AJIE - Asian Journal of Innovation and Entrepreneurship
(e-ISSN: 2477-0574; p-ISSN: 2477-3824)
Vol. 09, Issue. 02, May 2025
DOI: 10.20885/ajie.vol9.iss2.art1

Blue Carbon Potential of Salt Marshes in Kulon Progo for Climate Change Mitigation in Indonesia

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ABSTRACT

Salt marshes along the coast of Kulon Progo in Yogyakarta can act as blue carbon storage facilities to achieve the climate change mitigation goals outlined in Indonesia's Nationally Determined Contributions (NDC) for 2030. Three villages in Temon District became the location of this research: Glagah, Palihan, and Jangkaran Villages. A mixed-methods approach was employed in this research, encompassing direct field observation, soil and vegetation analysis in their capacity as carbon storage, and interviews with individuals in the 3 villages. The results of the analysis showed that there was a small amount of carbon content in various locations in the 3 villages. Mangroves and pine trees, particularly those growing around swamps, play a significant role in carbon absorption. However, this study revealed a decrease in the potential of salt marsh land due to changes in land use to Yogyakarta International Airport (YIA) and the surrounding city planning. As a result, carbon storage capacity is reduced, and carbon emissions from land that has changed function are higher. The study also sees the importance of strengthening government policies and regulations and increasing community participation in salt marsh conservation through village-based programs such as the Climate Village Program (PROKLIM) and Resilient Coastal Village. The study concludes that through salt marsh conservation, the potential for blue carbon becomes more significant, which also requires collaboration between stakeholders.

Keywords: Blue carbon, climate change mitigation, Kulon Progo, net zero emission, salt marshes

1. Introduction

Blue carbon, as carbon captured by ocean and coastal ecosystems, is currently prioritised as an effort to reduce greenhouse gas emissions, such as salt marshes, mangrove forests, coral reefs and seagrass beds (Stewart-Sinclair et al, 2020; Zurba and Effendi, 2017). Compared with terrestrial ecosystems, blue carbon ecosystems absorb carbon dioxide more effectively through photosynthesis or in saturated soil in the long term and sustainably (Yonvitner et al, 2020; Lestari et al, 2020; Ganefiani et al, 2019). In addition, blue carbon also plays a role in balancing carbon emissions. However, the blue carbon ecosystem is quite vulnerable to changes in land use around the coast (Shayka et al, 2023).

The coastal areas of Glagah Village, Palihan, and Jangkaran, which are located in Kulon Progo Regency, Yogyakarta, have great potential for the use of blue carbon ecosystems (Tanjung et al, 2017). The salt marsh ecosystem is a form of blue carbon available in this area, and it can absorb and store carbon in significant amounts (Barbier et al, 2011; McMahon et al, 2023).This ecosystem serves as a habitat for a range of flora and fauna, a vital source of income for local communities, and a protective barrier against coastal erosion and flooding in response to floods and abrasion (Liu et al, 2024; Besterman et al, 2022). Nonetheless, preservation of the salt marsh ecosystem in Kulon Progo is under threat due to large-scale infrastructure development and urbanisation in the area (Ningsih and Mutaqin, 2024). For example, the construction of Yogyakarta International Airport (YIA) affects changes in the salt marsh areas, which is also followed by the development of buffer city planning. This has also increased socio-economic activities, especially housing, productive agricultural activities, and other economic activities along the coast of Kulon Progo. As a result, the area of salt marshes on the coast of Kulon Progo is decreasing, which has an impact on the reduction in the capacity of salt marshes to absorb and store carbon.

Due to changes in land use on the Kulon Progo Coast, monitoring changes in carbon storage capacity in salt marshes is necessary to understand the potential of the remaining salt marshes to absorb and store carbon. This challenge arises as a form of blue carbon's contribution to climate change mitigation, especially related to national and global commitments to achieving net zero emissions in relation to coastal and marine ecosystem conservation (Jompa and Murdiyarso, 2023).

This study focussed on the potential for developing salt marshes in Kulon Progo to mitigate climate change through blue carbon. In addition, this study also attempts to analyse various land use changes on the carbon storage capacity of salt marshes, ultimately proposing a strategy for conserving salt marsh ecosystems in Indonesia. The potential and challenges in conserving salt marshes were analysed in depth in this study to provide scientific data that can be used to strengthen policies and regulations for protecting coastal ecosystems.

Salt marsh ecosystems play an important role in achieving net zero emissions through blue carbon. The Nationally Determined Contributions (NDC) document of Indonesia has committed to reducing greenhouse gas emissions in various sectors, including blue carbon ecosystems. Therefore, this study makes an important contribution not only to the sustainability of coastal communities, but also to commitments to climate change mitigation at the national and global levels.

2. Research Method

2.1. Literature Review

This research begins with a literature review of various documents related to blue carbon, especially those related to the potential for carbon absorption and storage in salt marshes, both in Indonesia and from a global perspective. Information in this section is obtained from journal articles and other sources, including policy documents. The method was conducted to understand the variety of salt marsh potentials in various locations, especially the benefits expected from the conservation of salt marshes. Government policies and regulations, including regulations from the Ministry of Environment and Forestry, to conserve blue carbon ecosystems in the context of regulatory development, opportunities and challenges for implementation, and the effectiveness of conservation efforts.

2.2. Field Observations

Field observations were conducted to assess the physical characteristics of the salt marsh, document the vegetation present in the ecosystem, and examine community activities that may influence its sustainability. This study was carried out in three coastal villages—Glagah, Palihan, and Jangkaran—in Kulon Progo Regency. The selection of observation sites within these villages was based on the presence of salt marsh patches and their accessibility for sampling. Vegetation cataloging was conducted in a modest manner, focusing only on plant species found near soil sampling sites to ensure consistency in data collection. The cataloging process identified dominant species such as mangroves, coastal pines, and other salt-tolerant vegetation. This approach allowed us to examine the relationship between vegetation composition and variations in carbon storage potential within the salt marsh ecosystem.

2.3. Soil Sampling

A total of nine soil sampling points were taken with an average depth of 30-50 cm based on the distribution of vegetation, swamp conditions, distance from the coast, and human intervention through changes in land use within it. The selection of sampling points took into account various physical conditions, such as natural salt marsh locations, areas close to development activities, and locations close to agriculture and plantations. Soil samples were taken at a certain depth to test organic carbon (C-organic) by applying a spectrophotometric method based on laboratory analysis technical guidelines. The difference in soil sampling locations aims to ensure comprehensive results.

2.4. Government Policy Analysis

Semi-structured interviews with local stakeholders were conducted to obtain detailed information related to local regulations and programs that focus on coastal ecosystem conservation. The purpose of these interviews was to see and understand various policies related to coastal ecosystems, especially salt marsh conservation efforts in the Kulon Progo Coast. Various opportunities and challenges in salt marsh conservation were also explored through informal discussions with various stakeholders at the research location. Information related to community perceptions including local participation was also explored to deepen and strengthen the results of the analysis. Various government-based programs were also an important part of the discussion, such as the coastal climate village program (*Program Kampung Iklim*/PROKLIM) committed by the Ministry of Environment and Forestry (MoEF) and the resilient coastal village (*Desa Tangguh Bencana*/DESTANA) developed by National Disaster Management Agency (NDMA).

3. Results and Discussion

3.1. The Potential of Salt Marshes in Kulon Progo Regency

Salt marshes on the Kulon Progo Coast have a potential to contribute to the reduction of greenhouse gas emissions in Indonesia (Triyatmo and Priyono, 2018). In addition to absorbing and storing carbon, salt marshes also have the capacity to provide ecosystem services, including buffer zones for flood disasters, protection from abrasion, and pollutant filtering on the coast (Islam et al, 2016). In Indonesia, the potential of salt marshes is very broad; therefore, many research activities, programs, and best practices have been carried out to improve conservation efforts in this ecosystem. The commitment of the Government of Indonesia (GoI), which is also integrated with global support, makes the salt marsh ecosystem part of a "nature-based solution" that has the capacity not only for climate resilience but also for increasing blue carbon in coastal areas.

This research is focused on the Kulon Progo area, which seeks to identify the opportunities and challenges of salt marsh conservation (Figure 1). Nature-based solutions have become an important integrated part of the Kulon Progo coastal area, not only strengthening coastal resilience, but also contributing to reducing greenhouse gas emissions in the coastal sector. As a stakeholder, the government is committed to several aspects of coastal rehabilitation and conservation, especially development activities in the area (Pratiwi et al, 2023).

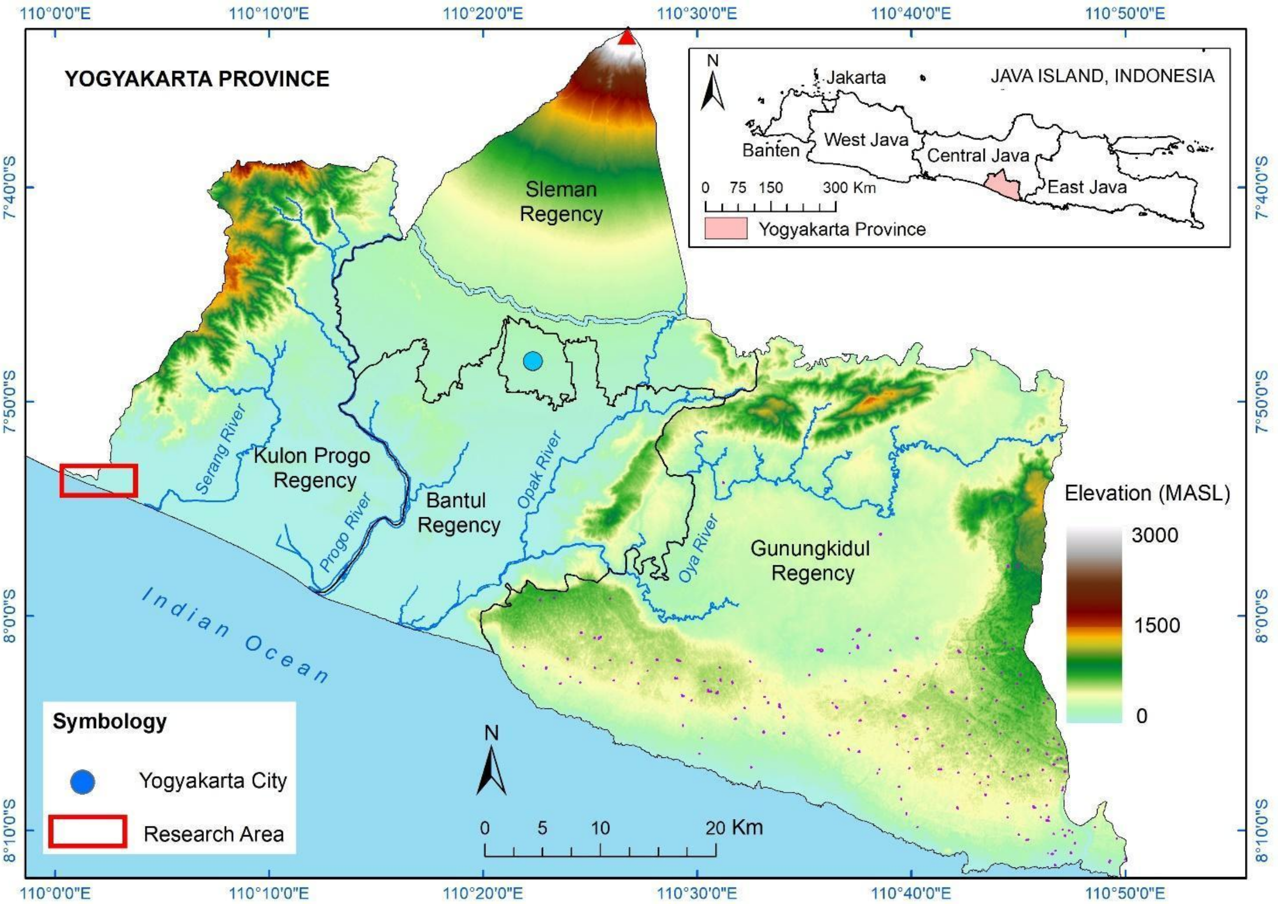

Figure 1. The location of salt marshes as blue carbon in Kulon Progo

Various ecological mechanisms occur in the process of carbon absorption and storage (Figure 2) by salt marshes (Mason et al, 2023). In salt marshes, carbon is stored in two ways: autochthonous carbon originating from within organisms and allochthonous carbon taken from external sources. Specifically, autochthonous carbon is obtained via photosynthesis through the absorption of carbon dioxide from the atmosphere. In contrast, allochthonous carbon enters the salt marsh ecosystem via the flow of water containing organic particles. The accumulation of carbon is then transformed into biomass that fills the salt marsh ecosystem along with the vegetation in it through storage above and below ground, in the form of roots, stems, and leaves (Miller et al, 2023). In the salt marsh ecosystem, there is an accumulation of most of the carbon underground as biomass (Lal et al, 2018). This condition has the potential to reduce the active carbon cycle through carbon storage in salt marshes with a much slower decomposition rate (Mason et al, 2023).

The level of carbon absorption and storage capacity in salt marshes depends on factors such as soil conditions, sedimentation, and the ability to accumulate organic matter (Yuan et al, 2020). The high organic content of salt marshes allows for the storage of carbon in higher amounts and longer storage times (Artigas et al, 2015). In addition, vegetation found in salt marshes plays an important role in absorbing and storing carbon through photosynthesis, which can also prevent abrasion and strengthen sediment accumulation. Solid vegetation in salt marshes can also increase the capacity of soil structures through strong root systems. In addition, high salinity in salt marshes can slow down or even inhibit the decomposition of organic matter, thereby reducing the amount of carbon released into the atmosphere (Yuan et al, 2020).

However, climate change intensified by human activities can reduce the capacity of salt marshes to absorb and store carbon (Ruiz-Fernandez et al, 2018). In the context of climate change, for example, sedimentation patterns in salt marshes can be disrupted by rising sea levels, which have great potential for abrasion. In addition, human activities such as massive coastal development in meeting social and economic needs reduce the area of salt marsh ecosystems, which reduces the area of carbon storage and nutrient cycles (Gedan et al, 2009).

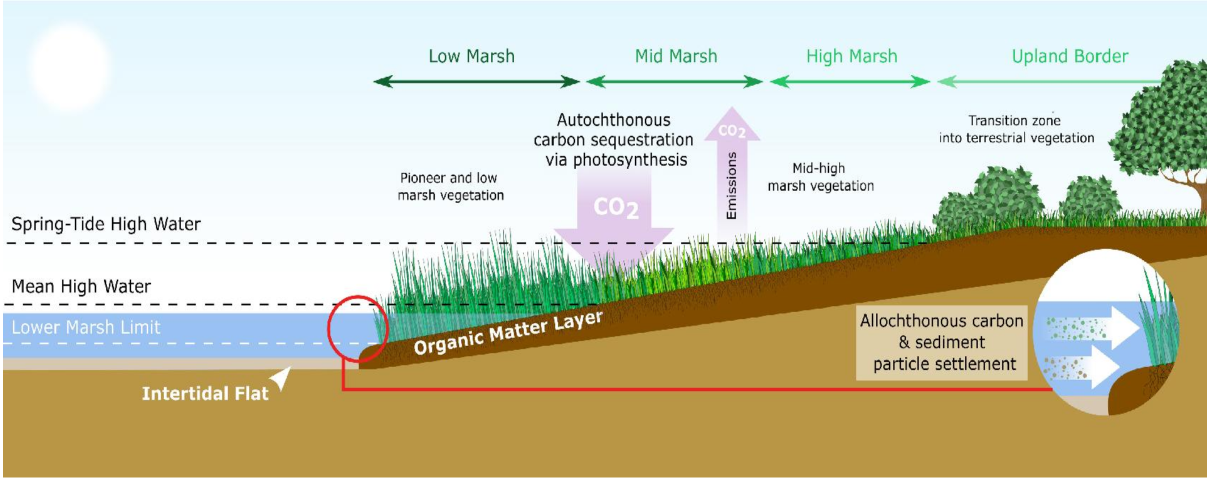

Figure 2. Mechanisms of carbon storage in salt marshes
Source: (Mason et al, 2023)

Recycling nutrients, such as organic matter and minerals, in coastal ecosystems (Figure 3) which are important as sources of livelihoods—can also be provided by salt marshes (Duarte et al, 2021). These nutrients are then integrated into the food chain and enter the trophic system through a sustainable ecological recycling process (Sousa and Dangremond, 2011). The transfer of nutrients in these salt marshes also plays a role in recycling phosphorus and nitrogen so that ecological functions in the ecosystem can be more sustainable (Sousa et al, 2012), including efforts to manage phosphorus and nitrogen levels so that they are not excessive in coastal areas (Banerjee et al, 2017). Excess nitrogen in coastal areas, which often arises from agricultural activities or wastewater, can be reduced by salt marshes through denitrification. Salt marshes also absorb phosphorus, which is harmful to coastal ecosystems because of its potential for eutrophication (Valiela et al, 2000).

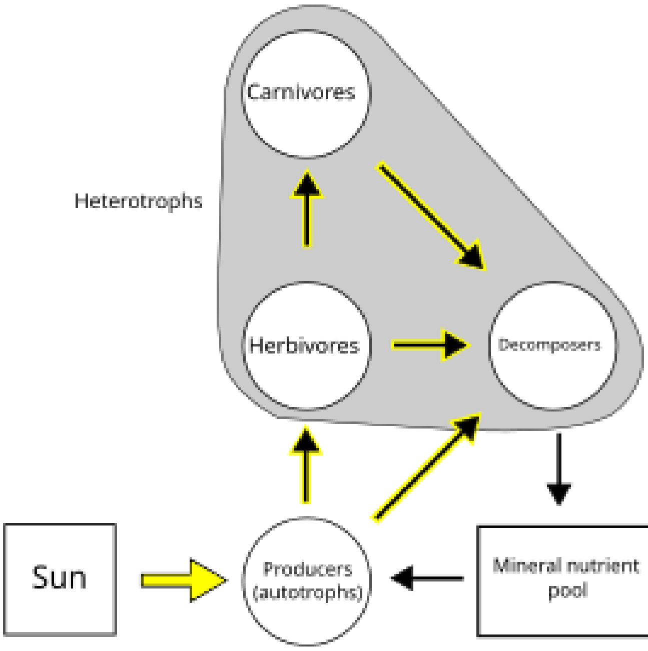

Figure 3. Nutrient cycling process
(Adapted from https://p2k.stekom.ac.id/ensiklopedia/Daur_nutrien)

3.2. Salt Marshes and Blue Carbon in Kulon Progo

About nine soil samples were collected from the coastal villages of Glagah, Palihan, and Jangkaran (all situated in Temon District, Kulon Progo) to assess the potential and capacity for blue carbon storage in the salt marsh environment (Figure 4). Each village has unique ecological and hydrological characteristics that collectively demonstrate the overall regional environment. Soil samples were collected from sites near the coast and river to assess how salinity and estuarine processes affect the soil's ability to store carbon. The condition of this area is also influenced by the ebb and flow and the meeting of freshwater and seawater, which may affect the carbon storage capacity. Several other sample points were placed at salt marsh locations that have been converted into agricultural land and residential areas, providing sufficient information regarding massive land use changes in the coastal area of Kulon Progo. The samples were also designed to determine how human activities can affect the carbon storage capacity on the coast.

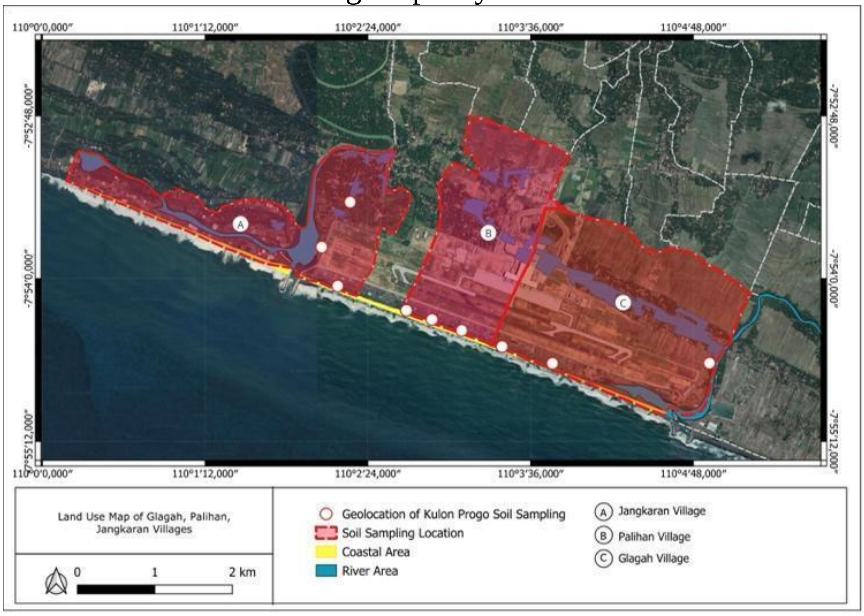

Figure 4. Soil sampling distribution in Temon Subdistrict, Kulon Progo

Substantial heterogeneity between one sampling point and another was observed in this study, considering that the coastal conditions in Kulon Progo are quite heterogeneous (Table 1). These differences are based on several main factors, such as salinity, sedimentation potential, vegetation cover, and human activities. These heterogeneous conditions can be used as a basis for developing more targeted coastal conservation policies and regulations, especially for salt marsh ecosystems.

Tabel 1. Information on area conditions at sample point distribution

Loc.	Village	Area Condition	Distance from Shoreline (m)
1.1	Jangkaran	Sandy soil, near the airport, river downstream.	467
1.2	Jangkaran	Agricultural area.	46
1.3	Jangkaran	Sandy soil near the coast, similar vegetation.	1172
2.1	Palihan	Sandy soil near the coast, similar vegetation.	37
2.2	Palihan	Sandy soil near the coast, similar vegetation.	44
2.3	Palihan	Sandy soil near the coast, similar vegetation.	35
3.1	Glagah	Sandy soil near the coast, similar vegetation.	921
3.2	Glagah	Sandy soil near the coast, similar vegetation.	63
3.3	Glagah	Riverbank downstream, peat soil.	31

Based on the analysis results, the organic carbon (C-organic) content at all the sample points was relatively low, with all points below 2%. In various related studies, the C-organic content in salt marsh ecosystems at different locations ranges from 3-15%, which is mostly determined by the type of salt marsh vegetation, organic material decomposition, and wetland hydrology. However, among the various sample points, point 3.1 had the highest C-organic content, with specific regional characteristics in the form of fertile land with surrounding vegetation. Low C-organic values are mostly found near the seawater meet, which is caused by the type of soil, surrounding vegetation, and the alleged pressure of climate change.

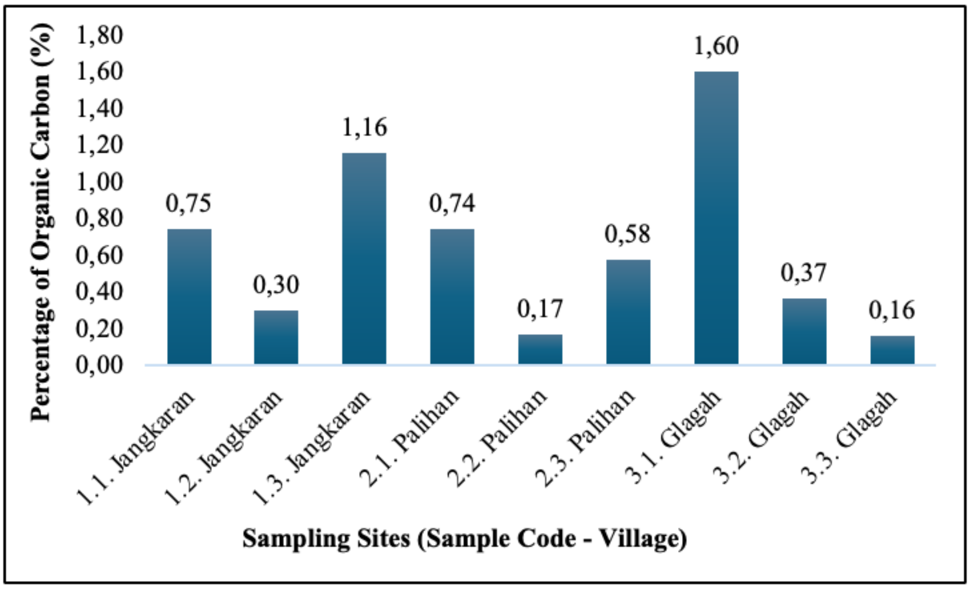

Figure 5. Percentage of organic carbon (% C-Organic) at different sampling sites across Jangkaran (1.1, 1.2, 1.3), Palihan (2.1, 2.2, 2.3), and Glagah (3.1, 3.2, 3.3). The second digit in each label represents the specific sampling point within the village

Massive land use changes, especially the construction of Yogyakarta International Airport, have impacted the salt marshes area, thus reducing the levels of organic carbon in Temon Sub-district. This condition is also intensified by the construction of the airport buffer zone, which makes it quite difficult to obtain soil samples in the area. Previous studies show that the conversion of natural land to built-up land can negatively impact the availability of soil organic matter levels (Lal et al, 2018). These phenomena not only reduce the potential for blue carbon storage but also have the potential to reduce environmental quality, including ecosystem health, in the Kulon Progo area.

The vegetation around the salt marshes in Kulon Progo (see Table 2) shows diverse potential as a blue carbon absorber (Figure 6), depending on the type and abundance of the species (Zhou et al, 2018). *Casuarina equisetifolia* (Sea Pine), which is abundant along the coastline, functions as a coastal protector and can store carbon in its woody biomass and leaves. The existence of sea pine has been promoted by national and regional government conservation programs as part of disaster risk mitigation and coastal protection strategies. *Ipomoea pes-caprae* (Beach Morning Glory), a wild species, also contributes to carbon storage by absorbing carbon dioxide through photosynthesis and stabilising beach sand, which indirectly supports the stability of coastal ecosystems. *Rhizophora apiculata* (Mangrove Apple), although it shows signs of drought mortality in certain areas, continues to play an important role in carbon storage, especially in areas with adequate moisture levels.

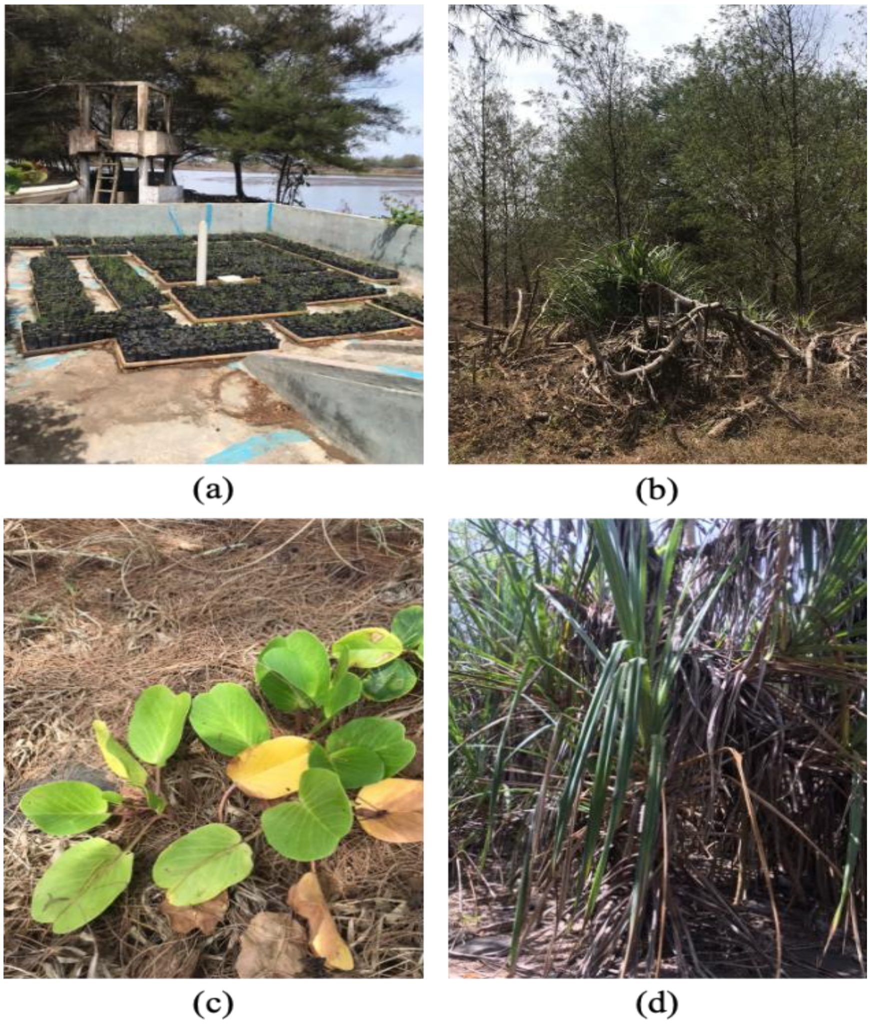

Figure 6. Distribution of vegetation in the Coastal Area of Temon, Kulon Progo

Pandanus tectorius also has a fairly good carbon storage capacity. This species is cultivated as one of the implementations of the green belt program to reduce abrasion because of its role in breaking high waves and reducing existing sedimentation. *Rhizopora* mangroves have also proven to have a much higher carbon storage capacity than other vegetation (Didik and Abdul, 2021) in various storage capacities, including roots, stems, leaves, and dead litter (Indrayani et al, 2021). This capacity further strengthens the role of mangroves in the production of blue carbon, which effectively absorbs and stores carbon in large quantities and of good quality (Choudhary et al, 2024).

Table 2. Detailed available vegetation in the coastal area of Kulon Progo

Vegetation	Availability	Blue Carbon Potential
Casuarina equisetifolia (Cemara Laut)	Abundant presence, included in the government's coastal protection program.	Moderate carbon storage potential; capable of trapping sand and protecting coastal soils from erosion.
Ipomoea pescaprae (Katang-katang)	Grows freely and wild, often found in coastal areas with good potential.	Low carbon storage potential; more effective as ground cover and sand stabilizer.
Rhizophora apiculata (Bakau Minyak)	Many are withered and dry due to climatic conditions, especially during prolonged droughts.	High carbon storage potential; effective in storing carbon in roots and water-saturated soils.

Pandanus tectorius (Pandan Duri)	Planted as a wave barrier, part of the green belt program.	Moderate carbon storage potential; serves as a wave breaker and soil stabilizer in coastal areas.
Rhizophora (Mangrove)	Abundant at the border of Kulon Progo and Central Java, but scarce along the Kulon Progo coast.	Very high carbon storage potential; capable of storing significant amounts of carbon in roots and saturated soils.

Note: The data was generally obtained through interviews and stakeholder discussions in Temon District, Kulon Progo.

3.3. Challenges and Opportunities on Salt marsh Conservation

3.3.1. Land-use Changes

Increased socio-economic activities in the area may encourage massive land-use changes (Widyatmanti et al, 2018). These changes often convert productive land into built-up land, thereby comprehensively reducing ecosystem function (Melati, 2021). For example, the Kulon Progo Coast has been affected by massive land use changes due to the construction of the Yogyakarta International Airport (YIA) and various supporting infrastructures in it (Figure 7). Changes that comply with environmental impact analysis will also support environmental sustainability, but unplanned changes that do not pay attention to environmental risks will reduce environmental carrying capacity, thus potentially causing future impacts (Utami et al, 2023).

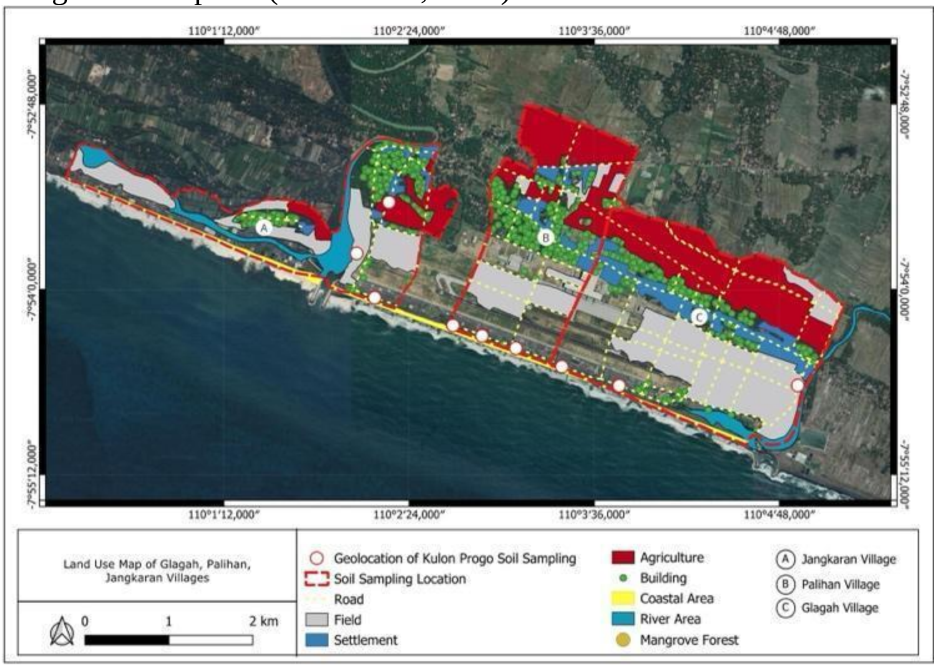

Figure 7. Land use map in the coastal area of Kulon Progo

Coastal areas provide a variety of high biodiversity as transition zones between land and sea, allowing various species of flora and fauna to be available with good ecological potential. However, significant development in coastal areas can disrupt the balance of ecosystems through decreased water quality, increased soil and water pollution, high sediment deposition, and even habitat damage (Laming and Rahim, 2020). In addition, the characteristics of salt marshes, which are the meeting point for fresh and sea water (Elma et al, 2020), are completely disrupted by changes in the ecosystem on the coast. Increasing human activity on the coast with various existing development activities can disrupt the structure of the natural habitat of salt marshes, threatening the ecological balance.

3.3.2. Government Policies and Stakeholder Roles

The challenges associated with the development of salt marshes in Kulon Progo also come with governance challenges. For example, the village government does not yet have full authority to manage coastal areas; therefore, various development policies and regulations are often not in line with village planning. Conservation efforts in coastal ecosystems are disrupted by the lack of synchronisation of policies between central, regional, and village governments. The gaps that occur certainly need to be addressed, for instance by approaching community-based policies and programs.

Furthermore, the lack of coordination between stakeholders is a crucial problem of the challenges of salt marsh conservation on the coast of Kulon Progo (Table 3). For example, in the construction of the YIA airport, various development decisions were largely determined by political and economic interests without sufficient attention to environmental aspects. In the end, the development carried out not only has an impact on not only the relocation of residents to other areas, but also the imbalance of the coastal ecosystem.

Table 3. Stakeholder analysis matrix

Stakeholder/ Parties	Interest	Power
Central Government	**High** (Supports national policies on climate change mitigation through blue carbon ecosystem conservation, while also promoting strategic infrastructure development)	**High** (Can shape national policies impacting conservation and development in coastal areas)
Provincial and Local Government	**High** (Aims to enhance local economic welfare through infrastructure development while considering environmental conservation)	**High** (Holds influence over the implementation of regional and local policies, as well as conservation oversight.)
Village Government	**Medium** (Interested in protecting local ecosystems for the welfare of village communities but has limited authority in strategic decision-making)	**Low** (Limited authority to manage local natural resources without approval from higher government levels.)
Non-Governmental Organizations (NGOs)	**High** (Advocates for the conservation of salt marsh ecosystems and promotes more sustainable policies)	**Medium** (Can influence public opinion and local policies through campaigns and research but lacks formal authority.)
Local Communities (Fishermen, Farmers)	**Low** (Depend on the health of salt marsh ecosystems for livelihoods (fishing, farming, etc.) and environmental sustainability)	**Low** (Limited in formal decision-making but can play a significant role through participation and local support.)
Academics and Researchers	**High** (Support salt marsh conservation through research and technological advancements related to climate change mitigation and blue carbon storage)	**Medium** (Can influence policies through research findings and scientific data.)
Private Sector (Developers, Investors)	**Medium** (Promote infrastructure and economic development in coastal areas, such as airports and tourism industries)	**High** (Possesses significant financial and economic influence over local and regional development.)

International NGOs	**High** (Support global climate change mitigation initiatives, blue carbon ecosystem conservation, and provide technical and financial assistance for salt marsh conservation)	**Medium** (Can influence policies through international cooperation, funding, and global advocacy.)

Note: The data was obtained through interviews and stakeholder consultation in Temon Sub-district, Kulon Progo

In addition, programs carried out in Indonesia are often limited to short-term interventions and pay little attention to long-term sustainability, both by the government and other parties, such as NGOs and development partners. For example, coastal conservation carried out on the coast by planting mangrove and sea pine trees is not followed by continuous monitoring and evaluation; thus, the impact is not visible in the long term. The weakness of this system requires a more holistic and ecosystem-based policy in the future.

However, with the various limitations that exist, there are significant opportunities that can be integrated into efforts to conserve salt marshes on the coast of Kulon Progo. For example, in Indonesia there are various village-based environmental programs, such as the Climate Village Program, Resilient Coastal Village, and Disaster Resilient Village which provide an integrated system in increasing community capacity for environmental issues. In increasing the capacity of coastal communities, these programs can be integrated in order to realize significant coastal ecosystem conservation.

3.3.3. Climate Change Impacts

The salt marsh ecosystem in Kulon Progo has been increasingly affected by climate change, particularly through rising sea levels, changing precipitation patterns, and escalating coastal erosion. Observations in the study area indicate that coastal abrasion is a major issue, as evidenced by the retreat of shoreline vegetation and the exposure of sediment layers in certain locations. Research by Sasmito et al. (2021), using the Net Shoreline Movement (NSM) method with Landsat 7 and 8 imageries from 2010 to 2020, identified that coastal abrasion in Temon District reached -18.04 meters, indicating severe shoreline retreat. This aligns with findings from Saintilan et al. (2019), who emphasize that prolonged inundation from rising sea levels disrupts sediment deposition processes, leading to land degradation and ecosystem loss. Additionally, changes in rainfall patterns, particularly the reduction in freshwater input, have been linked to increasing salinity levels in the salt marsh areas. Putriany and Sejati (2023) conducted a preliminary study using Geographic Information Systems (GIS) to analyze seawater intrusion in Temon, Kulon Progo, and found that approximately 26% or 9.68 km² of the area has been affected by seawater intrusion, with the highest impact detected in Jangkaran, Kalidengen, and Plumbon villages. Field observations in Jangkaran, for instance, reveal reduced freshwater seepage, resulting in high salinity conditions that may negatively impact salt-tolerant vegetation, which are crucial components of the local blue carbon ecosystem. Kirwan and Mudd (2012) further highlight that increased salinity and reduced sediment availability can limit the natural accretion processes necessary for salt marsh resilience, making them more vulnerable to submersion and degradation.

Beyond physical changes, climate change also influences the socio-ecological dynamics of the Kulon Progo salt marsh ecosystem. Local communities, particularly those reliant on small-scale aquaculture and coastal farming, have reported declining yields due to soil salinization and unpredictable flooding events (Morris et al., 2002). These disruptions reduce the ecosystem's capacity to function as a carbon sink, as disturbed and degraded salt marshes release stored carbon into the atmosphere. Furthermore, human activities such as land conversion for tourism and aquaculture expansion exacerbate these pressures, limiting the resilience of salt marsh ecosystems in adapting to climate change impacts. Kirwan and Mudd (2012) argue that while some marshes may naturally adapt by accumulating sediments at a rate that keeps pace with sea-level rise, excessive anthropogenic disturbances can hinder this process, accelerating ecosystem loss. Given the growing threat of erosion and seawater intrusion in Kulon Progo, as identified by Sasmito et al. (2021) and Putriany and Sejati (2023), integrated coastal management strategies are essential. These strategies should incorporate both ecological conservation and community-based adaptation efforts, ensuring the long-term sustainability of Kulon Progo coastal landscapes while mitigating the ongoing effects of climate change on salt marsh ecosystems.

3.4. The Potency on the Economic and Entrepreneurial Value of Salt Marshes in Kulon Progo

Salt marshes also have the capacity to increase significant economic and entrepreneurial value, especially in their role as blue carbon, which is currently being developed and monetized through the global blue carbon market. In national policy, the Carbon Economic Value (CEF) has been detailed in Presidential Regulation No. 98 of 2021 by detailing the national carbon economic value as a form of contribution to carbon trading at the global level. This regulation is also translated into the Regulation of the Minister of Environment and Forestry, No. 21 of 2022, which provides technical procedures for the implementation of carbon economic value, including the details of the methodology in measuring, reporting, and verifying carbon absorption from related sectors, such as salt marsh ecosystems.

Through this carbon-economic value scheme, salt marshes provide significant innovative opportunities for local governments and communities in coastal areas, including in Kulon Progo Regency. This strategy can provide an alternative source of livelihood for coastal communities, especially when dealing with the various impacts of climate change and can be integrated into strategic regional climate action planning. At the village level, the village government through the Village-Owned Enterprises (BUMDES) can play a more vital role in managing salt marsh conservation by registering with the National Registry System (SRN) and verifying national carbon standards to receive financial benefits from verified carbon compensation. This effort will also increase climate resilience by strengthening inclusive blue ecosystems at the village level.

The entrepreneurial potential of the salt marsh ecosystem can also be maximized through nature-based ecotourism efforts. In general, good salt marshes can provide biodiversity, unique landscapes, and edutourism potential with various forms of environmental literacy that can be offered to tourists. This opportunity would provide a livelihood for coastal communities by using coastal and marine resources. Integration of ecosystem-based livelihoods with market mechanisms not only increases income diversification but also strengthens incentives for sustainable resource management. In this way, salt marsh ecosystem conservation is no longer seen as an environmental obligation, but as an entry point for sustainable innovation, community empowerment, and climate-smart development.

4. Conclusions

This study explores the potential of salt marshes for storing and absorbing carbon although the environmental pressures that occur around salt marshes result in low storage potential. The low organic carbon content of the salt marsh ecosystem in Kulon Progo is influenced by massive land-use changes, including the construction of airports and various supporting infrastructures around the region. However, the potential for blue carbon on the coast of Kulon Progo, specifically around the salt marsh, is also supported by the presence of diverse vegetation that can play a role in storing and absorbing carbon with varying capacities. The next challenge is to maintain the potential of salt marshes and the various ecosystems around them under the conditions of environmental change that occur in coastal areas, one of which is also due to the various impacts of climate change.

Sustainable conservation of this salt marsh ecosystem is needed, especially support from various parties through coordination and collaboration. This sustainable conservation is related to integration with existing environmental programs in Indonesia, such as PROKLIM and DESTANA, so that various programs and good practices will focus more on efforts to restore coastal ecosystems. Support and coordination of the parties also need to be carried out, especially in strengthening policies, programs, and implementing best practices in climate change adaptation and mitigation commitments, especially in efforts to support the target of net zero emissions from blue carbon. In addition to their ecological function, salt marshes in Kulon Progo also offer significant economic and entrepreneurial potential through blue carbon trading, eco-tourism, and community-based coastal enterprises, presenting a strategic opportunity to align environmental conservation with local economic development. This initiative is undoubtedly valuable for expanding the potential for blue carbon in its role of supporting Indonesia's national pledge to address climate change as outlined in the country's NDC document.

Acknowledgement

This work was supported by an internal grant from the Department of Environmental Engineering, Universitas Islam Indonesia, under contract number 005/Ka.Jur.TL/70/Pen.Internal/VI/2024.

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