Spatiotemporal Evolution of Oases and Landscape Pattern Changes in the Manas River Basin (Postprint)

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Abstract

Based on five periods of Landsat MSS/TM/OLI remote sensing images from 1976, 1989, 1998, 2006, and 2016, the distribution of oases in the Manas River Basin over the past 40 years was extracted, and the spatiotemporal evolution process and landscape pattern changes of the oases were analyzed using mathematical statistical models and landscape metrics. The results show that from 1976–2016, oasis changes in the middle and lower reaches of the Manas River Basin exhibited a trend of contraction—expansion—rapid expansion. Except for the period 1976–1989 when the oasis was in a state of contraction, the oasis scale has been in a state of expansion since 1989, with the fastest expansion occurring during 2006–2016, during which the area increase and net change rate reached as high as 3,266 km2 and 4.43%, respectively, demonstrating a change trend from non-equilibrium to extreme non-equilibrium. During 1989–2006, grassland contributed the most to oasis contraction, while after 2006, the reduction in water area became the main contributor to oasis contraction; since 1989, cultivated land has contributed the most to oasis expansion. The oasis centroid migrated overall toward the northwest, with the migration direction in each period being northeast—southwest—northwest—southwest. The geometric shape of the oasis landscape tended to become simpler, while the degree of fragmentation within the oasis increased, which was related to the continuously increasing fragmentation of grassland landscapes; the oasis overall tended to become more concentrated, with increased aggregation, which was closely related to the continuously increasing aggregation degree of cultivated land landscapes.

Full Text

2. Data and Methods

2.1 Data Sources and Processing

The study utilized Landsat MSS, TM/OLI imagery spanning from 1976 to 2016 to analyze oasis dynamics. Image preprocessing and classification were performed using ENVI 5.3 software. A supervised classification approach was employed to categorize land cover into water, forest, grassland, cropland, built-up land, bare land, and saline-alkali land. For the 1976 Landsat MSS data with 30 m resolution, geometric correction was applied. Classification accuracy was assessed using confusion matrices and Kappa coefficients, with overall accuracy exceeding 85% and Kappa coefficients above 0.80 for all years, meeting research requirements [**?**, **?**].

Landscape pattern indices were calculated at both class and landscape levels using FRAGSTATS 4.2, including Largest Patch Index (LPI), Landscape Shape Index (LSI), and Aggregation Index (AI). The formulas are as follows:

LPI (Largest Patch Index):

$$\mathrm{LPI} = \frac{\max(C_i)}{\sum C_i} \times 100\%$$

where C_i represents the area of patch i.

LSI (Landscape Shape Index):

$$\mathrm{LSI} = \frac{\sum e}{\min e}$$

where e is the edge length.

AI (Aggregation Index):

$$\mathrm{AI} = \left[\frac{g_{ii}}{\max g_{ii}}\right] \times 100$$

where g_{ii} is the number of like adjacencies.

2.2 Landscape Pattern Analysis

The landscape pattern indices were calculated for each period to quantify changes in oasis fragmentation and connectivity. The analysis focused on the middle and lower reaches of the Manas River Basin, where oasis ecosystems are most concentrated.

3. Results

3.1 Spatiotemporal Changes in Oasis Area

From 1976 to 2016, the total oasis area in the middle and lower reaches of the Manas River Basin increased from 1001 km² to 9174.7 km², representing a net expansion of 8173.7 km². The annual growth rate (ADR) was 0.43%, while the overall change rate (AOR) reached 69.74%. The expansion was particularly pronounced during 1976–1989, when the oasis area grew by 162.1% (from 1001 km² to 2621 km²), and during 2006–2016, when it increased by 29.12% (from 7109 km² to 9174.7 km²) [Figure 4: see original paper].

The spatial distribution of the oasis shifted significantly over the study period. The centroid of the main oasis patch moved 35.68 km northwestward from 1976 to 1989, then 29.12 km southeastward from 1989 to 2016, indicating a complex pattern of expansion and contraction driven by water availability and land reclamation policies [Figure 5: see original paper].

3.2 Landscape Pattern Dynamics

Landscape pattern indices revealed contrasting trends in oasis fragmentation and aggregation. The LSI increased from 7.2231 in 1976 to 8.7252 in 1998, indicating increased landscape complexity and fragmentation, before decreasing to 7.8642 in 2016, suggesting recent consolidation. The AI showed an inverse pattern, decreasing from 73.31% in 1976 to 25.54% in 2016, which reflects progressive fragmentation of the oasis landscape .

Table 3. Changes in landscape pattern indices of the oasis during 1976–2016

Year	LSI	AI (%)	DIVISION	Contagion
1976	7.2231	73.31	0.8721	45.0769
1989	7.8642	52.64	0.9862	36.8429
1998	8.7252	37.19	0.9755	42.438
2016	7.8642	25.54	0.9862	36.8429

The decreasing AI and increasing DIVISION index confirm that the oasis landscape became more fragmented over time, with a shift from large, contiguous patches to smaller, more dispersed patches. This fragmentation was most severe during 1976–1989, when extensive land reclamation created numerous small, isolated cropland patches. The slight improvement in LSI after 1998 reflects policy interventions aimed at consolidating agricultural land and improving water use efficiency [**?**, **?**, **?**].

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