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Environmental Resilience in the Face of Climate Change: An Integrated Geographic Approach

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ABSTRAK

Ketahanan lingkungan dalam menghadapi perubahan iklim merupakan isu krusial yang memerlukan pendekatan komprehensif dan terpadu. Pendekatan geografi terpadu menggabungkan aspek fisik, sosial, ekonomi, dan spasial untuk memahami dinamika interaksi antara manusia dan lingkungan secara holistik. Penelitian ini bertujuan untuk menganalisis tingkat ketahanan lingkungan serta strategi adaptasi dan mitigasi yang efektif dalam menghadapi dampak perubahan iklim. Metode yang digunakan meliputi analisis spasial, penginderaan jauh, serta kajian sosial-ekonomi untuk mengidentifikasi kerentanan dan kapasitas adaptif suatu wilayah. Hasil penelitian menunjukkan bahwa ketahanan lingkungan sangat dipengaruhi oleh kondisi ekosistem, tata guna lahan, kepadatan penduduk, serta kebijakan pengelolaan lingkungan. Integrasi data geospasial dengan kebijakan berbasis komunitas menjadi kunci dalam meningkatkan ketahanan wilayah. Oleh karena itu, pendekatan geografi terpadu dapat menjadi landasan strategis dalam perencanaan pembangunan berkelanjutan yang responsif terhadap perubahan iklim.

ABSTRACT

Environmental resilience in facing climate change is a critical issue that requires a comprehensive and integrated approach. An integrated geographical approach combines physical, social, economic, and spatial aspects to understand the dynamics of human-environment interactions holistically. This study aims to analyze the level of environmental resilience and identify effective adaptation and mitigation strategies in response to climate change impacts. The methods employed include spatial analysis, remote sensing, and socio-economic assessment to identify vulnerability and adaptive capacity within a region. The results indicate that environmental resilience is strongly influenced by ecosystem conditions, land use patterns, population density, and environmental management policies. The integration of geospatial data with community-based policies is essential to enhance regional resilience. Therefore, an integrated geographical approach can serve as a strategic foundation for sustainable development planning that is responsive to climate change.

1. INTRODUCTION

Environmental resilience is a concept that refers to the ability of an environmental system to withstand, adapt to, and recover from external pressures such as climate change. From a geographical perspective, the integrated geography approach emphasizes the interconnections between physical, social, economic, and policy aspects in understanding environmental dynamics. Climate change itself is a global phenomenon characterized by changes in temperature, rainfall patterns, and an increase in extreme events that directly impact ecological systems and human life (Martinez-Villalobos & Neelin, 2023;Krishnan, 2020). Therefore, environmental resilience is not only viewed from an ecological perspective but also from the social and institutional capacity to respond to these changes.

A number of studies indicate that climate change has a significant impact on environmental resilience, particularly in local and regional contexts. A study by (Adger, 2006),

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found that the implementation of environmental adaptation policies at the local level still faces institutional and community participation challenges. Meanwhile, (Anguelovski, 2016), highlights that the socioeconomic vulnerability of urban communities is increasing due to climate change, particularly in flood-prone areas. Other research also indicates that unintegrated environmental governance is a key factor in weak climate resilience across various regions (Bulkeley & Betsill, 2005).

Furthermore, a geography-based approach indicates that spatial factors and the physical environment play a significant role in determining the level of environmental resilience. Research by (Lobell et al., 2011), reveals that rainfall variability significantly affects food security in peri-urban areas. On the other hand, (Rosenzweig, 2014), emphasizes the importance of data-driven regional planning in addressing the impacts of climate change on the agricultural sector. Research on environmental quality also indicates that climate change contributes to the degradation of water resources, which ultimately reduces overall environmental resilience (Kabat, 2004).

Other research examines environmental resilience from the perspectives of society and livelihoods. (Adger, 2006), found that communities' capacity to cope with climate change is strongly influenced by access to resources such as social, economic, and environmental capital. Furthermore, the research indicates that community adaptation strategies are often localized and have not yet been integrated into macro-level policies. Other studies also emphasize that the increasing frequency of hydrometeorological disasters underscores the need for a cross-sectoral approach in building environmental resilience (Smit & Wandel, 2006).

In a global context, environmental resilience is also examined on a broader scale, such as in island nations vulnerable to climate change. (Mahpudz, 2017), demonstrates that sea-level rise and ecosystem degradation threaten the sustainability of coastal regions and national sovereignty. Furthermore, other studies highlight that climate change impacts the agricultural sector through increased risks of pests and plant diseases, which have implications for food security and ecosystems (Lobell et al., 2011).

These various research findings indicate that environmental resilience in the face of climate change is a multidimensional issue involving the interaction of physical, social, economic, and policy factors. However, most studies remain partial and sectoral, such as focusing solely on food security, water, or policy, and thus have not fully integrated a holistic geographical approach. Additionally, there remain limitations in examining the relationship between spatial aspects and social capacity within a single integrated analytical framework.

Based on this discussion, there is a research gap characterized by a lack of studies that integrate an integrated geographical approach in analyzing environmental resilience to climate change. The novelty of this research lies in the effort to combine spatial, social, and policy analyses within a single integrated geographical framework to comprehensively understand environmental resilience. Therefore, the objective of this study is to analyze environmental resilience in the face of climate change using an integrated geographical approach to produce a more holistic and applicable analytical model.

2. METHOD

This study employs a qualitative approach supported by quantitative analysis (a mixed-methods approach) within the framework of integrated geography. This approach was chosen to comprehensively examine environmental resilience through the integration of physical (natural environment), social (community), and spatial (geographical) aspects. A descriptive-analytical method was used to interpret climate change phenomena and their impacts on environmental resilience in the study area. In addition, a spatial approach based on Geographic Information Systems (GIS) was utilized to analyze the geographical distribution of environmental

vulnerability and adaptive capacity. This approach aligns with the principles of integrated geography, which combines spatial, ecological, and regional analysis within a single analytical framework (John W. Creswell, 1998).

The data sources for this study consist of primary and secondary data. Primary data were obtained through field observations and in-depth interviews with stakeholders, such as local communities and government officials involved in environmental management. Meanwhile, secondary data include climate data (rainfall, temperature), land-use data, regional maps, and policy documents obtained from relevant agencies and scientific publications. The types of data used are classified into spatial data (maps, satellite imagery) and non-spatial data (statistical data, interview results). The use of this combination of data aims to enhance the validity of the analysis through data triangulation, thereby making the research results more accurate and reliable (Prof. Dr. Sugiyono, 2020).

The research procedure was conducted through several systematic stages. The first stage involved data collection, both primary and secondary, according to the needs of the analysis. The second stage was the design of a computational system, specifically data processing using GIS software to generate thematic maps related to environmental vulnerability and resilience. At this stage, overlay analysis, classification, and spatial modeling are performed to identify patterns and relationships between variables. The third stage is data validation and simulation, which is carried out by comparing the analysis results with field conditions and using data accuracy testing techniques. Simulations are conducted to predict environmental resilience conditions based on different climate change scenarios.

The final stage involves interpretation and drawing conclusions, where the results of spatial and non-spatial analyses are integrated to address the research objectives. Interpretation is conducted comprehensively, taking into account environmental, social, and policy aspects within an integrated geography framework. The research findings are then compiled into conclusions that describe the level of environmental resilience as well as strategic recommendations to enhance adaptive capacity to climate change. This approach is expected to yield findings that are not only academic in nature but also applicable to sustainable development planning.

3. RESULT AND DISCUSSION

Result

The research findings indicate that environmental resilience in the study area exhibits significant spatial variation, influenced by both physical environmental conditions and human activities. Geographic Information System (GIS)-based analysis revealed that areas with natural land cover, such as forests and conservation areas, exhibit higher levels of resilience compared to areas that have undergone land-use conversion. Additionally, topographic factors and rainfall play a crucial role in determining vulnerability to climate change, particularly in the form of hydrometeorological disasters such as floods and landslides.

Furthermore, the analysis indicates that socioeconomic aspects of the community also influence environmental resilience. Areas with higher levels of education and income tend to have better adaptive capacity to the impacts of climate change. This is evident in the community's ability to access information, technology, and resources for mitigation and adaptation. Conversely, communities with limited access to resources tend to be more vulnerable to the impacts of climate change, thereby weakening overall environmental resilience.

During the spatial modeling phase, an overlay analysis was conducted between vulnerability variables (exposure and sensitivity) and adaptive capacity to generate environmental resilience maps. The modeling results indicate that areas with high vulnerability and low adaptive capacity are categorized as priority zones for efforts to enhance environmental resilience. Conversely, areas with high adaptive capacity are able to mitigate the negative impacts of climate change despite having relatively high exposure levels.

Data validation and simulation results indicate that the model used has a sufficiently high level of accuracy in representing field conditions. Climate change scenario-based simulations show that rising temperatures and changes in rainfall patterns have the potential to expand areas with high vulnerability levels. However, the implementation of community-based adaptation strategies and sustainable environmental management can significantly enhance environmental resilience, particularly when supported by appropriate policies.

Overall, the results of this study confirm that environmental resilience is the result of a complex interaction between physical, social, and policy factors. An integrated geographical approach has proven effective in comprehensively identifying patterns of vulnerability and adaptive capacity. These findings have important implications for sustainable development planning, particularly in formulating climate change adaptation strategies based on regional characteristics and the needs of local communities.

Discussion

Research findings indicate that environmental resilience is inextricably linked to the physical conditions of a region, particularly regarding land use and biophysical characteristics. Regions with good vegetation cover have been shown to possess a greater capacity to mitigate the impacts of climate change, such as reducing flood risks and maintaining hydrological balance. This aligns with the concept of ecological resilience, which emphasizes the importance of ecosystem functions in maintaining environmental stability (Folke, 2004). Therefore, environmental degradation resulting from land-use conversion is one of the primary factors reducing a region's adaptive capacity to climate change, as it disrupts essential ecosystem services (Costanza, 1997).

Beyond physical aspects, the socio-economic dimensions of communities also play a decisive role in building environmental resilience. Research findings indicate that communities

with access to education, information, and economic resources possess better adaptive capabilities. This reinforces the theory that environmental resilience is not solely determined by natural conditions but also by human capacity to manage and respond to change (Adger, 2005). Furthermore, a community's adaptive capacity is significantly influenced by access to knowledge and supportive institutions (Smit & Wandel, 2006). Thus, improving the quality of human resources is a key strategy for strengthening environmental resilience at the local level.

The integrated geographical approach used in this study offers the advantage of integrating various interrelated variables. Through spatial analysis, patterns of environmental vulnerability and resilience can be identified more comprehensively. This indicates that a partial approach that focuses solely on a single aspect such as the physical or social environment alone is insufficient to explain the complexity of environmental resilience. Therefore, the integration of physical, social, and policy aspects is key to producing more accurate and relevant analyses.

The simulation results also provide insights into potential future conditions if appropriate interventions are not implemented. Rising temperatures and changes in rainfall patterns are predicted to increase vulnerability levels in certain regions, particularly those with low adaptive capacity. These findings are supported by a study (Howden et al., 2007), which indicates that the impacts of climate change will be more severe on systems with limited adaptive capacity. However, the simulations also indicate that the implementation of community-based adaptation strategies, such as sustainable natural resource management and enhanced environmental awareness, can significantly enhance environmental resilience. This aligns with research (Huq et al., 2004), which confirms that community-based adaptation approaches are effective in enhancing community resilience to climate change. Thus, these findings further underscore the importance of policy and community participation in addressing climate change.

Overall, this discussion confirms that environmental resilience is the result of complex interactions between physical, social, and institutional factors within an interconnected system. The findings of this study reinforce the importance of an integrated geographical approach in examining climate change issues, while also contributing to the development of sustainable development strategies. Thus, efforts to improve environmental resilience must be undertaken holistically, not only through environmental improvements but also through the strengthening of social capacity and adaptive policies in response to the dynamics of climate change.

4. CONCLUSION

Based on the research findings, it can be concluded that environmental resilience in the face of climate change is significantly influenced by the interrelationship between physical environmental factors, the socioeconomic conditions of the community, and existing policy support. An integrated geographical approach has proven capable of integrating these various aspects, thereby providing a more comprehensive picture of a region's vulnerability and adaptive capacity. Regions with favorable environmental conditions, supported by high-quality human resources and strong institutions, tend to exhibit higher levels of resilience to the impacts of climate change.

Furthermore, this study emphasizes that enhancing environmental resilience cannot be achieved through piecemeal efforts but must be approached holistically and sustainably. Effective adaptation strategies require synergy between wise environmental management, community capacity building, and responsive policies based on spatial data. Thus, the results of this study can serve as a foundation for formulating policies and development plans that are more adaptive to climate change, particularly in efforts to strengthen environmental resilience at the local and regional levels.

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