# Integrating Biodiversity Conservation into Municipal and County-Level Territorial Spatial Master Planning: Technical Approach and Practice

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**Abstract.** Integrating biodiversity conservation into territorial spatial planning is both a strategic requirement of the global conservation agenda and an intrinsic component of China's ecological civilization agenda. Municipal and county-level territorial spatial master planning is the most important level at which biodiversity conservation is translated into spatial governance. This paper analyzes biodiversity conservation needs at the municipal and county level, develops a working framework for introducing and strengthening biodiversity conservation throughout the planning process, and proposes a technical pathway of "constructing a whole-territory conservation spatial network—defining hierarchical conservation-oriented spatial governance—proposing restoration measures for important habitats." Taking Yunlong County, Yunnan Province, as a practical case, the paper explores specific application scenarios. It concludes that this technical pathway must be further improved through accumulated empirical evidence from multiple regions, and that future work should strengthen biodiversity monitoring and spatial database construction, unify planning technical standards, and promote coordinated management across ecological regions.

Keywords: biodiversity conservation; municipal and county-level territorial spatial master planning; technical approach; practice; Yunlong.

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## 1 Background and Significance of Integrating Biodiversity Conservation into Municipal and County-Level Territorial Spatial Master Planning

Biodiversity is vital to maintaining ecosystem stability and balance and is the foundation of human survival and development [1]. At the fifteenth meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD-COP15) in 2022, the Kunming-Montreal Global Biodiversity Framework (hereafter the "Kunming-Montreal Framework") was adopted. It set the landmark "30×30" spatial conservation target: by 2030, 30% of the planet's terrestrial, inland water, coastal and marine areas should be effectively conserved and managed. Expanding the area under effective conservation through integrated spatial conservation measures is the core means of achieving the "30×30" target.

Prioritizing ecological civilization is the core value underlying China's territorial spatial planning system [2-3]. Both the Kunming-Montreal Framework and other global biodiversity agendas, as well as China's national strategies such as the Opinions on Further Strengthening Biodiversity Conservation, emphasize the need to integrate biodiversity conservation into spatial planning (Table 1). China has established a terrestrial protected-area system covering about 18% of its land area, which plays an important role in protecting key ecosystems and protected species. Yet conservation gaps remain. Because of population density and economic development pressures, it will be difficult to create protected areas over very large additional areas in the future; strengthening in-situ biodiversity conservation outside formal protected areas is therefore equally important [9]. Territorial spatial planning can help realize the “30×30” target by building a more complete spatial network for biodiversity conservation and strengthening in-situ conservation measures across the entire territory outside protected areas.

Table 1 Requirements for integrating biodiversity conservation into spatial planning in global biodiversity conservation agendas and China’s national strategies

| **Document** | **Release date** | **Issuing body** | **Requirement for integrating biodiversity into territorial spatial planning** |
|---|---|---|---|
| China’s position paper for the United Nations Summit on Biodiversity, Building a Shared Future for All Life on Earth: China in Action | September 2020 | Ministry of Foreign Affairs; Ministry of Ecology and Environment | “Integrate biodiversity conservation into economic and social development plans, ecological protection and restoration plans, territorial spatial plans and related special plans” [4]. |
| Kunming Declaration of the High-Level Segment of the UN Biodiversity Conference 2020 (Part One) | October 2021 | Conference of the Parties to the Convention on Biological Diversity | “Strengthen and establish effective protected-area systems; adopt other effective area-based conservation measures and spatial planning tools; improve the effectiveness of regional conservation and management and expand conservation coverage globally, in order to protect species and genetic diversity and reduce or eliminate threats to biodiversity” [5]. |
| Kunming-Montreal Global Biodiversity Framework (GBF) | December 2022 | Conference of the Parties to the Convention on Biological Diversity | “Ensure that all areas are under participatory, integrated and biodiversity-inclusive spatial planning and/or effective management processes addressing land- and sea-use change” [6]. |
| Opinions on Further Strengthening Biodiversity Conservation | October 2021 | General Office of the CPC Central Committee; General Office of the State Council | “Integrate biodiversity conservation into medium- and long-term plans of all regions and relevant fields” and “continue to optimize the spatial pattern of biodiversity conservation” [7]. |
| China Biodiversity Conservation Strategy and Action Plan (2023-2030) | January 2024 | Ministry of Ecology and Environment | “Optimize the pattern of territorial spatial development and protection, and make biodiversity conservation an important component of territorial spatial planning” [8]. |

Within China's "five-level, three-type" territorial spatial planning system, municipal and county-level territorial spatial master plans constitute implementation-oriented local plans that organize territorial development and protection activities. They are responsible for safeguarding local ecological security baselines and for prioritizing the delineation of areas where development and construction are prohibited or restricted. They are therefore the key level for translating biodiversity conservation into spatial governance [10-11]. The Guidelines for Preparing Municipal Territorial Spatial Master Plans (Trial), issued by the Ministry of Natural Resources, and many provincial guidelines for municipal and county-level planning all stress the construction of important ecological barriers, corridors and networks, the formation of a continuous, complete and systematic ecological conservation pattern, and the maintenance of ecological security and biodiversity [12-14]. The "three zones and three lines" provide the foundation for building a spatial network for biodiversity conservation. Ecological conservation redlines already cover many endangered protected species and key habitats, but long-term and effective biodiversity conservation patterns still need to be constructed across the whole territory through master planning.

Before the reform of the territorial spatial planning system, some municipalities and counties prepared biodiversity conservation plans in accordance with the former Ministry of Construction's Notice on Strengthening Urban Biodiversity Conservation [15] and Measures for the Application and Evaluation of National Garden Cities [16]. These plans, however, often focused more on plants than animals, emphasized protection while lacking improvement measures, and stressed local areas rather than the whole territory [17]. In the current round of territorial spatial master planning, many municipalities and counties have responded to new biodiversity conservation requirements. For example, following the Guidelines for the Evaluation of Resource and Environmental Carrying Capacity and Territorial Spatial Development Suitability (Trial) [18], they have evaluated the importance of biodiversity maintenance functions. Yet they still lack whole-territory coordination of spatial elements for biodiversity conservation. Because of insufficient baseline data and supporting research, the habits, conservation requirements and spatial needs of key protected species are often not analyzed. As a result, territorial spatial planning has not fully enhanced the "well-being" of wildlife habitats or balanced ecological conservation with high-quality development. Against this background, this paper starts from the biodiversity conservation needs at the municipal and county-level master planning tier, explores the working framework and technical pathway for biodiversity conservation, and takes Yunlong County in Yunnan Province as an example to examine specific application scenarios.

## 2 Biodiversity Conservation Needs and Working Framework at the Municipal and County-Level Territorial Spatial Master Planning Tier

### 2.1 Biodiversity conservation needs at the municipal and county-level planning tier

From a planning perspective, urban and rural spaces can protect and enhance biodiversity through two main pathways: optimizing the pattern and quality of ecological land, and reducing disturbances from human activities [19]. Master planning is a macro-strategic level of planning that coordinates the total allocation of spatial resources and structural layouts. At this level, biodiversity conservation requires more than coordinating the delineation of the three zones and three lines. It also requires stronger analysis of a whole-territory species conservation spatial system [20, 21], the construction of a whole-territory multi-habitat conservation network [22-24], and habitat conservation measures with differentiated governance gradients based on the importance of conservation value [25]. Effective allocation of spatial resources and rational use control are needed to coordinate species habitats with human activities. Specifically, this includes the following:

(1) Delineating spatial bottom lines: rationally allocating “rights” over land-space resources between human activities and biological habitats, and ensuring, as far as possible, the proportion of land-space resources whose primary ecosystem-service function is biodiversity conservation.
(2) Identifying important habitats: according to the behavioral and ecological traits of target protected species, identifying important natural and near-natural habitat patches that are irreplaceable for biodiversity conservation, and designating them as priority conservation spaces.
(3) Constructing a whole-territory network: connecting natural, near-natural and semi-natural patches of different levels and sizes through corridors and “stepping stones” along major natural boundary zones, forming a networked and multi-gradient conservation spatial system. Human activities should be appropriately separated to reduce disturbance to major natural habitat areas and to support species survival, migration and evolution [17].

**2.2 Working framework for biodiversity conservation at the municipal and county-level planning tier**

Based on these conservation needs, the core tasks for integrating biodiversity conservation into municipal and county-level territorial spatial master planning can be summarized as constructing a whole-territory conservation network, defining hierarchical conservation-oriented spatial governance, and proposing restoration measures for important habitats. These tasks should be linked with Local Biodiversity Strategy and Action Plans (LBSAPs) prepared by ecology and environment departments, as well as with protected-area boundaries and conservation-restoration requirements managed by different departments. Among the basic work and planning contents for municipal territorial spatial master plans [7], the “dual evaluations,” overall spatial pattern, bottom-line constraints, urban functions, infrastructure, and remediation and restoration are closely related to biodiversity conservation. Figure 1 presents the working framework for introducing and strengthening biodiversity conservation in each stage of plan preparation.
(1) “Dual evaluations”: based on an analysis of biodiversity resources and spatial distributions at the ecosystem, species and genetic levels, identify important and extremely important areas for biodiversity conservation. These should serve as key references for delineating the “three zones and three lines” and optimizing the territorial spatial pattern.
(2) Overall spatial pattern: identify conservation gaps, construct a conservation spatial network, coordinate conservation elements of “mountains, waters, forests, farmland, lakes and grasslands,” and incorporate the habitat conservation network into the overall pattern of territorial development and protection.
(3) Bottom-line constraints: optimize ecological conservation redlines according to the importance of conservation areas, identify potential OECMs (other effective area-based conservation measures) outside protected areas, and reinforce ecological security barriers.
(4) Urban functions: optimize the spatial layout of towns and villages in accordance with biodiversity conservation spatial governance requirements, and realize the coupling and coordination of urban spatial layouts with ecological network patterns.
(5) Infrastructure: strengthen biodiversity-oriented environmental impact assessment for infrastructure construction and optimize infrastructure layouts.
(6) Remediation and restoration: in response to biodiversity loss and habitat degradation, clarify the objectives, key areas and major projects for biodiversity conservation and restoration, and propose restoration measures for important habitats.

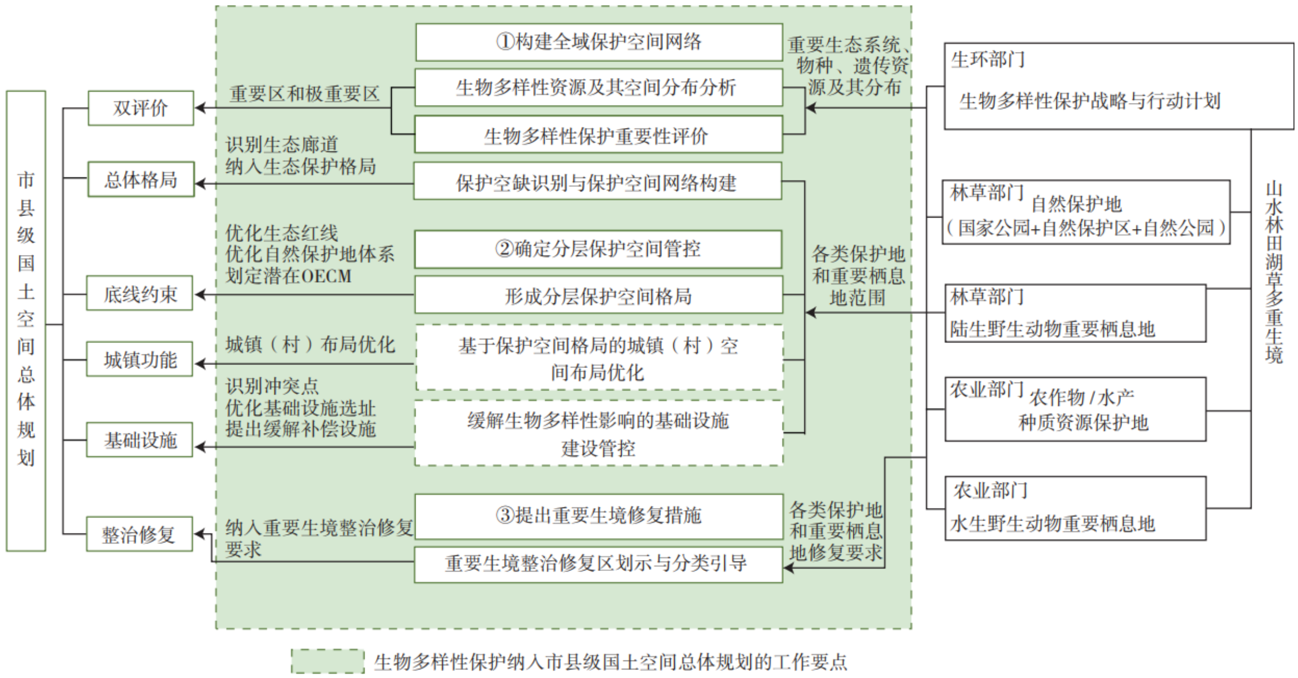


Figure 1 Framework for integrating biodiversity conservation into municipal and county-level territorial spatial master planning

## 3 Technical Pathway for Integrating Biodiversity Conservation into Municipal and County-Level Territorial Spatial Master Planning

### 3.1 Assessing resource status and constructing a whole-territory conservation network

#### 3.1.1 Analysis of biodiversity resources and their spatial distribution

A scientific biodiversity assessment system based on the current distribution of biodiversity resources is useful for quantifying conservation value. Because systematic and comprehensive biodiversity surveys are labor- and time-intensive, existing biodiversity data should first be assembled. Sources may include, but are not limited to, monitoring and survey data on animal and plant taxa, records, species lists, field guides, papers and books from local ecology and environment authorities and other sectoral departments, universities and research institutes, NGOs, citizen science activities, as well as species data from professional ecological databases. When time and funding permit, larger ecological patches may be selected for supplementary field surveys of species diversity, with reference to technical rules for biodiversity survey and assessment issued by the Ministry of Ecology and Environment. Based on the geospatial information in available materials, distribution maps of biodiversity resources by taxonomic group should be prepared.

#### 3.1.2 Evaluation of the importance of biodiversity conservation

The current Guidelines for the Evaluation of Resource and Environmental Carrying Capacity and Territorial Spatial Development Suitability (Trial) and Guidelines for Delineating Ecological Conservation Redlines set out relatively clear requirements for evaluating the importance of biodiversity conservation at the ecosystem level, but they pay insufficient attention to local habitat quality factors. Based on related studies, additional indicators are recommended for habitat quality evaluation, including surface-type factors (land-use type), ecological factors (vegetation cover and distance to water sources), and anthropogenic influence factors (distance to roads) [26-30].

In addition to the ecosystem level, species- and genetic-level biodiversity assessments should also be considered. Identifying key conservation targets is the first step in species-level assessment. In priority areas for biodiversity conservation, key targets can be selected according to protection status (Class I or II nationally protected animals, species listed in IUCN and CITES appendices), specificity (whether they are nationally or regionally endemic), ecological function in the ecosystem (whether they are umbrella species), and influence and public recognition (whether they are flagship species) [31-32]. Outside biodiversity conservation priority areas, key targets may be selected by considering the representativeness of local habitat types and the conservation, rarity or endangered status of species. In areas with distinctive biodiversity culture, local cultural factors may also be taken into account. Once conservation targets are determined, known species occurrence points can be used in species distribution models (SDMs), such as MaxEnt, GARP and Bioclim, to simulate and predict potentially suitable habitats [33-34].

At the genetic-resource level, the main natural distribution areas of important wild germplasm resources, such as crops, aquatic products and livestock, can be identified as areas of extreme importance for biodiversity maintenance [35]. Overall, important ecosystems and key habitats for species are the critical spatial carriers of biodiversity conservation. The genetic-resource level is usually combined with the ecosystem or species level and need not serve as an independent basis for evaluation.

**3.1.3 Identifying conservation gaps and constructing a conservation spatial network**

Key conservation areas can be identified by simulating suitable habitats for key protected species [36]. By overlaying these results with evaluations of conservation importance at the ecosystem and genetic-resource levels, existing protected areas and land cover, areas with conservation value that remain outside existing protection can be identified as conservation gaps.

Based on key conservation areas obtained from simulation and evaluation, the MSPA method can be used to identify core landscape structural components with the best ecological functions from the perspective of landscape pattern. Landscape connectivity indices can then determine patches suitable as ecological sources [37-38]. The minimum cumulative resistance model, circuit theory and related methods can be used to construct resistance surfaces and simulate ecological corridors [39-42]. Ecological nodes can be extracted from intersections of ecological corridors, intersections between ecological corridors and water systems, and key turning points of long-distance corridors [43]. A biodiversity conservation spatial network is then constructed, which can promote species exchange and migration and enhance ecosystem connectivity and stability [44].

**3.2 Defining conservation-oriented spatial governance requirements**

**3.2.1 Forming a hierarchical conservation spatial pattern**

Based on the identification and delineation of ecological sources, corridors and nodes, and in connection with the "three zones and three lines," planning zones and use-control requirements in territorial spatial planning, the biodiversity conservation spatial network should be refined and embedded in various territorial spatial zones. This produces an amended and optimized hierarchical conservation spatial pattern of "natural protected areas + ecological conservation redlines + OECMs + structural ecological corridors + key ecological patches."

Areas of extremely high biodiversity conservation importance that also represent conservation gaps should be managed in accordance with protected-area management requirements. Based on the results of biodiversity conservation importance evaluation and ecological source identification, the ecological conservation redline scheme defined in territorial spatial planning should be implemented, refined and verified. Land inside and outside protected areas that is identified through importance evaluation as having conservation functions should be regarded as a "conservation-compatible" continuum. Outside protected areas, hierarchical and gradient governance requirements should be proposed according to conservation importance, thereby facilitating the implementation of OECMs. Important conservation spaces inside and outside protected areas that are currently fragmented should be spatially connected through structural ecological corridors and key ecological patches, improving protected-area connectivity and the conservation network.

#### 3.2.2 Optimizing town and village spatial layouts based on biodiversity conservation requirements

Conservation-compatible land use should be incorporated into town and village spatial layout planning, with attention to industrial positioning, population size and construction-development needs in different zones, including ecological spaces inside and outside protected areas, agricultural spaces and urban spaces. For villages adjacent to protected areas, special attention should be paid to the impact of human-wildlife conflict on residents' livelihoods and to transforming the value of conservation-based ecological products, thereby promoting coordination between biodiversity conservation objectives and the production and living functions of towns and villages.

#### 3.2.3 Controlling infrastructure construction to mitigate impacts on biodiversity

In addition to the strict control required for ecological conservation redlines and natural protected areas, spatial governance should be strengthened in important wildlife habitats, migratory bird flyways, important distribution areas of fish and aquatic germplasm resources, and important distribution areas of rare and endangered plants. Spatial conflicts between important habitats and major infrastructure projects, such as roads, wind power and photovoltaic facilities, should be identified; infrastructure sites should be adjusted; and mitigation and compensation facilities should be proposed.

### 3.3 Proposing restoration measures for important habitats

According to the type and degree of degradation of damaged habitats, zones for remediation and restoration of important habitats should be delineated. Differentiated restoration requirements for forest, river, grassland, wetland and other ecosystems can be proposed according to ecosystem differences [45-46], guiding the subsequent identification of biodiversity conservation and restoration project lists in special plans for territorial ecological restoration.

## 4 Practical Exploration of Integrating Biodiversity Conservation into Territorial Spatial Planning in Yunlong County

Yunlong County is located in the northwest of Dali Bai Autonomous Prefecture, Yunnan Province. It lies at the southern end of the Mountains of Southwest China, one of the world's 36 biodiversity hotspots, and within the Yunling Mountains of the Southern Hengduan Mountains, one of China's 32 terrestrial biodiversity conservation priority regions. The county covers 4,400.95 km², and mountains account for 90% of its area [47]. Yunlong contains multiple habitat types, including forests, wetlands, farmland and grasslands. It has rich species diversity and many rare and endangered species; it is the southernmost distribution area of the Yunnan snub-nosed monkey and the northernmost distribution area of the western black crested gibbon. In recent years, Yunlong has been designated as an ecological demonstration county in western Yunnan and a key biodiversity conservation area in Dali Prefecture. It has initially established a natural protected-area system, but fragmented protected areas have not yet been connected with whole-territory spatial planning. Against the backdrop of a new round of urban-rural development and rural revitalization, agricultural and pastoral development may disturb the conservation of key species such as the Yunnan snub-nosed monkey, creating pressure to balance development and conservation.

Given its rich biodiversity resources, extremely high conservation value and conservation pressures, Yunlong County is selected as a representative case to examine in depth the technical pathway and implementation of integrating biodiversity conservation into municipal and county-level territorial spatial master planning.

### 4.1 Constructing a whole-territory biodiversity conservation spatial network based on multi-species suitability evaluation

Historical data and more than 3,000 infrared camera records were compiled to organize Yunlong County's animal and plant resource data, together with lists of key protected plants and protected animals and plants. Because historical biodiversity survey records are concentrated in natural protected areas, the maximum entropy model, MaxEnt, was selected to assess potential suitable habitats. MaxEnt can effectively predict species distribution even with relatively few occurrence points [48] and is suitable for habitat suitability simulation in areas where biodiversity data are incomplete [36, 49].

In areas where the Yunnan snub-nosed monkey serves as a flagship species, single-species suitability evaluation is a commonly used method for regional conservation planning and protected-area delineation [50-51]. Considering Yunlong's large elevation differences and diverse habitats across the county, this study adopted multi-species suitability evaluation. Based on species protection level, ecological function, population status in Yunlong County and known occurrence data, 14 target species were selected: Yunnan snub-nosed monkey, Asian black bear, leopard cat, rhesus macaque, Assam macaque, stump-tailed macaque, black muntjac, Himalayan red panda, yellow-throated marten, black-necklaced long-tailed pheasant, Temminck's tragopan, silver pheasant, Lady Amherst's pheasant and red-spotted newt (Figure 2). All 14 species are Class I or II nationally protected animals, and their habitats cover all elevation gradients and habitat types in the county. Four types of environmental variables—climate, topography, vegetation and water bodies, and anthropogenic influence—were selected to simulate each species' suitable distribution space and to conduct overlay analysis. Compared with single-species suitability evaluation, multi-species suitability evaluation increased the effectiveness of target-species habitat coverage by 29.16% [52]. Using species distribution suitability as the basis for evaluating biodiversity conservation importance, areas of medium and high suitability were identified as key areas for biodiversity conservation (Figure 3).

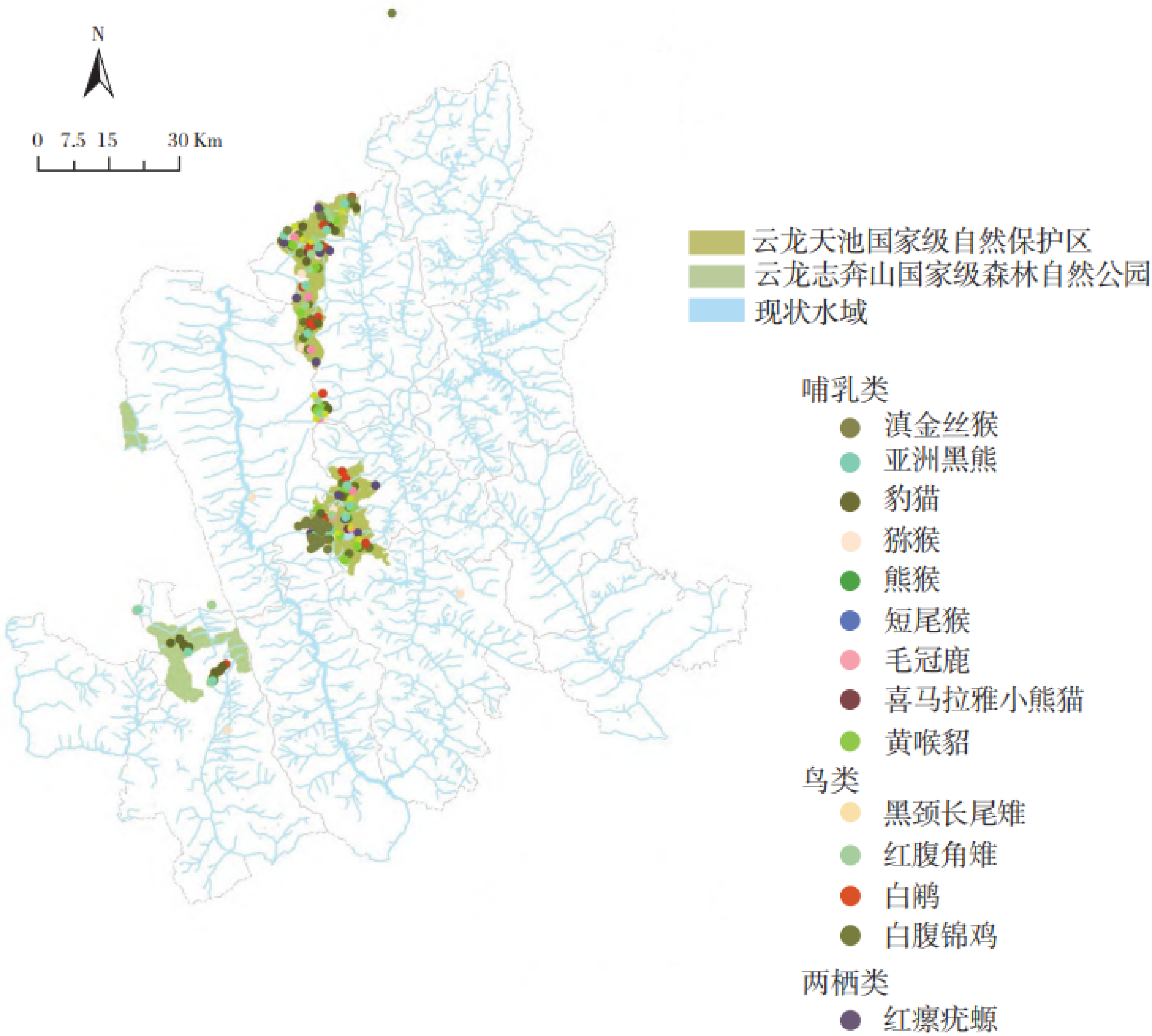


Figure 2 Distribution points of target species in Yunlong County

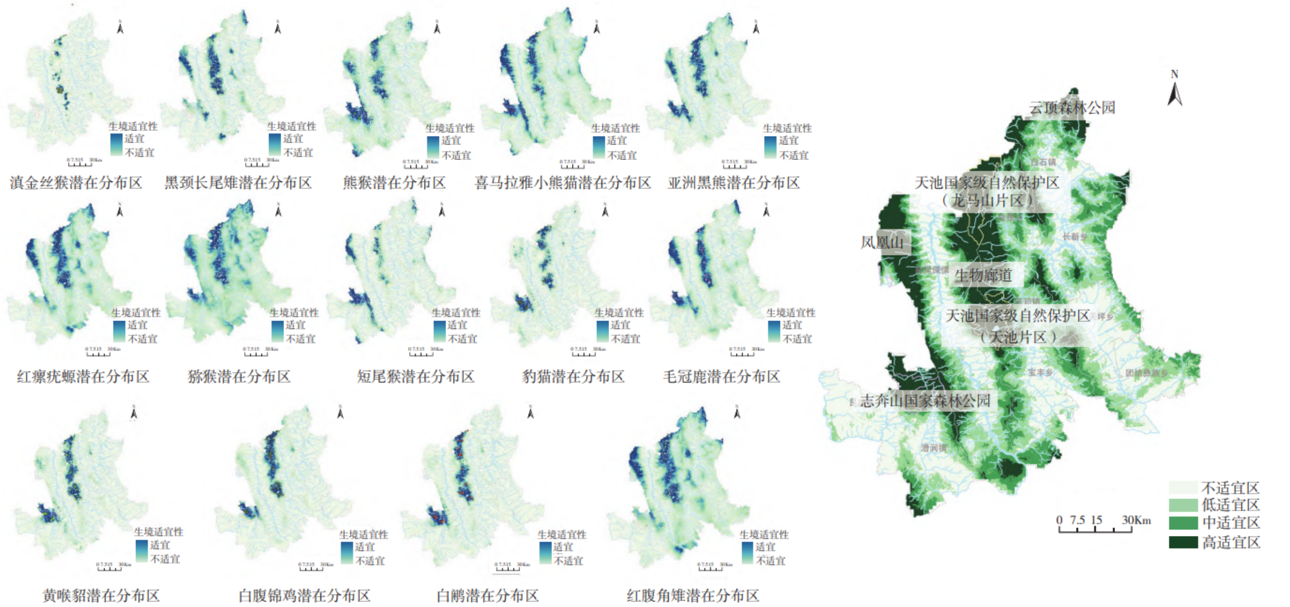


Figure 3 Simulated suitable distribution areas for individual target species (left) and multi-species distribution suitability evaluation results (right)

Key biodiversity conservation areas were compared with pre-planning natural protected-area boundaries and ecological conservation redlines to identify conservation gaps in existing protected areas (Figure 4). Areas of high conservation importance that were not yet covered were recommended for inclusion in natural protected areas.

The key biodiversity conservation areas were identified as ecological sources. A resistance surface was constructed using the minimum-cost path method, ecological corridors were identified, and a biodiversity conservation spatial network was built (Figure 5). This network fills corridor gaps between the Longma Mountain and Tianchi sections of Yunlong Tianchi National Nature Reserve, as well as conservation gaps in Fenghuang Mountain, Zhiben Mountain and Yunding Forest Park. It strengthens the spatial boundaries of ecological nodes and helps build a more complete biodiversity conservation spatial network.

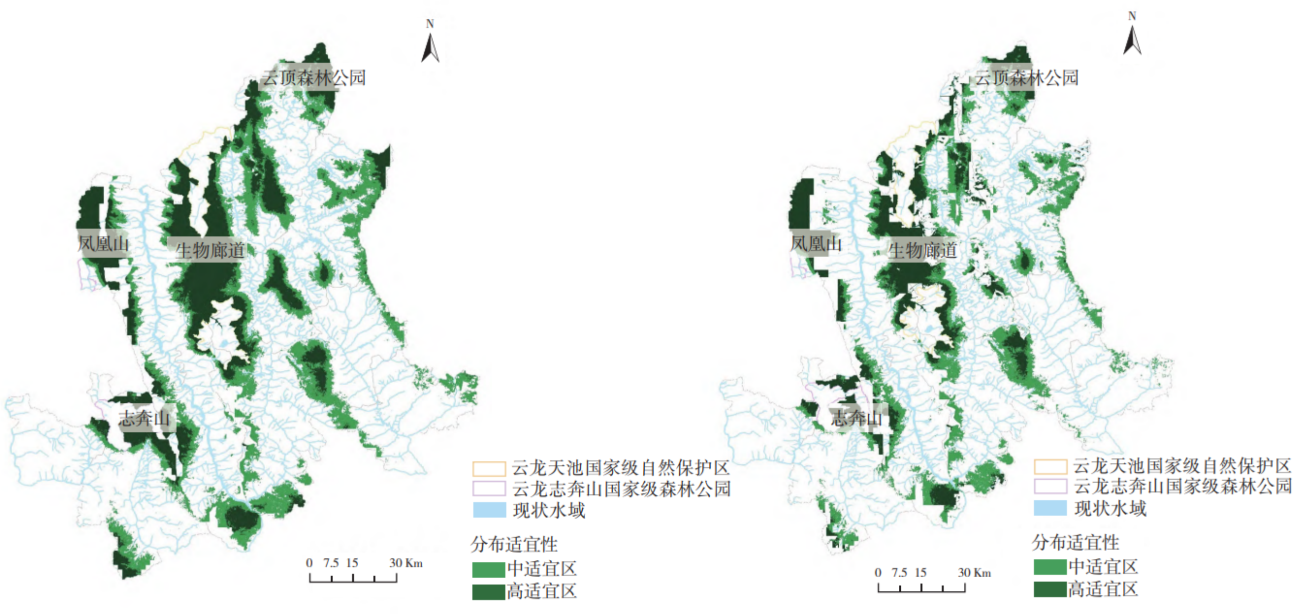


Figure 4 Conservation gaps in natural protected areas (left) and ecological conservation redlines (right)

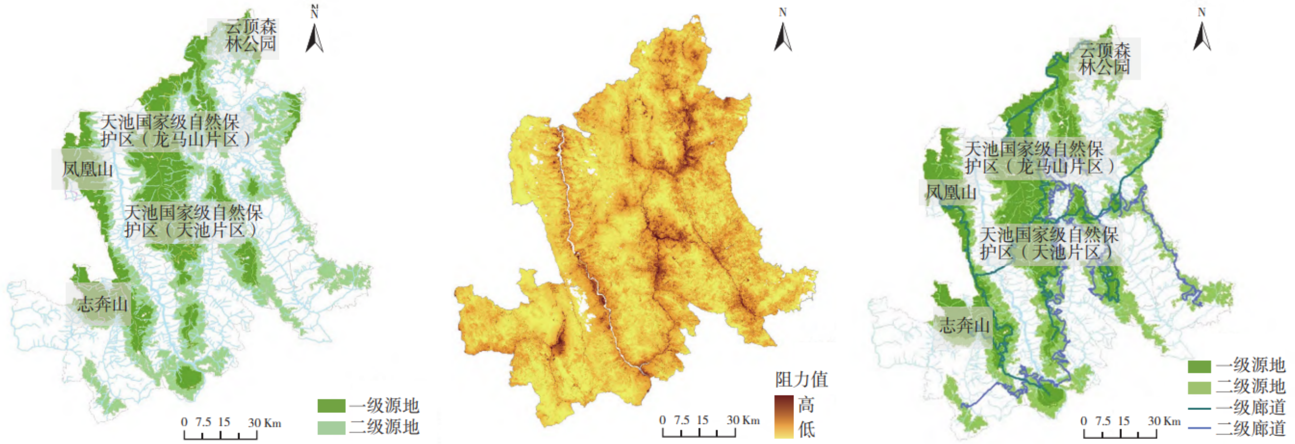


Figure 5 Ecological source areas (left), resistance surface (middle) and conservation spatial network (right)

**4.2 Multi-level spatial governance for biodiversity conservation based on a "conservation-compatible" continuum**

According to the importance of biodiversity conservation, a "conservation-compatible" continuum was constructed. It includes natural protected areas, non-protected areas within ecological conservation redlines, other highly suitable areas, and adjacent towns and villages. Whole-territory, multi-level spatial governance for biodiversity conservation was then implemented as follows:

(1) Refining and verifying the ecological conservation redline scheme and ecological spatial pattern identified in territorial spatial planning: in the current round of territorial spatial planning, the ecological conservation redlines were optimized in coordination with scientifically evaluated key biodiversity conservation areas. In line with the requirement that ecological conservation redlines remain generally stable while allowing local fine-tuning, conservation-gap areas that met the criteria for inclusion—such as Fenghuang Mountain and Zhiben Mountain—were incorporated into the redline, totaling about 80 $hm^2$. At the same time, areas that met the criteria for exclusion, such as sites for near-term provincial key projects, were removed from the redline, totaling about 156 $hm^2$. This achieved coordinated optimization of conservation space and development space.

In addition, ecological sources oriented toward biodiversity conservation were incorporated into ecological control zones within the territorial spatial land- and sea-use planning zoning system. This filled conservation gaps in corridors between the two sections of the Tianchi Reserve, as well as Fenghuang Mountain, Zhiben Mountain and Yunding Forest Park. Spatial governance of ecological spaces in ecological control zones was strengthened to reduce disturbance from human activities to biodiversity.

(2) Delineating county-level biodiversity conservation priority areas: according to ecological source and conservation-gap identification results, eight biodiversity conservation priority areas were delineated, including Longma Mountain, Tianchi, Fenghuang Mountain and Zhiben Mountain (Figure 6). The construction of OECMs, such as the Wubaoshan corridor forest between the two sections of the Tianchi Reserve, was promoted. Conservation-compatible livelihood activities, including organic, ecological and sustainable agricultural production, were proposed to protect biodiversity while also accommodating residents' production and living functions.

(3) Concentric layout and classified governance of biodiversity-friendly villages: based on different types of ecological zoning, biodiversity-friendly village layouts were guided by category (Figure 7, Table 2).

(4) Proposing impact assessment requirements for siting green energy facilities: as a key county for green energy in Dali Prefecture, Yunlong faces risks that new energy infrastructure sites may affect biodiversity.

Therefore, the master plan proposed comprehensive assessment for the siting of large green energy facilities. Facilities should avoid important habitats such as Yunlong Tianchi National Nature Reserve and important ecological spaces such as corridors between the two sections of the Tianchi Reserve. When assessing potential biodiversity risks from infrastructure construction, attention should be paid to habitat damage and fragmentation, indirect impacts between ecosystems, and risks from invasive species. Where impacts on important conservation areas cannot be avoided, ecological compensation measures, such as habitat reconstruction and species translocation conservation, should be adopted.

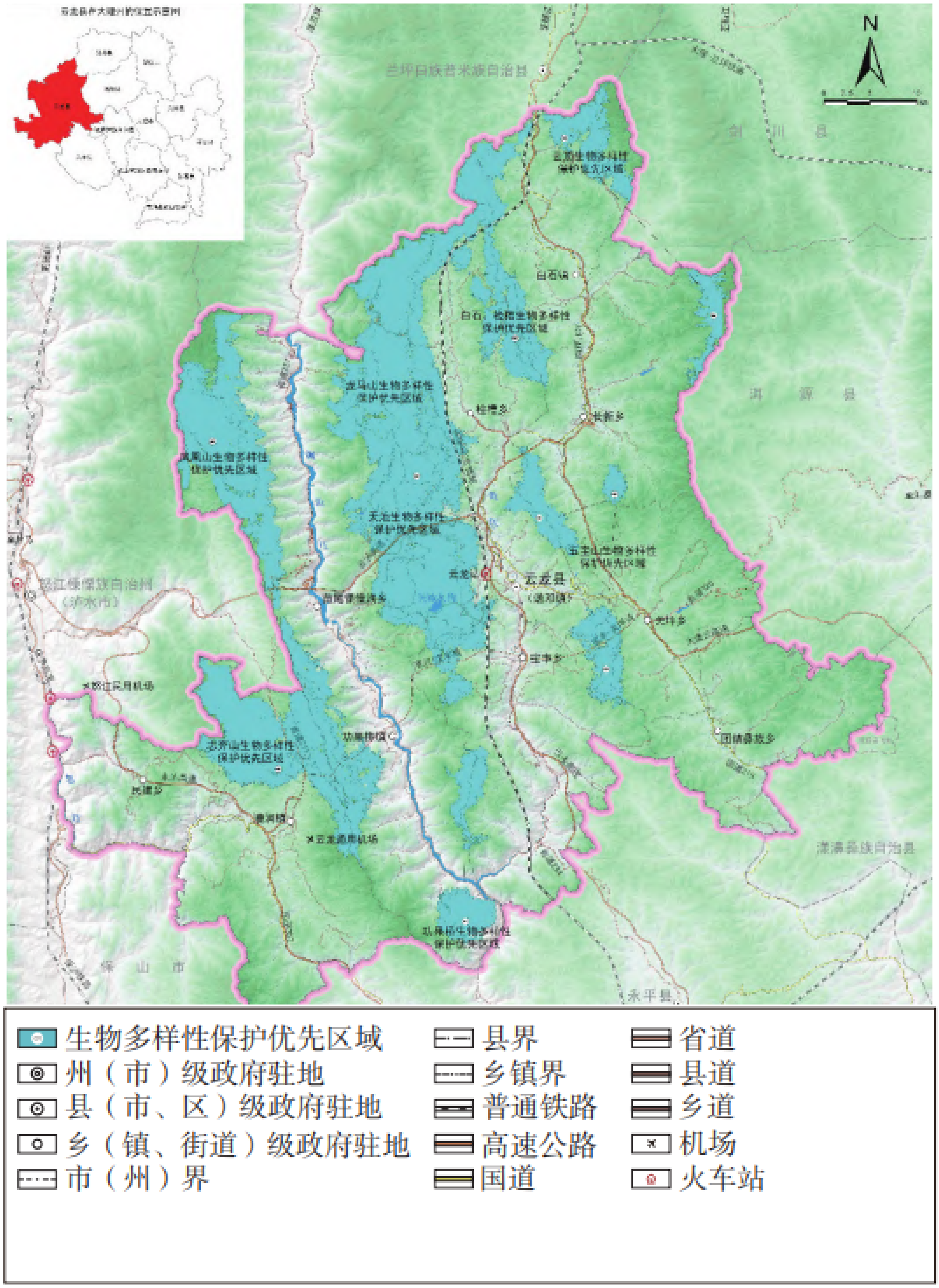


Figure 6 Biodiversity conservation priority areas in Yunlong County

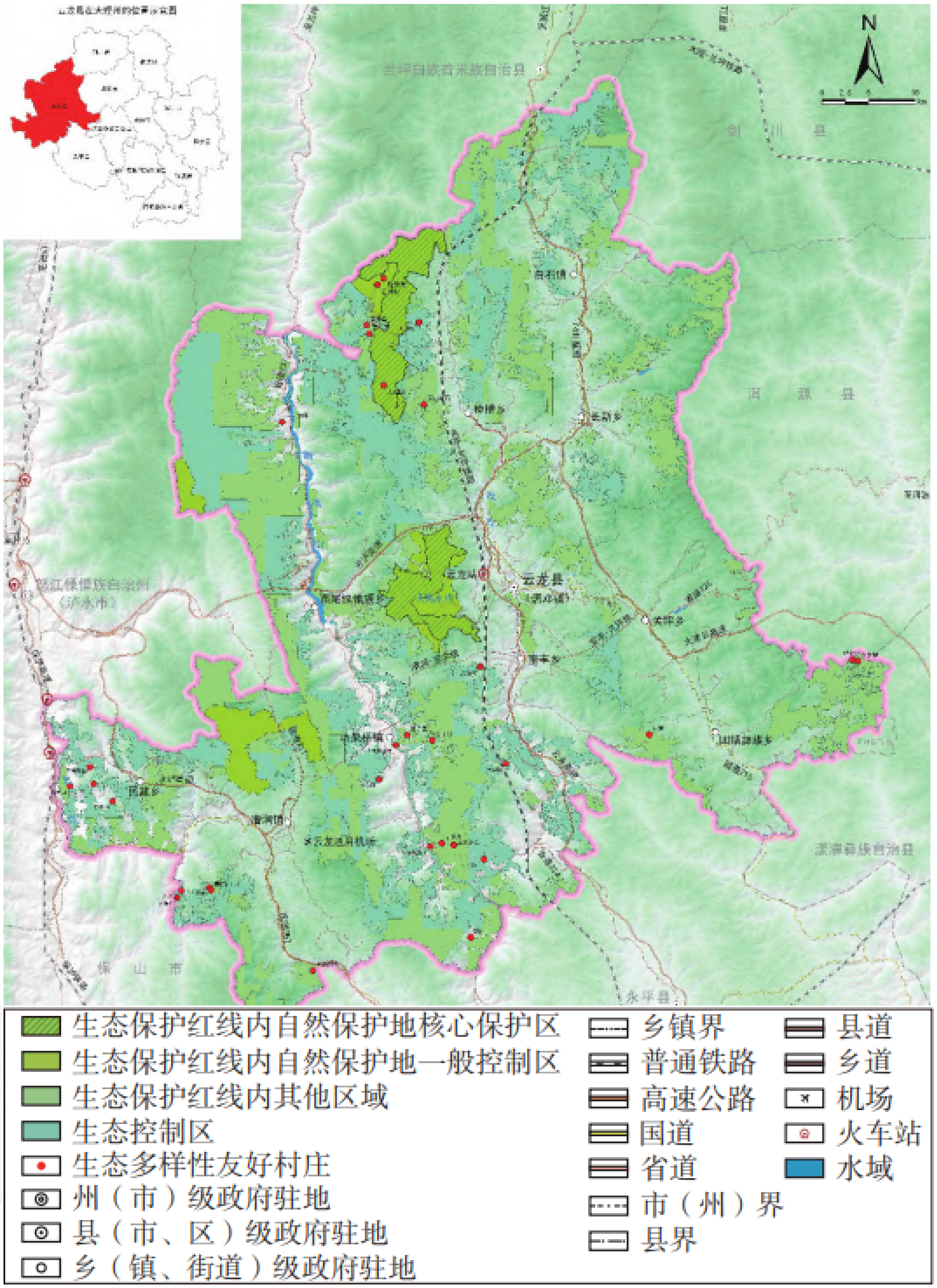


Figure 7 Layout of biodiversity-friendly villages

Table 2 Classification and governance of biodiversity-friendly villages

| Zonal category | Biodiversity-friendly villages | Corresponding measures |
|---|---|---|
| Core protection zones of natural protected areas within ecological conservation redlines | Dachuchang, Qinglang Village, Jianchao Township | Implement strict control and orderly relocation of existing villages. |

| | | |
|---|---|---|
| General control zones of natural protected areas within ecological conservation redlines | Lujiazhai and Laoxianchang, Shijing Village, Jianchao Township | Strictly control population size, intensity of industrial development, and the scope of infrastructure construction. |
| Other areas within ecological conservation redlines and ecological control zones | Maizidi in Shanxi Village, Shanglaoyazhuang in Minzhu Village, Yinshan in Gongguo Village, Gongguoqiao Town; Amiandiji in Daping Village and Huangzhushan in Lushan Village, Caojian Town; Yangmaodeng in Dagongchang Village and Liangshanpo, Qinglang Village, Jianchao Township; Wubanda and Shaoluozuo in Fengshou Village, Tuanjie Yi Township; Xiagangouping in Songping Village, Miaowei Lisu Township | Allow limited human activities. Subject to approval, economic activities, scientific monitoring and living-facility construction may be permitted where they do not affect biodiversity conservation; guide moderate development of biodiversity-friendly villages. |
| Biodiversity-friendly villages | Dayakou and Gantang in Lushan Village, Caojian Town; Xialao-yazhuang in Minzhu Village and Xiama-zhuangping in Shanxi Village, Gongguoqiao Town; Yuanxiaoqing in Zhuangping Village and Diaojiaolou in Nanxin Village, Baofeng Township; Sanjiaoshan in Chahua Village and Beiyinshan in Zhiga Village, Minjian Township | Actively build biodiversity-friendly demonstration villages; promote integrated agricultural-cultural-tourism development; coordinate land for integrated development of primary, secondary and tertiary rural industries; and guide villagers to develop distinctive, original ecological industries. |

**4.3 Guidance on multi-type ecosystem remediation and restoration measures for important habitat nodes**

For degraded vegetation communities within conservation spaces, measures such as artificial afforestation, mountain closure for forest regeneration, and conversion of farmland to forest and grassland should be adopted to restore vegetation cover. For example, afforestation restoration in the Wubaoshan ecological corridor can effectively protect the integrity of surrounding ecosystems and species diversity. For grassland ecological restoration, in townships where grassland degradation is relatively severe, such as Miaowei Lisu Township and Jianchao Town, projects should be implemented to convert farmland back to grassland, improve grasslands and restore damaged grassland vegetation. For wetland ecosystems, including river wetlands in the Lancang and Nujiang basins and lake wetlands such as Tianchi, measures such as pollution interception and treatment, ecological water replenishment and wetland restoration should be used to restore wetland biodiversity conservation functions. Agricultural non-point source pollution prevention and control should be strengthened, the habitat function of farmland should be enhanced, farmland shelterbelt networks should be established, and agroforestry systems should be formed to strengthen farmland's role as a connecting corridor in biodiversity-rich areas.

## 5 Conclusions and Prospects

The Kunming-Montreal Framework identifies spatial planning as a new action tool. Target 1 explicitly calls for "all areas" to be under participatory, integrated and biodiversity-inclusive spatial planning and/or other effective management processes addressing land- and sea-use change. As the chair of CBD-COP15 and a strong promoter of the Kunming-Montreal Framework, China urgently needs to strengthen biodiversity conservation in municipal and county-level territorial spatial arrangements and use control. This paper provides a preliminary exploration of the framework and technical pathway for integrating biodiversity into municipal and county-level territorial spatial master planning, and applies it in the planning practice of Yunlong County, Yunnan Province. Given differences across regions in biodiversity richness and in interactions between biodiversity and human settlements, the Yunlong case can only be regarded as a typical example of a conservation priority area. In the future, the technical methods should be continuously improved through empirical evidence from multiple regions. Through spatial transmission in special plans and detailed plans, and through further refinement of measures, source-area coordination inside and outside protected areas, corridor linkage and node correspondence should be strengthened, thereby enhancing the role of spatial planning in biodiversity conservation.

At present, the spatial-planning technical pathway for biodiversity conservation still faces deficiencies in baseline data, technical standards and cross-regional coordinated management. The following aspects urgently require further strengthening in order to better achieve integrated whole-territory coordination and layout for biodiversity conservation and to improve conservation effectiveness from a spatial perspective.

### 5.1 Strengthening biodiversity monitoring and spatial database construction

Current biodiversity monitoring generally focuses on natural protected areas and important wildlife habitats, while lacking full coverage across multi-gradient and multi-type habitats. Government statistics are often difficult to obtain. Fragmented surveys by different departments and research institutions usually lack top-level coordination in design; data types, formats and processing methods differ; and high-precision spatial information is often missing. As a result, data cannot sufficiently support the analysis required for spatial planning. Citizen-science data can provide a reference for biodiversity research, but data quality varies because professional review is often lacking and observations are constrained by the abilities and preferences of participants.

In the future, biodiversity monitoring networks should be optimized. Technologies such as remote sensing, video and sensor networks can support continuous observation of species distributions and habitat preferences. Some institutions have explored intelligent monitoring platforms; for example, a remote wildlife survey command system based on the Internet of Things [53] maps survey personnel, physical equipment and wildlife species information into an intelligent monitoring platform, enabling integrated sky-space-ground intelligent command and management of field surveys and information collection. Future work should strengthen alignment with territorial spatial planning needs, build monitoring networks linked with spatial information, and improve biodiversity information-sharing platforms.

### 5.2 Strengthening the unification of planning technical standards

At present, the selection of indicators in habitat suitability assessment models is somewhat subjective, including environmental variables in species distribution models and resistance-surface factors for ecological corridors. There is also no unified standard for the minimum area threshold of ecological sources, nor has the basis for source-area thresholds been standardized [45].

Future planning should strengthen the guiding role of basic research on ecological processes. For example, multi-source data integration and interdisciplinary research can be used to clarify the coupling mechanisms between landscape patterns and ecological processes, determine parameter assignments and threshold series in biodiversity assessment models, and effectively improve and optimize the identification methods for ecological sources and ecological corridors.

### 5.3 Strengthening coordinated management across ecological regions

Current planning practice usually uses administrative boundaries as its basis. This model offers certain advantages for data acquisition and helps local departments carry out conservation work. However, species movement is not constrained by administrative boundaries or geographical units. Therefore, the integrity among regions must be fully considered in conservation-oriented spatial governance [54], and biodiversity conservation planning across river basins, mountain regions and lake regions should be promoted.

In the future, full consideration should be given to the linkage of ecological functional areas among adjacent municipalities and counties. A functionally complete regional ecological network should be constructed to improve regional biodiversity as a whole.

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