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## The Assessment of Urban Ecological Environment in Watershed Scale

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### Abstract

Urban ecological environment is closely related to the harmonious development of the region. The interaction between ecological environment of the city and the watershed where it locates is less considered in current study. In this paper, making use of multi-source data with remote sensing data as the main data source and according to the "Technical Standard for Evaluation of Ecological Environment" (HJ192-2015) promulgated by Ministry of Environment Protection, we accomplished the quality assessment of ecological environment of Yanhe watershed in 250m × 250m pixel unit with synthetical index method. Based on this, we also combined demographic data, DEM data of Yanhe watershed to analyze the interaction between urban ecological environment and ecological environment status of the entire watershed. The results showed that: 1) The ecological environment quality levels of urban areas in Yanhe watershed were mainly "poor" and "worse", and the farther from the urban area, the better quality level of ecological environment in general, which indicated the existence of the city exerted stress on the ecological environment; 2) The ecological environment of the city at higher altitude was in poorer condition, indicating that the distribution of the topography of the watershed had a certain impact on the ecological environment of the city; 3) By comparing the distribution of the ecological environment quality of different cities in the watershed, the more concentrated population density of the city, the greater scope of the poorer ecological environment, indicating that human activities had great influences on the urban ecological environment. We can conclude that it is necessary to consider the interaction between urban ecological environment and watershed ecological environment where the city locates, so as to provide new ideas for the construction and protection of the ecological environment of the city.

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## Introduction

The ecological environment is the premise and foundation of human survival and development. It refers to the sum of various natural factors about human society and its surroundings. Based on the selected evaluation index system, the regional ecological environmental quality is assessed using comprehensive evaluation method. The results can provide fundamental basis for the management and construction of regional ecological environment<sup>[1]</sup>. With the continuous increase in population and development of economy, urbanization is the mainstream of the world's population gathering development. At the same time, it is also an important driving force of the world's cultural pattern and environmental change<sup>[2]</sup>. However, urbanization brings the problems of migration, the change of land use structure and urban environmental pollution and so on<sup>[3, 4]</sup>. Urban ecological environmental quality assessment is an important research field of city ecology and it can provide scientific basis for its sustainable development of planning and management<sup>[5]</sup>. Many foreign and domestic scholars have carried out relevant researches, for example, Queiroz<sup>[6]</sup> studied the ecological environment of Stockholm from the perspective of landscape ecology using GIS technology; Steven<sup>[7]</sup> made a comprehensive evaluation of ecological environment of a southern city in Mexico based on environment simulation model; Lang Yi<sup>[8]</sup> had finished the quantitative evaluation of the ecological environment quality of Yulin City in 2010 based on 3S technology; Wei Wang<sup>[9]</sup> analyzed the dynamic change of ecological environment quality in Beijing from 2001 to 2010.

However, the current studies mostly focus on the urban ecological environment itself, the interaction between ecological environment of the city and the watershed where it locates is less considered. As we know, the formation and development of the city is closely related to water, and for a long history, watershed is the most suitable place for human to live<sup>[10]</sup>. Watershed is the cradle of human civilization and the foundation of ecological civilization. At the same time, it is also an important natural resource for human to survive<sup>[11]</sup>. Since watershed is a complete ecological and geographic unit, the elements inside it have a high degree of correlation and integrity<sup>[12]</sup>. The ecological environment of the watershed and the city is closely related to each other. On the ground of these facts and according to the "Technical Standard for Evaluation of ecological environment" (HJ192-2015) promulgated by Ministry of Environment Protection, we accomplished the quality assessment of ecological environment of Yanhe watershed in 250m × 250m pixel unit through making use of multi-source data with remote sensing data as the main data source. Based on this, we also combined demographic data, DEM data of Yanhe watershed to analyze the interaction between urban ecological environment and ecological environment status of the entire watershed. This research can provide new ideas for the protection and management of urban ecological environment. And it can also provide a theoretical basis for regional planning, ecological environment construction and management of Yanhe watershed.

## 2. Study area and data source

### 2.1. Study area

Yanhe watershed is located in the hinterland of the loess plateau in Shaanxi Province (Fig.1), and its total area is approximately about 7687km<sup>2</sup>. This place is a typical semi-arid temperate continental monsoon climate region. Cold and dry in winter, drought and rainy in summer. The landform of Yanhe watershed is broken and it also has a serious problem of land degradation and soil erosion<sup>[13]</sup>. This area includes the major cities as Yan'an City, Jingbian County, Ansai County, Zhidan County, Yanchang County. Yan'an City has a profound historical heritage. It is a sacred place of the revolution in China and also the political, economic and cultural center of North Shaanxi<sup>[14]</sup>. However, with the development of economy, the ecological environment problems in Yan'an City, Ansai County, Jingbian County are more and more serious, which restrict the sustainable development of this region. So it is urgent

to analysis the ecological environment quality of Yanhe watershed and the cities within it in order to provide a reference for its ecological environment protection and management.

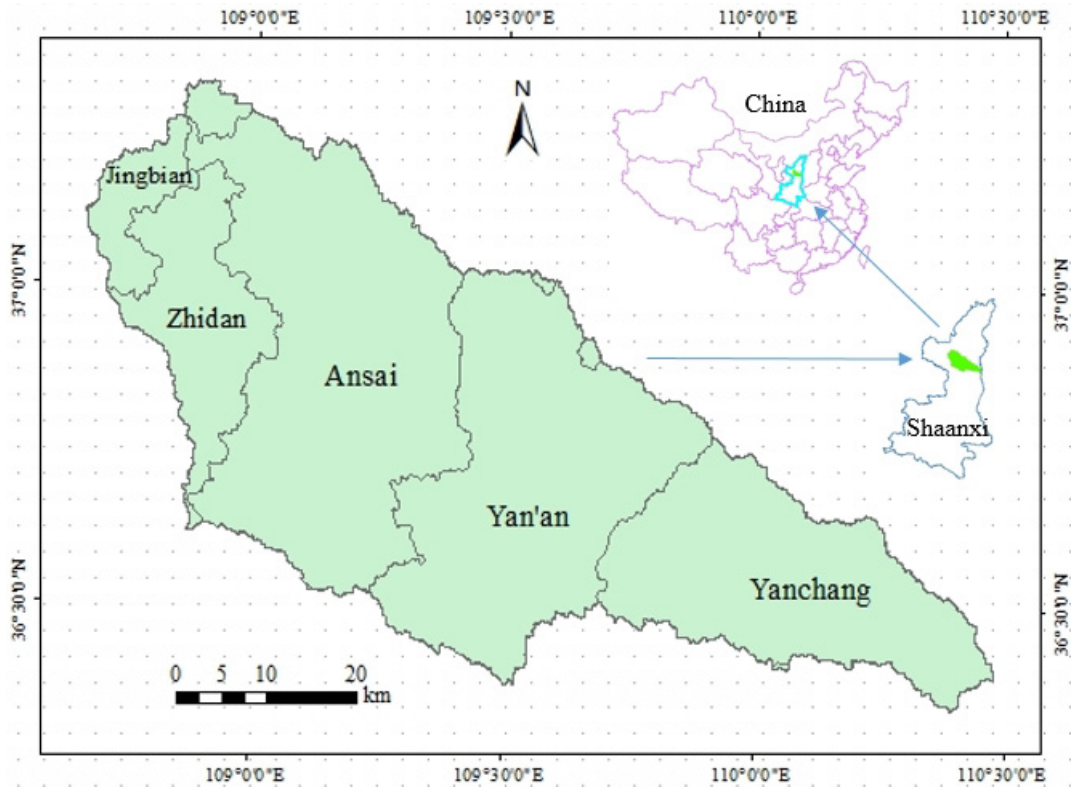


Fig.1. Location of the study area

## 2.2. Data source and processing

Normalized difference vegetation index (NDVI) dataset used in the study came from NASA (<https://ladsweb.nascom.nasa.gov/data>). The spatial resolution is 250m, and its temporal resolution is 16 days. The selected time ranged from May to September in 2010. MODIS reprojection tools (MRT) provided by MODLAND were used to convert the format and projection of NDVI dataset. Then the method of maximum value composite (MVC) was used to compile the NDVI dataset, as it could minimize atmospheric effects, scan angle effects, cloud contamination and solar zenith angle effects. Finally, we got the mean maximum monthly NDVI raster ranged from May to September in 2010 of Yanhe watershed.

Land-cover data came from GlobeLand30 (<http://www.globallandcover.com>), which was the world's first land-cover map with a spatial resolution of 30m made by China in 2014 <sup>[15]</sup>. The earth's surface was divided into forestland, cultivated land, grassland and other types, a total of 10 types. Its classification accuracy is more than 80 percent and it has been widely used in the field of ecological environment <sup>[16]</sup>. In this study, combined with the actual conditions of Yanhe watershed, its land-cover types were divided into six types, forestland, grassland, cultivated land, water wetland, construction land and unused land based on this dataset.

Digital elevation model (DEM) data and land stress data were provided by the Soil and Water Conservation of Chinese Academy of Science. Demographic data, annual rainfall data, water resources data and pollution load data came from "Statistical yearbook of Shaanxi province", "Statistical yearbook of Yan'an City" and the annual

statistical data of other counties in the study area.

Finally, all the above data was uniformly converted to WGS84/Albers equal area conic projection raster with a spatial resolution of 250m on ArcGIS in this paper.

### 3. Methods

Combined with the actual condition of ecological environment in the study area and making use of multi-source data with remote sensing data as the main data source, according to the "Technical Standard for Evaluation of Ecological Environment" (HJ192-2015) promulgated by Ministry of Environment Protection, we calculated the biological richness index (BRI), vegetation coverage index (VCI), water network denseness index (WDI), land stress index (LSI), and pollution load index (PLI) to analysis the biological abundance level, the degree of vegetation coverage, the abundance of water resources, the degree of stress suffered by land use and the bearing level of environmental pollution in Yanhe watershed [17]. And then, we accomplished the quality assessment of ecological environment of Yanhe watershed in 250m × 250m pixel unit with synthetical index method so as to reveal the ecological environment quality of the study area quantitatively and synthetically. The detailed calculation formula was as follows in Table 1.

Tab.1 Calculation Method of EI and Its Sub-indexes [17]

Index Name	Calculation Method
BRI	$A_1 * (0.35 * \text{forestland} + 0.21 * \text{grassland} + 0.28 * \text{water wetland} + 0.11 * \text{cultivated land} + 0.04 * \text{construction land} + 0.01 * \text{unused land}) / \text{region area}$
VCI	$A_2 * (0.38 * \text{forestland} + 0.34 * \text{grassland} + 0.19 * \text{cultivated land} + 0.07 * \text{construction land} + 0.02 * \text{unused land}) / \text{region area}$
WDI	$(A_3 * \text{river length} / \text{region area} + A_4 * \text{water area} / \text{region area} + A_5 * \text{water resources} / \text{region area}) / 3$
LSI	$A_6 * (0.4 * \text{severe erosion area} + 0.2 * \text{moderate erosion area} + 0.2 * \text{construction land area} + 0.2 * \text{other land stress area}) / \text{region area}$
PLI	$0.2 * A_7 * \text{COD emission} / \text{total annual precipitation} + 0.20 * A_8 * \text{NH}_4\text{N emission} / \text{total annual precipitation} + 0.2 * A_9 * \text{SO}_2 \text{ emission} / \text{region area} + 0.10 * A_{10} * \text{smoke and dust emission} / \text{region area} + 0.20 * A_{11} * \text{NO emission} / \text{region area} + 0.10 * A_{12} * \text{solid waste discards} / \text{region area}$
EI	$0.35 * \text{BRI} + 0.25 * \text{VCI} + 0.15 * \text{WDI} + 0.15 * (100 - \text{LSI}) + 0.10 * (100 - \text{PLI})$

Note:  $A_1$ – $A_{12}$  refer to normalization coefficients.

According to the results of the ecological index (EI), the regional ecological environment conditions are divided into five levels: better ( $EI \geq 75$ ), good ( $55 \leq EI < 75$ ), general ( $35 \leq EI < 55$ ), poor ( $20 \leq EI < 35$ ), worse ( $EI < 20$ ) [17]. According to this method, we got the distribution of ecological environment levels of Yanhe watershed in 2010, which was shown in Fig.2.

According to the demographic data, the distribution of population density in Yanhe watershed was obtained by Kriging interpolation method with a spatial resolution of 250m in Fig.3.

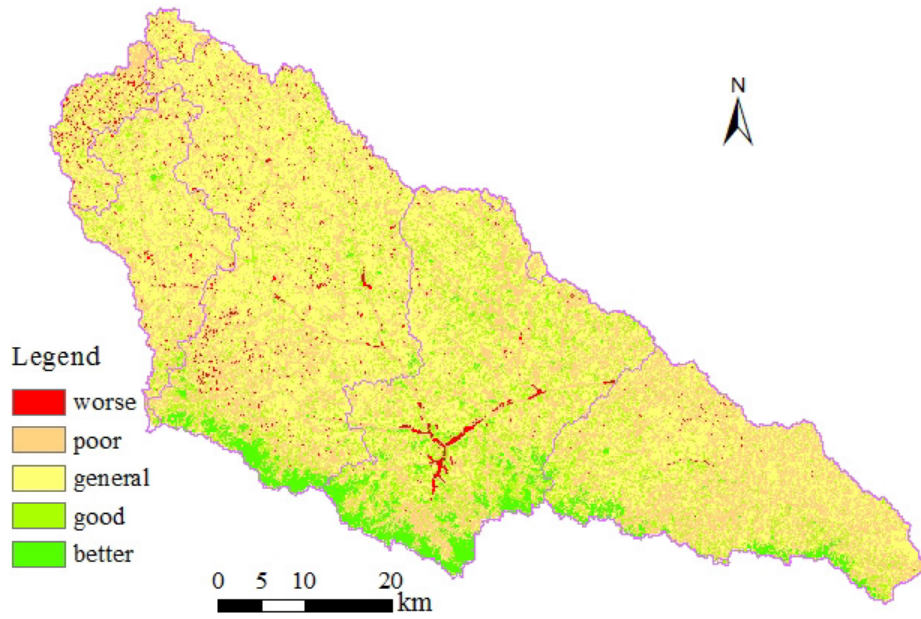


Fig.2. Distribution of ecological environment levels in Yanhe watershed

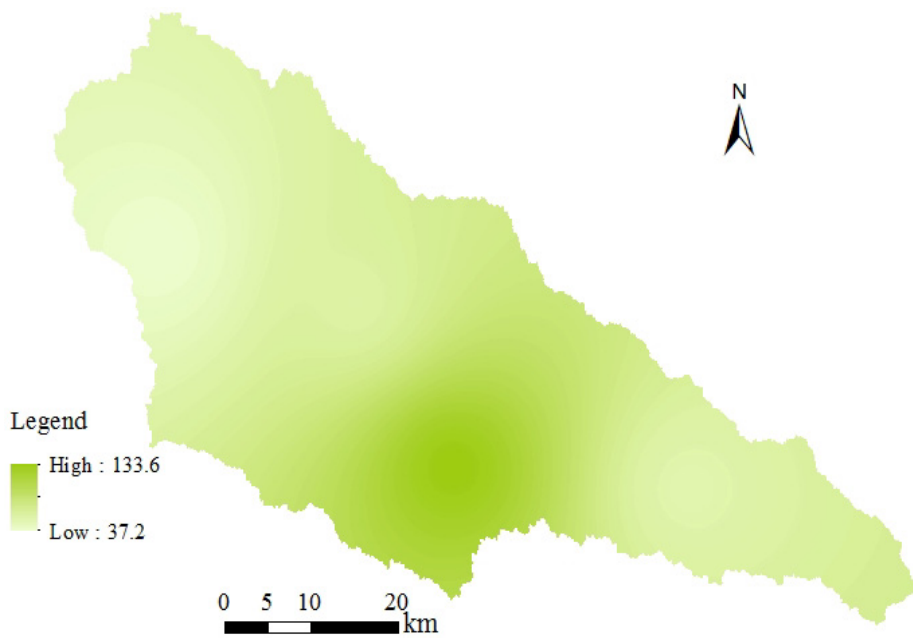


Fig.3. Distribution of population density in Yanhe watershed

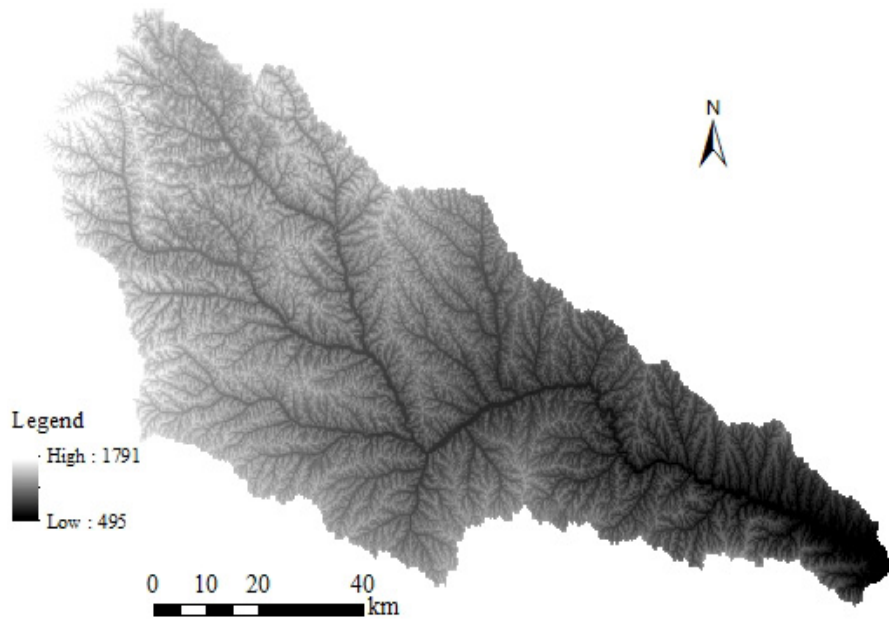


Fig.4. Distribution of DEM in Yanhe watershed

#### 4. Results and discussion

Viewing Yanhe watershed as the study area, and according to the "Technical Standard for Evaluation of Ecological Environment" (HJ192-2015), we had accomplished the quality assessment of ecological environment of Yanhe watershed in  $250\text{m} \times 250\text{m}$  pixel unit with synthetical index method (Fig.2). It showed that the ecological environment of Yanhe watershed was "general" overall in 2010. And from upstream to downstream, the ecological environment quality of Yanhe watershed showed ladder-like distribution. The ecological environment quality of its western and northwestern areas were worse, but the conditions in its southeast and southwest were better. Based on this, we also combined population density (Fig.3), DEM data (Fig.4) of Yanhe watershed to analyze the interaction between urban ecological environment and ecological environment status of the entire watershed. The results showed that: 1) The ecological environment quality levels of Yan'an City, Ansai Country and Jingbian Country were mainly "poor" and "worse", which indicated these areas had serious ecological environment problems. More specifically, the central area of Yan'an City, the northern and western areas of Ansai Country and most areas of Jingbian Country were key rehabilitation regions. The ecological environment quality levels of Yanchang Country and Zhidan Country were "better" overall. However, the conditions of both the northern area of Yanchang Country and the southeastern area of Zhidan Country were poor. At the same time, the farther from the urban area, the better quality level of ecological environment in general, which indicated the existence of the city exerted stress on the ecological environment; 2) From Fig.2 and Fig.4, we could conclude that the ecological environment of the city at higher altitude was in poorer condition, indicating that the distribution of the topography of the watershed had a certain impact on the ecological environment of the city; 3) From Fig.2 and Fig.3, by comparing the distribution of the ecological environment quality of different cities in the watershed, the more concentrated population density of the city, the greater scope of the poorer ecological environment, indicating that human activities had great influences on the urban ecological environment.

The city is closely related to the watershed where it locates. According to the results of this paper, we can conclude that it is necessary to consider the interaction between the ecological environment of the city and the

watershed where it locates, so as to provide new ideas for the construction and protection of urban ecological environment.

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