Postprint: Ecological Response to Land Development in the Tarim River Basin

Authors: Jiao Wei, Liu Xinping

Date: 2018-11-14T00:00:00+00:00

Abstract

Over the past 60 years, the cultivated land area in the Tarim River Basin has increased by a net amount of 100$\times10^{4}$ hm^2, creating numerous eco-environmental security issues within the basin. This study selected the water resources eco-environmental index, socio-ecological environmental index, and eco-environmental pressure index, employed the ESDA spatial analysis method and GWR model to investigate the spatiotemporal evolution characteristics of land development and ecology and their spatial response relationships in the Tarim River Basin over a 35-year period, and constructed a "land development-ecological risk early warning" model. The following conclusions were obtained: From 1980 to 2015, Kizilsu and Kashgar prefectures exhibited relatively large proportions of positive ecological grade transitions, with 84.86% of areas transitioning from lower grade (I) to low grade (II); the Keriya River Basin in Hotan Prefecture, the northern Aksu region, and Qiemo County at the terminus of the Tarim River experienced severe grade degradation, with a negative transition proportion of 23.46%. For every 1.0$\times10^{4}$ hm^2 increase in unused land reclamation scale, the comprehensive eco-environmental score decreased by 0.6 to 0.35 points in Hotan, Aksu, and Kashgar prefectures, while it increased by 1.3–2.1 points in Kizilsu Prefecture. For every 1.0$\times10^{4}$ ha of ecological restoration in Kashgar (upstream) and Aksu (midstream) regions, 32.06$\times10^{4}$ t and 15.60$\times10^{4}$ t of chemical fertilizer pollution pressure would be resolved per year, respectively. The ecological risk of land development in Aksu and Bayingolin prefectures exceeded 75% of the environmental resource carrying capacity index, with early warning levels surpassing Grade II, whereas land development in Kizilsu Prefecture remained within the ecological safety range. For every 1.0$\times10^{4}$ hm^2 of unused land development, the mean risk index increase across the entire basin was 0.0034; after increasing cultivated land by 15$\times10^{\{4\}-20\times10}$\{4\} hm^2, the ecological risk in the downstream Bayingolin region would approach and exceed the environmental early warning threshold, while the upstream Kizilsu region would enter a moderate warning

stage after 15 years.

Full Text

Preamble

ARID LAND GEOGRAPHY
doi:10.12118/j.issn.1000-6060.2018.06.28
ChinaXiv Partner Journal

JIAO Wei[1], LIU Xin-ping[2], ZHANG Lin[1], LIANG Ling-xia[1]
([1]School of Management, Xinjiang Agricultural University, Urumqi 830052, Xinjiang, China; [2]Institute of Land Science, Xinjiang Agricultural University, Urumqi 830052, Xinjiang, China)

Abstract: Over the past 60 years, the cultivated land area in the Tarim River Basin has increased by approximately 1 million hm^2, leading to numerous ecological and environmental security problems within the basin. Using Exploratory Spatial Data Analysis (ESDA) methods and the Geographically Weighted Regression (GWR) model, this study examines the ecological response to land development and its spatiotemporal evolution in the Tarim River Basin over a 35-year period from 1980 to 2015. The water resources ecological environment index, social ecological environment index, and ecological environment pressure index were selected as key indicators. Subsequently, a land development ecological risk early-warning model was constructed. The main findings are as follows: From 1980 to 2015, Kizilsu Kirgiz Autonomous Prefecture and Kashgar Prefecture exhibited a significant positive transfer in ecological levels, with 84.86% of the area moving from lower grade (I) to low level (II). In contrast, the Keriya River Basin in Hotan Prefecture, northern Aksu, and Qiemo County at the terminus of the Tarim River experienced severe degradation, with a negative transfer rate of 23.46%. In Hotan, Aksu, and Kashgar Prefectures, each increase of 10^4 hm^2 in reclaimed unused land resulted in a decrease of 0.6 to 0.35 points in the comprehensive ecological environment score, while in the Kizilsu Kirgiz Autonomous Prefecture, the score increased by 1.3 to 2.1 points. Developing 10^6 hm^2 of farmland annually in Kashgar and Aksu would reduce chemical fertilizer pollution pressure by 0.32 million tons and 0.15 million tons, respectively. The ecological risk of land development in Aksu and Bayingolin Mongol Autonomous Prefecture exceeds 75% of the environmental carrying capacity index, with an early-warning level above II. Land development in Kizilsu Kirgiz Autonomous Prefecture remains within the ecological security range. With the development of 10^4 hm^2 of unused land, the average risk index growth across the entire basin is 0.0034. If Bayingolin Prefecture increases its arable land by 0.15–0.20 million hm^2, the ecological risk will approach or even exceed the warning limit. Kizilsu Kirgiz Autonomous Prefecture will enter the moderate warning stage after 15 years.

Keywords: land development; ecological response; GWR; ecological early-

warning; Tarim River Basin

3. Study Methods

3.1 Data Sources

The study utilized water resources data from the *Xinjiang Water Resources Bulletin* (1980–2015), socioeconomic statistics from the *Xinjiang Statistical Yearbook* (1980–2015), and ecological environment data from the *Xinjiang Ecological Environment Status Bulletin*. The research focused on 35 county-level administrative units within the Tarim River Basin. Land reclamation area data were calculated based on unused land development statistics from the *Xinjiang Land Use Change Survey Data* and *Xinjiang Land and Resources Bulletin* for the period 1980–2015.

3.2 Comprehensive Ecological Environment Evaluation System

An evaluation index system was established comprising three components: water resources ecological environment index, social ecological environment index, and ecological environment pressure index. The specific indicators and their weights are presented in . The comprehensive ecological environment value was calculated using the weighted sum method:

$$E = \sum_{i=1}^{n}(w_i \times x_i)$$

where E represents the comprehensive ecological environment value, w_i represents the weight of each indicator, and x_i represents the standardized value of each indicator. The ecological environment quality was classified into five grades based on the comprehensive evaluation value: Grade I (excellent), Grade II (good), Grade III (moderate), Grade IV (poor), and Grade V (very poor).

Comprehensive Ecological Environment Evaluation Index System

3.3 Exploratory Spatial Data Analysis (ESDA)

ESDA methods were employed to analyze the spatial agglomeration characteristics and patterns of ecological environment changes in the Tarim River Basin. Global spatial autocorrelation was measured using Moran' s I index:

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \times \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

where n represents the number of spatial units, x_i and x_j represent the attribute values of units i and j, $\bar{x}$ represents the mean value, and w_{ij} represents the spatial weight matrix. The analysis was performed using ArcGIS software to calculate

Moran' s I for the comprehensive ecological environment values of each county in 1980 and 2015, thereby revealing the spatial clustering patterns of ecological changes.

4. Results and Analysis

4.1 Geographically Weighted Regression (GWR) Analysis

The GWR model was applied to analyze the spatially varying relationships between land reclamation and ecological environment changes. The model takes the form:

$$y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{p} \beta_k(u_i, v_i)x_{ik} + \varepsilon_i$$

where (u_i, v_i) represents the coordinates of the ith sampling point, y_i represents the ecological environment change value, x_{ik} represents the kth influencing factor, $\beta_k(u_i, v_i)$ represents the local regression coefficient, and ε_i represents the error term. The analysis revealed that the impact of land reclamation on the ecological environment exhibited significant spatial heterogeneity across the basin.

[Figure 2: see original paper] shows the spatial distribution of GWR model coefficients for ecological environment changes and cultivated land reclamation in the Tarim River Basin from 1980 to 2015. The results indicate that in Aksu and Kashgar regions, land reclamation had a significant negative impact on the ecological environment, with coefficient values ranging from -0.056024 to -0.003369. Conversely, in Kizilsu Kirgiz Autonomous Prefecture, the impact was positive, with coefficients between 0.013469 and 0.021410.

4.2 Ecological Risk Early-Warning Model

An ecological risk early-warning model was constructed based on the relationship between land development intensity and ecological environment carrying capacity. The model is expressed as:

$$Z = \frac{DI}{ECC}$$

where Z represents the early-warning index, DI represents the land development intensity index, and ECC represents the ecological carrying capacity index. The early-warning levels were classified as: Level I (no warning, Z < 0.2), Level II (mild warning, 0.2 ≤ Z < 0.35), Level III (moderate warning, 0.35 ≤ Z < 0.5), Level IV (severe warning, 0.5 ≤ Z < 0.75), and Level V (extreme warning, Z ≥ 0.75).

presents the results of the ecological risk early-warning model. The analysis shows that Aksu and Bayingolin Mongol Autonomous Prefecture have early-warning levels above II, with risk indices exceeding 75% of the environmental carrying capacity. Kizilsu Kirgiz Autonomous Prefecture remains in the ecological security range. The model predicts that developing 0.15–0.20 million hm^2 of arable land in Bayingolin would push the ecological risk to the warning limit, while Kizilsu would enter the moderate warning stage after 15 years of continuous development.

The spatial analysis reveals that 84.86% of the basin experienced a positive transfer from Grade I to Grade II ecological status, while 23.46% showed negative transfer patterns, particularly in the downstream regions. Each 10^4 hm^2 increase in unused land development resulted in a 0.6–0.35 point decrease in comprehensive ecological scores in developed areas, but a 1.3–2.1 point increase in ecologically restored regions.

References

[9] NOP, Qiao Y, Li S, et al. 50 years of water and land resource exploitation and eco-environmental issues in Xinjiang[J]. Arid Land Geography, 2006, 20(3): 58-63.

[12] Wang S. Study on soil and water resources development and ecological environment effect of oasis in Kaiken River Basin[D]. Urumqi: Xinjiang Agricultural University, 2008.

[13] Yang Y. Spatial-temporal evolution and driving forces of land use change in Tarim River Basin[J]. Arid Land Geography, 2014, 34(1): 105-114.

[14] Zhang L. Study on ecological security evaluation and early-warning of land resources in Tarim River Basin[D]. Urumqi: Xinjiang Agricultural University, 2008.

[15] Lei Y, Chen J, Sun B. Prediction of land use change and ecological response in Zhangjiagang[J]. China Rural Water and Hydropower, 2016, (5): 33-36+40.

[16] Chen Y, Wang Y, Wang Z, et al. Ecological risk assessment of land use change in arid oasis regions[J]. Arid Land Geography, 2015, 38(5): 1077-1084.

[17] Liu H. Analysis of ecological environment vulnerability in Tarim River Basin[J]. Environmental Science and Management, 2012, (12): 27-29.

[18] Xu D, Wang Y, Zhao H. Ecological security pattern and optimization of land use in Tarim River Basin[J]. Chinese Journal of Ecology, 2010, 30(3): 620-624.

[19] Zhou M. Study on ecological compensation mechanism for land development in Tarim River Basin[D]. Beijing: Beijing Forestry University, 2011.

[20] Yang J, Guo X. Spatial heterogeneity analysis of ecological environment quality in Tarim River Basin[J]. Arid Land Geography, 2016, 39(3): 513-520.

[21] Zhang Y, Liu J. Ecological footprint analysis of water resources utilization in Tarim River Basin[J]. Arid Land Geography, 2006, 29(1): 1-8.

[22] Xinjiang Statistical Bureau. Xinjiang Statistical Yearbook 2020[EB/OL]. http://www.xjtj.gov.cn, 2015-12-21.

Author Information:
JIAO Wei[1], LIU Xin-ping[2], ZHANG Lin[1], LIANG Ling-xia[1]
[1] School of Management, Xinjiang Agricultural University, Urumqi 830052, Xinjiang, China
[2] Institute of Land Science, Xinjiang Agricultural University, Urumqi 830052, Xinjiang, China

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