Patterns and Changes of Aeolian Landforms in Dingjie Region, Tibet, 1996-2016: Postprint

Authors: Ma Jianjun, Pan Meihui, Wu Yongqiu

Date: 2018-10-23T00:00:00+00:00

Abstract

This study utilized six-phase remote sensing imagery from Landsat4-5 TM, MSS, Landsat7 ETM, and Landsat8 OLI in the Dinggye region from 1996 to 2016, combined with field investigations, to conduct a quantitative study on the characteristics of aeolian landforms and their dynamic pattern changes over the past two decades in the Dinggye region of Tibet. The results indicate that: (1) The main types of aeolian landforms in the Dinggye region include climbing dunes, valley-slope shrub coppice dunes, barchan dunes, flat sandy land, and valley-bottom shrub coppice dunes, which are distributed in bands along the valleys of the Pengqu River, Xieling Zangbu, Yeru Zangbu, Gyirong Zangbu, and Quqiang Zangbu, concentrated in wide valley sections, and sporadically distributed in small areas around the lakes of Dengmacuo, Qiangzuocuo, Gongzuocuo, and Cuomuzhelin. (2) The changes in the aeolian landform pattern in the Dinggye region from 1996 to 2016 can be divided into two stages: from 1996 to 2004, it showed an expansion trend with an annual conversion rate of 0.87 and an increase of 151.2 km^2; from 2004 to 2016, it showed a reversal trend with an annual conversion rate of -0.59 and a decrease of 276.6 km^2. Overall, the total area conversion rate from 1996 to 2016 was -0.27, and the aeolian landform area exhibited a trend of initial expansion followed by contraction. Transfer matrix analysis revealed that mobile sandy land transitioned significantly to fixed and semi-fixed sandy land, and these change characteristics and transition directions confirm the increasingly significant warming and humidification trend of the climate on the Tibetan Plateau.

Full Text

Preamble

DOI: 10.12118/j.issn.1000-6060.2018.05.16
Journal: Arid Land Geography (ChinaXiv Cooperative Journal)

Authors: MA Jian-jun[1], PAN Mei-hui[1], WU Yong-qiu[2,3], XUE Wen-xuan[1]
Affiliations:
[1] College of Geography and Environment Science, Northwest Normal University, Lanzhou 730070, Gansu, China
[2] Open Research Laboratory of Environmental Changes and Natural Disaster of State Education Commission, Institute of Resource Sciences, Beijing Normal University, Beijing 100875, China
[3] Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China

Abstract: This paper examines the Dingjie area of Tibet, China, as the study region, utilizing Landsat 4–5 TM, MSS, Landsat 7 ETM, and Landsat 8 OLI datasets alongside field observation data from 2016 and 2017. The geomorphic types and distribution characteristics of aeolian landforms, as well as their change trends, were analyzed using geographic information tools such as ENVI and GIS combined with Google Earth for visual interpretation of remote sensing imagery, calculation of annual conversion rates, and analysis of transfer matrices. The change in aeolian landform geomorphological pattern is a positive response to climate change, which constitutes the main reason for these changes. In the Dingjie area, climbing dunes, coppice dunes on valley slopes, crescent dunes, flat sand land, and coppice dunes on valley bottoms are mainly distributed in strips in the broad sections of valleys along the Pengqu, Xilinzangbu, Yeruzangbu, Jilongzangbu, and Quqiangzangbu Rivers. Meanwhile, small dunes are sporadically distributed around lakes including Dengmu Lake, Qiangzuo Lake, Gongzuo Lake, and Cuomuzhelin Lake. From 1996 to 2016, the geomorphological pattern of aeolian landforms in the Dingjie area first expanded and then contracted. The area of moving dunes decreased, while the area of fixed dunes, semi-fixed dunes, and coppice dunes increased. The primary transition direction was from moving dunes to fixed dunes, semi-fixed dunes, and coppice dunes. The characteristics and direction of this change confirm the trend of climate warming and wetting on the Qinghai-Xizang Plateau. This study enriches the research content on aeolian landforms in the Dingjie area and provides a theoretical reference for the study of wind-sand geomorphology and wind-sand control.

Keywords: aeolian landform; geomorphological pattern; dynamic change; Dingjie area

2 Study Area and Data Sources

The Dingjie area is located in the southwestern part of the Qinghai-Xizang Plateau. Previous research on aeolian landforms in this region has primarily focused on classification and mapping. For instance, studies have examined aeolian landforms in northern China based on remote sensing imagery, while others have investigated mega-dunes in the Badain Jaran Desert. However, systematic analysis of spatiotemporal changes in aeolian landforms in the Dingjie

area remains limited. This study utilized Landsat TM, MSS, ETM, and OLI data from 1996, 2001, 2004, 2008, 2013, and 2016, supplemented by field observations conducted in 2016 and 2017. Geographic information tools including ENVI and GIS, combined with Google Earth for visual interpretation, were employed to analyze geomorphic types, distribution characteristics, and change trends of aeolian landforms through calculation of annual conversion rates and transfer matrix analysis.

1 Classification of Aeolian Landforms

Based on geomorphological characteristics and dynamic properties, aeolian landforms in the Dingjie area were classified into five types: climbing dunes, coppice dunes on valley slopes, crescent dunes, flat sand land, and coppice dunes on valley bottoms . The classification system comprises three hierarchical levels: geomorphic type, morphological characteristics, and dynamic characteristics. Climbing dunes and coppice dunes on valley slopes exhibit stable morphologies, while crescent dunes and flat sand land represent active geomorphic types. The intermediate forms between these end-members display semi-stable characteristics.

3.2 Classification System

The classification framework incorporates three key indicators: geomorphic type, morphological features, and dynamic behavior . Stable landforms such as climbing dunes and coppice dunes on valley slopes show minimal annual variation in area and maintain consistent morphological parameters. In contrast, active landforms including crescent dunes and flat sand land demonstrate significant annual area fluctuations and unstable configurations. This classification system provides the foundation for quantitative analysis of geomorphological changes.

4 Results and Analysis

4.1 Area Statistics and Temporal Trends

In 2016, the total area of aeolian landforms in the Dingjie region was 1551 km², accounting for 26% of the study area. The distribution comprised: climbing dunes (67.1 km², 4.3%), coppice dunes on valley slopes (184.7 km², 11.9%), crescent dunes (70.3 km², 4.5%), flat sand land (195.0 km², 12.6%), and coppice dunes on valley bottoms (1033.9 km², 66.7%) .

From 1996 to 2016, the overall change rate of aeolian landform area was -0.27, with a net decrease of 125.4 km² over the 20-year period [Figure 3: see original paper]. The temporal pattern exhibited two distinct phases: (1) 1996–2004, characterized by expansion with a change rate of 0.87 and an area increase of 151.2 km²; and (2) 2004–2016, marked by contraction with a change rate of -0.59 and an area decrease of 276.6 km² . This pattern reflects a transition from expansion to reduction in aeolian landform extent.

4.2 Transfer Matrix Analysis

Using ENVI software, we generated landform distribution maps for 1996, 2004, and 2016 to compute transfer matrices for three periods: 1996–2004, 2004–2016, and 1996–2016 [TABLE:4, TABLE:5, TABLE:6]. The results reveal that stable landforms (climbing dunes and coppice dunes on valley slopes) showed minimal net change, with area variations of only 5.1 km². In contrast, active landforms (crescent dunes and flat sand land) exhibited substantial transitions, with a net decrease of 120.3 km².

During 1996–2004, the conversion from moving dunes to fixed and semi-fixed forms was limited, with only 10.1 km² transitioning from climbing dunes to coppice dunes on valley slopes (3.9% conversion rate) and 11.5 km² transitioning in the reverse direction (16% conversion rate). Active landforms showed more dynamic behavior, with 17.7 km² of crescent dunes converting to flat sand land (10.6% rate) and 7.7 km² converting to coppice dunes on valley bottoms (1.1% rate). The period 2004–2016 demonstrated accelerated stabilization, with 79.8 km² of flat sand land converting to coppice dunes on valley bottoms (40% rate), indicating a significant trend toward vegetation stabilization and reduced aeolian activity.

Over the entire 1996–2016 period, the dominant transformation pathway was from active to stable landforms, with 71.3 km² of flat sand land ultimately converting to coppice dunes on valley bottoms. This long-term trend corroborates the regional climate shift toward warmer and wetter conditions on the Qinghai-Xizang Plateau [Figure 4: see original paper].

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