

# Ecological Conservation Redline (ECR) Delimitation—a Case Study of Heze in Shandong Province

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**Abstract.** With the overall trends of deterioration in resources and ecological environments not being completely reversed, the Chinese government has adopted the strategy of establishing the Ecological Conservation Redline (ECR). The ECR aims to define limits to the encroachment onto protected ecologically vulnerable and sensitive areas, to prohibit development in these areas, and to enforce strict protection to guarantee regional ecological security. Climate data, remote sensing data, and other related data were used to identify an ECR in Heze, thereby providing an example of principle and methodology for ECR delimitation. After assessment, comprehensive treatment, and coordination analysis, a total area of 924.17 km<sup>2</sup>, accounting for 7.55% of the city's total area, was identified as an ECR in Heze. This mainly comprised the area around the Yellow River, the old course of the Yellow River, and the Dongyu River.

## 1 Introduction

Enhancing nature conservation and promoting sustainable development have become the consensus worldwide[1-3]. Nature conservation issues have very strong regional characteristics. With different cultural and institutional backgrounds, resources, and environmental endowments, as well as different stages of economic development, the adoption of nature conservation patterns is different in different countries or regions [4-6].

China is the largest and fastest developing country in the world, with growth rates averaging 10% over the past 30 years[7-8]. The rapid urbanization for thirty years in China has resulted in severe ecological consequences, including resource depletion, environmental pollution, and ecological degradation, as demonstrated by the increased risks of flooding and hazy weather, public health concerns, biodiversity losses, reduced food and water security, as well as other undesirable social and economic consequences[9-11]. With the growing awareness of the importance of maintaining natural resources and delivering ecosystem services, the Chinese government has carried out a series of national policies for nature conservation, such as the nature reserve policy, the afforestation policy, and the zoning policy[12-14]. However, because of inherent design faults, human disturbances, spatial mismatches, isolation, poor protection, lack of coordination, and no clear boundaries, these policies have experienced major problems in terms of nature conservation[11,15-16].

To resolve the current problems of nature conservation, a massive and extensive program called "Ecological Conservation Redline (ECR)", is about to be implemented through a top-down mandate policy from the central law makers, with strong bottom-up support from local governments. The Chinese government is implementing a top-level strategy of ecological protection by delimiting ECR at the national level to establish a more scientific, reasonable, and feasible system of protection. The ECR program was first proposed in 2011, was seriously discussed by the People's Congress for implementation in 2013, and was effectively promoted in 2017. The ECR aims to achieve spatial optimization of existing PAs and enhance the quality of drinking water, important wetlands, ecosystems, aquatic germplasm, and critical coastal marine ecosystems. The success of this program will make China one of the countries with the most reasonable distribution of ecological protection.

## 2 Materials and methods

### 2.1 Study area

The study area is located in southwest Shandong province and comprises a narrow passage between the Taihang and Taiyi mountains (114°48'-116°24'E, 34°39'-35°52'N). The climate is temperate and continental, with abundant sunlight and heat. The four seasons are distinct, and the rain heat is the same season. Average annual temperature is 13.5-13.9 °C, and annual sunshine percentage is 54-59%, both of which make it

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the warmest and sunniest region in the Shandong province. The vegetation type is typical of warm temperate deciduous forest regions. There are 228 species of woody plants (representing 51 families), 8 species of rattan plants, and 668 species of herbaceous plants in this region. This area also supports 157 species of birds (representing 41 families of 16 orders), including 22 species covered by the special state protection (both first- and second-class state protection).

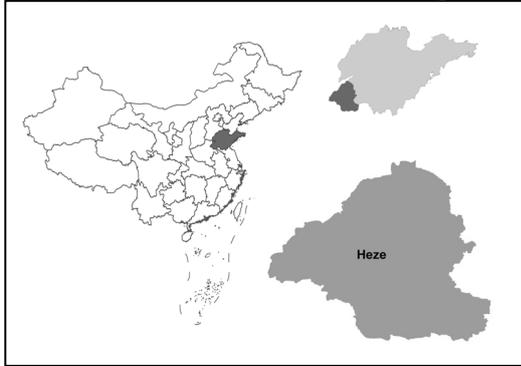


Fig. 1. Location of the study area.

## 2.2 Methods

Ecological Conservation Redline (ECR) refers to the ecological space that has special important ecological functions and must be within the scope of mandatory strictly protected. It has three important classified areas including areas with important ecological functions, ecologically environment sensitive areas and areas where development is forbidden[17]. The potential local areas for ECR can be obtained through the identification and comprehensive treatment of the three important classified areas.

### 2.2.1 Importance assessment of ecological service function assessment

1. Importance assessment of water conservation function  
Water conservation service capacity index is taken as an assessment index, with the calculation formula as follows:

$$WR = NPP_{mean} \times F_{sic} \times F_{pre} \times (1 - F_{slo}) \quad (1)$$

Where  $WR$  is the water conservation service capacity index,  $NPP_{mean}$  is multi-year mean net primary productivity,  $F_{sic}$  is the soil percolation factor,  $F_{pre}$  is the mean annual precipitation, and  $F_{slo}$  is the slope factor.

2. Importance assessment of soil conservation function

Soil conservation service capability index is taken as an assessment index, with the calculation formula as follows:

$$S_{pro} = NPP_{mean} \times (1 - K) \times (1 - F_{slo}) \quad (2)$$

Where  $S_{pro}$  is the soil conservation service capability index,  $K$  is the soil erodibility factor, and other parameters are as the above. The  $K$  value data are resampled to the 250m raster, and the maximum and minimum value method is used to normalize the

resampled data to 0-1. The soil conservation service capability index is calculated according to the formula.

3. Importance assessment of windbreak and sand fixation

Windbreak and sand fixation service capacity index is taken as an assessment index, with the calculation formula as follows:

$$S_{ws} = NPP_{mean} \times K \times F_q \times D \quad (3)$$

$$F_q = \frac{1}{100} \sum_{i=1}^{12} u^3 \left\{ \frac{ETP_i - P_i}{ETP_i} \right\} \times d \quad (4)$$

$$ETP_i = 0.19(20 + T_i)^2 \times (1 - r_i) \quad (5)$$

$$u_2 = u_1 \left( \frac{z_2}{z_1} \right)^{1/7} \quad (6)$$

$$D = 1 / \cos(\theta) \quad (7)$$

Where  $S_{ws}$  is the windbreak and sand fixation service capacity index,  $F_q$  is the multi-year mean climatic erosivity,  $u$  is the monthly mean wind speed at 2m high,  $u_1$  and  $u_2$  are the wind speeds at height  $z_1$  and  $z_2$ , respectively,  $ETP_i$  is the monthly potential evapotranspiration (mm),  $P_i$  is the monthly precipitation (mm),  $d$  is the number of days in the current month,  $T_i$  is the monthly mean temperature,  $r_i$  is the monthly mean relative humidity (%),  $D$  is the surface roughness factor, and  $\theta$  is the slope (radian), and other parameters are as the above.

4. Importance assessment of biodiversity maintenance function

Biodiversity maintenance service capability index is taken as an assessment index, with the calculation formula as follows:

$$S_{bio} = NPP_{mean} \times F_{pre} \times F_{tem} \times (1 - F_{alt}) \quad (8)$$

Where  $S_{bio}$  is the biodiversity maintenance service capability index,  $F_{tem}$  is the mean annual temperature, and  $F_{alt}$  is the altitudinal factor, and other parameters are as the above.

Various factors are unified into raster data with the resolution of 250m. In the ArcGIS Raster Calculator (Spatial Analyst→Raster Calculator), the maximum and minimum value method is used to normalize the resampled data to 0-1, and each ecosystem service function index is calculated according to the formula.

5. Assessment classification

Through model calculation, raster graphs of service values for different types of ecosystems (such as water conservation capacity) are obtained. In the GIS software, raster calculator is used to enter the formula "Int ([raster data of a function]/[maximum value of raster data of a function]) × 100" and obtain the normalized ecosystem service value raster graph. Raster data attribute table is exported, which records the ecosystem service values of each raster cell. The service values are sorted in a descending order and the cumulative service value is calculated. The raster values corresponding to the cumulative service values that account for 50% and 80% of the ecosystem total service value are used as the demarcation points of ecosystem service function assessment and classification. The reclassification tool of the GIS software is used to divide the importance of ecosystem service function into three levels, i.e. extremely important, important and generally important.

**Table 1.** Ecosystem service function assessment classification.

Importance Level	Extremely important	Important	Generally important
Cumulative service value as a percentage of total service value (%)	50	30	20

### 2.2.2 Ecological environment sensitivity assessment

Ecological environment sensitivity assessment is the sensitivity assessment of soil and loss water. According to the dynamic conditions of soil erosion, the sensitivity of soil and water loss caused mainly by water erosion is assessed as follows:

$$SS_i = \sqrt[4]{R_i \times K_i \times LS_i \times C_i} \quad (9)$$

Where  $SS_i$  is the sensitivity index of soil loss by water erosion in  $i$ -space unit, and the assessment factors include rainfall erosivity ( $R_i$ ), soil erodibility ( $K_i$ ), slope length and slope steepness ( $LS_i$ ), and surface vegetation coverage ( $C_i$ ).

Various factors are unified into raster data with the resolution of 250m. In the ArcGIS Raster Calculator (Spatial Analyst→Raster Calculator), the salinization sensitivity index is calculated according to the assessment model.

Reclassification module in ArcGIS is used to divide the sensitivity assessment results of the ecological environment, which is divided into three levels, i.e. generally sensitive, sensitive and extremely sensitive. The specific grading assignment and standard are shown in Table 2.

**Table 2.** Ecological environment sensitivity assessment classification.

Sensitivity level	Generally sensitive	Sensitive	Extremely sensitive
Grading assignment	1	3	5
Grading standard	1.0-2.0	2.1-4.0	>4.0

### 2.2.3 Prohibited development and other important protected areas

There are 36 prohibited-development and other important protected areas distributed in Heze, including nine wetland parks, one geological park, 14 important areas of protection for water sources, one state-owned forest farm, nine reservoirs, one water conservancy scenic area, and one germplasm conservation area.

## 2.3 Data collection

Using a geographic information system (ArcGIS 10.2) (ESRI) and the matrix laboratory, MATLAB

(MathWorks), the ecological importance and sensitivity were evaluated by land-use data, climatic data, a digital elevation model, and the normalized difference vegetation index (NDVI) (<http://landsweb.nascom.nasa.gov/data/search.html>). The data for development forbidden areas were provided by the local authorities, including the environmental protection, forestry, territorial resources, building, water conservancy, and agriculture departments.

## 3 Results

### 3.1 Evaluation of important areas of ecosystem services function

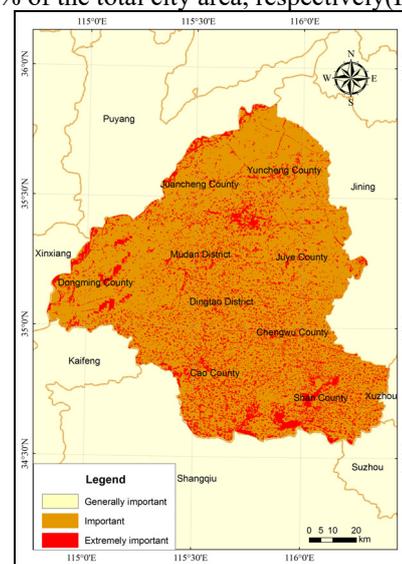
The extremely important, important, and generally important areas of water conservation had areas of 1693.49, 8964.21, and 1581.30km<sup>2</sup>, accounting for 13.84, 73.24, and 12.92% of the total city area, respectively.

The extremely important, important, and generally important areas of soil conservation had areas of 868.82, 10697.41, and 672.77km<sup>2</sup>, accounting for 7.10, 87.40, and 5.50% of the total city area, respectively.

The important and generally important areas of windbreak and sand fixation had areas of 7124.60 and 5114.40km<sup>2</sup>, accounting for 58.21 and 41.79% of the total city area, respectively.

The extremely important, important, and generally important areas of biodiversity conservation had areas of 1140.49, 10932.96, and 165.54km<sup>2</sup>, accounting for 9.32, 89.33, and 1.35% of the total city area, respectively.

The evaluation of the importance of the ecosystem service functions were obtained by an overlay analysis of the evaluations of the importance of water conservation, soil conservation, windbreak and sand fixation, and biodiversity conservation. As a result, the extremely important, important, and generally important areas of ecosystem service functions had areas of 2190.04, 9900.29, and 148.67km<sup>2</sup>, accounting for 17.89, 80.89, and 1.21% of the total city area, respectively(Fig. 2.).



**Fig. 2.** Evaluation of the importance of ecosystem services function.

### 3.2 Evaluation of ecologically environment sensitive areas

Extremely sensitive, sensitive, and generally sensitive areas of soil loss by water erosion had areas of 0.25, 4041.13, and 8197.62km<sup>2</sup>, accounting for 0.002, 33.02, and 66.98% of the total city area, respectively(Fig. 3.).

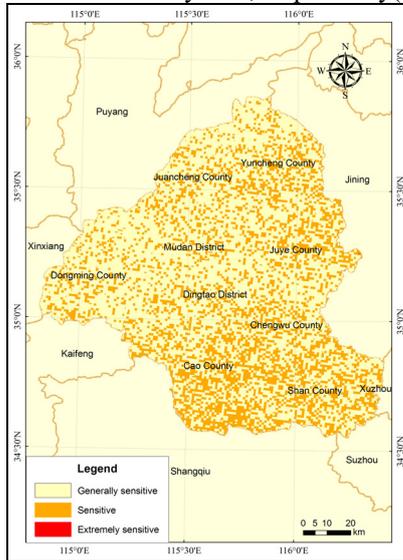


Fig. 3. Evaluation of ecologically environment sensitive areas.

### 3.3 Coordination between ecological protection and development

The investigation of key regions that satisfy the requirements of providing ecosystem services, being ecologically sensitive areas, and being areas in which development is prohibited identified a preliminary area of 1004.16 km<sup>2</sup>, accounting for 8.20% of the city's area, suitable for establishing as ECR (Fig. 4.). Further, the local social and economic development needs, coordinated analyses of the proposed ECR, and related development plans, such as the ecological function zoning plan, the land use and overall urban plan, and the environment protection plan, were taken into account to adjust the ECR boundary. This resulted in the elimination of areas with concentrated artificial production and operation activities, such as farmland, economic forest, and urban construction land, so as to reserve a certain amount of space for development.

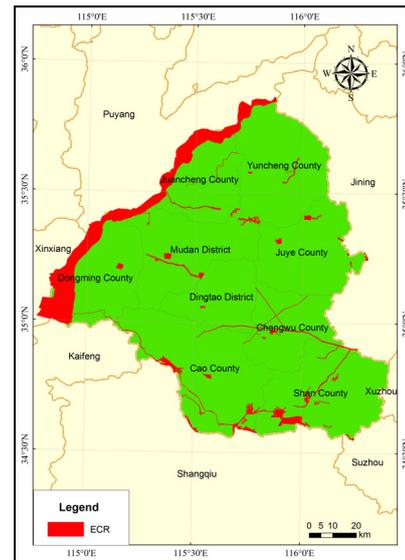


Fig. 4. Preliminary identified areas of the ECR.

### 3.4 Determination of ECR

On the basis of coordinated analysis and treatment of important areas of ecosystem services function, ecologically environment sensitive areas, and prohibited development and other important protected areas, an ECR comprising an area of 924.17 km<sup>2</sup>, accounting for 7.55% of the city's total area, was identified in Heze. This area was mainly distributed around the Yellow River, the old channel of the Yellow River, and the Dongyu River (Fig. 5.).

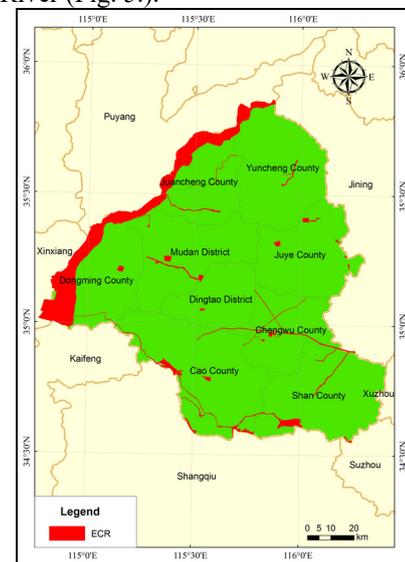


Fig. 5. ECR identification in Heze.

## 4 Conclusion

The implementation of ECR is an institutional innovation for Chinese ecological conservation. ECR is being identified as ecological baselines for the protection of the environment and its resources[18]. ECR in Heze was delimited by the overlay of important areas of ecosystem services function and the areas of ecologically environment sensitive, as well as the prohibited development and other important protected

areas. The preliminary identification area of ECR was 1004.16 km<sup>2</sup>, accounting for 8.20% of the whole city.

Considering the long-standing contradiction between development and protection, the necessary coordination was taken to optimize ECR to make it more reasonable and practical. After coordination, the identified area of ECR in Heze was 924.17km<sup>2</sup>, accounting for 7.55% of the whole city, which was mainly distributed in the Yellow River, old course of Yellow River and Dongyu Rover.

China is the first country to introduce the concept of redlines into the field of ecological protection. Delimiting and strictly observing redlines have become a new strategy for ecological protection, with Chinese characteristics[19]. The core of the new strategy lies in controlling important ecological spaces by drawing a line, realizing one map of national ecological protection. Ecological protection redlines have not yet spread to other countries; however, analogous formulations and classification systems play similar roles in the establishment and management of natural ecological reserves. For example, the establishment of global natural reserves have been promoted by the International Union for Conservation of Nature (IUCN), comprising Natural Reserve Networks in European Union (Natura 2000), and Ecological Protected Areas in America, Japan and other countries. Special Areas of Conservation and Special Protected Areas imply protection redlines. Moreover, delimiting redlines is similar to international Systematic Conservation Planning for the reasonable integration and optimization of various kinds of existing PAs.

ECR will provide maximum protection for ecological processes and functions in areas at specific scales to identify the protection gap. It comprehensively considers the objects, costs and methods of controlling protection, and identifies the major objects for protection in achieving the ultimate goal of preserving regional ecological security[20]. The Chinese government is accelerating its promotion of delimitation and policy formulation concerning ECR, and this strategy would play a key role in ecological conservation in the future.

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