BRI International Green Development Coalition
2020 Policy Study Series

Key Biodiversity Areas and Impact Assessment in BRI-covered Areas

December 2020

In April 2019, Chinese and international partners officially launched the BRI International Green Development Coalition (BRIGC) at the Second Belt and Road Forums for International Cooperation. BRIGC aims to establish a policy dialogue and communication platform, an environmental knowledge and information platform, and a green technology exchange and transfer platform, so as to advance global consensus, understanding, cooperation, and action of a green Belt and Road Initiative (BRI).

From the perspective of transportation infrastructure development, this report focuses on the research of Key Biodiversity Areas (KBAs) in the BRI region, as well as their conservation strategies, from the following aspects. First is the current status of biodiversity in regions along the Belt and Road. With technologies such as remote sensing and geographical information systems, we have analyzed the biodiversity sensitivity of different regions and identified the ecological risks stemming from the implementation of the BRI. Second is the relevance between transportation infrastructure construction and biodiversity conservation, as well as the potential impacts. Third is the current status and trends of biodiversity conservation. Building on exemplary experiences in biodiversity conservation, policy recommendations have been proposed to enhance biodiversity conservation in the BRI regions.

Secretariat of BRIGC Ms. Qiao Yujie

Tel: +86-10-82268647

Fax: +86-10-82200535

Address: No. 5, Houyingfang Hutong, Xicheng District, Beijing 100035, China

Website: www.brigc.net

Email: brigc@fecomee.org.cn; brigcsecretariat@163.com

Research Team*

Dr. ZHANG Linxiu, UNEP International Ecosystem Management Partnership (IEMP)

Dr. WANG Guoqin, UNEP International Ecosystem Management Partnership (IEMP)

Dr. XU Xiangbo, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Science

Mr. TIAN Fang, Foreign Environmental Cooperation Center, Ministry of Ecology and Environment of China

Ms. LI Nan, World Wide Fund for Nature (WWF) China

Mr. ZHANG Cheng, International Union for Conservation of Nature (IUCN)

Ms. ZHANG Yu, Conservation International (CI)

Ms. WEI Xiaona, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Science

* The authors and advisors of this policy study come from the Thematic Partnership on Biodiversity and Ecosystem Management of BRIGC and serve in their personal capacities. The views and opinions expressed in this report are those of the individual experts participating in the research and do not represent those of their organizations and the BRI International Green Development Coalition.

TABLE OF CONTENTS

Executive Summary

Biodiversity is fundamental for the survival and development of human society. Biodiversity protection is one of the core ecological environmental issues of global concern. The Belt and Road Initiative (BRI), with regional connectivity at its core, runs through a number of biodiversity hotspots, wilderness areas and other key conservation areas. Infrastructure construction, such as transportation construction, plays an important role in BRI cooperation. Infrastructure projects usually last for a long period of time and have big impacts on environment. If not properly planned, it will bring huge potential risks to biodiversity protection in the coming decades. Therefore, biodiversity conservation must be taken into serious account in BRI transportation infrastructure projects.

The countries joining BRI are mainly located on the Eurasian continent, covering both the east and west ends of the continent. BRI region has diverse climates and diverse landforms. The distribution of water resources and land resources varies in this region, while its per capita water resources are less than 2/3 of the global average, and its per capita arable land is about 3/4 of the global average. BRI region has abundant natural resources thanks to its complex and comprehensive geological phenomena. The oil and gas resources of BRI region account for 58% and 54% of the world total respectively, with the Middle East being the most abundant. As for mineral resources, the reserves of ferrous and non-ferrous metals in the BRI region are among the top in the world, and the reserves of non-metallic minerals in the BRI region are also considerable.

In order to further assess biodiversity status in the BRI region, this report carried out biodiversity visualization and sensitivity analysis of important regions of biodiversity. In order to recognize key areas for biodiversity, this report consolidated existing biodiversity databases including the World Database on Protected Areas, the World Database of Key Biodiversity Areas, WWF Priority Ecoregions, IUCN Red List of Threatened Species and Biodiversity Hotspots Reserve database. Based on those databases, we used WWF-SIGHT to visualize important biodiversity areas along BRI region. The identification results showed that BRI important biodiversity areas are mainly concentrated in Southeast Asia, India-Myanmar border, Europe and South Africa, where their climate and landscape contribute to forming good habitats.

In order to analyze the biodiversity sensitivity of the BRI region, this report selected typical biodiversity conservation habitats and identified the sensitivity factors suitable for the assessment areas according to natural, social and economic conditions. Through the comprehensive ecological sensitivity assessment, the ecological environment sensitivity was evaluated qualitatively and quantitatively by taking ecological system changes, animal and plant species and habitats changes, migration routes and other factors into overall consideration.

The result showed that in terms of geographical distribution, from east to west, the overall potential impact of BRI infrastructure construction on important biodiversity regions is decreasing. From south to north, there is also a downward trend. Infrastructure construction has the greatest overall impact on BRI important biodiversity regions in Southeast Asia and the easternmost border area between China and Russia in Eurasia, where ecological environment sensitivity is high. The

infrastructure impact on biodiversity in Central and Eastern Europe is generally less, where ecological environment sensitivity is relatively low. Development-wise, in developed regions in Europe, the overall impact of infrastructure construction on important biodiversity regions is relatively less, while in developing regions in Southeast Asia, Central China and border areas between China and Russia, the overall impact is relatively bigger. In terms of specific potential impacts, 32% of national protected areas in the BRI countries can be affected, and the BRI economic corridor overlaps with 265 threatened species distribution area. In general, there is a huge potential overlap between the BRI economic corridors and important areas of biodiversity. These areas are overlapped high risk areas where infrastructure construction may have negative impacts. Further in-depth analysis of these potential high risk areas is necessary to help identify potential solutions and create opportunities for ecological infrastructure investment.

Among BRI projects' impacts on biodiversity, the impact of transport infrastructure is particularly worthy of analysis. The transportation infrastructure plays an important role in promoting the economic development and trade and culture exchanges of the BRI region. However, as a linear network, transportation network cuts habitats with its long distance and wide range of traffic channels, bringing irreversible and far-reaching impacts on these surrounding ecosystems. The impacts of transportation infrastructure on biodiversity can be seen during construction period and operation period, including the deterioration of habitats and the disturbance of biological community structure, etc.

The road and railway networks among BRI countries varies. In general, the railway networks of Mongolia-Russia region and China are relatively complex, while China has the longest highways. On the other hand, there is great space for railway and highway development in Central Europe and Central-Western Asia.

This report visualized the overlaps of railway and road networks and important biodiversity conservation areas, and measured the impacts of the railway and road networks on biodiversity according to their degrees of overlapping. This report also selected a series of representative transportation infrastructure projects, and focused on measuring their impacts on vegetation cover and ecological resources, so as to specifically present the impacts of infrastructure on biodiversity sensitivity. The analysis results showed that the projects under construction have potential effect on ecological environment, while biodiversity losses are addressed after the establishment of those projects in couples of years.

To further explore how to harmoniously deal with the interaction between infrastructure and biodiversity, this report took the Sino-Russian land sea intermodal transport corridor project as an example for further analysis. The international transport corridor between China and Russia is rich in species and has fragile and diverse ecosystems. At the same time, it is an important gateway for cooperation between China and Russia, and has an important strategic area for economic development. Therefore, it is important to address these ecological environment issues during the construction and development of infrastructure in this region. Many strategies have been adopted to protect the biodiversity of the area. These measures include: Improved project top design to reduce ecological risks; establishing transboundary nature reserves through multi-level cooperation;

joint monitoring environmental quality and sharing experiences.

Looking forward, there are many areas for our attention, considering their rich biodiversity and fragile ecological environment in BRI region. Related negative impacts of these projects on local biodiversity must be measured, assessed and reduced to ensure effectively implementation of such infrastructure projects. It is important to evaluate the project impact on biodiversity during the project planning phase, and it is recommended to use biodiversity assessment tools when assessing project feasibility. Furthermore, the topic of how to improve transboundary cooperation on biodiversity conservation of global importance is also worth exploring.

Based on this, we put forward the following four recommendations: gearing up the BRI infrastructure guidelines with the UN Sustainable Development Goals of the United Nations, advocating for the use of biodiversity assessment tools before investing infrastructure projects, incorporating principles related to biodiversity conservation into the BRI green finance framework, strengthening science-based support and promoting the consistency of standards and norms related to biodiversity conservation.

Human beings depend on biodiversity for their survival and development. Biodiversity plays a crucial role in meeting people's basic needs for clothing, food, shelter and transportation, as well as many other aspects of people's material and cultural lives. In addition to China, the Belt and Road Initiative (BRI) mainly includes countries in Southeast Asia, West Asia, South Asia, Central Asia, Central Europe and Eastern Europe, covering around half of the world's population. The ecosystems of these countries are exceptionally complex and diverse. Some regions are endowed with abundant natural resources, although their ecological environments are vulnerable and sensitive, posing serious challenges for them in biodiversity conservation and sustainable development.

1. Geographical Conditions along the Belt and Road

Geographical conditions are the foundation of biodiversity. Most BRI-participant countries are situated in Eurasia and stretch across the vast continent from west to east. Apart from their diverse climate types, their different natural resources and their abundant array of landforms, the population densities of these countries vary significantly. Under these different natural conditions, different cultures have flourished, resulting in development gaps among these countries.

Eurasia is the largest continental area on Earth, covering a land area of 55 million square kilometers; Asia accounts for 80% of the landmass. The geographical features of Eurasia are characterized by its vast landlocked arid area (more than 20 million square kilometers), broken and zigzagging coastlines, huge peninsulas (with a total land area surpassing 10 million square kilometers), transcontinental plateaus and mountains, countless inland seas and fertile alluvial plains. This geographical macrostructure has not only shaped the natural conditions of Eurasia but has also affected its population distribution, as well as its economics, trade and geopolitics.

1.1 Climate Features[1]

In Eurasia, temperatures drop progressively from southwest to northeast, while precipitation decreases from the coastal areas to landlocked areas. The inner part of Eurasia, which is extremely arid, is mainly composed of deserts and arid grassland, with little precipitation, low temperatures and poor land productivity. By contrast, the coastal areas are rather humid (except for those on the Arabian Peninsula), including the plains in eastern China, the Great European Plain and other major peninsulas. Arable land and populations are mainly distributed in these areas due to their high land productivity.

Covering the polar, temperate and tropical zones from north to south, Eurasia is surrounded by the world's four oceans and contains a large variety of complex landforms, including "the Roof of the World" — the Tibetan Plateau — which generates many region-specific climate types. These climate types can be roughly divided into ten groups: (1) the tropical monsoon climate (which includes the southeast peninsula of Sulawesi), (2) the subtropical monsoon climate (which includes southeast China, Japan and South Korea), (3) the temperate monsoon climate (which includes northern China,

[1] Liu Weidong, et al. *Joint Construction of Green Silk Roads: Social, Economic and Environmental Context*, The Commercial Press, 2019.

northeastern China and northeast Asia), (4) the highland climate (which includes the Tibetan Plateau, the Ethiopian Highlands and the Iranian Plateau), (5) the temperate continental climate (which includes areas located between 35° N and 50° N in Asia, as well as Central Europe and Eastern Europe), (6) the subpolar continental climate (which includes areas of Eurasia above 65° N), (7) the polar tundra climate (which includes areas within the Arctic Circle in Eurasia), (8) the tropical dry climate (stretching from Southwest Asia to North Africa), (9) the Mediterranean climate (along the Mediterranean Sea) and (10) the temperate oceanic climate (Western Europe).

Regarding temperatures, Eurasia boasts four distinct seasons with huge temperature differences between extremely-high-temperature areas and extremely-low-temperature areas. In summer, the average temperature is above 10° C in most areas and may surpass 35° C in some low-latitude areas, although the temperature differences between regions is relatively small. In winter, however, the average temperature in different regions varies drastically. The coldest part — Northeast Eurasia — can be as cold as −40° C, while the temperatures of low-latitude regions may reach 30° C. Apart from latitudinal differences, landforms and the distribution of land and water can also significantly affect regional temperature differences. The Tibetan Plateau is a relatively localized low-temperature zone. Affected by the Gulf Stream, northwest Europe is much warmer than northeast Asia, especially in winter.

Due to the impact of summer monsoons, the annual precipitation in East Asia decreases progressively from the coastal areas in the southeast to the landlocked areas in the northwest. The rainy Southeast Asia has a recorded annual precipitation of more than 1,500 millimeters; whereas in dry regions like West Asia, Central Asia and northwest China, less than 200 millimeters of annual precipitation is reported. With a temperate oceanic climate, Western Europe's annual precipitation hovers around 800 millimeters, while that of Eastern Europe and North Asia is around 400 millimeters. Generally speaking, the geographical and seasonal factors affecting precipitation are more complex than those affecting temperatures.

As for aridity, the western part of East Asia, Central Asia, and some places in Siberia are the typical arid lands and semi-arid lands. Located far away from the oceans, these areas are most vulnerable to dryness due to the continental climate and the prevailing westerlies. The aridity of Mongolia, Central Asia, the Arabian Peninsula, and Iranian Plateau is severe and long-lasting, especially the Arabic Peninsula and the Iranian Plateau where the dryness may last for 20 months. With a greater annual precipitation, however, Southwest Asia has been also confronted with high risks of drought in specific years. In the past five decades, Southwest Asia has reported two severe droughts (1999/2000 and 2007/2008). Europe is bordered by the Atlantic Ocean in the west, and droughts have been reported not only in its semi-dry areas such as countries along the Mediterranean Sea, but also in some humid areas such as the British Isles, Scandinavia, and Russia. Generally speaking, Southern Europe is more vulnerable to droughts than other parts of Europe in terms of the frequency, persistency, and severity.

1.2 Features of Natural Resources

As one of the enabling factors for biodiversity, natural resources play an indispensable role in human being's production activities. Along the BRI corridors, the large variety of landforms and complex geological phenomena have generated abundant natural resources. However, there is huge difference in natural resources among regions, which has directly or indirectly influenced the pillar industries and productivity of different regions.

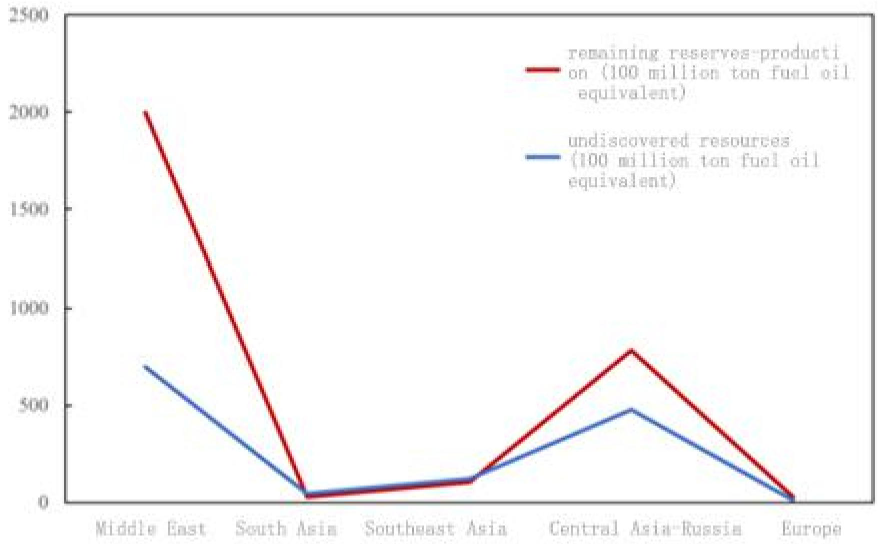


Figure1 Distribution of Petroleum and Natural Gas in the BRI Region

(1) Petroleum and Natural Gas

Covering countries with the world's largest petroleum and natural gas reserves, the BRI region is home to 60% of the global petroleum recoverable reserves and 63% of the global natural gas recoverable reserves. Moreover, 58% of the world's petroleum and 54% of the world's natural gas are produced in this region. Nevertheless, the distribution within the BRI region is extremely uneven. Nearly 80% of conventional petroleum resources and natural gas resources are concentrated in the Middle East, with the rest 20% distributed in West Asia, Central Asia, and Russia. According to such a geographical distribution, four major producing regions of petroleum and natural gas have been identified, namely the Middle East, Central Asia – Russia, Southeast Asia, and Europe. The petroleum and natural gas reserves vary greatly from one region to another, with the distribution in each region being extremely unbalanced (Figure1).

(2) Mineral Resources

The ferrous and non-ferrous metal reserves along the BRI corridors are ranked among the largest in the world (Figure2). Take iron as an example. The proven iron ore reserves in the BRI region are 67.6 billion metric tons, accounting for approximately 40% of the global reserves. These iron ore reserves are mainly located in Russia, China, India, Ukraine, Kazakhstan, and Iran. Among the six countries, Russia has proven iron ore reserves of 25 billion metric tons, ranking third in the world;

India has 8.1 billion metric tons, ranking fifth; and Ukraine has 6.5 billion metric tons, ranking seventh.

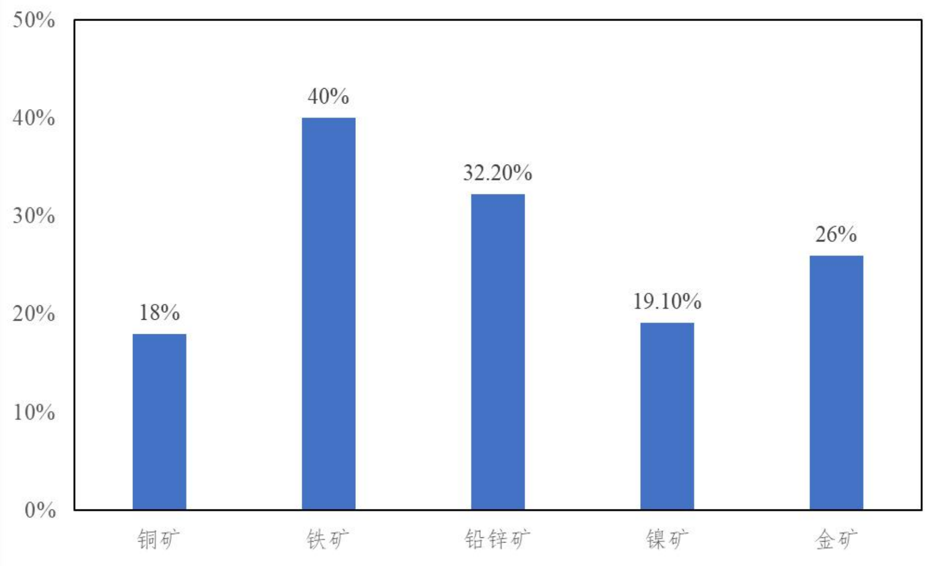


Figure2 Mineral Resources in the BRI Region by Percentage of the Global Reserves

Considerable non-metallic minerals reserves have also been found in the BRI region. For example, the proven reserves of bauxite account for around 17% of the global reserves, and the boron reserves take up approximately 69.5% of the world's proven boron reserves. There are a wide range of non-metallic minerals in the world. Due to the strong applicability, these minerals can significantly promote a country's economic development, which deserve our attention.

(3) Water Resources

Water resource distribution is obviously different among countries and regions along the Belt and Road. In general, the annual average precipitation and runoff depth in the BRI region are lower than the world's average. Due to the large variety of climate types and intraregional differences, the precipitation and runoff distribution varies greatly from one region to another. The precipitation and runoffs are relatively abundant in Southeast Asia, but not in West Asia and Central Asia. In terms of the per capita statistics, the water resources per capita in countries along the BRI corridors are less than two thirds of the world's average. Like the regional distribution of precipitation and runoffs, water resources per capita are relatively high in Southeast Asia and Northeast Asia, but relatively low in the Middle East and Central Asia. As for the availability of water resources by percentage, more water resources are available in West Asia, Central Asia, and South Asia than those in Eastern Europe, Northeast Asia, and Southeast Asia.

(4) Land Resources

A. Arable Land and Its Distribution

Countries and regions along the Belt and Road are endowed with a vast arable land of 695 million hectares, accounting for about 50% of the world's total arable land area. The arable land area per capita is 0.15 hectare, which is three fourths of the world's average. Arable land is mostly concentrated in the middle- and low-latitude regions. Among these regions, the China-Mongolia-Russia region has the largest arable land. India, Russia, and China are the top three countries with the most arable land – the arable land area of each country has all surpassed 100 million hectares. However, in countries including Kuwait and Montenegro, the arable land area is less than 10,000 hectares. During the past 15 years, Southeast Asia has witnessed the largest increase in arable land area, which has decreased drastically in South Asia. Due to the influence of climates and landforms, the land productivity is relatively high in Southeast Asia, but relatively low in some regions in the southern part of Central Asia.

B. Woodland and Its Distribution

The woodland area in countries and regions along the Belt and Road is 15.79 million square kilometers, accounting for 44% of the world's total. A wide range of woodlands have been seen, including various submerged aquatic vegetation in freshwater or saltwater, broadleaf woodlands, and coniferous woodlands. Along the Belt and Road, about 74.62% of woodlands are distributed in the China-Mongolia-Russia region, while Central Asia has the smallest woodland area, accounting for only 0.43%. The most common woodland in Southeast Asia is evergreen broadleaf vegetation, whose productivity is the highest. However, in Siberia and the Far East region of Russia, there are mostly deciduous coniferous woodlands, whose productivity is the lowest. In the past 20 years, there has been a trend of "decrease – substantial increase – decrease to a stable level" in terms of woodland area. The China-Mongolia-Russia region has witnessed the largest increase in woodland area, while Southeast Asia has seen the sharpest decrease.

C. Grassland and Its Distribution

The total grassland area in countries and regions along the Belt and Road is about 11.73 million square kilometers (approximately 23.11% of the BRI region's overall land area), 67.18% of which is located in the China-Mongolia-Russia region. Meanwhile, the overall grassland productivity decreases progressively from the low-latitude areas to high-latitude areas, and from coastal areas to landlocked areas. Different from woodlands, due to the global warming and overgrazing, the major grasslands have shrunk in size and most grasslands have degenerated. Global warming has resulted in an expanded area of the temperate ecosystem. The growing season of vegetation has been prolonged, and temperate forests have grown towards high-latitude and high-altitude areas, leading to a remarkable decline in the mountain grassland area in Asia and Europe.

1.3 Geological Features of Cultures and Economics[2]

The BRI covers over 64% of the world's population and 30% of the global GDP. The population distribution along the Belt and Road is featured by "large in the southern and eastern part, and small in the northern and western part". In regions in the east to the Ural Mountains of Russia, Kazakhstan, Mongolia, and Northeast China, the average population density is less than 1 person per square kilometer. In some other countries and regions, such as China's Yangtze River Delta,

[2] Liu Weidong, et al. Joint Construction of Green Silk Roads: Social, Economic and Environmental Context, the Commercial Press, 2019.

Pearl River Delta, and Beijing-Tianjin-Hebei region, India's Uttar Pradesh, Bihar, and West Bengal, Bangladesh, the northeastern part of Pakistan and the middle and upper courses of Indus River, the Hong River Delta in Vietnam, and Java of Indonesia, the average population density exceeds 1,000 people per square kilometer. As for the remaining part of the BRI region, the average population density ranges from 100 to 1,000 people per square kilometer. Among the BRI participating countries, big and medium-sized cities are mainly located in the middle and eastern parts of China, the Indochinese Peninsula, the Indian Subcontinent, and Central and Eastern Europe. Globally, there are 31 mega cities whose population has exceeded 10 million, and 17 of them are situated along the Belt and Road, in particular the two most populous countries in the world – China and India.

Among the BRI participating countries, most of them are developing countries and only a few are developed economies with a relatively small population, such as Singapore, Israel, and Qatar. In 2017, the GDP of BRI participating counties totaled USD 2.2 trillion (calculated according to the official exchange rates), and the GDP per capita reached USD 5,200, accounting for about 50% of the world's average. According to the World Bank's data, five countries are classified as low-income countries, namely Afghanistan, Syria, Tajikistan, Yemen, and Nepal; and 19 countries are lower-middle income countries. Besides, although the average incidence of poverty in the BRI participating countries is only 4% (as of 2015), which is far below the world's average, the incidence of poverty in some countries is very high, including India, the Laos, Yemen, and Uzbekistan. If measured by the Human Development Index, the BRI participating countries are faced with an unbalanced eco-social development, which is severer than the world's average, together with a huge gap between the rich and the poor.

Despite the relatively low income, many countries boast strong economic vitality and have maintained a rapid economic growth in the past years, in particular China and countries of Southeast Asia and South Asia. The BRI participating countries' contribution to the global GDP has increased from 17% to 30% since 2000. Emerging economies such as China, India, Indonesia, Russia, Saudi Arabia, and Turkey have become important drivers of the global economy. Owing to the relocation of global manufacturing, East Asia and Southeast Asia have taken steady steps to become "the world's factory" in the past five decades, and created a huge supply chain and a close-knit trade network. In addition, the Middle East has always been the world's energy base, and Russia and Central Asia are blessed with abundant petroleum and natural gas reserves. Hence, although some countries have been confronted with stagnant economic growth due to civil wars or domestic affairs, the BRI participating countries are places full of vigor and hope with huge potential for economic cooperation.

2. Key Biodiversity Areas along the Belt and Road

The concept of Key Biodiversity Areas (KBAs) derives from the Biodiversity Hotspots promoted by the Conservation International (CI). The identification method of KBAs originated from that of Important Bird Areas (IBAs), which was proposed in 1980. In the following 30 years, BirdLife International has been committed to applying this method to identify IBAs worldwide. To ensure the commensurability of data, different conservation organizations around the globe have universally adopted this identification method of IBAs3. Later on, this method has been gradually applied in the conservation of other species, not only birds, as in Important Plant Areas (IPAs), Important Freshwater Biodiversity Areas (IFAs), Prime Butterfly Areas (PBAs), and so on. In 2004, an expert workshop was held in Washington, D.C., the United States, to develop draft cross-taxon criteria for identifying KBAs, thus to integrate all these processes and knowledge into a single system. At the World Conservation Congress held in Bangkok, Thailand, in 2004, members of the International Union for Conservation of Nature (IUCN) proposed that "A global consultative network should be established to ensure an agreed methodology which enables countries to identify KBAs." In response to this initiative, IUCN Species Survival Commission (SSC) and World Commission on Protected Areas (WCPA) jointly established the IUCN WCPA/SSC Joint Task Force on biodiversity and protected areas, mobilizing IUCN experts and staff members, other conservation organizations, academia, governments, donators, and representatives from private enterprises to participate in the development of standard for identifying KBAs.

Following the IUCN Red List of Threatened Species and the Red List of Ecosystems, the Global Standard for the Identification of KBAs (2016) is another global standard prepared by IUCN, which has provided governments and the civil society with strong strategic support in developing a network of conservation areas. This global standard was established to: a) coordinate the existing methods and the identification method of KBAs; b) supplement and improve the scientific standard which has not taken biodiversity factors into consideration; c) help different users and organizations identify the sites contributing significantly to the global persistence of biodiversity from the temporal and spatial dimensions; d) ensure the objectivity, transparency, and rigidness of the identification results of KBAs through a scientific standard featuring quantified threshold; and e) propel policy makers to get a better understanding of the significance of KBAs, thus to contribute to the identification of KBAs around the globe.

2.1 Existing Biodiversity Databases

Subject to different identification standards of KBAs, several databases and categories on biodiversity have been established now.

2.1.1 The World Database on Protected Areas

The World Database on Protected Areas (WDPA) is a joint project between the United Nations Environment Programme (UNEP) and IUCN, which is prepared and managed by the UNEP World

[3] FOSTER M N, BROOKS T M, CUTTELOD A, et al. The Identification of Sites of Biodiversity Conservation Significance: Progress with the Application of a Global Standard[J]. Journal of Threatened Taxa, 2012, 4(8):2733-2744.

Conservation Monitoring Centre (UNEP-WCMC), together with governments, non-government organizations, academia, and industrial community. Taking economic and environmental factors into consideration, WDPA identifies protected areas via living and non-living things, including animals, plants, and geological structures. WDPA is the most comprehensive global database on terrestrial and marine protected areas, comprising spatial data (i.e. polygons and points) and associated attribute data (i.e. information appended in tabular form).

2.1.2 The World Database of Key Biodiversity Areas

The World Database of Key Biodiversity Areas evolves from the World Bird and Biodiversity Database managed by BirdLife International. Now, the database is managed by the KBA Partnership, which comprises 13 international organizations[4], and is served by the KBA secretariat hosted jointly by BirdLife International and IUCN. The selection criterion is "sites contributing significantly to the global persistence of biodiversity in the terrestrial, freshwater, and marine ecosystems." To be more specific, the standards include the following aspects: threatened biodiversity, geologically-confined biodiversity, ecological integrity, biological process, and irreplaceability. The KBAs identification standards are not necessarily related to all factors of biodiversity, although the threshold of each standard can be applied in all taxonomic groups (except for microorganism) and ecosystems.

2.1.3 The WWF Priority Ecoregions

The WWF Priority Ecoregions uses irreplaceability and distinctiveness to analyze the biodiversity features of different regions, thus, to identify more than 200 terrestrial, freshwater, and marine ecoregions that are most distinctive and representative. Hence, this database is also called the Global 200 Ecoregions, or G200 Ecoregions. The WWF Priority Ecoregions analyzed global patterns of biodiversity y to identify a set of the Earth's terrestrial, freshwater, and marine ecoregions that harbor exceptional biodiversity and are representative of its ecosystems. They placed each of the Earth's ecoregions within a system of 30 biomes and biogeographic realms to facilitate a representation analysis. Biodiversity features were compared among ecoregions to assess their irreplaceability or distinctiveness. These features included species richness, endemic species, unusual higher taxa, unusual ecological or evolutionary phenomena, and the global

rarity of habitats. Up to date, this database possesses 238 ecoregions, comprising 142 terrestrial, 53 freshwater, and 43 marine priority ecoregions. Effective conservation in this set of ecoregions would help conserve the most outstanding and representative habitats for biodiversity on this planet.

2.1.4 The IUCN Red List of Threatened Species

The IUCN Red List of Threatened Species (or IUCN Red List) was founded in 1963, and is now the most comprehensive inventory of the global conservation status of biological species in the world. It has been also recognized as the most authoritative guide to evaluate biodiversity status. It uses a set of strict criteria to evaluate the extinction risk of thousands of species and subspecies. Through

[4] The 13 international organizations include: BirdLife International, IUCN, American Bird Conservancy, Amphibian Survival Alliance, CI, Critical Ecosystem Partnership Fund, Global Environment Facility, Global Wildlife Conservation, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, WWF, and Wildlife Conservation Society.

criteria such as the decline rate, population size, geographical distribution, and distribution fragmentation, species to be protected are classified into nine groups, namely Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), and Not Evaluated (NE). The highest-ranking group is EX, followed by EW, and species included in the three categories of CR, EN, and VU are recognized as "threatened". Among all species that have been evaluated, there are 16,118 threatened species, including 7,725 species of animals, 8,390 species of plants, and three species of fungi. Major species assessors include BirdLife International, the Institute of Zoology (the research division of the Zoological Society of London), WCMC, and IUCN SSC. Collectively, assessments by these organizations account for nearly half the species on the Red List.

2.1.5 Biodiversity Hotspots

The database of Biodiversity Hotspots is produced by CI to select the most representative regions that are both biologically rich and deeply threatened. There are two criteria involved: a) the region must have at least 1500 or 0.5% of the world's vascular plants as endemics; and b) the region must have lost over 70% of its original vegetation. CI has identified 34 biodiversity hotspots around the globe, which are the biologically richest and most endangered regions in the world. Although they represent only2.4% of the Earth's land surface, they support more than 60% of the world's terrestrial species. Currently, these hotspots are deeply endangered and many of them have lost over 90% of their original vegetation.

2.2 Identification of KBAs along the BRI Corridors

Our identification of KBAs is based on the aforementioned databases and lists, taking into account economic and technological factors, Sustainable Development Goals, uniqueness of biodiversity and categories of threatened species.

2.2.1 Visualization Tools

The visualization tools for identifying key biodiversity areas that are available to the project team include WWF-SIGHT, Trends.Earth of CI, and IBAT of IUCN, each of which has its own strengths and weaknesses. SIGHT has a relatively comprehensive database, with databases of key biodiversity areas and key infrastructure development data, which can fulfill identification and sensitivity analysis tasks, but it cannot select a certain country or region for presentation and targeted analysis. Trends.Earth can do qualitative time series analysis of the situations of protected areas, but it lacks relevant data of infrastructure, so it cannot effectively carry out sensitivity analysis of infrastructure for the time being. IBAT can customize areas for analysis, and has comprehensive data on key biodiversity areas, but also lacks relevant data on infrastructure. Considering the strengths and weaknesses of the three tools, we have used WWF-SIGHT as the main visualization and analysis tool for this report, as shown in Figure 3.

Figure 3 Visual Operational Layers Interface

WWF-SIGHT is jointly developed by WWF, Simon Fraser University, the Luc Hoffmann Institute and Oxford University. WWF-SIGHT is a global smart platform based on Google Maps. This technology enables users to collect various spatial data sets and combine them with satellite images, thus visually demonstrating the real-time situation of the global natural resources that need protection. At present, there are two versions of WWF-SIGHT. WWF-SIGHT1.0 is open to the public, which only shows the global distribution of some natural resources and infrastructure, without details such as names, types, sizes, investors, countries or regions. WWF-SIGHT2.0 is an internal version, which includes not only the natural resource information possessed by WWF, but also some business data and detailed information of some projects, such as railways, highways, factories, etc.

With WWF-SIGHT2.0, we can overlay the layers of key protected areas and infrastructure (railways, highways, etc.). According to the degree of overlapping, we can judge and analyze the impact of infrastructure on biodiversity. Furthermore, WWF-SIGHT2.0 has a screening function, which can screen countries and coverage areas, so as to enable more targeted analysis.

2.2.2 Visualization Results of Key Biodiversity Protected Areas

The distribution of key biodiversity protected areas in the study region is displayed in Figures 4, 5, and 6. Based on WDPA, KBAs and WWF Priority Ecoregions, we have analyzed that the key biodiversity protected areas are mainly concentrated in Southeast Asia, the border area between China, India and Myanmar, Europe and South Africa. These areas are either plains or hills and mountains with a warm and humid climate, forming good living conditions for organisms. Figure 7 shows that the vast majority of the threatened species on the Red List are also distributed in these areas, especially in Southeast Asia and the border areas between China, India, and Myanmar.

Scattered but numerous key biodiversity protected areas can be found in Siberia. The climate in Siberia is cold with little precipitation, and the living environment is harsh. Although there are few human footprints, the harsh environment also makes these areas more vulnerable, and a considerable number of threatened species on the Red List are distributed in these areas. As human development gradually expands into Siberia, these areas need more attention and protection.

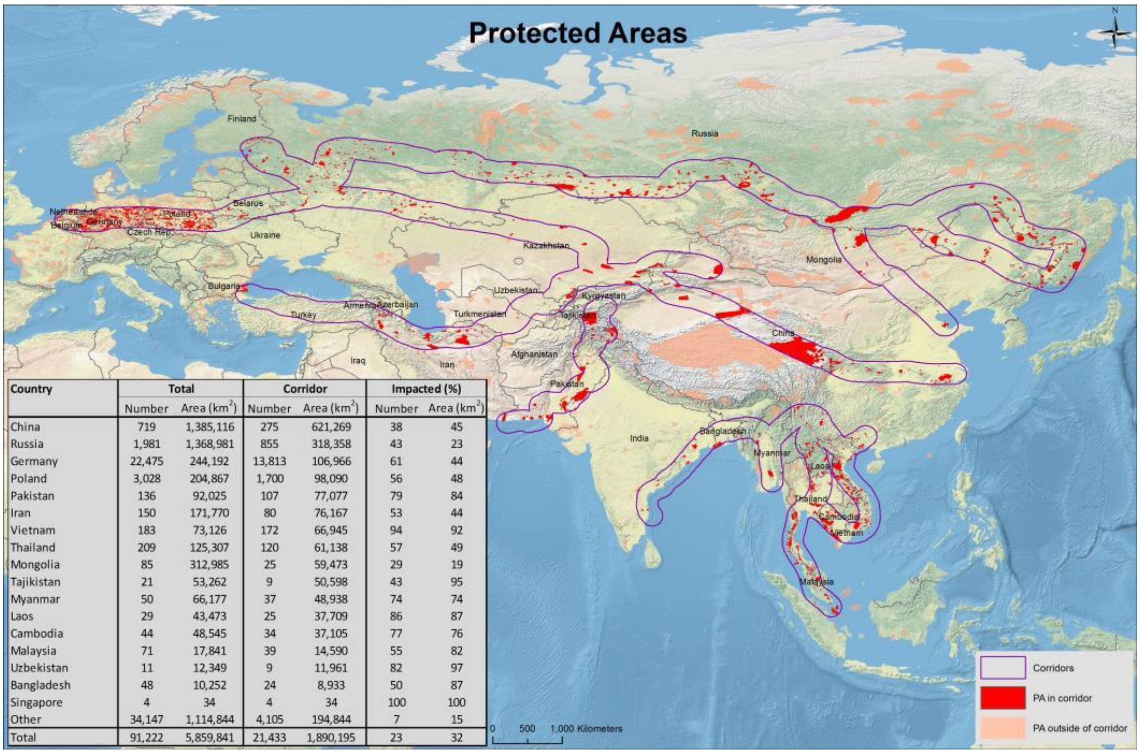
Figure 4 Distribution Map of WDPA

Figure 5 Map Overlay of WDPA and KBAs

Figure 6 Map Overlay of WDPA, KBAs and WWF Priority Ecoregions

Figure 7 Map Overlay of WDPA and IUCN Red List

Figure 8 shows the distribution of key biodiversity protected areas in the six economic corridors of the BRI. As shown in the figure, Northwest China is one of the main distribution areas of key biodiversity protected areas. This area is located in arid and semi-arid areas of China, in the dry climate zone with a serious trend of aridification; it is mostly comprised of plateaus and mountains, with mainly red sandy soil and Gypsisols. It is characterized by poor water and soil conservation function; scarce precipitation , which is not enough to turn into runoff; and inadequate vegetation, with the main vegetation types of grassland and bare land. Many factors lead to great ecological fragility in this area. Once destroyed, the area would be difficult to be restored, which would seriously affect the local biodiversity.



Country	Total		Corridor		Impacted (%)	
	Number	Area (km^2)	Number	Area (km^2)	Number	Area (km^2)
China	719	1,385,116	275	621,269	38	45
Russia	1,981	1,368,981	855	318,358	43	23
Germany	22,475	244,192	13,813	106,966	61	44
Poland	3,028	204,867	1,700	98,090	56	48
Pakistan	136	92,025	107	77,077	79	84
Iran	150	171,770	80	76,167	53	44
Vietnam	183	73,126	172	66,945	94	92
Thailand	209	125,307	120	61,138	57	49
Mongolia	85	312,985	25	59,473	29	19
Tajikistan	21	53,262	9	50,598	43	95
Myanmar	50	66,177	37	48,938	74	74
Laos	29	43,473	25	37,709	86	87
Cambodia	44	48,545	34	37,105	77	76
Malaysia	71	17,841	39	14,590	55	82
Uzbekistan	11	12,349	9	11,961	82	97
Bangladesh	48	10,252	24	8,933	50	87
Singapore	4	34	4	34	100	100
Other	34,147	1,114,844	4,105	194,844	7	15
Total	91,222	5,859,841	21,433	1,890,195	23	32

Figure 8 Distribution of Protected Areas in Six Major Economic Corridors[5]

Southeast Asia and the Bangladesh-India-Myanmar region are also the main region of key biodiversity protected areas. They are scattered, but the population is very considerable. Southeast Asia belongs to the equatorial climate zone, with some areas turning arid; the area is mostly made up of hills and mountains, and the soil is mainly acrisols and inceptisols; there is abundant precipitation, which easily turns into runoff; and plentiful vegetation, including woodland and cultivated land. The Bangladesh-India-Myanmar region belongs to the equatorial climate zone, and the eastern part of the region has a trend of aridification; the terrain is flat, and the soil is mainly Alfisols and Vertisols; it is rich in precipitation and vegetation including woodland and cultivated land. The climate in these two areas is warm and humid, and the soil mainly comprised of Alfisols has strong fertility, which is the ideal habitat for many organisms.

There are also a large number of key biodiversity protected areas in Central and Eastern Europe. This area belongs to the cool temperate climate zone, and the western part shows a trend of aridification; the terrain is low and flat with a gentle slope, and the soil mainly consists of podzols and chernozems; there is plentiful precipitation, which easily turns into runoff; the vegetation is mainly composed of woodland and cultivated land, which is also an area rich in biodiversity.

[5] WWF. The Belt and Road Initiative: WWF Recommendations and Spatial Analysis. 2017

2.3 Sensitivity Analysis of Biodiversity in the Six Economic Corridors of the BRI[6]

In the previous chapter, the key biodiversity areas of the BRI have been identified and visualized. This chapter mainly makes a preliminary spatial analysis of the potential areas where the biodiversity and natural resources may be affected by the development of the BRI. The report selects typical biodiversity protected ecological environments, and determines the sensitivity factors suitable for assessing areas according to the natural, social and economic conditions of different ecological environments. Through the comprehensive ecological sensitivity assessment method, the ecological environment sensitivity is evaluated both qualitatively and quantitatively by taking into account various factors such as ecosystem changes, animal and plant species and habitat changes, and migration routes.

The BRI involves many areas that are important to the environment, such as protected areas, key landscapes, WWF Priority Ecoregions, biodiversity hotspots that major species inhabit, and important areas that produce social and economic benefits and provide ecosystem services. Combined with the map data set of the BRI overland economic corridors, the ecological environment sensitivity analysis is carried out, including the following aspects:

a) Threatened species. The analysis of the IUCN Red List data shows that the six economic corridors in the BRI overlap with the habitats of 265 threatened species, including 39 critically endangered species and 81 endangered species, such as the saiga antelope, tiger and giant panda.
b) Areas of great significance to the environment. We believe that the overlapping parts of the six major economic corridors of the BRI and the identified key biodiversity areas will be the areas of great significance to environmental protection in the corridors.
c) Biodiversity protected areas. All protected areas that the six major economic corridors of the BRI pass through may be affected. Specifically, 32% of the total protected area of the BRI participating countries may be affected.
d) Ecological environment characteristics. In the regions with the greatest ecological environment characteristics, the newly built roads connecting remote areas will have a more serious long-term impact than the expansion or reconstruction of existing roads.
e) Overall impact. The overall impact of the six major economic corridors of the BRI on the key biodiversity protected areas is presented through the equal-weighted average of the above factors (Figure 9).

We have divided the degree of impact into five levels, and expressed them by color. The greener the color, the lower the impact; the redder the color, the higher the impact. At the same time, we have marked the six major economic corridors of the BRI on the map, so as to more clearly reflect the potential impact of infrastructure development in countries and regions along the BRI.

[6] WWF. The Belt and Road Initiative: WWF Recommendations and Spatial Analysis. 2017

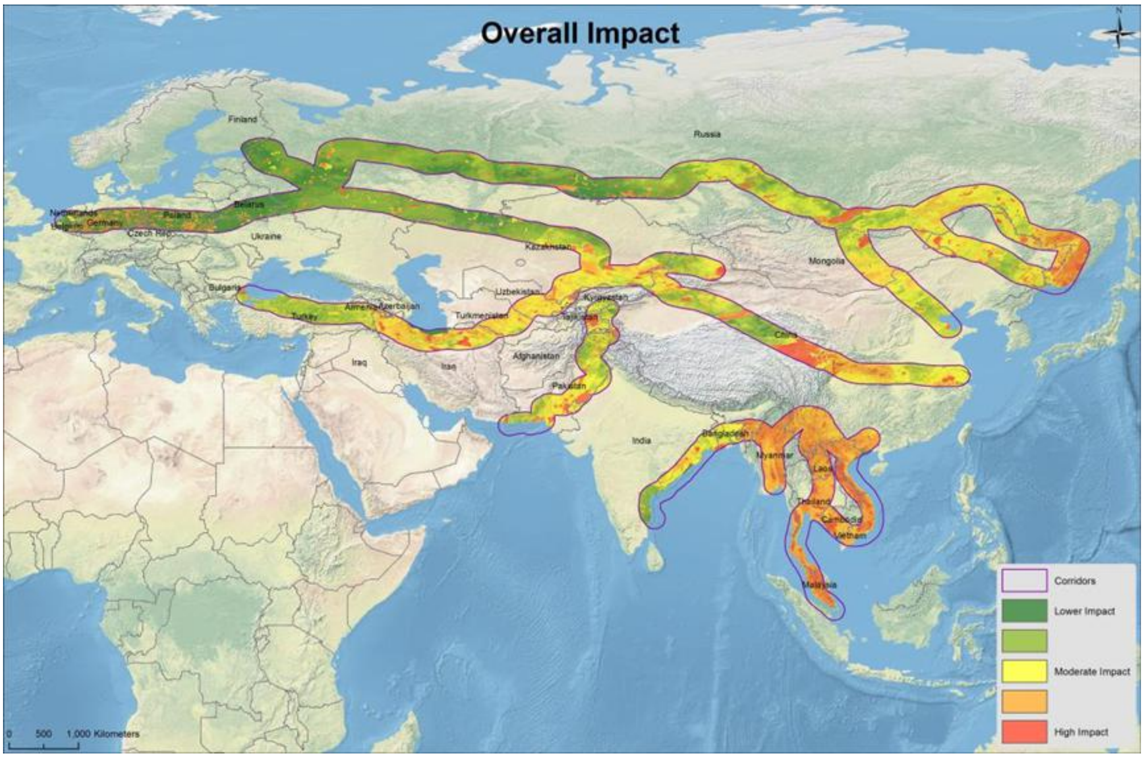


Figure 9. Potential Impacts of the Six Economic Corridors of the BRI on KBAs

According to the results of this analysis, the potential overall impact of economic corridors on KBAs presents a trend of decreasing spatial distribution progressing from the east to the west and from the south to the north. Southeast Asia and the border area between China and Russia at the east end of the Eurasian continent show the highest potential impact and are the most ecologically sensitive areas, while central and east European regions show exactly the opposite.

In the context of differing levels of economic development, the potential impact of this construction on biodiversity is lower in Europe than in less developed regions including Southeast Asia, Central China and the China-Russia border area. Part of the difference may be explained by the fact that the environmental vulnerabilities of these regions differ:

1) The ecological environment of Central Asia is of moderately high sensitivity. As the world's largest non-zonal arid area, water resources are extremely scarce. In recent years, ecological and environmental issues have become ever more prominent, marked by water shortages and the Aral Sea ecological crisis. For example, the water shortage crisis is worsening as melt-water from mountain ranges is reducing due to global warming, and more water is being used for large-scale agricultural irrigation as a result of rapid population growth.

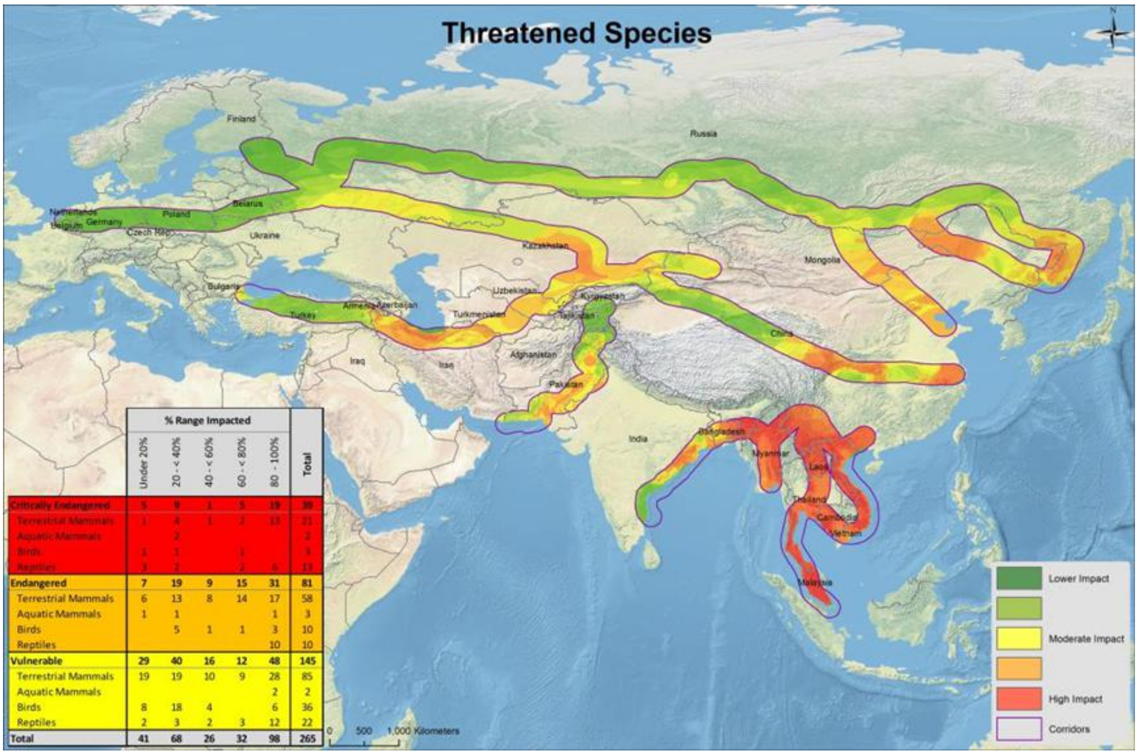
2) West Asia features a moderately-sensitive ecological environment. Given its shortage of rivers and underground water, it is one of the driest places on Earth. Today, water shortages have been one of the most significant impacts of climate change on countries in this region. As wet seasons shorten, the frequency of droughts increase and the ecosystem deteriorates, making the region more ecologically sensitive. Meanwhile, as a result of water shortage, Central and

West Asia are in desperate need of water infrastructure to extract water resources, the construction of which may increase the sensitivity of the local ecological environment.

3) In Southeast Asia, the overall ecological sensitivity is high. The main reason for this lies in marine disasters caused by extreme weather, which is fueled by climate change.

4) The China-Russia border area at the east end of Asia and the Tibetan plateau in Central China are characterized by low temperatures, poor rainfall, simple ecosystem structures, low resistance to disturbance, high frequencies of natural disasters, and high vulnerability to changes in the global environment. The Tibetan plateau is witnessing intensified localized and short-term changes as its ecosystem stability is weakened by human activities. In addition, economic activities such as mining, biological and tourism development are severely damaging local grassland ecosystems, and have caused localized grassland degradation, loss of wetland and desertification, generating a far-reaching impact on the overall vulnerable alpine ecosystems.

The analysis also examined the sensitivity of threatened species within the six economic corridors to find out how severely they may be affected by the proposed infrastructure (see Figure 10). They are divided into three groups: critically endangered, endangered and vulnerable, on the basis of the degree of the threat of extinction. Each group is categorized in a five-level range from lower potential impact (indicated in green on the maps) through to higher potential impact (indicated in red), with each level increasing by 20 percentage points.



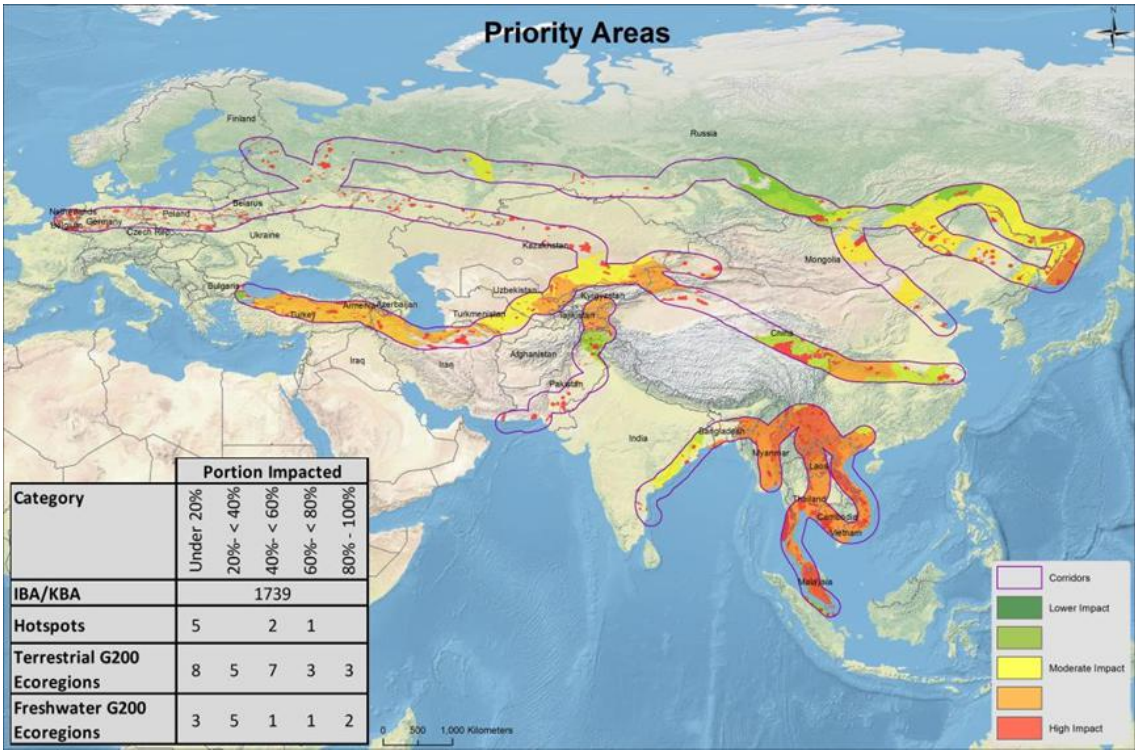
	% Range Impacted					
	Under 20%	20 - < 40%	40 - < 60%	60 - < 80%	80 - 100%	Total
Critically Endangered	5	9	1	5	19	39
Terrestrial Mammals	1	4	1	2	13	21
Aquatic Mammals		2				2
Birds	1	1		1		3
Reptiles	3	2		2	6	13
Endangered	7	19	9	15	31	81
Terrestrial Mammals	6	13	8	14	17	58
Aquatic Mammals	1	1			1	3
Birds		5	1	1	3	10
Reptiles					10	10
Vulnerable	29	40	16	12	48	145
Terrestrial Mammals	19	19	10	9	28	85
Aquatic Mammals					2	2
Birds	8	18	4		6	36
Reptiles	2	3	2	3	12	22
Total	41	68	26	32	98	265

Figure 10. Potential Impacts of the Six Economic Corridors of the BRI on Threatened Species

As shown in Figure 10, in terms of absolute numbers, fewer critically endangered species are likely to be affected, followed by endangered species, then vulnerable species in ascending order. With regard to species, terrestrial mammals will be the most widely affected, with about 56.8%, 71.6% and 58.6% of critically endangered, endangered and vulnerable terrestrial mammals subject to potential impact respectively. The next are reptiles, of which about 29.7%, 12.3% and 15.2% of critically endangered, endangered and vulnerable reptiles are expected to be affected respectively. Birds and aquatic mammals come third and fourth in terms of potential impact.

The results are in line with the construction environments of the planned infrastructure. Mostly located on land, these projects will take up or even destroy the habitats of species living predominantly or entirely on land, leading to a high potential impact on terrestrial mammals and reptiles. Geographically, Southeast Asia shows the highest potential impact, because the mild and humid region covered by rich vegetation is home to a large number of species, especially those under threat.

Figure 11 shows the ecological sensitivity of major biodiversity areas. Identified in accordance with the databases mentioned above, KBAs, biodiversity hotspots and WWF priority ecoregions within the proposed economic corridors are categorized in a five-level range from lower potential impact (indicated in green) through to higher potential impact (indicated in red), with each level increasing by 20 percentage points.



Category	Portion Impacted: Under 20%	20%- < 40%	40%- < 60%	60%- < 80%	80% - 100%
IBA/KBA	1739				
Hotspots	5		2	1	
Terrestrial G200 Ecoregions	8	5	7	3	3
Freshwater G200 Ecoregions	3	5	1	1	2

Figure 11. Potential Impacts of the Six Economic Corridors of the BRI on WWF Priority Ecoregions

According to the results of the analysis, 1,739 major biodiversity areas in the six economic corridors are likely to be affected. Among the KBAs whose potential impacts can be identified, 56.5% show a potential impact less than 40%, and 57% are terrestrial priority ecoregions. Among the WWF priority ecoregions, 13% of those on land and 6% of those at sea may be affected.

These findings are consistent with those of the analysis looking at the ecological sensitivity of threatened species. Terrestrial KBAs can be more easily affected or even destroyed by the construction of infrastructure projects, while only a limited number of marine ones show a potential impact and most of these are located in Southeast Asia. Europe sees a relatively sparse scattering of KBAs expecting to be affected, but their potential impacts are generally upper-moderate or high. European KBAs indicating high risks are mostly found in developed countries at the western end of the continent, where dense populations are taking up more natural space, despite their remarkable records with regard to potential overall impact and the impact on threatened species.

The results of this sensitivity analysis reveal two important points: (1) there is significant potential overlap between the terrestrial BRI corridors and areas that are important for biodiversity conservation and for the provision of social and economic benefits to people; (2) these overlaps indicate risk areas for potentially negative impacts of infrastructure development. Follow up analysis is required to fully document the potential overlap, to identify potential solutions, and to develop opportunities for investment in ecological infrastructure.

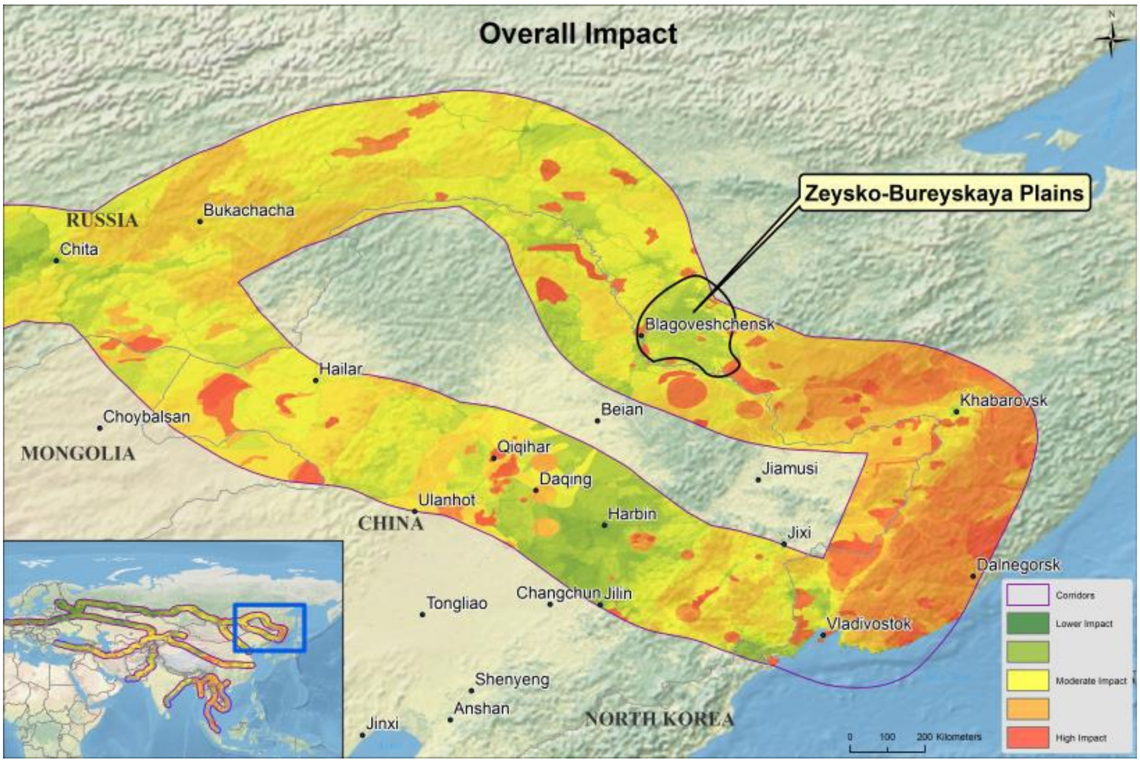


Figure 12. Potential Impacts of the BRI on Zeysko-Bureyskaya Plains

The current analysis still has a number of limitations. For instance, “green” on the map does not mean that the infrastructure project in question is eco-friendly. The Russian Far East contains large areas of intact forest landscapes and valuable wetland ecosystems, home to many threatened species that will all be impacted by the BRI. The spatial analysis correctly identifies high risk areas of the BRI corridors in Primorsky and Khabarovsky provinces, which are home to the Korean pine (Pinus koraiensis) broadleaf forests and the habitat of the Amur tiger (Panthera tigris altaica). However, in the spatial analysis, the Zeysko–Bureyskaya plains (Amursky province) show up in “green,” which indicates “low risk” (see Figure 12), despite the fact that this is a very important area for the conservation of several threatened species: including the Oriental white stork (Ciconia boyciana), the Red-crowned crane (Grus japonensis) and the Daurian crane. This example shows the need for further detailed analysis before planning and implementing BRI projects.

3. Impact of Transportation Infrastructure on Biodiversity under the BRI

According to *Vision and Proposed Actions Outlined on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road*, the BRI focuses on building six main economic corridors: (1) the China-Mongolia-Russia corridor; (2) the New Eurasian Land Bridge; (3) the China-Central Asia-West Asia corridor; (4) the China-Pakistan corridor; (5) the China-Indochina Peninsula corridor; and (6) the Bangladesh-China-India-Myanmar corridor. In building these corridors, one of the top priorities is to construct transportation infrastructure to achieve interconnectivity, which is based on respect for other nations' sovereignty and security interests. This will further align with the BRI-related countries' planning and technical standards for the construction of transportation infrastructure, jointly advance the construction of key international passageways, and gradually establish a network of transportation infrastructure connecting every subregion in Asia, and between Asia, Europe and Africa[7].

The construction of transportation infrastructure plays a major role in promoting economic development, trade and cultural exchange among the BRI-related countries. However, traffic road networks, as a linear type of network, consist of long-distance and large-scale traffic passages that lead to the fragmentation of habitats, while also exerting a profound and irreversible impact on the ecosystem of the surrounding area. This impact is regarded as one of the most extensive human disturbances to the natural ecosystem of the past century —[8], and countries worldwide have attached great importance to it.

A. Impact During Construction

During the construction of transportation infrastructure, the construction site and its ancillary facilities have led to the occuption and use of a large amount of land, destroying all the vegetation in the construction area and the animal habitats, as well as altering the biodiversity of the affected area. Moreover, the construction activities and the movement of heavy machinery and workers will destroy and affect the vegetation in and around the construction site to varying degrees, thus affecting the living conditions of certain animals and plants[9].

The composition of vegetation in the project area has undergone significant changes, seeing sharp decreases in the number of certain species. For example, around the transportation infrastructure, the arbor trees within the roadside area are the most negatively affected. An investigation found that a great number of formerly dominant trees have been felled during the road construction process, resulting in there being almost no trees near the road. Without the competitive arbor trees, shrubs and herbs have gained more access to sunlight, water, and space, finally replacing arbors as the new dominant species.

---

7 .Jin Jing. "Risk Assessment Study on the Construction of International Railway Corridors under BRI [D]. China Academy of Railway Science, 2019.

8 Noss R F and Cooperrider A Y. Saving nature's legacy. [M]. Washington, D. C.: Island Press, 1994.

9 Shangguan Baoguo. Analysis of the Impact of Construction of the Ningde Section of Quning Railway on Regional Biodiversity [J]. Forest Investigation Design, 2019(01):40-42.

Wildlife living conditions in the project area have also been changed. Cropland, parkland, woodland, mudflats, and other landforms are the basis for wildlife survival and habitats. Railway construction will radically alter these landforms, forcing wildlife to migrate to nearby areas, some of which will not survive, thus affecting the wildlife population for a certain period. With the continuous improvement of railway construction technology, large machinery is mainly used for construction, causing beneficial wildlife such as frogs and insects to be buried as they run too slowly to avoid the large machinery. In an ecosystem, species are interconnected with other species and the environment, and the demise of one species is very likely to trigger a series of chain reactions.

At the same time, the transportation network will also bring about an ecological island effect. The road network fragments the originally unified ecosystems into individual ecological islands. Among the birds and mammals that have become extinct in modern times, three quarters are island creatures, and history has shown that species diversity is more fragile in an isolated island ecosystem. As wild animals have a very wide range of activities, their survival and reproduction are at the greatest risk from the ecological island effect. For example, the Tibetan antelope native to the Qinghai-Tibetan Plateau in China usually spends the cold and harsh winter in the Goluo Basin and in the summer migrates in groups to the Zhuonai Lake, Sun Lake, and Hoh Xil Lake, where there are abundant resources and few natural enemies, to reproduce. The fragmentation of their habitat by roads results in inadequate food and the inability to mate, posing a great challenge for them to survive. The impact of roads on wildlife is not only to hinder their migration, but also to increase poaching, deforestation, and threats to endangered species[10].

B. Impact During Operations

Human activities alter regional biodiversity. With the increased frequency of human activities, such as trains stopping to wait for another train passing, and the management and maintenance of equipment used for rail transport, the level of human disturbance towards regional biodiversity increases accordingly. Water pollutants such as domestic sewage and animal and plant oils that are discharged from human living areas during operations will alter the living conditions for plants and animals. Frequent human activities increase the risk of invasive alien species, which to some extent may threaten the forest ecosystem in the surrounding area.

Noise also affects the distribution and quantity of animal populations. More tunnels mean an increased number of sirens from rail transport vehicles, and the physical barriers between tunnels and mountains increase sound penetration and reverberation, which will disturb the normal activities of animals and force them to migrate elsewhere, resulting in reduced regional animal populations and even affecting population distribution. Moreover, the lower demand for rail transport in mountainous areas means less frequency of departures, and occasional noise is more likely to disturb animal behavior than continuous noise.

Railway safety facilities restrict the range of animal activities. As mountains are steep, huge numbers of protective nets are required on both sides of the railway to ensure safe rail transport.

[10] Xie Yulin. Analysis of the Impact of Transportation Industry on Ecological Environment. Shanxi Architecture, 2018, 44(10):181-183.

However, the installation of protective nets, to some extent, restricts the activities of animals, and when it comes to the predator food chain, the nets may determine life and death of the prey, thus affecting the balance of the ecosystem.

3.1 Analysis of Railway Project's Awareness of Ecological Environment[11]

The total length of the railway networks connecting the countries participating in the BRI is about 384,500 km, accounting for 28% of the world's total railways. This large-scale network has significant region-specific differences in terms of scale, distribution density, and technical level. See the basic information in Figure 13 and Table 1. The Mongolia-Russia region, due to its vast land area and large route network, has the longest railway mileage of 78,700 km, accounting for 20.46% of the total railway mileage of BRI countries; China comes next, with a large-scale road network and railway mileage accounting for 20%, and then comes Southeast Asia and Eastern Europe, with their railway mileage accounting for 17% and 14.3% respectively, while Central Europe and West Asia account for 9.9% and 8.29% respectively, and Southeast Asia and Central Asia have a shorter railway mileage, accounting for 5.6% and 4.5% respectively.

In terms of network density, Central Europe has the highest rail network density of 714.13 km/10,000 km^2, which is the result of a long history of construction; Eastern Europe has a rail network density of 332.9 km/10,000 km^2, then comes South Asia with a higher railway network density of 127.05 km/10,000 km^2, and China has reached 78.87 km/10,000 km^2. Central Asia, the Mongolia-Russia region, Southeast Asia and West Asia have similar rail network densities, ranging between 42 and 49 km/10000 km^2 (see Table 1).

Railway development in Russia, Central Asia, West Asia, and South Asia has been slow, with aging railway lines and technical equipment lagging seriously behind the Chinese and European railway networks. The railway network of Tajikistan has not yet been electrified, the electrification rate in Uzbekistan and Belarus is only 16.7% and 16.5% respectively, and in Kazakhstan, it stands at 28.3%. High-speed railway is currently the most efficient mode of railway transport and has become a symbol reflecting the level of railway technology in a country (see Table 2). China has 22,000 km of high-speed railways, Turkey has 1,420 km, and few other countries have high-speed railways.

[11] Liu Weidong et al, Third-party Assessment Report on the Progress of Construction under BRI, The Commercial Press, 2019.

Table 1 Fact Sheet about Railway and Highway Construction in BRI Regions

Region	Railway		Highway	
	Length (km)	Density (km/10,000 km^2)	Length (km)	Density (km/10,000 km^2)
Central Asia	17132	42.81	25129	62.8
Mongolia-Russia	78669	42.09	42196	22.6
Southeast Asia	21706	48.28	64236	142.9
South Asia	65264	127.05	56451	109.9
Central Europe	38093	714.13	18994	356.1
Eastern Europe	55027	332.96	45491	275.3
West Asia	31858	43.22	95685	129.8
China	76773	78.87	169254	173.9

Table 2 Statistics on the Mileage of Major High-speed Railways in BRI Countries

Country/Region	Operation/km	Construction/km	Length/km	Speed/km/h
China	22000	18155.5	38155.5	350
Turkey	1420	1506	2926	250
Russia	645	770	1415	250
Uzbekistan	344	256	600	250
Poland	85	322	417	200

Table 3 Railway Construction Projects along BRI

Railway Name	Railway Starting City/Country	Status
China-Laos Railway	China-Laos	Under Construction
Tehran-Isfahan High-speed Railway	Tehran-Isfahan, Iran	Under Construction
Jakarta-Bandung High-speed Railway	Jakarta-Bandung, Indonesia	Under Construction
China-Thailand Railway	Nong Khai-Bangkok, Thailand	Under Construction
Lao Cai-Haiphong Railway	Lao Cai-Haiphong, Vietnam	Under Research
Tehran-Mashhad High-speed Railway	Tehran-Mashhad, Iran	Under Construction

Moscow-Kazan High-speed Railway	Moscow, Russia-Beijing, China	In Design
China-Kyrgyzstan-Uzbekistan Railway	Kashgar, China-Andijan, Uzbekistan	In Design
Hungary-Serbia Railway	Budapest, Hungary-Belgrade, Serbia	Open to Traffic
Addis Ababa–Djibouti Railway	Djibouti-Addis Ababa	Open to Traffic

Roughly estimated data as of August 2020.

Figure 13 Railway Networks Across BRI Countries

Figure 13 shows a visualization of the distribution of railways in BRI country regions (red lines in the figure) and their overlap with Key Biodiversity Areas (green blocks of different shades in the figure). The visualization shows that the railway network has the highest density in the east and west sides of BRI regions, and reach the highest density in Europe. In the European region with the highest rail network density, almost all the Key Biodiversity Areas (KBAs) are heavily impacted by infrastructure, although they are sparse and scattered. In Southeast Asia, with its lower rail network density, KBAs are distributed in contiguous areas and moderately or heavily impacted by infrastructure.

In Europe, where the economy is more developed, the railway network has a long history of construction and operation, and the impact on KBAs has taken place over a long period and wide geographic range. According to the above analysis of the impact of transportation on biodiversity, there has been a cumulative impact on biodiversity during the construction and operation of railways, especially in the early stages of industrial development, when people's awareness of environmental protection was very low, and therefore the ecological side effects of railway construction were rarely considered. Consequently, KBAs within the scope of Europe are greatly affected by infrastructure.

Meanwhile in Southeast Asia, although the railways are not very densely distributed, many KBAs have also been significantly affected, probably due to the fragile ecology of the region. Therefore, railway projects on a smaller scale than those in Europe can also have a great impact on KBAs. Another reason is that the large number and dense distribution of KBAs in the region have various connections, and even the smallest change can easily affect the whole system. The damage to KBAs by the construction and operation of railway projects can easily lead to ecosystem imbalance in the vicinity of KBAs. For example, the animals whose habitats are invaded have to migrate to the surrounding protected areas and become invasive species in those areas. Additionally, the countries in Southeast Asia are less economically developed, so they have a high demand for railways in order to drive economic development, while investing less in ecological and environmental protection. Under such circumstances, these countries are prone to adopting "treatment after pollution" measures, resulting in greater damage to the ecological environment.

3.2 Analysis of the Highway Project's Awareness of Ecological Environment[12][6]

In 2019, the mileage of arterial highways in BRI countries has totaled about 517,400 km, with the mileage and network density varying significantly by region, as shown in Figure 14. Among the BRI regions, China has the longest mileage of arterial highways at 169,300 km, accounting for 32.7%, followed by West Asian countries, accounting for 18.49%, and Southeast Asia, South Asia, Eastern Europe, and Mongolia-Russia region, accounting for 12.4%, 10.9%, 8.79%, and 8.15% respectively, while Central Asia and Central Europe have the shortest mileage, accounting for 4.86% and 3.67% respectively.

In terms of the distribution density of the road network (see Table 1), Central Europe has the highest density of arterial highway network, which is 356 km/10,000 km^2; in Eastern Europe, the density is 275.3 km/10,000 km^2, much higher than other regions. In China, Southeast Asia, West Asia, and South Asia, density ranges from 105 to 175 km/10,000 km^2. Central Asia and the Mongolia-Russia region have the lowest density of road networks, especially in the Mongolia-Russia region, where it is only 22 km/10,000 km^2.

Countries except for China and the European region generally have lower technical levels of roads (fewer lanes), congestion on arterial roads, old and dilapidated roads with poor pavement conditions (cracked and aging), and fewer high-grade roads, especially in national border areas. In 2017, China's highway mileage reached 136,500 km, much higher than other countries, followed by Russia with a highway mileage of 30,000 km, and Saudi Arabia with 3,900 km. There are no

[12] Liu Weidong et al, Third-party Assessment Report on the Progress of Construction under BRI, The Commercial Press, 2019.

highways in Central Asia, and the scale of highways in South Asia is relatively small. Pakistan has a highway mileage of 708 km, and Myanmar has 358 km, but their highways are not fully enclosed and have poor quality road surface, so they are essentially only pseudo-highways.

As shown in Table 4, an analysis of the technical level of Asian highway networks shows that only four countries, namely China, Pakistan, Iran, and Turkey, have arterial highways, and the highways are mainly found in China, Russia, India, Kazakhstan, and Iran, at 10,800 km, 17,300 km, 11,700 km, 12,800 km and 11,100 km in length, respectively. While the countries with an above-average share (above 73.6%) of highways are China (97%), Russia (83.5%), Bangladesh (97.2%), India (92.5%), Uzbekistan (77.4%), Iran (100%), Turkey (89.6%), Armenia (89.9%), Azerbaijan (100%) and Georgia (84.2%). The proportion of high-grade Asian Highway (AH) roads in Central Asia is generally low, only 45.6%. For more details, see the "Fact Sheet about Highway Projects in BRI Regions" in Table 5. Most have already been completed and opened to traffic.

Table 4 Distribution of Roads at Different Technical Levels[13] in BRI Countries

Country/Region	Primary	Class I	Class II	Class III	Below Class III
China	8437	230	1855	321	4
Russia		2367	12080	1616	814
Four South Asian Countries	447	6485	8234	4970	3167
Bangladesh		311	1400	44	5
India	90	4738	5984	782	96
Myanmar		320	575	1702	1928
Pakistan	357	1116	275	2442	1138
Five Central Asian Countries		1812	8078	9861	1849
Kazakhstan		557	5407	6389	475
Kyrgyzstan			303	1324	136
Tajikistan		20	978		914
Turkmenistan		60		2120	24
Uzbekistan		1195	1101	670	
Six West Asian Countries	3344	7972	10414	791	1501
Afghanistan		10	2549		1461
Iran	1885	4179	5070		

[13] Asian Highway Network (AH) classifies highways into four types: primary, class I, class II and class III. Primary class are access-controlled vehicular highways, built with asphalt or cement concrete. Class I highways have four or more lanes, built with asphalt or cement concrete. Class II are two-lane roads built with asphalt or cement concrete. Class III are two-lane roads built using double bituminous treatment.

Turkey	1459	3272	3	551	
Armenia		147	721	58	40
Azerbaijan		290	1174		
Georgia		74	897	182	
Total	12228	18886	40372	18201	7035

Table 5 Fact Sheet about Highway Projects in BRI Regions

Highway Name	Highway Starting City/Country	Status
Second Beilun River Bridge	Dongxing, China-Mong Cai, Vietnam	Open to Traffic
Heihe-Blagoveshchensk Heilongjiang Highway	Heihe, China-Blagoveshchensk, Russia	Open to Traffic
Blagoveshchensk-Heihe Cable Line	Heihe, China-Blagoveshchensk, Russia	Under Construction
China-Kyrgyzstan-Uzbekistan International Highway	Kashgar, China - Tashkent, Uzbekistan	Open to Traffic
Karakoram Highway Phase II	Havellian-Thakot, Pakistan	Open to Traffic
Ethiopian AA Highway	Addis Ababa-Adama, Ethiopia	Open to Traffic
Brunei Temburong Bridge	Local Area-Temburong District, Brunei	Open to Traffic
Western Europe-Western China International Highway	Lianyungang, China-St. Petersburg, Russia	Open to Traffic
Gwadar East Bay Expressway	Gwadar Port-Makran Coastal Highway, Pakistan	Open to Traffic
Karachi-Peshawar Highway	Karachi-Peshawar, Pakistan	Under Construction

Roughly estimated data as of August 2020.

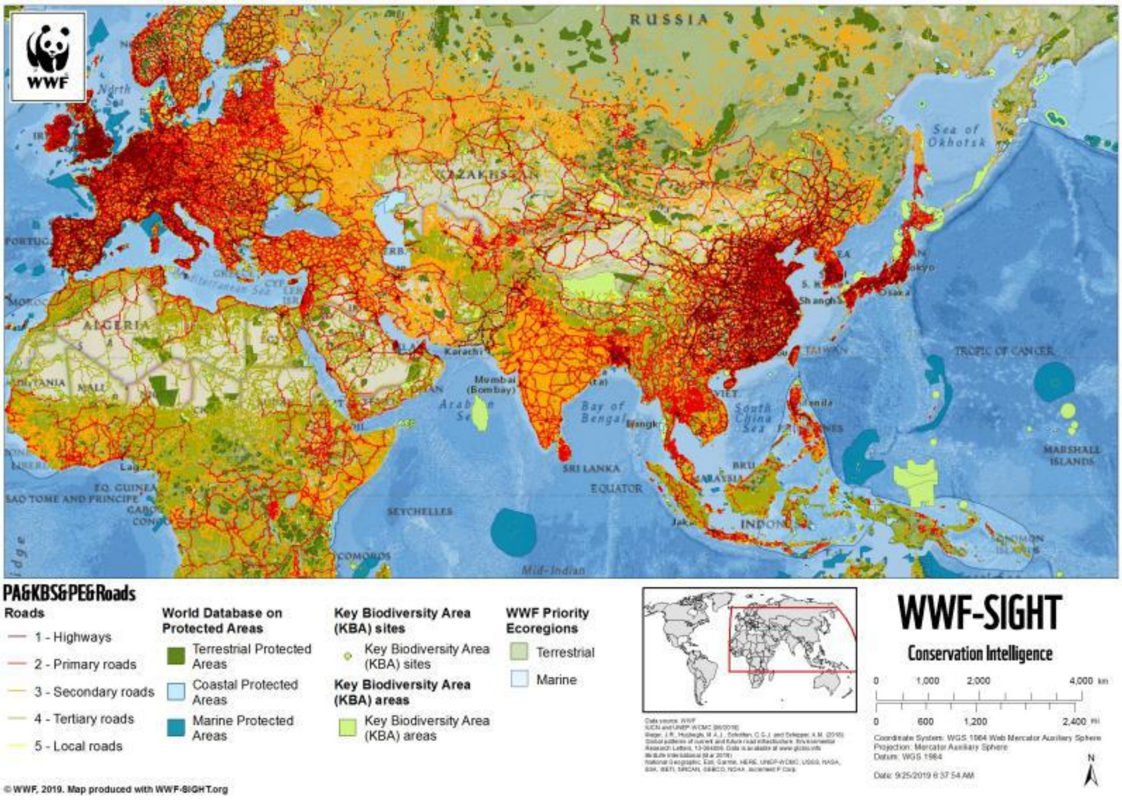


Figure 14 Highway Networks Across BRI Countries

Figure 14 shows the visualization results of the overlap between highway networks in BRI countries and KBAs. The visualization shows that the density of the road network decreases and then increases from east to west, with the densest distribution and highest grades of roads in Europe and eastern China.

The density of the road network is positively correlated with the extent to which KBAs are affected, which is to say, the denser the road distribution, the greater the extent to which KBAs are affected. However, even for regions with similar road densities, KBAs are affected differently, and vice versa. Southeast Asia has a lower road network density compared with central China, but its KBAs are affected to a greater extent than those of central China. West Asia has a similar density of road network to Southeast Asia, but its biodiversity is affected to a lesser extent than Southeast Asia. The easternmost region of the Eurasian continent, i.e., the China-Russia border region, has a lower road network density, but the KBAs are greatly affected.

The reasons for these differences may be related to the characteristics of the local ecological environment, and the conservation policies adopted by different countries or local authorities. The China-Russia border region has a cold climate and a homogeneous and fragile ecosystem, native to many rare species that are vulnerable to road construction. Southeast Asia, although rich in ecological diversity, is more affected by disasters such as marine storms brought about by climate change, and has a higher environmental vulnerability. Most of the KBAs in the Sino-Russian border region and Southeast Asia stretch the borders of multiple countries, and due to political considerations and division of power and responsibilities, it is difficult for unilateral national or local environmental conservation policies to influence the ecological environment of these areas, and such areas are easily left unattended. Therefore, a certain level of bilateral or multilateral cooperation is needed for conservation purposes, but the negotiation process is time-consuming and involves a wide range of parties and considerations, so it is more difficult to implement the negotiated results than that of the KBAs in a single territory. Due to a variety of such factors, these areas are more affected by the construction and operation of infrastructure, such as roads, than other areas.

3.3 Monitoring and Assessment of the Impact of Transportation Infrastructure Projects on the Ecological Environment[14]

The above sections have conducted a macro analysis of the biodiversity impact of two main transportation infrastructures, i.e., railways and roads. The analysis provided is mainly based on the construction of railways and roads and their overall impact on KBAs. However, the impact of railways and roads on biodiversity is multi-faceted. Moreover, as major projects have a longer duration and a wider range of influence, their impact on biodiversity is more representative and comprehensive. Therefore, this report refers to the results of the Ecological Status and Situation in BRI Regions (2018), selecting representative major transportation infrastructure projects to focus on measuring their impact on vegetation coverage and ecological footprint, then to present the impact of infrastructure on biodiversity in a more specific way.

3.3.1 Impact of Completed Projects on Ecological Environment

(1) Impact on Vegetation

Vegetation coverage is one of the most important ecological parameters in the field of remote sensing science and correlates significantly with vegetation growth and biodiversity. The higher the vegetation coverage, the higher coverage of the vegetation on the land surface. Before the project's construction and in the summer of 2017, the National Remote Sensing Center of the Ministry of Science and Technology of the People's Republic of China (2018) extracted information about the vegetation coverage within the 10.00 km buffer zone along the completed projects (see Table 6) based on Landsat-8 satellite remote sensing images. Based on this information, the center compared and analyzed the impact of project construction on the ecological environment along the project route.

The analysis shows that the vegetation coverage along the project routes is mainly in the range of 0.40-0.80. Less than 50% of the areas along the Mombasa-Nairobi Standard Gauge Railway, Addis Ababa-Djibouti Railway, and Angren-Pap Railway have a vegetation coverage greater than 0.60, which is closely associated with the local arid climate. For example, the East African plateau is affected by a tropical grassland climate, with low and unevenly scattered annual precipitation, which is unfavorable for vegetation growth. Among the four railways that have been built, the

[14] National Remote Sensing Center of the Ministry of Science and Technology of China, Ecological Status and Situation in BRI Regions (2018), 2018.

vegetation coverage along the Addis Ababa-Djibouti Railway is the lowest, and 35.00% of such areas have a vegetation coverage ranging from 0.00 to 0.20; while the vegetation coverage along the Jakarta-Bandung High-speed Railway is the highest, with 78.88% of such areas having a vegetation coverage greater than 0.60.

A comparative analysis of the vegetation coverage before the project construction and in 2017 shows that all the four constructed railways have seen an increase in vegetation coverage in 2017 compared with the coverage before construction. Additionally, as for the proportion of the areas with a vegetation coverage ranging from 0.40 to 1.00, Mombasa-Nairobi Standard Gauge Railway has seen an increase from 74.85% to 89.09%, up 14.24%; Addis Ababa-Djibouti Railway has seen an increase from 35.54% to 40.13%, up 4.59%; and Angren-Pap Railway has seen an increase from 51.48% to 51.98%, up 0.47%.

Table 6 Statistics of Different-range Vegetation Coverage at Project Completion in 2017 and Before Construction

Project Name	Year	Category	Vegetation Coverage Range					0.40-1.00 Subtotal	Total
			0.00-0.20	0.20-0.40	0.40-0.60	0.60-0.80	0.80-1.00		
Mombasa-Nairobi Standard Gauge Railway	2013	Area (km^2)	94.98	2306.66	5700.96	1446.25	0.95	7148.16	9549.80
		Proportion (%)	0.99	24.15	59.71	15.14	0.01	74.85	100.00
	2017	Area (km^2)	85.98	955.54	4063.78	3539.30	904.80	8507.88	9549.80
		Proportion (%)	0.90	10.01	42.55	37.06	9.48	89.09	100.00
Addis Ababa-Djibouti Railway	2011	Area (km^2)	5862.21	2851.07	4175.35	626.90	1.94	4804.19	13517.47
		Proportion (%)	43.37	21.09	30.89	4.64	0.01	35.54	100.00
	2017	Area (km^2)	4741.95	3350.50	4020.38	1354.84	49.80	5425.02	13517.47
		Proportion (%)	35.08	24.79	29.74	10.02	0.37	40.13	100.00
Angren-Pap Railway	2012	Area (km^2)	459.35	348.08	337.05	288.45	231.35	856.85	1664.28
		Proportion (%)	27.60	20.91	20.25	17.33	13.90	51.48	100.00
	2017	Area (km^2)	488.24	311.48	284.52	286.42	293.62	864.56	1664.28
		Proportion (%)	29.34	18.72	17.10	17.21	17.64	51.85	100.00

(2) Ecological Footprint

By visualizing the distribution of ecological resources in the 10.00 km buffer zone along the project route before the start of construction, the ecological resources are classified into woodland, grassland, cropland, and other land usages. Then, the ecological footprint area required by the project construction and the area that will suffer temporary and permanent ecological loss can be estimated based on the width of the project roadbed, the area with permanent construction, and the overall width of the construction area. Losses that cannot be repaired, such as roadbeds and other permanent ecological footprints, are permanent ecological losses; other occupations required by construction are temporary ecological losses, which in theory can be repaired after project completion.

The results of remote sensing monitoring of the ecological resources before the construction of the four projects are shown in Table 7. In general, the proportion of woodland, grassland, and cropland along each project route exceeds 50.00%, with grassland dominating along the Mombasa-Nairobi Standard Gauge Railway, Addis Ababa-Djibouti Railway, and Jakarta-Bandung High-speed Railway, accounting for 47.82%, 56.38%, and 45.15% respectively, while Angren-Pap Railway is dominated by other ecological land types that account for 49.11%.

Table 7 Pre-construction Information about the Ecological Resources Within the 10 km Buffer Zone Along the Completed Project Route

Project Name	Category	Woodland	Grassland	Cropland	Other Lands	Total
Mombasa-Nairobi Standard Gauge Railway	Area (km^2)	399.12	4567.12	3477.66	1105.90	9549.80
	Proportion (%)	4.18	47.82	36.42	11.58	100.00
Addis Ababa-Djibouti Railway	Area (km^2)	666.51	7621.81	669.52	4559.63	13517.47
	Proportion (%)	4.93	56.38	5.95	33.73	100.00
Angren-Pap Railway	Area (km^2)	118.89	399.66	328.34	817.39	1664.28
	Proportion (%)	7.14	24.01	19.73	49.11	100.00
Jakarta-Bandung High-speed Railway	Area (km^2)	1339.61	1603.44	416.74	192.06	3551.85
	Proportion (%)	37.72	45.15	11.73	5.40	100.00

According to the statistics on the ecological footprint of different projects (see Table 8), the average ecological area occupied per kilometer of the four completed railways (Mombasa-Nairobi Standard Gauge Railway, Addis Ababa-Djibouti Railway, Angren-Pap Railway, and Jakarta-Bandung High-speed Railway) is 0.04, 0.07, 0.03 and 0.02 km2 respectively. The types of ecological resources with the greatest ecological occupation (or ecological loss) vary greatly from project to project: the relatively high loss of cropland is found along the Angren-Pap Railway and Jakarta-Bandung High-speed Railway; and the relatively high loss of grassland is found along the Mombasa-Nairobi Standard Gauge Railway and Addis Ababa-Djibouti Railway.

Table 8 Fact Sheet about the Ecological Print of Completed Projects

Project Name	Category	Ecological Footprint (km^2)	Permanent Footprint (km^2)	Temporary Footprint (km^2)
Mombasa-Nairobi Standard Gauge Railway	Grassland	9.81	2.14	7.67
	Woodland	0.48	0.10	0.38
	Cropland	8.59	1.86	6.73
Addis Ababa-Djibouti Railway	Grassland	46.56	12.41	34.15
	Woodland	3.22	0.82	2.40
	Cropland	5.04	1.31	3.73
Angren-Pap Railway	Grassland	1.32	0.39	0.93
	Woodland	0.33	0.09	0.25
	Cropland	1.51	0.39	1.12
Kosekoy-Inonu High-speed Railway	Grassland	0.31	0.01	0.30
	Woodland	0.94	0.13	0.81
	Cropland	3.37	0.48	2.89

(3) Ecological Restoration

After the completion of the projects, artificial planting will be carried out to accelerate the restoration of vegetation on the roadbed slopes and the vegetation damaged by construction. The steep slopes will be reinforced or planted with vegetation to minimize the ecological risk to plant life. Figure 15 shows an example of the ecological restoration of the Mazelas section of the Mombasa-Nairobi Standard Gauge Railway.

(a) August 21, 2016 (b) December 25, 2017

Figure15. Comparative Monitoring Map of Remote Sensing Images of Ecological Restoration During (a) and After (b) the Construction of the Mazelas Section of the Mombasa-Nairobi Standard Gauge Railway.

For the Mombasa-Nairobi Standard Gauge Railway, Addis Ababa-Djibouti Railway, Angren-Pap Railway, and Kosekoy-Inonu High-speed Railway that have been opened to traffic, the ecological restoration within the 1.00 km buffer zone along the project route after the opening (see Table 9) is assessed by comparing the changes in the Normalized Difference Vegetation Index (NDVI) of Landsat remote sensing images in the corresponding period before, during, and after construction. NDVI is one of the effective parameters in remote sensing science for reflecting the growth of vegetation, with higher values indicating better vegetation restoration.

Table 9 Statistics of NDVI Changes within 1 km Buffer Zone Along the Route of Completed Projects

Project	Average NDVI			Average NDVI Variation (%)		
	Pre-construction	Under Construction	After Opening to Traffic	Pre-construction - Under Construction	Under Construction - After Opening to Traffic	Pre-construction - After Opening to Traffic
Mombasa-Nairobi Standard Gauge Railway	0.48	0.42	0.51	-8.59	27.19	13.20
Addis Ababa-Djibouti Railway	0.29	0.26	0.27	-1.59	8.75	5.25
Angren-Pap Railway	0.31	0.30	0.33	-0.74	14.12	12.62
Kosekoy-Inonu High-speed Railway	0.49	0.47	0.52	-7.94	16.93	9.01

Since opening to traffic, the average NDVI within the 1.00 km buffer zone along the railways has exceeded or is close to the pre-construction level, showing an overall growth trend, and the Mombasa-Nairobi Standard Gauge Railway and Angren-Pap Railway have seen an average NDVI increase of over 12.00%, which shows that the vegetation along these railways has been well restored after the completion of the project, and even improved compared with the pre-construction level.

3.3.2 Assessment of the Impact on Ecological Environment Along the Route of Ongoing Projects

(1) Current Status of the Ecological Environment Along the Route of the Ongoing Project

Table 10 shows the remote sensing monitoring results of the vegetation coverage of the four ongoing projects in 2017, namely the China-Laos-Thailand Railway, Jakarta-Bandung High-speed Railway, Hungary-Serbia Railway, and Peshawar-Karachi Highway. In general, the vegetation coverage ranges from 0.60 to 0.80, and more than 60.00% of the areas along the China-Laos-Thailand Railway, Peshawar-Karachi Highway, and Hungary-Serbia Railway have a vegetation coverage of higher than 0.60. Although the terrain in these areas is complex, the climate is both rainy and hot during the same period, which is favorable for vegetation growth. 24.85% of the areas along the Jakarta-Bandung High-speed Railway have a vegetation coverage of less than 0.20, and 36.22% have a vegetation coverage of more than 0.80.

Table 10 Statistics of Different-range Vegetation Coverage Along the Route of Ongoing Projects

Project Name	Vegetation Coverage Range	0.00-0.20	0.20-0.40	0.40-0.60	0.60-0.80	0.80-1.00	Total
China-Laos-Thailand Railway	Area (km^2)	27.66	5293.59	9588.10	23117.76	56.39	38083.50
	Proportion (%)	0.07	13.90	25.18	60.70	0.15	100.00
Jakarta-Bandung High-speed Railway	Area (km^2)	653.12	57.25	419.5	546.6	951.85	2628.32
	Proportion (%)	24.85	2.18	15.96	20.79	36.22	100.00
Hungary-Serbia Railway	Area (km^2)	74.00	203.70	875.40	2784.70	3793.40	7731.2
	Proportion (%)	0.96	2.63	11.32	36.02	49.07	100.00
Peshawar-Karachi Highway	Area (km^2)	91.71	1097.57	15145.98	26944.13	612.79	43892.18
	Proportion (%)	0.20	2.50	34.51	61.39	1.40	100.00

(2) Ecological Footprint

Table 11 shows the remote sensing monitoring results of the ecological resources before the construction of the four ongoing projects, namely China-Laos-Thailand Railway, Jakarta-Bandung High-speed Railway, Hungary-Serbia Railway, and Peshawar-Karachi Highway. In general, woodland and cropland dominate along the route of each project, and more than 80.00% of the areas along the project routes belong to woodland, grassland, and cropland. The area along the China-Laos-Thailand Railway is dominated by woodland, accounting for 56.46%; the area along the Jakarta-Bandung High-speed Railway is dominated by other landforms, accounting for 37.57%; the area along the Hungary-Serbia Railway is dominated by cropland, accounting for 54.29%; and the area along the Peshawar-Karachi Highway is also dominated by cropland, accounting for 78.89%.

Table 11 Pre-construction Ecological Resources within 10 km Buffer Zone Along the Route of Ongoing Projects

Project Name	Type	Woodland	Grassland	Cropland	Other Lands	Total
China-Laos-Thailand Railway	Area (km^2)	21593.06	94.89	14635.96	1849.59	38083.50
	Proportion (%)	56.46	0.25	38.43	4.86	100.00
Jakarta-Bandung High-speed Railway	Area (km^2)	482.61	572.37	585.84	987.50	2628.32
	Proportion (%)	18.36	21.78	22.29	37.57	100.00
Hungary-Serbia Railway	Area (km^2)	840.17	1380.01	4197.60	1313.42	7731.2
	Proportion (%)	10.87	17.85	54.29	16.99	100.00
Peshawar-Karachi Highway	Area (km^2)	1401.66	120.48	34625.33	7744.71	43892.18
	Proportion (%)	3.19	0.28	78.89	17.64	100.00

Note: “Proportion” refers to the fraction of the total area of the 10 km buffer zone

The ecological footprint of the four ongoing projects is shown in Table 12. For China-Laos-Thailand Railway, Jakarta-Bandung High-speed Railway, Hungary-Serbia Railway and Peshawar-Karachi Highway, their average ecological footprint per kilometer are 0.07, 0.05, 0.05, and 0.08 km2 respectively. The types of ecological resources suffering from the largest ecological footprint (or loss) vary considerably from project to project: the loss of cropland along the China-Laos-Thailand Railway and Peshawar-Karachi Highway accounts for a large proportion of the three types of resources; the Jakarta-Bandung High-speed Railway occupies a similar proportion of grassland, woodland, and cropland; and the loss of cropland along the Hungary-Serbia Railway accounts for a large proportion of the three types of resources.

Table 12 Ecological Footprint of Ongoing Projects

Project Name	Type	Ecological Footprint (km^2)	Permanent Footprint (km^2)	Temporary Footprint (km^2)
China-Laos-Thailand Railway	Grassland	0.25	0.04	0.21
	Woodland	55.76	9.81	45.95
	Cropland	63.38	10.24	53.14
Jakarta-Bandung High-speed Railway	Grassland	2.82	1.70	1.12
	Woodland	2.01	1.26	0.75
	Cropland	2.22	1.36	0.86
Hungary-Serbia Railway	Grassland	3.81	0.62	3.19
	Woodland	1.52	0.25	1.27
	Cropland	2.22	1.36	0.86

3.3.3 Assessment of the Impact on Ecological Environment Along the Route of Proposed Projects

(1) Current Status of the Ecological Environment Along the Route of Proposed Projects

This report has extracted the vegetation coverage in the summer of 2017 within the 10.00 km buffer zone along the route of proposed projects (Moscow-Kazan High-speed Railway and Serenje-Chipata Railway) as a technical indicator for remote monitoring of the status of the ecological environment along the project route. Currently, the proportion of the area with a vegetation coverage greater than 0.60 along the Serenje-Chipata Railway and Moscow-Kazan High-speed Railway is 96.61% and 84.58% respectively. The Moscow-Kazan High-speed Railway is in a mid- to high-latitude region, where the climate conditions or human disturbance on vegetation is relatively small; and the Serenje-Chipata Railway is in a tropical region, where the hydrothermal conditions are favorable for the growth of vegetation.

(2) Current Status of the Ecological Environment Along the Route of the Proposed Projects and Estimation of Ecological Footprint

The report has analyzed the distribution of ecological resources in 2017 within the 10.00 km buffer zone along the route of proposed projects. To estimate the loss of major ecological resources, these resources have been categorized into woodland, grassland, cropland, and other landforms. The status of ecological resources within the 10.00 km buffer zone along each proposed project is shown in Table 13.

Table 13 Current Status of the Ecological Resources within the 10 km Buffer Zone Along the Route of Proposed Projects

Project Name	Type	Woodland	Grassland	Cropland	Other Lands	Total
Serenje-Chipata Railway	Area (km^2)	1275.32	3622.11	1229.43	314.32	6441.18
	Proportion (%)	19.80	56.23	19.09	4.88	100.00
Moscow-Kazan High-speed Railway	Area (km^2)	10230.00	10434.41	1575.53	6150.45	28390.39
	Proportion (%)	36.03	36.75	5.56	21.66	100.00

The 10.00 km buffer zone along the proposed project is dominated by three types of ecological resources: woodland, grassland, and cropland, which together account for about 80.00%. The proportion of the three types of ecological resources vary from project to project: the grassland along the Serenje-Chipata Railway accounts for the largest proportion of the three types of resources, which is 56.23%, and the proportion of woodland and grassland along the Moscow-Kazan High-speed Railway is identical, accounting for 36.03% and 36.75% respectively.

For the proposed project, the related width of the roadbed, the area of permanent construction, and the overall scale of the construction are estimated based on the corresponding results of the previously completed projects, and the ecological footprint and the temporary and permanent ecological loss caused by the construction of the proposed project are also estimated accordingly. The estimated ecological footprint caused by the construction of the proposed projects is shown in Table 14. The Serenje-Chipata Railway and Moscow-Kazan High-speed Railway have mainly caused the loss of grassland, accounting for 49.17% and 61.65% of the three types of resources respectively.

Table 14 Estimation of the Ecological Footprint of Proposed Projects

Project Name	Type	Ecological Footprint (km^2)	Permanent Footprint (km^2)	Temporary Footprint (km^2)
Serenje-Chipata Railway	Grassland	7.19	1.18	6.01
	Woodland	2.51	0.44	2.07
	Cropland	4.92	0.79	4.13
Moscow-Kazan High-speed Railway	Grassland	40.83	4.77	36.06
	Woodland	17.45	2.23	15.22
	Cropland	7.95	0.92	7.03

4. Case Study: China-Russia International Land-Sea Transport Corridor

The China-Russia International Land-Sea Transport Corridor (the "China-Russia Transport Corridor") is a classic case illustrating the interaction between infrastructure and biodiversity. Along the Transport Corridor, there is a unique, vulnerable, and diverse ecosystem comprised of rich species, which is second to none as a research subject in ecological environment research. In the context of economic development, the Transport Corridor is a key China-Russia cooperation platform of great strategic importance, as it is an essential trade route between the two neighboring countries and the start of the China-Europe marine trade route. Therefore, the promotion of infrastructure construction and development along the Corridor is inevitable. Meanwhile, the local unique yet vulnerable ecological environment must be well protected, presenting additional challenges to infrastructure projects. Given the special requirements on development and ecological protection along the China-Russia Transport Corridor, we have carried out a case study of this program based on the findings of the ecological sensitivity analysis mentioned above, in an effort to provide practical insights into policy-making.

4.1 Basic Facts

(1) Ecological Environment

The China-Russia Transport Corridor is designed to connect Heilongjiang Province in China, and the Republic of Buryatia, Irkutsk Oblast and Zabaykalsky Krai in Russia. These areas are high in forest coverage and boast an outstanding ecological environment characterized by rich biodiversity. As of the end of 2015, these four areas reported a forest coverage of 43.2%, 63.7%, 83.6% and 68.3% respectively, which were all considerably higher than the world average. They also have a total of over 250 national-level nature reserves, home to precious animal species such as Sables (*Martes zibellina*), Muskrats (*Ondatra zibethicus*), Moose (*Alces alces*), Amur tigers (*Panthera tigris altaica*), Red-crowned cranes (*Grus japonensis*) and *Naemorhedus goral*. Between the Republic of Buryatia and Irkutsk Oblast, there is a famous World Natural Heritage Site known as Lake Baikal. Stretching over an area of 31,500 km^2, with a volume of 23.6 trillion m^3, and a peak depth of 1,637 m, it is the largest freshwater lake in Eurasia and the world's deepest lake. The lake is rich in biodiversity and has nurtured abundant fauna and flora, making it a goldmine of precious ecological resources.

(2) Transport Projects

The China-Russia Transport Corridor is located in the Russian Far East (see Figure 16), which is an important hub in the Eurasian transport corridor. As one of the terminus points of the Trans-Siberian Railway, the longest railway line in Russia, and the Baikal-Amur Mainline, the region has an annual transport carrying capacity of more than 100 million metric tons, and is expected to gain an additional capacity of 65 million metric tons by 2020. Along the coastline of the Russian Far East, there are 29 ports and harbors, including the ports of Vladivostok, Nakhodka, Vostochniy and Vanino, and Sovetskaya Gavan that represent one fourth of the total cargo throughput of Russia.

The Arctic coast of the Russian Far East is part of the shortest passage connecting Asia and Europe.

According to Russian experts, the passage will be navigable for ships without icebreaking capabilities throughout the year by 2050. Today, the passage is already showing considerable competitiveness in facilitating the transportation of goods from and into northeast Asia. The Russian government plans to modernize the transport infrastructure of the passage to achieve an annual capacity of 80 million metric tons by 2024. Once fully modernized, the country's Arctic route will gain significant attractiveness as a time-efficient alternative to the Suez Canal.

Figure 16. Railway Projects in Russian Far East

The China-Russia Transport Corridor is comprised of transportation corridors "Binhai No.1" and "Binhai No.2", highway and railway bridges connecting China and Russia across the Heilongjiang River (known in Russia as the Amur River), and the China Railway Express linking China, Russia and Europe. Specifically, "Binhai No.1" is designed to connect Harbin and Suifenhe in China, Grodekovo, Vladivostok, Vostochniy Port and Nakhodka in Russia, and other ports in Asia Pacific; and "Binhai No.2" is designed to connect Changchun and Hunchun in China, Kraskino, Posyet and Zarubino in Russia, and other ports in Asia Pacific.

Once completed, the Transport Corridor will greatly intensify trade between China and Russia. Northeast China will have access to more ports, gaining new transportation advantages. In November 2018, *the Plan on China-Russia Cooperation and Development in the Russian Far East Region (2018-2024)* was officially approved, placing the projects "Binhai No.1" and "Binhai No.2" on the top of the agenda for strategic and infrastructure cooperation between the two countries.

4.2 Ecological Risks of the China-Russia Transport Corridor

The construction and operation of major projects under the China-Russia Transport Corridor framework will greatly affect the quality of the ecological environment and ecosystemic landscape of regions along the route. These projects are very likely to damage local plant life and ecosystems, and divide the habitats of animals, presenting threats to the function of ecosystem services and current biodiversity balance of the areas. (see Figure 17)

Figure 17. Ecological Risk Assessment of China-Mongolia-Russia High-speed Railway Project

The proposed transport infrastructure will create corridors for the species near the Sino-Russian border, which may cause changes to the current composition of the ecosystem. The Heilongjiang River has nurtured a number of different ecosystems, such as the East Siberian Taiga, the Mixed Broadleaf-Coniferous Forests of the Russian Far East and the Daurian Forest Steppe, which are identified as globally important ecoregions. The river area is home to many precious or even threatened wildlife, including Amur tigers (*Panthera tigris altaica*), Moose (*Alces alces*), Red-crowned cranes (*Grus japonensis*), Oriental white storks (*Ciconia boyciana*), Chinese mergansers (*Mergus squamatus*), Korean pines (*Pinus koraiensis*), and Japanese yews (*Taxus cuspidata*). As cross-border migration of wild animals is already becoming increasingly common in the China-Russia border along the Heilongjiang River, the Transport Corridor will very likely intensify this norm and aggravate the risk of invasion for the ecosystems of both countries. In addition, the transport lines overlapping with animals' migration routes will increase the possibility of animals being injured on roads or rail tracks, presenting new threats to precious local species.

Moreover, railway projects, and particularly large cross-border railway projects, will present additional risks to local biodiversity, as their construction usually lasts for a longer duration. Although China and Russia have signed a number of agreements to strengthen their cooperation around interconnectivity, the progress of the infrastructure projects has been slow due to the sheer number of issues to be negotiated. The longer the time a project takes to be completed, the longer the time that animal habitats or vegetation will be disrupted by raw materials or construction waste, and the greater the impact temporary roads for construction will generate on the animal habitats they divide, resulting in a greater impact on local species and ecosystems.

4.3 Biodiversity Protection Strategies for Corridor Construction

(1) Appropriate Layout of Projects to Minimize Ecological Risks

The railway projects under the China-Russia Transport Corridor framework are designed with their potential impact on local ecological environments in mind. They are located in densely populated areas as far as possible from forests. In this way, they will avoid natural habitats, and particularly key nature reserves, to effectively reduce their occupation of such land, and thus minimize the threat to local biodiversity.

According to the plan, the eastern line of the China-Mongolia-Russia High-speed Railway project will connect Manzhouli in China, and Zabaykalsky Krai, the Republic of Buryatia and Irkutsk Oblast in Russia. In terms of demographics, Chita, Ulan-Ude and Irkutsk are the most populous cities in Zabaykalsky Krai, the Republic of Buryatia and Irkutsk Oblast respectively. Home to 339,900, 426,700, and 620,100 residents, the three cities account for 31.26%, 43.6% and 25.6% of the total population of their governing federal subjects, and have a population density of 636.6, 1,131.4 and 2,252 people per km2 respectively. Their populations and population densities are much higher than those of other cities in their federal subjects.

Besides, Chita, Ulan-Ude and Irkutsk are the capitals and the political, economic, education, technology and tourism centers of Zabaykalsky Krai, Republic of Buryatia and Irkutsk Oblast respectively, featuring the best rail infrastructure of each region. Therefore, it can be concluded that these cities are key nodes along the east line, and will significantly reduce the potential economic and social impacts on the implementation of the high-speed railway project.

As the Transport Corridor develops, more people in borderless rural areas will move to live along the route and benefit from more prosperous markets and comprehensive services, leading to less deforestation and lower risks of biodiversity loss. Moreover, the route is located in economically well developed regions, with other pipelines and railway lines currently under construction. Occupying ecological environments that have already witnessed human activities, the Transport Corridor will minimize its impact on natural habitats and original ecological environments.

(2) Multi-dimensional Cooperation to Build Cross-border Natural Reserves

Although the best possible locations have been selected for road construction or improvement projects, some will inevitably overlap with forests or other natural habitats, often with negative impacts on biodiversity. There are several solutions for species conservation in these areas[15]. (1) reserves can be established in biologically sensitive areas along the proposed road projects, where strict protection measures will be implemented; and (2) compensatory reserves can be built in areas far away from the road projects to offset the loss of natural habitats caused by these projects. As of now, China and Russia have jointly established various kinds of nature reserves.

At the national level, China and Russia have established six cross-border nature reserves, namely: the Lake Xingkai-Khankaisky, Lake Dalai-Daursky, Sanjiang-Bolshekhekhtsirsky, Bacha Island-Bastak, Honghe-Khingansky and Sanjiang-Bolonsky nature reserves. At the local level, the government of Heilongjiang Province has been cooperating with the government of Amur Oblast to protect biodiversity in the border region and discuss the establishment of a special cross-border nature reserve. The Heilongjiang Provincial Government has also been working with the government of Khabarovsky Krai to establish a joint nature reserve for the conservation of the water ecosystem, as well as the conservation and study of the unique species of flora and fauna in the border region. The government of Inner Mongolia has been running a special cross-border nature reserve with the government of Zabaykalsky Krai, and supporting the Technical Working Group on the Conservation of the Ergune River and its Landscape and Biodiversity under the China-Russia Standing Task Force on the Ecological Conservation of the Ergune River.

(3) Joint Monitoring of Environment Quality and Experience Sharing

Apart from man-made nature reserves, long-term monitoring of the overall environmental quality can also contribute to biodiversity conservation and tracking. Given that ecosystems such as water systems constantly flow across border lines, joint monitoring is of great importance. To this end, Chinese and Russian governments at different levels have carried out various pilot programs and made considerable achievements in this area. Since 2004, governments of the two countries have been jointly conducting a water quality testing program for the Heilongjiang River, and found that its overall quality has been improving. According to the test results, the quality of the river is between Class I and II, and the riverside ecological environment along the border has been optimizing. In addition, the government of Heilongjiang Province has been cooperating with the government of Khabarovsky Krai on air quality monitoring, and with the government of Amur Oblast on water surface and ecological water resource monitoring.

Additionally, China and Russia have been regularly organizing events to share their experience and expertise regarding environmental quality monitoring and environmental protection. For example, they have shared environmental monitoring technologies, information on developing environmental education programs for residents in border areas, and data on water resources, air and other elements of the environment. Through annual seminars, they have shared their experience in environmental protection. They have also strengthened cooperation with waste treatment plants and established joint ventures to share technologies for environmentally-friendly production, and the use and processing of industrial and domestic waste. They have put in place

[15] Saunier, Richard E. and Richard A. Meganck, eds. 1995. Conservation of Biodiversity and the New Regional Planning. Chapter 2. Washington, D.C.: OAS/IUCN. http://www.oas.org/usde/publications/Unit/oea04e/oea04e.pdf, pp. 13-21, 113.

expert exchange programs in order to promote research in optimizing production processes and organizational structures, and contribute to the development of ecological policies, laws and regulations.

5. Future Outlook

The BRI regions have complex and diverse climate and terrain, and most of the areas (such as Southeast Asia and the Russian Far East) are rich in biodiversity and have higher requirements for the ecological environment. Meanwhile, the BRI countries have significant demand for improvement and new infrastructure, for example, the regions like Russia and Central Asia are faced with the slow development of railways and seriously aging lines, and in the regions like South Asia and Central Asia, highways are scarce and pavement quality is low. In recent years, China has worked with the BRI countries to facilitate the construction of highways and railways and has made a significant contribution to promoting the economic development of these countries. However, as mentioned above, many areas along the BRI regions have rich biodiversity and fragile ecological environment. Therefore, to complete the infrastructure construction projects, it is necessary to measure, evaluate, and reduce the negative impact of the projects on local biodiversity.

For the regions with rich biodiversity and the fragile ecological environment, such as the eastern end of Eurasia and Southeast Asia, they have a higher demand for infrastructure development, and any lack of control in such development would significantly affect local biodiversity. For example, in the Greater Mekong region, our analysis shows that almost the entire Greater Mekong subregion is part of the India-Myanmar ecological hotspot and the conservation of local biodiversity is globally significant. The analysis also shows that the potential environmental costs of the current road construction projects in the region are extremely high, as most of these projects overlap with the established KBAs. One good example that has better control of the impact of infrastructure on the ecological environment is the construction of the China-Russian transport corridor, which is home to a variety of rare animals and of great ecological importance. In the process of planning the construction of railways in the corridor, China, Russia, and Mongolia, guided by the principle of sustainable development, have actively cooperated in exploring and implementing biodiversity protection from route selection, ecological monitoring to the establishment of conservation areas, and thus have achieved certain results.

Based on the above analysis, we believe that it is very important to consider the impact of infrastructure projects on biodiversity as part of the BRI development process. It is also important to have this in mind in the planning process, and it is necessary to adopt biodiversity-related assessment tools when measuring the feasibility of projects. Also, it prompts a good question as to how to better cooperate internationally to conserve biodiversity. About this, we have the following four suggestions:

(1) Align the guidelines of BRI infrastructure construction with the United Nations Sustainable Development Goals

The United Nations 2030 Sustainable Development Goals (SDGs) are a series of new development goals that are agenda targets to guide the global development efforts by 2030. The 14th and 15th SDGs are directly related to the protection of aquatic species, terrestrial species, and biodiversity. The BRI infrastructure development should be in line with the SDGs and focus on biodiversity conservation in BRI countries. For example, the *Convention on Migratory Species* should be followed in the construction of transportation infrastructure. When the BRI railway or highway construction projects come across multiple national parks or conservation areas, the route design should avoid such parks and areas to reduce the impact of the projects on the local ecological environment. As to the wildlife protection, in order to prevent the construction from segmenting the migration route of wild animals or blocking their habitats when the projects have to overlap with the conservation area, it is necessary to construct a large number of bridge culverts or special wildlife corridors and flyovers for wildlife to move freely, so as to protect the integrity of the ecosystem in their habitats.

(2) Promote the use of biodiversity assessment and decision-making tools before infrastructure investment

It is recommended to use the internationally recognized biodiversity assessment and decision-making tools to estimate the biodiversity sensitivity of infrastructure development before the infrastructure planning and construction in BRI countries. Promote the use of visual assessment tools for biodiversity assessment in relevant decision-making departments, such as WWF's SIGHT, IUCN's IBAT, and CI's Trend. Earth, etc., to identify the degree of overlap between KBAs and infrastructure construction areas, predict biodiversity conservation risks in advance, and avoid such risks in the early stages of planning and construction, which reflects the green development philosophy of China's BRI. The results of this study's visualized and sensitivity analysis have identified the KBAs for biodiversity conservation in the infrastructure development, including the central-eastern corridor of the Bangladesh-China-India-Myanmar Economic Corridor, the eastern corridor of the China-Mongolia-Russia Economic Corridor, and the China-Central Asia-West Asia Economic Corridor, where special attention should be paid to biodiversity conservation during the infrastructure investment in these regions.

(3) Integrate relevant principles of biodiversity conservation into the Green Finance Framework

The development of the green financial market is significantly important to the green BRI construction and the support for the realization of green and sustainable development in BRI countries. China's experience in building a green financial system and developing green financial markets can be a reference for the BRI countries and regions, for example, the *Green Investment Principles for the Belt and Road* jointly drafted by the Green Finance Committee of China Society for Finance and Banking and the City of London Green Finance Initiative. The support for the development of multilateral financial institutions, such as the Silk Road Fund and the Asian Infrastructure Investment Bank, to strengthen biodiversity conservation measures in the investment process, has made them an essential part of project construction. Besides, China has implemented specific green finance practices in Guizhou and has formulated various green finance guidance, such as *Green Finance Guidance Standards for Key Supported Industries in Guizhou Province (Trial)*, and *Evaluation Method of Key Green Projects Supported by Green Finance in Guizhou Province (Trial)*. It is recommended to apply China's green finance framework, especially the principles related to biodiversity conservation, to the BRI infrastructure investment, so as to guide capital investment and protect the biodiversity of BRI countries.

(4) Strengthen scientific support and promote the integration of standards and norms related to

biodiversity conservation

Develop land planning methods like Ecological Red Line based on scientific research, and promote the formulation of unified standards. For the construction of the BRI project, it is necessary to design appropriate route, identify KBAs, and implement strict conservation and management measures, as well as to strengthen real-time monitoring of the local ecosystem, maintain the integrity, stability, and adaptability of KBAs, and reduce the impact of the change of land use on KBAs, in order to establish a virtuous circle of economic development and ecological conservation. While in spatial planning for BRI development, it should be ensured that the conservation needs of KBAs are met.

Appendix: China's Biodiversity Conservation Policies for Reference

1. Planning of China's Key Function Oriented Zone[16]

In December 2010, the State Council of China issued the *National Plan for Major Function Oriented Zone* (hereinafter referred to as the Plan), which is a strategic, fundamental, and binding plan for China's national land and spatial development. The Plan categorizes China's land and space in the following manner: by the way of development, it is categorized into optimized developed areas, key development areas, restricted development areas, and prohibited development areas; by the nature of development, it is categorized into urbanized areas, major agricultural production areas and key ecological function areas; and by the level of development, it is categorized into the national level and provincial level development areas.

The urbanized areas, major agricultural production areas, and key ecological function areas are categorized by the types of main products they provide. The main function of the urbanized areas is to provide industrial and service products, as well as agricultural and ecological products; while the main function of the major agricultural production areas is to provide agricultural products, in addition to ecological products, service products, and some industrial products; and the main function of the key ecological function areas is to provide ecological products, along with certain agricultural products, service products, and industrial products.

The optimized developed areas refer to the urbanized areas with a more developed economy, more dense population, more intensive development, and more prominent resource and environmental problems, and thus these areas should be optimized for industrialized urbanization development.

The key development areas refer to the urbanized areas with a certain economic basis, large environmental and resource capacity, great development potential, and better conditions for boosting population and economic growth, and thus great attention should be paid to implement industrialized urbanization development in these areas. The optimized development areas and the key development areas are both urbanized areas, with basically the same nature of development, but they are different in the level and methods of development.

The restricted development areas are classified into two categories. One is the main agricultural production areas, with more croplands and better conditions for agricultural development. Although they are also suitable for industrialized urbanization development, the top development priority in these areas is still to increase the overall production capacity of agricultural products since these areas are essential to ensuring the safety of China's agricultural products and the need for sustainable development. Therefore, such areas are restricted to be developed towards the large-scale and intensive industrialized urbanization. The other is the key ecological function areas, with fragile ecosystems or important ecological functions, and small resource and environmental capacity, which means they are not suitable for the large-scale and intensive industrialized urbanization development. Therefore, such areas are also restricted to be developed in that way,

[16] http://www.gov.cn/zhengce/content/2011-06/08/content_1441.htm

and the top priority in these areas is to increase the production capacity of ecological products.

The prohibited development areas refer to the areas established by law for the conservation of natural and cultural resources at all levels and of all kinds, as well as other key ecological function areas that are prohibited from industrialized urbanization and require special protection. The prohibited development areas at the national level include national nature reserves, world cultural and natural heritage sites, national scenic spots, national forest parks, and national geoparks. While the prohibited development areas at the provincial level include the areas for the conservation of natural and cultural resources, and important water sources at and below the provincial level, as well as other areas prohibited from development as determined as needed by the provincial government. The Plan identifies 1,443 national prohibited areas, with a total area of about 1.2 million square kilometers, accounting for 12.5％ of China's land area, of which the state-level nature reserves account for 9.67％ of China's land area, mainly for the conservation of biodiversity.

The Plan states that to facilitate the establishment of Key Function Oriented Zone, it is necessary to properly handle the relations of the key functions with other functions, and the relations of Key Function Oriented Zone with agricultural development, the exploitation of energy and mineral resources, and the overall regional development strategies, as well as the relations between the government and the market. According to the Plan, the development of the Key Function Oriented Zone should follow the principles of structure optimization, nature conservation, intensive development, coordinated development, and coordinated land and marine development.

The principle of structure optimization requires that the development focus of national land space should be shifted from the outward expansion of land use to the adjustment and optimization of the spatial structure. Specifically, it requires to adjust the spatial structure to meet the requirements of production development, affluent living, and good ecology; strictly control the expansion of the total urban space and reduce the space for industrial and mining construction; adhere to the most stringent system for the protection of cropland; strictly control the occupation of the farmland by various constructions; implement the basic grassland protection system; increase the space for rural public facilities; appropriately expand the space for transportation facilities; and adjust the regional distribution of urban space.

The principle of nature conservation requires that, under the requirements of building an environment-friendly society and the specific features of national land space, the development should be implemented in an appropriate and orderly manner on the premise of conserving the ecology and based on the capacity of water and soil resources and the environment, to achieve harmonious development between humans and nature. Specifically, it requires that equal importance should be attached to the conservation of water, wetlands, woodlands, grasslands, and cropland; the development of industrialized urbanization must be based on a comprehensive evaluation of the regional capacity of the resources and environment, and be strictly controlled within the capacity limit of the water resources and environment; for the regions with fragile and important ecology, the development of industrialized urbanization must be strictly controlled, with appropriate regulation of other development activities, to mitigate the adverse impacts of development activities on the ecology; and various development activities that damage the ecology should be strictly prohibited. It also requires to enhance the conservation of the primitive ecology of rivers; manage to avoid the fragmentation of important natural landscapes and ecosystems in the construction of the infrastructure related to transportation and power transmission, etc., and strictly control the crossing of prohibited development areas; actively promote the role of agriculture in the ecology, landscape, and spatial fragmentation, with full consideration of the impact of agricultural development on the ecosystem; continue to work on the “Grain for Green” project in suitable areas by turning the low-yielding farmland back into forests, pasture and lakes, without reducing the area of provincial cropland and basic farmland; areas that have suffered ecological damage should be restored as soon as possible; and conserve the natural spaces such as grasslands, swamps, reeds, tidal flats, permafrost, glaciers, and permanent snow.

The principle of intensive development requires that, under the requirements of building a resource-conserving society, the increase of space-use efficiency should be considered as an important task in the development of national land space, and the relatively concentrated distribution of the population and the concentrated economy layout should be practiced, to achieve the intensive use of the space. Specifically, it requires to strictly control the intensity of development and regulate the timing of development, to make most of the national lands as a space for ensuring ecological security and sufficient supply of agricultural products; for the urbanized areas with greater resource and environment capacity and higher population density, urban clusters should be adopted as the main pattern to promote urbanization; all kinds of development activities should make full use of the existing construction space, and make as much use of idle land, vacant property and abandoned land; the project construction should be concentrated under the principles of developing a circular economy and being conducive to centralized pollution control; and the transportation construction should manage to use the existing infrastructure to increase the capacity, and the transportation to be newly constructed should use the existing transport corridor as much as possible.

The principle of coordinated development requires that the development should be implemented under the requirements of the harmonization among population, economy, resources, and environment, and the coordinated urban, rural, and regional development, to promote spatial balance among population, economy, resources, and environment. Specifically, it requires that the development should be carried out in line with the requirements of coordinating population and economy, population and land, and population and water resources; the development should also be carried out in line with the requirements of balancing large areas and coordinating urban and rural areas, upstream and downstream, and above-ground and underground; and the scale, layout, and density of the construction of transportation facilities should be coordinated with the population, economic scale and industrial structure of the Key Function Oriented Zone. It also requires to reinforce the establishment of a comprehensive transportation system, and improve the transit and connection capabilities between various modes of transportation such as railway, highway, water transportation, and air transportation.

The principle of the coordinated land and marine development requires that the development should be implemented in accordance with the coordination of land and marine territorial space and the relative independence of marine systems, to promote the coordinated development of land and marine territorial space. Specifically, it requires that the division of the main functional areas of the oceans should fully consider the capacity of the national marine resources and environment, the nature of marine development and the current development status, and coordinate with the main functional areas of land space; the scale of the population and economy concentrated in coastal areas should be adapted to the capacity of the marine environment, with consideration of marine environmental protection and land-based pollution prevention and control; coastline resources should be strictly conserved, and the functions of the coastline should be appropriately divided in a specific, relatively concentrated yet non-interference way. Port construction and marine-related industries should make intensive use of shoreline resources and near-shore waters; all kinds of development activities should be based on the conservation of the marine ecology, and avoid altering their nature as much as possible; estuarine wetlands should be conserved, coastal beaches should be appropriately developed and utilized, the mangroves, coral reefs, and seagrass beds should be protected and restored, and the damaged marine ecosystems should be restored.

The Plan identifies 25 key ecological function areas, with a total area of 3.86 million square kilometers, accounting for 40.2％ of China’s land area. The national key ecological functions are classified into four categories: water conservation, soil and water conservation, sand dune stabilization, and biodiversity protection. And there are seven biodiversity conservation areas.

Besides, the Ministry of Ecology and Environment of China and the Chinese Academy of Sciences have jointly worked on the revision based on the *National Ecological Function Zones* issued in 2008 and released the *National Ecological Function Zones (Revised)* in November 2015. The newly revised National Ecological Function Zones include three categories, nine types, and 242 ecological function zones. It identifies 63 key ecological function zones, covering 49.4% of China’s land area. The newly revised division of national ecological functions further underlines the importance of protecting ecosystem functions and reinforces the integration with the *National Plan for Major Function Oriented Zone*, which is significantly important for the scientific and appropriate construction of the production, living and ecological spaces, and for safeguarding national and regional ecological security.

2. Development Plan for the Yangtze River Economic Belt[17]

In 2016, China released the outline of the Yangtze River Economic Belt Development Plan, stating that improving the ecological environment is the top priority in the development strategy of the Yangtze River Economic Belt. The outline emphasizes restoring the ecological environment of the Yangtze River, respecting natural rules and river evolution, and protecting and improving the ecosystem service functions of the river basin. It requires that the water environment and ecology must be comprehensively improved by 2030, and states specific goals for ecological construction, such as the excellent water (meeting or exceeding Level 3 standards) ratio (over 75% by 2020) and forest coverage (43% by 2020). Based on the principle of ecological priority, the outline emphasizes the need to properly manage the relations between rivers and lakes, strengthen the protection of

[17] http://www.gov.cn/zhengce/2016-10/10/content_5116939.htm

aquatic biodiversity, and enhance the conservation and ecological restoration of riverside forests. Specifically, the outline will focus on the reinforcement of the Yangtze River reservoir clusters, along with the joint efforts on optimization and scheduling for the conservation of the Yangtze River.

On the one hand, to strengthen the management, development, and protection of the Yangtze River, after many years of effort, several hydroelectric projects centering around the Three Gorges Reservoir for the control purpose have been built in the Yangtze River basin, which has played an enormous role in flood control, ecological conservation, water supply, power generation and shipping in the basin. As a result, the hydrological situation in the middle and lower reaches of the Yangtze River has changed, so does the relations between rivers and lakes, and the changes of sedimentation and siltation have become more complicated, which has raised new requirements for the joint scheduling of reservoir clusters. To maximize the overall benefits of the clusters, in 2009, the Yangtze River (Changjiang) Conservancy Commission of Ministry of Water Resources conducted a study on the comprehensive scheduling of the reservoirs centering around the Three Gorges Reservoir for the control purpose on the mainstream and tributaries of the Yangtze River, and formulated the *Optimized Scheduling Plan for Controlling Reservoirs on the Upstream of the Yangtze River*. The joint scheduling has been implemented for 30 controlling reservoirs on the main and tributary streams of the Yangtze River, and nearly 200 billion cubic meters of water has been supplied to the middle and lower reaches of the river, thus alleviating the dry season problem, improving the aquatic ecology, and effectively protecting aquatic biological resources and populations. The next step is to continue to follow the principle of “water conservancy giving way to flood control, power transfer giving way to water diversion, comprehensive study prevailing over specialty, and the general good prevailing over sectional interests”, and gradually establish a consultation mechanism and management system for joint scheduling of controlling water and hydropower projects with extensive participation of stakeholders by improving laws, regulations, and management systems, establishing compensation mechanism, strengthening technical support, and reinforcing supervision and management. By 2020, China will strive to achieve 90% coverage of joint scheduling for the controlling reservoir clusters on the upper and middle reaches, and better exert the comprehensive benefits of the Yangtze River’s main and tributary reservoir clusters in flood control, water supply, ecological and environmental protection. Meanwhile, improve the emergency scheduling plan to better respond to emergencies such as extreme dry seasons, water pollution, water security incidents, and engineering incidents.

On the other hand, the development of the Yangtze River economic belt involves many aspects. Joint efforts are required to protect the Yangtze River, strengthen integrated planning and overall coordination in the management of water-related affairs, and give full play to the role of the Yangtze River Conservancy Commission and other river basin management agencies. It also requires to reinforce unified supervision and management of the river basin, and enhance the joint prevention and control across departments and regions to establish a coordinated and integrated working mechanism, and pool together individual efforts to protect the Yangtze River. Firstly, it is necessary to reinforce the comprehensive management of the river basin, strengthen the supervision and management of water-related resources, environment, ecology, shoreline, sand mining, etc., and strictly investigate and deal with water-related illegal acts. As the rivers, lakes, and shoreline resources are an important part of the Yangtze River's water ecosystem, it is also necessary to reinforce the control of the spatial use of the rivers and lakes, strictly prohibit land and river reclamation, improve the institutional mechanism for river and lake management with the vigorous promotion of the "river chief system", and strengthen the protection responsibilities of local governments. Secondly, efforts should be made to promote water conservancy reform in key areas. Under the principle of "he who profits should compensate", explore pilot schemes for horizontal ecological compensation on the upstream and downstream watersheds, advance the pilot work of ecological compensation in the Chishui River and the Han River, and improve the compensation system for the ecological benefits of soil and water conservation. Also, establish and improve the initial allocation system of water rights, promptly formulate water allocation plans for major rivers across provinces, and encourage and guide the trading of water rights between regions, upstream and downstream of the basin, as well as the trading between industries and between water users. Besides, deepen the comprehensive reform of agricultural water pricing, and establish a sound agricultural water pricing mechanism that reasonably reflects the cost of water supply and is conducive to water conservation and innovation in farmland water conservancy systems. Thirdly, work on the acceleration of the legislative process in the Yangtze River basin. Expedite the formulation and promulgation of laws on the protection of the Yangtze River, to further clarify the protection responsibilities of the relevant state departments, river basin management agencies, and local governments, and to make clear legal provisions on water-related acts in the river basin, thereby providing solid legal support for the protection of the Yangtze River.

3. National Park[18]

After years of discussions and planning consultations, the Chinese government released its *Master Plan for the Establishment of a National Park System* in September 2017, which is based on the pilot national parks starting in 2015.

National parks are terrestrial or marine areas with clear boundaries approved and managed by the state, the main purpose of which is to protect nationally representative ecosystems and achieve scientific conservation and rational use of natural resources. The main goal is to protect large areas of ecosystems and large-scale ecological processes and emphasize the need to maintain the authenticity and integrity of ecosystems. The national parks are classified as prohibited development zones in the national key functional areas, which are planned to be under the ecological conservation redline management and the strictest protection. As the generations-old national representation, they are the valuable natural heritage for future generations that can inspire national pride. They insist on universal welfare, provide citizens with environmental education and recreational opportunities, and encourage people's recognition of nature conservation.

Since the launch of the pilot national park system in 2015, China has piloted 10 national parks, including the Northeast Tiger and Leopard, the Qilian Mountains, the Giant Panda, the Sanjiangyuan, the Hainan Rainforest, the Wuyi Mountains, Shennongjia, Potatso, Qianjiangyuan,

[18] http://www.forestry.gov.cn/main/5497/20200816/085301468615067.html

and Nanshan, covering 12 provinces and a total area of more than 220,000 square kilometers, accounting for about 2.3% of China's land area. Through several years of effort, the pilot national park system has already achieved some milestones. The standards for the establishment of national parks, monitoring indicators, and monitoring technology systems, as well as the management methods for ecological conservation and natural resource in national parks, and the supervision of ecological conservation will soon be introduced. The National Forestry and Grassland Administration has worked with the relevant provincial governments to set up respective leading groups for the coordination of the pilot projects concerning the Northeast Tiger and Leopard, the Qilian Mountains, and the Giant Panda, and has jointly worked on the building of a model province with national parks as the main nature reserve system in Qinghai Province. 12 pilot provinces have set up pilot work leading groups led by provincial leaders. Each pilot area has established a management organization to prepare and implement overall plans, and completed the demarcation of natural resource ownership and the ownership related determination and registration.

The 10 pilot areas have established and conscientiously implemented the concept that lucid waters and lush mountains are invaluable assets by prioritizing ecological conservation, integrating various nature reserves at all levels into pilot national parks, and implementing unified management, all-around protection, and systematic restoration, which has achieved remarkable results. An integrated monitoring system has been established in the Northeast Tiger and Leopard, covering 5,000 square kilometers. In the Wuyi Mountains, 6,500 acres of ecological restoration have been completed, 7,300 acres of mountains with illegal planting of tea trees have been fixed, and 39 illegal constructions have been demolished. In the Giant Panda, ecological and habitat restoration projects have been implemented, a reintroduction base for giant pandas has been constructed, and nearly 40,000 acres of giant panda habitat have been restored. In Sanjiangyuan and Potatso, the enterprises in the line of mineral and hydropower development have seceded, and in the pilot areas like Qilian Mountains, the Giant Panda, and Nanshan, over 50% of the enterprises have seceded. In Shennongjia, a comprehensive law enforcement team has been established to comprehensively enforce the laws regarding natural resources in the park.

The pilot areas are making their best efforts to protect the authenticity and integrity of the natural ecosystem, and meanwhile actively exploring effective ways to realize the concept that lucid waters and lush mountains are invaluable assets. They are also establishing coordinated community development and ecological compensation systems to realize ecological conservation and benefits for the people. In Sanjiangyuan, an innovative ecological management and conservation system has been established, with one household responsible for the ecological management and conservation of a certain area, which enables 17,211 herders to work as the ecological management and conservation staff, and the average annual household income has increased by RMB 21,600. In the Northeast Tiger and Leopard, the implementation of the cattle project has promoted the transformation and development of the cattle breeding industry. Moreover, the Qianjiangyuan has completed the reform of collective forest rights and easement, and formulated and implemented a compensation policy for collective forest land. And the Wuyi Mountains has implemented a system of paid use of landscape resources, to guide the park residents to participate in resource conservation, and more than 1,200 jobs have been created.

4. Ecological Conservation Redline (ECR)

The Ecological Conservation Redline (ECR) is an important institutional innovation in China's environmental protection. It refers to the spatial boundaries and management limits that require strict protection in terms of ecological service functions, environmental safety, and the use of natural resources, to maintain national and regional ecological safety and sustainable economic and social development, and safeguard people's health. In 2014, the Ministry of Ecology and Environment (formerly the Ministry of Environmental Protection) of China issued the *Ecological Conservation Redline-Technical Guidelines for Delineating the Baseline of the Ecological Function (Trial)*, listing Inner Mongolia, Jiangxi, Hubei, and Guangxi as the pilot areas for the delineation of ECR. Specifically, ECR can be classified into a baseline for safeguarding ecological functions, a bottom line of environmental safety, and an upper limit for the use of natural resources.

The baseline for safeguarding ecological functions includes the ecological red line for prohibited development zones, the ecological red line for key ecological function zones, and the ecological red line for ecologically sensitive and vulnerable areas. The included areas are prohibited from industrialization and urbanization development, to effectively protect China's rare, endangered, and representative animal and plant species and ecosystems, and maintain the dominant functions of China's important ecosystems. The red line for the prohibited development zones includes nature reserves, forest parks, scenic spots, world cultural and natural heritage, and geoparks. All the nature reserves should be included in the control scope of the ecological conservation red line, and their spatial distribution boundaries should be clearly defined. The inclusion of other types of prohibited development zones should be based on the importance of their ecological conservation and the evaluation results of the importance of their ecosystem services.

The bottom line of environmental safety is the safety line to ensure fresh air, clean water, and safe food, as well as the basic environmental standards for human survival. It includes the red line of environmental standards, the red line for the control of total pollutant emissions, and the red line of environmental risk management. The red line of environmental standards requires all kinds of environmental factors to meet the requirements of the environmental function area. Specifically, it requires air, water, and soil to meet the national standards to ensure people's safety and health. The red line for the control of total pollutant emissions requires the comprehensive completion of emission reduction tasks and the effective control and reduction of total pollutant emissions. The red line of environmental risk management requires the establishment of an environmental and health risk assessment system, the improvement of environmental risk management measures, the improvement of environmental incident handling and damage compensation and restoration mechanisms, and the promotion of the whole process of environmental risk management. It also requires the establishment of an emergency response mechanism for sudden pollution incidents, the improvement of the emergency response management system for environmental emergencies, and the strengthening of the environmental early-warning system to ensure that environmental risks are minimized.

The upper limit for the use of natural resources is to promote resource and energy conservation and ensure the efficient use of energy, water, land, and other resources, and it serves as a reminder not to exceed the maximum limit. The upper limit for the use of natural resources should align with the basic needs of economic and social development and be compatible with the current resource and the environment capacity. The red line for the use of energy indicates the level of energy use under the specific economic and social development goals, including total energy consumption, energy structure, and energy consumption per GDP. The red line for the use of water resources is the basic requirement for building a water-conserving society and ensuring water security, which includes total water consumption and water use efficiency. The red line for the use of the land resources is the requirement for optimizing the pattern of land and space development, and promoting the orderly use and conservation of land resources, to ensure the effective protection of cropland, forests, grasslands, wetlands, and other natural resources.

In general, the ECR system is based on the delivery of ecological services, disaster mitigation, and control, and biodiversity conservation, as compared to global protected areas. It integrates the existing types of protected areas and includes the areas with extremely important ecological service functions or extremely sensitive and fragile ecological environments. With a more comprehensive array of protected areas, more scientific distribution, more prominent regional functions, and stricter control, the ECR system is a major improvement and innovation in the establishment of a protected area system. Through the delineation and strict management of ECR, it has not only effectively protected biodiversity and important natural landscapes, but also played an important role in purifying the atmosphere and increasing the capacity of the water environment. Meanwhile, ECR also serves as a control line for the spatial development of land. It allows China to maintain its adherence to green development, provides solid support for maintaining national ecological security, and promotes sustainable economic and social development. For this reason, ECR is sometimes referred to as China's "another lifeline after the cultivated land red line".

In February 2017, the Chinese government issued the *Opinions on the Delimitation and Strict Management of the Ecological Conservation Redline*, which clarified the general ECR related requirements and specific tasks. In June 2018, the *Opinions of Central Committee of the CPC on Strengthening Ecological Environmental Protection and Resolutely Winning the Battle to Prevent and Control Pollution* further stated that the ECR area should account for 25 % of China's total land area.

At present, China has made the following progress in the delineation of ECR:

- Establish a coordination mechanism. The Ministry of Ecology and Environment of China has taken the lead in establishing the ECR Inter-ministerial Coordination Leading Group.
- Develop guidance documents. Documents such as ECR delimitation guidelines, opinions, and recommendations on the distribution of ECR in the individual province (region and municipality), and the technical regulations on ECR delimitation (pilot) have been issued to guide the orderly delimitation of ECR in each region.
- Establish a regulatory system. The integrated monitoring network has been improved, and the ECR regulatory platform has been launched and organized for operation. The platform is expected to be completed by the end of 2020.
- With the increased efforts on the publicity of ECR, the ECR logo has been released, and the

ECR publicity video has been planned and produced, which summarizes the useful experience of ECR delimitation, and the media is invited to follow up and publicize ECR, and enhance the dissemination of ECR knowledge. An ECR delimitation toolkit has been developed through cooperation with IUCN, and China's experience in ecological conservation has been communicated to the international community.

- Positive progress has been made in ECR delineation. In February 2018, the State Council approved ECR delimitation plans for 15 provinces, including the Beijing-Tianjin-Hebei region, the Yangtze River Economic Belt, and the Ningxia Hui Autonomous Region, covering about 25％ of the land area. Provincial governments of the 15 provinces have promulgated and implemented their respective ECR delimitation. At present, 15 provinces are working on the pilot ECR delimitation, and the other 16 provinces have established the preliminary plans for ECR delimitation, which will be revised and improved based on the Ministry's opinions and submitted to the State Council for approval.
- In August 2019, The Ministry of Ecology and Environment of China and the Ministry of Natural Resources of China jointly issued the Technical Regulations on the Survey and Delimitation of Ecological Conservation Redline, which details the technical standards for the survey and delimitation of ECR. 15 provinces (regions and municipalities), including the Beijing-Tianjin-Hebei region, the provinces in the Yangtze River Economic Belt, and the Ningxia Hui Autonomous Region will carry out the survey and delimitation based on the assessment results of the ECR identified by the State Council. Other provinces will start the survey and delimitation after the State Council approves the ECR delimitation plan. According to the requirements of the Opinions on Delimitation and Strict Adherence to Ecological Conservation Redline, the survey and delimitation of ECR should be completed by the end of 2020[19].

Next, each region will implement ECR delimitation according to the delimitation plan approved by the State Council. Also, the spatial planning and the efforts to establish a land conservation system will promote the precise implementation of ECR and realize more detailed supervision on the ecology. Meanwhile, the Chinese government will formulate and promulgate ECR management measures to clarify the management principles of human activities, and the requirements for management and control, conservation and restoration, ecological compensation, and regulatory assessment. And the ECR legislation will be promoted based on local management practices.

[19] http://www.mee.gov.cn/xxgk2018/xxgk/xxgk05/201909/t20190910_733265.html