Land Degradation Neutrality Assessment and Analysis of Influencing Factors in the "Great Bend" of the Yellow River (Postprint)

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Abstract

Achieving Land Degradation Neutrality (LDN) is a critical pathway for addressing the global environmental challenge of land degradation. As a key region for ecological protection and high-quality development in the Yellow River Basin, the "Ji-shaped Bend" of the Yellow River faces severe issues of soil erosion and desertification-driven land degradation. Based on the LDN assessment framework and integrated with regional degradation processes, this study constructed a localized multi-scale LDN analysis framework. Using methods such as Geographically Weighted Regression (GWR), we systematically measured and analyzed the spatial patterns and influencing factors of LDN attainment in this region from 2000 to 2023. The results indicate that: (1) At the pixel scale, the area of land improvement was larger than the area of degradation, with land in improved, degraded, and stable states accounting for 69.69%, 23.74%, and 6.57% of the total area, respectively. (2) At the regional scale, the LDN target was not achieved overall; however, 47.42% of the land achieved LDN at the grid scale, 36.00% at the county scale, and only 7 out of 21 cities achieved LDN. (3) There is spatial heterogeneity in the dominant factors influencing LDN; wind speed, population density, and elevation exhibited negative effects on LDN in most areas, while factors such as precipitation, actual evapotranspiration, soil moisture, and Normalized Difference Vegetation Index (NDVI) showed positive effects. The research findings provide a reference for the regional application of the LDN framework and offer a basis for decision-making in land degradation management within the "Ji-shaped Bend" of the Yellow River.

Full Text

Land Degradation Neutrality Assessment and Analysis of Influencing Factors in the "Yellow River Bend" Region

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Abstract

Achieving Land Degradation Neutrality (LDN) is a critical objective for addressing the global environmental challenge of land degradation. As a core target of the United Nations Sustainable Development Goals (SDG 15.3), LDN aims to maintain or enhance the amount and quality of land resources necessary to support ecosystem functions and services and improve food security. This study focuses on the "Great Bend" of the Yellow River, utilizing multi-source remote sensing data and the "three indicators" (land cover, land productivity, and soil organic carbon) recommended by the United Nations Convention to Combat Desertification (UNCCD). We assessed the land degradation status of the study area from 2000 to 2023 and employed Geographically Weighted Regression (GWR) and Geodetector models to analyze the natural and anthropogenic factors influencing land degradation.

The results indicate that: (1) At the pixel scale, the area of land improvement exceeds that of land degradation, with proportions of improvement, degradation, and stability at 69.69%, 23.74%, and 6.57%, respectively. (2) At the regional scale, the LDN target has not been fully achieved; 47.42% of the land reached LDN status at the grid scale, and 36.00% at the county scale. (3) The dominant factors influencing LDN exhibit significant spatial heterogeneity. Wind speed, population density, and elevation exert negative effects in most regions, while precipitation, actual evapotranspiration, soil moisture, and the Normalized Difference Vegetation Index (NDVI) demonstrate positive effects. This research provides a scientific basis for ecological restoration and sustainable land management in the Yellow River basin.

Keywords: Land Degradation Neutrality; Ecosystem Services; Geographically Weighted Regression; Influencing Factors; "Great Bend" of the Yellow River

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1. Introduction

Land degradation is a global environmental challenge that threatens food security, biodiversity, and the stability of ecosystem services. To address this, the United Nations Convention to Combat Desertification (UNCCD) proposed the concept of Land Degradation Neutrality (LDN), which aims to maintain or enhance the amount and quality of land resources necessary to support ecosystem functions and services. Achieving LDN requires a comprehensive understanding of the spatial-temporal dynamics of land degradation and its relationship with ecosystem service values.

The "Great Bend" of the Yellow River (the "Ji-shaped" bend) serves as a critical ecological barrier in northern China, characterized by a fragile environment and high sensitivity to climate change and human activities. This region encompasses diverse landscapes, including deserts, loess plateaus, and alluvial plains. Despite its ecological importance, the region faces persistent pressure from soil erosion, desertification, and salinization. Previous studies have extensively explored the mechanisms of land degradation; however, there is a lack of integrated research examining the spatial heterogeneity of factors influencing LDN within this specific context.

By integrating multi-source geospatial data, this research aims to: (1) evaluate the status and trends of land degradation in the "Great Bend"region; (2) quantify the spatial distribution of ecosystem service values; and (3) identify the primary natural and anthropogenic drivers using the GWR and Geodetector models.

2. Data and Methods

2.1 Study Area Overview

The "Great Bend" of the Yellow River is located in north-central China, spanning the junction of the central and western regions across five provinces and autonomous regions: Gansu, Ningxia, Inner Mongolia, Shaanxi, and Shanxi. The total area is 4.09×10^5 km^2. Elevation ranges from 380 to 3400 m. The region is primarily situated within arid and semi-arid zones, characterized by limited precipitation (104.4 to 743.3 mm) and high evaporation rates. It contains several major deserts, including the Kubuqi, Mu Us, Ulan Buh, and Tengger deserts [**?**].

2.2 Data Sources

The research data includes precipitation (PRE), temperature (TEM), potential evapotranspiration (PET), and actual evapotranspiration (AET) derived from the National Tibetan Plateau Data Center and TerraClimate datasets. Normalized Difference Vegetation Index (NDVI) and Land Use/Cover (LULC) data were obtained from NASA and the Chinese Academy of Sciences. Wind speed (WIND) data were processed using ANUSPLIN for spatial interpolation. All data were standardized to the WGS_{{{1984}}_{{Albers}}} coordinate system with a 1 km spatial resolution.

2.3 Research Framework and Indicators

This study constructs a regional LDN assessment framework based on the UNCCD guidelines, incorporating four primary indicators: 1. **Land Use Change:** Transitions between land cover types (forest, grassland, cropland, wetland, artificial surfaces, and unused land). 2. **Land Productivity:** Measured via Net Primary Productivity (NPP) using the Carnegie-Ames-Stanford Approach (CASA). 3. **Soil Conservation:** Estimated using the Revised Universal Soil Loss Equation (RUSLE):

$$A_c = A_p - A_r = R \cdot K \cdot L \cdot S \cdot (1 - C \cdot P)$$

where A_c is soil conservation, A_p is potential erosion, and A_r is actual erosion. 4. **Windbreak and Sand Fixation:** Calculated using the Revised Wind Erosion Equation (RWEQ) to determine the capacity of ecosystems to reduce soil loss and stabilize shifting sands.

The evaluation follows the "one-out, all-out" (1OAO) principle: if any single indicator shows degradation, the pixel is classified as degraded.

2.4 Statistical Analysis

- **Trend Analysis:** The Theil-Sen Median method was used to quantify trends in implicit indicators, with the Mann-Kendall test for significance ($|Z| \geq 1.96$).
- **Influencing Factors:** The Optimal Parameter Geographic Detector (OPGD) was used to identify the explanatory power (q-value) of factors and their interactions.
- **Spatial Heterogeneity:** Geographically Weighted Regression (GWR) was employed to model spatially varying relationships:

  $$y_i = a_0(u_i, v_i) + \sum a_k(u_i, v_i)x_{ik} + \epsilon_i$$

  where y_i is the LDN index and (u_i, v_i) are the geographic coordinates of pixel i.

3. Results and Analysis

3.1 Spatio-temporal Patterns of LDN Indicators

From 2000 to 2023, land use changes showed that forest, grassland, and water bodies increased from 59.46% to 59.97% of the total area. Construction land increased by 1.78%. Land productivity showed a significant improving trend across 86.83% of the region.

[Figure 2: see original paper] [Figure 3: see original paper]

The spatial distribution of windbreak and sand fixation capacity is lower in the southeast and higher in the northwest. Soil conservation capacity is highest in the south and east. Overall, 69.69% of the pixels in the study area showed improvement, primarily driven by land productivity increases resulting from ecological projects like the "Grain for Green" initiative.

3.2 Analysis of Driving Mechanisms

The Geodetector analysis reveals that precipitation and vegetation types are the dominant natural factors, while population density and land-use intensity are the primary anthropogenic drivers. The interaction between DEM and precipitation showed significant explanatory power ($q = 0.35$).

GWR results indicate that the influence of these factors is not uniform. In arid regions, precipitation variability is the primary determinant of land productivity. In urbanizing areas, construction land expansion is the dominant factor disrupting LDN balance.

4. Discussion and Conclusion

The "Great Bend" of the Yellow River has undergone a transition from desertification expansion to ecological recovery since 2000. This shift is attributed to the synergy between favorable climatic trends (increased precipitation) and large-scale ecological restoration programs. However, the LDN target has not been fully achieved at the regional scale, particularly in the arid desert fringes where water scarcity remains a constraint.

Future land management should prioritize the balance between land productivity and hydrological sustainability. Targeted interventions are needed in "degradation hotspots" identified in this study to ensure the long-term resilience of the Yellow River basin's ecological health.

Note: Figure translations are in progress. See original paper for figures.

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