	0.261	2.108	4.318	2.505	0.670
2015	0.462	3.326	3.796	1.839	0.218
2020	0.967	3.88	3.391	1.347	0.033

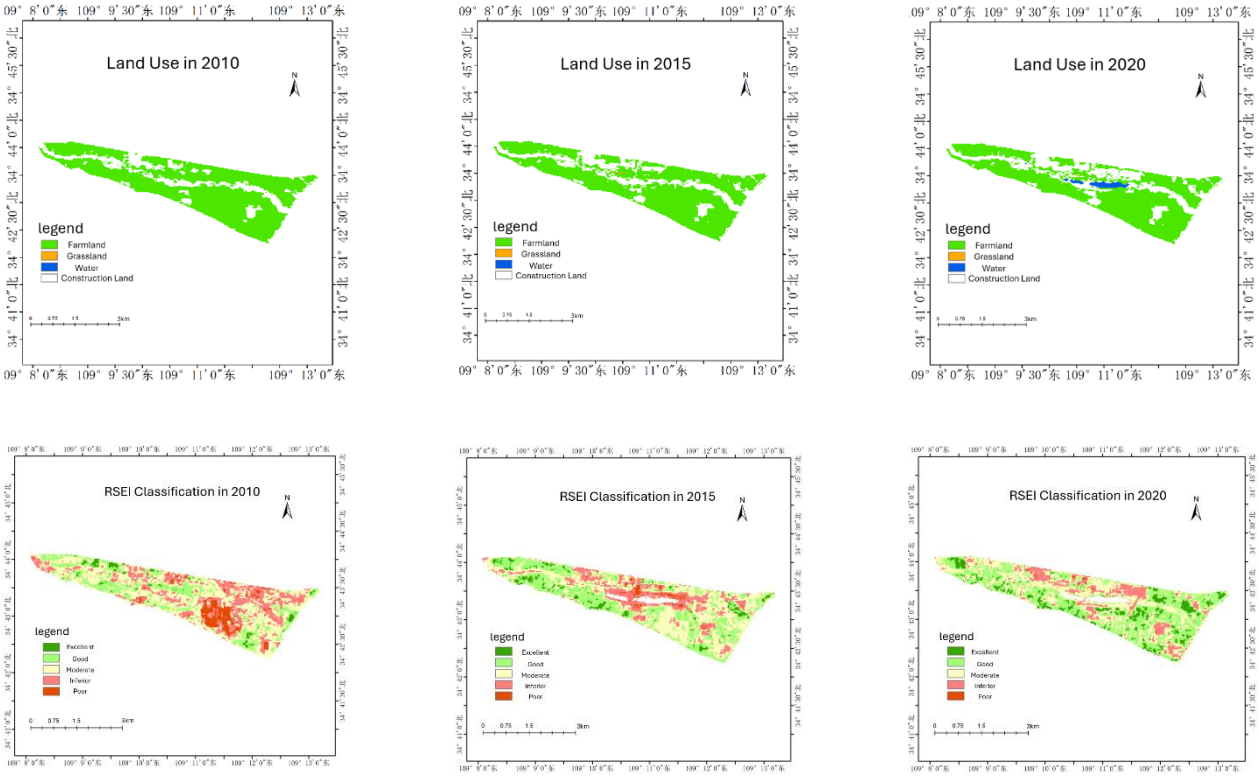

Figure 2. Land use and RSEI classification in 2010,2015 and 2020）

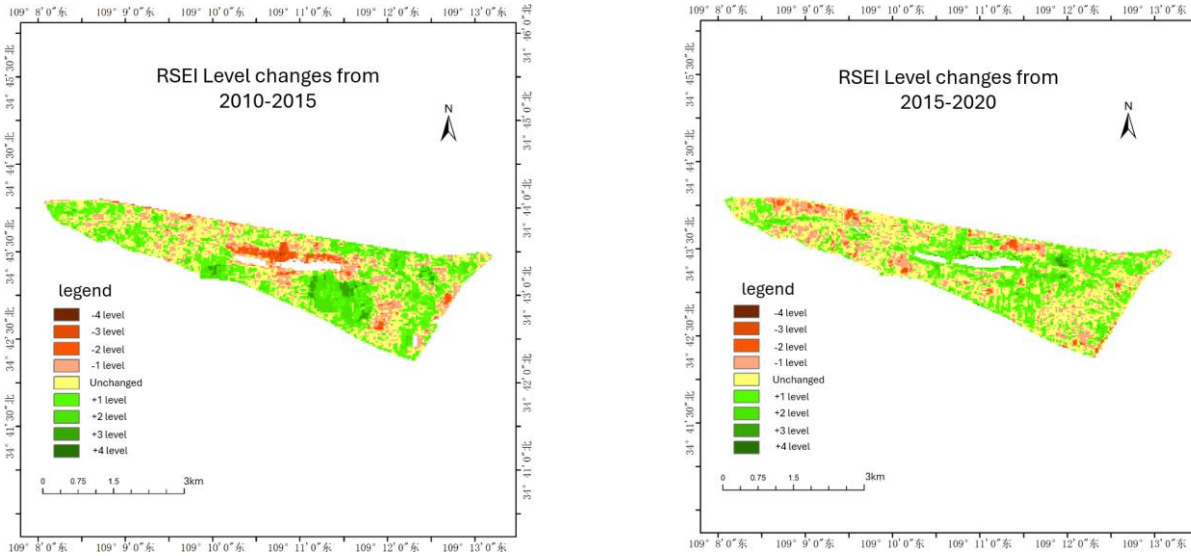

Figure 3. RSEI level changes from 2010 to 2015 and 2015 to 2020

In order to better identify and study the changes in RSEI in 2010, 2015 and 2020, we created three RSEI level change maps from 2010 to 2015 and 2015 to 2020. As shown in Figure 3, the areas where the ecological environment quality level improved from 2010 to 2015 were much larger than those where the level decreased. The areas where the ecological environment quality level improved were mainly concentrated in the eastern region, and some areas had their RSEI levels increased by three levels, indicating that the ecological environment governance work in this region has achieved obvious success.

5. Conclusion

According to the calculation results of the RSEI, the contribution rates of PC1 in 2010, 2015 and 2020 were all above 70%, indicating that PC1 in these three periods of data has concentrated most of the characteristics of the four

indicators of Greenness, Humidity, Heat, and Dryness. However, there are significant differences in the contribution of the four component indicators to PC1. The greenness index and humidity index have a positive contribution to PC1, with greenness having the largest load, indicating that vegetation coverage and ecological construction have the greatest impacts. The dryness index and heat index have a negative contribution to PC1.

From 2010 to 2020, the overall ecological quality of Fuping County continued to improve, especially the green ecological barrier located in the southern part of Jingshan mountain, with most areas transitioning from poor to excellent. The RSEI of the comprehensive land improvement project in the Shichuan River Basin has also shown a continuous upward trend, increasing from 0.475 to 0.592, an increase of 24.63%. The area with poor ecological level has decreased by 95.07%, and the ecological environment quality in the eastern part of the study area is significantly higher than that in the western part, achieving significant results in ecological construction. Research has found that there is a high negative correlation between the area of construction land and RSEI, indicating that the urbanization process in counties has a significant negative impact on the ecological environment. The increase in forest, grassland and water will lead to the improvement of ecological environment quality. There is a significant positive correlation between precipitation, temperature, relative humidity and RSEI. This research has improved the regional environment, especially the temperature and humidity around the Shichuan River, through comprehensive land improvement, which can effectively enhance the quality of living environment.

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