Identifying Ecological Security Patterns Considering the Stability of Ecological Sources in Ecological Fragile Areas

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Supplementary Information

Part A. Related tables and parameters of ecosystem service assessment

Table S1. Threat factor parameters for the habitat quality model.

Threat factors	Maximum influence distance	Weights	decay
Cropland	2	0.2	Linear
Urban land	10	1	Exponential
Unused land	5	0.2	Exponential

Table S2. Habitat suitability and its relative sensitivity to different threat factors.

Land use/cover types	Habitat suitability	Threat factors		
		Cropland	Urban land	Unused land
Cropland	0.4	0	1	0.5
Forest	1	0.5	1	0.6
High coverage grassland	0.8	0.4	0.7	0.6
Medium coverage grassland	0.7	0.5	0.8	0.7
Low coverage grassland	0.6	0.5	0.8	0.7
Water	0.6	0.2	0.8	0.4
Urban land	0	0	0	0
Unused land	0.2	0.1	0.1	0

Table S3. The root depth and evapotranspiration coefficient of land use type for water yield model.

Land use/cover types	Root_depth(mm)	Kc	LULC_veg
Cropland	2000	0.65	1
Forest	5200	1	1
High coverage grassland	2600	0.85	1
Medium coverage grassland	2300	0.65	1
Low coverage grassland	2000	0.65	1
Water	100	1	0
Urban land	100	0.3	0
Unused land	300	0.2	0

Part B. Model validation of ecosystem services

For the validation of our estimates on habitat quality and soil conservation, we utilized the Spatial Distribution Dataset of Terrestrial Ecosystem Service Value in China, provided by the Resource and Environment Science and Data Center of Chinese Academy of Sciences (https://www.resdc.cn). The resolution of validation raster data is 1 km × 1 km and the ecosystem service values are expressed with Chinese currency (CNY H-1). Utilizing the random sampling tool of ArcGIS10.5, we generated 100 random points within the study area and extracted the relevant ecosystem service values from the selected dataset to these points. To mitigate the effects of discrepancies in measurement units, a normalization process was applied to both the estimated and validation data prior to performing regression analyses. Owing to constraints in data availability, the validation process was exclusively conducted for the year 2020. The results showed a logarithmic regression trend for the habitat quality model (R^2 = 0.6041) (Figure S1 (a)) and a linear regression trend for the soil conservation model (R^2 = 0.7182) (Figure S1 (b)). These trends indicate a good consistency between the simulation results and the reference data, suggesting that the results of this study were relatively reasonable.

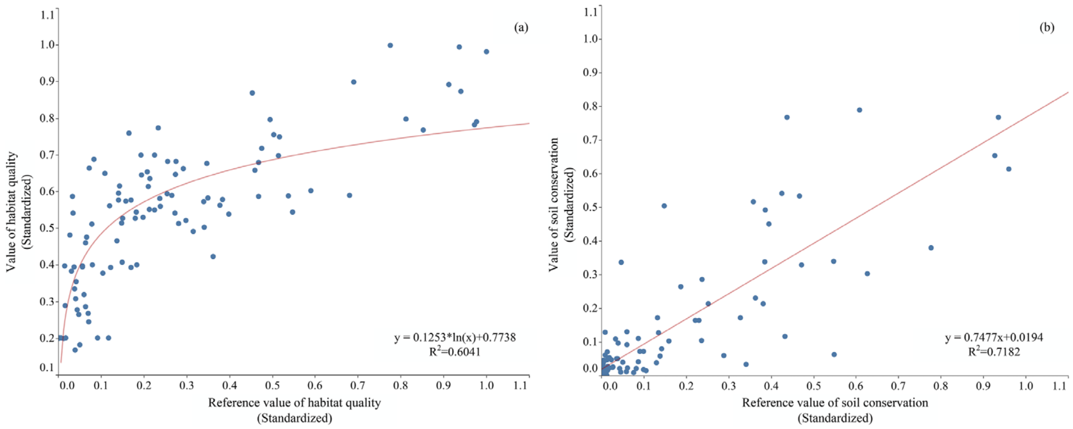

Figure S1. Validation of reference and simulated values for habitat quality (a) and soil conservation (b) in the year 2020.

To validate the simulated results of water yield, we compared our estimated values with the NHAR's total water resources as recorded in the Ningxia Water Resources Bulletin (http://slt.nx.gov.cn/xxgk_281/fdzdgknr/gbxx/szygb). Table S4 illustrates that the simulated results closely align with the total water resources of the study area as reported in official statistics, with relatively minor absolute errors ranging from 0.04% to 0.09%.

Table S4. Comparison of simulated and statistical water yields of the NHAR.

Years	Simulated water yields derived from InVEST model (10^8 m³)	The total water resources reported in Ningxia Water Resources Bulletin (10^8 m³)	Error
2000	6.999	6.993	0.09%
2010	9.314	9.322	0.08%
2020	11.036	11.032	0.04%

Part C. The identification of the optimal area threshold and determination of distance thresholds

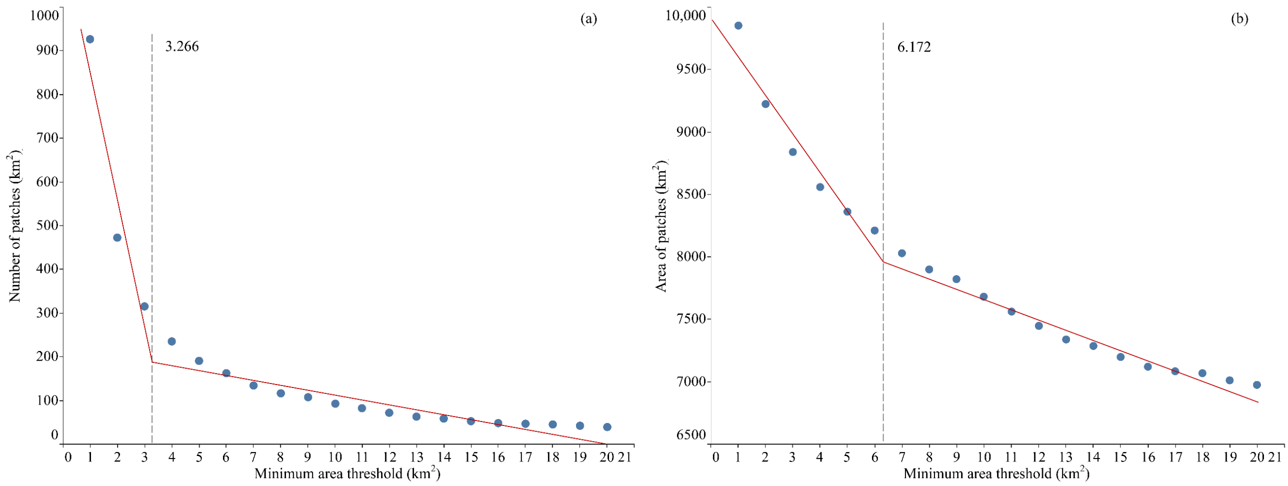

Figure S2. Change of the number (a) and total area (b) of stable ecological patches under various area thresholds.

Note: The optimal area threshold for identifying stable ecological sources in the research area was determined by examining the relationship between the area threshold and the number and total area of ecological patches. Initially, the number and total area of ecological patches above each area threshold were calculated using a 1 km² step size. Subsequently, piecewise linear regression was applied to identify breakpoints, and the initial area threshold was determined to be within the range of 3.266 to 6.172. This range effectively eliminated the influence of small patches while preserving important ecological patches. Additionally, overlaying the patches with nature reserves revealed that when the area threshold was adjusted to 4 km², ecological patches occupied the maximum proportion of the nature reserve area. Therefore, 4 km² was determined as the optimal area threshold for screening ecological source areas.

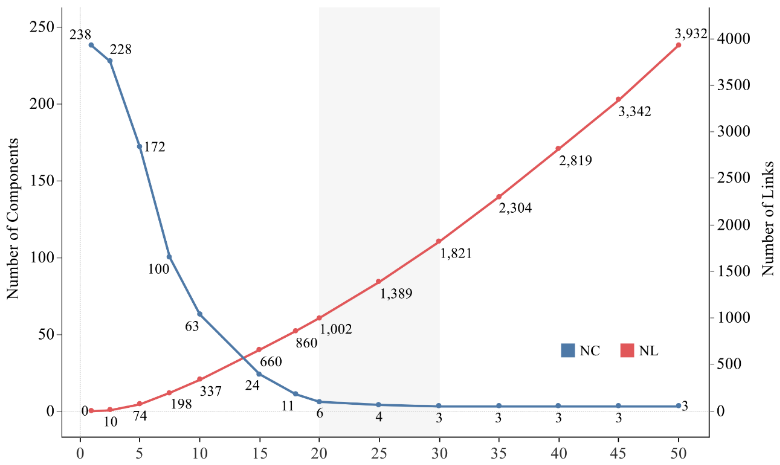

Figure S3. The number of components (NC) and number of links (NL) of preliminary ecological sources under different distance thresholds.

Note: According to the NC and the NL under different distance thresholds, the appropriate range of distance threshold was between 20 and 30km.

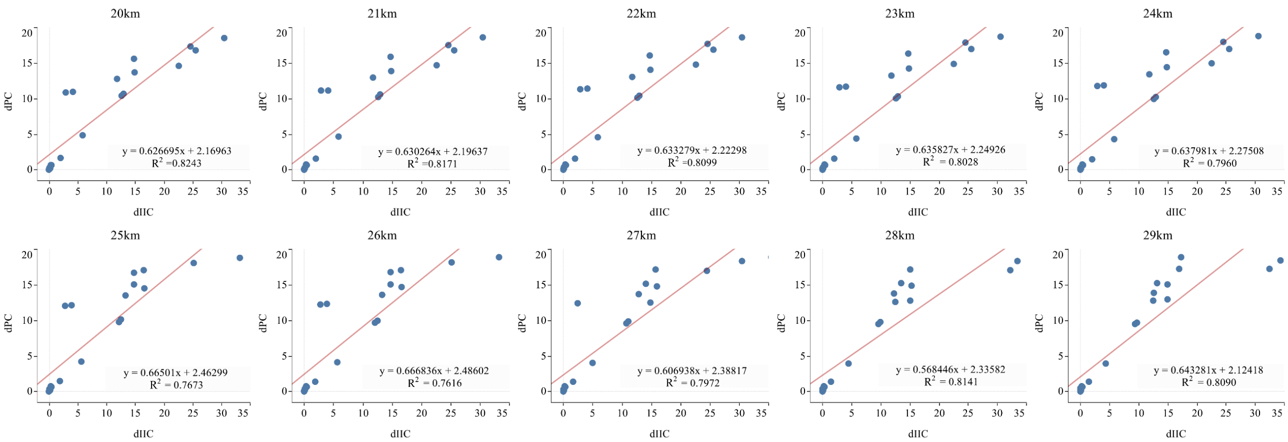

Figure S4. Appropriate distance thresholds identification of preliminary ecological sources.