Spatial Differentiation Characteristics of Urban and Rural Settlements and Oasis Nurturing Degree Analysis in the Hexi Corridor: Postprint

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Abstract

Oases and the urban and rural settlements nurtured by oases constitute the core of human production, life, and ecology in the arid regions of northwestern China. Investigating the relationship between oases and settlements is of great significance for new-type urbanization construction and rural revitalization in arid regions. This study identified and extracted spatial characteristic information of oases and urban-rural settlements throughout the Hexi Corridor through Google Earth visual interpretation, and systematically analyzed the scale, morphological structure, and typological characteristics of urban-rural settlements in the Hexi Corridor in 2016 using GIS spatial analysis and landscape pattern indices. Furthermore, it proposed for the first time the Oasis Nurturing Index for settlements in arid regions, and further analyzed the oasis nurturing degree of urban-rural settlements. The results indicate: (1) The scale and density differentiation characteristics of settlements in the Hexi Corridor are significant. Settlement land scale is generally small, with an average size of only 0.05 km². Settlement distribution exhibits characteristics of high-density small-scale and low-density large-scale agglomeration. Both settlement density and agglomeration degree follow a distance decay pattern centered on cities. "Hotspot" detection reveals that the area east of Shandan County is a hotspot region for settlement distribution in the Hexi Corridor. (2) Analysis of settlement morphological structure indicates that the connectivity and stability of rural settlements gradually weaken from east to west. The difference in settlement area gradually decreases along the urban "center-edge" gradient. In areas such as Guazhou County, Yumen City, and Jinta County, the coupling degree between the mean shape index and mean fractal dimension of settlements is high, with strong natural distribution patterns and complex patch shapes. (3) Jiayuguan, with a higher Oasis Nurturing Index, exhibits prominent "human-land" relationship contradictions, with urban-rural development greatly constrained by oasis

scale. In contrast, the broad oasis hinterland spaces in Liangzhou District, Minqin County, and other areas are conducive to the development of urban-rural settlements.

Full Text

Spatial Differentiation Characteristics and Oasis Breeding Degree of Urban and Rural Settlements in the Hexi Corridor

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Abstract:
Oases and rural settlements constitute the core of human production, living, and ecological activities in the arid regions of Northwest China. Exploring the relationship between oases and settlements is crucial for new urbanization construction and rural revitalization in these areas. This study takes the Hexi Corridor in Gansu Province as the research area. Settlement and oasis data were derived from visual interpretation of Google Earth imagery, and GIS spatial analysis, landscape pattern indices, and hierarchical clustering methods were employed to systematically analyze the spatial scale, morphological structure, and typological characteristics of urban and rural settlements in the Hexi Corridor in 2016. Against the background of the ecological environment, an oasis breeding index for settlements in arid areas was proposed to analyze the degree of oasis breeding. The results show that: (1) The scale difference between rural and urban settlements is obvious, demonstrating that the larger the distribution pattern scale, the smaller the proportion of patches, with high-density distribution of small patches and low-density large-scale distribution being the main characteristics. The residential land scale is generally small, with an average size of only 0.05 km^2, and both the density and agglomeration of settlements decline from the city core outward. Hotspot detection revealed that the eastern part of Shandan County is the hotspot region for settlement spatial distribution. (2) Morphological structure analysis indicates that the connectivity and stability of rural settlements gradually weaken from east to west, and the area differentiation of settlements gradually reduces from the city "center-edge." The mean shape index and mean patch fractal dimension of settlements in Guazhou County, Yumen City, and Jinta County are highly coupled, patch shapes are complex, and natural distribution is strong. (3) The oasis ecological environment in Jiayuguan City is the most vulnerable, greatly restricting urban and rural development. However, the oasis hinterlands of Liangzhou District, Min-

qin County, and Ganzhou District have ample space, which is conducive to urban and rural development.

Keywords: settlement; spatial scale; morphological structure; oasis breeding index; Hexi Corridor

1. Introduction

Oases are the foundation of human survival and development in arid regions, while settlements serve as carriers of human activities. Understanding the spatial relationship between settlements and oases is essential for sustainable development in water-scarce environments. Previous studies have examined settlement patterns, landscape ecology, and water resource constraints . However, comprehensive analysis of settlement spatial differentiation and oasis breeding potential remains limited.

2. Study Area and Data Sources

The Hexi Corridor, located in Gansu Province, represents a typical arid region where oasis agriculture and settlement distribution are strictly constrained by water resources. This study utilized 2016 Google Earth imagery with high spatial resolution for visual interpretation of settlement boundaries. The interpretation process followed these protocols: (1) Settlement patches were digitized based on building clusters and road networks, with a minimum mapping unit of 0.05 km^2. Settlement boundaries were delineated according to the outermost edges of contiguous built-up areas, excluding isolated structures and temporary buildings. (2) A 5 km $\times$ 5 km grid system was established across the study area to facilitate spatial analysis and sampling. (3) Quality control measures included cross-validation between interpreters and field verification of sample plots.

3. Methods

3.1 Landscape Pattern Analysis Landscape pattern indices were calculated at both patch and class levels to characterize settlement morphology. Key metrics included patch density, mean patch size, shape index, fractal dimension, and aggregation index. These indices quantify the spatial configuration and complexity of settlement distributions across the oasis landscape.

3.2 Oasis Breeding Index An innovative oasis breeding index (OBI) was proposed to evaluate the potential for settlement expansion within oasis boundaries. The index integrates water resource availability, land suitability, and ecological vulnerability metrics: . Higher values indicate greater capacity for sustainable settlement growth.

3.3 Hierarchical Clustering Settlements were classified into typologies using hierarchical clustering based on scale, shape complexity, and spatial aggregation characteristics. This approach identified distinct settlement patterns associated with different oasis environments and development stages.

4. Results

4.1 Settlement Scale Characteristics A total of 21,773 settlement patches were identified, with significant scale variation. The average settlement area was only 0.05 km², indicating generally small residential land parcels. The size distribution showed: 2,177 patches >1 km², 126 patches >5 km², and 91 patches >10 km². Remarkably, 99.8% of settlements were smaller than 1 km², demonstrating the dominance of small-scale, dispersed settlement patterns in the oasis environment [Figure 1: see original paper].

The spatial distribution exhibited clear scale-dependent patterns. Settlement density and agglomeration both decreased with distance from city centers, forming a core-periphery gradient. Hotspot analysis using Getis-Ord Gi* statistics identified the eastern portion of Shandan County as a significant hotspot ($p < 0.05$) for settlement clustering, suggesting favorable conditions for concentrated development.

4.2 Morphological Structure Analysis Settlement shape complexity varied systematically across the region. The mean shape index (MSI) and mean patch fractal dimension (MPFD) showed high coupling in Guazhou County, Yumen City, and Jinta County, where complex, naturally-shaped patches predominated. In contrast, more regular, geometric shapes characterized urban peripheries.

Connectivity analysis revealed that rural settlement networks gradually weakened from east to west, correlating with decreasing water resource availability. The stability index, calculated as the ratio of core settlement area to total oasis area, showed similar longitudinal trends [Figure 6: see original paper].

4.3 Oasis Breeding Degree Assessment The oasis breeding index analysis yielded critical insights for regional planning. Jiayuguan City exhibited the lowest OBI values (0.119–0.223), indicating high ecological vulnerability and limited capacity for settlement expansion. Water resource constraints and fragile ecosystems severely restrict development potential.

Conversely, Liangzhou District, Minqin County, and Ganzhou District showed relatively high OBI values (1.062–1.223), suggesting substantial available space within oasis boundaries for sustainable urban and rural development. These areas maintain a balance between settlement distribution and ecological carrying capacity [Figure 7: see original paper].

The hierarchical clustering identified three primary settlement typologies: (1) Compact urban settlements with high density and regular shapes; (2) Dispersed

rural settlements with low density and natural shapes; and (3) Transitional settlements exhibiting intermediate characteristics. Each type corresponded to distinct oasis breeding capacity levels.

5. Discussion

The pronounced scale differentiation of settlements reflects the historical adaptation to water resource distribution in the Hexi Corridor. The predominance of small patches (<1 km²) indicates that traditional dispersed settlement patterns remain prevalent, though urbanization is gradually creating larger, more compact forms.

Morphological analysis demonstrates that settlement shape complexity is not merely a product of natural terrain, but also reflects planning interventions. Regular geometric shapes dominate areas with active land consolidation, while natural, fractal-like patterns persist in regions with minimal planning control.

The oasis breeding index provides a quantitative framework for guiding sustainable development. Areas with high OBI values should prioritize ecological protection while allowing controlled expansion, whereas low OBI regions require strict development limits and ecological restoration. The index successfully integrates multiple dimensions of sustainability, offering practical value for arid region planning.

6. Conclusions

This study reveals significant spatial differentiation in settlement patterns across the Hexi Corridor, with scale, morphology, and distribution closely linked to oasis ecological conditions. The proposed oasis breeding index effectively quantifies development potential while accounting for environmental constraints. Key findings include:

1. Settlement scales are predominantly small (average 0.05 km²), with density decreasing from urban cores.
2. Morphological complexity and connectivity weaken longitudinally from east to west.
3. The oasis breeding index identifies Jiayuguan as most vulnerable and Liangzhou-Minqin-Ganzhou as development-suitable zones.

These results provide scientific guidance for optimizing settlement layouts and implementing differentiated development strategies in arid regions. Future research should incorporate temporal dynamics and socioeconomic factors to enhance the robustness of the oasis breeding index.

References

[1] YANG Ren, LIU Yansui, LONG Hualou, et al. Spatio-temporal characteristics of rural residential land use change and spatial directivity identification

based on soil and water conservation search [J]. *Arid Land Geography*, 2015, 34(6): 1077-1087.

[2] LONG Hualou, LI Yurui, LIU Yanrui. Analysis of evaluative characteristics and their driving mechanism of hollowing villages in China [J]. *Acta Geographica Sinica*, 2009, 64(10): 1203-1213.

[7] CRECENTER, ALVAREZ C, FRAU. Economic, social and environmental impact of land consolidation in Galicia [J]. *Land Use Policy*, 2002, 19(2): 135-147.

[8] WANG Cheng, WANG Liping, LIXiaoqing, et al. The source of the forward-security of farmers' livelihood and settlement integration: Based on survey of 477 farmers in Bailin Village, west suburbs of Chongqing [J]. *Acta Geographica Sinica*, 2011, 66(8): 1141-1152.

[14] ZHANG Bailin, ZHANG Fenrong, ZHOU Jian, et al. Functional evolution of rural settlement based on micro-perspective: A case study of Hetayuan Village in Yishui County, Shandong Province [J]. *Scientia Geographica Sinica*, 2015, 35(10): 1272-1279.

[15] ZHANG Bailin, ZHANG Fenrong, ZHOU Jian, et al. Economic geography of rural settlement landscape aggregation in suburb [J]. *Scientia Geographica Sinica*, 2015, 35(6): 674-682.

[16] DING Wenhui, MENG Bao. Interaction between oasis water resource and oasis urbanization: Taking Northwest Region as example [J]. *Journal of Inner Mongolia Normal University (Natural Science Edition)*, 2005, 34(4): 502-505.

[17] MENG Jun, WU Xiuqin. Research on the landscape spatial pattern of Suzhou in the middle-western Hexi Corridor [J]. *Arid Land Geography*, 2004, 27(2): 179-185.

[18] TAN Xuelan, LIU Zhuo, HE Yanhua, et al. Spatio-temporal change of rural settlements and its spatial coupling relationship with water and soil resources based on grid in the Hexi Oasis [J]. *Journal of Natural Resources*, 2018, 33(5): 775-787.

[22] LI Heying, WANG Yanhui. Discrete degree of village settlement and its correlation with net income of rural residents in poverty county [J]. *Geographical Research*, 2014, 33(9): 1617-1628.

[23] NIE Xiaoying, SHI Peiji, LYU Rui, et al. The Spatio-temporal evolution of spatial interaction among oasis urban of Hexi Corridor [J]. *Economic Geography*, 2016, 36(7): 76-83.

[24] WANG Fuhai, ZHOU Qigang, CHEN Dan, et al. Influences of reclamation and new construction rural settlement spatial distribution pattern in low mountain hilly area [J]. *Research of Soil and Water Conservation*, 2016, 23(3): 144-149.

[25] MA Libang, TIAN Yaya, GUO Xiaodong, et al. Spatial-temporal change of rural settlements and its spatial coupling relationship with water and soil resources based on grid in the Hexi Oasis [J]. *Journal of Natural Resources*, 2018, 33(5): 775-787.

[26] ZHANG Qiuju, FU Bojie, CHEN Liding. Several problems about landscape pattern [J]. *Scientia Geographica Sinica*, 2003, 23(3): 264-270.

[27] LIU Yanxu, WANG Yanglin, PENG Jian, et al. Selection of different clustering algorithms for settlement landscape aggregation in suburb [J]. *Scientia Geographica Sinica*, 2015, 35(6): 674-682.

[28] ZHOU Liang, ZHU Yanru, SUN Dongqi. Spatial differentiation characteristics and oasis breeding degree of urban and rural settlements in Hexi Corridor [J]. *Arid Land Geography*, 2020, 43(1): 26-35.

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