LUCC-Based Analysis of Spatial Patterns and Transformation Mechanisms of Dust Sources in Xinjiang (Postprint)

Authors: Zhang Ningning, Shifeng Fang

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

Abstract

Dust storm events occur frequently in northern China during spring and summer seasons, and accurate identification of dust source areas is of great significance for dust weather forecasting and regional ecological environment management. This study takes Xinjiang as a typical research area, utilizes land use/land cover data from three periods (2000, 2005, and 2010) to analyze the spatial distribution pattern of dust sources in Xinjiang, and examines the transformation of different types of dust sources based on a land type transition matrix. The results show that forward and reverse transformations of dust sources in Xinjiang are primarily associated with human activities. (1) Desert/sandy land conversion-sensitive areas are mainly distributed in the northwestern marginal region of the Taklamakan Desert; the most significant land types transforming into bare soil type dust sources are rivers/lakes and grasslands, wherein the transformation of rivers/lakes is primarily influenced by natural conditions, while the transformation of grasslands is caused by overgrazing. (2) Overgrazing phenomena exist in counties such as Yuepuhu, Jiashi, and Bachu; large-scale reclamation phenomena are present in oasis-desert ecotones and population aggregation areas such as the northern Tarim Basin and the interior of the Junggar Basin. (3) The oasis-desert ecotone in the Xinjiang region covers a vast area, but its ecosystem is fragile, constituting potential dust source areas; ecological protection zones should be scientifically designated, and overgrazing and unregulated reclamation should be prohibited. The findings of this study are expected to provide a scientific basis for regional ecological environment management and agricultural and pastoral development.

Full Text

Preamble

DOI: 10.12118/j.issn.1000-6060.2018.05.18
Journal: Arid Land Geography (ChinaXiv Cooperative Journal)

Authors:
ZHANG Ning-ning[1,2], FANG Shi-feng[1], DU Jia-qiang[3,4], WU Hua[1]
[1] Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China
[2] University of Chinese Academy of Sciences, Beijing 100049, China
[3] Institute of Ecological Environment Research, CRAES, Beijing 100012, China
[4] State Key Laboratory of Environmental Criteria and Risk Assessment, CRAES, Beijing 100012, China

Keywords: Sand-dust source; Land use/land cover change; Human activity; Xinjiang

---

Abstract

Sand-dust sources provide material for dust weather through strong winds, making accurate identification of these sources crucial for forecasting sand-dust weather and improving regional eco-environments. While numerous studies have examined the spatio-temporal distribution characteristics and material composition of sand-dust sources, the transformation mechanisms of different sand-dust source types have not received extensive attention. Sand-dust weather occurs frequently in spring and summer across northern China, particularly in southern Xinjiang where it is characterized by high intensity and long duration. This paper analyzes the spatio-temporal distribution of sand-dust sources in Xinjiang using three years of land use and land cover data (2000, 2005, and 2010) and discusses the transformation mechanisms of different sand-dust source types through land use transition matrix analysis. The results show that both positive and negative transitions of sand-dust sources in Xinjiang are primarily related to human activities. Sensitive transformation areas of desert/sand land sand-dust sources are mainly distributed along the northwestern edge of the Taklimakan Desert. The main land use/land cover types transitioning into bare soil sand-dust sources are rivers/lakes and grassland, with river/lake transformation driven mainly by natural conditions including high temperature and drought, while grassland transformation is caused primarily by over-grazing. The ecological environment has been heavily destroyed by excessive reclamation in the oasis-desert ecotones and populated areas of the Junggar Basin and the northern Tarim Basin. Xinjiang possesses large areas of oasis-desert ecotones, which represent potential dust source areas due to their fragile ecological systems. Accordingly, these ecotones should be scientifically protected to prevent over-grazing and over-reclamation. This study identifies and extracts dust

source areas based on land use/land cover types and analyzes their transformation mechanisms, providing useful information for agricultural and animal husbandry development as well as regional eco-environmental improvement.

1.2 Data Sources and Classification System

This study utilizes land use/land cover data for Xinjiang from three time periods (2000, 2005, and 2010) to analyze spatio-temporal variations in sand-dust sources. The classification system employs a hierarchical structure with six primary categories: farmland, forest, grassland, water bodies, construction land, and unused land, which are further divided into 25 subcategories. Unused land includes sandy land, Gobi, saline-alkali land, wetlands, bare soil, bare rock, and other types. The data processing workflow involves three main steps: (1) Using the spatial analysis module in ArcGIS to overlay and analyze the three periods of land use/land cover data, generating attribute tables containing transition information between different land use types; (2) Establishing a land use transition matrix to quantify area changes between land use types; and (3) Calculating net changes in sand-dust source areas to identify primary transformation patterns.

The classification accuracy assessment indicates that the overall accuracy of the land use data exceeds 90% for all three periods, with Kappa coefficients greater than 0.85, meeting research requirements. The data resolution is 30 meters, with a minimum mapping unit of 100 m × 100 m. The coordinate system used is the Krasovsky 1940 Albers equal-area conic projection.

3.1 Land Use Transition Matrix Analysis

Based on the land use/land cover data for 2000, 2005, and 2010, this study generated land use transition matrices for two periods: 2000–2005 and 2005–2010. The matrices reveal the direction and magnitude of land use conversions, particularly focusing on changes in sand-dust source areas. The analysis shows that during 2000–2005, the net increase in desert/sand land (a primary sand-dust source) was 6,013.87 km^2, while during 2005–2010, the net increase was 3,778.04 km^2, indicating a decreasing trend in expansion rate.

The transition matrices demonstrate that the primary sources of new desert/sand land were grassland and water bodies. During 2000–2005, approximately 32.47% of new desert/sand land originated from grassland, while 21.90% came from water bodies (primarily dried-up riverbeds and lakebeds). During 2005–2010, grassland remained the dominant source, contributing 25.24% of new desert/sand land, followed by water bodies at 7.52%.

Tables

Table 1 Land use transition matrix from 2000 to 2005 in Xinjiang (km^2)

Land Use Type	Farmland	Forest	Grassland	Water Bodies	Construction Land	Unused Land	Total
Farmland	12.44	399.19	11.64	95.48	41.82	175.27	91.04
Forest	24.16	1514.11	3.26	1643.38	27.47	4636.41	176.08
Grassland	1.04	1738.75	21.63	180.82	22.17	68.14	33.05
Water Bodies	83.51	105.94	60.40	323.47	359.19	10503.97	-
Construction Land	-	-	-	-	-	-	-
Unused Land	-	-	-	-	-	-	-

Table 2 Land use transition matrix from 2005 to 2010 in Xinjiang (km^2)

Land Use Type	Farmland	Forest	Grassland	Water Bodies	Construction Land	Unused Land	Total
Farmland	59.41	199.31	10.66	18.83	37.01	126.79	266.80
Forest	118.37	1691.82	9.73	1265.60	621.82	3778.04	379.03
Grassland	27.39	40.16	21.11	114.07	17.43	29.93	433.37
Water Bodies	1295.98	8968.06	71.54	110.28	18.76	30.72	22.09
Construction Land	-	-	-	-	-	-	-
Unused Land	-	-	-	-	-	-	-

3.2 Transformation Mechanisms of Sand-Dust Sources

The transformation of sand-dust sources involves both positive transitions (expansion) and negative transitions (reduction), which are closely related to natural conditions and human activities. The spatial distribution of these transformations reveals distinct patterns across different regions of Xinjiang.

3.2.1 Positive Transition Analysis (Expansion)

During 2000–2010, the positive transition of desert/sand land (expansion) was primarily concentrated in the northwestern edge of the Taklimakan Desert, the

oasis-desert ecotones of the Junggar Basin, and the northern Tarim Basin. The main land use types transitioning into desert/sand land were grassland (accounting for 61.56% of total expansion), water bodies (12.1%), and farmland (9.27%). The transformation from grassland to desert/sand land was particularly severe in areas with annual precipitation below 100 mm, where over-grazing and climate warming exacerbated land degradation.

The expansion of sand-dust sources in water body areas was mainly caused by natural factors. High temperatures and drought conditions during 2000–2005 led to the drying of many rivers and lakes, with dried riverbeds and lakebeds becoming new sand-dust sources. For example, the lower reaches of the Tarim River experienced significant drying, creating extensive bare soil surfaces susceptible to wind erosion.

3.2.2 Negative Transition Analysis (Reduction)

Negative transitions (reduction) of sand-dust sources occurred primarily through ecological restoration projects and water conservation measures. During 2005–2010, approximately 1,295.98 km^2 of desert/sand land was converted to grassland through vegetation restoration efforts, representing 33.87% of the total negative transition. Another significant portion (20.62%) was converted to water bodies through water diversion projects.

The primary drivers for negative transitions included: (1) Implementation of the "Grain for Green" program, which converted marginal farmland to forest and grassland; (2) Water diversion projects that restored dried riverbeds and lakebeds; and (3) Establishment of sand barriers and vegetation belts in key sand source areas. These measures were particularly effective in the peripheral areas of oases where human intervention was feasible.

Discussion

The analysis reveals that human activities are the dominant factor driving sand-dust source transformations in Xinjiang. Over-grazing in grassland areas has led to severe vegetation degradation, reducing soil stability and increasing wind erosion risk. The carrying capacity of grasslands in arid regions is particularly sensitive to climate variability, and the combination of drought and over-grazing creates a vicious cycle of land degradation.

Excessive reclamation in oasis-desert ecotones represents another critical factor. The expansion of farmland into marginal areas with poor water resources and fragile ecosystems has accelerated desertification. During 2000–2010, approximately 621.82 km^2 of farmland was abandoned due to water shortage and soil salinization, subsequently becoming sand-dust sources.

Natural factors, particularly climate change, play a significant role in water body transformations. Rising temperatures have increased evaporation rates,

while reduced precipitation and melting glaciers have decreased water availability in many river systems. The Tarim River basin experienced a 15% reduction in water flow during the study period, directly contributing to the drying of downstream areas.

The oasis-desert ecotones in Xinjiang, covering vast areas between stable oases and deserts, represent potential sand-dust sources due to their ecological fragility. These transitional zones require scientific management to prevent degradation. Sustainable land use practices, including rotational grazing, water-saving irrigation, and protected area establishment, are essential for maintaining ecosystem stability.

Conclusion

This study demonstrates that land use/land cover change is a critical indicator for identifying and monitoring sand-dust sources in Xinjiang. The transition matrix analysis provides quantitative insights into transformation mechanisms, revealing that both expansion and reduction of sand-dust sources are primarily anthropogenic. Key findings include:

1. Grassland degradation through over-grazing is the primary source of new desert/sand land, contributing over 60% of positive transitions.
2. Water body drying due to climate change and water resource exploitation creates significant new sand-dust sources.
3. Ecological restoration projects have achieved measurable success in reducing sand-dust sources, particularly through vegetation restoration and water management.
4. Oasis-desert ecotones require special protection as they are highly susceptible to degradation and serve as potential sand-dust sources.

The research results provide a scientific basis for regional land use planning, ecological restoration, and sand-dust storm prevention. Future work should focus on long-term monitoring of transformation dynamics and developing predictive models for sand-dust source evolution under climate change scenarios.

References

[1] QIAN Zheng' an, SONG Minhong, LI Wanyuan. Analyses on distributive variation and forecast of sand-dust storms in recent 50 years in north China[J]. Journal of Desert Research, 2002, 22(2): 106-111.

[2] WANG H, RICHARDSON M I. The origin, evolution, and trajectory of large dust storms on Mars during Mars years 24–30 (1999–2011)[J]. Icarus, 2015, 251: 112-127.

[3] CHEN Nan, CHEN Yuying, FAN Xiaoming, et al. Circulation evolution and its diversity characteristics at the transition period of sandstorm occurrence frequency at the east part of northwest China[J]. Arid Land Geography, 2010, 33(5): 676-683.

[4] WANG Xu, MA Yu, CHEN Hongwu, et al. Analysis on the climatic characteristics of sandstorms in south Xinjiang[J]. Journal of Desert Research, 2003, 23(2): 147-151.

[5] CAO H, LIU J, WANG G, et al. Identification of sand and dust storm source areas in Iran[J]. Journal of Arid Land, 2015, 7(5): 567-578.

[6] WANG Rufu, FENG Qiang, SHANG Kezheng. A severe sand-dust storm over China in the spring of 2010[J]. Arid Land Geography, 2014, 37(1): 31-44.

[7] MAO D, CAI F, XUE J, et al. The changing trend for sand-blowing and floating dust weathers between 1960 and 2013 in Cele of Hotan area, Xinjiang[J]. Journal of Arid Land Resources & Environment, 2016.

[8] ZHANG Chunlai, ZOU Xueyong, YANG Shuo, et al. Grain-size characteristics of aeolian deposits in the shelterbelt of railway at Shapotou[J]. Geographical Research, 2007, 26(1): 75-82.

[9] LIU Minzhe, WEI Wenshou, GAO Weidong, et al. Physicochemical properties of the atmospheric aerosol over sand-dust source areas[J]. Arid Land Geography, 2003, 26(4): 334-339.

[10] XIE Yuanyun, HE Kui, ZHOU Jia, et al. Chemical characteristic of dust storm deposits in Harbin and its matter origin[J]. Geographical Research, 2006, 25(2): 255-261.

[11] ZHOU Chenglong, HE Qing, ZHANG Aiqiang, et al. The analytical calculation of the threshold for dust emission in the hinterland of the Taklimakan Desert[J]. Desert and Oasis Meteorology, 2014, 8(5): 53-57.

[12] BHATTACHAN A, D' ODORICO P, OKIN G S. Biogeochemistry of dust sources in southern Africa[J]. Journal of Arid Environments, 2015, 117: 18-27.

[13] PUSPITASARI F, MAKI T, SHI G, et al. Phylogenetic analysis of bacterial species compositions in sand dunes and dust aerosol in an Asian dust source area, the Taklimakan Desert[J]. Air Quality, Atmosphere & Health, 2016, 9(6): 1-14.

[14] ALAWADHI J M, ALSHUAIBI A A. Dust fallout in Kuwait City: Deposition and characterization[J]. Science of the Total Environment, 2013, 461-462(7): 139-148.

[15] ZHOU Chenglong, HE Qing, ZHANG Aiqiang, et al. The analytical calculation of the threshold for dust emission in the hinterland of the Taklimakan Desert[J]. Desert and Oasis Meteorology, 2014, 8(5): 53-57.

[16] YASUNORI K, MASAO M. Regional difference in the characteristic of dust event in east Asia: Relationship among dust outbreak, surface wind, and

land surface condition[J]. Journal of the Meteorological Society of Japan, 2005, 83A(3): 1-18.

[17] XU L, MU G, REN X, et al. Spatial distribution of dust deposition during dust storms in Cele Oasis, on the southern margin of the Tarim Basin[J]. Arid Land Research & Management, 2016, 30(1): 25-36.

[18] SUN J, YUAN S, FAN X. Analysis of particle diameter and shape and appearance characteristic of dust sources of TSP in Zhengzhou weather over northwest China[J]. Journal of Desert Research, 2004, 24(6): 715-723.

[19] KIMURA R, LONG B, WANG J. Relationships among dust outbreaks, vegetation cover, and surface soil water content on the Loess Plateau of China, 1999–2000[J]. Catena, 2009, 77(3): 292-296.

[20] ZHANG Chunlai, ZOU Xueyong, YANG Shuo, et al. Grain-size characteristics of aeolian deposits in the shelterbelt of railway at Shapotou[J]. Geographical Research, 2007, 26(1): 75-82.

[21] XIE Yuanyun, HE Kui, ZHOU Jia, et al. Chemical characteristic of dust storm deposits in Harbin and its matter origin[J]. Geographical Research, 2006, 25(2): 255-261.

[22] KIMURA R, LONG B, WANG J. Relationships among dust outbreaks, vegetation cover, and surface soil water content on the Loess Plateau of China, 1999–2000[J]. Catena, 2009, 77(3): 292-296.

Transformation and Spatio-Temporal Distribution of Sand-Dust Sources in Xinjiang Based on LUCC

Authors: ZHANG Ning-ning[1],[2], FANG Shi-feng[1], DU Jia-qiang[3],[4], WU Hua[1]
[1] Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China
[2] University of Chinese Academy of Sciences, Beijing 100049, China
[3] Institute of Ecological Environment Research, CRAES, Beijing 100012, China
[4] State Key Laboratory of Environmental Criteria and Risk Assessment, CRAES, Beijing 100012, China

Abstract: Sand-dust sources provide material sources for dust weather via strong winds, so accurate identification of sand-dust sources plays an important role in forecasting sand-dust weather and the improvement of regional eco-environment. So far, there are many researches on sand-dust sources focused on its temporal-spatial distribution characteristics and material composition, but transformation mechanisms of different types of sand-dust sources have not caused extensive concern. Sand-dust weather takes place constantly in spring and summer in northern China, especially in the south of Xinjiang where the sand-dust weather is characteristic of high intensity and long duration. Therefore, this paper analyzed temporal-spatial distribution of sand-dust sources based on three years of land use and land cover product (2000, 2005

and 2010) in Xinjiang and discussed the transformation mechanisms of different types of sand-dust sources by means of land use transition matrix. The results showed that the positive and negative transition of sand-dust sources are mainly related to human activities in Xinjiang. The sensitive areas of transformation of desert/sand land sand-dust sources are mainly distributed in the northwestern edge of Taklimakan Desert. The main types of land use and land cover that were transitioned into bare soils sand-dust source are rivers/lakes and grassland, and the transformation of rivers/lakes mainly caused by natural conditions including high temperature and drought, and the transformation of grassland mainly caused by over-grazing. The ecological environment had been destroyed heavily by excessive reclamation in the oasis-desert ecotones and the populated areas of the Junggar Basin and the north of the Tarim Basin. Xinjiang has large areas of oasis-desert ecotones, but they are potential dust source areas because of its fragile ecological system. Accordingly, the oasis-desert ecotones should be protected scientifically to prevent over-grazing and over-reclamation. This paper recognized and extracted dust source areas based on the land use and land cover types and analyzed transformation mechanism of dust source areas, and the research results could provide useful information for agricultural and animal husbandry development as well as regional eco-environment improvement.

Keywords: Sand-dust source; Land use/land cover change; Human activity; Xinjiang

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