Impact of Land Use/Cover Change in the Manas River Basin over the Past 57 Years

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Date: 2019-09-10T00:00:00+00:00

Abstract

Using interpreted data from 1958 aerial photographs and five periods of remote sensing images from 1976, 1987, 1998, 2006, and 2015, vector data were extracted using ArcGIS software to analyze land use/cover changes in the Manas River Basin over the past 57 years. The results show: Land use/cover in the Manas River Basin underwent widespread changes from 1958 to 2015, with the areas of cultivated land, unused land, and construction land continuously increasing, accounting for 15.27%, 4.6%, and 1.53% of the total basin area, respectively; while grassland, forest land, and water areas continuously decreased, with the reduced areas accounting for 13.5%, 5.3%, and 2.55% of the total basin area, respectively. Analysis of land use dynamic changes indicates that, over the past 57 years in the Manas River Basin, construction land experienced the fastest change rate, with an annual change rate of 12.37% of the total basin area; followed by cultivated land, with an annual change rate of 6.01% of the total basin area; additionally, the annual change rates of unused land, forest land, grassland, and water area were 0.21%, -0.99%, -0.54%, and -1.39%, respectively.

Land use changes altered the landscape pattern of the basin, leading to fragmentation of the landscape structure. From 1958 to 2015, the number of patches increased most significantly for cultivated land, grassland, and unused land, increasing by 8.50×10 , 6.54×10 , and 2.68×10 patches, respectively; while the mean patch size (MPS) continuously decreased, decreasing by 1.83 km^2, 26.11 km^2, and 20.26 km^2, respectively, with fragmentation of cultivated land and grassland increasing. Analysis of land use/cover changes in the Manas River Basin is of great significance for revealing the internal mechanisms of watershed land use changes, promoting rational development of water and soil resources, and maintaining regional ecological security.

Full Text

Land Use/Cover Change in the Manas River Basin in Recent 57 Years

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Received: 2018-08-10
Revised: 2018-11-09
Funded by: National Natural Science Foundation of China (41561103)
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1 Introduction

Land use/cover change (LUCC) represents one of the most direct manifestations of human-environment interactions and serves as a critical indicator of regional ecological security. As a key component of global environmental change research, LUCC profoundly influences landscape patterns, ecological processes, and sustainable development in arid regions. The Manas River Basin, located in the arid zone of northwestern China, exemplifies the complex dynamics between agricultural expansion and ecological conservation in inland river basins.

Previous studies on LUCC in the Manas River Basin have primarily focused on limited time periods or specific land cover types, often lacking comprehensive long-term analysis. While remote sensing technology has enabled monitoring of surface changes, few studies have integrated historical aerial imagery with multi-temporal satellite data to examine landscape fragmentation patterns over decadal scales. This study addresses these gaps by analyzing 57 years of land use/cover dynamics (1958–2015) using a combination of historical aerial photographs and multi-source remote sensing imagery. The objectives are to quantify spatiotemporal changes in land use/cover, characterize landscape fragmentation trends, and provide scientific support for sustainable land and water resource management in the basin.

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2 Materials and Methods

2.1 Study Area

The Manas River Basin, situated in northern Xinjiang, covers a total area of approximately 3.09×10 km². Geographically, it extends from 43°05 to 46°04 N and 84°56 to 86°42 E. The basin features a typical continental arid climate with mean annual precipitation ranging from 100–200 mm in the plains and 1500–2100 mm in the mountainous headwaters. The mean annual temperature varies between 4.7–5.7°C. The region represents a critical agricultural zone and ecological corridor in the arid northwest, making it an ideal study area for examining long-term LUCC processes.

2.2 Data Sources and Preprocessing

Multi-source remote sensing data spanning six time periods were acquired for this study: aerial imagery from 1958; MSS imagery from 1976; TM imagery from 1987, 1998, and 2006; and Landsat 8 OLI data from 2015. The 1976 MSS data were resampled using bands 4, 2, and 1 for false-color composition, while data from 1987, 1998, 2006, and 2015 utilized bands 5, 4, 3, and 6 for standard false-color visualization. All images were geometrically corrected to a 1:100,000 topographic map base using ArcGIS 10.1, with a registration error of less than 0.5 pixels. Radiometric calibration and atmospheric correction were applied to ensure consistency across sensors and acquisition dates.

2.3 Land Use/Cover Classification and Landscape Metrics

A supervised classification approach was employed to classify land use/cover into six categories: cultivated land, grassland, woodland, water bodies, construction land, and unused land. Classification accuracy was assessed using ground reference data and historical maps, with overall accuracy exceeding 85% for all time periods.

To quantify landscape pattern changes, we calculated five landscape metrics at the class level using Fragstats 4.2:
- **Number of Patches (NP)**: Measures landscape fragmentation
- **Patch Density (PD)**: Indicates the degree of landscape subdivision
- **Mean Patch Size (MPS)**: Reflects the average area per patch
- **Largest Patch Index (LPI)**: Represents the percentage of total landscape area comprised by the largest patch
- **Landscape Shape Index (LSI)**: Quantifies shape complexity and edge effects

The dynamic degree of land use change was calculated using the following formula:

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\%$$

where K is the annual change rate, U_a and U_b are the initial and final areas of a land use type, and T is the study period in years.

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3 Results

3.1 Temporal Changes in Land Use/Cover (1958–2015)

Over the 57-year study period, the Manas River Basin experienced substantial land use/cover transformations. Cultivated land exhibited the most significant expansion, increasing by 5116.72 km^2 (15.27% of total basin area), followed by unused land (+1543.32 km^2, 4.6%) and construction land (+513.83 km^2, 1.53%). Conversely, grassland decreased by 13.5%, woodland by 5.3%, and water bodies by 2.55%.

The temporal dynamics varied across sub-periods. During 1958–1976 and 1976–1987, cultivated land expanded rapidly, with annual growth rates of 44.31% and 41.46%, respectively. The period 1987–1998 showed the fastest expansion of construction land (15% annual increase), while the most recent period (1998–2015) witnessed accelerated growth in unused land (27% annual increase) and continued cultivated land expansion (17% annual increase).

3.2 Landscape Fragmentation Analysis

Landscape pattern analysis revealed significant fragmentation across major land use types. The number of patches (NP) increased most dramatically for cultivated land, grassland, and unused land, rising by 8.50×10 , 6.54×10 , and 2.68×10 patches, respectively. Simultaneously, mean patch size (MPS) decreased for these categories, indicating progressive subdivision of contiguous areas. Cultivated land MPS declined by 1.83 km^2, grassland by 26.11 km^2, and unused land by 20.26 km^2.

Construction land demonstrated the highest dynamic degree (12.37% annual change rate), reflecting rapid urbanization and infrastructure development. Cultivated land ranked second with a 6.01% annual change rate, while water bodies showed the most negative change rate (−1.39% annually), indicating substantial loss of aquatic habitats.

3.3 Landscape Metrics Dynamics

The Largest Patch Index (LPI) analysis showed that cultivated land, construction land, and unused land experienced decreasing dominance of largest patches, suggesting fragmentation into smaller, more dispersed parcels. In contrast, grassland and woodland patches became more isolated, with increasing LPI values indicating concentration in fewer, larger remnants.

The Landscape Shape Index (LSI) increased for all land use types except water bodies, with the most pronounced changes in cultivated land and grassland.

This trend reflects greater edge complexity and irregular patch shapes, consistent with anthropogenic disturbance and land conversion processes. The combination of increasing NP, decreasing MPS, and rising LSI confirms that the Manas River Basin landscape has become progressively more fragmented and heterogeneous over the study period.

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4 Discussion and Conclusions

This 57-year analysis of LUCC in the Manas River Basin reveals clear trajectories of agricultural intensification and landscape fragmentation. The expansion of cultivated land (5116.72 km^2) and construction land (513.83 km^2) at the expense of natural ecosystems (grassland, woodland, and water bodies) reflects the dominant role of agricultural development and urbanization in shaping the regional landscape.

The observed fragmentation patterns have important implications for ecological security. The proliferation of small patches and increased landscape complexity can disrupt habitat connectivity, alter hydrological processes, and increase edge effects. The substantial loss of water bodies (−2.55%) and grassland (−13.5%) threatens biodiversity and ecosystem services in this arid region.

These findings underscore the need for integrated land management strategies that balance agricultural production with ecological conservation. Future research should focus on identifying critical thresholds of fragmentation and developing spatially explicit models to predict future land use scenarios under climate change and policy interventions. The long-term dataset and analytical framework developed in this study provide a robust foundation for sustainable land use planning in the Manas River Basin and similar arid inland river basins.

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

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