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Assessment of the Impact of Guangxi's Territorial Spatial Planning on the Environment: Based on the 2021-2035 Plan

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Abstract. Guangxi, a critical ecological region in southwestern China, faces pressing environmental challenges, including soil erosion, rocky desertification, biodiversity loss, and water pollution, intensified by industrialization and anthropogenic activities. In response, the "Guangxi Zhuang Autonomous Region Spatial and Territorial Planning (2021-2035)" was formulated to address these issues through comprehensive ecological protection and restoration strategies. This study critically evaluates the Plan's impact on key ecological aspects, such as water resource management, biodiversity conservation, and climate change adaptation. A detailed analysis of Guangxi's current ecological status highlights the region's vulnerabilities and environmental degradation. The paper assesses the Plan's major initiatives, including the establishment of ecological red lines, the creation of nature reserves, and extensive land restoration projects, examining their effectiveness in enhancing ecological resilience. Findings indicate significant improvements in water quality and reductions in soil erosion; however, challenges such as air pollution and long-term ecological stability persist. The study concludes that while the Plan represents a vital framework for promoting sustainable development in Guangxi, its success will depend on sustained interdisciplinary efforts, enhanced monitoring mechanisms, and continued investment in ecological governance.

Keywords: Guangxi, Planning, Ecological environment.

1. Introduction

The rapid industrialization and urbanization initiated by the Industrial Revolution have led to an increased reliance on natural resources, which in turn has intensified pressure on global ecosystems. This reliance has been accompanied by a series of environmental challenges, including global warming, soil degradation, and the loss of biodiversity. Such environmental degradation poses severe threats to ecological stability and accelerates climate change, demanding immediate and strategic attention from both scholars and policymakers. As an ecologically critical region, Guangxi in southwestern China plays a pivotal role in both national and global environmental sustainability, serving as a key node in climate regulation and biodiversity conservation. With a forest coverage rate of 60.2% and an ecological quality index (EQI) of 74.85, Guangxi is often referred to as the "Southern Lung" of China, underscoring its importance in safeguarding the ecological security of the region [1,7].

In response to these ecological imperatives, the Guangxi Zhuang Autonomous Region introduced the Guangxi Zhuang Autonomous Region Spatial and Territorial Planning (2021–2035), hereafter referred to as the "Plan," in November 2022. This comprehensive Plan, the result of nearly three years of

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collaborative efforts involving over 200 experts from 46 institutions, was designed to align with major national development strategies while addressing local ecological and environmental needs. The Plan outlines strategic directions across various sectors, with a strong emphasis on preserving ecological integrity through spatial planning, ecological restoration, and the creation of nature reserves. As Guangxi is positioned to play a crucial role in China's "Belt and Road" Initiative, the Plan is not only locally significant but also of considerable international importance, enhancing regional cooperation and ecological resilience while fostering sustainable development across multiple sectors.

This study aims to critically evaluate the ecological impact of the Plan, particularly its effects on water conservation, biodiversity protection, and climate change adaptation in Guangxi. Through a detailed analysis of the region's current ecological challenges, including soil erosion, biodiversity loss, and water pollution, this research explores how the implementation of the Plan aligns with environmental improvement strategies. By assessing the specific ecological dimensions addressed by the Plan, this paper offers insights into the broader implications for regional sustainability and the potential long-term benefits of Guangxi's environmental policies in addressing global environmental concerns [2].

2. Analysis of Guangxi's Ecological Environment

2.1. Geographic and Natural Features

Guangxi is situated in the second terrace of China's terrain system, characterized by a predominantly mountainous and hilly landscape. Middle and low mountain ranges and hills cover approximately 68.3% of its total area, while plains and basins account for 23.4%. The region's topography generally slopes from northwest to southeast. Guangxi's geographical position in the low latitudes subjects it to a subtropical monsoon climate, marked by abundant rainfall, small annual temperature variations, and long summers with high temperatures and significant precipitation. Winters are shorter, with generally warm and dry conditions. The region boasts a rich network of rivers—about 1.89 million in total—that flow from the northwest to the southeast, contributing to Guangxi's substantial water resources. Soils are primarily composed of red and reddish soil types, which make up 35.0% and 30.1% of the territory, respectively. Additionally, the region's 60.2% forest coverage includes predominantly subtropical evergreen broad-leaved forests. Its monsoonal climate supports a rich biodiversity, with species such as white-headed leaf monkeys, Chinese white dolphins, and golden camellias.

One of Guangxi's defining geographical features is its extensive karst formations, created through the dissolution of soluble rocks by groundwater. These karst landscapes are marked by a lack of surface water, low plant coverage, and poor soil conditions, contributing to challenges such as soil erosion and geological hazards like landslides and mudslides. Despite these difficulties, underground rivers in these areas provide essential water resources, contributing positively to the local ecosystem and helping to maintain biodiversity.

2.2. Overview of Ecological Environment Status

In recent years, the district government has implemented comprehensive environmental pollution control measures, focusing on addressing heavy pollution days, preventing and controlling ozone pollution, and reducing straw burning. As a result, the air quality has continuously improved, with the proportion of days with excellent urban air quality increasing from 91.6% in 2018 to 97.9% in 2023, marking a 6.3% improvement. This demonstrates significant progress in addressing environmental pollution. Guangxi has consistently prioritized the fight against water pollution by applying tailored approaches to control river pollution in different areas. Comprehensive measures have been taken to improve water quality in unstable river basins, centralize sewage treatment in industrial parks, and enhance the ecological protection and restoration of rivers and lakes. Notably, the Lijiang River in Guilin has been recognized as one of the first "beautiful rivers and lakes" in the country, and sewage from 135 large industrial parks across the region has been centrally treated.

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In terms of preventing and controlling soil pollution, Guangxi has also achieved substantial results. Key measures include improving waste classification, investigating the sources of heavy metal pollution in soil, ensuring groundwater safety, and establishing relevant pollution prevention and control systems. The Guangxi regional government has issued various directives focused on enhancing the ecological protection classification system, promoting the restoration of mountains, rivers, forests, fields, lakes, and grasslands, and building a strong ecological barrier in the south.

Since 2011, Guangxi's ecological environment quality has significantly improved. For instance, the area affected by soil erosion has decreased from 39,300 square kilometers to 36,900 square kilometers, a reduction of 6.11%. Additionally, the area of rocky desertification has dropped from 15,300 square kilometers during the third monitoring period (2011-2016) to 10,500 square kilometers in the fourth monitoring period, marking a decrease of 31.37%. Forest coverage has increased from 56.5% to 60.2%, reflecting a 6.55% growth. Moreover, the discovery of new species in regions like the Beibu Gulf and the Dayao Mountains highlights Guangxi's rich and improving biodiversity.

Table 1 and Table 2 compare the national (average) and Guangxi's ecological environment indicators from 2021 to 2023. Table 1 shows that, in both 2021 and 2022, Guangxi performed better than the national average in terms of air quality days, nearshore water quality, and surface water quality. In particular, Guangxi achieved a 100% excellent surface water quality rate in 2022, demonstrating the effectiveness of the water pollution prevention and control measures in the "Plan." However, despite the improvements in water quality, the concentration of fine particulate matter in Guangxi remained higher than the national average, indicating that further efforts are required in air pollution control.

Table 2 provides a comparison of ecological environment indicators for 2023, further demonstrating that Guangxi maintained superior performance in key areas compared to the national average. Guangxi achieved a 97.9% rate of days with good air quality, significantly higher than the national average of 85.5%. Similarly, Guangxi's excellent surface water quality rate reached 99.1%, compared to the national rate of 89.4%. However, the fine particulate matter concentration, though improved, still presents challenges, underscoring the need for continued efforts in air quality management.

Table 1. Comparison of National (Average) and Guangxi Ecological Environment Indicators from 2021 to 2022

Type	2021		2022	
	China	Guangxi	China	Guangxi
Annual average concentration of fine particulate matter (ug/m^3)	28.0	30.0	26.0	29.0
Ratio of days with good air quality (%)	87.5	95.8	86.5	95.1
Rate of excellent water quality in nearshore waters (%)	81.3	92.6	81.9	94.5
Rate of excellent surface water quality (%)	84.9	97.3	87.9	100.0
EQI	59.8	74.9	59.6	74.9

Table 2. Comparison of National (Average) and Guangxi Ecological Environment Indicators in 2023

Type	2023	
	China	Guangxi
Annual average concentration of fine particulate matter (ug/m^3)	30.0	26.0
Ratio of days with good air quality (%)	85.5	97.9
Rate of excellent water quality in nearshore waters (%)	85.0	94.5
Rate of excellent surface water quality (%)	89.4	99.1
EQI	59.8	74.9

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2.3. Current ecological environment issues

2.3.1. Serious phenomena of soil erosion and rocky desertification

Despite improvements, Guangxi still faces significant challenges related to soil erosion and rocky desertification. Hydraulic erosion remains the primary form of soil degradation, with landslides and mudslides frequently occurring in mountainous areas. As of 2023, the total area affected by soil erosion stood at 36,900 square kilometers, representing 16% of the region's total land area. The regions most affected—Baise, Hechi, and Guilin—are prone to frequent soil erosion due to both natural factors and human activities, such as deforestation and over-exploitation of land resources. Large-scale agricultural transformations have exacerbated the situation, leading to reduced plant coverage and increased vulnerability to rocky desertification [3].

2.3.2. Destruction of ecosystems and biodiversity

Guangxi's vast land area, covering 237,600 square kilometers, supports over 9,494 species of higher plants and 1,906 species of wild vertebrates. However, rapid industrialization and unsustainable resource extraction have severely disrupted the stability of these ecosystems. Urbanization has led to habitat destruction and fragmentation, further threatening the region's biodiversity. In the Beibu Gulf region, unchecked tourism development has damaged coastal zones, leading to marine ecosystem degradation and a significant reduction in biodiversity [4].

2.3.3. Human caused water resource pollution problems occur from time to time

Although surface water quality in Guangxi has seen marked improvements—with excellent water quality rates reaching 98.2% in 2023—periodic incidents of water pollution continue to occur, primarily due to industrial activities. Four significant water pollution events were reported in November 2023, all attributed to excessive discharge of pollutants, malfunctioning wastewater treatment systems, and illegal pollutant discharges through hidden pipes. While efforts to address water pollution have shown progress, these recurring incidents highlight ongoing challenges in fully safeguarding water resources.

2.4. Analysis of Vulnerability and Advantages of Ecological Environment

Guangxi's ecological landscape, particularly its karst formations, is marked by inherent vulnerability. These areas are prone to environmental stresses such as landslides, droughts, and floods, which exacerbate the region's ecological fragility. Karst ecosystems are particularly sensitive to changes in climate and human activities, necessitating careful management to prevent further degradation.

Human activities remain a key factor in the region's ecological vulnerability. Tourism, infrastructure development, and agricultural expansion have led to habitat destruction and increased pressure on local ecosystems. Managing population pressures and balancing economic development with ecological preservation are critical to maintaining the integrity of Guangxi's environment moving forward.

3. Overview of the Guangxi Zhuang Autonomous Region Land Spatial Planning (2021-2035)

3.1. Planning Background and Objectives

In the context of escalating global climate change and unsustainable resource exploitation, China is experiencing dual pressures of environmental degradation and resource scarcity, particularly in regions that are both resource-rich and ecologically fragile, such as Guangxi. Despite concerted efforts to safeguard the ecological environment, resource constraints continue to intensify, environmental pollution remains a significant challenge, and ecosystem degradation persists. These issues are becoming more complex, and the overall trend of environmental deterioration has not been effectively reversed. Additionally, overlapping protected areas and inadequate spatial planning have led to inefficiencies in ecological conservation efforts. Guangxi, often referred to as the "Green Lung" of South China, holds immense ecological value, serving as a critical water conservation zone for the Pearl River Basin.

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The primary objective of the Planning is to preserve and enhance Guangxi's ecological strengths, emphasizing that its ecological advantages cannot be sacrificed for short-term economic gains. The Planning aims to bolster ecological protection and governance, contributing to China's national goals of carbon neutrality and peak carbon emissions. By instituting a strict ecological red line system and safeguarding over 95% of Guangxi's species diversity areas, the Planning seeks to ensure the integrity of ecological space and the sustainability of ecosystem functions. The ultimate vision is to transform Guangxi into a livable region with picturesque landscapes, pristine waters, and a stable, healthy ecosystem, fostering the region's sustainable economic development.

3.2. Core Content of Ecological Protection

The ecological protection strategy articulated in the Planning delineates three fundamental ecological baselines: the red line for development exclusion zones, the red line for critical ecological function zones, and the red line for ecologically sensitive and vulnerable areas. These zones are designated to restrict industrial and urban expansion, aiming to safeguard China's rare and endangered species, preserve key ecosystems, and maintain essential ecological functions. The designated red lines encompass nature reserves, forest parks, scenic areas, UNESCO world heritage sites, and geological parks. Clear demarcation of these protected areas ensures effective conservation management, while other development-restricted zones are included based on their assessed ecological value, evaluated through ecosystem service assessments.

(1) Ecological Security Framework:

The Planning introduces a national ecological security structure characterized by "one shield, six zones, one corridor, and one sea." This framework emphasizes the establishment of a resilient ecological barrier in Guangxi's western and northern regions, coupled with the preservation of five major ecological function zones across the eastern, western, northern, southern, and central regions. Furthermore, the Xijiang River green corridor, a vital ecological artery, is prioritized for conservation, alongside a focus on marine ecological protection within the Beibu Gulf, a crucial maritime area for Guangxi.

(2) Ecological Red Line for Biodiversity Conservation:

The ecological red line is the cornerstone of China's environmental security architecture. In recognition of Guangxi's diverse topography and rich biodiversity, the Planning underscores the necessity of delineating red lines around ecologically sensitive regions and critical nature reserves, such as the Shiwandashan and Dayao Mountains. These red lines serve to shield endangered species and crucial ecosystems from anthropogenic threats, ensuring their long-term protection from developmental pressures.

(3) Expansion of Nature Reserves:

To enhance Guangxi's ecological resilience, the Planning advocates for the expansion of the region's nature reserves, including the establishment of new national parks. The objective is to develop a comprehensive, tiered system of protected areas, with nature reserves at the core, supplemented by nature parks. This expansion is aimed at increasing the overall extent of protected areas, thereby securing long-term biodiversity conservation and ecological sustainability.

(4) Targeted Ecological Monitoring:

The Planning also identifies specific zones outside the ecological red lines that require enhanced monitoring and protection. These zones include 27 districts, 16 river corridors, and 3 migratory bird corridors, which are earmarked for targeted intervention to mitigate ecological disturbances arising from human activities such as mining and industrial expansion.

(5) Ecological Restoration and Sustainable Development:

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Addressing ongoing environmental degradation is a key focus of the Planning, which emphasizes continued efforts in ecological restoration, comprehensive land reclamation, and mining remediation. Measures such as soil quality enhancement, afforestation, and disaster resilience initiatives are prioritized, with particular attention to restoring marine ecosystems and coastal areas, including through the "Blue Bay" initiative. These interventions are designed to promote sustainable rural development, improve the overall living environment, and guide urban development in harmony with ecological preservation.

3.3. Strategic Significance of Planning

The Planning is not only the core guiding document for ecological protection in the region, but also the strategic basis for achieving sustainable economic development in Guangxi, especially in promoting the the Belt and Road and regional cooperation, and improving the level of ecological civilization construction. Its implementation is not only in line with China's carbon neutrality goals, but also closely linked to the United Nations Sustainable Development Goals (SDGs). Through international cooperation and green development, Guangxi will become an important demonstration area for global ecological protection and sustainable development.

4. Impact of Planning on the Ecological Environment of Guangxi: Results and Discussion

4.1. Impact and Assessment of Ecological Security Pattern

The ecological security framework established in the Planning integrates various ecological regions within Guangxi into a cohesive, interconnected network. Guixi and Guibei, as key ecological barriers, play a fundamental role in Guangxi’s ecological construction efforts. The region’s northwest, characterized by mountainous and hilly terrains with substantial forest coverage—including areas such as Mount 90000 and Mao'er Mountain—serves as a critical natural reserve. The protection of these areas is crucial for maintaining ecological stability within Guangxi. The six zones outlined in the Planning refer to essential ecological function zones across different parts of the province, contributing to Guangxi's overall ecological health. The Xijiang River Basin, as Guangxi's most significant watershed, is crucial for enhancing water quality, increasing biodiversity, and improving the surrounding ecological environment. Additionally, the Beibu Gulf, Guangxi’s only maritime port, holds strategic importance for both ecological and economic considerations. Marine protection efforts in this area are integral to maintaining ecosystem balance and mitigating the impact of population growth and human activities on the ocean.

4.2. Protection Effect of Ecological Red Line and Its Impact on Biodiversity

The ecological protection red line delineated in the Plan encompasses over 30 major mountain ranges in the region, including the Dashan and Dayao Mountains, as well as key ecological functional areas such as coastal natural shorelines. A total of 52,000 square kilometers of ecological protection red lines have been established, covering 50,300 square kilometers of land and 1,700 square kilometers of marine areas. The establishment of these red lines is a critical step in improving Guangxi’s ecological environment, mitigating pollution, and reversing ecological degradation. Furthermore, by defining clear ecological boundaries, the red line enhances the region's capacity for sustainable economic and social development, offering valuable guidance for population distribution and economic planning. A well-managed population distribution and economic layout can lead to more efficient and intensive resource use, contributing to the positive development of Guangxi’s ecological environment.

The Plan also highlights five key resource constraints: the ecological protection red line, the permanent basic farmland protection red line, the upper limit of water resource utilization, the safety risk bottom line, and the upper limit of cultivated land occupation and compensation. Together, these constraints anchor the broader ecological security framework in Guangxi, while significantly enhancing the effectiveness of biodiversity protection.

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In addition to the ecological red lines, the Plan designates 27 ecological zones, 16 river corridors, and 3 migratory bird corridors outside the red line areas, creating a cohesive ecological network. These zones complement the red lines, working together to address many of the region's current environmental challenges, which are largely caused by human activities. The impact of this measure is evident in its ability to reduce the harm caused by industrial pollution to rivers and lakes, as well as curbing soil erosion and rocky desertification resulting from unsustainable mining and land use practices. After the red lines were introduced, the levels of soil erosion and rocky desertification in Guangxi decreased significantly.

However, a key challenge remains in balancing land use demands both within and outside the red line areas, particularly in the face of rapid economic development. Care must be taken to avoid conflicts between economic growth and ecological protection, ensuring that environmental conservation efforts are not undermined.

From 2000 to 2020, Guangxi experienced a significant increase in soil erosion, with the affected area rising from 10,469.04 square kilometers to 38,454.01 square kilometers. This placed substantial pressure on the region's ecological systems. However, since 2020, this trend has begun to reverse, with soil erosion levels declining. Projections indicate that by 2029, the area of soil erosion is expected to fall below 20,000 square kilometers. This improvement is closely linked to the implementation of the ecological protection measures outlined in the Plan [5,7].

4.3. Construction and Evaluation of Nature Reserve System

The construction of a comprehensive natural reserve system is essential for protecting Guangxi's terrestrial ecosystems, safeguarding endangered species, and preserving biodiversity. According to data released in early 2023, Guangxi ranks first in China for rare and endangered species, including endemic species such as the white-headed langur, Debao cycad, and Narrow-leaved Slope Ridge. Before the Planning was formally introduced, numerous nature reserves, including the karst mountains in Chongzuo City (designated as a national reserve in 2012), had already been established. These reserves have proven effective, as evidenced by the population of white-headed langurs, which increased from 598 in 2013 to over 1,400 in 2023. Forest coverage in Guangxi remains robust, with large areas in the 90000 Mountains, 100000 Mountains, and Dayao Mountains under protection.

The establishment of nature reserves is vital for mitigating ecological degradation, regulating climate, and maintaining natural stability. By building a well-structured system of nature reserves and enhancing public awareness of environmental protection, Guangxi aims to strengthen its ecological resilience. This system not only protects biodiversity but also ensures the long-term availability of ecological resources, further supporting sustainable regional development [6].

4.4. Ecological effects of ecological restoration and soil and water conservation

Ecological restoration, a cornerstone of the Planning, improves ecosystem resilience by enhancing biodiversity, increasing the self-purification capacity of soil and water, and mitigating pollution and erosion. Restoration strategies such as afforestation, vegetation rehabilitation, and waterbody management are designed to reduce soil erosion, increase vegetation cover, and stabilize ecosystems. In the long term, these efforts promote sustainable land use, increase agricultural productivity, and improve living conditions, fostering harmony between human development and the natural environment. The Planning prioritizes the restoration of areas affected by soil erosion and rocky desertification, aiming to restore soil health and create a self-sustaining ecosystem. Additionally, the strategy incorporates land consolidation projects to optimize land use, particularly in rural areas, and improve the overall living environment [7,10].

The Planning also emphasizes the need for comprehensive remediation of mining areas and coastal regions. Initiatives such as the "Blue Bay" remediation campaign focus on restoring damaged marine ecosystems and establishing an ecologically robust coastal zone. Through these measures, Guangxi can quickly enhance its environmental quality, increase biodiversity, and stabilize ecosystems. In the long run, these improvements are expected to boost tourism, attract investment, and promote sustainable

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economic growth. However, the long-term success of ecological restoration will depend on continued policy support and financial investment [8].

4.5. Water Resource Management and Water Quality Improvement

The Plan outlines comprehensive measures to improve the allocation of water resources, focusing on the construction of a secure regional water supply network. This network is designed around the concept of "two horizontal and eight vertical lines," connecting six rivers and integrating mutual assistance between rivers and reservoirs. The goal is to provide a multi-source guarantee to strengthen regional water supply security. In addition to improving water allocation, the Plan emphasizes the construction of river management systems, flood control projects, and related infrastructure, combining water quality improvement with disaster prevention and control measures.

Table 3. Statistics of Major Water Quality Indicators in Guangxi

Year	Annual assessment section water quality excellent rate (%)	Centralized drinking water source compliance rate in prefecture level cities (%)	Nearshore water quality excellent rate (%)
2023	99.1	100.0	94.5
2022	98.2	97.1	94.5
2021	97.3	94.3	92.6
2020	97.3	90.6	95.5
2019	96.2	97.4	90.9

Table 3 presents the key water quality indicators in Guangxi from 2019 to 2023, which include the annual assessment section water quality excellent rate, the compliance rate of centralized drinking water sources in prefecture-level cities, and the nearshore water quality excellent rate. These indicators provide a clear reflection of the improvements in water quality over the years.

The data in Table 3 highlights the continuous improvement in water quality across various indicators following the implementation of the Plan. The excellent rate of water quality in annual assessment sections has steadily increased, reaching 99.1% in 2023, up from 96.2% in 2019. Similarly, the compliance rate for centralized drinking water sources in prefecture-level cities has shown significant progress, achieving a perfect 100.0% compliance rate in 2023. This improvement is a clear indicator of the effectiveness of the water resource management strategies implemented in Guangxi. Moreover, the nearshore water quality excellent rate has also remained high, with a stable rate of 94.5% in 2022 and 2023, reflecting the success of the coastal water management measures.

5. Conclusion

This study critically examines the "Guangxi Zhuang Autonomous Region Land Spatial Planning (2021-2035)" and its impact on Guangxi's ecological environment. The research identifies key environmental challenges faced by the region, including soil erosion, rocky desertification, biodiversity loss, and water pollution. Through a comprehensive analysis, the paper evaluates the strategic importance of the plan, particularly its core components such as the establishment of ecological red lines, the expansion of nature reserves, and the implementation of ecological restoration measures. The findings suggest that the Planning has already had a significant positive influence on Guangxi's environmental health, particularly in terms of soil and water conservation, biodiversity protection, and climate change mitigation.

However, several limitations remain within this research. The analysis of ecological and environmental challenges could benefit from further depth and data-driven insights, and certain arguments lack persuasiveness due to insufficient empirical support. Future research should aim to fill these gaps by incorporating more robust datasets and applying advanced environmental assessment models to validate the effectiveness of the proposed strategies.

Looking forward, the Planning provides a clear framework for Guangxi's future development, balancing economic growth with environmental protection. As the region faces both opportunities and

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challenges, it must continue to prioritize sustainable practices, focusing on green development while addressing the unique rural characteristics of the area. By adhering to the principles of ecological civilization and sustainable growth, Guangxi can set a national and global example in achieving long-term environmental and economic success.

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