Dynamic Analysis of Oasis-Desert Transition Zone Width on the Northern Margin of the Tarim Basin Postprint

Authors: Liu Xiaoxiao, Gou Qianqian, Wang Guohua(1, 2)

Date: 2025-04-08T16:51:16+00:00

Abstract

This study utilized Landsat remote sensing imagery data for oases on the northern margin of the Tarim Basin, supplemented by high-resolution remote sensing imagery from Google Earth Pro at 4800 pixels to establish interpretation criteria, and classified the oasis-desert transition zone on the northern margin of the Tarim Basin into three types: oasis-rocky bare mountain, oasis-sandy desert, and oasis-gravel desert. At four different scales (30, 60, 90, 120 m), NDVI at the oasis edge exhibited two linear variation trends; the distance between the intersection point of these two trend lines and the oasis boundary was identified as the width of the transition zone. Simultaneously, buffer analysis and scale-specific focal analysis methods were employed to analyze the width and scale-dependent characteristics of the transition zone on the northern margin of the Tarim Basin from 1994 to 2020. The results indicated that the linear variation trends of NDVI on the northern margin of the Tarim Basin were all highly significant ($P<0.01$). The width of the oasis-rocky bare mountain transition zone remained stable at 540 m from 1994 to 2020; however, the width of the oasis-gravel desert transition zone decreased annually, being 540 m in 1994, declining to 420 m in 2009, and 360 m in 2020. The width of the oasis-sandy desert transition zone also decreased significantly, being 600 m in 1994, reducing to 420 m in 2009, and shrinking to 300 m in 2020. This was primarily due to the continuous increase in cultivated land area at the edges of oasis-gravel desert and sandy desert on the northern margin of the Tarim Basin over the past 30 years, coupled with decreasing temperature and precipitation. The combined changes in anthropogenic activities and natural climate led to the gradual shrinkage of the oasis-gravel desert and oasis-sandy desert transition zones; however, the area of rocky bare land remained unchanged, and the width of the oasis-rocky bare mountain transition zone remained stable. The oasis expansion process on the northern margin of the Tarim Basin has accelerated significantly, with a clear decreasing trend in the width of the oasis-gravel desert and oasis-sandy

desert transition zones. Therefore, further strengthening of ecological environment protection and improvement efforts in the oasis-desert transition zone of this region remains necessary.

Full Text

Analysis of the Width Dynamics of the Oasis-Desert Ecotone at the Northern Margin of the Tarim Basin

LIU Xiaoxiao[1], **GOU Qianqian**[1], **WANG Guohua**[1,2]

[1]College of Geographical Sciences, Shanxi Normal University, Taiyuan 030031, Shanxi, China
[2]Linze Inland River Basin Research Station, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences, Lanzhou 730010, Gansu, China

Abstract

This study employs Landsat remote sensing imagery of oases at the northern margin of the Tarim Basin, supplemented by high-resolution Google Earth Pro imagery at 4800 pixels to establish interpretation markers. The oasis-desert transition zone at the northern margin of the Tarim Basin was classified into three types: transitions between oasis and stony bare mountains, sandy desert, and gravelly desert. At four different scales (30 m, 60 m, 90 m, and 120 m), the NDVI values at oasis edges exhibited two distinct linear trends. The distance between the intersection point of these two trend lines and the oasis boundary was defined as the width of the transition zone. Buffer analysis and focal analysis methods for different scales were simultaneously applied to analyze the width and scale-dependent characteristics of the transition zone from 1994 to 2020. The results demonstrate that the linear trends of NDVI change at the northern margin of the Tarim Basin were all highly significant ($P < 0.01$). The width of the oasis-stony bare mountain transition zone remained stable at 540 m from 1994 to 2020. In contrast, the width of the oasis-gravelly desert transition zone decreased annually, from 540 m in 1994 to 420 m in 2009 and 360 m in 2020. Similarly, the width of the oasis-sandy desert transition zone showed a significant reduction, from 600 m in 1994 to 420 m in 2009 and 300 m in 2020. This shrinkage is primarily attributed to the continuous expansion of cultivated land at the edges of both gravelly and sandy deserts over the past 30 years, coupled with decreasing temperatures and precipitation. The combined effects of anthropogenic activities and natural climate changes have led to the gradual narrowing of these transition zones. However, the area of bare rocky land remained unchanged, resulting in a stable width for the oasis-stony bare mountain transition zone. These findings indicate that oasis transformation processes have significantly accelerated at the northern margin of the Tarim Basin, with particularly pronounced narrowing of the gravelly and sandy desert transition

zones. Consequently, enhanced efforts for ecological protection and environmental improvement in the oasis-desert transition zone are urgently needed.

Keywords: width of oasis-desert ecotone; buffer analysis; focal analysis; northern margin of the Tarim Basin

1.1 Study Area Overview

The study area, located at the Weigan-Kuqa River Delta oasis on the northern margin of the Tarim Basin, falls within an arid to extremely arid climate zone. With an average annual temperature of 9.9–11.5 °C and mean annual precipitation of 42.4–94.4 mm, the region experiences a temperate continental climate characterized by abundant sunlight and heat resources, diverse topography, and significant seasonal temperature variations. The oasis ecosystem borders three distinct landscape types: stony bare mountains, sandy desert, and gravelly desert [Figure 1: see original paper].

1.2 Data Sources

Remote sensing data were obtained from the Geospatial Data Cloud platform (http://www.gscloud.cn/), selecting imagery with high quality, minimal cloud cover, and captured during peak vegetation growth periods. Landsat TM/ETM and Landsat 8 images were utilized for this analysis. Meteorological data, including temperature, precipitation, dew point, wind direction and speed, cloud cover, and atmospheric pressure, were downloaded from NOAA' s ISD database (ftp://ftp.ncdc.noaa.gov/pub/data/noaa/isd/). Land use data for China from 1995 to 2020 were sourced from the Resource and Environmental Science Data Platform (https://www.resdc.cn/), classified into six primary categories: cultivated land, forestland, grassland, water bodies, construction land, and unused land, with secondary classifications based on land resource attributes.

1.3.1 Data Processing and Interpretation

Prior to interpretation, ENVI 5.6 software was used for geometric correction, radiometric calibration, and FLAASH atmospheric correction of the imagery, followed by image cropping. High-resolution remote imagery served to establish interpretation markers. An object-oriented classification method was employed to interpret five surface cover types: farmland, stony bare mountains, gravelly desert, sandy desert, and water bodies. The ArcGIS Eliminate tool was subsequently applied to merge these classified types.

1.3.2 Classification of Transition Zone Types and Sample Plot Setup

The transition zone was categorized into three types: oasis-stony bare mountain, oasis-sandy desert, and oasis-gravelly desert. To ensure consistency in influencing factors, each transition zone sample plot was standardized at 2000 m × 2500

m. Given the rapid oasis expansion in this region, a translation method was applied for sampling across different time periods.

1.3.3 Identification of Transition Zone Boundaries

Buffer analysis was first conducted to create an outer baseline defining the oasis boundary, which integrates desert and water areas into the oasis body [15]. Based on this boundary baseline, buffer zones were established at varying intervals: 100 m increments for 0-300 m, 200 m increments for 300–600 m, and 2000 m increments beyond 1000 m, with a maximum buffer distance of 2000 m. Sample plots covering these buffer ranges were established at each junction of different landscape types [Figure 2: see original paper]. Focal analysis was then applied to NDVI data to calculate statistical values within each pixel' s neighborhood, using window sizes of 30 m × 30 m (original resolution), 60 m × 60 m, 90 m × 90 m, and 120 m × 120 m. This approach reduces the influence of vegetation clustering in single or few grid cells [Figure 2: see original paper].

2.1 Changes in Boundary Width of Oasis-Stony Bare Mountain Transition Zone

At the 60 m × 60 m scale, NDVI values in the oasis-stony bare mountain transition zone showed a sharp productivity decline at 480 m from the boundary, fluctuating between 0.0671 and 0.0458. Beyond 480 m, values averaged a reduction of 0.0002 per 100 m. The transition zone width stabilized at 480 m. At the 90 m × 90 m scale, the turning point occurred at 540 m, with NDVI values ranging from 0.0758 to 0.0439, and the boundary remained stable at 540 m. At the 120 m × 120 m scale, the inflection point also appeared at 540 m, with values between 0.0791 and 0.0428, and the boundary position unchanged at 540 m. All linear trends were highly significant ($P < 0.01$). Based on these results, the oasis-stony bare mountain transition zone location was mapped [FIGURE:3, FIGURE:4], showing a stable width of 540 m, likely due to thin or absent soil layers on stony bare mountains with low vegetation cover unsuitable for cultivation.

2.2 Changes in Boundary Width of Oasis-Gravelly Desert Transition Zone

At the 60 m × 60 m scale, the oasis-gravelly desert transition zone exhibited a sharp productivity decline at 480 m, with NDVI values fluctuating between 0.0810 and 0.0527. Beyond 480 m, values decreased by an average of 0.0002 per 100 m, stabilizing the transition zone width at 480 m. At the 90 m × 90 m scale, the turning point remained at 480 m, with the boundary stable at 480 m. At the 120 m × 120 m scale, the width stabilized at 540 m, with all linear trends highly significant ($P < 0.01$).

At the 60 m × 60 m scale for 2009 data, a sharp decline occurred at 420 m, with

NDVI values between 0.0461 and 0.0301, stabilizing the boundary at 420 m. At the 90 m × 90 m scale, the boundary remained stable at 420 m, and at the 120 m × 120 m scale, the width stayed at 420 m. All trends were highly significant ($P < 0.01$).

For 2020 data at the 60 m × 60 m scale, the turning point appeared at 360 m, with NDVI values ranging from 0.0554 to 0.0376, stabilizing the boundary at 360 m. At the 90 m × 90 m scale, the boundary remained at 360 m, and at the 120 m × 120 m scale, the width was also stable at 360 m. All linear trends were highly significant ($P < 0.01$). Based on these findings, the oasis-gravelly desert transition zone location was mapped [FIGURE:5, FIGURE:6], showing a clear decreasing trend in width from 540 m to 360 m, likely due to reduced temperature and precipitation coupled with expanding cultivated land at the oasis-gravelly desert margin.

2.3 Changes in Boundary Width of Oasis-Sandy Desert Transition Zone

At the 60 m × 60 m scale, the oasis-sandy desert transition zone showed a sharp productivity decline at 600 m in 1994 data, with NDVI values between 0.1085 and 0.0850, stabilizing the width at 600 m. At the 90 m × 90 m scale, the boundary remained stable at 600 m, and at the 120 m × 120 m scale, the width was also stable at 600 m. All linear trends were highly significant ($P < 0.01$).

For 2009 data at the 60 m × 60 m scale, the turning point occurred at 420 m, with NDVI values ranging from 0.0904 to 0.0648, stabilizing the boundary at 420 m. At the 90 m × 90 m scale, the boundary remained at 420 m, and at the 120 m × 120 m scale, the width stayed at 420 m. All trends were highly significant ($P < 0.01$).

For 2020 data at the 60 m × 60 m scale, a sharp decline appeared at 300 m, with NDVI values between 0.0415 and 0.0260, stabilizing the boundary at 300 m. At the 90 m × 90 m scale, the boundary remained at 300 m, and at the 120 m × 120 m scale, the width was also stable at 300 m. All linear trends were highly significant ($P < 0.01$). The oasis-sandy desert transition zone location was mapped accordingly [FIGURE:7, FIGURE:8], showing a significant decreasing trend from 600 m to 300 m, likely driven by reduced temperature and precipitation alongside expanding cultivated land at the oasis-sandy desert margin.

3.1 Scale Dependency and Dynamics of Oasis-Desert Ecotone Width

Oases represent the primary space for human production and living in arid regions. As an ecological buffer zone, the oasis-desert transition zone plays a crucial role in maintaining energy flow, material cycling, and landscape stability [16]. The width of the oasis-stony bare mountain transition zone remained at

540 m from 1994 to 2020, showing scale dependency at neighborhood settings greater than 90 m × 90 m but no scale dependency at settings less than 60 m × 60 m. In 2009 and 2020, the width stabilized at 540 m without scale dependency.

For the oasis-gravelly desert transition zone, scale dependency existed at neighborhood settings greater than 90 m × 90 m in 1994, with width stable at 540 m. No scale dependency was observed at settings less than 60 m × 60 m. In 2009, the width stabilized at 420 m without scale dependency, and in 2020, it remained at 360 m, also without scale dependency.

The oasis-sandy desert transition zone showed scale dependency at settings greater than 90 m × 90 m in 1994, with width stable at 600 m, but no scale dependency at smaller settings. In 2009, the width ranged from 360–420 m with scale dependency at settings greater than 90 m × 90 m, but no dependency at smaller settings. By 2020, the width stabilized at 300 m without scale dependency. NDVI values consistently decreased from the oasis edge toward the transition zone exterior, aligning with findings from the Hexi Corridor [15] and Qira oasis [17]. Overall, the oasis-stony bare mountain transition maintained a stable width of 540 m, while gravelly and sandy desert transition zones exhibited significant narrowing trends.

3.2.1 Natural Factors

The study area lies in an arid to extremely arid region with a fragile ecological environment. Long-term climate changes, including precipitation and temperature fluctuations, can alter transition zone width [18]. Precipitation directly affects soil moisture and vegetation productivity, while temperature influences growth cycles and biomass [19]. Statistical analysis of climate data from 1994–2020 shows declining trends in both annual precipitation and mean annual temperature [Figure 9: see original paper]. Consequently, the narrowing of the oasis-gravelly and sandy desert transition zones is likely associated with these climatic changes.

3.2.2 Human Factors

Cultivated land area increased significantly from 1995–2020 [Figure 10: see original paper], consistent with previous research on spatiotemporal evolution of the Tarim Basin' s oasis-desert transition zone [7]. Agricultural expansion and land use changes have modified transition zone widths. Over the past 30 years, cultivated land has increased at the edges of both gravelly and sandy deserts, with sand migration to farmland reaching 47 km^2 and Gobi desert conversion to farmland totaling 25 km^2, while bare rocky land remained unchanged. This explains why the sandy desert transition zone showed the most pronounced narrowing, followed by the gravelly desert transition, while the stony bare mountain transition remained stable. Although the combination of manual interpretation and NDVI methods improved extraction accuracy, the relatively coarse resolution of Landsat imagery may introduce sampling errors. Therefore, field verification is recommended to enhance identification accuracy.

4 Conclusions

From 1994 to 2020, the linear trends of NDVI change at the northern margin of the Tarim Basin were all highly significant ($P < 0.01$). The width of the oasis-stony bare mountain transition zone remained unchanged at 540 m, while the widths of both the oasis-gravelly desert and oasis-sandy desert transition zones decreased significantly, with the sandy desert transition showing the greatest reduction. This narrowing is primarily attributed to the continuous expansion of cultivated land at the edges of gravelly and sandy deserts over the past 30 years, combined with decreasing temperatures and precipitation. The interplay of anthropogenic activities and natural climate changes has caused gradual shrinkage of these transition zones. However, the area of bare rocky land remained stable, resulting in an unchanged width for the oasis-stony bare mountain transition zone. These findings underscore the need for strengthened ecological protection and environmental improvement efforts in the oasis-desert transition zone of this region.

References

[1] Teng Yufeng, Chen Bin, Ma Jian, et al. Vegetation community species diversity and soil moisture variation characteristics in desert oasis transition zone of Zhangye, Gansu Province[J]. Bulletin of Soil and Water Conservation, 2024, 44(4): 45-54.

[2] Zhao Peng. Spatial Distribution of Plant Communities and Environmental Interpretation in Minqin Oasis Desert Ecotone[D]. Lanzhou: Gansu Agricultural University, 2014.

[3] Lu Jiaqi. Spatial and Temporal Variation Characteristics of NDVI in the Oasis Transition Zone and Desertification Control Strategies[D]. Lanzhou: Northwest Normal University, 2023.

[4] Hu Guanglu, Wang Dejin, Liao Yaxin, et al. Effect of meteorological factors on sand activities at oasis desert ecotone in the middle reaches of the Heihe River Basin of China[J]. Journal of Desert Research, 2015, 35(4): 865-873.

[5] Wei Yajuan, Dang Xiaohong, Wang Ji, et al. Morphological characteristics of *Nitraria tangutorum* nebkhas in Jilantai desert oasis ecotone[J]. Arid Zone Research, 2023, 40(3): 403-411.

[6] Jia Baoquan, Ci Longjun, Ren Yiping. The analysis on the oasis landscape dynamics[J]. Acta Ecologica Sinica, 2001, 21(11): 1947-1951.

[7] Bian Huiqin, Wang Xuemei. Analysis on space time evolution of oasis desert transition zone at north margin of Tarim Basin based on NDVI[J]. Ecological Science, 2020, 39(3): 80-87.

[8] Wang Qian, Chen Ying, Ruan Xirui, et al. The changes of NDVI in China from 1982 to 2012 and its relationship with climatic factors[J]. Acta Agrestia Sinica, 2017, 25(4): 691-700.

[9] Liu Xianfeng, Pan Yaozhong, Zhu Xiufang, et al. Spatiotemporal variation of vegetation coverage in Qinling Daba Mountains in relation to environmental factors[J]. Acta Geographica Sinica, 2015, 70(5): 705-716.

[10] Pan Guangyao, Mu Guijin, Yue Jian, et al. Change of the oasis desert ecotone and its causes in Qira county during the period of 2001-2010[J]. Arid Zone Research, 2014, 31(1): 169-175.

[11] Chang Xueli, Ji Shuxin, Qiao Rongrong, et al. NDVI based identification of oasis desert transitional zone wideness: A case study in the central Hexi Corridor[J]. Acta Ecologica Sinica, 2020, 40(15): 5327-5336.

[12] Ji S X, Bai X L, Qiao R R, et al. Width identification of transition zone between desert and oasis based on NDVI and TCI[J]. Scientific Reports, 2020, 10(1): 8672.

[13] Zhao Qi, Wang Lin, Pan Shibing, et al. Evolution of NDVI and analysis of its correlation with influencing factors in desert oasis transition zone[J]. Journal of China Institute of Water Resources and Hydropower Research, 2024, 22(3): 239-249.

[14] Sun Fan, Wang Yi, Chen Yaning. Dynamics of desert oasis ecotone and its influencing factors in Tarim Basin[J]. Chinese Journal of Ecology, 2020, 39(10): 3397-3407.

[15] Chang J, Gong L, Zeng F, et al. Using hydro climate elasticity estimator and geographical detector method to quantify the individual and interactive impacts on NDVI in oasis desert ecotone[J]. Stochastic Environmental Research and Risk Assessment, 2022, 36(10): 3131-3148.

[16] Li Menghua, Han Yingjuan, Zhao Hui, et al. Analysis on spatial temporal variation characteristics and driving factors of fractional vegetation cover in Ningxia based on geographical detector[J]. Ecology and Environmental Sciences, 2022, 31(7): 1317-1325.

[17] Shi Song, Li Wen, Yang Ziyi, et al. Spatiotemporal variations and topographic differentiation of fractional vegetation cover in Changbai Mountain[J]. Bulletin of Soil and Water Conservation, 2023, 43(3): 254-264, 276.

[18] Yang Shasha, Yang Yuqing, Zhou Zhongfa, et al. Analysis on spatiotemporal variation between vegetation coverage and topographic factors in FAST radio quiet zone[J]. Ecological Science, 2023, 42(4): 145-153.

[19] Wang Xuemei, Cao Lijun. Analysis of soil particle size of typical plant communities in oasis desert ecotone on northern margin of Tarim Basin[J]. Southwest China Journal of Agricultural Sciences, 2019, 32(12): 2848-2855.

[20] Ji Shuxin. Width Identification and Dynamic Analysis of Transition Zone Among Different Sandy Landscape Types[D]. Yantai: Ludong University, 2021.

[21] Feng Hanlin. Responses of Plant Reproductive Phenology to Changing Precipitation Seasonality in a Semiarid Grassland of Inner Mongolia[D]. Baoding: Hebei University, 2024.

[22] Yin Zhenliang, Feng Qi, Wang Lingge, et al. Vegetation coverage change and its influencing factors across the northwest region of China during 2000-2019[J]. Journal of Desert Research, 2022, 42(4): 11-21.

[23] Yan Danni, Wu Xinyue, Wang Boheng, et al. Characteristics and driving forces of changes in vegetation coverage on the Loess Plateau, 1982-2015[J]. Acta Ecologica Sinica, 2023, 43(23): 9794-9804.

[24] Shen Zi' ao, Wu Jing, Li Chunbin. Temporal and spatial changes of vegetation cover and its driving forces in the Hexi inland river basin from 2000 to 2020[J]. Journal of Desert Research, 2024, 44(3): 119-127.

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