

Exploring Karst Area Management for State Revenue Generation in the Aru Islands, Maluku Province

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ABSTRACT

This research explores the potential for karst area management to generate state revenue in the Aru Islands, Maluku Province, Indonesia. Karst landscapes, characterized by limestone formations, caves, and underground rivers, are integral to the ecological, socio-economic, and cultural fabric of the region. However, challenges such as unsustainable resource exploitation, environmental degradation, and governance gaps threaten the long-term sustainability of karst ecosystems and the well-being of local communities. Through a multi-disciplinary approach integrating ecological surveys, socio-economic analyses, and stakeholder consultations, this study assesses the ecological value of karst landscapes, identifies socio-economic opportunities and challenges, and proposes policy recommendations for sustainable development and revenue generation. Key findings underscore the ecological significance of karst areas, the importance of community engagement, and the need for strengthened governance mechanisms to promote inclusive growth, environmental conservation, and social equity in the Aru Islands. The research contributes to the growing body of knowledge on karst area management and provides actionable insights for policymakers, government agencies, civil society organizations, and local communities striving to achieve sustainable development goals in karst regions.

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1. INTRODUCTION

The Aru Islands, situated within the Maluku Province of Indonesia, are a collection of approximately 95 islands located in the Arafura Sea, off the southwestern coast of Papua (Barri et al., 2019). This archipelago, encompassing a total land area of around 8,563 square kilometers, holds immense significance due to its unique ecological features, cultural heritage, and strategic location within the Indonesian archipelago (Haji-Othman, 2005).

Geographically, the Aru Islands are characterized by their diverse landscapes, ranging from lush tropical forests to expansive mangrove swamps and coastal plains (Paijmans, 1976). However, one of the most notable features of the Aru Islands is the presence of extensive karst landscapes. Karst formations, characterized by limestone outcrops, caves, sinkholes, and underground rivers, are not only geologically fascinating but also harbor rich biodiversity and provide vital ecosystem services (Clements et al., 2006).

The significance of the Aru Islands extends beyond their natural beauty and ecological importance (Anderson, 2003). Historically, these islands have been inhabited by indigenous communities whose livelihoods are intricately linked to the land and sea (Capistrano, 2010).

Traditional practices, such as fishing, agriculture, and hunting, have sustained these communities for generations, contributing to the cultural richness of the region.

Despite their ecological and cultural value, the Aru Islands face various challenges, including issues related to karst area management and state revenue generation (Martias, 2015). Karst landscapes, while biologically diverse and ecologically sensitive, are also susceptible to degradation and exploitation (Bonacci, 2009). Unsustainable mining activities, deforestation, and improper waste management practices pose significant threats to the integrity of karst ecosystems in the region (Danielopol et al., 2003). Additionally, unregulated tourism and infrastructure development may exacerbate environmental degradation and disrupt local communities' way of life.

Karst areas are geological formations characterized by the dissolution of soluble rocks, such as limestone, dolomite, and gypsum, resulting in unique surface and subsurface landscapes (Stevanović, 2015). The distinctive features of karst landscapes include sinkholes, caves, underground rivers, disappearing streams, and rugged limestone cliffs. These formations are primarily shaped by the chemical weathering of carbonate rocks through the process of carbonation, where rainwater combines with carbon dioxide to form a weak carbonic acid that dissolves the soluble rock over time (Olajire, 2013).

In the context of the Aru Islands, karst areas hold significant ecological, geological, and socio-economic importance (Monk & De Fretes, 2012). These karst landscapes contribute to the region's biodiversity by providing habitat for a wide range of plant and animal species, including endemic and rare flora and fauna. The unique microclimates within karst caves support specialized ecosystems, hosting species adapted to the dark, humid environments (Mammola, 2019). Additionally, underground rivers and aquifers associated with karst systems play a crucial role in regulating water flow, recharge groundwater reserves, and providing freshwater resources for local communities.

Beyond their ecological significance, karst areas in the Aru Islands also hold cultural and historical importance (O'Connor et al., 2005). Indigenous communities often regard karst formations as sacred sites and cultural landmarks, incorporating them into myths, legends, and traditional rituals. These landscapes serve as repositories of cultural heritage, containing archaeological remains, ancient cave paintings, and other artifacts that offer insights into human history and prehistoric activities in the region (Reynard & Giusti, 2018).

Moreover, karst landscapes in the Aru Islands present opportunities for sustainable development and eco-tourism (Suriamihardja, 2015). The scenic beauty, biodiversity, and geological wonders of karst areas attract visitors interested in cave exploration, birdwatching, and nature-based activities. Sustainable tourism initiatives centered around karst landscapes can generate economic benefits for local communities while promoting environmental conservation and cultural preservation (Xiong et al., 2023).

However, karst areas in the Aru Islands also face threats from anthropogenic activities and natural processes (Sunkar et al., 2022). Unsustainable limestone quarrying, mining, and deforestation can lead to habitat loss, soil erosion, and degradation of karst ecosystems. Pollution from agricultural runoff, industrial waste, and untreated sewage poses risks to water quality in karst aquifers, compromising the integrity of freshwater resources. Additionally, natural hazards such as sinkhole formation, cave collapses, and karst-related subsidence may pose risks to human safety and infrastructure development in the region (Gutiérrez et al., 2014).

In light of these challenges, there is a pressing need for research and concerted action to address issues related to karst area management and state revenue generation in the Aru Islands (Ambo-Rappe & Moore, 2019). By adopting an integrated approach that balances conservation with socio-economic development goals, stakeholders can work towards preserving the ecological integrity of karst landscapes while unlocking their economic value for the benefit of local communities and the broader society. Effective governance mechanisms, community engagement initiatives, and sustainable financing mechanisms are essential for realizing the full potential of karst area management in the Aru Islands and ensuring the long-term prosperity of this unique and invaluable region within the Maluku Province of Indonesia.

According to White and Culver (2012), effective karst management requires understanding the hydrogeological processes, biodiversity patterns, and socio-economic dynamics unique to each karst region (APRILIA et al., 2021). Management strategies often involve zoning, land use planning, and regulatory measures to mitigate threats such as habitat fragmentation, pollution, and land degradation (Ford and Williams, 2020).

The literature on state revenue generation from natural resources highlights the potential economic benefits and associated challenges. In the context of karst areas, revenue generation strategies vary depending on factors such as tourism potential, mineral resources, and ecosystem services. For instance, Gopaldas and Smith (2018) found that eco-tourism in karst regions can contribute significantly to local economies while promoting environmental conservation and cultural heritage preservation. However, concerns about over-tourism, infrastructure development, and socio-economic inequities require careful planning and management (Dixon and Sherman, 2019).

Studies conducted in other karst regions provide valuable insights into management practices and revenue generation strategies applicable to the Aru Islands. For example, research in Guilin, China, has demonstrated the economic viability of karst tourism through visitor expenditures, entrance fees, and related services (Xu et al., 2017). Similarly, studies in the Yucatan Peninsula, Mexico, have explored the potential for groundwater management and carbon sequestration in karst aquifers as revenue-generating mechanisms (Herrera-Silveira et al., 2019).

Moreover, lessons from karst management initiatives in Europe, such as the Dinaric Karst Aquifer System, emphasize the importance of transboundary cooperation, stakeholder engagement, and adaptive governance mechanisms (Bonacci et al., 2015). These studies highlight the need for context-specific approaches tailored to the socio-economic and environmental conditions of each karst region.

While existing literature provides valuable insights into karst area management and state revenue generation, several gaps remain that the current research aims to address (Parise et al., 2018). Many studies on karst area management and state revenue generation focus on well-known karst regions such as Guilin in China or the Yucatan Peninsula in Mexico (Timo, 2021). However, there is a paucity of research specifically addressing the Aru Islands in the context of Maluku Province, Indonesia. The unique socio-economic, cultural, and environmental characteristics of the Aru Islands warrant dedicated research to assess the feasibility of karst area management and revenue generation strategies tailored to this region (OMAR, 2015).

While some studies examine the economic potential of karst landscapes, there is often a lack of integration with socio-economic perspectives (Qiu et al., 2022). Understanding the socio-economic dynamics, community needs, and cultural values is essential for designing effective management strategies that benefit local stakeholders. The current research aims to bridge this gap by incorporating socio-economic analyses to assess the implications of karst area management for livelihoods, employment opportunities, and local economies in the Aru Islands (Hanson et al., 2022).

Effective karst area management requires supportive governance structures, policy frameworks, and institutional capacities. However, existing literature often overlooks the governance dimensions of karst management and the role of policy interventions in promoting sustainable development and revenue generation (Sunkar, 2008). By examining governance mechanisms, policy instruments, and stakeholder engagement processes, the current research seeks to provide insights into the institutional arrangements needed to facilitate karst area management in the Aru Islands (Suhartini & Jones, 2019).

While some studies highlight the economic benefits of karst tourism or ecosystem services, there is a need for more comprehensive analyses of revenue generation strategies (Nie et al., 2022). The current research aims to explore a range of revenue sources beyond tourism, such as carbon sequestration, water management, and sustainable agriculture, to maximize the economic potential of karst areas in the Aru Islands. By identifying alternative revenue streams and assessing their feasibility, the research aims to diversify income sources and enhance the resilience of local economies.

2. RESEARCH METHOD

The methodology begins with a detailed description of the study area, including the geographical features, land use patterns, and socio-economic characteristics of the Aru Islands. Geographic information system (GIS) mapping techniques will be utilized to delineate karst areas, identify key ecological hotspots, and assess land cover changes over time. Additionally, socio-economic surveys and interviews with local communities will provide insights into livelihood strategies, cultural practices, and perceptions of karst area management.

The research adopts a mixed-methods approach, integrating qualitative and quantitative methods to gain a comprehensive understanding of karst area management and state revenue generation in the Aru Islands.

Data collection methods will encompass both quantitative and qualitative approaches to capture diverse aspects of karst area management and state revenue generation. Field surveys will be conducted to assess the ecological value of karst landscapes, including biodiversity assessments, vegetation mapping, and water quality monitoring. Economic valuation techniques, such as contingent valuation and cost-benefit analysis, will be applied to estimate the monetary value of ecosystem services provided by karst areas.

Furthermore, stakeholder interviews and focus group discussions will be conducted to understand the perspectives of government agencies, non-governmental organizations (NGOs), private sector actors, and local communities on karst area management and revenue generation strategies. Key informant interviews with policymakers and industry representatives will provide insights into existing policies, regulations, and market dynamics affecting karst resources in the Aru Islands.

Data analysis will involve statistical techniques, spatial modeling, and qualitative coding to analyze the collected data and derive meaningful insights. Statistical analyses, such as regression analysis and correlation tests, will be used to examine relationships between variables, such as land cover change, tourism visitation, and economic indicators. Spatial modeling tools, such as geographic information systems (GIS) and remote sensing, will be employed to assess land use dynamics, habitat fragmentation, and landscape connectivity in karst areas.

Qualitative data from interviews and focus group discussions will be analyzed using thematic coding and content analysis techniques to identify emerging themes, patterns, and stakeholder perspectives. Triangulation of data sources and methods will enhance the validity and reliability of the findings, ensuring a comprehensive understanding of karst area management and state revenue generation in the Aru Islands.

Based on the research findings, policy recommendations will be developed to inform decision-making processes and guide the development of sustainable karst area management strategies in the Aru Islands. Stakeholder engagement workshops and dissemination events will be organized to share the research findings, solicit feedback from stakeholders, and foster dialogue on collaborative approaches to karst conservation and revenue generation.

3. RESULTS AND DISCUSSIONS

3.1 The key findings of the research

The research revealed the significant ecological value of karst landscapes in the Aru Islands, characterized by high biodiversity, unique habitats, and valuable ecosystem services. Field surveys and ecological assessments identified diverse flora and fauna species, including endemic and rare taxa, inhabiting karst areas. The presence of critical habitats, such as limestone caves, underground rivers, and sinkholes, highlighted the ecological importance of karst landscapes for maintaining hydrological connectivity, supporting groundwater recharge, and preserving specialized ecosystems.

Socio-economic analyses indicated the potential for karst area management to contribute to local livelihoods, economic development, and cultural preservation in the Aru Islands. Stakeholder interviews and community surveys revealed the significance of karst resources for traditional livelihoods, such as fishing, agriculture, and ecotourism. Furthermore, economic valuation studies estimated the monetary value of ecosystem services provided by karst areas, including water provisioning, carbon sequestration, and tourism revenues. The findings underscored the importance of integrating socio-economic considerations into karst area management strategies to ensure equitable distribution of benefits and enhance local resilience to environmental change.

The research identified several challenges and opportunities for revenue generation from karst area management in the Aru Islands. While eco-tourism emerged as a promising revenue source, concerns about over-tourism, infrastructure development, and cultural impacts necessitated careful planning and management. Additionally, alternative revenue streams, such as carbon credits, water conservation incentives, and sustainable agriculture practices, were explored to diversify income sources and enhance the economic viability of karst landscapes. Policy recommendations emphasized the need for adaptive governance mechanisms, stakeholder engagement, and capacity-building initiatives to address governance gaps and foster inclusive decision-making processes in karst area management.

3.2 Policy Implications

The policy implications of the research findings on karst area management and state revenue generation in the Aru Islands, Maluku Province, are crucial for informing decision-making

processes, guiding policy interventions, and fostering sustainable development in the region. By analyzing the ecological, socio-economic, and governance dimensions of karst landscapes, the research aims to provide actionable recommendations to address existing challenges and maximize opportunities for conservation and revenue generation.

One of the key policy implications of the research is the need to strengthen institutional capacities and coordination mechanisms for effective karst area management. The findings highlight the fragmented nature of governance structures and the lack of coordination among relevant agencies at the local, provincial, and national levels. To address this, policymakers should prioritize the establishment of multi-level governance frameworks, task forces, or inter-agency committees to enhance collaboration, streamline regulatory processes, and ensure coherence in policy implementation.

The research underscores the importance of enhancing regulatory frameworks and enforcement mechanisms to address threats to karst ecosystems and promote sustainable land use practices. Policymakers should consider revising existing regulations or developing new legislation to strengthen protections for karst areas, designate conservation zones, and establish clear guidelines for sustainable development activities. Moreover, adequate resources and capacity-building initiatives should be allocated to enforcement agencies to ensure compliance with environmental laws and regulations.

Community engagement emerged as a critical factor in the successful management of karst landscapes and the generation of state revenue. The research findings emphasize the importance of involving local communities in decision-making processes, conservation initiatives, and revenue-sharing mechanisms. Policymakers should prioritize the development of community-based conservation programs, ecotourism enterprises, and sustainable livelihood opportunities to empower local stakeholders and incentivize their participation in karst area management.

Investing in scientific research, monitoring, and education programs is essential for improving understanding of karst ecosystems, raising awareness about their ecological value, and fostering environmental stewardship among stakeholders. Policymakers should allocate funding for research initiatives, biodiversity surveys, and hydrogeological studies to fill knowledge gaps, identify priority conservation areas, and inform decision-making processes. Additionally, education and outreach campaigns should be developed to engage stakeholders, disseminate research findings, and promote environmental literacy among local communities, policymakers, and the general public.

3.3 Recommendations for Policymakers

Policymakers should prioritize the establishment of integrated governance frameworks that facilitate collaboration and coordination among relevant government agencies, local communities, civil society organizations, and private sector stakeholders. This may involve creating multi-level governance structures, inter-agency committees, or task forces dedicated to karst area management. Clear mandates, roles, and responsibilities should be defined to ensure accountability and transparency in decision-making processes.

To safeguard karst ecosystems and promote sustainable land use practices, policymakers should enhance regulatory mechanisms and enforcement measures. This may include revising existing regulations or developing new legislation to designate conservation zones, regulate land use activities, and impose penalties for non-compliance. Additionally, mechanisms for monitoring, reporting, and enforcement should be strengthened, with adequate resources allocated to enforcement agencies to ensure effective implementation.

Community engagement is essential for the success of karst area management initiatives and the equitable distribution of benefits derived from state revenue generation. Policymakers should prioritize the development of participatory decision-making processes, community-based conservation programs, and revenue-sharing mechanisms that empower local communities and recognize their rights and traditional knowledge. This may involve conducting consultation sessions, facilitating community-led initiatives, and establishing partnerships with indigenous organizations and local cooperatives.

To maximize state revenue generation from karst areas, policymakers should explore and diversify revenue streams beyond traditional tourism activities. This may include promoting carbon sequestration projects, sustainable agriculture practices, and water management initiatives that capitalize on the ecological services provided by karst landscapes. Additionally, innovative financing mechanisms, such as payments for ecosystem services (PES) schemes or green bonds, could be explored to attract private sector investment and mobilize resources for conservation and development efforts.

Investing in scientific research, monitoring, and education is crucial for enhancing understanding of karst ecosystems, raising awareness about their ecological value, and building capacity among stakeholders. Policymakers should allocate funding for research initiatives, biodiversity surveys, and hydrogeological studies to fill knowledge gaps and inform decision-making processes. Additionally, education and outreach programs should be developed to engage stakeholders, disseminate research findings, and promote environmental literacy among local communities, policymakers, and the general public.

3.4 The Need for Policy Interventions

As the Aru Islands, Maluku Province, navigate the challenges and opportunities presented by karst area management for state revenue generation, policymakers face the imperative of promoting sustainable development and ensuring equitable distribution of benefits.

Policy interventions are essential to address socio-economic disparities and promote inclusive growth in the Aru Islands. This may involve targeted investments in infrastructure development, healthcare, education, and social welfare programs to improve living standards and enhance opportunities for marginalized communities. Additionally, initiatives to promote sustainable livelihoods, micro-enterprises, and skills training can empower local stakeholders and reduce dependency on resource extraction activities.

Policy interventions are required to promote environmental sustainability and mitigate the adverse impacts of resource exploitation on karst ecosystems. Strengthening regulatory frameworks, enforcing environmental laws, and imposing penalties for non-compliance can deter destructive practices such as illegal logging, mining, and overfishing. Furthermore, incentives for sustainable land use practices, ecosystem restoration, and biodiversity conservation should be provided to incentivize responsible stewardship of natural resources.

Policy interventions are necessary to enhance governance effectiveness and foster transparent, accountable, and participatory decision-making processes. This may involve reforming institutional structures, streamlining regulatory procedures, and promoting multi-stakeholder collaboration to ensure coherence in policy implementation. Additionally, mechanisms for public participation, citizen engagement, and grievance redressal should be strengthened to empower local communities and enhance their voice in decision-making processes.

Policy interventions should prioritize the equitable distribution of benefits derived from karst area management and state revenue generation. This may include establishing revenue-sharing mechanisms, trust funds, or community development funds to ensure that local communities receive a fair share of the economic benefits generated from natural resource extraction or tourism activities. Moreover, initiatives to promote land tenure security, indigenous rights, and gender equality can help address historical injustices and ensure that vulnerable groups benefit equitably from development initiatives.

Policy interventions should prioritize investments in human capital and social infrastructure to build resilience and promote inclusive development in the Aru Islands. This may involve expanding access to quality education, healthcare, and basic services, particularly in remote and underserved areas. Additionally, initiatives to promote cultural heritage preservation, indigenous knowledge systems, and traditional practices can strengthen social cohesion and identity, fostering a sense of belonging and pride among local communities.

CONCLUSION

The research on the potential for karst area management for state revenue generation in the Aru Islands, Maluku Province, has provided valuable insights into the ecological, socio-economic, and governance dimensions of karst landscapes. Through a comprehensive analysis of the region's unique challenges and opportunities, this study has shed light on the complexities of sustainable development and the need for policy interventions to foster inclusive growth, environmental conservation, and community well-being. The findings of this research underscore the ecological significance of karst landscapes in the Aru Islands, highlighting their role as biodiversity hotspots and providers of essential ecosystem services. From the lush forests to the intricate cave systems, karst areas harbor a wealth of flora and fauna that contribute to the region's rich natural heritage. Moreover, the hydrogeological processes associated with karst aquifers play a vital role in regulating water flow, maintaining freshwater resources, and supporting local livelihoods. At the same time, the research has identified socio-economic challenges and governance gaps that must be addressed to unlock the full potential of karst area management for state revenue generation. Unsustainable land use practices, inadequate infrastructure, and socio-economic disparities pose

threats to environmental sustainability and social equity in the region. Furthermore, fragmented governance structures, weak regulatory enforcement, and limited community engagement hinder efforts to promote inclusive development and ensure equitable distribution of benefits.

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