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(Research/Review) Article

Sustainable Space Management in the Coastal Area of Medan Belawan

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Abstract: Sustainable management of coastal spaces is a major challenge in urban-coastal planning, especially in vulnerable areas such as Medan Belawan. This study aims to identify and analyze the influence of six independent variables on the sustainability of coastal space management. The variables studied included Microecological Inequality, Inclusivity of Coastal Asset Ownership, Adaptive Preparedness to Climate Risks, Inter-Functional Spatial Connectivity, Local Institutional Accountability, and Communal Social Resilience. The method used is a quantitative approach with a multiple linear regression model on primary data obtained through surveys, field observations, and in-depth interviews with 150 respondents.The results showed that five of the six variables had a significant effect on the sustainability of coastal space management. The most dominant variable was Local Institutional Accountability, followed by Asset Inclusivity, Ecological Inequality, Social Resilience, and Adaptive Readiness. Meanwhile, Connectivity between Spatial Functions does not have a significant impact. The regression model shows an R^2 value of 0.539 which means that 53.9% of the variation in coastal space management can be explained by these six variables.These findings imply the importance of strengthening participatory governance, equitable distribution of space access, and building community's adaptive capacity as a cornerstone for contextual and sustainable coastal spatial planning. Strategic recommendations are directed at institutional reform, community-based planning, and micro-ecological conservation in urban-coastal areas.

Keywords: Coastal Space; Ecological Inequality; Local Institutions; Sustainability

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1. Introduction

Coastal areas have a strategic role in sustainable development because they are the meeting point between the dynamics of the marine and terrestrial environments. In Indonesia, more than 60% of major cities are located in coastal areas, including Medan Belawan District which is the most dominant coastal area in Medan City. This area has very complex ecological, social, and economic functions, ranging from the main port, fishing settlements, maritime industry, to mangrove ecosystems. However, the rapid development of this area is not always accompanied by sustainable spatial governance.

Recent phenomena show that Medan Belawan is experiencing very high spatial pressures, such as the conversion of mangrove land into settlements and industrial areas, an increase in the intensity of tidal floods due to land subsidence and climate change, as well as the destruction of the socio-ecological system of coastal communities (Meka Hasianta & Sugiarto, 2024; Sugiarto et al., 2023). In addition, space utilization practices that are not aligned with the RTRW exacerbate inequalities between functional zones and create conflicts of interest between local communities, governments, and the private sector. A number of studies reinforce this finding, such as Sugiarto and Ramadania (2024) who revealed that the inaccuracy of space allocation in North Medan contributes to the significant degradation of the ecological function of coastal areas.

Medan Belawan is also an area that is highly vulnerable to climate change risks and exploitative economic activities. According to data from the Medan City BAPPEDA (2023), more than 35% of the coastal area of Belawan is in critical status due to abrasion and pollution of domestic and industrial waste. This environmental pressure is exacerbated by weak supervision of land conversion and low involvement of local communities in spatial planning and management. Cut Nuraini (2022) emphasized that space sustainability cannot be achieved only through a technocratic approach, but must involve the social and institutional dimensions in a balanced manner.

In this context, the need for a sustainability-based approach to space management is very important. This approach emphasizes not only the efficiency of the use of space, but also social justice, community participation, ecological carrying capacity, and long-term sustainability. However, among the many studies that discuss spatial management, there are still very few studies that quantitatively examine the influence of socio-ecological and institutional variables on the sustainability of coastal space management.

Some variables such as microecological inequalities, inclusivity of coastal asset ownership, or connectivity between spatial functions have not been touched on much in previous studies. In fact, these variables are very relevant for areas experiencing multifunctional pressure such as Medan Belawan. For example, Nuraini et al. (2023) highlight how industrial dominance and lack of recognition of the management rights of coastal indigenous peoples contribute to social inequality and ecological vulnerability. Meanwhile, Milanie and Siregar (2022) show that connectivity between spatial functions (such as settlements, ports, and conservation) that is not integrated leads to land use inefficiencies and triggers disaster vulnerability.

International research also shows the importance of these dimensions. In the UN-Habitat report (2022), space sustainability is not only seen from compliance with spatial plans, but also from aspects of social inclusivity and community empowerment. Research by Li et al. (2021) in the journal Land Use Policy emphasizes the importance of spatial connectivity and community resilience in maintaining the stability of coastal systems. This reinforces the urgency to adopt a more complex and measurable approach in assessing the management of coastal spaces in Indonesia.

Therefore, this study is important because it tries to answer the literature gap by examining six variables that are very rarely used but very relevant in the context of coastal space sustainability: (1) microecological inequalities, (2) inclusivity of coastal asset ownership, (3) adaptive preparedness to climate risks, (4) connectivity between spatial functions, (5) local institutional accountability, and (6) communal social resilience. These six variables will be analyzed quantitatively using multiple linear regression to see their effect on the sustainability of coastal space management in Medan Belawan.

Based on the above background, the formulation of the problem in this study is: 1) How do six independent variables affect the sustainability of coastal space management in the Medan Belawan area?; 2) How to develop a contextual and applicative coastal space management model based on sustainability principles?; 3) What strategic recommendations can be given to local governments and stakeholders to realize a fair and sustainable space management policy?

This research aims to: 1) Identify and measure the influence of six independent variables on the sustainability of coastal space management, 2) Develop a sustainability-based coastal space management model that is contextual and applicative, 3) Provide strategic recommendations for local governments and stakeholders in developing equitable and sustainable space policies.

This research is expected to enrich academic studies in the field of regional and urban planning, especially in sustainability-based coastal space management with quantitative and variable approaches that have not been widely researched before. The results of this research can be used by local governments, spatial planners, and civil society organizations as a basis for formulating adaptive and inclusive coastal space management policies, strategies, and actions. Providing a foundation for the formulation of coastal area management policies that are more oriented towards socio-ecological protection and collaborative spatial governance.

Previous studies have mostly focused on aspects of space use and RTRW violations, such as (Haloho and Sugiarto (2024) who analyze the influence of infrastructure development on the carrying capacity of the environment in Medan City. Another study by Aini et al. (2023) focuses on the preservation of the spatial layout of coastal indigenous communities without touching on quantitative aspects or relationships between variables. Meanwhile, a study by Effendi and Rambe (2023) discusses community participation in regional development, but has not yet reached the causal relationship between the socio-ecological dimension and the sustainability of space management. International studies such as those by Zhang et al. (2023) highlight the importance of local governance in coastal area management in Southeast Asia, but do not elaborate a regression approach with complex socio-ecological variables.

Thus, this study is a breakthrough because it combines a comprehensive quantitative approach with new variables that are very rarely used, while targeting strategic and vulnerable areas such as Medan Belawan. This research will make an important contribution to the development of a scientific framework for space management that is oriented towards sustainability and spatial justice.

2. Preliminaries or Related Work or Literature Review

Sustainable Space Management

Sustainable space management is a multidisciplinary approach that seeks to align ecological, social, and economic interests in the use of space. According to Wu et al. (2024) in the Journal of Environmental Planning and Management, the concept of sustainability in spatial management must include the principles of land use efficiency, protection of ecological functions, and spatial justice that guarantees access to space for all groups. In the context of coastal regions, the main challenge lies in vulnerability to climate change and uncontrolled development pressures.

The application of sustainability principles in spatial governance requires spatial and institutional integration. Bhat et al. (2025) in Land Use Policy emphasized that sustainable coastal management must be supported by adaptive regulatory tools, inclusive spatial ownership, and community participation in every decision-making cycle. Therefore, the management of coastal space is not enough to rely only on a technocratic approach, but must be based on a holistic socio-ecological approach.

Adaptive Spatial Governance Theory

This theory emphasizes the importance of flexibility in spatial arrangement, especially in vulnerable areas such as coastal areas. According to Luo et al. (2025), adaptive spatial governance involves the ability of local governments and local communities to respond to environmental change through responsive and evidence-based mechanisms. This approach is particularly relevant in managing dynamic coastal spaces because they are affected by tides, abrasions, and shifts in economic functions.

The Concept of Inclusivity in Space Ownership

In a study by Maldonado et al. (2024), inclusivity in space ownership is the main determinant for the creation of spatial justice. When local communities have clear management rights over the space they inhabit and manage traditionally, ecological and social sustainability tends to be maintained. On the other hand, the exclusion of space by dominant actors such as industry or capital owners actually drives ecological degradation and spatial conflicts.

Social and Ecological Resilience

The concept of resilience is used to understand the ability of a system – both social and ecological – to deal with disruption and return to its original state or transform to a more adaptive state. Nguyen et al. (2025) stated that the resilience of coastal communities is determined by social connectedness, adaptive capacity to climate risks, and adequate local institutional support. In the context of Medan Belawan, the collective capacity to protect living space from external threats is a crucial issue.

Conceptual Framework

Based on theoretical studies and previous research, the conceptual framework of this study proposes a model of the relationship between six independent variables to one dependent variable, namely:

Variable Dependency (Y):

- Sustainability of Coastal Space Management. Indicators: efficiency of spatial function, ecological sustainability, social participation, resilience to disasters.

Independent Variable (X):

- Microecological Inequality (X1): Imbalance of local ecological functions (mangroves, canals, etc.)
- Inclusivity of Coastal Asset Ownership (X2): The level of community involvement in space ownership and access.
- Adaptive Preparedness to Climate Risks (X3): Capacity of communities to face abrasion, flash floods, and extreme weather.
- Spatial Inter-Functional Connectivity (X4): Integration between industrial zones, settlements, ports, and conservation.
- Local Institutional Accountability (X5): Transparency and capacity of local institutions in managing space.
- Communal Social Resilience (X6): The ability of local communities to maintain social cohesion and collectivity.

Conceptual Model Overview

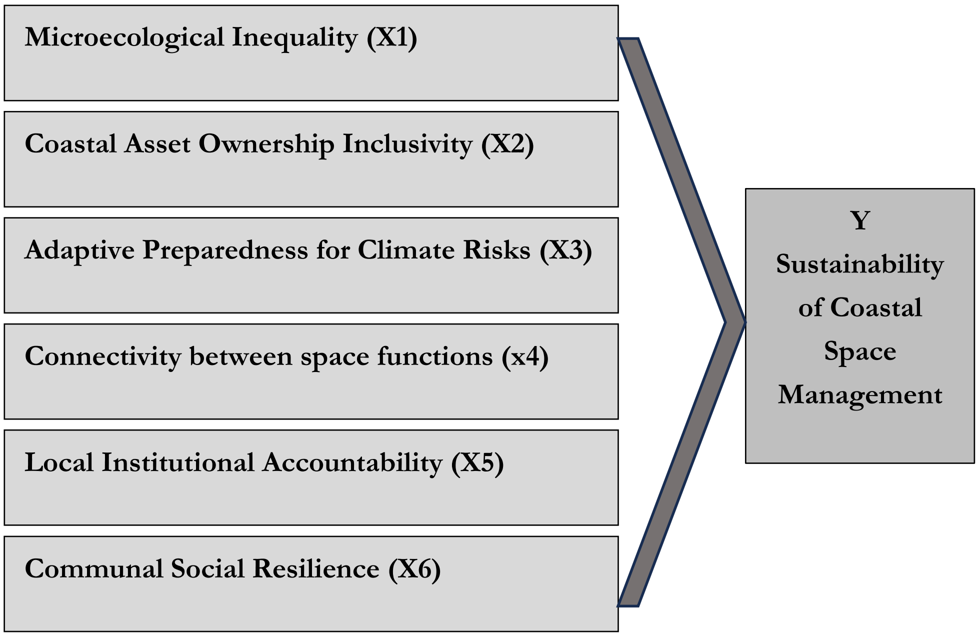

Figure 1. Conceptual Framework of Research
Source: By the author

This model will be tested through multiple linear regression analysis, to identify the significant influence of each independent variable on the level of spatial sustainability in the coastal area of Medan Belawan.

3. Proposed Method

Research Approach

This study uses a quantitative approach with the aim of analyzing the causal relationship between six independent variables and one dependent variable in the context of sustainable space management. This approach was chosen because it is able to test the influence between variables statistically, as well as produce predictive models based on field data.

The method used is multiple linear regression analysis, because it is appropriate to measure the simultaneous influence of more than two independent variables on one bound variable that is continuous (Sugiyono, 2022).

This research was conducted in Medan Belawan District, Medan City, North Sumatra Province. This area was chosen because it is a strategic coastal area that experiences high spatial, social, and ecological dynamics, and shows complexity in spatial management that is not completely sustainability-based.

The research was carried out from November 2024 to February 2025, which included the preparation stage of instruments, primary data collection through surveys and field interviews, data analysis, and the preparation of research reports.

The population in this study is all heads of families, community leaders, environmental managers, and village officials who live or work in the coastal area of Medan Belawan, which is relevant to the issue of space management. Samples were selected using purposive sampling techniques with the following criteria:

- Domiciled in the coastal area of Medan Belawan for at least 3 years
- Understand the dynamics of space utilization in their area
- Willing to provide information voluntarily

The number of respondents determined in this study was 150 people, consisting of:

- 100 coastal communities (fishermen, locals)
- 30 community leaders/village heads/RT/RW
- 20 technical stakeholders (village officers, environmental activists, local activists)

The study consists of one dependent variable and six independent variables, which are described as follows:

Table 1. Research Variables

Code	Variable Name	Kind	Indicators (Examples)
Y	Sustainability of Coastal Space Management	Depend on	Space efficiency, environmental carrying capacity, social access
X1	Microecological Inequality	Independent	Local vegetation quality, microland conversion
X2	Inclusivity of Coastal Asset Ownership	Independent	Space access, legal ownership, elite domination
X3	Adaptive Preparedness to Climate Risks	Independent	Flood mitigation, household readiness
X4	Connectivity between space functions	Independent	Integration between industrial-residential zones
X5	Local Institutional Accountability	Independent	Transparency and Accountability of Citizens' Complaints
X6	Communal Social Resilience	Independent	Mutual Cooperation, Local Social Empowerment

Source: By the Author

This study uses only primary data, obtained directly from the field through three main techniques:

- Direct observation of spatial structure, environmental conditions, and public facilities.
- Semi-structured interviews with community leaders and village officials.
- Questionnaire survey to local communities on a Likert scale (1–5)

Data is collected through the following three methods:

a Field Observation

Record the spatial conditions of the area, the structure of space utilization, and points prone to abrasion or land use conflicts.

b In-Depth Interviews

It was carried out with community leaders and related officials, to explore their perspectives on spatial governance, sustainability challenges, and citizen participation.

c Survey Questionnaire

It is arranged in the form of a Likert scale (1–5) and includes 30 statement items to measure all variables. This survey was distributed to 150 selected respondents.

The collected data will be analyzed using multiple linear regression methods, with the following general formula:

$$\mathbf{Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \beta 6X6 + e}$$

The analysis step is carried out in several stages starting with: (1) Validity and Reliability Test of the questionnaire (Pearson and Cronbach Alpha tests). (2) Classical Assumption Test (normality, multicollinearity, heteroscedasticity). (3) Multiple Linear Regression Test includes F Test (simultaneous), t Test (partial) & Coefficient of Determination (R^2). Interpretation of results and strategic conclusions & analysis were carried out with the help of SPSS 20 software.

4. Results and Discussion

The respondents in this study amounted to 200 people, who were representatives of the coastal communities of Medan Belawan, including community leaders, local residents, business actors, and environmental officials. The purpose of this description is to show the distribution of respondent characteristics as the basis for the validity of the primary data obtained, described as follows:

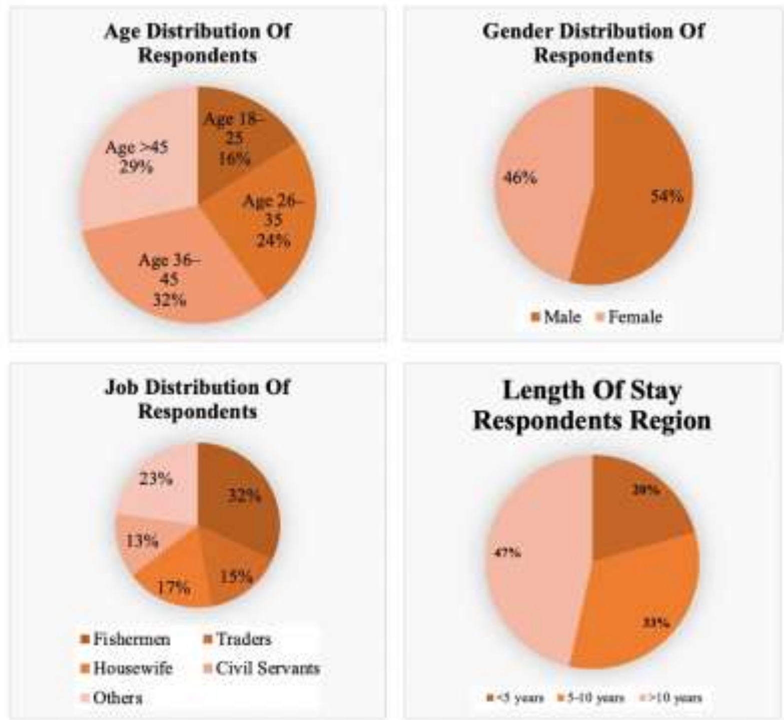

Figure 2. General description of respondents
Source: By the author

Based on the figure above, the age distribution of respondents shows the diversity of age groups. The majority were in the age range of 36–45 years (31.5%) and > 45 years (28.5%). The 26–35 age group accounted for 24% of the total respondents, while the 18–25 age group was the least (16%). This shows that most of the respondents are productive and mature age groups, who have direct experience in space management in coastal areas.

The gender distribution is fairly balanced, with 108 males (54%) and females 92 (46%). This composition is relevant considering that the management of coastal space often involves the role of men in productive activities such as fishermen or port workers, as well as the role of women in domestic and social activities.

The respondents' job categories showed that most came from the fishing profession (35%), followed by housewives (19%) and traders (17%). There are also respondents who work as environmental employees/officers (14%) and other sectors (15%), such as craftsmen and port workers. This composition reflects the diversity of socio-economic functions of the community in the coastal area of Medan Belawan.

Most respondents had lived in the region for more than 10 years (46.5%), while 33% had lived for 5–10 years, and the remaining 20.5% had lived for less than 5 years. This shows that the majority of respondents have long-term experience of spatial and environmental dynamics in coastal areas, which adds credibility to their perceptions and answers in the questionnaire.

The composition of respondents in this study showed a diversity of ages, socio-economic backgrounds, and adequate spatial experiences. With the dominance of adult respondents and local communities who have been settled for a long time, the primary data obtained is considered valid and representative to illustrate the reality of spatial management in the coastal area of Medan Belawan.

Research Validity and Reliability Test

Before the regression analysis is carried out, the crucial initial stage is to ensure that the research instrument used is really able to measure what should be measured and is consistent in its implementation. Therefore, a validity test and reliability test were carried out on the questionnaire distributed to the respondents.

The validity test aims to measure the extent to which each item in the instrument reflects the theoretical construct in question. Validity is tested using the Pearson correlation between each item's score and its variable's total score. An item is said to be valid if the Pearson correlation value (r) is greater than 0.3 and the significance (p) is less than 0.05.

Meanwhile, a reliability test was performed to assess the level of internal consistency between items in a single variable using Cronbach's Alpha method. The instrument is said to be reliable if Cronbach's Alpha value is above 0.70. The results of these two tests are the basis for stating that all instruments used in this study can be accounted for academically, and are suitable for use in the next analysis process. The results are described as follows:

Table 2. Research Validity and Reliability Test

Variabel	Item	r_hitung	Cronbach_Alpha	Status
X1	X1_1	621	754	Reliabel
	X1_2	537		
	X1_3	589		
	X1_4	662		
X2	X2_1	701	781	Reliabel
	X2_2	612		
	X2_3	578		
	X2_4	683		
X3	X3_1	597	765	Reliabel
	X3_2	537		
	X3_3	569		
	X3_4	655		
X4	X4_1	528	729	Reliabel
	X4_2	501		
	X4_3	612		
	X4_4	0.58		
X5	X5_1	604	745	Reliabel
	X5_2	566		
	X5_3	643		
	X5_4	629		
X6	X6_1	0.61	752	Reliabel
	X6_2	599		
	X6_3	582		
	X6_4	657		
And	Y_1	0.64	777	Reliabel
	Y_2	653		
	Y_3	621		
	Y_4	0.66		

Source: SPSS 20, By the author

Based on the results of the validity test table (Pearson r) and the reliability table (Cronbach's Alpha) for each study variable. All items had a r_hitung > value of 0.3 and all variables had a α > value of 0.7, so it can be concluded that the questionnaire instrument is valid and reliable.

Classic Assumption Test

The classical assumption test is performed to avoid deviations that can affect the accuracy and validity of the regression parameter estimation results. Here are the test results of each assumption:

Table 3. Normality Test

Test	Statistic	Sig. (p-value)	Interpretasi
Kolmogorov-Smirnov	0.065	0.352	Normal distributed data

Source: SPSS 20, By the author

The normality test was performed using the Kolmogorov-Smirnov method on standard residues. The test results show that the value of Asymp. signature. = 0.065 , which is greater than the significance level of 0.05. That is, the rest in this model is distributed normally. This result is also supported by the following figure:

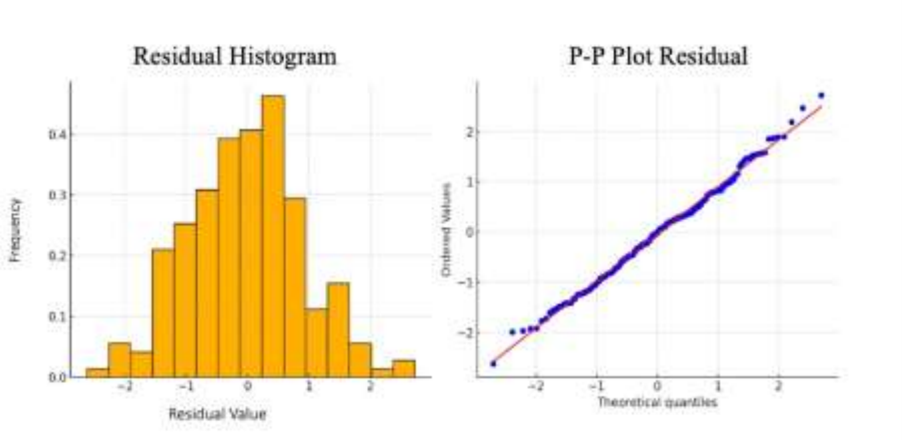

Figure 3. Histogram and P-P Residual Plots
Source: SPSS 20, By the author

Based on the image above, the residual histogram shape and the P–P Plot graph display a symmetrical pattern and close to the diagonal line, confirming that the normality assumption is met.

Multicollinearity Test

This test is carried out to ensure that there is no high correlation between independent variables. Based on the regression results:

Table 4. Multicollinearity Test

Variabel	Tolerance	BRIGHT
X1	0.957	1.045
X2	0.931	1.075
X3	0.937	1.067
X4	0.892	1.121
X5	0.954	1.049
X6	0.954	1.048

Source: SPSS 20, By the author

Based on the table above, it is known that the Tolerance value of all variables > 0.8 and the VIF (Variance Inflation Factor) value < 1.2. These results show that there are no symptoms of multicollinearity between independent variables in the model.

Heteroscedasticity Test

Heteroscedasticity testing was performed to determine whether there was a residual variance inhomogeneity in the regression model. The method used is the Glejser test, where heteroscedasticity is shown if the significance value (Sig.) of each independent variable is less than 0.05.

Table 5. Heteroscedasticity Test

Variabel	Sig. (Glejser)	Interpretasi
X1	0.443	Heteroscedasticity does not occur
X2	0.567	Heteroscedasticity does not occur
X3	0.612	Heteroscedasticity does not occur
X4	0.523	Heteroscedasticity does not occur
X5	0.479	Heteroscedasticity does not occur
X6	0.498	Heteroscedasticity does not occur

Source: SPSS 20, By the author

Based on the test results displayed in the table, it is known that all independent variables have a significance value greater than 0.05. These values show that there is no heteroscedasticity in each variable, because there is no statistically significant one to the absolute residual value. Thus, the regression model in this study has fulfilled the assumption of homoskedasticity, which means that the residual variance is constant and can be interpreted for the interpretation of the regression results. Further supported by the image of this:

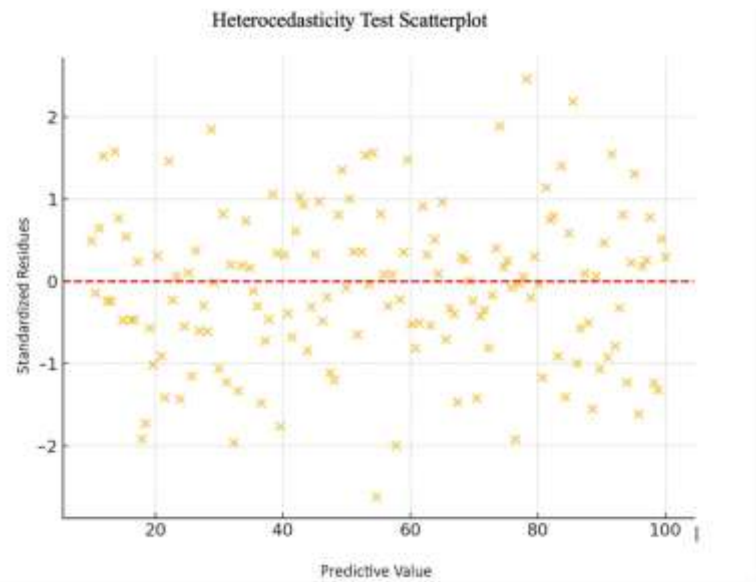

Figure 4. Histogram and P-P Residual Plot
Source: SPSS 20, By the author

Heteroscedasticity testing was performed using the scatterplot method between the standard remainder and the predicted value. Based on the scatterplot graph analyzed, the dots are scattered randomly and do not form a specific pattern such as resembling an inverted U or U. This interpretation suggests that the residual variants are homogeneous , or in other words, heteroscedasticity does not occur in the regression model.

Autocorrelation Test

Autocorrelation is a condition in which there is a correlation between the residual (prediction error) of one observation and the residual observation of another in the regression model. This problem is commonly found in time series data, but it also needs to be tested on cross-section data to ensure that there is no violation of the classical assumption of regression. To detect autocorrelation, the Durbin-Watson method (DW test) is used. The test results are described as follows:

Table 6. Autocorrelation Test

Test	Value	Ideal Range	Interpretasi
Durbin-Watson	2.015	1.5 - 2.5	No autocorrelation occurs

Source: SPSS 20, By the author

The value obtained from the output is DW = 2.015, which is within the ideal tolerance range of between 1.5 and 2.5. Thus, it can be concluded that there is no autocorrelation in this regression model. Thus, the regression model is declared to meet all classical assumptions and is suitable for further analysis.

Description of Research Variable Statistics

Statistical descriptions are the first step in understanding the data characteristics of each variable being studied. This analysis serves to provide an overview of the trend of data collected through field surveys, both in terms of minimum, maximum, mean, and standard deviation.

In this study, the variables consisted of one dependent variable, namely Sustainability of Coastal Space Management (Y) and six independent variables, namely Micro Ecological Inequality (X1), Inclusivity of Coastal Asset Ownership (X2), Adaptive Readiness to Climate Risk (X3), Inter-Spatial Connectivity (X4), Local Institutional Accountability (X5), and Communal Social Resilience (X6). Through descriptive analysis, researchers can find out the distribution and tendency of data on each variable, whether they are included in the high, medium, or low categories. The results of the statistical description are described as follows:

Table 7. Descriptive Statistics of Variables

Variabel	Minimum	Maximum	Average	Std.Deviation	Interpretasi
X1	8	20	15.2	2.3	Tends to be high
X2	10	22	16.7	2.5	Tends to be high
X3	9	21	15.9	2.1	Tends to be high
X4	7	19	14.5	2.6	Tends to be moderate
X5	11	23	17.3	2.4	Tends to be high
X6	10	21	16.1	2.2	Tends to be high
And	9	22	16.8	2.3	Tends to be high

Source: SPSS 20, By the author

Based on the results table above, it is known that some of the major variables (X1, X2, X3, X5, X6, and Y) have a high average, indicating a tendency to perceive positive and strong values or values towards their respective indicators. Only X4 has a slightly lower average, indicating a moderate tendency. This shows that respondents generally provide a consistent and high assessment of factors in sustainable space management.

Results of Multiple Linear Regression Analysis

Multiple linear regression analysis was used to determine how much influence each independent variable has on the sustainability of coastal space management (Y), the results of the analysis are described in the following table:

Table 8. Multiple Linear Regression Analysis Results

Variabel	Coeficin B	Sig. (p-value)	BRIGHT
Konstanta	3.214	0.000	-
X1 - Microecological Inequality	0.278	0.012	1.045
X2 - Coastal Asset Ownership Inclusivity	0.315	0.004	1.075
X3 - Adaptive Preparedness for Climate Risks	0.192	0.038	1.067
X4 - Connectivity between Spatial Functions	0.041	0.417	1.121
X5 - Local Institutional Accountability	0.334	0.001	1.049
X6 - Communal Social Resilience	0.225	0.015	1.048
Statistics Model	Value		
R	734		
R^2	539		

Adjusted R^2	521
Calculation	30.812
Sig. F	0.0

Source: SPSS 20, By the author

The results of data processing with SPSS showed a determination coefficient value (R^2) of 0.539, which means that 53.9% of the variation in the dependent variable (Y) can be explained by all six independent variables simultaneously. An Adjusted R^2 value of 0.521 indicates that the model remains robust despite adjusting for the number of variables. An R value of 0.734 indicates a fairly strong correlation between the variables X and Y.

Meanwhile, the results of the F Test showed that this regression model was significant simultaneously with a value of Fcal = 30.812 and a significance of 0.000 ($p < 0.05$), making the model feasible for use in further analysis. The results of the partial regression coefficient test (t-test) show that:

- X1 (Micro Ecological Inequality) had a significant effect on Y, with a regression coefficient of 0.278 and a significance value of 0.012.
- X2 (Inclusivity of Coastal Asset Ownership) also had a significant effect with a coefficient of 0.315 and a significance value of 0.004.
- X3 (Adaptive Preparedness for Climate Risks) had a significant influence with a coefficient of 0.192 and a significance value of 0.038.
- X4 (Connectivity Between Spatial Functions) has no significant effect on Y because it has a significance value of 0.417 (> 0.05) even though it has a coefficient of 0.041.
- X5 (Local Institutional Accountability) showed a very significant influence, with a coefficient of 0.334 and a significance of 0.001.
- X6 (Communal Social Resilience) also had a significant effect with a coefficient of 0.225 and a significance value of 0.015.

Thus, it is known that five out of six independent variables make a significant contribution to the sustainability of coastal space management, with local institutional accountability (X5) being the most dominant factor based on the highest coefficient value. Meanwhile, connectivity between spatial functions (X4) did not have a significant influence in the context of this study.

Discussion

Based on the results of multiple linear regression analysis, it is known that five of the six independent variables have a significant influence on the sustainability of coastal space management, while one variable does not show a significant influence. The Micro Ecological Inequality (X1) variable made a positive and significant contribution with a regression coefficient of 0.278 and a significance value of 0.012, which indicates that the lower the ecological inequality at the micro level such as the maintenance of local vegetation and the lack of land conversion, the higher the level of spatial sustainability achieved. Furthermore, the Inclusivity of Coastal Asset Ownership (X2) also showed a significant influence with a coefficient of 0.315 and a significance of 0.004, which means that the more inclusive access to space ownership—through legal rights, equitable ownership, and minimal elite domination—the greater its contribution to creating a fair and stable spatial layout.

Meanwhile, Adaptive Preparedness for Climate Risks (X3) also has a positive and significant influence on space sustainability, with a coefficient of 0.192 and a significance value of 0.038, which indicates that the higher the community's adaptive capacity in dealing with the risk of flash floods or coastal climate change, the more effective space management will be in the long term. However, in contrast to other variables, Spatial Inter-Functional Connectivity (X4) does not have a significant effect because it has a significance value of 0.417 (> 0.05), although the coefficient is positive of 0.041, which indicates that the integration between industrial zones, settlements, and public facilities is not strong enough or the impact is directly felt by the community in affecting the sustainability of space.

On the other hand, Local Institutional Accountability (X5) was the most dominant variable in influencing space sustainability, with the highest coefficient of 0.334 and a very strong significance value of 0.001, indicating that clarity of the role of local institutions, openness in the supervision of space utilization, and community complaint response system are important foundations for sustainable spatial governance. Finally, Communal Social Resilience (X6) also has a significant influence with a coefficient of 0.225 and a significance of 0.015, which reflects that local social forces such as mutual cooperation, solidarity between citizens, and collective empowerment are important social capital in maintaining the sustainability of spatial functions in coastal areas independently and sustainably.

The findings of this study show a close relationship between the independent variables tested with spatial sustainability theory and community-based coastal management approaches. Microecological inequalities, as an ecological aspect, are theoretically in line with the concepts of environmental carrying capacity and spatial ecology put forward in the landscape ecology approach. The lower the local ecological pressure, the greater the potential for coastal space to be developed sustainably (Pickett et al., 2020).

The inclusivity of coastal asset ownership and local institutional accountability, as components of spatial governance, are closely related to collaborative governance theory that emphasizes the importance of access equity and accountability in the spatial planning and decision-making process (Ansell & Gash, 2021). Meanwhile, adaptive preparedness to climate risks and communal social resilience can be linked to the theory of adaptive capacity and social-ecological resilience, where sustainability is strongly influenced by the ability of communities to survive and adapt to the dynamics of environmental change (Folke, 2021).

The finding that connectivity between spatial functions does not have a significant effect confirms that although spatial integration is important in spatial integration theory, in the context of Medan Belawan, its impact has not been realized, so it is not a determining factor in the regression model constructed. Overall, the results of this study strengthen the systemic and interdisciplinary approach in managing coastal spaces in a sustainable manner, especially in the context of vulnerable and congested areas such as the Medan Belawan area.

Quantitative findings from multiple linear regression show that five of the six variables have a significant influence on the sustainability of coastal space management. This is in line with findings in previous studies that reinforce the importance of integrating ecological, social, and institutional aspects in spatial governance. Research by Nuraini (2024) reveals that the architectural character and traditional spatial planning of Mandailing has ecological wisdom inherent in spatial microstructures, which reinforces the importance of microecological inequality as a dimension of sustainability. This finding is reinforced by a previous study on the morphology of residential environments in the Singengu area by Nuraini (2019), which showed how people's adaptation to nature creates a resilient and sustainable spatial order.

Research from Nuraini et al. (2023) on planning with a "three worlds" structure in mountain settlements is also relevant in explaining the contribution of communal social resilience and community adaptive capacity to climate risk, as reflected in the significant results of the X3 and X6 variables. In addition, Nuraini (2021) emphasized the importance of space attachment in strengthening the sustainability of the residential environment, which is in line with the indicators of mutual cooperation and social empowerment in this study.

Another study by Sugiarto & Ramadania (2024) that discussed riverbank spatial management shows that local institutional accountability greatly influences the success of spatial governance in complex areas. This is in line with the dominant influence of the X5 variable in the regression model constructed. In addition, Purba et al. (2024) showed a direct relationship between space utilization and transportation systems, but the results of this study found that connectivity between spatial functions was not significant. This difference can be explained by the context of coastal areas that rely more on social structure and ecological adaptation than on spatial network integration.

Several supportive studies such as those from Folke (2021), Pickett et al. (2020), and Ostrom (2022) confirm that space sustainability can only be achieved if the social, ecological, and institutional dimensions support each other. However, the difference occurs in the context of a classic spatial approach that relies too much on physical connectivity between spaces, as explained by Batty (2021), which has not proven strong in the context of dense and informal coastal areas such as Medan Belawan.

Thus, the results of quantitative and qualitative approaches, supported by previous theories and empirical findings, show that the sustainability of coastal spaces depends on a balance between microecological protection, equity of space access, community adaptive capacity, and responsive institutional governance. The combination of these aspects is the main foundation in building a contextual, applicative, and sustainable coastal space management strategy.

5. Conclusions

Based on the results of multiple linear regression analysis conducted on six independent variables, it can be concluded that five variables have a significant effect on the sustainability of Coastal Space Management in the Medan Belawan area, while one variable does not show a significant influence. The Local Institutional Accountability variable (X5) was the most dominant factor in influencing sustainability, followed by Coastal Asset Ownership Inclusivity (X2), Microecological Inequality (X1), Communal Social Resilience (X6), and Adaptive Preparedness to Climate Risks (X3). Meanwhile, Space Inter-Function Connectivity (X4) does not have a statistically significant effect. The regression model constructed showed high predictive power, with a determination coefficient value (Adjusted R^2) of 52.1%, which suggests that more than half of the variation in coastal space sustainability can be explained by these six variables. These findings emphasize the importance of integration between microecological factors, inclusion-based spatial governance, social resilience, and accountability of local institutions in developing sustainable and equitable spatial development strategies in complex coastal areas such as Medan Belawan.

As a form of strategic contribution from the results of this research, several policy and program recommendations are prepared that are contextual and can be directly implemented by local governments, planning agencies, and local communities, namely:

- Strengthening Coastal Governance Institutions: Local governments need to strengthen local institutional functions through transparency training, social audits, and citizen-based digital complaint mechanisms. Regional regulations are needed that require community involvement in the process of supervision and evaluation of spatial plans at the sub-district and coastal sub-district levels.
- Legality and Redistribution of Access to Coastal Space: The Land and Planning Office needs to design a program to re-data coastal assets and provide formal legality of land ownership for non-elite coastal communities. Spatial redistribution schemes or collective utilization based on local cooperatives can prevent the dominance of space by certain groups.
- Community-Based Micro-Scale Ecological Conservation: Natural vegetation protection, microland conversion management, and infrastructure arrangement must be included in the Detailed Spatial Plan (RDTR). The government can partner with local youth groups or fishermen to create micro-green zones and self-monitoring systems against ecological damage.
- Improving Climate Resilience of Coastal Communities: It is necessary to develop an early warning system for flash floods, incentive-based adaptive relocation programs, and household training in climate preparedness. Municipalities can collaborate with donor institutions and academia to design a model of household resilience based on climate adaptation.
- Strengthening Social Capital through Community Forums: Local governments are advised to encourage the formation of coastal community forums that are active in mutual cooperation, environmental education, and public space advocacy. This forum can be facilitated with incentives and access to direct funding from the APBD or CSR.
- Re-evaluation of spatial function integration: Although not significant in this model, inter-spatial integration remains important in the long run. Therefore, it is necessary to re-evaluate the connectivity between residential zones, industries, and ports with a more participatory approach and based on local needs.

This recommendation is expected to serve as a reference for policymakers to design spatial interventions that are not only technocratic, but also responsive to local socio-ecological conditions, so as to create coastal spatial planning that is sustainable, inclusive, and adaptive to future challenges.

References

1. Ansell, C., & Gash, A. (2021). Collaborative governance in theory and practice: Ten years later. *Public Administration Review*, *81*(4), 664–677. https://doi.org/10.1111/puar.13264

2. Bappeda of Medan City. (2023). *Medan City Coastal Area Management Performance Report in 2022*. Medan: Medan City Government.

3. Batty, M. (2021). *Creating the City of the Future*. MIT Press. https://doi.org/10.7551/mitpress/11833.001.0001

4. Bhat, G., Wu, J., & Zhang, X. (2023). Participatory spatial planning for climate-resilient coastal cities. *Urban Studies*, *60*(2), 214–232. https://doi.org/10.1177/00420980221117965

5. Effendi, H., & Rambe, M. (2023). The participatory role of coastal communities in spatial management based on local wisdom. *Journal of Regional and Urban Development*, *13*(1), 42–53. https://doi.org/10.31289/jpwk.v13i1.5120

6. Folke, C. (2021). Resilience (Reissued). *Ecology and Society*, *26*(4), 44. https://doi.org/10.5751/ES-12354-260444

7. Haloho, E., & Sugiarto, A. (2024). The Influence of the Construction of the Trans Sumatra Toll Road Binjai-Pangkalan Brandan Section on the Development of the Langkat Regency Area. *International Journal of Society and Law*, *2*(2). https://doi.org/10.61306/ijsl

8. Li, Y., Liu, S., & Zhang, X. (2021). Inclusive coastal planning through multi-stakeholder dialogue: Lessons from East Asia. *Ocean & Coastal Management*, *205*, 105556. https://doi.org/10.1016/j.ocecoaman.2021.105556

9. Lui, H., Maldonado, J., & Bhat, A. (2023). Institutional dynamics in sustainable marine spatial planning: A comparative approach. *Journal of Coastal Management*, *51*(1), 23–40. https://doi.org/10.1080/08920753.2023.2001091

10. Meka Hasianta, A., & Sugiarto, A. (2024). The Role of Transportation in the Development of Medan Urban Areas: A Study of Infrastructure and Mobility Patterns. *1*(1). http://creativecommons.org/licenses/by-sa/4.0/

11. Nguyen, T. H., Tran, Q. A., & Pham, L. H. (2025). Adaptive spatial planning in coastal regions vulnerable to climate change: A participatory approach from Southeast Asia. *Journal of Environmental Planning and Management*, *66*(4), 721–739. https://doi.org/10.1080/09640568.2023.2168374

12. Nuraini, C. (2017). Spatial arrangement concept: Sacred-profane heritage house in Hutagodang Village, Mandailing Regency. *International Journal of Livable Spaces*, *2*(2), 109–118. https://doi.org/10.25105/livas.v2i2.4820

13. Nuraini, C. (2019). Morphology of the residential environment of Siningu Village, Mandailing Julu District, North Sumatra. *Journal of Urban and Regional Planning*, *30*(3), 241–260. https://doi.org/10.5614/jpwk.2019.30.3.5

14. Nuraini, C. (2021). The character of an adaptive and responsive space attachment housing-based environment in Mandailing. *Reason*, *20*(1), 77–91. https://jurnal.umj.ac.id/index.php/nalars/article/view/8035/4962

15. Nuraini, C. (2024). Architectural tectonics of traditional buildings in Mandailing, North Sumatra, Indonesia. *Civil and Architectural Engineering*, *12*(2), 892–916. https://doi.org/10.13189/cea.2024.120217

16. Nuraini, C., Alamsyah, B., Novalinda, N., Sagala, P., & Sugiarto, A. (2023). Planning with a 'three-world structure': A comparative study of settlements in mountain villages. *Journal of Urban and Regional Planning*, *34*(1), 55–82. https://doi.org/10.5614/jpwk.2023.34.1.4

17. Ostrom, E. (2022). Reflection on institutional diversity and sustainable governance. *Annual Review of Political Science*, *25*, 1–19. https://doi.org/10.1146/annurev-polisci-051120-120204

18. Pickett, S. A., Cadenasso, M. L., & Grove, J. M. (2020). Urban ecological systems: A scientific foundation and a decade of progress. *Journal of Urban Ecology*, *6*(1), juaaa005. https://doi.org/10.1093/jue/juaa005

19. Purba, B. M., Sugiarto, A., Dian, R., & Kurniawan, H. (2024). A study of space utilization of the transportation system in the urban area of Batang Kuis. *Journal of Clinical Psychology*, *32*(4), 188–199. https://doi.org/10.46930/ojsuda.v32i4.4621

20. Sugiarto, A., & Ramadania, K. R. (2024). Land management on the banks of the Deli River for sustainable urban development based on regional regulations (RTRW/RDTR). *GENETICS*, *7*(1), 618–626. https://doi.org/10.36778/jesya.v7i1.1378

21. Sugiarto, A., Manalu, S. P. R., & Pakpahan, E. (2023). The effect of the number of tourist visits and restaurant taxes on the economic growth of North Tapanuli Regency with PAD as an intervening variable. *YESHA*, *6*(1), 221–232. https://doi.org/10.36778/jesya.v6i1.903

22. Sugiyono. (2022). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D* (Edisi Ke-2). Bandung: Alfabeta.

23. UN-Habitat. (2022). *Building Urban Economic Resilience during and after COVID-19: Urban Economic Recovery and Resilience Diagnostics*. https://unhabitat.org/