DEVELOPING A SUSTAINABLE WETLAND MANAGEMENT MODEL FOR POST-DISPLACEMENT SETTLEMENTS: A CASE STUDY OF BONTANG KUALA

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Abstract - The relocation of communities from wetland areas often creates complex challenges related to social, economic, and environmental sustainability. This study focuses on developing a post-displacement wetland management model in Bontang Kuala, East Kalimantan, a region where relocation efforts have significantly impacted local communities and ecosystems. Using a mixed-methods approach, including field surveys, Geographic Information System (GIS) analysis, and stakeholder interviews, the research identifies key spatial, ecological, and socio-economic factors that influence sustainable wetland management.The findings reveal the importance of integrating traditional ecological knowledge with modern planning techniques to ensure balanced outcomes for displaced communities and the surrounding wetland ecosystems. The proposed model emphasizes the need for inclusive policy frameworks, adaptive land use planning, and participatory governance to address the socio-economic needs of the relocated population while conserving critical wetland habitats. This study contributes to the broader discourse on sustainable wetland management and provides a replicable framework for addressing similar challenges in other regions.

Keywords - Community Resilience, Bontang Sustainable Development, Kuala, GIS, Post-Displacement, Wetland Management.

I. INTRODUCTION

Wetlands, as important ecosystems, play a crucial role in maintaining ecological balance, supporting biodiversity, and providing essential natural resources to surrounding communities [1]–[3]. However, wetland management often poses challenges especially when interacting with human development needs, as seen in Bontang Kuala. The region faces a dilemma between the need to relocate settlements for infrastructure development and the need to preserve wetlands. The relocation of settlements in Bontang Kuala not only reconfigures the physical landscape, but also affects the social and economic structure of the community. This research aims to develop a wetland arrangement model that can integrate social, economic, and ecological aspects holistically and sustainably. This model is expected to provide a framework for realignment that minimizes negative impacts on ecosystems and improves the well-being of local communities. By understanding the dynamics between settlement displacement and wetland management, the proposed model will lead to more inclusive and sustainable policies [4]–[6].

The methodology used in this study includes detailed field surveys, interviews with various stakeholders involved, and Geographical Information System (GIS) analysis to gain a deep understanding of land characteristics and ongoing socioeconomic dynamics. This approach allows the identification of community-specific needs as well as potential and barriers to wetland management.

Preliminary results suggest that settlement displacement has had a significant impact on the social structure and economic conditions of local communities. Therefore, the policy recommendations resulting from this study are expected to provide guidance for policymakers in Bontang Kuala and other regions with similar contexts to implement effective and efficient wetland management strategies. In addition, the study also emphasizes the importance of inter-sectoral cooperation in the implementation of programs related to settlement transfer and wetland management. The implications of the developed model are expected to be a reference in designing development policies and programs that not only consider economic growth, but also environmental preservation and social welfare [7]–[9].

The authenticity in the wetland arrangement model research after the relocation of Bontang Kuala settlement can be explained through several aspects that show a unique and innovative approach. This includes the adaptation of new techniques, the application of concepts not yet widely used in the region, and the adaptation to local conditions. Here are the details:

- A multidisciplinary approach, this research integrates various disciplines such as ecology, civil engineering, urban planning, and sociology. Authenticity emerges from the way the research team brings together these perspectives to create holistic and sustainable solutions for wetlands.

- Evidence-based policy adaptation, in-depth research on the effects of wetland structuring policies on socio-economic and ecological sustainability. Authenticity comes from using empirical data to propose adaptive policies that can adapt to changing environmental and social conditions.
- Experimental design and planning, the use of planning techniques and experimental design, such as hydrological simulations and ecological models to predict the impact of land-use change on wetland ecosystems. This approach is rarely used in depth in the context of wetland restoration in Indonesia.
- Long-term impact measurement, conducting longitudinal studies to measure the impact of long-term interventions on biodiversity and economic benefits of wetlands, provides new insights and significant contributions to the scientific literature.

This research offers scientific contributions by integrating the latest technology, participatory approaches, and innovative financial models in a very specific context and has not been widely studied, so that it has a high value of authenticity.

II. METHODS

The research method used in this study is a combination of qualitative and quantitative techniques to collect and analyze the data needed in developing a model of post-settlement wetland arrangement in Bontang Kuala (Figure 1).

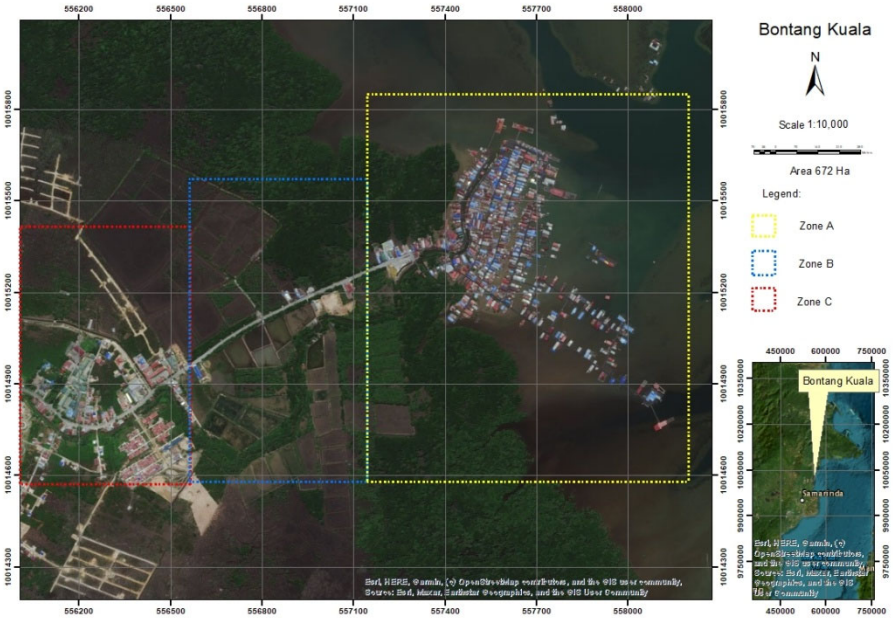


Figure 1. Location of Bontang Kuala Fisherman Settlement

This approach allows researchers to delve deeply into the social, economic, and ecological impacts of settlement displacement and to design effective management strategies [10]–[12].

- Field surveys are conducted to collect data on the physical and ecological condition of wetlands. Measurements include water quality, vegetation, and the presence of local fauna. The survey team used standard ecological and GPS measuring instruments to map the area in detail. The survey also involves direct observation of current land use and community interactions with the environment [13]–[15].
- In-depth interviews were conducted with various stakeholders, including local residents, policy makers, local entrepreneurs, and environmental experts. The purpose of the interview was to identify each party's perceptions and needs regarding settlement displacement and wetland management. These interviews help in collecting qualitative data on the social and economic impacts of displacement as well as expectations for the structuring model to be developed [16]–[18].
- Analysis Geographical Information System (GIS) is used to map and analyze spatial data from wetlands and surrounding areas. The data analyzed include land use, topography, and hydrological dynamics. This analysis helps in identifying critical areas that require conservation as well as potential areas for sustainable economic and social development [19]–[21].
- Data processing and development models collected from field surveys, interviews, and GIS analysis are integrated using statistical software and environmental modeling. The resulting development model will offer structuring

scenarios that consider ecological, social, and economic factors. This scenario will be assessed based on sustainability criteria and implementation feasibility [22]–[24].

Research Flow

Research flow of wetland arrangement model after Bontang Kuala settlement transfer (Figure 2).

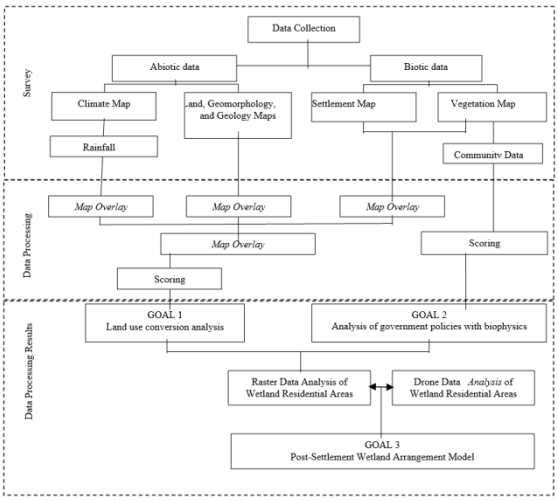


Figure 2. Research Flow Model of wetland arrangement after the relocation of Bontang Kuala settlement

This research is expected to make a significant contribution in designing effective policies and strategies for wetland management in Bontang Kuala, by considering the multidisciplinary aspects involved in settlement displacement and wetland conservation.

III. RESULTS AND DISCUSSION

Result

The results of this study show that settlement relocation in Bontang Kuala has had a far-reaching impact on local communities. From field surveys, stakeholder interviews, and GIS analysis, it was found that ecological impacts, wetlands undergo significant changes in vegetation composition and habitat availability for endemic species. GIS data shows a decrease in fully functional wet areas due to land conversion for development (Figure 3, Table 1).

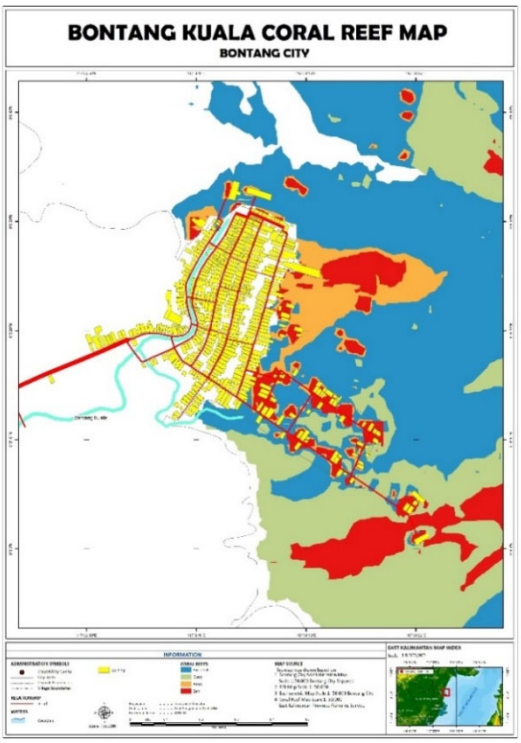
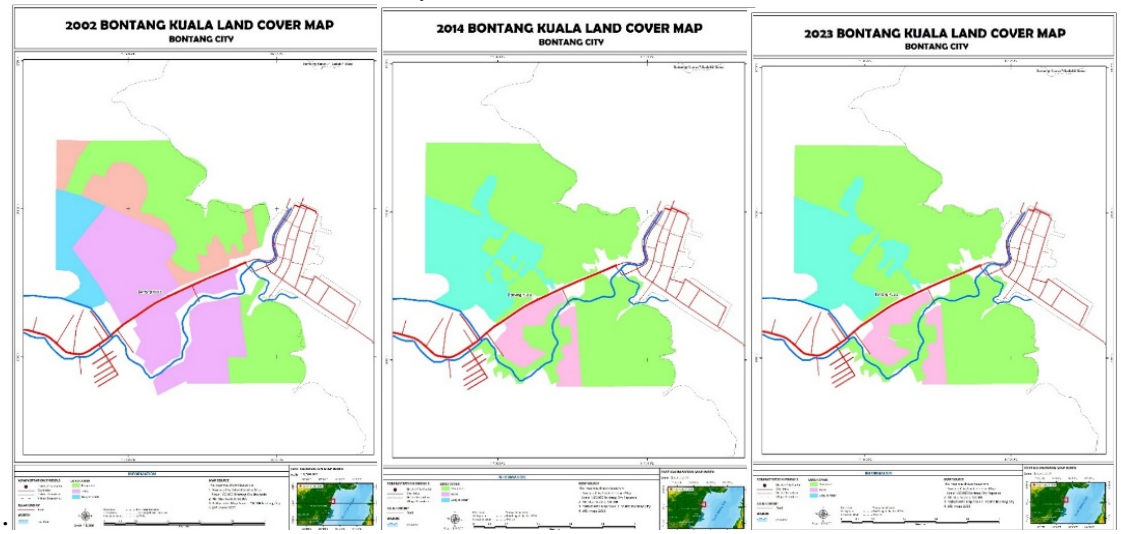


Figure 3. Map of Bontang Kuala Coral Reef

No	Coral Reefs	Hectare
1	Excellent	2.261,869
2	Good	2.845,352
3	Keep	351,388
4	Bad	963,846

Table 1. Trumbu Karang Bontang Kuala

Hectare This is a unit of area measurement used to express the area of coral reef area in each condition category. One acre is equivalent to 10,000 square meters. In the context of this table, hectare measurements provide an idea of the spatial distribution of coral reefs based on their conditions, it can be interpreted that although there are large areas with good and very good coral reef conditions, there are also significant areas that are in moderate to poor condition, indicating the need for conservation and restoration efforts to ensure the continuity of coral reef ecosystems in Bontang Kuala. The area covered by the Good category is the largest, indicating that most coral reefs are still in relatively healthy condition but still require wise management to prevent further degradation.As a result of social and economic impacts, communities experience changes in their social structure and decreased incomes due to reduced access to natural resources that previously supported local economic activities such as fisheries and agriculture (Figure 4, Table 2-4)



Year 2002 **Year 2014** **Year 2023**

Figure 4. Bontang Kuala Land Cover Map

No	Land Cover	Hectares
1	Mangrove	58.454
2	Pond	60.494
3	Open Ground	21.517
4	Water Body	12.833

Table 2. Land cover in 2002 Bontang Kuala

Table 2. Land Cover Year 2002 Bontang Kuala, provides information on the distribution and extent of various types of land cover found in Bontang Kuala in 2002. Each type of land cover is represented in hectares.

- Mangroves (58.454 Hectares): Mangroves are a type of forest that grows in tidal areas. The Bontang Kuala area has an extensive mangrove ecosystem, covering 58.454 hectares in 2002. Mangrove ecosystems play an important role in protecting coastlines from erosion, providing habitat for various marine species and birds, and aiding in carbon storage. Mangroves also have economic value, such as firewood, building materials, and areas for fisheries.
- Pond (60.494 Hectares): Pond generally refers to an area used for aquaculture or aquaculture, including shrimp, fish, and shellfish. In Bontang Kuala, the pond area in 2002 was 60,494 hectares, which shows that aquaculture activities are an important economic activity in the area. Pond activities can contribute significantly to the local economy through seafood production.
- Open Land (21.517 Hectares): Open land includes areas that are not covered by dense vegetation or buildings. This can include fields, pastures, or untapped wasteland. In Bontang Kuala, the open land area covered 21.517 hectares in 2002. This area could have the potential for future agricultural, residential, or

industrial development.

- Body of Water (12.833 Hectares): A body of water includes all areas permanently or seasonally covered by water, such as lakes, streams, swamps, or reservoirs. In Bontang Kuala, the total area of the body of water was 12.833 hectares in 2002. The presence of this body of water is important for the life of local ecosystems, providing a source of water for humans and habitat for aquatic species. In addition, the water body area also supports recreational and tourism activities.

Table 2. The 2002 Bontang Kuala Land Cover provides an overview of the wide distribution of various types of land cover in Bontang Kuala that year, reflecting the diversity of ecosystems and land use potential in the area.

No	Land Cover	Hectare
1	Mangrove	110.026
2	Pond	13.091
3	Open Ground	0.000
4	Water Body	34.675

Table 3. Land Cover in 2014 Bontang Kuala

Table 3. Bontang Kuala Land Cover 2014 shows changes in the distribution and extent of different types of land cover in Bontang Kuala in 2014, with each type displayed in hectares. Here is a detailed explanation for each type of land cover as listed in the table:

- Mangroves (110.026 hectares): There has been a significant increase in mangrove area, from 58.454 hectares in 2002 to 110.026 hectares in 2014. This indicates a successful mangrove conservation or rehabilitation effort or a change in more accurate measurement methods. Mangroves play a crucial role in protecting coastlines, providing habitat for biodiversity, and absorbing carbon dioxide.
- Ponds (13.091 Hectares): There has been a drastic decrease in pond area, from 60.494 hectares in 2002 to only 13.091 hectares in 2014. This decrease can be caused by various factors, such as conversion of pond land to other types of land use, decreased productivity, or efforts to reduce the environmental impact of pond aquaculture.
- Open Land (0 Hectares): In 2014, there were no more areas categorized as open land, indicating significant changes in land management and use. This may indicate that previously unused or open land has now been converted to other types of land use, such as mangrove expansion, agriculture, housing, or industry.
- Water Body (34.675 Hectares): There was an increase in the area of the water body, from 12.833 hectares in 2002 to 34.675 hectares in 2014. This increase can be due to a variety of factors, such as the construction of new reservoirs, the expansion of lakes or swamps, or natural changes in ecosystems that increase the amount of watery area. The presence of this larger body of water area is important to support biodiversity, provide water resources, and support economic and recreational activities.

Changes in land cover from 2002 to 2014 in Bontang Kuala reflect significant land use dynamics. The increase in mangrove area and water bodies indicates a positive change in the management of natural resources and the environment. Meanwhile, the drastic decline in pond area and loss of open land signal a transformation in the local economy and a potential change in land use policy.

No	Land Cover	Hectares
1	Mangrove	112.835
2	Pond	13.061
3	Open Ground	0.000
4	Water Body	31.896

Table 4. Land Cover in 2023 Bontang Kuala

Table 4. Land Cover in 2023 Bontang Kuala displays the latest data on the area of various types of land cover in Bontang Kuala in 2023, with each type displayed in hectares. Here is a detailed explanation for each type of land cover listed in the table:

- Mangroves (112.835 Hectares): The area of mangroves has increased slightly from 110.026 hectares in 2014 to 112,835 hectares in 2023. This increase indicates a continuation in conservation efforts or rehabilitation of mangrove ecosystems. Mangroves play a vital role in protecting coastlines, providing habitat for various species, and sequestering carbon dioxide, which makes them an important component in climate change mitigation efforts.
- Ponds (13.061 Hectares): The area of ponds has remained virtually unchanged, experiencing a very small decrease from 13.091 hectares in

2014 to 13.061 hectares in 2023. This stability suggests that the pond industry may have achieved a balance between production and environmental sustainability, or that there has been a replacement of unproductive pond areas with new ones on a similar scale.

- Open Land (0 Hectares): Just like in 2014, no more land is categorized as open land in 2023. This indicates that previously unused or open land has been converted to other types of land use or has become part of an existing ecosystem such as mangroves or water body areas.
- Water Body (31.896 Hectares): There is a decrease in the area of water bodies from 34.675 hectares in 2014 to 31.896 hectares in 2023. This decline could signal a variety of possibilities, including land use for other purposes such as development or natural changes in ecosystems that reduce the amount of watered area. Water bodies play an important role in ecosystems, including providing habitat for aquatic species, supporting biodiversity, and providing water resources for various purposes.

Changes in land cover from 2014 to 2023 in Bontang Kuala show a continuing trend in land conservation and management efforts, especially with small increases in mangrove area and pond stability. The loss of open land and the decline in the area of water bodies can reflect constantly changing land-use dynamics, emphasizing the importance of sustainable and adaptive natural resource management to environmental and socioeconomic changes.

DISCUSSION

As a result, the study developed a wetland structuring model that includes several key strategies:

- Ecosystem conservation, this strategy suggests the establishment of buffer zones to protect critical areas from further development. The use of native plants in reforestation and restriction of access to sensitive areas is recommended to restore and maintain the ecological function of wetlands [25]–[27]. Improving the quality of life of the community, the model proposes the development of environmentally friendly infrastructure and the development of environmental education programs to increase public awareness about the importance of conservation. In addition, the development of sustainable economic activities such as ecotourism which can provide alternative income for local communities [28]–[30] (Figure 5).



Figure 5. Illustration of environmentally conscious settlements on coral reefs

- Local Economic Empowerment: Initiatives such as training in new skills to diversify incomes and granting access to new markets for wetland-based products were identified as critical components in the structuring model [31]–[33].

Based on the proposed model, policy recommendations include:

- Sector Integration: Encourage closer collaboration between the public, private and civil society sectors for effective wetland management [34]–[36].
- Subsidy and Incentive Policy: Implementation of subsidies for sustainable agricultural practices and incentives for businesses that support environmental conservation [37]–[39].
- Development Regulations: Implement stricter regulations on land use and zoning to protect wetlands from overexploitation [40]–[43].

The implications of this model suggest that with an integrated approach, sustainable development policies and practices can be achieved, resulting in long-term benefits for the environment and society. The model also offers a framework that can be adapted in other regions with similar challenges, providing valuable lessons in managing the interaction between development needs and environmental preservation. The study underscores the importance of a deep understanding of local dynamics in wetland management planning, and how well-thought-out interventions can help in creating a balance between development and conservation.

IV. CONCLUSION

The research on the development of a sustainable wetland management model for post-displacement settlements in Bontang Kuala highlights the critical need to balance social, economic, and ecological aspects. The study reveals that community displacement, while addressing urban development and conservation challenges, can disrupt local livelihoods and ecological harmony if not managed holistically. The integration of Geographic Information Systems (GIS) analysis, field surveys, and stakeholder interviews has proven effective in identifying the key spatial, environmental, and social dynamics of the area.The proposed management model emphasizes participatory planning, ensuring the involvement of the displaced community in decision-making processes. It incorporates strategies to preserve wetland ecosystems, such as maintaining biodiversity, enhancing water quality, and optimizing land use for both residential and commercial purposes. Furthermore, the model addresses economic resilience through sustainable tourism and aquaculture development tailored to the unique needs of the community.In conclusion, the study provides a replicable framework for wetland settlement management that aligns with sustainable development principles. Implementing such a model in Bontang Kuala can serve as a blueprint for similar coastal and wetland regions facing displacement challenges, ensuring a harmonious integration of human activity and ecological preservation.

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