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# Spatial Correlation and Ecological Characteristics Analysis of Management Area for Biodiversity Conservation and Relevant Regionalization

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**Abstract:** Formulation of different ecological zone plans according to the corresponding protection targets and the necessity of proper conservation policy is one of the measures to achieve the goal of ecological conservation in China. In order to clarify the interrelation among key ecological zone plans, this paper carried out the research on spatial relation of priority areas of biodiversity conservation and three key ecological areas (key ecological function areas, key regions of ecological service function, national nature reserves) and the research on ecological conditions, based on multi-scale ecological spatial theme information, which incorporates elements like ecological quality and type, and by the aid of spatial information analysis and GIS modeling. The results showed a contrastively fine spatial consistency with 68.8% of priority areas of biodiversity conservation overlapping with three key ecological areas. Although the environment in priority areas of biodiversity conservation were in good conditions, protection pressure is also increasing, powerful supervision and protection should not be ignored. The environmental conditions in the overlapping areas, as a whole, were superior to those in the non-overlapping areas. Since two areas have different characteristics, targeted protection measures should be formulated based on this difference, which will be very important for biodiversity conservation in priority areas of biodiversity conservation.

**Keywords:** biodiversity conservation; ecological regionalization; ecological pressure; ecological service; spatial correlation analysis

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## 1 Introduction

China has always attached great importance to regionalization. According to specific protection targets and policies for the ecology, several planning projects have been implemented in recent years, including the ′Planning of the National Main Functional Areas′, ′The National Ecological Functional Regionalization′ (http://www.zhb.gov.cn/info/bgw/bgg/200808/t20080801_126867.htm) and ′Planning of the National Nature Reserves′. At the same time, those areas that require improvement in terms of management and supervision have been identified, including key ecological function areas, key regions of ecological service function, and national nature reserves (referred to the ′three key ecological areas′). In addition, conservation and wise management of biodiversity is critical for better livelihoods, especially in developing countries (Adenle, 2012). The ′China Na-

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tional Biodiversity Conservation Strategy and Action Plan′ was initiated and drafted by the Ministry of Environmental Protection of China (2011), which was responsible for the regionalization of 35 priority areas of biodiversity conservation (referred to the ′priority areas′).

Though different regionalizations have different management needs, the planning for the three key ecological areas and the priority areas must consider the biodiversity conservation functions of all areas. It is important to clarify the spatial correlation between the priority areas and three key ecological areas, their ecological backgrounds, and their planning protection targets. Determining such questions is significant for the justification of management policies and for the distribution and utilization of management resources.

With the distinctness of protection targets and the necessity for the formulation of protection policy being taken into consideration, various ecological function regions were regionalized and it was maintained that the areas in need of enhanced management and protection are at the core of environmental protection in China. Conducting research on the relationship between major ecological function areas plays an essential role in performing the function of ecological function regions more efficiently and in improving the environmental protection efficiency in ecological function regions.

Currently, it is lack of studies of the partition management mode in biological diversity. The researches of the conservation of biological diversity focused on the conservation of biodiversity, monitoring and evaluation methods and indicators system (David, 2003; Fisher and Christopher, 2007; Boutin *et al*., 2009; Lawrence and Turnhout, 2010; Li and Nigh, 2011; Laura, 2012). There were also some researches concerning the relationship between biological diversity and other factors, such as environmental factors, ecosystem structure, ecosystem functioning and ecosystem values (Swift *et al*., 2004; Bene and Do, 2008; Schneiders *et al*., 2012; Liu *et al*., 2012). Domestic researches mainly focused on the regionalization own characteristics including the main functional divisions or ecological function regionalization (The Group of ′The Research of the Relationship between Main Function Regionalization and Ecological Function Regionalization′, 2007), and were lack of the researches on the relationship between the main function regionalization, ecological function regionalization, and the national nature reserve regionalization (Yan and Yu, 2003; Ren, 2007; Ding, 2009; Cai *et al*., 2010).

This study conducted an analysis on the spatial correlation between the priority areas of biodiversity conservation and three key ecological areas, clarified the differences among the defined protection objectives, and investigated the relationship between the different environmental conditions among those protection areas. The aims of this study were to: 1) identify the differences between the management spaces of regionalization to provide a scientific basis for improving the efficiency of ecological management and for optimizing the management resources more rationally; 2) analyze the differences between the different protection targets among the regionalized spaces to provide a scientific basis for the implementation of classified guidance and to establish management policies based on the protection targets; and 3) define the ecological background of each protection area to provide basic data for drawing up relevant protection policies.

## 2 Materials and Methods

### 2.1 Study areas

The study areas of this paper could be classified into four classes, key ecological function areas in National Ecological Functional Regionalization, national nature reserves, and key regions of ecological service function areas in Planning of the National Main Functional Areas (three key ecological areas), priority areas of biodiversity conservation in China National Biodiversity Conservation Strategy and Action Plan (priority areas) (Fig. 1).

There are 50 key regions of ecological service function were set up depending on the significance of various ecological function regions for safeguarding the national ecological safety in National Ecological Functional Regionalization in 2008, occupying a total area of $2.224 \times 10^6$ km$^2$ (Table 1). Nature reserves are natural regions under particular protection by national laws and regulations. As of the end of 2008, the sum of national nature reserves totaled up to 303, occupying a total area of $9.120 \times 10^5$ km$^2$. In 2010, 25 key ecological function areas were set up in Planning of the National Main Functional Areas, occupying a total area of $2.698 \times 10^6$ km$^2$ based on the preconditions like ′ecosystem is a priority′, ′the allocated zones concern the ecological safety

throughout the nation or within a large area′. In order to effectively carry out the task of biodiversity conservation, China National Biodiversity Conservation Strategy and Action Plan was adopted in 2010 (effective from 2011 to 2030), in which 35 priority areas of biodiversity conservation were established, including 32 inland and aquatic areas with a total area of $2.322 \times 10^6$ km$^2$ and 3 oceanic and coastal areas.

## 2.2 Methods

To study spatial correlation and ecological characteristics of the priority areas and other key ecological areas, the three key ecological areas were selected to overlap separately with the priority areas in the map. Then, the priority areas were identified as overlapping and non-overlapping areas and conducted a comparative analysis based on ecological conditions and pressures of environmental protection in the overlapping and non-overlapping areas between the priority areas and three key ecological areas (Fig. 2).

## 2.3 Data and processing

In this paper, assessment includes two aspects of ecological status and ecological stress. So, two assessment indices were established to indicate ecological conditions, specifically ecosystem types and occupied proportion of ecosystem areas, and quality of environment on a county scale (Roy, 2009; Wei *et al*., 2010; Bai *et al*., 2011). In addition, six assessment indices were established to determine ecological pressure, which are population density, agricultural land use and its change in areas, land use in urban and rural construction and its change in areas, length of main road per unit area, coverage areas and damaging extent of acid rain, and water quality of main rivers. The comprehensive and specific determination of these assessment indices accurately re-

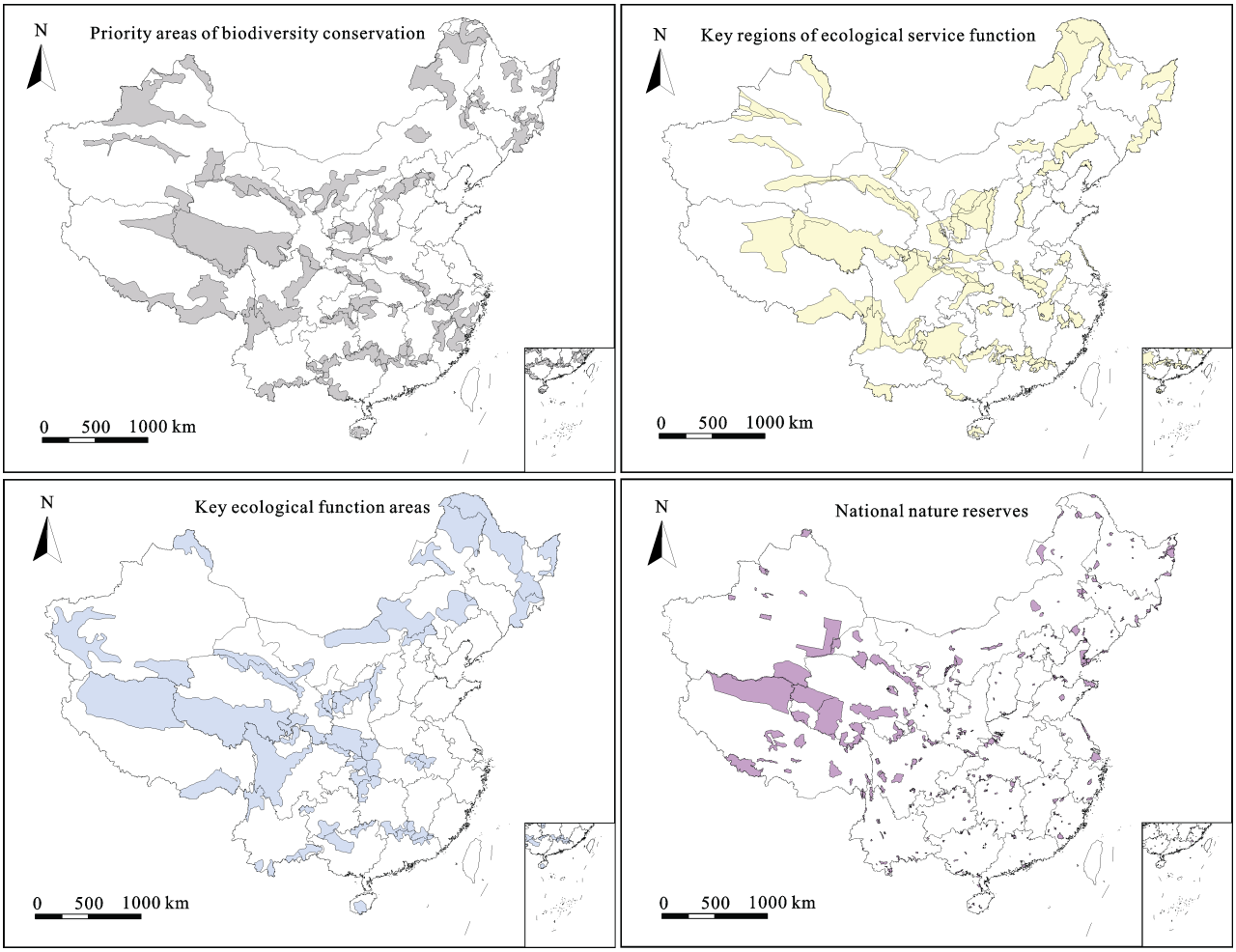


**Fig. 1** Distribution of four study areas in China

**Table 1** General conditions of biodiversity conservation priority areas and three key ecological areas

| Study area | Type | Number | Area ($10^4$ km$^2$) | Area (%) | Planning objective |
|---|---|---|---|---|---|
| Priority areas of biodiversity conservation | Terrestrial and aquatic biodiversity conservation | 32 | 232.20 | – | Protecting unique species and habitats and specific ecosystems in areas |
| | Marine and coastal biodiversity conservation | 3 | – | – | |
| Key ecological function areas | Biodiversity conservation | 7 | 91.40 | 33.90 | Protecting essential ecosystems (primitive forests, wetlands and plateau desert) and animal and plant resources |
| | Water conservation | 8 | 98.20 | 36.40 | Conserving and improving capability of water conservation in essential ecosystems |
| | Soil and water conservation | 4 | 23.40 | 8.70 | Conserving and improving soil and water conservation in Loess Plateau, Dabie Mountain, Karst Rocky Desertification Area and Three Gorges Reservoir Area |
| | Windbreak and sand fixation | 6 | 56.80 | 21.00 | Conserving and improving windbreak and sand fixation in midwestern Inner Mongolia and midwestern Xinjiang to prevent desertification |
| Key regions of ecological service function | Biodiversity conservation | 16 | 67.40 | 30.00 | Protecting primitive forest ecosystems such as Changbai Mountains, Hainan Island, Xishuangbanna and Hengduan Mountains; grassland ecosystems such as western Yili-Tianshan Mountain; wetland ecosystems like Sanjiang Plain, Liaohe River Delta and North Jiangsu tidal flat; and essential animal and plant resources and habitats in every region |
| | Water conservation | 17 | 85.40 | 38.10 | Protecting and improving water conservation in ecosystems such as forests, grasslands and wetlands |
| | Soil and water conservation | 4 | 27.90 | 12.40 | Conserving and improving local soil conservation |
| | Windbreak and sand fixation | 7 | 34.30 | 15.30 | Conserving and improving windbreak and sand fixation |
| | Regulation and storage of flood | 6 | 9.40 | 4.20 | Conserving and improving regulation and storage of floodwater in Dongting Lake, Poyang Lake and wetlands of Jingjiang River |
| National nature reserves | Conservation areas of wild plant | 15 | 0.88 | 1.04 | Protecting specific rare and endangered animals and plants in each area |
| | Conservation areas of wild animal | 75 | 21.80 | 25.86 | |
| | Conservation areas of forest ecology | 133 | 14.80 | 17.56 | Conserving specific ecosystems such as forests, wetlands, deserts, grasslands and oceans to preserve ecosystems integrity and maintain specific habitats of animal and plant |
| | Conservation areas of inland wetland | 28 | 19.60 | 23.25 | |
| | Conservation areas of desert ecology | 12 | 24.00 | 28.47 | |
| | Conservation areas of grasslands and meadows | 4 | 0.91 | 1.08 | |
| | Conservation areas of marine and coastal | 16 | 0.51 | 0.61 | |
| | Conservation areas of paleontological remains | 6 | 1.23 | 1.46 | Protecting geological relics and paleontological remains |

Note: '–' means no data

flected the ecological and environmental conditions. Assessment indices and data source are shown in Table 2.

## 3 Results and Analyses

### 3.1 Spatial consistency

A total of 68.8% of priority areas of biodiversity conservation ($1.599 \times 10^6$ km$^2$) overlapped with the three key ecological areas, which comprised 57.2% of the key ecological function areas, 50.2% of the key regions of ecological service function, and 69.1% of the national nature reserves (Fig. 3). There was a slight difference between the leading function defined for the non-overlapping areas and the biodiversity conservation function defined for the priority areas; nevertheless, most of the non-overlapping areas also possessed biodiversity conservation functions as the priority areas. Geographically, the overlapping regions between the priority areas and

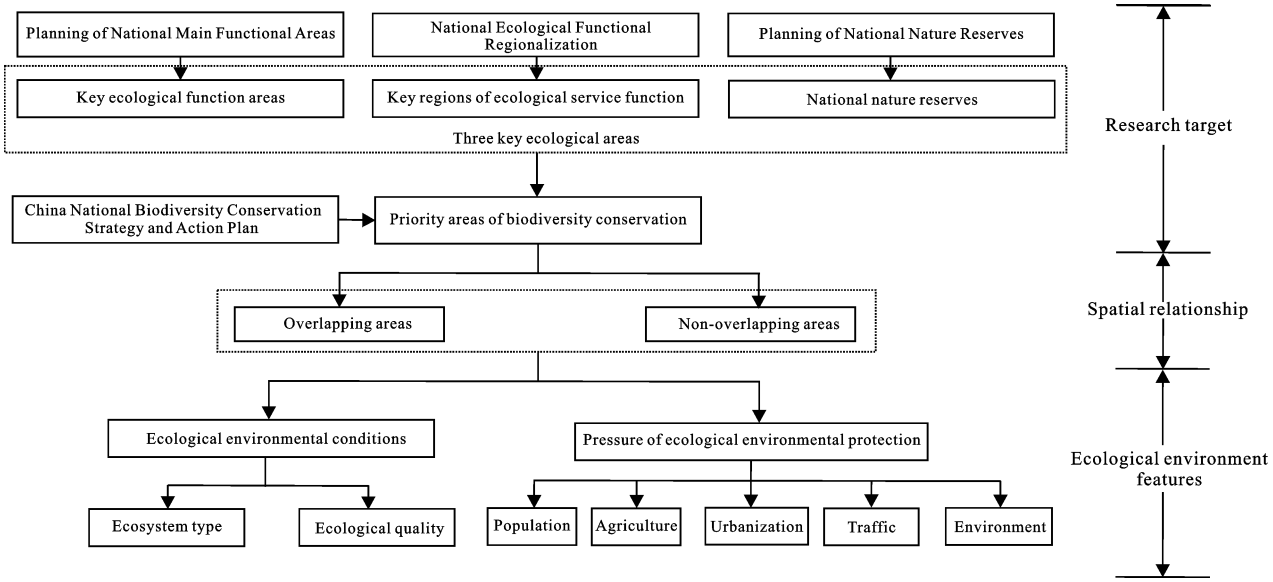


**Fig. 2** Framework of spatial correlation analysis between priority areas of biodiversity conservation and three key ecological areas

**Table 2** Selection of indices and data source

| Assessment content | Ecological condition | | Ecological pressure | | | | |
|---|---|---|---|---|---|---|---|
| | Ecosystem type | Ecological quality | Population | Agriculture | Urbanization | Traffic | Environment |
| Assessment indices | Area and proportion of all sorts of ecosystems | Quality of ecological at county level | Population density | Area of agricultural land and its change | Area of urban and rural construction land use and its change | Length of main roads per unit area | Area of acid rain and water quality of main rivers |
| Data source | Remote sensing interpretation data of ecosystem from Landsat 5 in 2007 | China Environmental Quality Report (Ministry of Environmental Protection of the People′ Republic of China, 2009) | Data of national population density distribution in 2000 (Jiang *et al*., 2004) | Remote sensing interpretation data of national land use from Landsat 5 in 2007 | Remote sensing interpretation data of national land use from Landsat 5 in 2007 | Data of national main roads from National Fundamental Geographic Database in 2004 | China Environmental Quality Report (Ministry of Environmental Protection of the People′ Republic of China, 2009) |

three key ecological areas mainly lay in the northeastern mountainous and plain regions, Inner Mongolia-Xinjiang Plateau desert region, cold regions of the Qinghai-Tibet Plateau, southwestern mountain gorge regions, central-southern mountain and hilly regions, and low mountain and hilly regions in South China. The non-overlapping regions mainly lay in the Loess Plateau, eastern part of the hilly and plain regions in East and Central China, and the eastern part of the Inner Mongolia-Xinjiang Plateau desert region.

### 3.2 Protection target and spatial characteristic

In the key ecological function areas, there are seven regions regarding the biodiversity conservation as the leading function, in which the overlapping areas occupied 37.7% of the biodiversity conservation area (Table 3). In addition, 68.3% of water conservation function areas, 15.7% of the soil and water conservation function areas, and 27.8% of the windbreak and sand fixation function areas overlapped within priority areas. These results demonstrate that the three main function areas play a key role to biodiversity conservation.

Sixteen biodiversity conservation areas within key regions of ecological service function overlapped with the priority areas, in which the overlapping regions occupied 63.5% of biodiversity conservation function area, 69.1% of the water conservation function areas, and 12.8% of the flood storage areas. The overlapping areas between the priority areas and the windbreak and sand fixation and soil function areas were smaller.

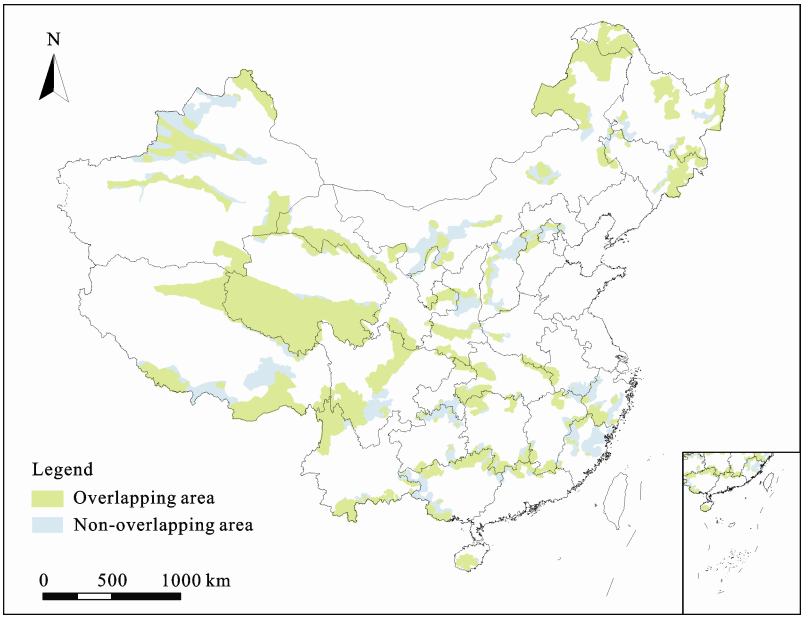


**Fig. 3** Distribution of overlapping and non-overlapping areas between the priority areas and three key ecological areas

More than 70% of the wildlife and nature ecosystem conservation areas within the national nature reserves overlapped with the priority areas, proportion of the geological and paleontological conservation areas that overlapped with the priority areas were less than 30%.

According to Table 4, there are six areas where no overlapping occurred between the key regions of ecological service function and the priority areas, which comprised three areas for the regulation and storage of floodwater, two conservation areas for water resource, and one windbreak and sand fixation area. Ninety areas showed no overlap between national nature reserves and the priority areas, and included 20 wildlife reserves, 61 natural ecosystem reserves, and other nine reserves. The reason that wildlife reserves and natural ecosystem reserves were not included in the priority areas possibly was that centralized and continuous areas of natural ecological conservation should be preferentially considered when allocating the priority areas (Table 4).

### 3.3 Ecological conditions and carrying pressure

Based on the spatial correlation between three key ecological areas and the priority areas, ecological conditions and its carrying pressure in the overlapping and non-overlapping areas were studied by comparative analysis.

#### *3.3.1 Ecological conditions*

Disruption of the ecosystems leads to degradation of ecosystem function, destruction of wildlife living environment and habitat pose main threat to the biodiversity conservation in China. Ecosystem with intact function and sound structure safeguards the biodiversity conservation. Currently within the priority areas, area of natural ecosystems, such as forest, grassland and wetland-claim accounts for over 75% (Table 5). Comparison with other areas, ecosystem types in the priority areas are more representative and unique, possesses special ecological functions and reasonable structure, providing integrative living environment and habitats for wild species. Given that fact, those areas stand out as the shelters for bountiful species and a whole raft of rare and endangered animals, showing evident regional representativeness and scientific research value.

Ecological quality is one of the key indices for regional ecological conditions and ecological service and will play a central role in biodiversity conservation if kept in ideal level. According to ′2008 Report on the State of Environment in China′, the quality levels considered ′moderate′, ′good′ or ′excellent′ account for nearly 90% of the priority areas, within which ′excellent′ and ′good′ sections take up over 50% (Fig. 4). This indicates that there is good ecological quality, low level of pollution and destruction of the environment in the priority areas, which could provide ideal environment for wildlife to survive and boost the biodiversity conservation.

**Table 3** Protection objectives and spatial features of overlapping range between three key ecological areas and priority areas of biodiversity conservation

| Three key ecological areas | Type of conservation area | Overlapping range | Protection target |
|---|---|---|---|
| Key ecological function areas | Biodiversity conservation | Seven areas with $3.45 \times 10^5$ km$^2$, 37.7% of biodiversity conservation areas | Essential ecosystems and essential resources of animal and plant such as primitive forests, primitive wetlands and plateau deserts |
| | Water conservation | Eight areas with $6.27 \times 10^6$ km$^2$, 63.8% of water conservation areas | Essential ecosystems such as forest, wetland, and grassland. Potentially, any destruction and degradation to these essential aquatic-ecosystems poses a massive threat on whole biodiversity conservation areas |
| | Windbreak and sand fixation | Six areas with $8.9 \times 10^4$ km$^2$, 15.7% of the windbreak and sand fixation areas | Functions of windbreak and sand fixation in midwestern Inner Mongolia and midwestern Xinjiang to prevent desertification, control sand sources and decrease ecological safety threat on midwestern regions |
| | Soil and water conservation | Four areas with $6.5 \times 10^4$ km$^2$, 27.8% of the soil and water areas | Functions of water and soil conservation in Loess Plateau, Dabie Mountain, Karst rocky desertification areas and three gorges reservoir areas to improve capability of water and soil conservation |
| Key regions of ecological service function | Biodiversity conservation | Sixteen regions with $4.28 \times 10^5$ km$^2$, 63.5% of the biodiversity conservation areas | Forest ecosystems in Changbai Mountains, Hainan Island, Xishuangbanna and Hengduan Mountains, grassland ecosystems in western Yili-Tianshan Mountain and Beiqiangtang Alpine desert, wetland ecosystems on Sanjiang Plain, Liaohe River Delta and North Jiangsu tidal flat, and crucial sources of animals, plants, and habitats in each area |
| | Water conservation | Fifteen areas with $5.9 \times 10^5$ km$^2$, 69.1% of water conservation areas Mountain, and Gannan possess key functions of biodiversity conservation | Water conservation function of ecosystems such as forest, grassland and wetland to improve water conservation and prevent ecological degradation. Ten areas, including Dabie Mountain and Qinba Mountain, have important biodiversity conservation function |
| | Windbreak and sand fixation and soil conservation | Ten areas with $1.47 \times 10^5$ km$^2$, 23.6% of windbreak and sand fixation and soil conservation areas | Two function areas that are water and soil conservation and windbreak and sand fixation, whose main protection targets are local water resource and vegetation on ground surface to improve windbreak, sand fixation, and soil conservation and prevent degradation of land and ecosystems |
| | Regulation and storage of floodwater | Three areas with $1.2 \times 10^4$ km$^2$, 12.8% of regulation and storage areas of floodwater | Functions of regulation and storage of floodwater in wetlands in Dongting Lake, Poyang Lake and Jingjiang section of Changjiang (Yangtze) River to improve regulation and storage of wetlands, conserve habitats of animals and plants in wetlands, and secure mechanism of flood prevention and ecosystem safety in lower reaches of a river. These three areas possess crucial functions of biodiversity conservation |
| National nature reserves | Natural ecosystem conservation | One hundred and thirty-one areas with $4.29 \times 10^5$ km$^2$, 71.8% of natural ecosystem conservation areas | Specific ecosystems like forest, wetlands, desert, grassland and marine environment to preserve ecosystem integrity, prevent ecosystems destruction, and maintain specific habitats of animals and plants |
| | Animal and plant protection | Seventy areas with $1.67 \times 10^5$ km$^2$, 73.5% of protection areas of animals and plants | Specific rare and endangered animals and plants in areas to maintain biodiversity |
| | Others | Seven regions with 5200 km$^2$, 28.9% of other areas | Geological relics and paleontological remnants |

Through comparing overlapping and non-overlapping areas, it is found that there is not much difference between the two areas in ecosystem structure, similar to the case in the priority areas (Table 5). During the course of delimiting the priority areas, the areas with diversified ecosystem types, strong ecological function, and abundant biological species resources are major parts of the priority areas. Living areas of endangered and threat-stricken biological species were also classified into the priority areas, and the environment in the latter areas may be inferior and under serious impact of environmental disruption. That may be the reason why the ecological quality is superior in overlapping areas to that in non-overlapping areas (Fig. 5). Due to aforementioned analysis, current state in overlapping areas should be sustained and steadiness of the ecosystem

**Table 4** Protection objects and spatial features of non-overlapping areas between three key ecological areas and priority areas of biodiversity conservation

| Three key ecological areas | Types of conservation areas | Number | Protection target |
|---|---|---|---|
| Key ecological function areas | – | – | – |
| Key regions of ecological service function | Regulation and storage of floodwater | 3 | Wetland ecosystems in riverside in Anhui Province, wetland ecosystems in middle and lower reaches of Huaihe River and in Songnen Plain, whose biodiversity conservation within wetland ecosystems is extremely important |
| | Water conservation | 2 | Forest ecosystems in upper reaches of Liaohe River and Zhujiang River source area, both of which possess essential biodiversity conservation functions |
| | Windbreak and sand fixation and soil conservation | 1 | Soil and vegetation in middle and lower reaches of Heihe River to prevent desertification and salinization, in which *Populous euphratica Oliv*, *Tamarix chinensis* and grassy marshland are common species |
| National nature reserves | Animal and plant protection | 20 | Rare and endangered wildlife resources, which are a part of biodiversity conservation areas |
| | Natural ecosystem conservation | 61 | Specific natural ecosystems which are part of biodiversity conservation |
| | Others | 9 | Geological and paleontological remains with little correlation to biodiversity conservation |

**Table 5** Structure of ecosystems in priority areas of biodiversity conservation

| Type of ecosystem | Priority areas | | Overlapping areas | | Non-overlapping areas | |
|---|---|---|---|---|---|---|
| | Area ($10^4$ km$^2$) | Percentage (%) | Area ($10^4$ km$^2$) | Percentage (%) | Area ($10^4$ km$^2$) | Percentage (%) |
| Forest | 83.20 | 35.8 | 55.96 | 34.3 | 27.24 | 38.7 |
| Grassland | 82.80 | 35.6 | 61.21 | 37.7 | 21.59 | 30.4 |
| Watershed and wetland | 11.30 | 4.9 | 8.02 | 6.1 | 3.26 | 5.9 |
| Farmland | 17.40 | 7.5 | 9.63 | 5.5 | 7.80 | 12.1 |
| Desert | 36.60 | 15.8 | 28.62 | 16.2 | 7.95 | 12.0 |
| Others | 1.05 | 0.4 | 0.52 | 0.3 | 0.53 | 0.8 |

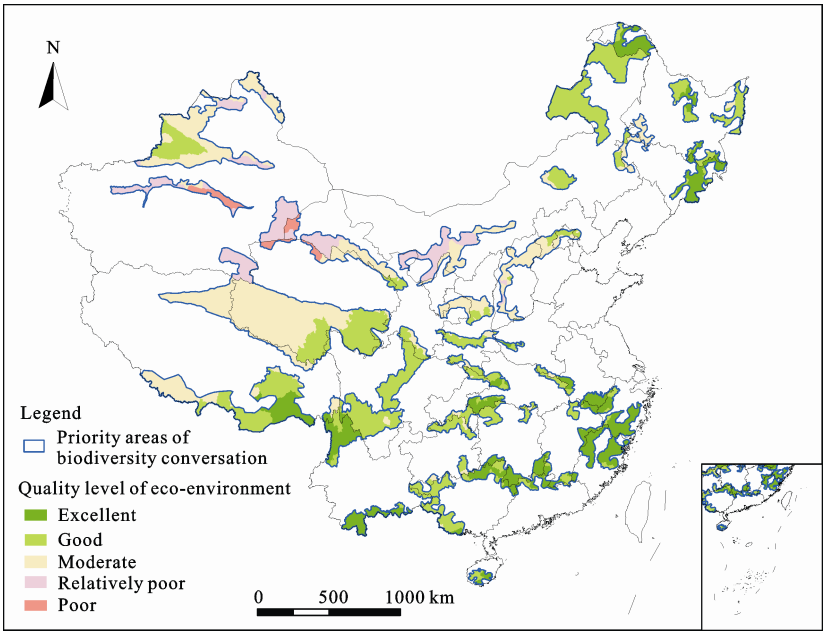


**Fig. 4** Quality level of eco-environment in priority areas of biodiversity conservation in China

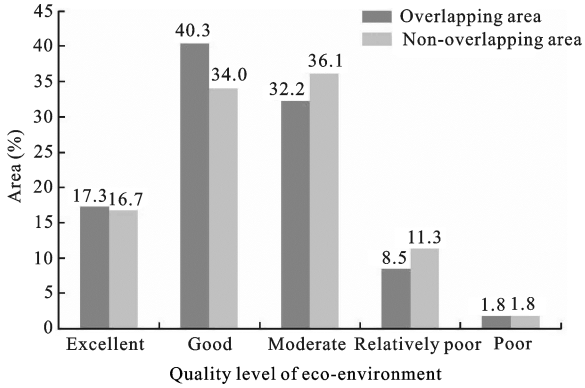


**Fig. 5** Comparison of ecological environment quality between overlapping and non-overlapping areas

and ecological quality should be kept. While in non-overlapping areas and especially the habitat for rare and endangered species, ecological environment management should be enhanced, living areas and habitats for wild species should be recovered and ecological quality should be improved.

### *3.3.2 Pressure of ecological protection*

Currently human activity should claim the main responsibility for causing destruction of the living environment of the species and loss of the habitats. Agricultural production, urban construction, traffic booming and environmental pollution are the major factors by which human exert pressure directly on the environment. Population density in the priority area is around 37/km$^2$, identical to 1/4 of the national average, showing a low level of population density. Percentage of agricultural and urban land is fairly low (Table 6), road network is low density (Table 7). Merely 13% of the area is affected by the acid rain (Fig. 6). Water quality of the main rivers is generally satisfactory, in which over 75% of the rivers could be regarded as level III or above, where impact is relatively slight when it comes to the pressure exerted on priority area by human activity, one of the main reasons that biodiversity in priority area remain ideal state.

Through comparing overlapping areas and non-overlapping areas, it could be seen that population density in the overlapping area is somewhere near 1/3 of that in non-overlapping area. Percentages of agricultural, urban and road network density of the former are all lower than that of the latter. Growth area of the residential and construction land in the former is about 2/5 of that in the latter (Table 6). The growth length of overlapping area is similar to the non-overlapping area, the difference could be overlooked (Table 7). Percentage of areas affected by acid rain was up to 9% in the former, lower than 23% claimed by the latter. Main rivers with quality classified as level III and above account for nearly 80%, higher than 72% claimed by the latter.

Overlapping area is the key ecological function area defined by all sorts of regional plans, the core area for ecological conservation. Ecological background is excellent in those areas, where population density is relatively low and national policy is favorable. Thus human activity intensity and ecological conservation pressure are patently weaker than those of the non-overlapping area, possibly one of the reasons that ecological quality

**Table 6** Ecological protection pressure caused by agricultural production and urbanization in overlapping areas, non-overlapping areas, and priority areas of biodiversity conservation

| Source of ecological protection pressure | Land use | Priority areas | | | Overlapping areas | | | Non-overlapping areas | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Area ($10^4$ km$^2$) | Percentage (%) | Growth area (km$^2$/$10^4$ km$^2$) | Area ($10^4$ km$^2$) | Percentage (%) | Growth area (km$^2$/$10^4$ km$^2$) | Area ($10^4$ km$^2$) | Percentage (%) | Growth area (km$^2$/$10^4$ km$^2$) |
| Agricultural production | Dry land | 13.39 | 5.76 | 34.90 | 6.81 | 4.26 | 43.80 | 6.58 | 9.09 | 15.19 |
| | Irrigated field | 3.99 | 1.72 | 6.90 | 2.05 | 1.28 | 21.30 | 1.94 | 2.68 | –24.90 |
| Urbanization | Residential land | 8475.90 | 3.65 | 6.50 | 3780.40 | 2.36 | 5.26 | 4695.50 | 6.48 | 9.28 |
| | Construction land | 2018.40 | 0.84 | 5.60 | 786.20 | 0.49 | 3.20 | 1232.20 | 1.70 | 10.75 |

**Table 7** Ecological protection pressure caused by road density in overlapping areas, non-overlapping areas and priority areas of biodiversity conservation

| Priority areas of biodiversity conservation | | Overlapping areas | | Non-overlapping areas | |
|---|---|---|---|---|---|
| Density (km/km$^2$) | Growth length (km/km$^2$) | Density (km/km$^2$) | Growth length (km/km$^2$) | Density (km/km$^2$) | Growth length (km/km$^2$) |
| 0.30 | 0.23 | 0.26 | 0.20 | 0.37 | 0.27 |

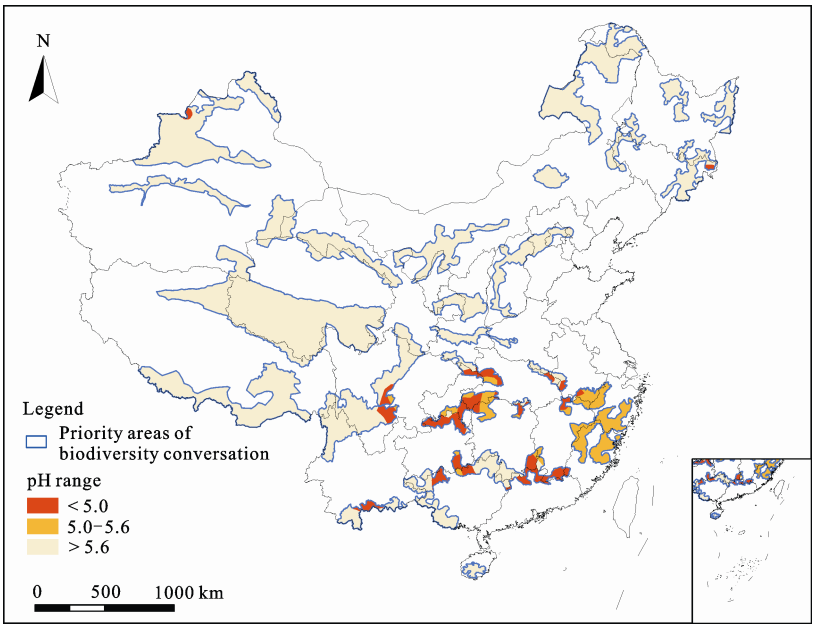


**Fig. 6** Spatial distribution of acid rain zone in priority areas of biodiversity conservation

in the former is generally superior compared to that in the latter. It should be noted that as a core area for ecological conservation, overlapping area assume a backward appearance that features lagging socio-economic development, where primary industry is usually the pivotal industry, possibly leading to the higher growth rate of agricultural land in the overlapping area than that in the non-overlapping area.

## 4 Discussion

### 4.1 Disparity and connectedness of different ecological regionalization

Under the influence of disparity between the background and objective of planning, various ecological regionalization differ in the range of spatial management and protection, protection target and main functions, indicated, for example, by the fact that nearly 1/3 of the priority areas have no overlapping with the three key ecological areas. The above mentioned area was deemed, by China Biodiversity Conservation Strategy and Action Plan (2011–2030), to possess critical biodiversity conservation functions, which was not acknowledged by other ecological regionalization.

Meanwhile, there is close connection between various ecological function regions, and over 2/3 of priority areas overlap with other ecological regionalization. Improvement of ecological functions like water conservation, soil and water conservation and biodiversity conservation in the three key ecological areas is beneficial to the protection of ecosystem, species and biodiversity. Thus beefing up ecological function protection in various areas will undoubtedly have patently boosting effect of biodiversity conservation in the priority areas. Biodiversity conservation will in effect promote the ecological conservation in the three key ecological areas.

### 4.2 Effect on environmental management

Clarifying the interrelation between protection space and protection target of various ecological regionalization is crucial for ensuring that ecological conservation policies are scientific, rational, effective, original and coordinated. In the current stage, little effort has been exerted into this field in China and the issue of relationship between key ecological regionalization failed to draw attention from managers, causing hidden trouble to our environmental protection career.

Carrying out the research on relationship between key ecological regionalization and defining concordance and contradiction will offer substantive reference for formulating and implementing ecological conservation measures, pushing forward coordination of multiple sectors and rational distribution of funds, lifting efficiency, saving manpower and resources, providing guidance in drawing ecological red line and in regionalizing disaster area, lowering redundancy and evading disagreement

with the regionalization.

### 4.3 Future research

Presently there is little research on relationship between key ecological zonings in China, and sound methodology and theoretical system has not come into shape. In this paper, the research of relationship between key ecological regionalization focuses on the range of spatial management and orientation of ecological functions, lacking in-depth probing into the interconnectedness concerning other aspects. At the same time, due to constraint by difficulties in collecting the data, systematicness and integrity of ecological condition and protection pressure analysis still need to be improved. Uncertainty on the boundary of ecological zoning still exists, which could bring certain effects on the precision of research findings to some extent.

Future research should be focused on the following four aspects: 1) conducting more detailed and specific researches, analyzing the spatial range and protection target of ecological regions respectively, determining the disparity and connection between the ecological regions; 2) improving ecological condition and protection pressure indicator system, to which indicators of ecological quality change, social economy and pollutant discharge *etc*., should be added for reflecting and comparing the regional ecological conditions and protection pressure generally; 3) carrying out analysis on a region-specific basis according to factors in relation to various natural regions and economic development levels, and analyzing the relationships between various regionalization under various natural geographical conditions and economic development levels; 4) summarizing the drawbacks or shortcomings which possibly exist in regionalization of our country from the study of areas mentioned in this article, bringing forward feasible countermeasures for future ecological region planning and regionalized management and lending support to ecological conservation.

## 5 Conclusions

The priority areas and three key ecological areas showed relatively fine spatial consistency, with 68.8% of the priority areas overlapping with the three key ecological areas. Therefore, improving the management of priority area of biodiversity conservation will improve the ecological conditions in the overlapped areas of the three key ecological areas as well. We believe that the very reason eventually leading to what the status has become of is that the specific protected target of each main function in the three key ecological areas is different from that in the priority areas of biodiversity conservation.

In general, ecological condition is superior in priority area, where ecological environment structure is intact, ecological quality is high, human activity impact is small, environmental pressure is low and ecological background quality is high, one of the main reasons that biodiversity in the priority area remain ideal. Based on that, wildlife is endowed with superb survival ground, through which positive factors could be activated to boost biodiversity conservation. Despite this, non-ecological land occupation is exploding within priority area recently, environmental pollution is aggravating and environmental protection pressure is mounting, all of which emphasize the importance of ecological superintendence and protection.

Overlapping area is the key ecological function area defined by all sorts of regional plans, the core area for ecological conservation and safeguard for regional ecological safety and ecological function. Compared to non-overlapping area, ecological background is better, population density is lower, national policy is more favorable and thus human activity is less intensive and ecological conservation pressure is lower in overlapping area, possibly one of the reasons that ecological quality in the overlapping area is generally superior compared to that in the non-overlapping area. Ecological conservation in both areas is crucial and countermeasures could be tailored to take the individual features into account. Sustaining the ecosystem steadiness and ecological quality and ensuring that habitats are intact is essential to biodiversity conservation within the area. Enhancement of ecosystem steadiness, improvement of ecological quality and reinforcement of ecological environment management in non-overlapping area are also the key factors in recovering the surviving environment and habitats for rare and endangered wild species.

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