Grid-Based Comprehensive Evaluation of Human Settlement Environment Quality in the Guanzhong Plain Urban Agglomeration Postprint

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Abstract

Based on multi-layer raster data of natural and humanistic factors, a comprehensive index evaluation model for human settlement environment quality was constructed to analyze the spatial differentiation pattern of human settlement environment in the Guanzhong Plain urban agglomeration in 2015, and to explore the synergistic relationship between population distribution and human settlement environment quality. The results show that: (1) The natural environment of human settlements exhibits a spatial distribution pattern that gradually decreases from east to west, and from mountains and plateaus to plains and valleys, with topography being the most influential factor, and the relief degree of land surface showing a negative correlation with the natural environment of human settlements. (2) The humanistic environment of human settlements demonstrates a spatial distribution pattern characterized by lower values in plains and higher values in mountainous areas, and higher values in towns than in rural areas, significantly influenced by urban administrative hierarchy. (3) The comprehensive quality index of human settlement environment in the Guanzhong Plain urban agglomeration ranges between 0.216 and 0.716, displaying a zonal spatial distribution pattern that gradually decreases stepwise outward from the Guanzhong Plain and Fen River Valley. (4) The spatial distribution of population density in the Guanzhong Plain urban agglomeration shows significant consistency with human settlement environment quality, generally following a spatial distribution pattern where plains are higher than mountainous areas and cities are higher than rural areas; the higher the human settlement environment quality, the greater the population density and the more intensive the land use.

Full Text

Evaluation Methods and Data Sources

Temperature Humidity Index (THI)

The Temperature Humidity Index (THI) is calculated using the formula:

$$THI = T - 0.55 \times (1 - f) \times (T - 58) \quad (2)$$

where $T = 1.8t + 32$ converts temperature to Fahrenheit, t represents temperature in Celsius, f denotes relative humidity, and additional parameters include wind velocity v at 10m height and sunshine duration S. The THI and related indices are normalized to a 0-1 range for comparative analysis.

Habitat Index (HI)

The Habitat Index is computed as:

$$HI = NAP \times \alpha + NWD \times \beta$$

where NAP and NWD represent specific environmental parameters, with weighting coefficients $\alpha = 0.8$ and $\beta = 0.2$ [?].

Land Cover Index (LCI)

The Land Cover Index is defined by:

$$LCI = NDVI \times LT_i$$

where $NDVI$ is the Normalized Difference Vegetation Index and LT_i is a land type coefficient derived from land cover classification [?].

NPP-VIIRS Nighttime Light Data

NPP-VIIRS nighttime light composite data is utilized to extract built-up urban areas. The data processing involves radiometric calibration and threshold segmentation to identify urban extents [Figure 2b: see original paper]. Settlement density is calculated based on these extracted built-up areas [Figure 2c: see original paper], and the comprehensive quality index integrates multiple environmental dimensions [Figure 2d: see original paper].

Results and Analysis

Spatial Differentiation Characteristics

The natural environment of human settlements exhibits a spatial distribution pattern of successive diminishing from east to west, and from mountainous areas and plateaus to plains and valleys, primarily influenced by topographic factors. Terrain relief amplitude shows a negative correlation with human settlement environment quality [Figure 2e: see original paper]. Statistical analysis reveals significant spatial clustering, with Moran' s I values exceeding 0.6, indicating strong positive spatial autocorrelation. Local indicators of spatial association (LISA) show that high-high clusters dominate the distribution pattern, accounting for over 50% of the study area.

Population Distribution Patterns

GDP density demonstrates a clear spatial concentration, forming distinct agglomeration centers and corridors [FIGURE:3a, 3d]. PM2.5 concentrations display a distribution pattern that correlates with population density, showing higher values in urban cores and along major transportation arteries, gradually decreasing toward suburban and rural areas [Figure 3b: see original paper]. Terrain factors exhibit moderate spatial correlation with population distribution, with relief degree and elevation influencing settlement patterns [Figure 3c: see original paper].

Comprehensive Evaluation of Settlement Environment Quality

The comprehensive index of human settlement environmental quality for the Guanzhong Plain urban agglomeration ranges from 0.216 to 0.716. The spatial distribution appears in strip shapes that gradually descend from the Guanzhong Plain to the Weihe Valley to the outer fringes. Factor analysis reveals five principal components: terrain (130-), population density (rs-), economic development (†t-), and land use intensity (Lb-), each contributing differentially to the overall quality assessment .

The correlation analysis indicates that terrain factors exhibit the strongest influence (correlation coefficient 0.424), followed by economic indicators and land use efficiency. Population density shows significant positive correlation with settlement quality ($p < 0.005$), confirming that higher-quality environments attract and sustain larger populations [Figure 4: see original paper]. The spatial distribution of population density [Figure 5: see original paper] closely mirrors the pattern of settlement quality, with densities exceeding 1,556 persons/km^2 in high-quality areas.

Factor Contribution Analysis

Among the evaluated factors, terrain relief demonstrates the highest correlation with settlement quality (0.424), while population density shows the most significant statistical relationship ($p < 0.005$). The hierarchical influence follows the order: terrain > population density > economic factors > environmental amenities. This pattern underscores the fundamental role of topographic suitability in shaping human settlement patterns in the Guanzhong region.

The synergistic relationship between population distribution and settlement environment quality indicates a co-evolutionary process. Areas with superior environmental quality, characterized by moderate terrain, adequate vegetation cover, and favorable climatic conditions, naturally attract higher population densities and more intensive land use. This concentration, in turn, drives infrastructure development and service provision, further enhancing settlement quality [Figure 6: see original paper].

Discussion

The integration of multi-source grid data enables comprehensive assessment of human settlement environments, revealing the complex interplay between natural conditions and human activities. The significant correlation between population density and settlement quality (correlation coefficient 0.72) suggests that population distribution serves as both a cause and consequence of environmental quality. Policy interventions should prioritize sustainable land use planning in high-quality areas to prevent environmental degradation from over-concentration, while improving infrastructure and services in moderate-quality zones to promote balanced regional development [Figure 7: see original paper].

The results demonstrate that grid-based evaluation methods provide robust spatial analysis capabilities for understanding settlement patterns and informing regional planning decisions. Future research should incorporate dynamic temporal analysis to track evolution patterns and assess the effectiveness of planning interventions.

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