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Effects of Land Use Change on Habitat Quality in the Tumen River Basin

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Abstract: Habitat quality is one of the important factors to measure ecosystem services, and its quality is directly related to regional ecosystem service capacity. The Tumen River Basin is located in the border area of China, Korea and Russia. The temporal and spatial evolution of habitat quality in Tumen River Basin is of great significance to the ecological security and sustainable development of Northeast Asia. Based on InVEST model and spatial autocorrelation, this study analyzed the temporal and spatial changes of habitat quality and the interaction of elevation in Tumen River Basin (Chinese side). The results showed that: 1) Land transfer mainly occurred from cultivated land to construction land and grassland, and from forest land to cultivated land from 2000 to 2018. 2) In the past 20 years, habitat quality in the study area fluctuated, showing an upward trend and then a downward trend, but the overall fluctuation was not significant, with an average value of 0.87. 3) The elevation effect of habitat quality and degradation degree was obvious on elevation. The distribution of low-grade habitat quality was consistent with that of cultivated land and construction land, while that of high-grade habitat quality was consistent with that of forest land. Overall, the habitat quality index increased with elevation. The results can provide some reference for biodiversity conservation and ecological sustainable development in Northeast Asia.

Keywords: InVEST model; Land use change; Habitat quality

1 Introduction

Habitat Quality refers to the potential of an ecosystem to provide the conditions necessary for species survival and reproduction[1] . As a critical metric for evaluating ecosystem services, its quality status directly correlates with the capacity of regional ecosystem services[2] . Land use changes can alter material and energy flow between habitat patches, thereby modifying habitat productivity and service levels to some extent[3] . The rapid development of modern economies and the increasingly intensive dynamics of resource allocation have profoundly influenced regional land use patterns and spatial configurations[4-5] . These changes have further contributed to the degradation or even loss of ecosystem service functions[6-7] . Therefore, assessing spatiotemporal characteristics and evolution of habitat quality under the impact of land use changes holds significant importance for regional ecological conservation and land use management[8-9]. With the continuous advancements in remote sensing, GIS technologies, and modeling methodologies, the establishment of habitat-related ecosystem service models has enabled the assessment and monitoring of regional habitat conditions[10] . Notably, the widespread application of the InVEST model's Habitat Quality module has significantly propelled research progress in habitat quality[11-12] . Currently, the InVEST model has been successfully implemented in habitat quality studies across diverse scales, including national, provincial, and watershed levels .

This study employs the InVEST model to simulate and estimate habitat quality in the Tumen River Basin (Chinese section), aiming to quantitatively assess its spatiotemporal evolution with three objectives: 1) evaluating the characteristics of habitat quality's spatiotemporal variation, 2) revealing its response to land use changes, and 3) elucidating the interactive effects between habitat quality and elevation. The findings are crucial for biodiversity conservation and sustainable ecological development in the basin.

2 Materials and methods

2.1 study area

The Tumen River Basin (Chinese section) is situated within the Yanbian Korean Autonomous Prefecture in eastern Jilin Province, bordering China, North Korea, and Russia. As a critical ecological functional zone and a pilot area for China's national park system, it forms a core component of the Northeast China Tiger and Leopard National Park. The basin experiences a temperate monsoon climate, characterized by an annual average temperature of 2–6°C, annual precipitation of 400–650 mm, and 2,150–2,480 hours of sunshine per year, with the warmest period coinciding with the rainy season. Map of the study area can be seen in Figure 1.

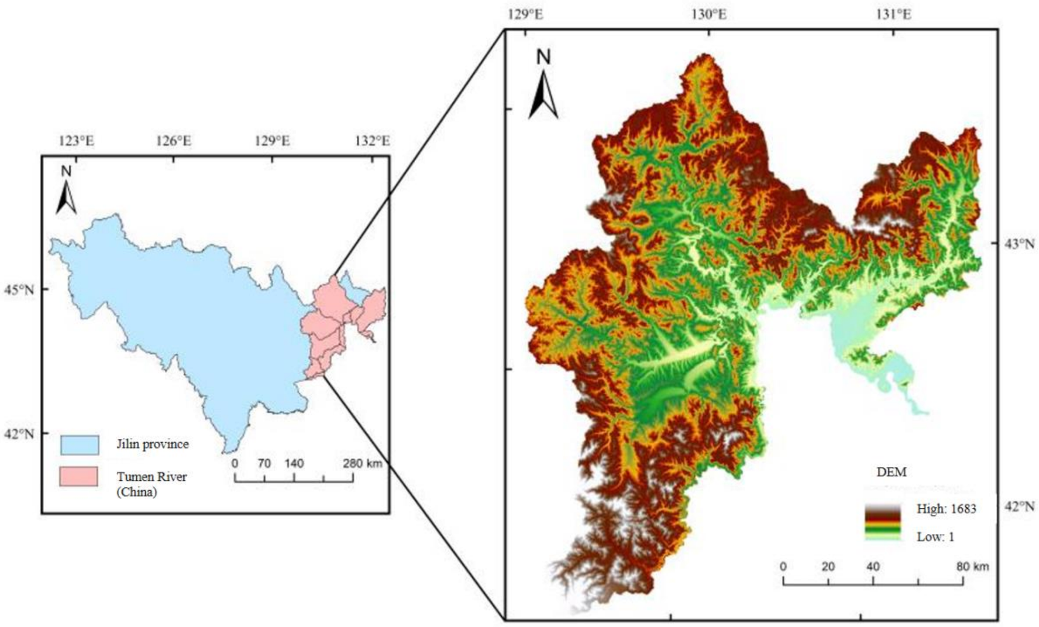

Fig1. Map of the study area

2.2 Research methods

2.2.1Sources of data

The land use data was sourced from the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences (http://www.Resdc.cn). Using the reclassification tool in ArcGIS software, the land use types were categorized into six primary land categories: cropland, forest, grassland, water bodies, construction land, and unused land, with further subdivisions into 24 secondary subcategories. The DEM (Digital Elevation Model) data was obtained from the Geospatial Data Cloud (http://www.gscloud.cn/) with a spatial resolution of 30 meters. For the study area, prohibited development zones were limited to those at or above the provincial level, and vector layers of natural reserves and other protected areas were derived from the *Jilin Provincial Major Function Zone Plan*, published on the official website of the Jilin Provincial People's Government (http://www.jl.gov.cn/).

2.2.2 Research methods

This study first conducts land cover change analysis by performing a Combine calculation on the Tumen River Basin's land use data in ArcGIS 10.5 to derive the land use transition patterns. To further investigate the intensity of dynamic land use changes, a transition probability matrix model is applied. This study employs the Habitat Quality module of the InVEST model to evaluate habitat quality and degradation in the study area. The module assesses the adverse impacts of threatening factors on habitats and calculates habitat quality by integrating the habitat suitability of various land use types and the threat intensity of factors within the study area. Finally, a set of randomly distributed points were uniformly generated across the study area to investigate the distribution patterns of habitat quality and habitat degradation degree in relation to elevation.

3 Results and analysis

3.1 Analysis of land cover change

Analysis of the land use structure (Figure 2) and changes in area proportions (Figure 3) in the Tumen River Basin (Chinese section) from 2000 to 2018 indicates that cultivated land and forest land were the primary land use types in the study area, accounting for approximately 95% of the total area. From 2000 to 2018, land use changes were primarily characterized by increases in grassland, water bodies, construction land, and unused land.

By constructing a land use transition matrix for the study area over the past two decades, this study reflects the transition characteristics of land use changes (Table 1). The results indicate that the spatial structure and transition trends of land use changes during different periods exhibiting distinct patterns. Overall, over the past two decades, the interconversion among cultivated land, forest land, and grassland have dominated land use changes in the Tumen River Basin. Construction land has experienced significant inflow with minimal outflow, indicating a persistent expansion of built-up areas. In contrast, water bodies and unused land have remained relatively stable, with both conversion and loss occurring at much lower magnitudes compared to other land types.

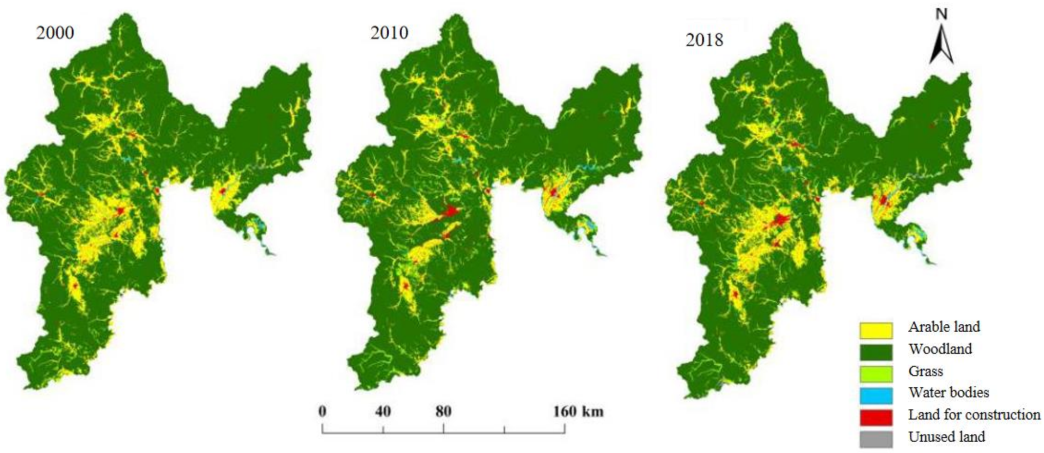

Fig 2. Distribution and change of land use types in the study area from 2000 to 2018

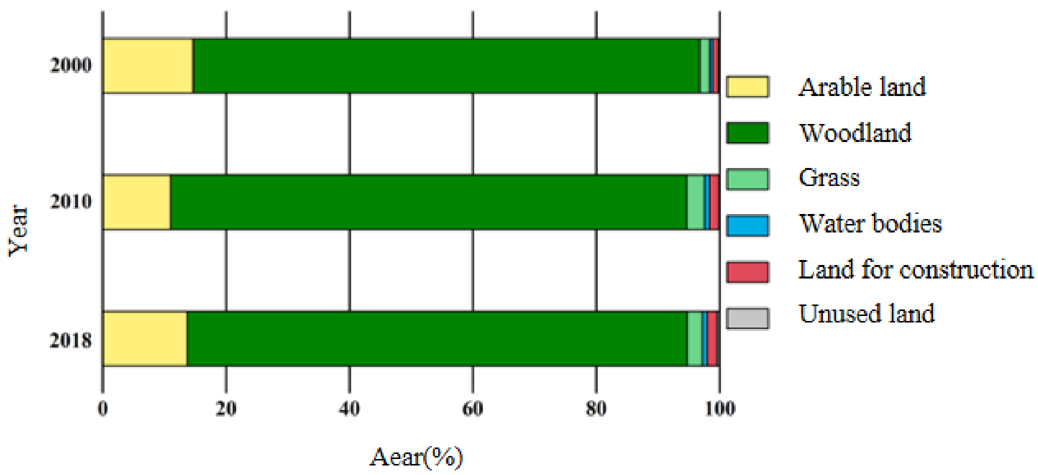

Fig 3. Proportion of land use types in the study area from 2000 to 2018

Table 1 land use transfer matrix from 2000 to 2018 （km^2）

Year	Land use	Arable land	Woodland	Grass	Water bodies	Land for construction	Unused land
2000～2010	Arable land	1898.59	1021.47	212.09	58.62	189.66	7.45
	Woodland	536.31	18068.14	360.97	38.29	21.11	12.11
	Grass	42.17	241.90	81.39	3.37	2.38	1.01
	Water bodies	17.43	9.41	3.29	68.05	1.64	1.47
	Land for construction	54.16	26.15	3.69	2.26	137.46	0.02
	Unused land	11.45	19.21	4.03	13.46	1.04	2.40
2010～2018	Arable land	2333.78	119.50	38.54	14.88	45.48	7.65
	Woodland	696.86	18586.76	34.09	7.18	20.17	31.97
	Grass	105.90	55.69	476.98	3.58	1.73	21.52
	Water bodies	7.30	4.34	0.68	153.28	0.53	14.12
	Land for construction	27.38	3.62	1.15	1.81	319.29	0.03
	Unused land	6.41	0.54	3.64	1.99	0.03	11.85
2000～2018	Arable land	2322.79	593.75	153.08	68.35	220.94	27.40
	Woodland	690.43	17901.40	323.98	39.42	27.48	43.55
	Grass	53.47	239.11	69.68	4.22	2.58	3.02
	Water bodies	19.20	9.68	3.32	64.16	2.82	1.10
	Land for construction	70.79	13.99	2.92	3.02	132.63	0.40
	Unused land	20.95	12.51	2.10	3.55	0.78	11.67

3.2 Spatial and temporal characteristics of habitat change in the study area

The habitat quality in the study area exhibits a distinct spatial pattern: high-grade zones dominate the northeastern and southern regions, mixed-grade zones are concentrated in the central and north-central areas, while low-grade zones are primarily located in the southeast. This spatial heterogeneity in habitat quality is clearly illustrated in Figure 4. Over the past two decades, the primary areas of habitat degradation have been concentrated in the central and southeastern parts of the study region, while regions with moderate or higher levels of degradation are predominantly distributed in the northern areas and extending to the northwest (Figure 5). The mean values of the Habitat Degradation Index across three periods were 0.009, 0.008, and 0.008, respectively, indicating no significant expansion in the spatial extent of habitat degradation. However, the maximum degradation value increased from 0.141 to 0.159 (Table 2), suggesting localized intensification of habitat degradation intensity.

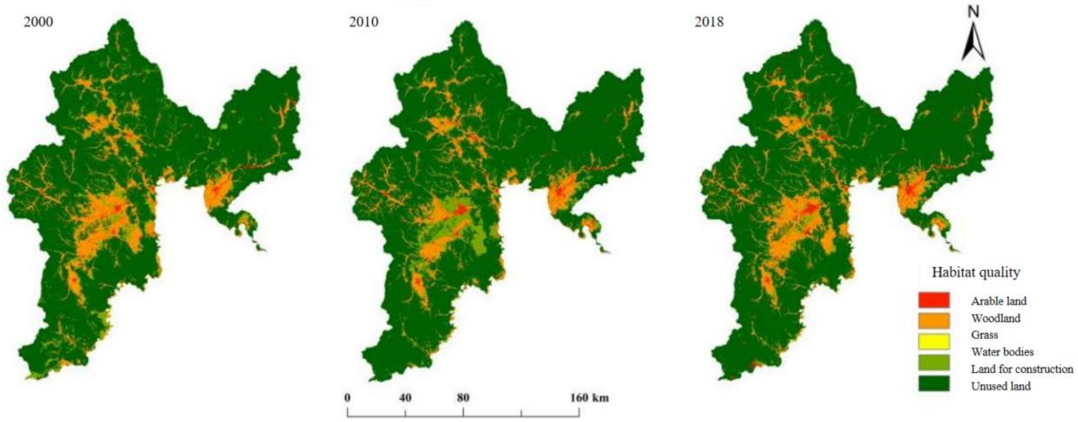

Fig. 4 spatial distribution of habitat quality in the study area

Table2 Statistics of habitat quality and degradation space in the study area

Year	Statistics of habitat quality parameters				Habitat degradation parameter statistics			
	Min	Max	Mean	SD	Min	Max	Mean	SD
2000	0	1	0.867	0.268	0	0.141	0.009	0.016
2010	0	1	0.884	0.253	0	0.138	0.008	0.013
2018	0	1	0.871	0.274	0	0.159	0.008	0.015

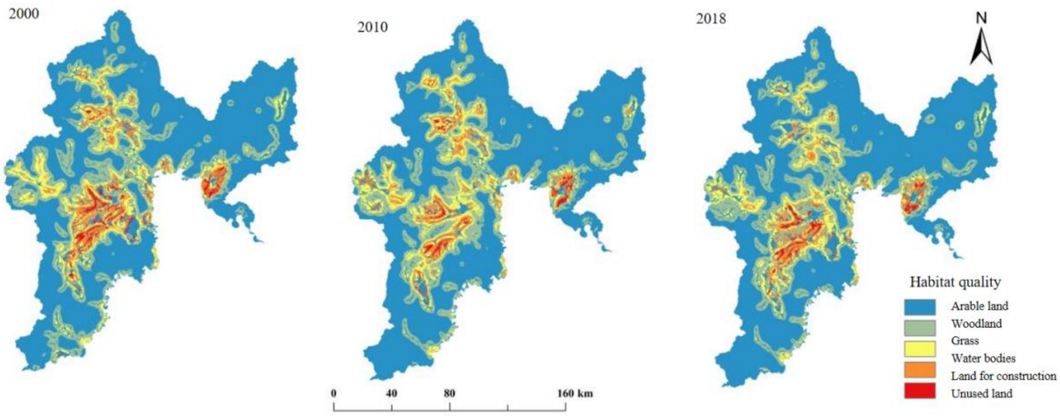

Fig. 5 spatial distribution characteristics of habitat degradation in the study area

3.3 Habitat quality and gradient distribution characteristics of degraded terrain in the study area

Research indicates that habitat quality and degradation levels exhibit significant spatial disparities across elevation gradients. Overall, above 400m elevation, high-level habitat quality and low degradation indices show a persistent upward trend, while below 400m, medium-, lower-, and low-level habitat quality and degradation degrees gradually decline with increasing elevation (Figure 6).

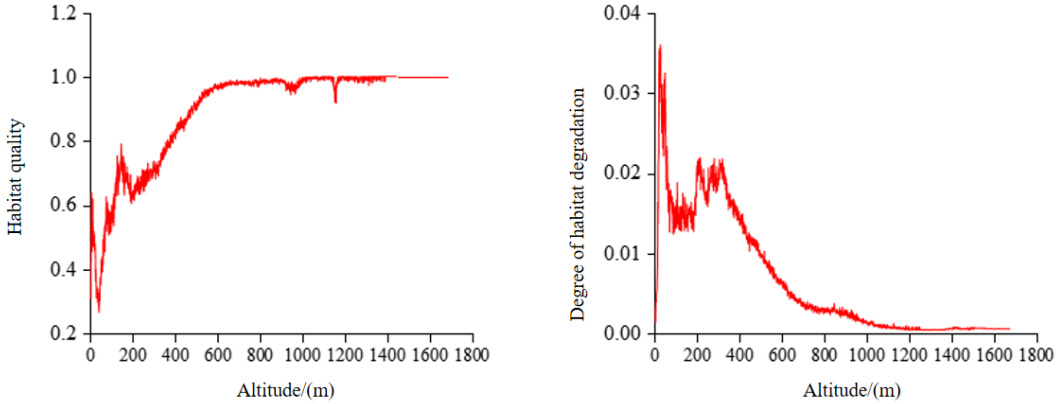

Fig 6. Spatial distribution of elevation, habitat quality and habitat degradation in the study area

4 Discussion and conclusion

4.1 Discussion

This study evaluates the impact of land use changes on habitat quality in the Tumen River Basin over the past two decades (Figure 2). The findings demonstrate that the evolution of habitat quality within the basin is closely linked to land use changes, aligning with previous research findings[13] . Habitat quality exhibits distinct effects across different altitudinal gradients (Figure 6), with significantly higher values in high-elevation areas compared to low-elevation zones. This disparity may be attributed to the material cycles and energy flows within mountain ecosystems, as well as reduced human disturbance and the influence of altitudinal zonation effects in high-elevation regions[14-16]. Furthermore, high-altitude areas are predominantly dominated by forest ecosystems, which contribute to their superior habitat quality relative to low-altitude areas[17-18]. Over the past two decades, habitat quality in the Tumen River Basin has exhibited minimal changes, which are likely related to the inherent regional characteristics of the study area. As a critical ecological conservation zone in China, the basin is predominantly covered by forestland, the primary land use type. Recent vigorous implementation of ecological protection policies in Jilin Province—such as the establishment of the Northeast China Tiger and Leopard National Park and the Chagan Lake Water-Forest-Farmland-Lake-Grassland Ecological Restoration Project —has contributed to the stability of habitat quality in the region.

Current research has certain limitations and areas requiring enhancement. Future efforts should focus on establishing a comprehensive assessment framework for habitat quality based on integrated multiple ecological functions, while further analyzing the dynamic coupling mechanisms of multiple stressors (e.g., climate change and human activities) and their driving pathways on habitat quality[19].

4.2 Conclusion

This translation integrates domain-specific terminology and references, ensuring alignment with both academic standards and practical ecological management needs. The results showed that: 1. Over the past two decades, land use changes in the study area have primarily involved the conversion of cultivated land to built-up land and grassland, as well as mutual transitions between forestland and cultivated land; 2.This translation concisely captures the temporal dynamics while contextualizing the ecological implications through integrated references;3. The habitat quality in the study area exhibits pronounced disparities in its spatial pattern, reflecting significant heterogeneity in distribution characteristics;4. The habitat quality and degradation degree of the study area had obvious elevation effect, and the habitat quality index increased with the increase of elevation.

Data sharing agreement

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, author-ship, and publication of this article.

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