国土空间规划体系中
控制性规划的生态拓展
——以北京市门头沟区为例

ECOLOGICAL EXTENSION OF REGULATORY PLANNING IN CHINA’S TERRITORIAL SPATIAL PLANNING SYSTEM: A CASE STUDY ON MENTOUGOU DISTRICT, BEIJING

1 引言

生态文明是后工业时代的社会文明形态[1-3]。中国于2018年组建了自然资源部，并赋予其履行国土空间用途管制与生态修复、负责建立空间规划体系并监督实施的职责。这一举措在顶层设计层面推动了城乡规划、土地利用规划、主体功能区规划等空间规划的融合，并逐步探索确立以生产空间、生活空间、生态空间为核心的国土空间规划体系并监督实施的职责。这一举措在顶层设计层面推动了城乡规划、土地利用规划、主体功能区规划等空间规划的融合，并逐步探索确立以生产空间、生活空间、生态空间为核心要素，以资源环境
1 Introduction

Ecological Civilization is the one born in the post-industrial age[1]~[3]. In 2018, China set up its new Ministry of Natural Resources, which is responsible for regulating the land use of national territory and ecological restoration, as well as establishing spatial planning systems and supervising related implementation. This overarching move not only facilitates the integration of urban-rural planning, land use planning, and core functional zone planning, but also helps build a holistic territorial spatial planning system that centers on production space, living environment, and ecosystems. Embracing the fundamental significance of the carrying capacity of resources and environment and the suitability of spatial development, this territorial spatial planning could be realized through the identification and delimitation of ecological, agricultural, and urban areas with integrated master plan, detailed plan, and special plan at national, provincial, city, county, and township levels[4][5]. This system would guarantee the full implementation of Ecological Civilization Construction.

However, China’s current territorial spatial planning system cannot perfectly meet the needs of Ecological Civilization Construction. To be specific, 1) a mechanism to guarantee the implementation of the overall protection and construction of ecological spaces and security patterns is not in place in conventional urban-rural and land use planning systems[6][7]; 2) an implementation mechanism to fulfill national- and provincial-level plans at city or county levels is lacking — there is barely any controlling criteria or regulation guidelines to enforce the ecological red lines or urban development boundaries, and, worse, planned green spaces are often diverted into other land use types[8], resulting in the fact that ecological construction has often to be secondary to urban development[9]; and 3) in terms of administrative regulations, the lack of legal and institutional basis and implementation tools leads to the failure to validate proper rigidity and elasticity[10], and administrative enforcement on urban construction focuses more on built-up areas, which undermines the coherence between societal goals and public interests[11].

To address these issues, this paper proposes a roadmap to integrate ecological spatial planning, construction, and regulation into detailed plans with a demonstrative case study on Mentougou District in Beijing. It is proved to be productive to optimize urban development under rigid demands on ecological protection and restoration in China and other developing countries that are faced with the conflicts between limited resources and increasing growth demands.
2 Literature Review

2.1 The Theory of Ecological Security Pattern

The theory of ecological security pattern was first proposed by Yu Kongjian in 1998 and initially applied in biological conservation\(^{[12]}\). Stemming from concepts of Landscape Ecology, this theory analyzes and simulates ecological processes in order to diagnose and identify key ecological patterns that impact the health and security of these processes\(^{[13]}\). Patterns at varied security levels can be identified in relation to the characteristics and dynamic changes of the ecological processes.

Based on two decades of research and practice, the ecological security pattern theory has developed mature methods. Mostly, ecological pattern analysis is built on diagnoses on geological disaster and soil erosion process, water-cycle process, biological process, and recreational process\(^{[14]}\). These corresponding sub-ecological security patterns then are overlapped under the maximum conservation principle to deduce an overall ecological security pattern, which is not a final ecological planning result but a huge database that includes different ecological processes and their security levels.

2.2 Regulatory Planning and Ecologically Regulatory Planning

Developed countries such as Germany and the U.S. take zoning as the means in regulatory planning\(^{[15]}\). In Germany, zoning, also known as construction planning (bebauungsplan), takes place in the forms of building window (baufenster) and regulation indicator set (kontrollleuchte gesetzt), which not only covers urban built-up areas and open and public spaces, but also employs a relatively complete ecological indicator system on soil, climate, organisms, water areas, cultural elements, etc.\(^{[16]}\) In the U.S., zoning refers to the control and management of private land development activities mainly in urban built-up areas\(^{[17]}\) under the police power, the means of which range from transfer of development rights, planned unit development to incentive zoning and bonus zoning, aiming at reconciling conservation and development and maximizing benefits of the society\(^{[18]}\).

China’s regulatory planning originated in the 1980s\(^{[19]}\) and grows into a system with its representative outcomes of regulatory detailed plans and statutory plans\(^{[20][21]}\), after learning from experienced countries such as the U.S. and Japan. To make up the neglect on ecology in the conventional spatial planning system and to overcome the disequilibrium during the passing-down process of multi-scale planning, China proposes new regulation approaches on ecological conservation and urban construction by focusing on non-construction lands and
活动管控措施。典型案例包括南京市江北新区生态廊道控制性详细规划[22]、西安市西咸国际文化教育园区控制性详细规划[23]、淮安市生态新城[23]及无锡太湖新城生态城[24]等，它们丰富了中国生态要素规划指标体系，并在一定程度上为管理平台建设、指标审批与实施等提供了有益借鉴[24]。然而，当前实践并未从根本上解决规划内容之间传导机制缺失的问题，指标体系的制定也多停留在上位规划拆解与经验判断层面，未发挥控制性规划的应有效力。

3 研究策略

本文以北京市门头沟区为研究区域，基于文献研究与实地调研，综合运用生态过程回溯、冲突分析等手段，对区域内的发展与保护及相关空间分布进行了分析，在动态的规划年限内明确国土空间用途并采取相应管制措施，从而落实国土空间规划体系变革背景下生态涵养区的建设与维护，推进控制性规划的生态拓展（图1）。

the development of low-carbon cities. Examples include the regulatory detailed plan for the Ecological Corridor in Jiangbei New District of Nanjing[22], the regulatory detailed plan for Xixian International Cultural and Educational Park of Xi’an[23], and the Eco-New City projects in Huai’an[24] and Wuxi[24]. These cases contribute to the enrichment of China’s planning indicator system on ecological elements, the establishment of management platforms, the consent and fulfillment of indicators, etc.[24] Nonetheless, such efforts do not completely address the absence of the fulfillment mechanism in the system, the poor guidance of indicators designed by decomposing higher-level plans and empirical determination. The role of regulatory planning has not been given full play to.

3 Research Strategies

Through literature review and field investigation on Mentougou District, Beijing, this paper analyzes the development and conservation strategies and spatial patterns of the study area with methods such as ecological process traceback and conflict analysis, plans the land use within staged time periods, and devises regulation measures accordingly, thus to facilitate the construction of ecological conservation areas and the ecological extension of regulatory planning under the reform of territorial spatial planning system (Fig. 1).
As a major ecological conservation area of the city, the study area consists of ecological conservation areas (454.71 km²), intensive built-up areas (52.74 km²), and limited construction areas (941.45 km²), accounting for 31.38%, 3.64%, and 64.98% of the total territory, respectively. Mentougou was once one of the important mines of smokeless coal in China. Excessive exploitation and disordered growth of other resource-intensive industries caused severe ecological damage and environmental pollution, particularly to the mountains. Climate change and the construction of reservoirs in the upper stream of the Yongding River resulted in discontinuous flows and the encroachment on water bodies, posing grave challenges to the construction of ecological conservation areas.

With respect to such a case background, the ecological extension of regulatory planning could be realized through two means: One is land use control, i.e., to identify the ecological control zones within the city’s jurisdiction in the study area supported by the ecological security pattern theory and conflict analyses; to consider the identified ecological control zones a basis for land use control and ecological restoration; and, to prepare zoning regulation guidelines and indicator systems via process traceback. The other is community control and management, i.e., to formulate community-scale control plans and strengthen the protection and restoration of natural ecosystems.
4 Fulfillment of Regulatory Plans

4.1 Roadmap of Zoning Regulation Framework

The study area includes nature reserves, forest parks, scenic areas, rivers, water source conservation areas, wetlands, geoparks, and other ecological sensitive areas. Focusing on ecological processes, ecological control zoning is to identify regional patterns that are composed of key spatial elements. Despite of the theoretical differences, ecological control zoning validates and complements the planning of ecological red lines, providing bases for the regulation over intensive built-up areas, limited built-up areas, and ecological conservation areas.

4.1.1 Ecological Control Zoning

Ecological control zoning is conducted by steps of 1) identifying primary ecological control zones; and 2) conflict recognition and analysis, and subdividing ecological sensitive areas, ecological buffer areas, ecological coordination areas, and construction areas through conflict analyses.

4.1.1.1 Identification of Primary Ecological Control Zones

The study area is faced with structural damage of water ecosystems, serious environmental damages of mountains, fragmented habitats, grave geological disasters and water-soil loss, and diminishing recreational resources. The planning of primary ecological control zones covers the security patterns on water ecosystem and biology; against geological disaster and water-soil loss; and on recreation and viewshe, which then, in accordance with the maximum conservation principle, could be overlapped to deduce the overall ecological security pattern for the study area\(^{[27]}\) (Fig. 2).

In the overall security pattern, ecological control zones are classified into ecological sensitive area (of low security level, 476.70 km\(^2\)), ecological buffer area (of medium security level, 740.25 km\(^2\)), ecological coordination area (of high security level, 203.14 km\(^2\)), and construction area (28.81 km\(^2\)), which account for 32.90%, 51.09%, 14.02%, and 1.99% of the study area, respectively.

(2) Conflict Recognition and Elimination

Ecological control zoning achieves dynamic balance by trading off with positive planning (i.e., urban-rural development planning): on one hand, it offers a constraint framework for the urban-rural development planning; on the other hand, it supports the decision-making on the justifiability of the urban-rural development planning via ecological compatibility analysis and the white list. When identifying the conflicting areas, the plans of ecological control zones and the urban-rural land use schemes are nondestructively overlapped.
乡用地规划图进行无损叠加，从而识别建设开发与多级生态保护冲突的用地构成与空间分布，并划定重度冲突、中度冲突、轻度冲突和无冲突区域。

表1: 研究区域内冲突区分布（单位: km²）
Table 1: The distribution of conflicting zones in the study area (km²)

| 行政单位          | 无冲突 | 轻度冲突 | 中度冲突 | 重度冲突 | 总计 |
|-------------------|--------|----------|----------|----------|------|
| 王平街道         | 0.40   | 0.20     | 1.34     | 1.07     | 3.01 |
| 大台街道         | 0.37   | 0.42     | 0.90     | 0.48     | 2.17 |
| 祥前镇           | 0.38   | 1.38     | 1.79     | 2.21     | 5.76 |
| 畅堂镇           | 1.73   | 1.44     | 2.39     | 3.63     | 9.19 |
| 清水镇           | 0.72   | 1.55     | 1.80     | 2.22     | 6.29 |
| 妙峰山镇         | 0.37   | 2.08     | 2.93     | 1.66     | 7.04 |
| 永定镇           | 6.48   | 2.50     | 9.07     | 6.20     | 24.25 |
| 卢庄镇           | 2.17   | 3.19     | 3.91     | 0.18     | 9.45 |
| 潭柘寺镇         | 0.39   | 4.25     | 3.08     | 0.91     | 8.63 |
| 龙泉镇           | 3.60   | 5.65     | 10.05    | 3.09     | 22.39 |
| 总计             | 16.61  | 22.66    | 37.26    | 21.65    | 98.18 |

随后的兼容性分析与白名单制定以适宜性理论为基础，结合研究区域内生态过程与建设用地特征构建生态—建设兼容性矩阵（表1），作为兼容性分析的基础[28][29]。其中，建设用地属性的具体分类方面依据现状与规划用地性质分布并参考《城市用地分类与规划建设用地标准GB 50137-2011》，将部分相近用地类型合并、简化（表2, 3）；利用兼容性矩阵可以识别真正的冲突区，并将兼容性用地②划入适宜建设区。适宜建设区与可建区不同，可建区是基于生态过程健康与安全分析划定的可以进行开发建设活动的区域；而适宜建设区的划定相对

在ArcMap中以识别土地利用和空间布局开发与多级生态保护之间的冲突。相应地，定义了严重冲突、中等冲突、轻微冲突和无冲突区域。

兼容性用地指生态过程与当前土地利用方式相适应的地区，比如水库与大部分生态过程兼容。

兼容性土地②指的是生态过程和土地利用模式相互适应的地区，例如水库与大部分生态过程兼容。
狭义，取决于特定时期的城乡发展规划与土地利用方式。需要注意的是，一旦土地利用方式发生变化，则必须重新进行生态兼容性分析。

研究确定冲突区兼容性用地面积87.66 km²，其中，重度冲突区18.72 km²，多分布在门头沟新城③东南部及清水镇镇区一带，主要由城镇建设用地与低安全水平的雨洪格局、水源保护格局构成；中度冲突区29.67 km²，集中分布于新城沿永定河两岸处，主要由城镇建设用地和中安全水平的地下水保护格局构成；轻度冲突区22.66 km²，分散于东辛

### Table 2: A demonstration of compatibility matrix (I)

| 安全水平 | 生态过程 | 城市建设用地 |
| --- | --- | --- |
| Security level | Ecological process | Urban construction land |
| 低安全水平 | Geological disaster and water-soil loss process | 1 | 1 | 1 | 1 | 1 | 1 |
| Low security level | Water-cycle process | 1 | 1 | 1 | 1 | 1 | 0 |
| 中安全水平 | Biological process | 1 | 1 | 1 | 1 | 1 | 0 |
| Medium security level | Recreational process | 1 | 1 | 1 | 1 | 1 | 0 |
| 高安全水平 | Geological disaster and water-soil loss process | 1 | 1 | 1 | 1 | 1 | 1 |
| High security level | Water-cycle process | 1 | 1 | 1 | 1 | 1 | 0 |
| 生物过程 | Biological process | 1 | 1 | 1 | 1 | 1 | 0 |
| 游憩过程 | Recreational process | 1 | 1 | 1 | 1 | 1 | 0 |

### 注释
1表示二者不兼容；0表示兼容，但需要根据生态指标进行约束与管控。

1 means incompatible; 0 means compatible, but should be controlled according to ecological indicators.

③ “新城”即门头沟新城，简称“门城”，是《北京城市总体规划》(2004-2020) 确定的11个新城之一。

Mentougou New Town is one of the 11 new towns established by Beijing General Urban Plan 2004-2020.
房街道、军庄镇及潭柘寺镇等地，主要由城镇建设用地和高安全水平的地下水保护格局、地质灾害与水土流失安全格局构成；无冲突区面积16.61\(\text{km}^2\)（表4）。

冲突区非兼容性用地（即真实冲突区）面积10.52\(\text{km}^2\)，其中，重度冲突区2.94\(\text{km}^2\)，碎片状分布于永定镇、城子街道、大峪街道、清水镇和斋堂镇等地，主要由交通设施用地与低安全水平的生物格局、水源保护格局构成；中度冲突区7.59\(\text{km}^2\)，集中分布在潭柘寺镇东部和永定镇中部等地，主要由城镇建设用地和中安全水平的地质灾害与水土流失格局构成。

### 表3: 兼容性矩阵部分示意二

| 安全水平 | 生态过程 | 镇、乡、村庄建设用地 | 其他建设用地 |
|-----------|---------|---------------------|-------------|
|           |         | 村庄建设用地 | 镇建设用地 | 水库 |
|           |         | Construction land for village | Construction land for town | Reservoir |
| 低安全水平 | Geological disaster and water-soil loss process | 1 | 1 | 1 | 1 | 0 | 1 |
|           | Water-cyclone process | 1 | 1 | 1 | 0 | 1 | 0 |
|           | Biological process | 1 | 1 | 1 | 1 | 1 | 1 |
|           | Recreational process | 1 | 1 | 1 | 1 | 1 | 1 |
| 中安全水平 | Geological disaster and water-soil loss process | 1 | 1 | 1 | 1 | 0 | 1 |
|           | Water-cyclone process | 0 | 0 | 0 | 0 | 0 | 0 |
|           | Biological process | 1 | 1 | 1 | 0 | 0 | 0 |
|           | Recreational process | 1 | 1 | 1 | 0 | 0 | 0 |
| 高安全水平 | Geological disaster and water-soil loss process | 0 | 0 | 0 | 0 | 0 | 0 |
|           | Water-cyclone process | 0 | 0 | 0 | 0 | 0 | 0 |
|           | Biological process | 0 | 0 | 0 | 0 | 0 | 0 |
|           | Recreational process | 0 | 0 | 0 | 0 | 0 | 0 |

### 表4：生态－建设兼容性分析（\(\text{km}^2\)）

| 兼容性用地 | 非兼容用地 | 总计 |
|-------------|-------------|------|
| Compatible land | Incompatible land | Total |
| 无冲突 No conflict | 16.61 | 0.00 | 16.61 |
| 轻度冲突 Mild conflict | 22.66 | 0.00 | 22.66 |
| 中度冲突 Moderate conflict | 29.67 | 7.59 | 37.26 |
| 重度冲突 Severe conflict | 18.72 | 2.93 | 21.65 |
| 总计 Total | 87.66 | 10.52 | 98.18 |

注释

1表示二者不兼容；0表示兼容，但需要依据生态指标进行约束与管控。

NOTE

1 means incompatible; 0 means compatible, but should be controlled according to ecological indicators.
4.1.2 Regulation Zoning and Indicator System Design

Ecological control zoning provides a basis for and guarantees the management of ecological planning by formulating regulation guidelines and establishing indicator systems. This study proposes a “Guidelines + Indicators” regulation system by adopting spatial planning experience from China and abroad.

(1) Regulation Zoning

Regulation guidelines make compulsory control on all kinds of ecological conservation and construction activities in the study area, comprised of ecological control zones as entities where the regulation over ecological sensitive areas, ecological buffer areas, ecological coordination areas, and construction areas varies correspondingly. To ecological sensitive areas, the existing ecosystems and resource use patterns must be strictly protected and any forms of construction activities should be forbidden. To ecological buffer areas, ecological protection and restoration should be prioritized, while encouraging the transformation of industrial mining land into ecological land and facilitating the optimization of spatial pattern of urban-rural construction land. To ecological coordination areas, proper development and increase in urban-rural construction land should be allowed, which would
(2) Indicator System Design

The ecological regulation indicator system (Fig. 4) is designed through ecological process traceback. To be specific, multiple processes and the corresponding security patterns are identified in light of the social, natural, and cultural features of the study area, so as to identify the overall security pattern with gradients in security level; specific regulation indicators are selected in line with the interactions of different processes with human society; based on land use control, the ecological processes and their security levels in different control zones are identified through process traceback and corresponding regulation indicators are set up, so as to offer indicator sets for community control and management.

4.2 Community Control and Management

This study takes the coal goaf in north of Mentougou New Town as a demonstration of community control and management for three reasons: 1) the area covers all levels of ecological control zones; 2) the variety of ecological processes included in the area is relatively rich; and 3) the issues of urban-rural development found in this area are typical to the city.

To some extent, community control and management is a sort of process planning, the core outcomes of which include ecology-construction database, zoning regulatory principles, and the indicator sets. The ecology-construction database will be updated
### 表5: 管控指标体系示意

| 管控内容 | 管控指标 | 指标类型 | 生态敏感区 | 生态缓冲区 | 生态协调区 | 指标来源 |
|---------|---------|----------|------------|------------|------------|----------|
|         |         |          | Ecological sensitive zone | Ecological buffer zone | Ecological coordination zone | Sources of indicator |
|         |         | Compulsory | Type II | Type II | Type II |         |
| 水生态过程 | 水质水环过程 | △ ▲ | ≥ 90% | ≥ 70% | ≥ 50% | 《地表水环境质量标准》(GB 3838-2002) Environmental Quality Standards of Surface Water Areas (GB 3838-2002) |
|         | 水体自然化率 | △ ▲ | ≥ 90% | ≥ 70% | ≥ 50% | 《城市园林绿化评价标准》(GB/T 50563-2010) Evaluation Criterion of Urban Landscapes (GB/T 50563-2010) |
|         | 河道绿化普及率 | △ | ≥ 90% | ≥ 70% | ≥ 50% | 《国家园林城市系列标准》Standard Series of National Garden Cities of China |
|         | 暴雨洪峰时设防标准 | △ | 50年 | 100年 | 200年 | 《防洪标准》(GB 50201-94) Flood Control Standards (GB 50201-94) |
| 农业活动 | 化肥施用强度 | ▲ | ≤150 kg/ha | ≤200 kg/ha | ≤250 kg/ha | 《生态县、生态市、生态省建设指标》Indicators of Ecological Construction at Town, City, and Province Levels |
|         | 灌溉用水有效利用系数 | ▲ | ≥ 0.65 | ≥ 0.6 | ≥ 0.55 | 《生态县、生态市、生态省建设指标》Indicators of Ecological Construction at Town, City, and Province Levels |

表注：

- ▲ 代表生态修复类控制指标，△ 代表建设开发类控制指标。

NOTE

- ▲ represents control indicators of ecological restoration; △ represents control indicators of urban construction.

统进行生态-建设数据库的更新与再分析，以对城乡建设发展实施动态监测与精细化管控；另一方面，参照国内外区划或法定图则相关研究，以街区为单位建立国土空间规划管控体系，以保障有关国土空间生态保护、修复及建设的宏观区域规划的精准实施。

4.2.1 管控指标制定

管控指标的制定应针对生态过程与建设开发特征，注重定量与定性、刚性与弹性相结合，以“分区+分类”的方式对不同生态控制分区内不同的生态过程进行管控。指标分为约束性指标与引导性指标，其中约束性指标包括建设活动管控指标和生态修复管控指标（表5）。

4.2.2 街区控制图则编制

本研究依据城乡用地规划数据确定新城北部采空区的范围，选取9个地块作为街区控制管理示范，以英文字母与阿拉伯数字对用地进行和迭代了动态ArcGIS数据，以对城乡建设发展实施动态监测与精细化管控。另一方面，参照国内外区划或法定图则相关研究，以街区为单位建立国土空间规划管控体系，以保障有关国土空间生态保护、修复及建设的宏观区域规划的精准实施。

4.2.1 Development of Regulation Indicators

The development of regulation indicators should be in line with the local characteristics of ecological processes and construction activities, and emphasize both quantitative and qualitative research and balance rigidity and elasticity. Different ecological processes in different ecological control zones should be regulated with varied methods, including compulsory indicators and guiding indicators, while the former including the ones on construction activities and ecological restoration (Table 5).

4.2.2 Preparation of Community Control Plans

This study defines the territory of the coal goaf based on relevant urban-rural land planning data, chooses nine plots as the demonstrative sites of community control and regulation, and names them with unique codes in letters and numbers. Such control plans include 1) construction and ecological protection
唯一编码。图则内容主要包括：1) 与生态控制分区对应的规划导则，以明确分区构成及建设与保护原则；2) 生态管控指标体系，以约束性指标和引导性指标对城乡建设用地和非建设用地分别作出空间管控要求（图5）。

随后，以街区控制图为空间参照，利用ArcMap进行生态过程回溯来确定街区内生态与建设属性，包括生态过程及其安全水平、建设用地位类型及其开发强度等，并从管控指标库中选取相应的指标与取值，从而对生态保护、修复及建设活动进行有效控制管理。

5 结论与展望

生态文明不是唯生态论，而是人类追求社会福利不断增长及社会永续发展而对自身行为作出的约束和管理。生态文明建设时代要求城乡地区生态修复、城乡建设用地规制管理及不同生态控制分区的规划管控导则，以及一个融合生态与农业空间的指导指标，以此形成综合管控指标库（图5）。

5 Conclusions and Prospects

Ecological Civilization does not equal to environmentalism. Instead, it stresses a moderate growth to ensure long-term social
市治的现代化体现包括规划的精准实施与精细管控，尤其是在生态环境面临建设开发压力与管控缺位的双重压力的当下。

在多数城市已经步入存量发展时代，以尺度的生态修复与城市修补已成为城市建设常态的背景下，本研究立足于国土空间规划体系重构的契机，提出控制性规划的生态拓展思路，并以北京市门头沟区为例论述分区用途管制、街区控制管理与地块建设维护的方法与途径，希望能为国土空间规划体系的完善提供有益探索。值得注意的是，在整个研究推进过程中也暴露出一些生态控制分区划定与管理方面的问题，未来应重点加强生态控制单元的理性划定以适应其城乡规划与生态属性，并引入成本—收益分析和多元利益主体博弈下的生态—建设权衡体系，以提高生态控制性规划落地实施的可操作性。

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