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Ecological connectivity networks for multi-dispersal scenarios using UNICOR analysis in Luohe region, China

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Introduction

With the rapid increase of industrialization and urbanization, **natural ecosystems and ecosystem services** in China are experiencing **landscape fragmentation and degradation** due to urban sprawl (PENG et al. 2018, UPADHYAY et al. 2017).

In effect, landscape fragmentation and degradation **cause habitat loss and impact the movement of species** (CLOSSET-KOPP et al. 2016).
Thus, maintaining landscape connectivity and mitigating the fragmentation of habitat may be critical for ecological processes such as gene flow, dispersal and migration (RUDNICK et al. 2012).

Ecological Networks (ENs) can
mitigate the damage caused by intensified land use (JONGMAN 2008)
promote landscape connectivity
reduce landscape fragmentation
Therefore, an optimized ecological network (EN) is of great significance for **the sustainable development of urban and rural ecosystems**

We have three goals in this article:
(1) **to map and compare resistant kernels (connectivity)** at multi-dispersal scenarios,
(2) **to map and compare factorial least-cost paths (pathways)** at multi-dispersal scenarios,
(3) **to rank conservation priority of ecological connectivity network.**

Study area

Luohe region is located in **central Henan province** (113º27′—114º16′E, 33º24′—33º59′N). The total municipal territory of Luohe region is **2617 km2**, including Yuanhui district, Yancheng district, Shaoling district, Wuyang county and Linying county (Figure 1), spanning **76 km from east to west and 64 km from north to south**. Luohe city is developed along **Sha and Li rivers which meet in the central area.**

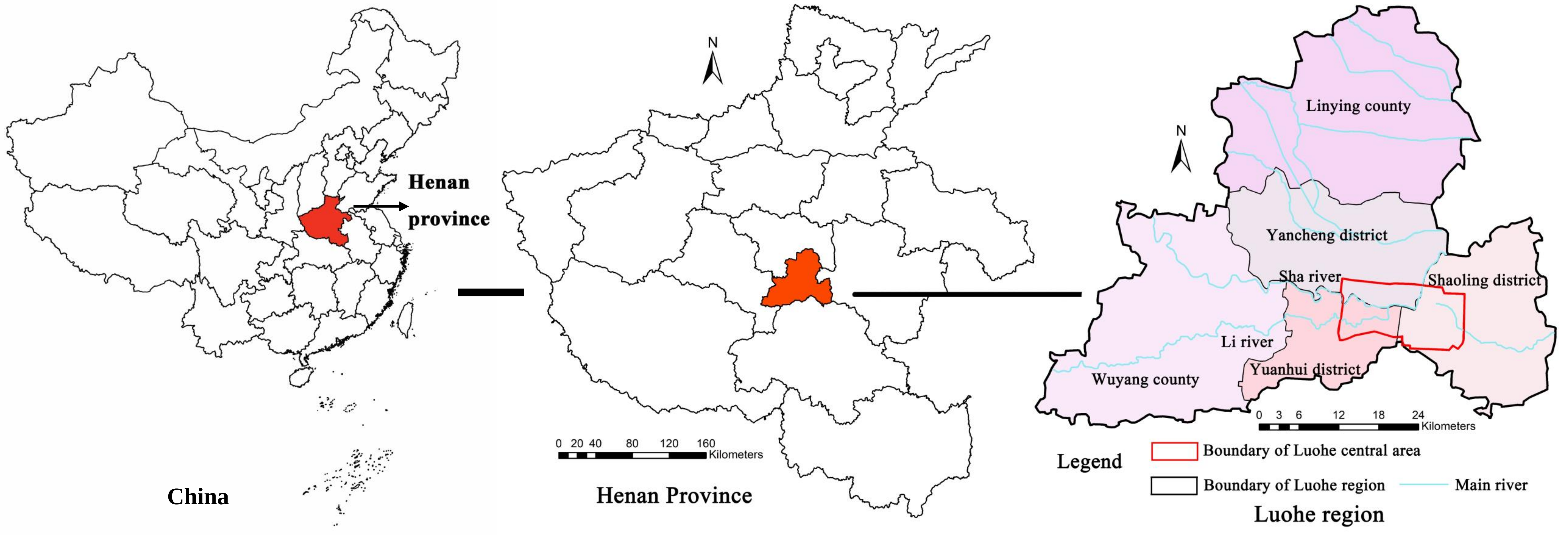


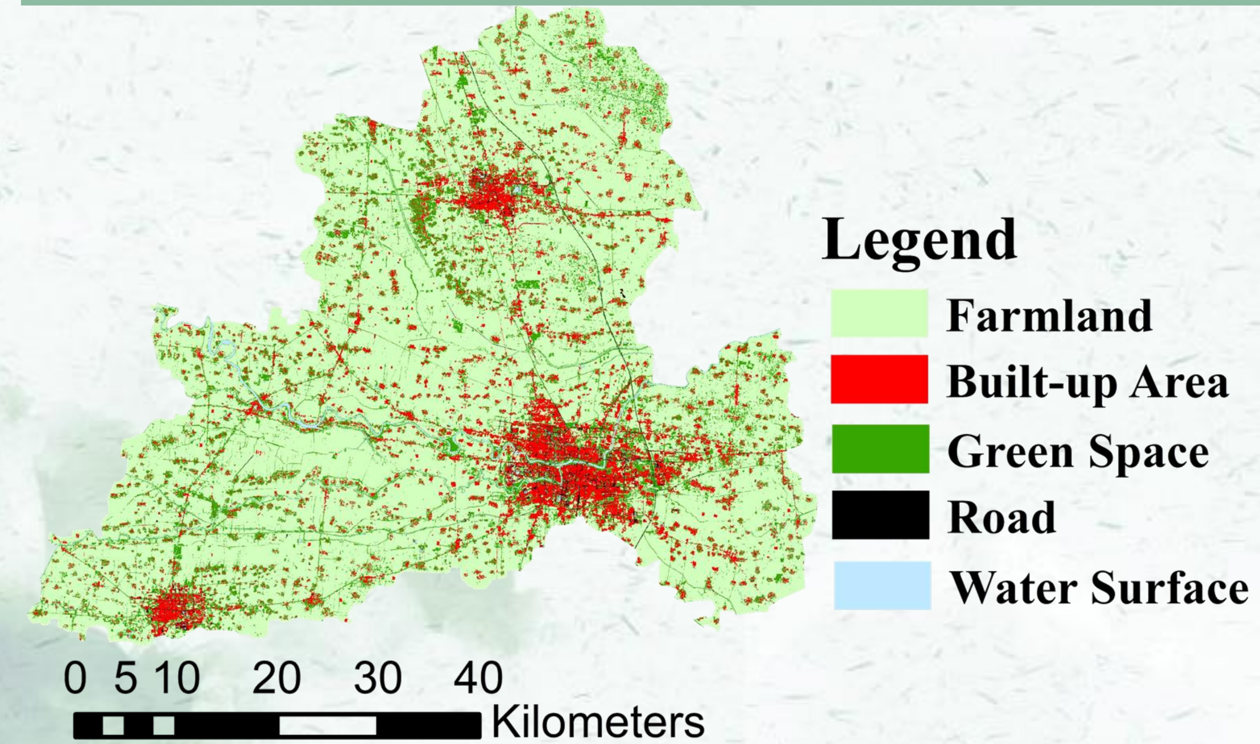
Fig. 1: Location of Luohe region within Henan Province.

1 Multi-dispersal scenarios and ecological source selection

We evaluated connectivity network predictions across **seven dispersal thresholds**, including 1 km, 2 km, 4 km, 8 km, 16 km, 32 km, 64 km (MATEO SANCHEZ et al. 2013). In this way, we evaluated **a general sensitivity** of ecological network for **species associated with green space.**

2 Remotely sensed image acquisition and preprocessing

1) We downloaded **two Landsat 8 images** (Resolution: 30 m) and performed **a supervised classification** to classify **five types of the land use** in ENVI 5.3 – **farmland, built-up area, green space, road, water surface**



2) Accuracy assessment. We chose 100 ground truth points on a Sentinel-2 image (Resolution: 10 m) to test the accuracy of classification using the Confusion Matrix Using Ground Truth ROIs function in ENVI.

3) Fragmentation analysis. Calculated five class metrics including **Patch Density (PD), Percentage of Landscape (PLAND), Radius of Gyration_Area-Weighted Mean (GYRATE_AM), Edge Density (ED), and Aggregation Index (AI)** in Fragstats (MCGARIGAL et al. 2002 and 2012) **to quantify the structure and composition** of the land use.

3 Identifying core areas

We used two criteria to assess the importance of core areas of green habitat.

1) The size of green space, since species often have minimum patch area requirements to occupy and persist in a habitat patch**.** We used **Morphological Spatial Pattern Analysis** to extract core, then we selected core areas **greater than 5 hectare**.

2) Degree of Probability of Connectivity (dPC), representing habitat availability and connectivity (HOFMAN et al. 2018). **We used Conefor 2.6 to identify the important nodes, and chose core areas whose dPC is larger than 1 to represent the important nodes for the connectivity network** across the Luohe region. Then we calculated landscape metrics of PD, GYRATE_AM, ED, AI to measure the landscape pattern of important nodes.

4 Ecological connectivity network mapping and assessment

The UNIversal CORridor and network simulation model (UNICOR) (LANDGUTH et al. 2012) includes two approaches for quantifying landscape connectivity. 1) **Resistant kernel modeling** (COMPTON et al. 2007) **is to get the resistant kernel which represents the connectivity of species movements.** 2) **Factorial least-cost path modeling predicts corridors and corridor strength** (CUSHMAN et al. 2013) for species with multi-dispersal abilities.

1 Land use classification

Accuracy assessment (Table 1) showed the overall accuracy is 92.1478%, with a Kappa Coefficient of 0.8806. This showed the classification is highly **successful and robust** for use as the basis of the rest of the analysis.

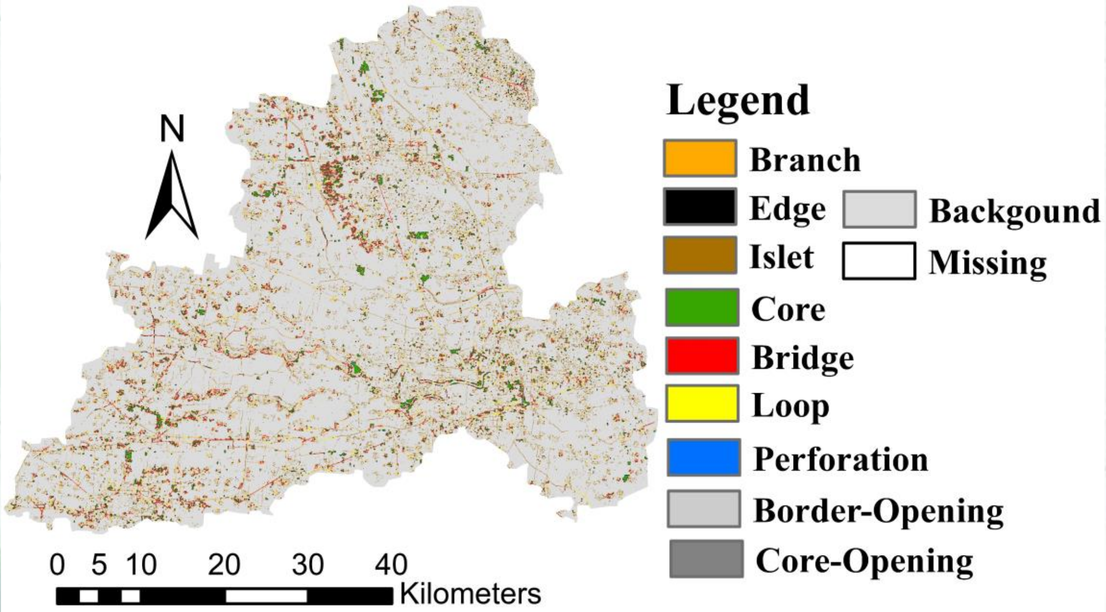
Table 1: Accuracy assessment of land use classification (Overall Accuracy = 92.1478%, Kappa Coefficient = 0.8806)

Class	Commission (%)	Omission (%)	Prod. Acc. (%)	User Acc. (%)
Farmland	3.88	0	100	96.12
Built-up Area	16.07	7.84	92.16	83.93
Green Space	26.47	28.57	71.43	73.53
Road	4.55	46.15	53.85	95.45
Water Surface	6.74	2.35	97.65	93.26

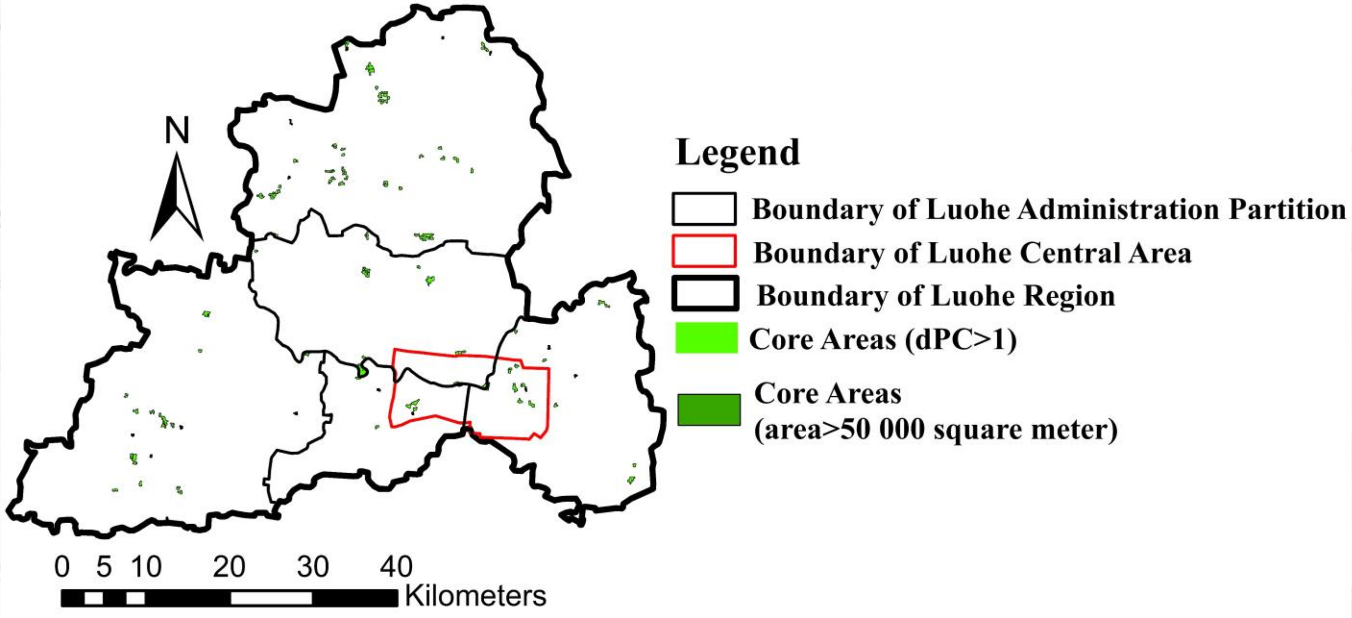
2 Definition of Core areas

MSPA analysis indicated that Core is 1.4%, islet is 4.65%, perforation is 0.01%, Edge is 2.85%, loop is 0.37%, bridge is 1.18%, branch is 2.77% of the extent of the region.

Through MSPA analysis we chose 96 **core areas bigger than 5 hectare.** Conefor analysis showed there are **80 core areas with the value of dPC (degree of Probability of Connectivity) greater than 1**.



MSPA map



Core area map

3 Fragmentation analysis

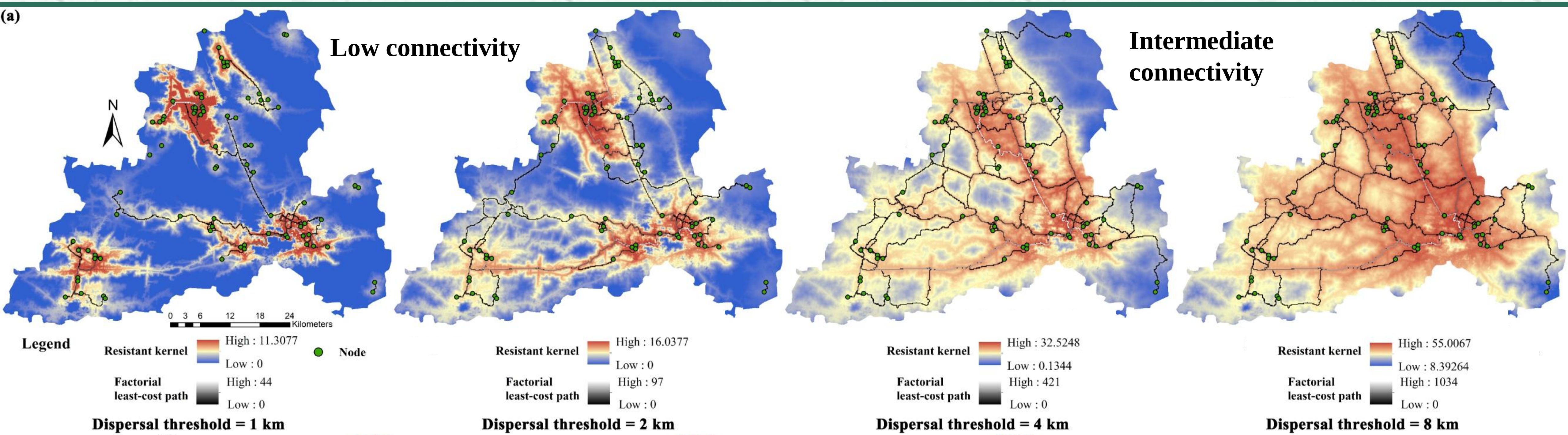
Fragmentation analysis of land use types is reported in Table 2. The PD and ED of green space are 12.3583 and 70.1397 respectively, showing that green space in the region is highly fragmented.

Table: Fragmentation analysis of land use types (class metrics)

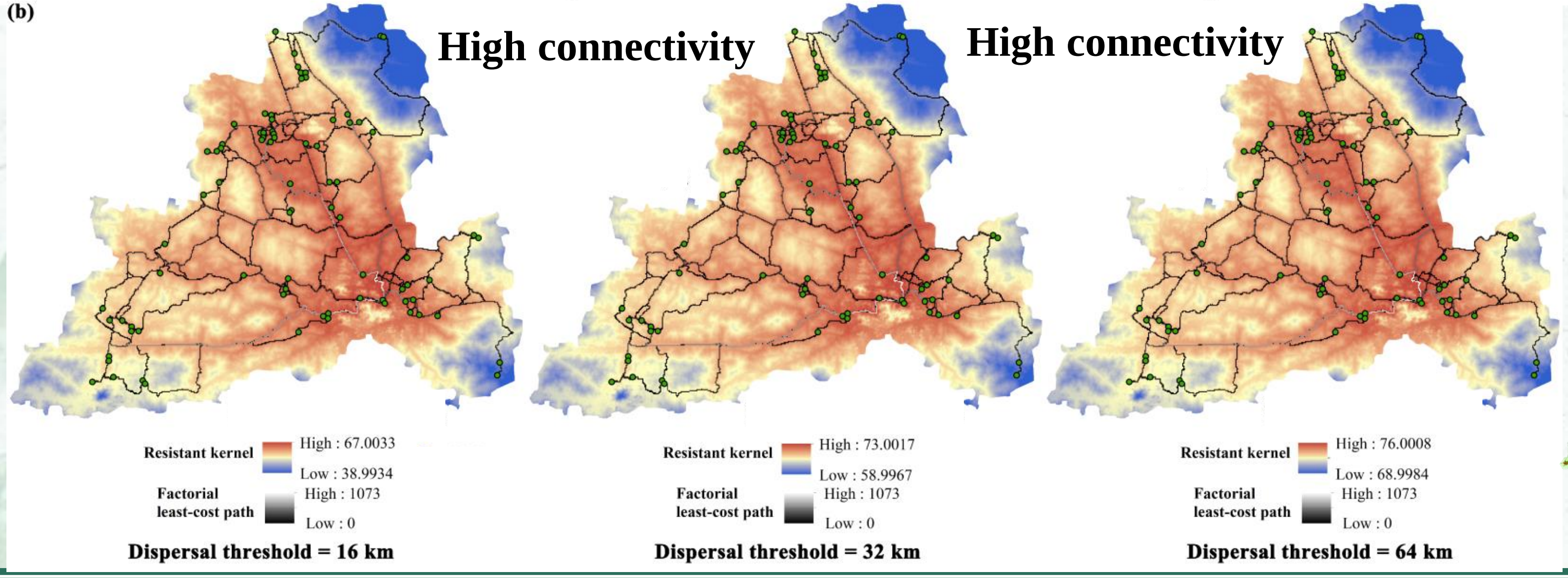
Class	**PLAND** (%)	**PD** (number/hectare)	**ED** (m/hectare)	**GYRATE_AM** (m)	**AI** (%)
Farmland	75.3	4.36	70.30	8906.89	92.94
Built-up Area	9.3	4.81	36. 10	600.35	71.15
Green Space	13.2	12.36	70.14	280.58	60.21
Road	0.8	1.99	6.13	118.31	40.39
Water Surface	1.4	2.22	7.34	3327.68	59.95

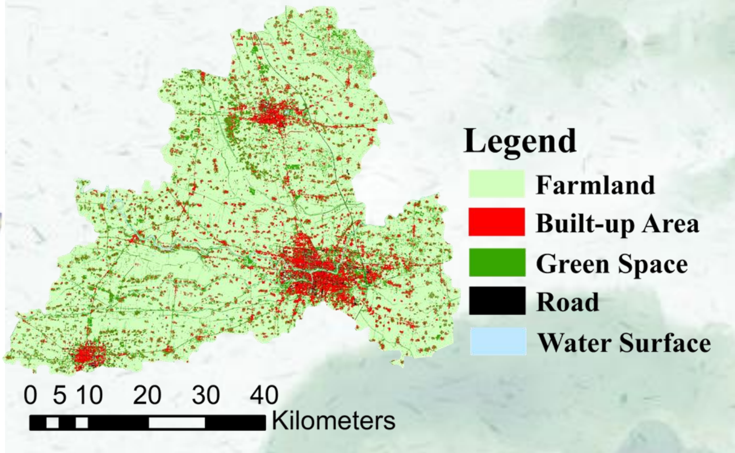
Table: Fragmentation analysis of core areas (landscape metrics)

TYPE	**PD**	**ED**	**GYRATE_AM**	**AI**
Core Areas	7.9146	0	225.3534	84.2022



Resistant kernel (connectivity) and Factorial least-cost path (corridor)





5 Overlapping map evaluation

Main roads and rivers passed through high connectivity areas, and most factorial least-cost paths are aligned with main roads and rivers (Figure 7). It reminds planners to build more green space combined with other landscape elements, for instance, river corridors and transport corridors.

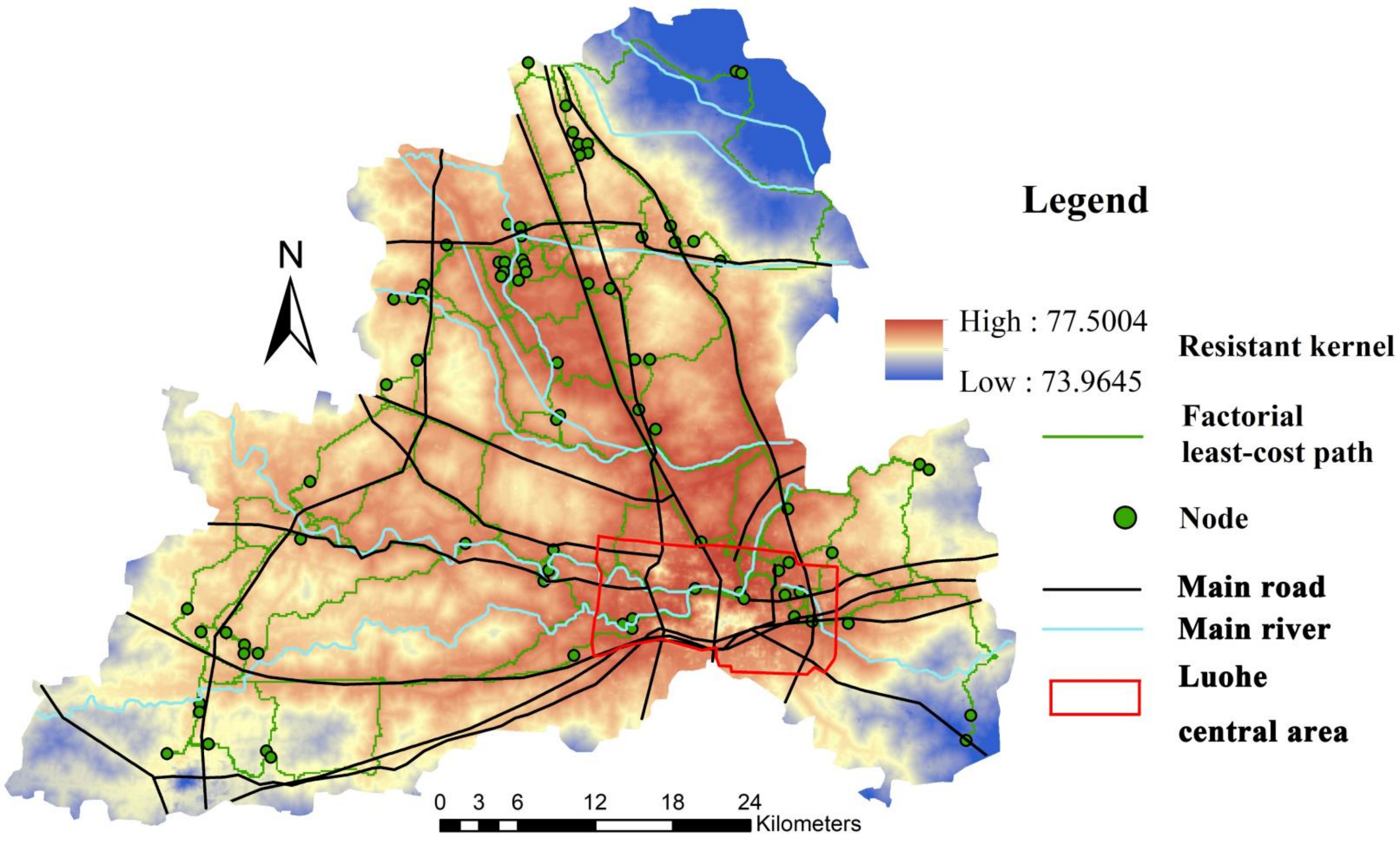


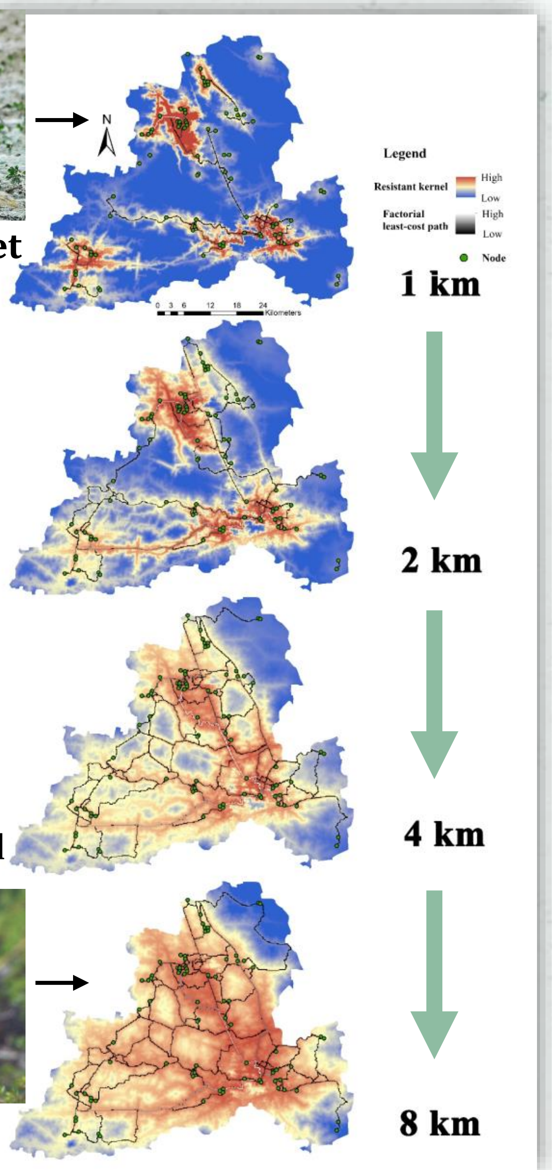
Fig. 7: Overlapping map of main road & main river and resistant kernel & factorial least-cost path

We identified three hypotheses to discuss.

Small Indian civet

Hypothesis 1: Kernel connectivity increases with dispersal ability. The area provides low connectivity for species with small dispersal abilities, the area provides high connectivity for species with big dispersal abilities.

Hypothesis 2: Symmetry of thresholds in kernel connectivity and factorial least-cost path connectivity. Our analysis showed that the number and strength of paths increased dramatically with small dispersal abilities, but stayed stable with big dispersal abilities. This means the number of factorial least-cost path is related with the strength of the kernel connectivity.



Siberian weasel

Hypothesis 3: Most ecological connectivity networks are along with roads and rivers in Luohe. It says planners should build ecological networks with other landscape elements.

In UNICOR analysis, we had three conclusions based on the results and goals:

1) **Resistant kernel analysis predicted the density of dispersal movement across the landscape**. At small dispersal abilities of 1 and 2 km there were high levels of fragmentation, and as dispersal ability increased kernel connectivity produced broader extents of interconnected habitat.

2) **Factorial least-cost paths predicted the routes of highest potential connectivity linking all pairs of source points.** Different dispersal abilities have similar pattern of corridors, but the extent and strength of the corridors are highly sensitive to dispersal ability.

3) **Conservation priority based on the results.** Species with dispersal ability of 1 and 2 km is the first conservation priority, species with dispersal ability of 4 km and 8 km is the second conservation priority, species with dispersal ability of ≥ 16 km is the third conservation priority. It means planners should build more corridors and stepping stones for the first conservation priority.

Thank you for your attention