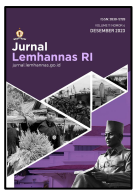

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The Role of Remote Sensing and GIS in Sustainable Development and National Resilience

Muhammad Saiful Ruuhulhaq
Amcolabora Institute, Indonesia

*) Corresponding Author: msaiful@amcolabora.or.id

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Abstract

Purpose: This study explores the critical role of Remote Sensing (RS) and Geographic Information Systems (GIS) in supporting Sustainable Development Goals (SDGs) and strengthening national resilience. It aims to highlight the originality and significance of RS and GIS as strategic tools for spatial data collection, analysis, and visualization.

Study Design/Methodology/Approach: This research employs a qualitative methodology based on a literature review and case studies. The study evaluates the application of RS and GIS in various sectors, including disaster mitigation, environmental preservation, and resource optimization.

Findings: The findings indicate that RS and GIS significantly contribute to SDGs by facilitating actions on climate change, biodiversity conservation, equitable resource distribution, and poverty alleviation. Additionally, RS and GIS strengthen national resilience through economic optimization, ecological disaster mitigation, conflict resolution, and strategic area monitoring.

Originality/Value: This study underscores the integrative role of RS and GIS in aligning SDGs and national resilience objectives, offering practical implications for decision-making across multiple sectors. The results provide a foundation for policymakers and practitioners to leverage RS and GIS for holistic and sustainable development.

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INTRODUCTION

The achievement of the Sustainable Development Goals (SDGs) adopted by the United Nations (UN) in 2015 has become a major global agenda in an effort to achieve inclusive and sustainable development until 2030. The SDGs consist of 17 goals that cover various aspects of life, including poverty alleviation, quality education, gender equality, clean water management, affordable and clean energy, and climate change mitigation (Alisjahbana & Murniningtyas, 2018). One of the main pillars in achieving the SDGs is sustainable natural resource management. Effective natural resource management not only ensures the availability of resources for the current generation but also maintains the balance of the ecosystem for future generations. Sustainable natural resource management is an important foundation in achieving the goals of the SDGs, such as SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), SDG 13 (Addressing Climate Change), and SDG 15 (Life on Land), see figure 1.

Source: United Nations (2015)

Figure 1. Sustainable Development Goals

National resilience is an integral component of sustainable development that includes a country's ability to face and overcome various threats that can disrupt economic, social, and environmental stability. National resilience is not only related to physical security aspects, but also includes adaptation to climate change, disaster risk management, and protection of strategic resources. In an increasingly complex and dynamic global context, national resilience is becoming increasingly important to ensure the sustainability of development and community welfare. Therefore, the integration

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between national resilience and sustainable development is key in creating a society that is resilient and adaptive to various challenges.

Sustainable natural resource management is closely linked to national resilience. Effective natural resource management can strengthen national resilience by ensuring the availability of vital resources, such as clean water, energy and food, and by maintaining the stability of life-sustaining ecosystems (Chirici, 2021). For example, good forest management not only maintains biodiversity and prevents deforestation, but also supports climate resilience through carbon storage and regulation of the water cycle. Sustainable management of clean water can reduce the risk of drought and flooding, which in turn improves national social and economic resilience. Sustainable natural resource management not only supports the achievement of SDGs but also strengthens overall national resilience.

Remote Sensing and Geographic Information Systems (GIS) technology has evolved into a strategic tool in supporting sustainable natural resource management and the achievement of the SDGs. These technologies enable the efficient collection, analysis and visualization of spatial and temporal data, which is critical in monitoring environmental change, managing natural resources and designing data-driven policies (Bachmann et al., 2022). Remote sensing provides the ability to monitor large areas with high accuracy, while GIS enables the integration of different types of data for more in-depth analysis and more detailed mapping. With these capabilities, RS and GIS can be used to monitor SDG indicators in real-time, such as water quality, land cover and greenhouse gas emissions, thus providing a strong basis for informed and timely decision-making.

The role of RS and GIS extends beyond environmental monitoring and resource management. In the context of national resilience, these technologies facilitate real-time disaster prediction and response, allowing for faster and more effective mitigation strategies (Persello et al., 2022). Governments and emergency response agencies can use RS and GIS to monitor critical areas vulnerable to forest fires, floods, landslides, and climate-induced hazards. By analyzing satellite data and geographic trends, policymakers can implement early warning systems that significantly reduce the risk to human lives and economic assets.

Moreover, RS and GIS have crucial applications in defense and security, particularly in border surveillance, strategic infrastructure protection, and intelligence gathering. Military and defense agencies use geospatial technologies to map terrain, track movements, and enhance security planning. These tools support national resilience by identifying potential geopolitical threats and ensuring efficient allocation of security resources. As global security challenges become more complex, integrating geospatial intelligence with national defense strategies has become a necessity.

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The implementation of RS and GIS in support of SDGs and national resilience faces various challenges. Some of the main challenges include limited access to data in developing countries, the need for adequate human resource capacity, and financial and technical constraints in developing technological infrastructure (Fei et al., 2021). Ethical issues related to data privacy and the lack of global standards for data integration are also obstacles that need to be overcome (Avtar et al., 2020). However, there are opportunities to overcome these challenges through international collaboration, increased investment in geospatial technologies, and the development of more inclusive and efficient analysis methods. By taking advantage of these opportunities, RS and GIS can be optimized to make a greater contribution to supporting the achievement of SDGs and strengthening national resilience in the future.

Sustainable management of natural resources is a key pillar in achieving the SDGs and strengthening national resilience. RS and GIS technology plays a strategic role in supporting these two agendas through data-driven decision-making, predictive analytics, and dynamic mapping capabilities. Despite challenges in its implementation, RS and GIS's potential to provide real-time intelligence and comprehensive spatial analysis makes it an invaluable tool in the effort to achieve sustainable development and maintain national stability. Therefore, further research and development in geospatial intelligence and remote sensing applications is essential to maximize its benefits in supporting increasingly complex global and national agendas.

Literature Review

Remote Sensing and Geographic Information System

Remote sensing and Geographic Information Systems (GIS) are technologies that play an important role in the collection, analysis, and visualization of spatial data. Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data obtained with a device without direct contact with the object under study (Somantri, 2009). Meanwhile, GIS is a system tasked with presenting and collecting geography-related data or information, which contains facts about locations on the earth's surface (Adil, 2017). The combination of RS and GIS enables comprehensive analysis of various geospatial phenomena, such as land use change, natural resource monitoring, and spatial planning.

Sustainable Development Goals

Sustainable Development Goals (SDGs) is a global development agenda adopted by the United Nations (UN) in 2015 as a continuation of the Millennium Development Goals (MDGs). The SDGs consist of 17 goals, 169 targets and 232 indicators covering various aspects of economic, social and environmental development. The agenda aims to eradicate poverty, reduce inequality, address climate change, and create a just and sustainable society by 2030 (United Nations, 2015).

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Unlike the MDGs, which focused more on basic needs and developing countries, the SDGs adopt a universal approach that is relevant to all countries, both developed and developing. This reflects the global realization that development challenges require an integrated approach involving all stakeholders, including governments, the private sector, academia and civil society.

The SDGs rest on three main pillars: economic, social and environmental. The economic pillar emphasizes inclusive growth, job creation, and reducing income inequality. The social pillar focuses on social welfare through quality education, gender equality, and public health. Meanwhile, the environmental pillar targets ecosystem protection through sustainable natural resource management and climate change mitigation. These three pillars are interrelated to ensure the sustainability of development in the future.

National Resilience

National resilience is a dynamic condition of a country that includes tenacity and enthusiasm to face all challenges and obstacles that threaten the integrity, identity, and survival of the nation and state (Pasla, 2024). National resilience is a dynamic condition that involves adaptability, risk mitigation, and conflict resolution to maintain territorial integrity, sovereignty, and community welfare.

The concept is rooted in systems theory, where national resilience is seen as the result of interactions between various components, including natural resources, infrastructure, technology and society. National resilience aims not only to protect the country from external threats but also to ensure internal stability that supports long-term development.

National resilience consists of several interrelated dimensions. The economic dimension involves the state's ability to manage resources to achieve economic independence and community welfare. Economic stability is an important foundation to strengthen the country's resilience to global and internal crises. The ecological dimension emphasizes the importance of environmental preservation and sustainable management of natural resources, where the state's ability to deal with environmental risks such as natural disasters and climate change determines national resilience. The social dimension includes social harmony, justice and community welfare, which are strengthened through poverty alleviation, increased access to education and conflict resolution. Finally, the security dimension includes efforts to maintain territorial sovereignty, national integrity, and the safety of citizens from internal and external threats, including border control and strengthening defense (Irhamsyah, 2020).

In the era of globalization, national resilience is not only influenced by domestic dynamics but also by external pressures, such as climate change, global pandemics, geopolitical conflicts, and international economic challenges. National resilience is

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becoming increasingly important in maintaining state stability and sovereignty amid complex global challenges.

METHODS

This study employs a descriptive qualitative approach to explore the role and contribution of Remote Sensing (RS) and Geographic Information Systems (GIS) in achieving the Sustainable Development Goals (SDGs) and strengthening national resilience. The qualitative method provides a more comprehensive understanding of how RS and GIS contribute to environmental sustainability, disaster mitigation, and strategic national security planning (Creswell & Poth, 2018).

The data sources in this study include secondary data collected from scientific articles, government policies, books, and reports related to the implementation of RS and GIS within the context of SDGs and national resilience (Bowen, 2009). Additionally, primary data is obtained through semi-structured interviews with geospatial technology experts, policymakers, and environmental analysts involved in the application of RS and GIS (Kvale & Brinkmann, 2015). These data sources are crucial in providing both theoretical insights and practical perspectives on the utilization of geospatial technologies for sustainability and resilience strategies.

The data analysis process in this study follows a systematic literature review approach and thematic content analysis, enabling the identification of key patterns, research gaps, and challenges in the utilization of RS and GIS (Hart, 2018). The study's findings aim to provide practical recommendations for policymakers and stakeholders, emphasizing the importance of global collaboration, technological investment, and capacity building to enhance the effective use of RS and GIS in achieving sustainable development and strengthening national resilience.

RESULT AND DISCUSSION

Sustainable development and national resilience are closely linked. Sustainable development ensures that the needs of the current generation are met without compromising the ability of future generations to meet their needs. This is in line with the concept of national resilience, which emphasizes the nation's ability to survive and thrive in the face of various challenges. Thus, the implementation of sustainable development will strengthen national resilience, while strong national resilience will support the achievement of sustainable development goals.

The Role of RS and GIS in Supporting SDGs

Remote Sensing and Geographic Information Systems (GSIS) plays an important role in supporting the implementation of the Sustainable Development Goals (SDGs)

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through various applications. In the effort to eradicate poverty (No Poverty), RS and GIS is used to identify areas with high poverty rates through spatial analysis, which helps with targeted program planning. To achieve the goal of Zero Hunger, this technology monitors soil conditions and crop yields using remote sensing, supporting improved food security. In the health sector (Good Health and Well-Being), RS and GIS helps track disease outbreaks and the location of health facilities, enabling rapid response to health crises. In addition, RS and GIS also plays a role in ensuring equitable access to education (Quality Education) through mapping the distribution of education resources, as well as supporting gender equality policies by mapping gender disparities in access to resources and services.

In clean water and sanitation management, RS and GIS is used to map water distribution systems and sanitation coverage to ensure equitable access. Meanwhile, to support Affordable and Clean Energy, the technology maps potential renewable energy sources such as solar and wind. In Decent Work and Economic Growth, RS and GIS analyzes spatial patterns of unemployment and economic activity, helping to formulate more effective policies. In Industry, Innovation, and Infrastructure, RS and GIS supports smart city planning with spatial data integration, creating efficient and sustainable infrastructure.

In addition, RS and GIS plays a role in Reduced Inequalities by visualizing income inequality and access to services, supporting policies to reduce social disparities. In Sustainable Cities and Communities, it assists spatial planning with 3D modeling and GIS mapping. RS and GIS also supports Responsible Consumption and Production through supply chain mapping to track sustainable resources. In Climate Action, RS and GIS is used to analyze climate change impacts, enabling better mitigation and adaptation planning.

In terms of marine ecosystem preservation (Life Below Water), RS and GIS monitors marine ecosystems and fisheries using satellite imagery, while for terrestrial ecosystems (Life on Land), the technology tracks deforestation and biodiversity loss, promoting environmental conservation. In Peace, Justice, and Strong Institutions, RS and GIS maps conflict zones and supports peacebuilding efforts. Finally, in Partnerships for the Goals, RS and GIS facilitates data sharing through GIS platforms, strengthening collaboration between parties. With these various applications, RS and GIS becomes a strategic tool in supporting the implementation of SDGs through the utilization of accurate spatial data and technology-based analysis, see figure 2.

Case studies of RS and GIS implementation in various sectors also show its significant impact. In forest fire mitigation, for example, RS and GIS is used to monitor weather conditions, soil moisture, and the presence of dry vegetation that could potentially trigger fires. With this system, early detection can be done, so that preventive measures can be taken before the fire spreads. In the peat restoration sector, RS and GIS functions in mapping the condition of peat ecosystems and identifying areas that require

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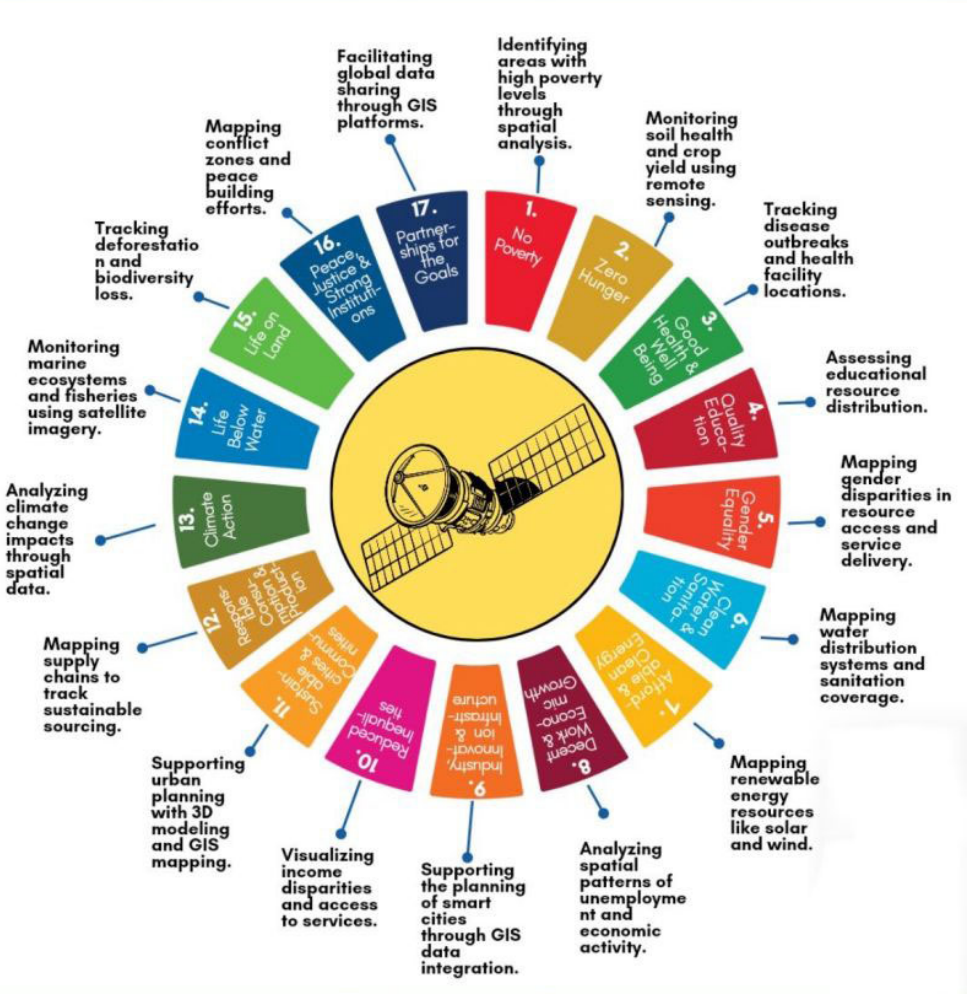
rehabilitation. This geospatial information enables restoration programs to be more targeted and effective, resulting in more optimal results. In addition, in clean water mapping efforts, RS and GIS contributes through the collection of spatial data on water sources, water quality, and distribution networks, which helps the government in ensuring equitable access to clean water for the community.



Source: LinkedIn (2024)

Figure 2. 17 Applications of RS and GIS in Sustainable Develompment

RS and GIS Contribution to National Resilience

In the context of national resilience, RS and GIS has a very broad contribution, covering economic, ecological, social and security aspects. From an economic aspect, RS and GIS enables the mapping of potential natural resources such as minerals, forests, and agricultural land, which can be optimally utilized to improve people's welfare. With accurate data, exploitation of natural resources can be done more wisely and sustainably, reducing the risk of environmental damage and social conflict. From an ecological aspect, RS and GIS supports disaster mitigation and environmental preservation by providing

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relevant geospatial information to detect potential disasters such as floods, landslides, or forest fires. This information allows mitigation actions to be taken early, so that the impact of disasters can be minimized.

In terms of social aspects, RS and GIS helps resolve resource conflicts by providing transparent and accountable data. Conflicts that often arise due to the struggle for land or natural resources can be minimized with clear and accurate spatial information. Meanwhile, from a security aspect, RS and GIS provides the ability to monitor strategic areas, such as national borders, conflict-prone areas, or areas that are strategic targets for development. By using geospatial data, threats to national security can be detected more quickly, and appropriate responses can be designed to address those threats. Overall, the contribution of RS and GIS to national resilience not only increases the effectiveness of resource management but also strengthens coordination between sectors in facing various national challenges.

Relations SDGs and National Resilience through RS and GIS

Relations between SDGs and national resilience can be achieved through the utilization of RS and GIS to support areas where these two goals complement each other. Some of the areas of intersection between the SDGs and national resilience are natural resource management, disaster mitigation, basic infrastructure development, and improving social and economic welfare. In this context, RS and GIS serves as a tool that can integrate information and analysis to support more comprehensive planning. For example, sustainable natural resource management not only supports the SDGs' goal of preserving the environment but also strengthens national resilience through reducing conflict risks and improving economic stability.

The RS and GIS integration strategy to achieve both goals involves several key steps. First, the development of a comprehensive national geospatial database is essential to ensure that all needed data is available and accessible to stakeholders. This database will not only be a key source of information but also support coordination between different agencies. Second, training and capacity building for human resources in the use of RS and GIS is a priority to ensure that this technology can be optimally utilized. With competent experts, the implementation of RS and GIS can be done more effectively.

Third, collaboration between institutions, both at the national and local levels, needs to be strengthened to ensure that national development and resilience programs can be implemented synergistically. This collaboration involves the government, academia, the private sector, and civil society, all of which have important roles in supporting the sustainable utilization of RS and GIS. Thus, the integration of RS and GIS in the planning

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and implementation of development programs will not only accelerate the achievement of SDGs but also strengthen national resilience as a whole.

Discussion

The integration of Remote Sensing (RS) and Geographic Information Systems (GIS) into sustainable development and national resilience frameworks provides a strategic advantage in addressing environmental, economic, and security challenges. By enabling real-time monitoring, predictive analysis, and data-driven decision-making, RS and GIS facilitate proactive disaster risk management, enhance resource optimization, and support security initiatives such as border surveillance, infrastructure protection, and conflict monitoring (Avtar et al., 2019). The ability to track climate change indicators, deforestation patterns, and population displacement further reinforces their role in strengthening national resilience while advancing SDGs. Recent studies have shown how AI-enhanced satellite imagery can be effectively utilized to monitor socioeconomic indicators such as poverty levels and agricultural productivity, which are critical for achieving SDG targets (Burke et al., 2020). Similarly, RS-based Essential Variables (EVs) have been identified as key instruments in tracking deforestation rates, land use changes, and biodiversity loss, directly supporting SDG 15 (Life on Land) (Reyers et al., 2017).

However, several implementation challenges hinder the full potential of RS and GIS, particularly in developing countries. Limited access to high-resolution satellite data, inadequate technical expertise, and high infrastructure costs present barriers to widespread adoption (Fei et al., 2021). Moreover, ethical concerns surrounding data privacy and geospatial surveillance necessitate the establishment of standardized policies to regulate geospatial intelligence applications (Persello et al., 2022). Additionally, a lack of inter-agency collaboration and integration of GIS into national security policies often leads to inefficiencies in disaster response and security planning (Irhamsyah, 2020). To overcome these obstacles, government collaboration with academia and the private sector is essential in fostering open-access geospatial data initiatives, capacity-building programs, and cross-border technology exchanges. Furthermore, the integration of RS and GIS into urban resilience strategies has gained attention, particularly in addressing vulnerabilities in coastal cities and densely populated urban centers where climate change impacts are more pronounced.

To maximize the impact of RS and GIS, future research should focus on integrating artificial intelligence (AI) and machine learning algorithms to enhance automated spatial analysis and predictive modeling (Chirici, 2021). Additionally, exploring the use of RS

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and GIS in cybersecurity, smart infrastructure resilience, and conflict resolution can expand their application beyond environmental sustainability (Persello et al., 2022). By strengthening institutional frameworks, investing in geospatial capacity-building, and fostering international cooperation, RS and GIS can serve as powerful tools for achieving sustainable development and national security in a rapidly evolving global landscape (Farikha & Trimurtini, 2024)

CONCLUSION

Remote Sensing and Geographic Information Systems (RS and GIS) contribute significantly to the achievement of the Sustainable Development Goals (SDGs) and the enhancement of national resilience. The implementation of RS and GIS enables the accurate collection, analysis, and visualization of spatial data, which is crucial for multiple sectors, including disaster mitigation, environmental preservation, urban planning, and monitoring of strategic areas. In the context of SDGs, RS and GIS plays a vital role in addressing climate change, preserving biodiversity, ensuring equitable distribution of educational resources, and alleviating poverty. These technologies offer an evidence-based approach that allows policymakers and stakeholders to develop more targeted and effective strategies for sustainable development.

Beyond its contributions to sustainable development, RS and GIS serve as a critical tool in enhancing national resilience. These technologies enable real-time monitoring of disaster risks, resource management, and infrastructure planning, which are essential for economic stability and security. In the economic sector, RS and GIS optimize the sustainable utilization of natural resources, supporting long-term economic growth while minimizing environmental degradation. Ecologically, RS and GIS facilitate proactive disaster mitigation, reducing the impacts of climate-related hazards such as floods, wildfires, and droughts. Additionally, in the social dimension, RS and GIS play an instrumental role in conflict resolution by providing transparent and data-driven insights into resource distribution and land-use disputes.

From a security and defense perspective, RS and GIS offer strategic advantages in national security operations, including border surveillance, intelligence gathering, and monitoring of geopolitical threats. These technologies improve national resilience by providing geospatial intelligence for decision-making, enabling governments to respond proactively to emerging security challenges. The ability to integrate multi-layered geospatial data enhances situational awareness, allowing for rapid response and strategic planning. Moreover, RS and GIS support military operations and disaster response efforts, reinforcing the stability and sovereignty of a nation.

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Despite its vast potential, several challenges hinder the full-scale adoption of RS and GIS, including limited access to high-quality data, insufficient human resource capacity, and financial constraints in developing countries. Additionally, ethical concerns surrounding data privacy and interoperability standards require further attention. To maximize the benefits of RS and GIS, increased investment, capacity building, and cross-sector collaboration are essential. Future research should focus on developing more adaptive geospatial technologies, improving AI-driven analytics in remote sensing, and strengthening policy frameworks for geospatial data governance. By addressing these challenges, RS and GIS can continue to evolve as a transformative force in achieving sustainable development and national resilience in an increasingly complex global landscape.

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