Paving the path

Systematic Conservation Planning for North Chinese Lepoard's Return to Beijing

Statement

This is a systematic conservation planning effort dedicated to building a harmonious coexistence between humans and nature in the North Taihang area of China. The North Chinese Leopard, a subspecies of leopard unique to China, was once widely distributed across North China, including Beijing. However, its habitat has become highly fragmented due to human activities. To facilitate the return of leopards to Beijing, we developed a plan based on field monitoring, extensive simulation, and in alignment with policies.

Based on long-term camera trap data and field surveys, we simulated the current and potential suitable habitats and corridors for leopards and their prey. We identified four challenges including inadequate protection of habitats and corridors, habitat fragmentation caused by roads, conflicts between cropland and conservation, and impacts of recreation activities on habitats.

To address these challenges, we proposed four targeted strategies:
(1) Forming a conservation network to expand protected habitat coverage,
(2) Building wildlife crossings to improve habitat connectivity,
(3) Recovering and restoring cropland to improve biodiversity,
(4) Managing recreation activities to reduce human impact.

Based on solid data and rigorous calculations, the plan achieves a balance between preservation and usage, outlining a resilient conservation network to foster living in harmony with nature.

Paving the path

Systematic Conservation Planning for North Chinese Lepoard's Return to Beijing

Background and Significance

The North Chinese Leopard (*Panthera pardus japonensis*) is crucial to the ecosystem in North China as it is an apex predator and umbrella species. It is also a subspecies of leopard unique to China. However, due to the expansion of human activities, the habitat area of the North Chinese Leopard is continuously reduced, and the habitat fragmentation is serious. It is categorized as Vulnerable (VU) on the IUCN Red List and Endangered (EN) on the China Red List. Beijing is the historic habitat of the North Chinese Leopard, but currently there are no leopards, resulting in an incomplete ecosystem food web. Beijing has put forward the vision of "welcoming leopards back to Beijing".

Under the dual threat of climate change and human influence, the global biodiversity loss is a huge crisis for humanity. The Kunming-Montreal Global Biodiversity Framework (KMGBF), which sets out a vision of "Living in Harmony with Nature" in 2050, aims to increase the coverage of global protected areas to 30% by 2030. China is promoting the establishment of a system of protected areas with national parks as the main body. From the perspective of global, national and regional policies, it is of great significance to establish a conservation network for the leopard's return to Beijing.

We chose the North Taihang Mountain Range and Yan Mountain Range as the research area for analysis, involving Beijing, Hebei and Shanxi provinces. The research area is 117,514 km^2. North China Leopards are distributed in the North Taihang Mountain Range (belonging to Shanxi and Hebei provinces) in the southern part of the research area, while the Yan Mountain Range (belonging to Beijing and Hebei provinces) in the northern part of the research area only have leopard's prey species distribution, but no leopard distribution. We hope that leopards will return to Beijing along the North Taihang Mountain Range, and that leopards will serve as an umbrella specie to improve regional biodiversity and ecosystem integrity.

Modeling and spatial analysis

Collecting basic spatial data

Based on data related to protected areas in Beijing, Hebei and Shanxi provinces, we generated a complete spatial range of existing protected areas in the research area. For spatial analysis, we collected land cover data from 30 m annual China land cover dataset (CLCD), road and railway data form National Catalogue Service For Geographic Information System.

Identify Priority Conservation Areas (PCAs) for leopard protection.

Based on long-term infrared camera monitoring data, we generated occurrence points data for leopards and leopard's 14 prey species. We generated a total of 169 leopard's occurrence points in Shanxi and Hebei provinces, and 1997 prey species' occurrence points in Beijing, Shanxi and

Hebei provinces. We also collected data on environmental variables, including climate, terrain, and human impact, across 15 layers. The resolution of 15 environment variables is 1km.

Based on the occurrence points of species and environment variables, we used the R-package SSDM to simulate habitat suitability for leopard and each prey species using multiple machine learning models. Based on the habitat suitability of leopards, we identified the suitable habitats of leopard by natural breaks classification, and then we simulated the corridors between the suitable habitats and current density in the corridors by using Linkage Mapper software and Circuitscape software. We added the habitat suitability of all prey species to obtain the total habitat suitability of prey, and then use the natural breaks classification to generate potential habitats of leopard. We simulated the potential corridors between potential habitats and the current density in the potential corridors.

Finally, suitable habitats, suitable corridors, potential habitats and potential corridors of leopard together constitute Priority Conservation Areas (PCAs) for leopard's survival and return to Beijing. The area of PCAs accounts for 20% of the research area.

Identifying recreation hotspots.

Due to its proximity to metropolises such as Beijing, there are plenty of recreational activities in the study area. Studies have shown that a large number of recreational activities have a negative impact on wildlife habitat. Therefore, we make a spatial analysis of recreational activities in the research area.

We downloaded all the shared recreational trajectory data in the study area from the Two-Step Outdoor Assistant website, and then counted the number of recreation trajectories with a 1km spatial grid to generate recreational activity density data. We then identified recreation hot spots using Hotspot-Analysis (Getis-Ord Gi*).

Identifying challenges

We overlaid PCAs with other layer data and found the following four challenges.

Challenge 1 PCAs are not effectively protected by current protected areas.

We calculated the area of PCAs in the existing protected areas, and found that PCAs were not effectively protected. The protection coverage of suitable habitats, suitable corridors, potential habitats and potential corridors are only 31.6%, 19.5%, 30.6% and 14.1% respectively.

Challenge 2 Roads have serious conflicts with PCAs and cause habitat fragmentation.

We superimposed roads with PCAs and found a large number of conflicts between roads and PCAs. 23.6% of the length of roads in the research area are located within the PCAs.

Challenge 3 There is a large area of cropland in PCAs, where human-animal conflict exists.

By superimposing PCAs with cropland areas and finding out the conflict areas, we can see that cropland is a great threat to PCAs. The cropland coverage of suitable habitats, suitable corridors, potential habitats and potential corridors are 11.6%, 28.2%, 6.75% and 24.6% respectively.

Challenge 4 Recreation activities have a serious negative impact on biodiversity.

Through the overlay analysis of recreation hotspots and PCAs, we can find that the recreation conflict area coverage of suitable habitats, suitable corridors, potential habitats and potential corridors are 3.0%, 0.3%, 8.7% and 3.49% respectively.

Systematic Conservation Planning

To address these challenges, we developed a systematic conservation planning and four targeted strategies for the leopard's survival and return. We increased the protection coverage of research area from 10.6% to 28.3%, bringing all Priority Conservation Areas (PCAs) into the conservation network. We developed strategies for challenges including habitat fragmentation caused by roads and railways, conflicts between cropland and conservation, and impacts of recreational activities on habitats.

Strategy 1 Forming a conservation network to expand protected habitat coverage.

We planned a conservation network of protected areas, corridors and OECMs, covering all PCAs and existing protected areas. The coverage of protected areas, corridors and OECMs in the research area is 20.3%, 5.1% and 2.9% respectively. Protected areas include national parks, nature reserves and natural parks. We propose to establish two national parks in the research area where there are no national parks to effectively protect the most important habitat for leopards and the most important recreational resource for humans.

Strategy 2 Building wildlife crossings to improve habitat connectivity.

In the roads within the priority conservation areas, we extracted areas with high current density and identified connectivity pinch-point. Based on the topography and field research at each pinch point, we determined the wildlife crossing types of each connectivity pinch-point. A total of 15 wildlife crossings were planned, including 3 Cross-road elevated passageways, 1 Viaducts, 7 Underpass (culverts) and 4 Multiuse overpass.

Strategy 3 Recovering and restoring cropland to improve biodiversity.

The cropland with conservation network is divided into 2 types: cropland to restore and cropland to recover. Cropland to restore is the cropland within protected areas, covering 1.7% of research area and will be gradually restored to its natural state to expand the habitat. Cropland to recover is the cropland within OECMs, covering 2.9% of research area, and will be transformed using biodiversity-friendly agricultural practices to improve biodiversity.

Strategy 4 Managing recreation activities to reduce human impact.

We identified the overlapping areas of recreation hotspots and conservation networks as recreation management areas, covering 1.6% of research area. Recreation management areas are distributed in national parks, nature reserves and natural parks.

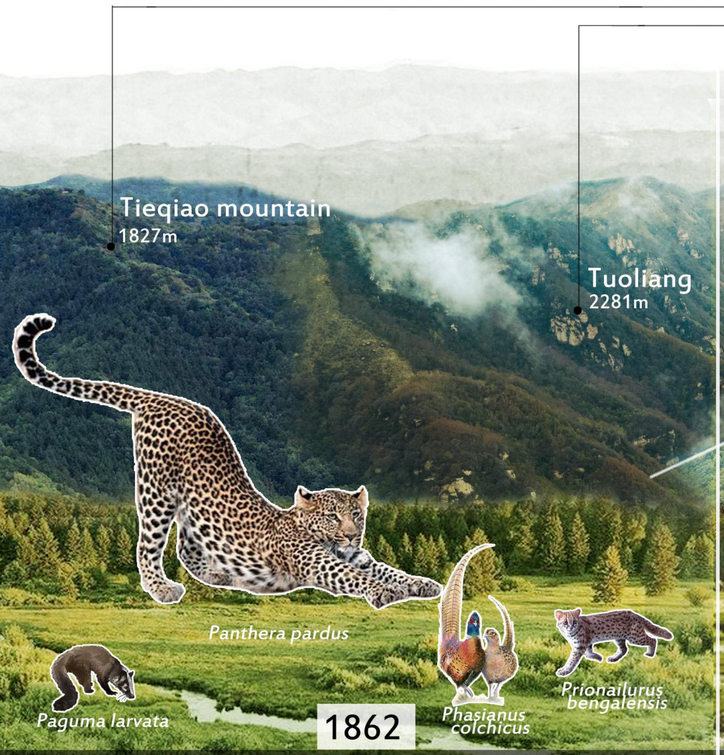
PAVING THE PATH

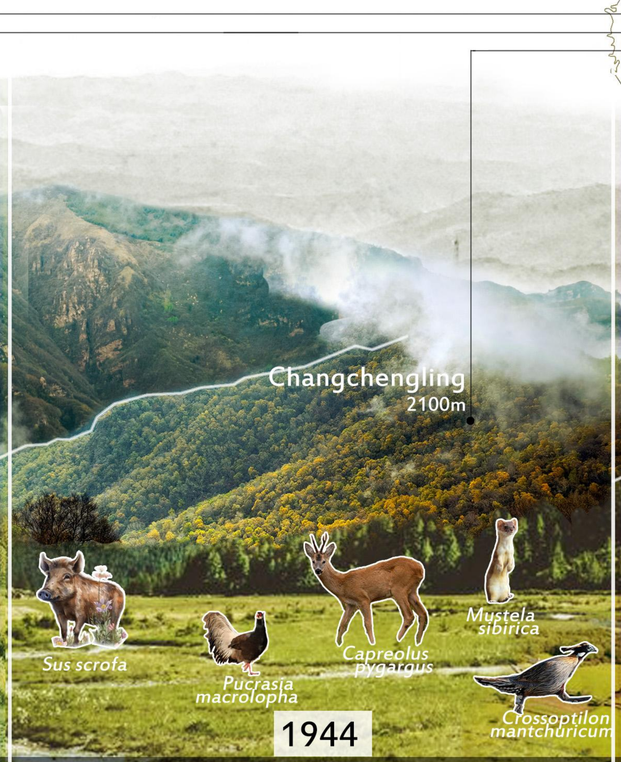
Systematic Conservation Planning for North Chinese Lepoard's Return to Beijing

The North Chinese Leopard, a subspecies of leopard unique to China, has a highly fragmented habitat due to human activities. Although Beijing is historically the habitat of the North Chinese Leopard, there are currently no leopards in Beijing, leading to an incomplete ecosystem food web. Beijing has put forward the vision of "welcoming leopards back to Beijing". In order to facilitate the return of leopards to Beijing along the North Taihang Mountain Range, we developed an ambitious systematic conservation planning.

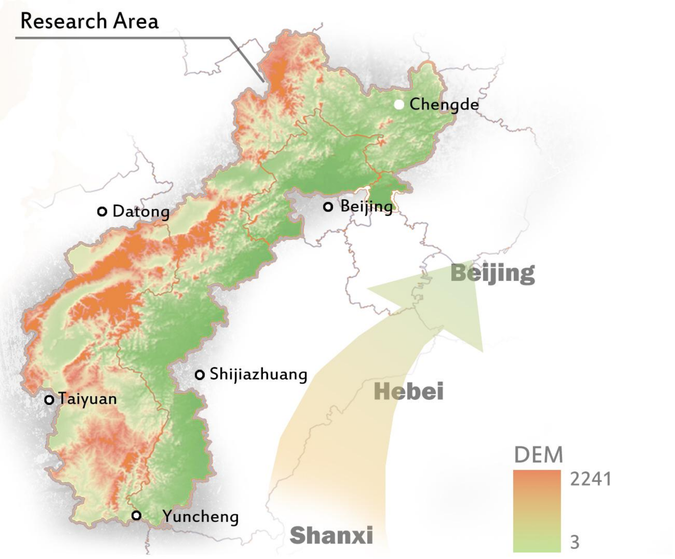
Based on long-term infrared camera trap monitoring data, we simulated current suitable habitats and corridors for leopards, as well as leopard's potential habitats and corridors in Beijing and surrounding areas. These areas are Priority Conservation Areas (PCAs) for leopard's survival and return to Beijing. Overlaying PCAs with other spatial data revealed 4 main challenges: (1) Inadequate protection of PCAs by current protected areas, (2) Significant conflicts between roads and PCAs, (3) Extensive cropland within PCAs, and (4) Detrimental impact of recreational activities on biodiversity.

To address these challenges, we proposed 4 targeted strategies: (1) Forming a conservation network to expand protected habitat coverage, (2) Building wildlife crossings to improve habitat connectivity, (3) Recovering and restoring cropland to improve biodiversity, and (4) Managing recreation activities to reduce human impact.





BACKGROUND



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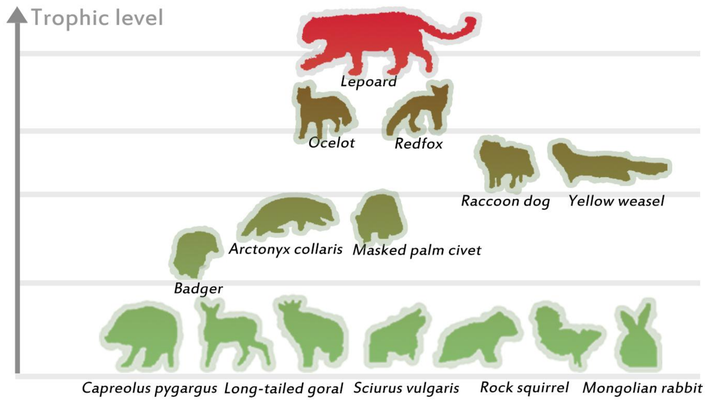

Significance

The North Chinese Leopard (Panthera pardus japonensis) is crucial to the ecosystem in North China as it is an apex predator and umbrella species. It is categorized as Vulnerable (VU) on the IUCN Red List and Endangered (EN) on the China Red List.

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Global context

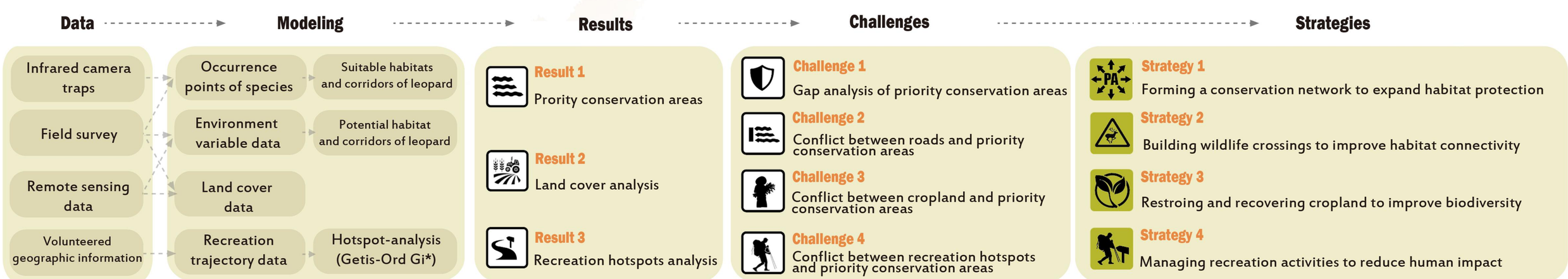
Under the dual threat of climate change and human influence, the global biodiversity loss is a huge crisis for humanity. The Kunming-Montreal Global Biodiversity Framework (KMGBF), which sets out a vision of "Living in Harmony with Nature" in 2050, aims to increase the coverage of global protected areas to 30% by 2030.

China is promoting the establishment of a system of protected areas with national parks as the main body.

As a flagship and umbrella species, the return of the leopard could significantly enhance Beijing's biodiversity and ecosystem integrity.

From the perspective of global, national and regional policies, it is of great significance to establish a conservation network for the leopard's return to Beijing.

Technical FLow



MODELING

Habitat Stimulation and Connectivity Analysis of Leopard

Algorithms | **Variables** | **Results**

SSDM
Stacked species distribution model

Final algorithm evaluation and correlations

Mean contribution (axes.metric)

Final uncertainty map

Diversity and endemism maps

Number of repetitions(rep)

ESDM
Ensemble species distribution model

Algorithm evaluation and correlations

Mean contribution (axes.metric)

Uncertainty map

Mean habitat suitability and binary map

5 *ESDM leopard's prey species*

Species stacking

Consensus method

SDM
Species distribution model

Evaluation(cv, cv.param,metric)

Variable contribution (ax-es.metric)

Habitat suitability and binary map

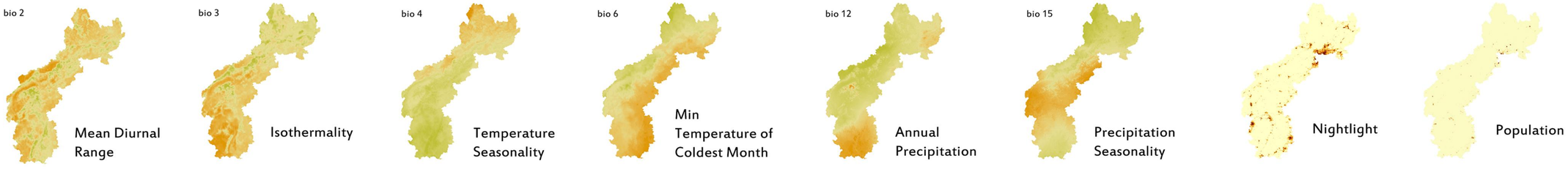
9 machine learning methods:
GAM、GLM、MARS、CTA、GBM、MAXENT、ANN、RF、SVM

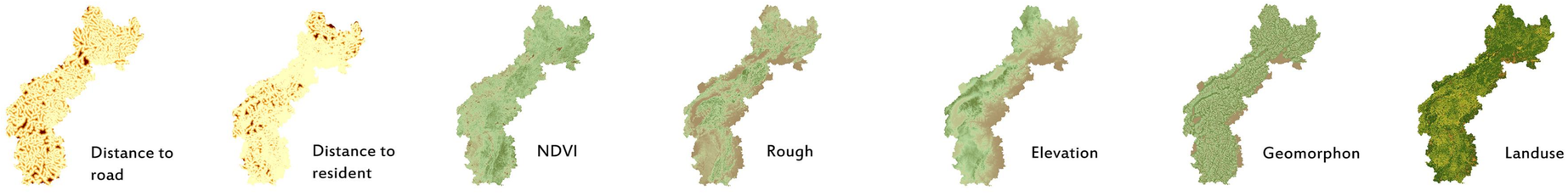
1 INPUT

Occurence point

+

Environment Variables





6 pSSDM
Leopard's prey species

Natural breaks classification

Negative exponential transformation

Leopard's potential habitats 7

Leopard's resistance surface

Least-cost path model

Circuit theory model

2 ESDM
Leopard

Natural breaks classification

Negative exponential transformation

Leopard's suitable habitats 3

Leopard's potential resistance surface

Least-cost path model

Leopard's Suitable Corridors 8

Leopard's Suitable Corridors Density

+

Leopard's Potential Corridors 4

Leopard's Potential Corridors Density

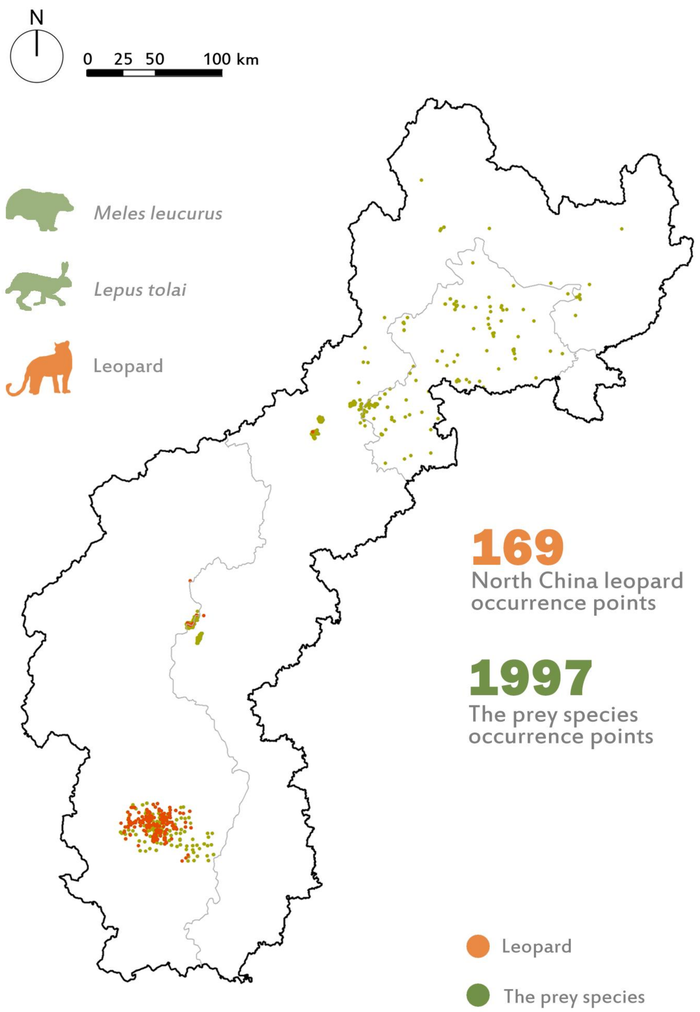
MODELING

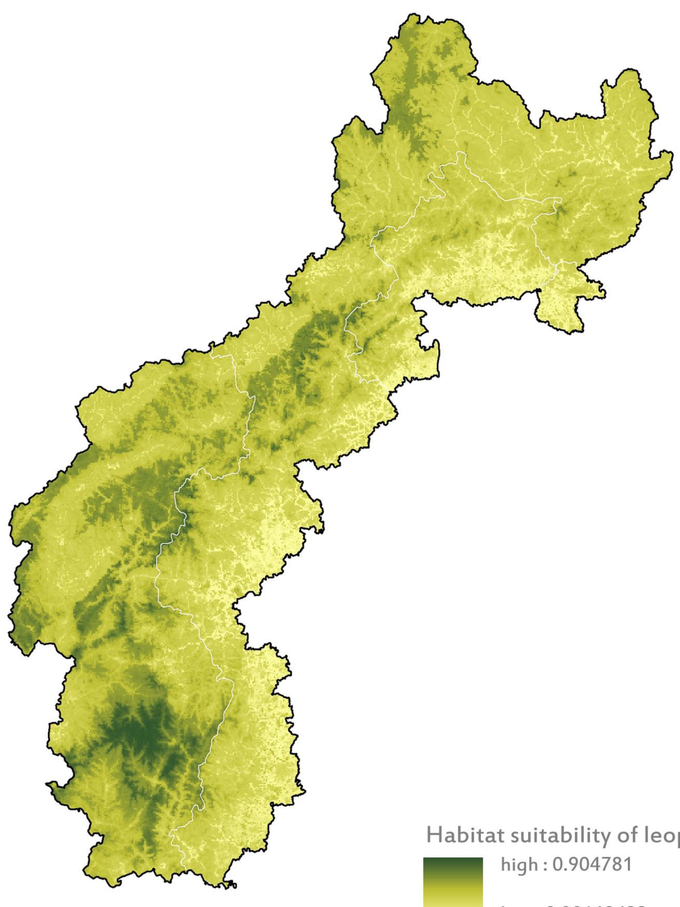
Simulating Suitable Habitats and Corridors of Leopard based on ESDM Model

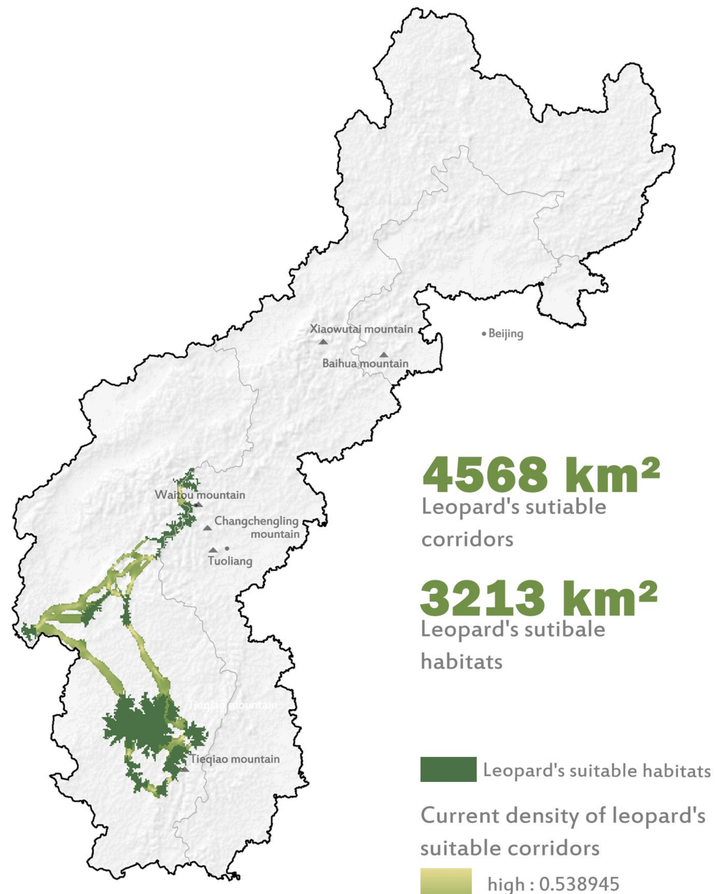
Species occurrence data were primarily collected by infrared cameras installed by CFCA (Chinese Felid Conservation Alliance), supplemented and refined with data from literature research (mostly from highly reliable open online datasets). The R package spThin is used to sort out points within a 1km grid, reducing interference from overly concentrated data points.

Num	Item	Family	Name	National protect level
1	*Carnivora*	*felidae*	*Prionailurus bengalensis*	II
2	*Carnivora*	*Canidae*	*Nyctereutes procyonoides*	II
3	*Carnivora*	*Canidae*	*Vulpes vulpes*	II
4	*Carnivora*	*Mustelidae*	*Mustela sibirica*	None
5	*Carnivora*	*Mustelidae*	*Meles leucurus*	None
6	*Carnivora*	*Mustelidae*	*Arctonyx collaris*	None
7	*Carnivora*	*Viverridae*	*Paguma larvata*	None
8	*Artiodactyla*	*Suidae*	*Sus scrofa*	None
9	*Artiodactyla*	*Cervidae*	*Capreolus pygargus*	None
10	*Artiodactyla*	*Bovidae*	*Naemorhedus griseus*	II
11	*Lagomorpha*	*Leporidae*	*Lepus tolai*	None
12	*Rodentia*	*Sciuridae*	*Sciurotamias davidianus*	None
13	*Rodentia*	*Sciuridae*	*Tamias sibiricus*	None
14	*Rodentia*	*Sciuridae*	*Sciurus vulgalis*	None

1 **Occurrence Points** — Ensemble Modeling (ML method) → 2 **ESDM of Leopard** — Natural breaks classification (Least-cost path model) → 3 4 **Leopard's Suitable Habitats and Corridors**



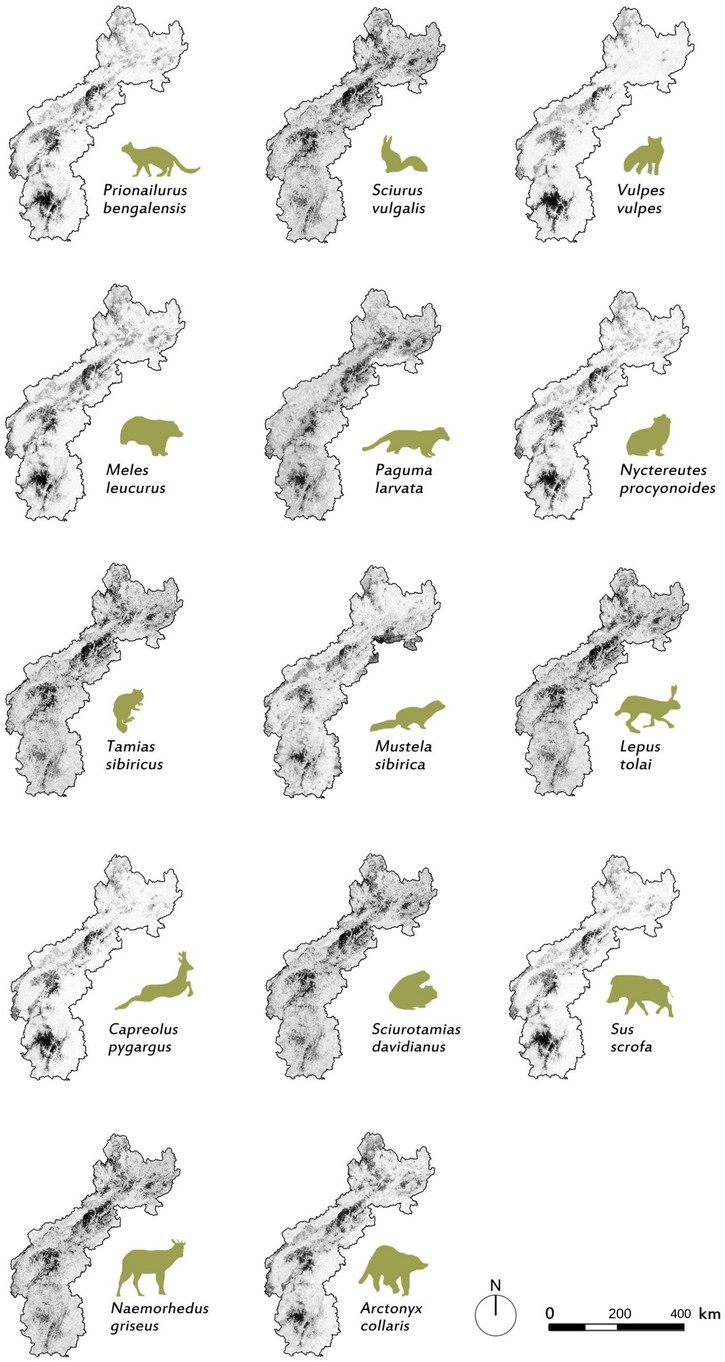


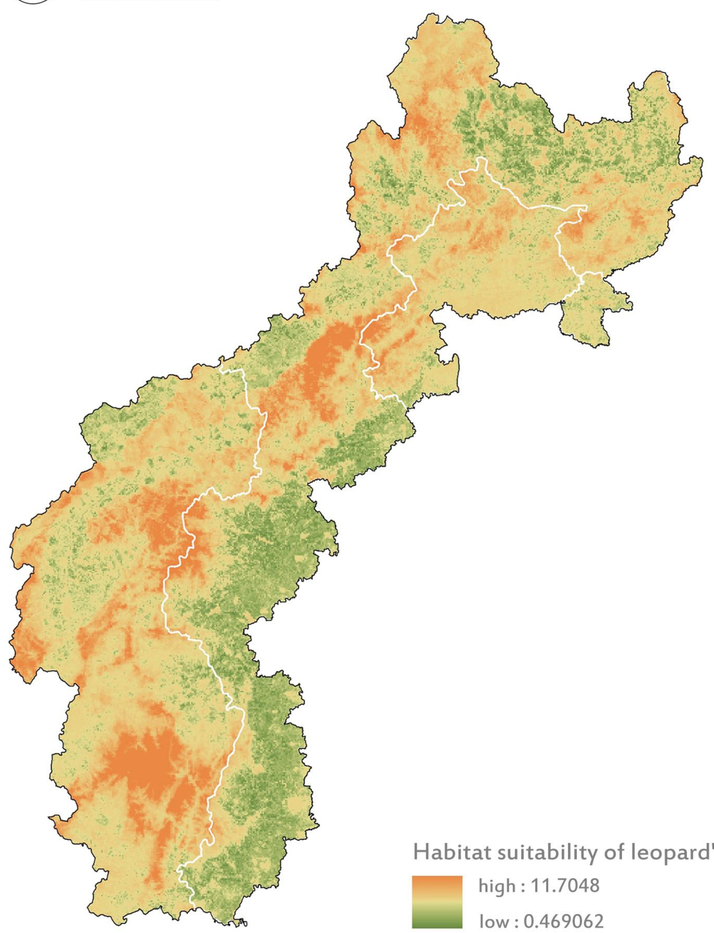


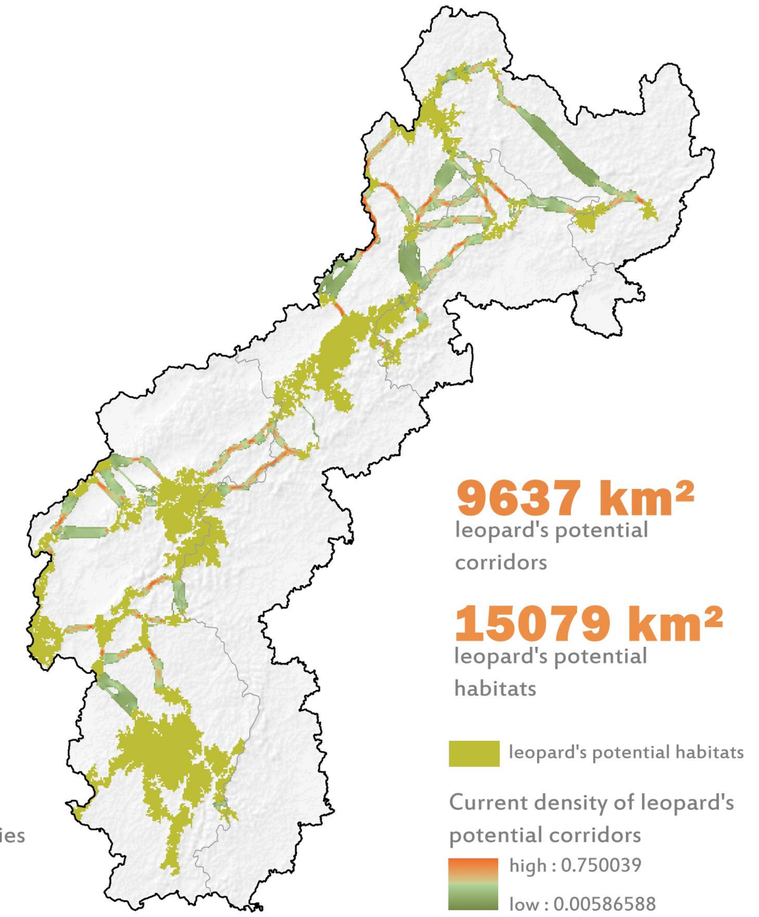
MODELING

Simulating Potential Habitats and Corridors of Leopard based on SSDM Model

5 **ESDM of Prey Species** → 6 **Prey's pSSDM** → Natural breaks classification (Least-cost path model) → 7 8 **Leopard's Potential Habitats and Corridors**

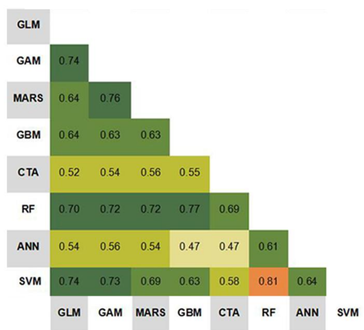






Classification

The pSSDM map of leopard's prey species is classified by the natural breaks method, and relatively intact patches are selected to form the leopard's potential habitats. Taking these habitats as the source, the potential corridors of leopard are calculated.



Correlation Analysis

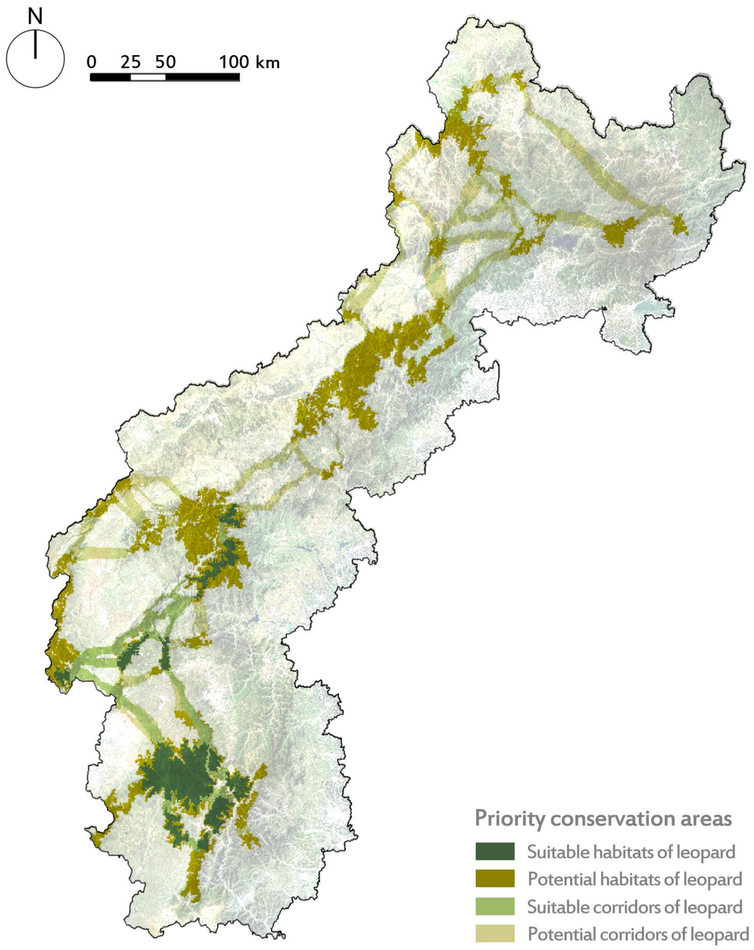
Our modeling results of pSSDM of the prey species are based on a variety of machine learning methods. The contribution of each machine learning method to the final model is weighted according to the correlation value among all the methods.

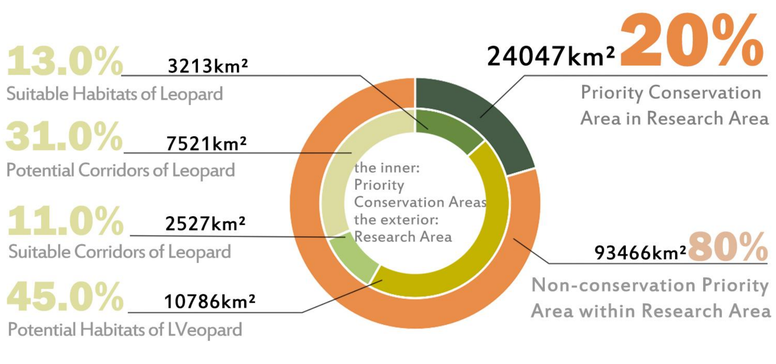
The RF and SVM models have the highest fitting correlation, and the results of these two are given the highest weight in the final stacking process.

RESULTS

Result1

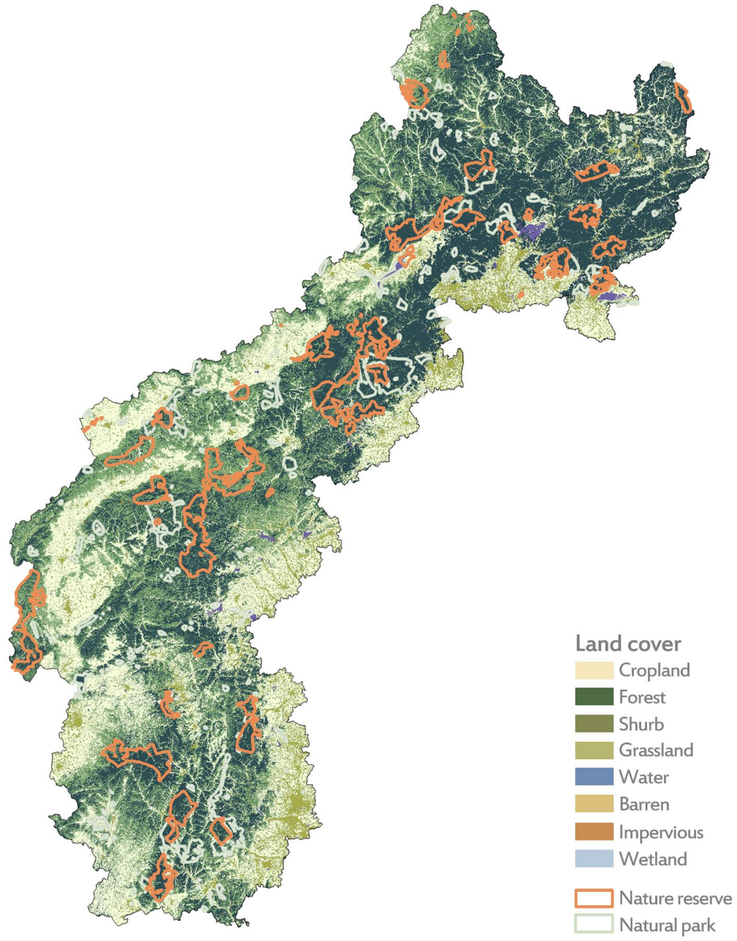
Priority conservation Areas



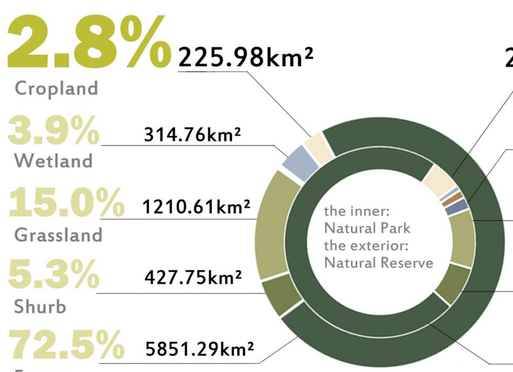


Result2

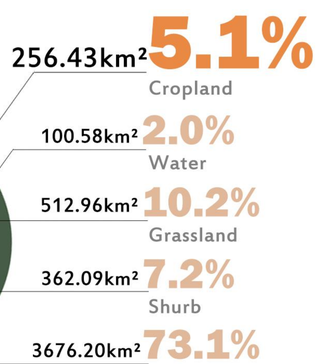
Land cover Analysis



Land Cover in Nature Reserve

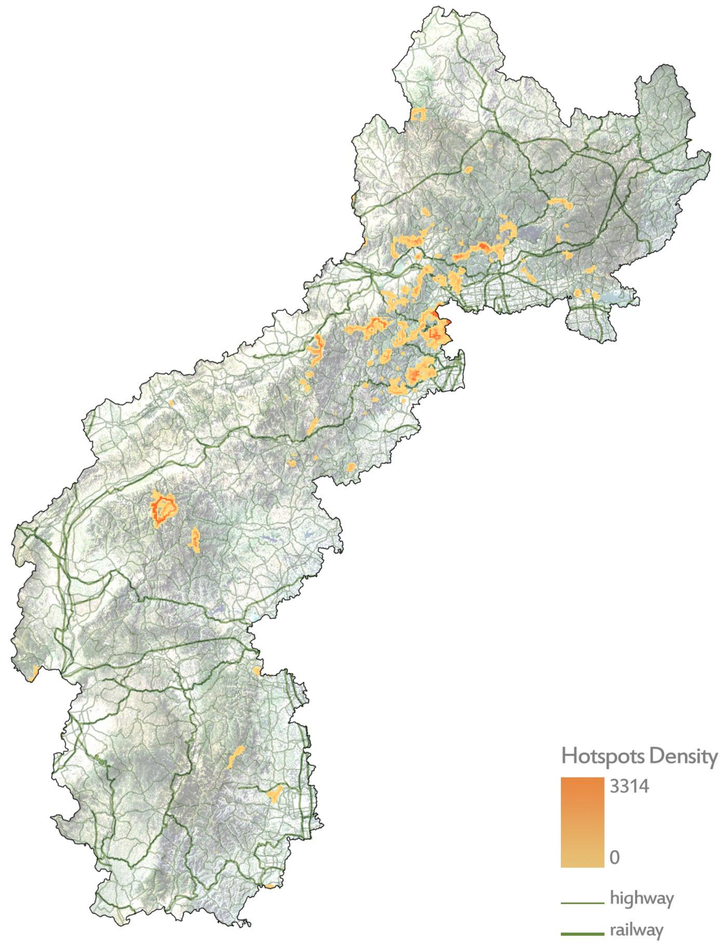


Land Cover in Natural Park



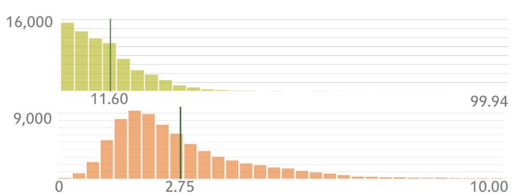
Result3

Recreation hotspots analysis



We use the open GPS walking trajectory data on Two-Step website in 2019 and analyze the trajectory density and filter out the hotspots in Arcgis pro. Highway and railway data from National Catalogue Service For Geographic Information are used to analyze current transportation.

11.6km AVR Mileage
660.8m AVR Rise
2.75km/h AVR Spead
5.5h AVR Time

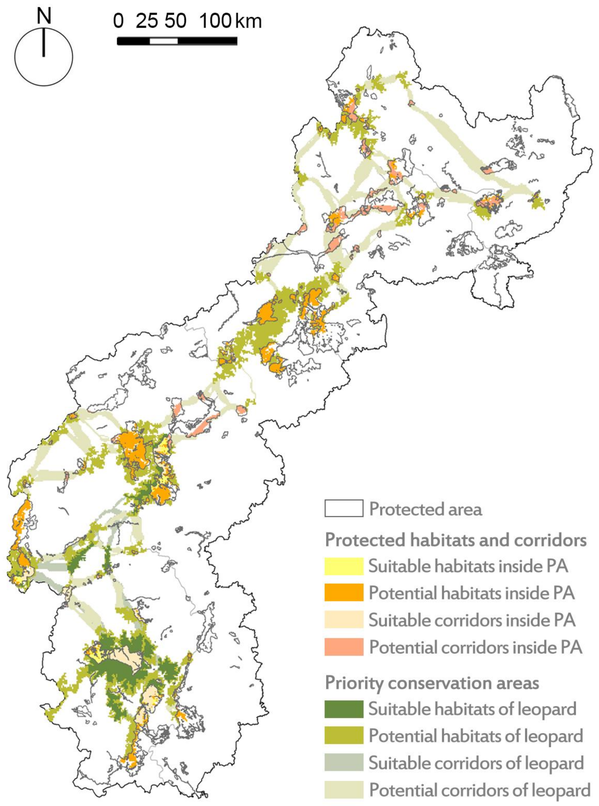


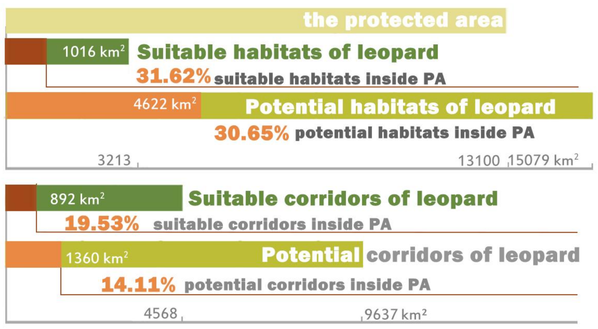
CHALLENGES

Challenge1

Gap Analysis of Priority Conservation Areas

We calculated the area of habitats and corridors located in the existing protected areas, and found that the habitats and corridors of North China leopard were not effectively protected.

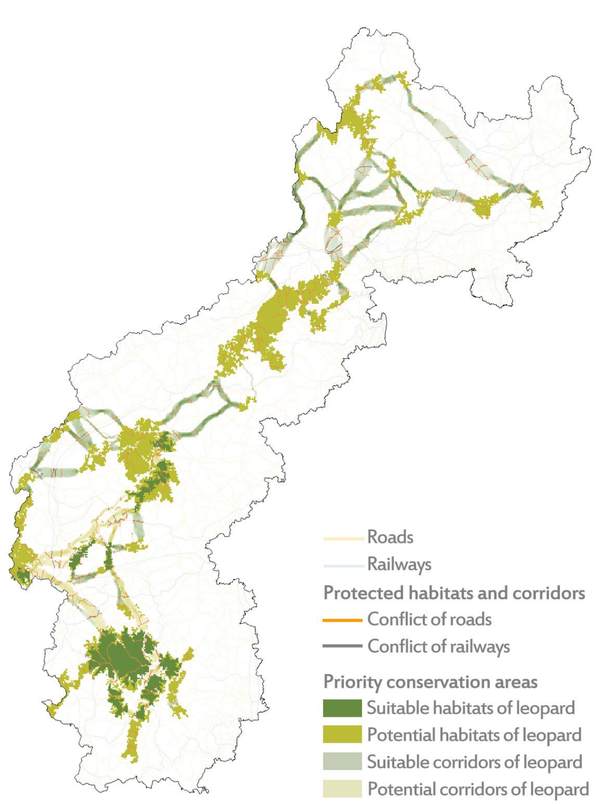


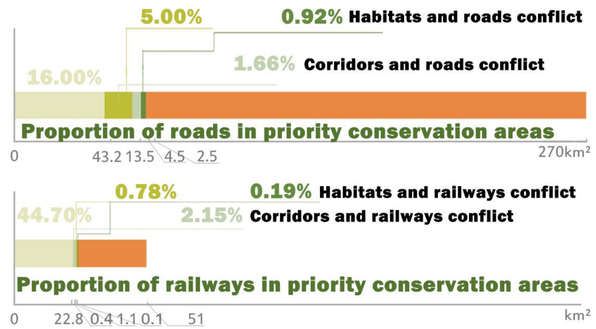


Challenge2

Conflict between Roads and Railways & Priority Conservation Areas

We superimposed roads and railroads on the North China Leopard Priority Conservation Area and found a large number of conflict points on the corridor network.

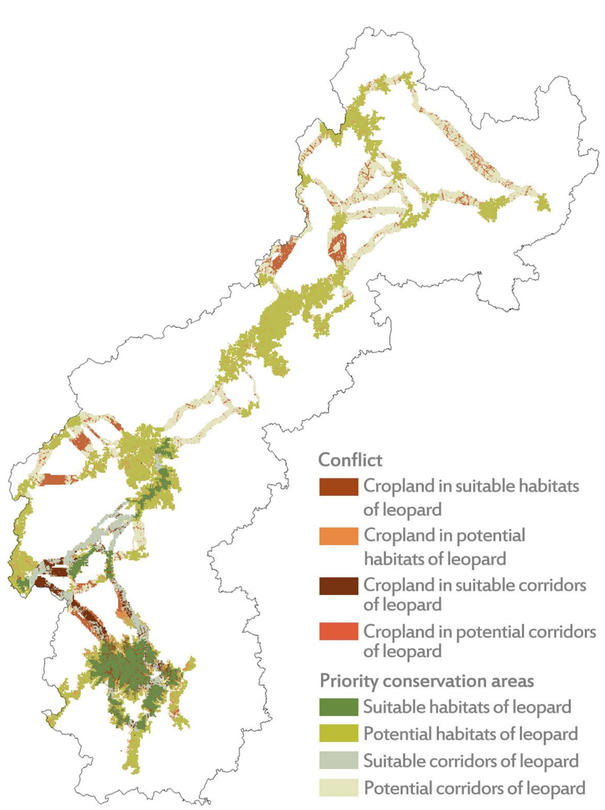


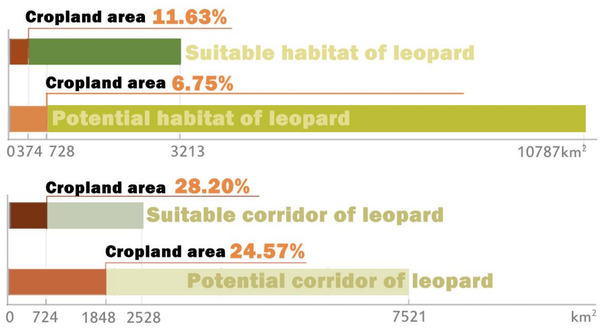


Challenge3

Conflict between Cropland & Priority Conservation Areas

By superimposing four kinds of habitats and corridors with cropland areas and finding out the conflict areas, we can see that cropland is a great threat, in which there are more cropland in corridors than in habitats.

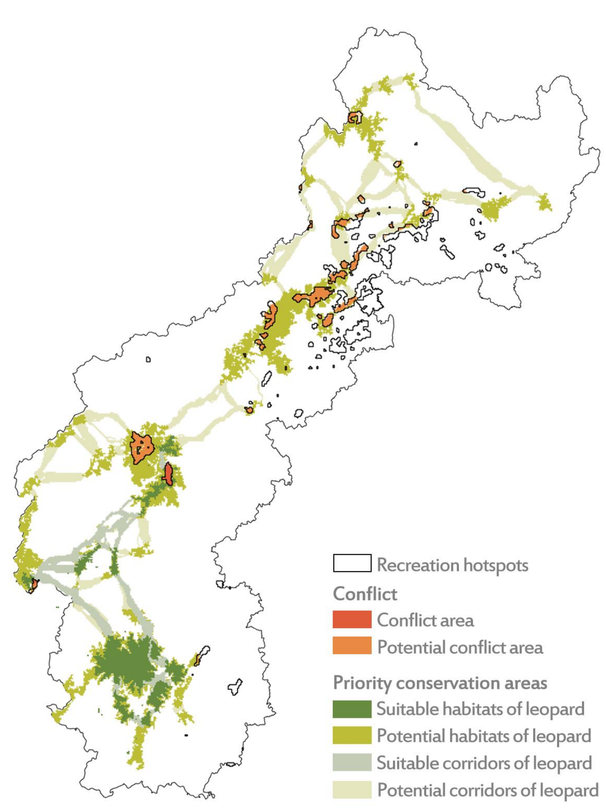


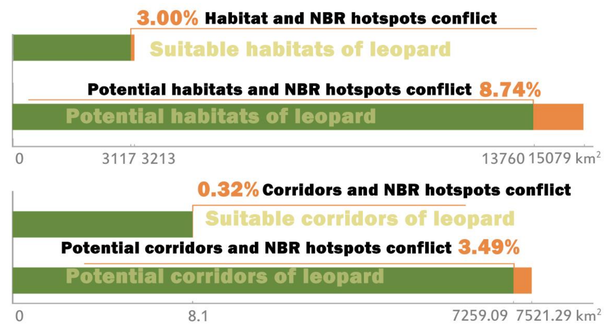


Challenge4

Conflict between Recreation Hotspots & Priority Conservation Areas

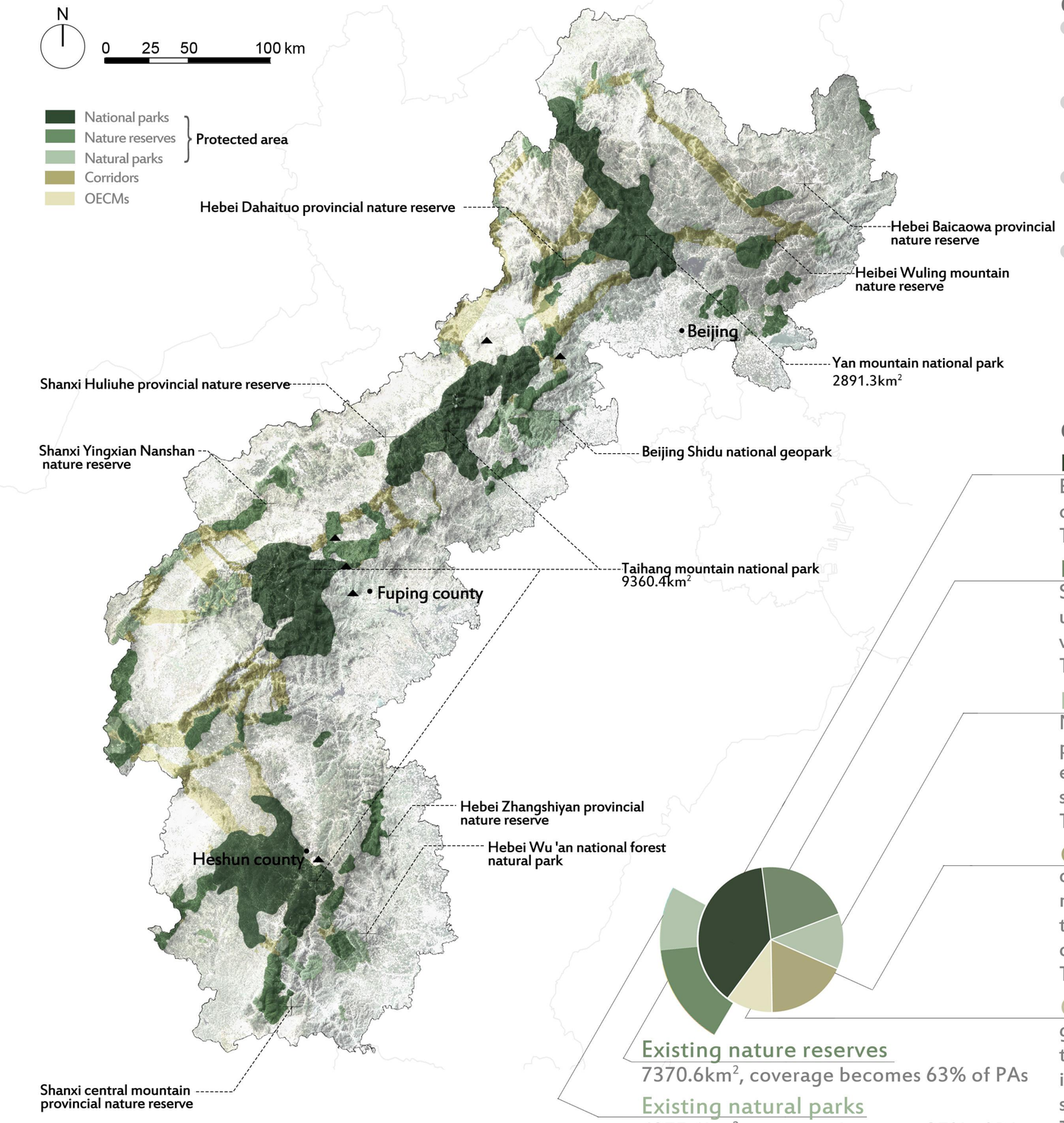
Through the overlay analysis of recreation hotspots and priority conservation areas of leopards as well as potential habitats network, we find significant conflicts, especially between recreation hotspots and potential habitats network.





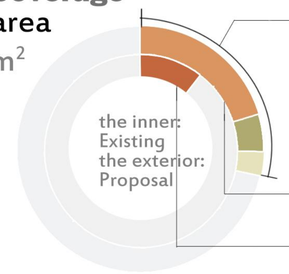
STRATEGIES

Strategy1 Forming a Conservation Network to Expand Protected Habitat Coverage



Conservation Network Coverage

- Increasing protected area
  9.7%-10798.3 km²
- Adding corridors area
  5.1%-5724 km²
- Adding OECMs area
  2.9%-3265.7 km²



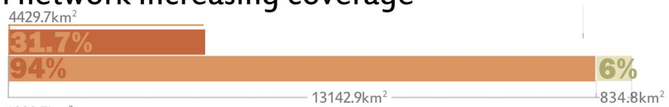
Conservation network area
28.3%-31533.7 km²

Area / 22544km²
Coverage / 20.3%
Area / 11745.7km²
Coverage / 10.6%

Existing protected area
Proposed protected area
Corridors
OECMs

- Diversified types of conservation network increasing coverage

68.3% of habitats



89.1% of corridors

Conservation Network Category

National parks / IUCN II , Ib

Emphasizes the protection of ecological integrity, restriction of exploitation, and provision of compatible opportunities for human activities

The area has increased by 11958.1km², coverage becomes 53% of PAs

Nature reserves / IUCN Ia

Strictly protected to conserve biodiversity and possibly geological features. Human visitation, use, and impacts are strictly controlled and limited to ensure the protection of conservation values.

The area has decreased by 692.8km², coverage becomes 30% of PAs.

Natural parks

Natural parks are a type of protected area, including scenic spots, forest parks, geological parks, ocean parks, wetland parks, desert park and grassland parks. It protects important natural ecosystems, natural relics and natural landscapes, and has ecological, ornamental, cultural and scientific values.

The area has decreased by 467km², coverage becomes 17% of PAs.

Corridors / IUCN

corridor as a clearly defined geographical space that is managed over the long term to maintain or restore effective ecological connectivity. These corridors are crucial for ensuring the movement and interaction of species between core habitats within protected areas and other conservation measures.

The area has added by 5724km².

OECMs / IUCN

geographically defined areas outside traditional Protected Areas that are managed in ways that deliver long-term and effective conservation outcomes for biodiversity. These outcomes include the associated ecosystem functions and services, and where applicable, cultural, spiritual, socio-economic, and other locally significant values.

The area has added by 3265.7km².

Existing nature reserves

7370.6km², coverage becomes 63% of PAs

Existing natural parks

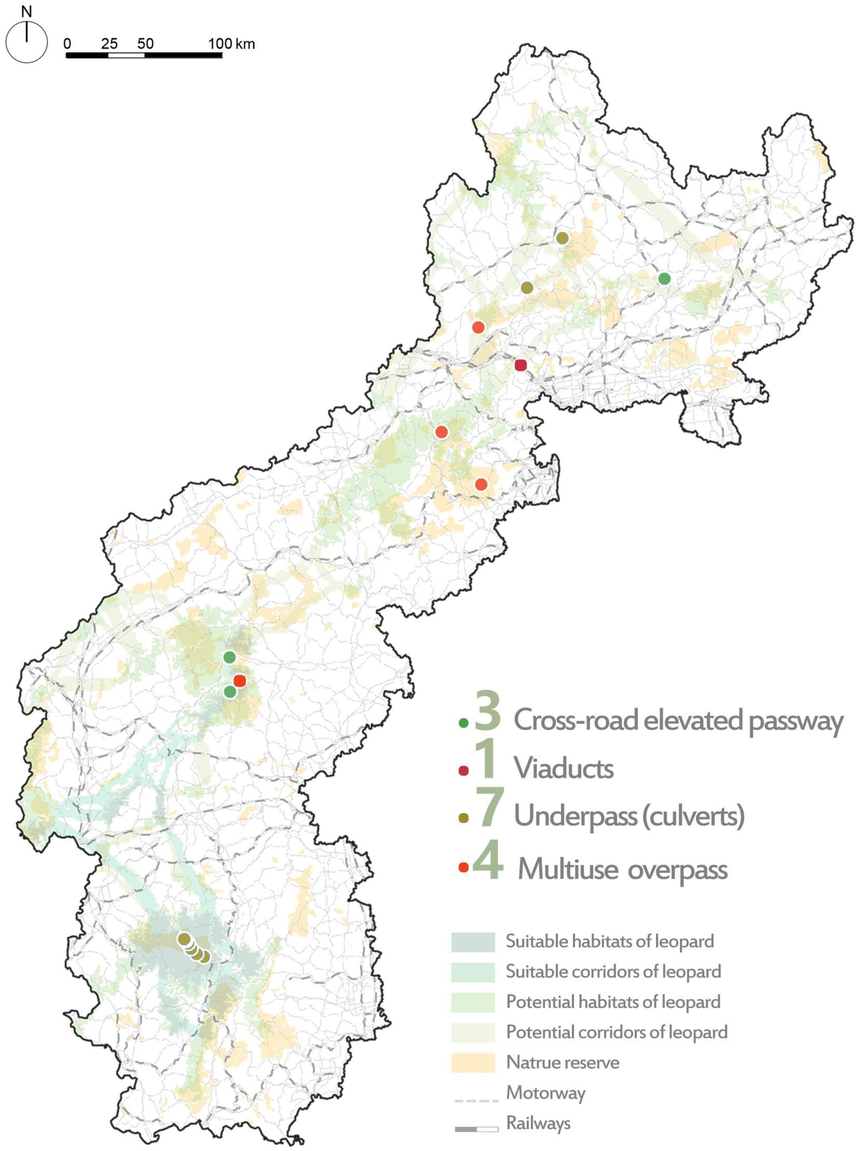
4375.1km², coverage becomes 37% of PAs

STRATEGIES

Strategy2 Building Wildlife Crossings to Improve Habitat Connectivity

Identify connectivity pinch-point

In the roads within the priority conservation areas, we extracted areas with high current density and identified connectivity pinch-point. Based on the topography and field research at each pinch point, we determined the wildlife crossing types of each connectivity pinch-point.



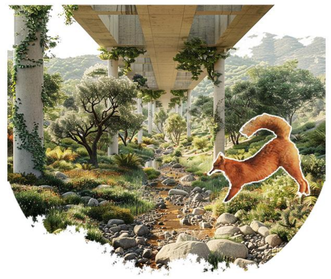
Four scenarios of wildlife crossings

Cross-road elevated passway

Construct elevated corridors above major roads to provide safe traversing paths for wildlife and reduce the impact of traffic accidents on them.

Underpass (culverts)

Construct underpasses in areas of high animal activity, allowing animals to migrate freely without interfering with traffic.



Viaducts

Utilize the space of bridges under viaducts to provide shelter and migration for small animals, increasing the diversity of ecological corridors.

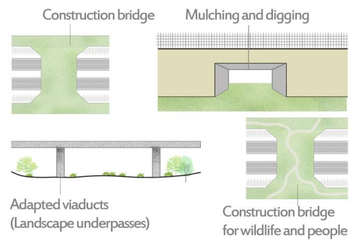
Multiuse overpass

Design multi-functional passages to meet human passage needs and provide safe migration routes for animals, realizing harmonious coexistence between humans and nature.

Four steps to build wildlife crossings

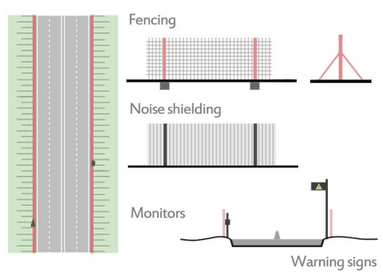
Survey and monitoring

Topographical surveys and wildlife monitoring to ensure that the site is traversed by wildlife.



Starting construction

Make a judgement on the selected site and decide on the type of construction, taking into account the cost and ease of construction.



Add facilities

Construction of ancillary facilities such as fencing, warning signs and infrared cameras to help reduce road kill accidents.

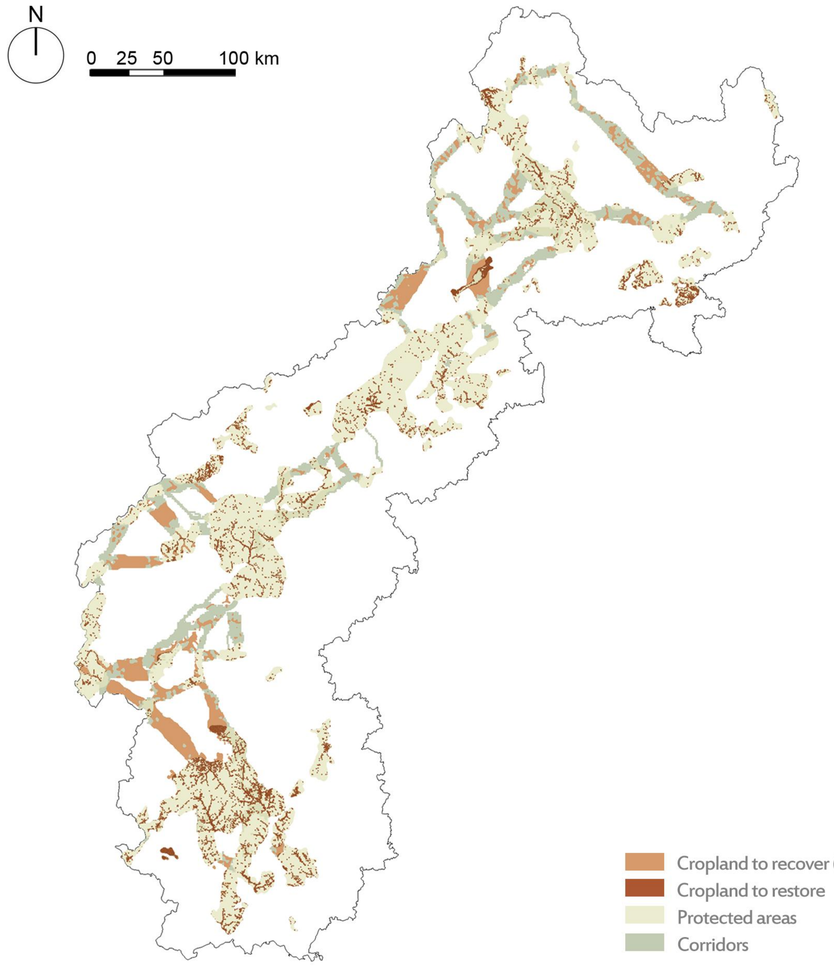
Planting

Creating natural-like habitats to attract wildlife through by adding ground cover, shrubs and trees favoured by wildlife.

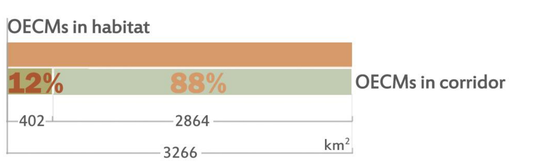
STRATEGIES

Strategy3 Recovering and Restoring Cropland to Improve Biodiversity

The cropland with conservation network is divided into 2 types: cropland to restore and cropland to recover. Cropland to restore is the cropland within protected areas, and will be gradually restored to its natural state to expand the habitat. Cropland to recover is the cropland within OECMs, and will be transformed using biodiversity-friendly agricultural practices to improve biodiversity.

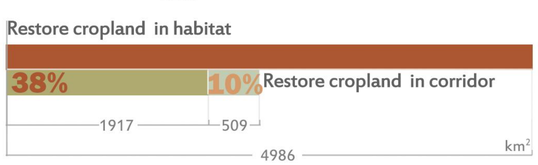


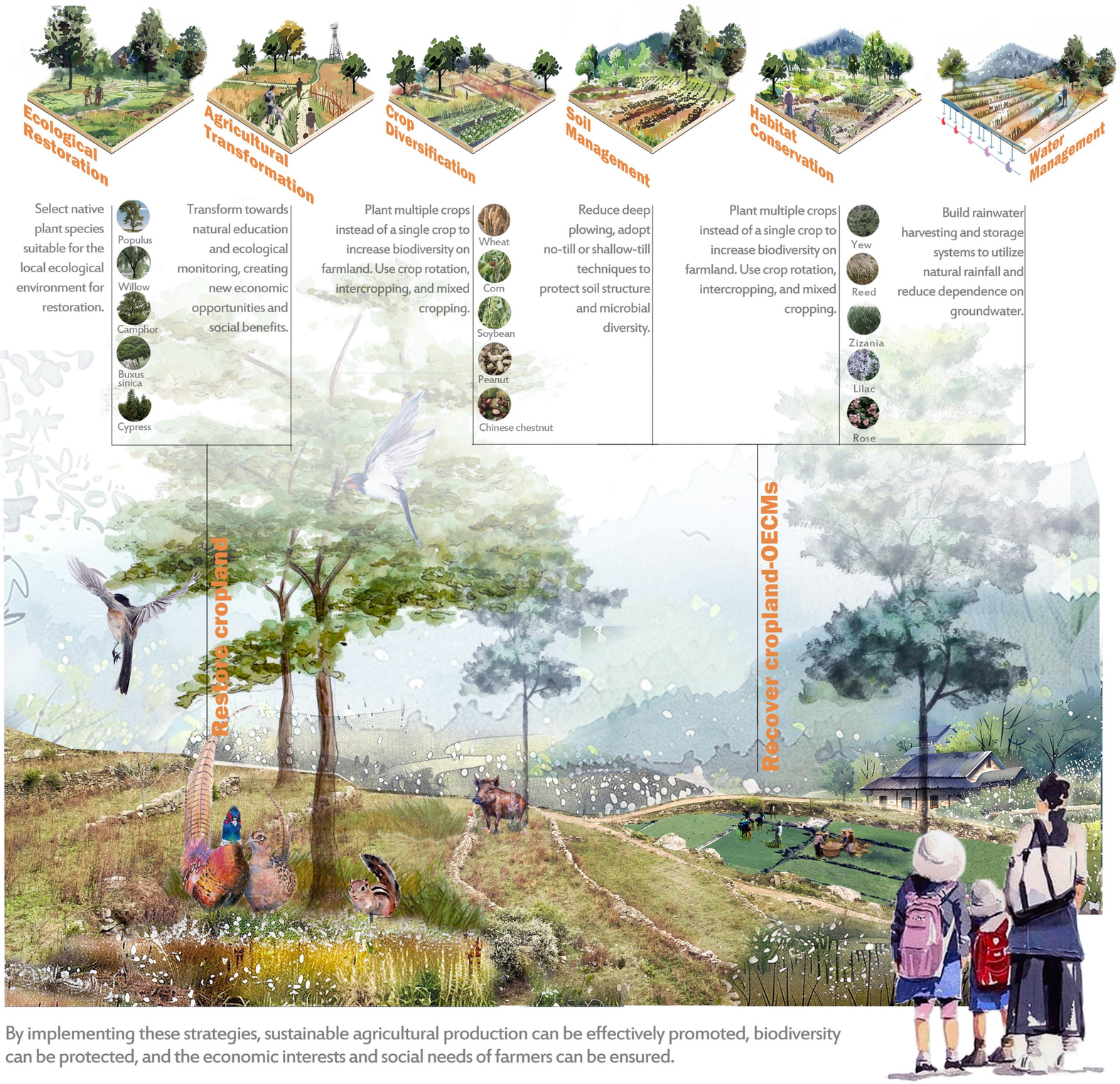
7.3% (OECMs) Cropland to recover in conservation network



7.9% Cropland to restore in conservation network

11% Cropland to restore in protected area





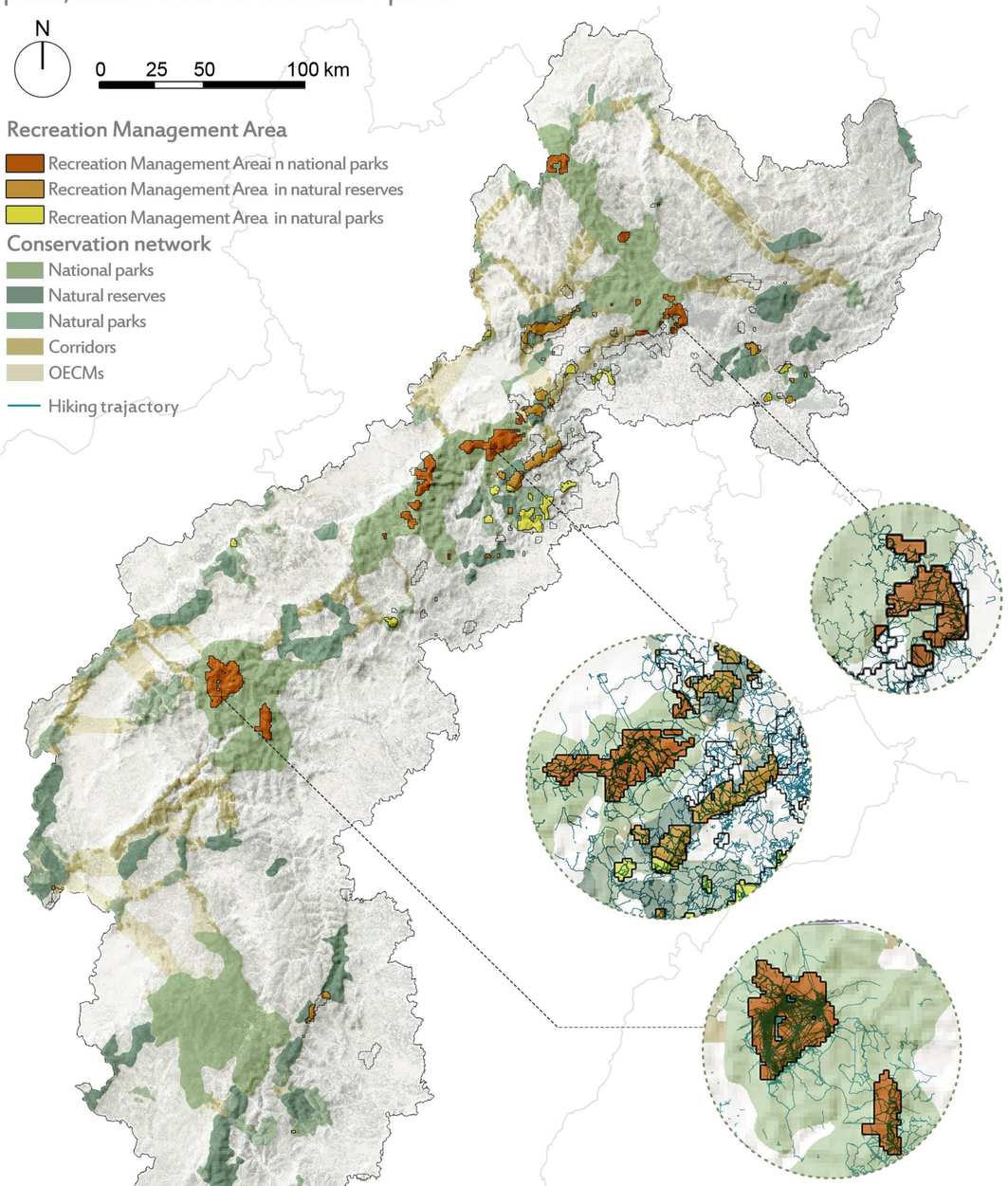
By implementing these strategies, sustainable agricultural production can be effectively promoted, biodiversity can be protected, and the economic interests and social needs of farmers can be ensured.

STRATEGIES

Strategy4 Managing Recreation Activities to Reduce Human Impacts

Identifying The Recreation Management Areas

We identified the overlapping areas of recreation hotspots and conservation networks as recreation management areas. Recreation management areas are distributed in national parks, nature reserves and nature parks.

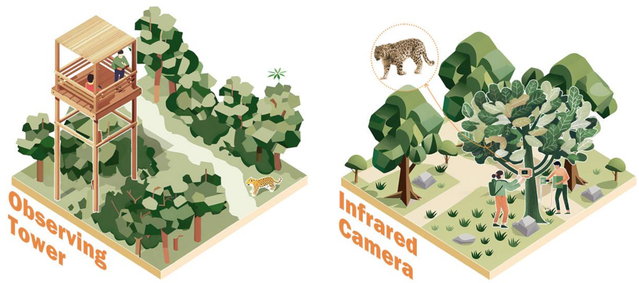


- **Eco-trail**

  Volunteers use local natural materials such as wood and stones to create handmade trails, along which there are explanatory signs, directional signs, and other markers.

- **Eco-observation**

  Diverse wildlife observation activities, including ascending to a leopard-watching tower for a distant view and setting up infrared cameras to observe leopard.



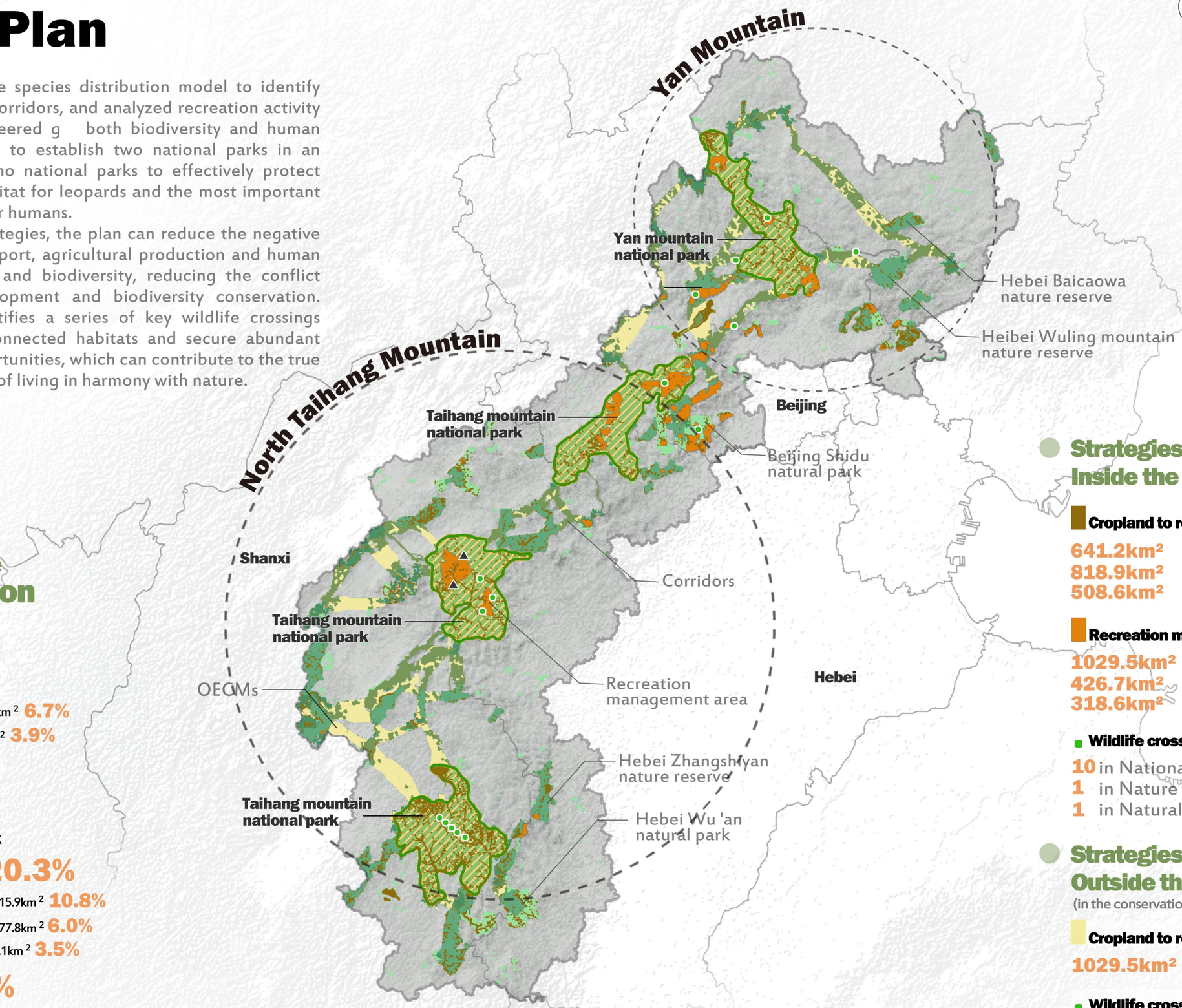
- **Eco-experience**

  There are some ecological buildings for scientific education in some villages. People can also enjoy eco-friendly picking.

Master Plan

The plan uses ensemble species distribution model to identify leopard's habitats and corridors, and analyzed recreation activity pattern through volunteered g both biodiversity and human well-being.We propose to establish two national parks in an area where there are no national parks to effectively protect the most important habitat for leopards and the most important recreational resource for humans.

Through a range of strategies, the plan can reduce the negative impacts of human transport, agricultural production and human recreation on habitats and biodiversity, reducing the conflict between human development and biodiversity conservation. Further, the plan identifies a series of key wildlife crossings to form functionally connected habitats and secure abundant natural recreation opportunities, which can contribute to the true realization of the vision of living in harmony with nature.



The coverage of conservation

from 10.6%

Protected areas

- Nature reserves, 7370.6km² 6.7%
- Natural parks, 4375.1km² 3.9%

to 28.3%

Conservation network

Protected areas 20.3%

- National parks, 12015.9km² 10.8%
- Nature reserves, 6677.8km² 6.0%
- Natural parks, 3908.1km² 3.5%

Corridors 5.1%

OECMs 2.9%

Strategies Inside the protected areas

Cropland to restore 1.7%

641.2km² in National parks
818.9km² in Nature reserves
508.6km² in Natural parks

Recreation management areas 1.6%

1029.5km² in National parks
426.7km² in Nature reserves
318.6km² in Natural parks

Wildlife crossings 12

10 in National parks
1 in Nature reserves
1 in Natural parks

Strategies Outside the protected areas

(in the conservation network)

Cropland to recover 2.9%

1029.5km² in OECMs

Wildlife crossings 3

3 in Corridors