Open Access, April 2023
p-ISSN : 2087-9423
e-ISSN : 2620-309X
J. Ilmu dan Teknologi Kelautan Tropis, 15(1): 65-84
https://journal.ipb.ac.id/index.php/jurnalikt
DOI: https://doi.org/10.29244/jitkt.v15i1.43125

COASTAL MANAGEMENT STRATEGIES TO FACE CLIMATE CHANGE AND ANTROPHOGENIC ACTIVITY: A CASE STUDY OF TAMBAN BEACH, MALANG REGENCY, EAST JAVA

STRATEGI PENGELOLAAN PESISIR UNTUK MENGHADAPI PERUBAHAN IKLIM DAN AKTIVITAS ANTROPOGENIK: STUDI KASUS PANTAI TAMBAN, KABUPATEN MALANG, JAWA TIMUR

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ABSTRACT

This research was set against the backdrop of low levels of coastal ecosystem services at the global, regional, national, and local levels. Changes in land use in coastal areas are mainly caused by an increasing intensity of climate change and irrational land use. The aim of this research was to develop coastal management strategies to deal with intensified climate change and anthropogenic processes. The methods used included using the drone approach to perform a spatial analysis, measuring the parameters of Tamban coastal waters, and applying the Partial Least Squares (PLS) method to determine community assessments and opinions about tsunami. The results of the study indicate that Tamban Beach is highly vulnerable to tsunami hazards even though the water parameters are still on the verge of pollution and that the coastal ecosystem services are not excellent. The results of this study require that the people affected by the tsunami, especially residents on Tamban beach, need to be moved to an area that is safer from the brunt of the tsunami. The area is approximately 10 kilometers from the shoreline. Besides that, this area also needs to be designated as a marine ecotourism area, but free from the tsunami disaster.

Keywords: *coastal management, climate change, spatial*

ABSTRAK

Perubahan penggunaan lahan di wilayah pesisir disebabkan oleh meningkatnya intensitas perubahan iklim dan penggunaan lahan yang tidak rasional serta upaya mitigasi untuk masyarakat terhadap bencana tsunami. Tujuan penelitian untuk mengembangkan strategi pengelolaan pesisir menghadapi perubahan iklim yang intensif dan proses antropogenik (kegiatan manusia). Metode drone digunakan untuk menganalisis spasial, mengukur parameter perairan pantai Tamban, dan menggunakan metode Partial Least Squares (PLS) untuk menentukan penilaian dan opini masyarakat tentang tsunami. Hasil penelitian menunjukkan bahwa Pantai Tamban sangat rentan terhadap bahaya tsunami meskipun parameter perairannya masih di ambang batas pencemaran dan pelayanan jasa ekosistem pesisir yang belum prima. Hasil penelitian ini mensyaratkan masyarakat yang terkena tsunami terutama penduduk di pantai Tamban perlu dipindahkan ke daerah yang lebih aman dari terjangan tsunami Kawasan tersebut berjarak keurang lebih 10 kilometer dari bibir pantai. Disamping itu kawasan ini perlu juga ditetapkan sebagai kawasan ekowisata bahari, namun bebas dari bencana tsunami.

Kata Kunci: *perubahan iklim, tata ruang, pengelolaan pesisir*

I. INTRODUCTION

Biodiversity and ecosystem services are declining faster now than any other time in human history (United Nations report, 2019). The main drivers of this decline are several activities, such as loss of ecosystem habitat from unsustainable agricultural activities, deforestation, unsustainable use of resources, intensified climate change, and the invasiveness of alien species. The decline in ecosystem services, especially in coastal areas, leads to a decrease in fish supply from 90% (1974) to 67% (2015). For this reason, it is recommended by the United Nations (2019) and Dingemans *et al.* (2020) to improve the quality of marine waters in terms of acidity as there will be a process of ocean acidification at a rate from 100% to 150% until 2100. The marine waters area is one part of natural capital, which includes the interaction between ecosystems and ecosystem processes, both biotic and abiotic, as a functional unit (e.g., the coral reef ecosystem, mangrove ecosystem, and seagrass ecosystem). Sea waters as the world's future economic capital are highly potential assets, but due to changes in their lower capacity due to anthropogenic processes, their ability as economic capital is decreasing. (Patil *et al.*, 2016); Mace *et al.*, 2015).

The coastal ecosystem services in Indonesia are continuously decreasing. Darjati *et al*. (2016) grouped Indonesia's territory into seven bioregions with bioregional characteristics and a high number of endemic species by the biogeography of flora and fauna. There are three types of biodiversity: ecosystem, species, and genetic biodiversity. The biodiversity of coastal ecosystems includes biodiversity in mangroves, coral reefs, and seaweed. However, according to Zid *et al.* (2021), the decline in coastal ecosystem services in Indonesia as a result of land changes shows that development planning has yet to consider coastal ecosystem services. There are damages to coastal areas in Malang Regency, especially the mangrove forests on the Tamban coast. According to Harahab & Setiawan (2017), the effort of preserving mangroves is faced by the challenge of illegal logging activities, considering that mangrove wood generates high charcoal quality, suitable for use as firewood.

Referring to Mycoo *et al.* (2013) conducted research related to coastal management and climate change adaptation and sustainability for coastal communities related to the starfish and beach loss. The study found that the research results have a global application for coastal communities who are at risk of exposure and highly vulnerable to natural resource damage due to anthropogenic pressure and potential climate change. These communities need policy reforms to strengthen current coastal management practices and adaptation responses aimed at ensuring long-term sustainability. This is based on the fact that coastal communities around the world are facing issues of natural resource and economic sustainability in the context of natural coastal dynamics and unsustainable coastal management practices, and they might be even more vulnerable given the forecast for climate change. In communities where habitats of endangered species and sustainable livelihoods are threatened, research of this kind is needed to close the gap between scientific findings and the implementation of policy reforms aimed at adaptation to these threats and achieving sustainability of natural resources and livelihoods.

Climate change is causing seawater to expand and glaciers to melt. Ice sheet melt occurs over a much larger area and scale. This requires clear policies and action plans, so that the intensity of greenhouse gas emissions is limited. The impact of a 1 meter sea level rise at some point in the future implies changes in the long term. The Committee in Climate Change (2018) states that climate change on the UK coast is exacerbating coastal conditions with flooding and erosion. The UK's current coastal management approach is unsustainable in the face of climate change. This approach includes the following: First, coastal communities, infrastructures, and landscapes face the threat of flooding and coastal erosion. This threat will increase in the future. The problem is that coastal development does not always take into account long-term sustainability. The natural environment that has become a coastal "body guard" that is resistant to change has been transformed into a tough coastal defense construction. Many coastal communities are highly vulnerable to climate change. Second. Some coastal communities and infrastructures that have been built may not be able to survive in the current conditions. Communities living on the coast more often choose to maintain the status quo by building bigger and stronger defenses to protect all coastal communities in the future at a very high cost. Consequently, the intrinsic value of the coast will also decrease. This disrupts the natural adaptation of the coast to sea level rise. Dealing with the inevitable change requires difficult decisions. Coastal communities need to be involved to plan for their future for decades, but the capacity and political will to do so have not yet existed. Third, sustainable coastal adaptation is possible to provide many benefits. However, long-term commitment and proactive steps are needed to inform and facilitate change in social attitudes. Legislative reform is primarily concerned with asset relocation and community displacement. For this reason, it is necessary to draft legislation that provides an initial opportunity to start campaigning for this need. Realignment of management and restoration efforts offers beneficial natural coastal adaptations that communities expect and are most feasible in the region. However, the population density variable requires investment, facilitation, and monitoring activities. Key coastal assets, such as cities and critical infrastructures, require investment in protection of higher standards from things such as sea level. Long-term plans to adapt to change are needed everywhere, with a sharper focus on long-term resilience, community involvement and support for adaptation, integration with other local priorities, and the cost-effectiveness of the proposed policy.

There are important challenges in identifying three main actions to address climate change in coastal areas, namely, (a) refocusing local wisdom practices more on an awareness approach to climate change, (b) developing a more comprehensive and multidimensional risk framework and non-stationary components with a consideration of uncertainty, and (c) building bridges between risk assessment and adaptation theory and practice (Toimil *et al.*, 2020). The study concluded that to deal with this uncertain way forward, many activities need to be carried out, including improved climate projections and their integration into climate change impact models, impact assessments on local scales, and dynamic projections of spatially distributed exposure, vulnerability, and exploration of options that are inherently adaptive. In this regard, more practical guidelines are needed in the future. Such a kind of research above has not shown any integration between aspects of space, the existence of ecosystems, and the assessment and understanding of the community about the impacts of climate change and anthropogenic processes. Therefore, this research aim is to provide a model to integrate aspects of spatial planning, the configuration of water quality aspects, and the perception and assessment of local people at Tamban Beach, Malang Regency.

II. RESEARCH METHODS

2.1. Time and Place of Research

This research was conducted from March to May 2022 in the Tamban coastal area, Tambakrejo Village, Sumbermanjing Wetan sub-district, Malang Regency. Figure 1 below shows the research location with a map scale of 1: 20,000.

2.2. Material and Data

2.2.1. *Unmanned Aerial Vehicle* (UAV)

The topographic mapping of the coastal area of Tamban as well as its surrounding in a total area of 450 hectares used photogrammetric techniques and aerial photo mapping using drones. The aim of this work was to compile detailed base map sources, namely, orthophoto mosaic maps and 1:20,000-scale topographic maps. Aerial photographs were taken by taking into account a flying height of 300 meters from the average ground level (Budhiati *et al.*, 2015) The camera used had a minimum resolution of 18 MP and a sensor of the APS-C type. There were 80% ± 5% overlap and 70% ± 5% overlap. The aerial photo dataset geotaging system used the *Post Processing Kinematic* (PPK) method, which used 2 GNSS GPS modules that were placed on the ground as a base and on a UAV aircraft as a GPS rover. The projection system used was Universal Transverse Mercator (UTM) with an ellipsoid datum WGS-84 or according to the local coordinate system. The process of generating Digital Elevation Model (DEM) was in the form of digital elevation data for Digital Surface Model (DSM) and Digital Terrain Model (DTM).

2.2.2. Measurement of Mangroves

The method used for data sampling was purposive random sampling with three stations. Each position of stations as follows: Station 1: 8^{0}24,51’48”S, and 112^{0}42,47’83”E Station 2: 8^{0}24,53’60”S and 112^{0}42.55”10’E, Station 3: 8^{0}25.0’.60” S and 112^{0}42.53’80” E. based on specific objectives and considerations of the high distribution of mangrove species variations (Mycoo *et al.*, 2013). Each station was deployed three 10 x 10 m square plots for measuring the tree class DBH Diameter at Breast Height ≥ 20 cm), and each plot is divided into two 5 x 5 m plots, for belta/sapling class (DBH ≥ 2 - <10 cm), and 2 x 2m for seedling class (DBH< 2 cm). The result of magrove measurement can be seen bellow Table 1.

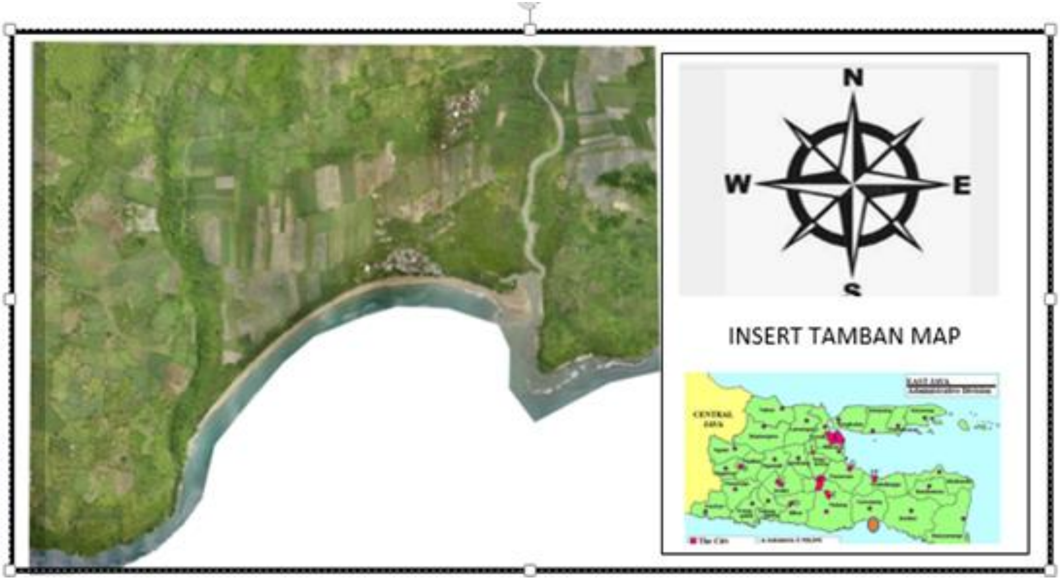


Figure 1. Map of the Research Location on Tamban Beach, Malang Regency.

Table 1. The relative density of the mangrove forests

	Trees			Belta			Seedling		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Avicennia alba	633.33	0	0	166.6	0	0	0	0	0
Avicennia marina	1333.33	666.6	0	833.3	233.3	0	0	0	0
Rhizophora sp.	366.67	166.67	1933	200	266.67	1800	0	0	0
Xylocarpus granatum	0	800	0	0	166.67	0	0	0	0
Bruguiera gymnorrhiza	0	1133.33	0	0	100	0	0	0	0

2.2.3. Measurement of Coral Reef

Coral reef measurements were carried out at two stations (Table 2). Coral reef measurements were carried out at two stations with a depth of 5 meters and 7 meters. In addition, data collection in the field is carried out by shooting using an underwater digital camera or an ordinary digital camera that is given a waterproof case (housing) (Giyanto *et al.*, 2017). The photos taken from the shooting were then analyzed using computer software to obtain quantitative data.

2.2.4. Measurement of Data for Partial Least Square (PLS)

From the questionnaire responses from 51 respondents, the characteristics of the respondents were identified as follows: 30 respondents for local people, 10 respondents for small local enterprises and the remaining 11 of local govenments. The average age of the respondents was 41.7 years. Male respondents accounted for 52.9% of the total number of respondents, while female respondents did 47.1%. A total of 37.3% of the respondents were high school graduates. As many as 35.3% of the respondents were fishermen, while 29.4% were farmers. In terms of income per month, 39.2% of the respondents earned non-fixed income and 29.4% did less than Rp1 million/month. Thirty-one respondents filled in income data, and it can be seen that the average respondent had an income of Rp 2,116,129 the smallest amount of income was Rp 500,000, and the largest was Rp25,000.000. Since PLS does not assume a specific distribution for parameter estimates, parametric techniques to test parameter significance are not required (Dingemans *et al*., 2020). To carry out the PLS analysis, it is necessary to translate the variables into sub-variables (Table 3).

2.3. Data Analysis

The method used was directed at realizing integrated restoration management in order to restore damaged ecosystems according to their original species, then at protecting and improving the quality of marine waters, managing natural resources sustainably, and promoting marine ecotourism areas. The integrative method used refers to the use of several methods to integrate results into a single coastal area management model. The methods used to realize an integrated coastal ecosystem management model with taking into account: Firstly, using GIS to map the existence of ecosystems by recognizing distribution and density and by mapping the conditions of the ecosystems. The categories obtained include healthy, moderate, and bad categories. Information about objects found in coastal areas was recorded using satellite sensors. Then, according to the objectives of the activities to be carried out, this information was processed, analyzed, interpreted, and presented in the form of spatial information and spatial thematic maps using GIS. According to Retno

Table 2.The positions of the coral reef stations on Tamban Beach

No	Station Name	Position	Depth (meters)
1.	Station 1	08° 24' 53.6" S, 112° 42' 55.1" E	5
2.	Station 2	08° 25' 38.1" S, 112° 42' 17.5" E	7

Table 3. Sub-Variable Model

Symbols	Variable Items
	Sub-variables of the Mangrove Ecosystem
A1	The community considers that mangroves are very beneficial for the Tamban Hamlet community, both for community protection from disasters as well as for food security and protection of marine life;
A2	The community considers that the mangrove forest on the Tamban coast is currently experiencing quite a serious damage;
A3	The community considers that the mangrove forest on the Tamban coast must be protected and must not be destroyed;
A4	The community considers that Pokmaswa Tamban Indah is very active in protecting mangroves from damage;
A5	The community considers that the mangrove forest on the Tamban coast must be protected and must not be destroyed;
A6	The community considers that Pokmaswa Tamban Indah is very active in protecting mangroves from damage;
A7	The community considers that the mangrove forest on the Tamban coast can be used as an alternative source of food;
A8	The community considers that the regency government does not care about the damage to mangrove forests;
A9	The community considers that until now the community has not cared about overcoming the damage to mangrove forests;
A10	The community considers that until now they do not know the function and role of the mangrove forest in the protection Tamban Beach;
	Sub-variables of the Coral Reef Ecosystem:
B1	The community considers that coral reefs are very beneficial for the Tamban Hamlet community, both for community protection from disasters as well as for food security and protection of marine life;
B2	The community considers that the coral reefs on Tamban Beach are currently experiencing quite a serious damage;
B3	The community considers that the coral reefs on the Tamban beach must be protected and must not be damaged;
B4	The community considers that Pokmaswa Tamban Indah is very active in protecting coral reefs from damage;
B5	The community considers that the coral reefs on the Tamban beach must be protected and must not be damaged;
B6	The community considers that Pokmaswa Tamban Indah is very active in protecting coral reefs from damage;
B7	The community considers that the coral reefs on Tamban Beach can be used as an alternate source of food;
B8	The community considers that the regency government does not care about the damage to coral reefs;
B9	The community considers that until now the community has not cared about overcoming the damage to coral reefs;
B10	The community considers that until now the community does not know the function and

Symbols	Variable Items
	role of coral reefs in the protection of Tamban Beach;
	Sub-variables of the Seagrass Ecosystem
C1	The community considers that seagrass is very beneficial for the people of Tamban Hamlet, both for protecting the community from disasters as well as for food security and protection of marine biota;
C2	The community considers that the seagrass on Tamban Beach is currently experiencing a serious damage;
C3	The community considers that the seagrass on Tamban Beach must be protected and must not be damaged;
C4	The community considers that Pokmaswa Tamban Indah is very active in protecting seagrasses from damage;
C5	The community considers that the seagrass on Tamban Beach must be protected and must not not be damaged;
C6	The community considers that Pokmaswa Tambaan Indah is very active in protecting seagrasses from damage;
C7	The community considers that the seagrass on Tamban Beach can be used as an alternative source of food;
C8	The community considers that the regency government does not care about the damage to seagrass;
C9	The community considers that until now the community has not cared about overcoming the damage to seagrass;
C10	The community considers that until now the community does not know the function and role of seagrass in the protection of Tamban Beach.
	Sub-variables of Climate Change Impact
D1	The community considers that Tamban Beach often experiences tidal flooding caused by high sea waves;
D2	The community considers that the temperature at Tamban Beach is increasingly hotter over time;
D3	The community assesses that almost every year the Tamban Fishing Village is flooded;
D4	The community considers that the reallocation of people who are always inundated by water needs to be carried out by the government;
D5	The community considers that mangroves and coral reefs can withstand inundation and flooding;
D6	The community considers that tsunami leads to a loss of coastal land due to abrasion;
D7	The community considers that big waves are continuously eroding the land;
D8	The community considers that big waves will make the community lose their land;
D9	The community considers that big waves will make fishing communities lose their boats;
D10	People think that extreme weather (sudden changes in environmental conditions) makes people panic;
D11	People think that big waves always occur on Tamban Beach;
D12	People think that climate change always happens in an unpredictable way.
	Sub-variables of Assessment of Damaged Mangroves, Coral Reefs, and Seagrass
E1	The community considers that mangroves, coral reefs, and seagrasses are coastal ecosystems that can provide benefits for people's livelihoods;
E2	The community considers that mangroves, coral reefs, and seagrasses can;
E3	The community considers that the damage to mangroves, coral reefs, and seagrasses is caused by irresponsible human activities;
E4	The community considers that the damage to mangroves, coral reefs, and seagrass causes high waves to be unstoppable;
E5	The community does not understand that coastal ecosystems (mangroves, coral reefs, and seagrasses) provide protection to Tamban Beach, including the life of fishermen;

Symbols	Variable Items
E6	The community considers that past human activities have caused a damage to mangroves, coral reefs, and seagrasses;
E7	The community considers that there are no more fishermen who use bombs made with potassium nitrate to catch fish;
E8	The community considers that there are no more people who cut down mangrove trees to meet their needs;
E9	The community considers that seagrass meadow is currently shrinking because the land is used for mooring boats or for other purposes;
E10	The community considers that the potential of coastal ecosystems can be utilized for marine ecotourism;
E11	The community considers that human activities such as the constructions of settlements, roads, bridges, and buildings are increasing on Tamban Beach;
E12	The community considers that one of the factor of the occurrence of disaster at Tamban Beach is community activities that do not take the use of mangroves, coral reefs, and seagrass into consideration.
	Sub-variables of Developing Strategies for Managing Coastal Ecosystems
F1	The community considers the need for relocation of residents whose houses are flooded;
F2	The community considers that the local government needs to make policies for the relocation of flood-affected communities;
F3	The community considers that there is a need for awareness from the flooded community to want to be reallocated to a safer place;
F4	The community considers that the government needs to make a policy regarding the use of land that is safe for the community in the future so that they are safer from the tsunami disaster;
F5	The community considers that there are high tides 3 to 4 times a year and it needs to be anticipated by the Malang Regency Regional Disaster Management Agency (BPBD) and the local government in order to avoid loss of life and property;
F6	The community considers that the local government needs to have procedures as a response when the community is hit by a natural disaster;
F7	The community views that the Malang Regency government and the village government need to provide counseling about disasters;
F8	The community considers that there is a need for assistance by the government for victims of natural disasters;
F9	The community considers that the community must try to avoid the disaster area if the wave height is still on land;
F10	The community considers that the government does not have guidelines regarding disaster-affected communities;
F11	The community, after a disaster, is assisted by the police, army, and local government officials to buy materials and learn skills to recover their homes from the disaster;
F12	Many social organizations/NGOs come to help the community during a disaster on Tamban Beach.
	Sub-variables of Efforts to Develop a Strategy for Managing Coastal Ecosystems
G1	The community considers that mangroves, coral reefs, and seagrasses must be preserved by both the government and the community;
G2	The community needs to propose to the government to make the Tamban Beach area a conservation area;
G3	The community considers that the management of coastal ecosystems must be based on the values of local wisdom;
G4	The community considers that the government provides a way for the community to seek other sources of income that do not damage coastal ecosystems (mangroves, coral reefs, and seagrass).

Symbols	Variable Items
G5	The community considers that there is a need to strengthen Pokmaswas, both in terms of institution and funding;
G6	The community considers that the government needs to provide funding assistance for Pokmaswas to operationally monitor the existence of coastal ecosystems (mangroves, coral reefs, and seagrass);
G7	The community believes that the village government needs to include a mangrove, coral reef, and seagrass recovery plan in its development plan;
G8	The community thinks that there is a need for guidelines for the restoration of coastal ecosystems on the Tamban coast provided by the government;
G9	The community considers that the role of universities to provide input for climate change on the Tamban coast is very important;
G10	The community considers that the existence of the community on Tamban Beach cannot be separated from the life of mangroves, coral reefs, and seagrass;
G11	The community considers that the design of the Tamban coastal layout is very important for sustainable development.

Budhiati *et al.* (2015), a spatial analysis of coastal ecosystem management constitutes an effort to analyze the spatial appearance of digitized interpretation to find out how varied and how extensive the coastal ecosystem is. This analysis was carried out by describing all the spatial features obtained from the interpretation activity. Spatial data compilation is an activity of entering spatial data into a GIS database and arranging them. Degradation of coastal ecosystems (mangroves, coral reefs, and seagrass beds) caused by anthropogenic processes due to overexploitation was analyzed by measuring the shrinkage of coastal ecosystems using IKONOS-1m satellite imagery. Secondly, Using the PLS method. There are 2 models in PLS, namely, the structural model, also called the inner model, which is a structural model that connects latent variables, and the outer model, which is a measurement model that connects indicators to latent variables. A PLS analysis was conducted to determine the effect between variables. According to Rudianto (2019), primary and secondary data processing uses the Partial Least Squares (PLS) analysis to understand the level of influence of one variable on another. PLS can analyze constructs formed with reflexive and formative indicators. Reflexive indicators view (mathematically) indicators as variables that are influenced by the same factor (latent variable). This means that if there is a change in one indicator, it will result in changes in other indicators in the same direction. Meanwhile, formative indicators view (mathematically) indicators as if they were variables that affect latent variables. This is indeed different from the factor analysis, in that, if one indicator increases, it does not have to be followed by an increase in other indicators in one construct, but it will imply an increase in the latent variable.

III. RESULTS AND DISCUSSION

The data analysis included three stages, namely, aerial photo mapping using an unmanned aerial vehicle (UAV), Partial Least Squares (PLS) analysis, and Interpretative Structural Modeling (ISM). The combination of two models will produce an integrated model of coastal ecosystem restoration management at Tamban Beach.

3.1. Unmanned Aerial Vehicle (UAV) Modelling Results

The process of identifying the similarity of objects based on the similarity of photo pixel values was aimed to get the coordinates of the binding points on each photo which results in camera calibration parameters or Internal Orientation (IO) and External Orientation (EO) parameters or camera position at the time of shooting, hence producing a 3D shape. The coverage of the mapping area as a result of UAV can be seen on Figure 2 below.

Based on the measurements on the UAV map, Tamban Beach covers an area of 5,308,114 square meters or 530.8 ha. The inundation area covers 3,333,481 square meters or 333.3 ha, accounting for 62.7%. As shown by Figure 3, a tsunami event truly endangers the lives of the people living along the Tamban coast. The areas near the coast of Tamban, both upstream and downstream, are with a coast "guard", that is, mangrove forest, that has been badly damaged and unable to survive high waves. Figure 3 below shows the inundation area in the event of a tsunami in the coastal area of Tamban.

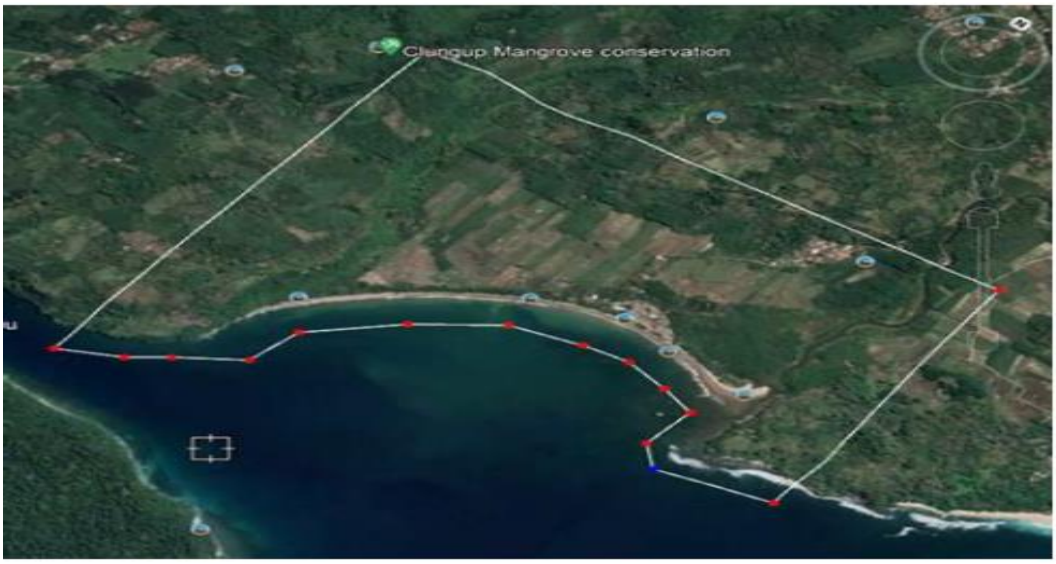


Figure 2. Coverage of the Mapping Area at Tamban Beach, Malang Regency.

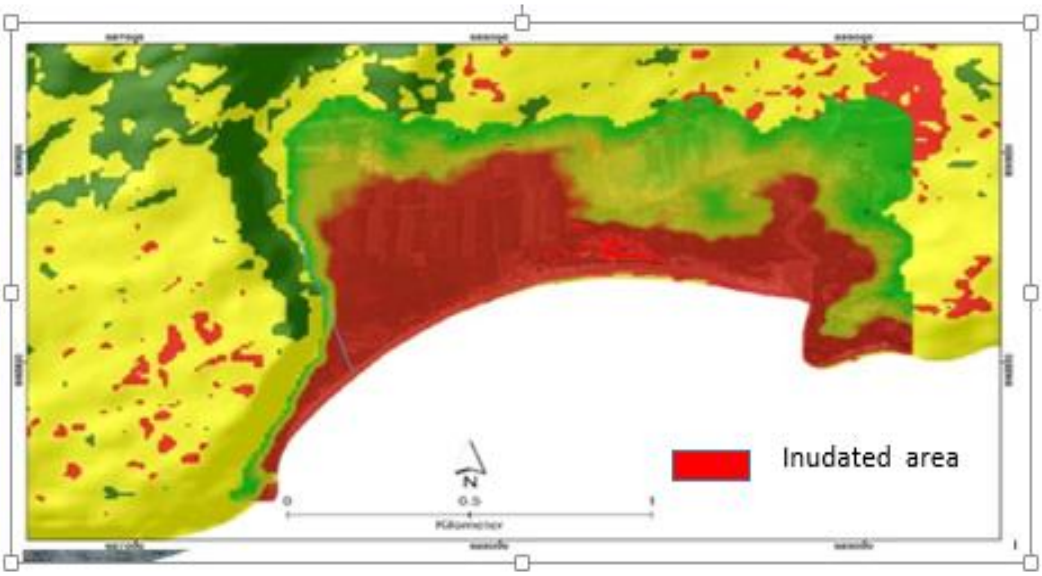


Figure 3. Map of the inundation area on Tamban Beach.

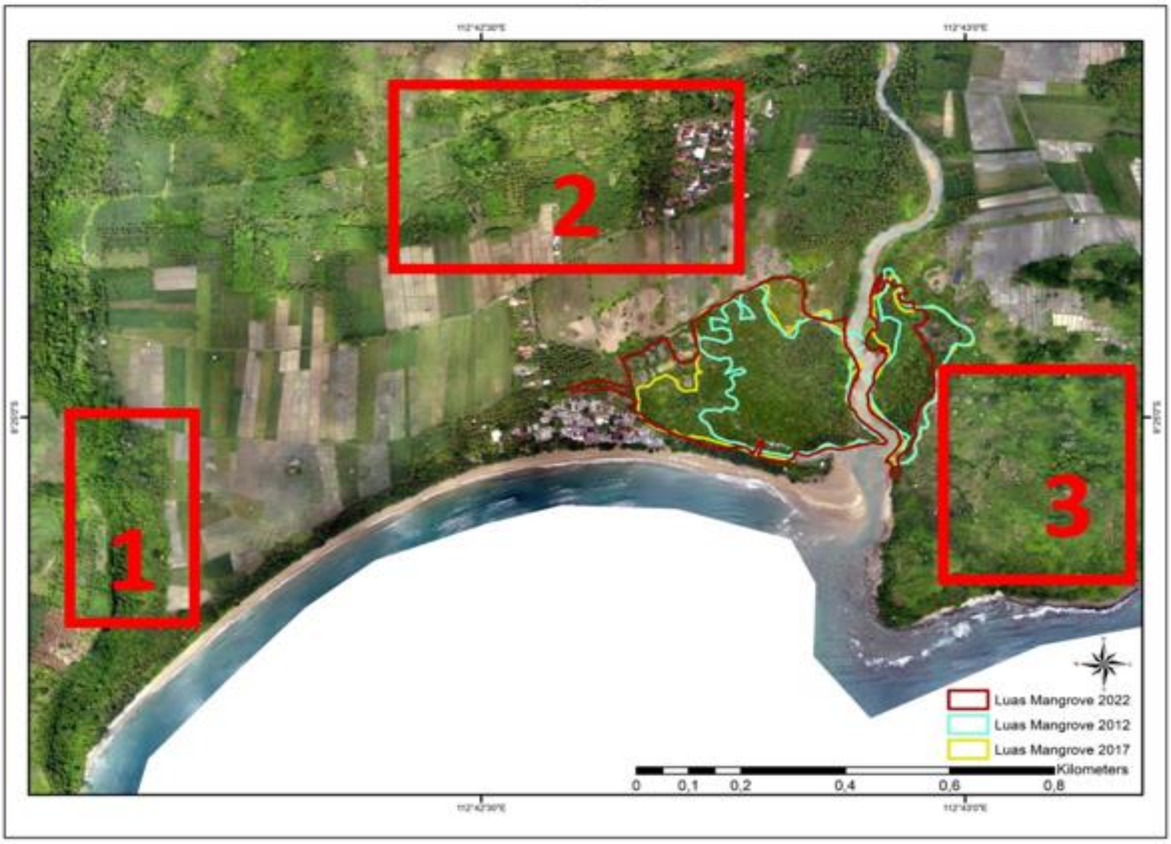


Figure 4. The mangrove forest areas on Tamban Beach in 2012, 2017, and 2022.

The inundation map above is supported by data on measurements of mangroves and coral reefs as well as measurements of the quality of Tamban coastal waters, the results of which can be described as follows.

3.1.1. Mangrove Measurements

Measurements of mangrove forests were carried out at 3 (three) stations (see fig 4). These are covering measurements of relative density, the Importance Value Index, and the mangrove ecology index. Identification of mangroves forest distribution in Tamban coastal area shows in figure 4.

To measure the relative density of mangrove forests in the research area, both trees, belta and sedling can be seen in Table 4.

The most common tree species of mangroves found at station 1 was *Avecenia marina*, thanks to the sand, muddy sand, and sandy silt substrates existing there. Meanwhile, the least frequently found species was *Rhizophora* sp. This is because the substrate for *Rhizophora* sp. is muddy, smooth, deep, and flooded soil during normal tides. *Rhizophora apiculata* does not like hard substrates (with a high sand composition), while the dominant substrates in the location are sand, muddy sand, and sandy silt. The Importance Value Index is the sum of the values of the relative density of species (*RDi*), relative frequency of species (*RFi*), and relative density of species (*RCi*).

INP = RDi + RFi + RCI

Information: Important Value Index (*INP*), Relative Density of Species (*RD*i), Relative Frequency of Species (*RFi*) and Relative Density of Species (*RCi*).

Table 4. The relative density of the mangrove forests

Species	The Relative Density of the Mangrove Forests								
	Trees			Belta			Seedling		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Avicennia alba	633.33	0	0	166.6	0	0	0	0	0
Avicennia marina	1333.33	666.6	0	833.3	233.3	0	0	0	0
Rhizophora sp.	366.67	166.67	1933	200	266.67	1800	0	0	0
Xylocarpus granatum	0	800	0	0	166.67	0	0	0	0
Bruguiera gymnorrhiza	0	1133.33	0	0	100	0	0	0	0

Table 5. The importance value index

Species	The Importance Value Index								
	Trees			Belta			Seedling		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Avicennia alba	56.87	0	0	15.88	0	0	3.17	0	0
Avecennia marina	103.59	67.08	0	60.01	20.06	0	4.76	0	0
Rhizophora sp.	33.58	9.78	183.15	18.96	18.10	114.7	3.17	0	0
Xylocarpus granatum	0	62.20	0	0	18.45	0	0	0	0
Bruguiera gymnorrhiza	0	93.03	0	0	10.44	0	0	0	0

The importance of a species ranges from 0% to 300%. This importance value index provides an overview of the influence or role of a mangrove species in a mangrove community.

The Important Value Index (IVI) is an index that is calculated based on the amount obtained to determine the level of species dominance in a plant community. In this research, the Importance Value Index of trees and mangrove vegetation saplings was determined. The IVI could be obtained from the sum of the relative frequency, relative density, and relative cover of vegetation, which is expressed in percent (%) (Indriyanto, 2006). From the results of the calculations that had been carried out at the three observation stations, it can be seen that there were differences in the Importance Index Value between observation stations, where *Avecennia marina* had the highest Importance Value Index (300%), while the lowest was shown by the mangrove vegetation of the *Avecennia marina* species (103.59%). The high Importance Value Index on Tamban Beach was because the stations had a salinity value of 33 ppt, a temperature of 28.3 °C, and muddy sand substrate conditions. The Importance Value Index (INP) shows the range of the index that describes the community structure and distribution pattern of mangroves (Supriharyono, 2007). The difference in the Importance Value Index of the mangrove vegetation at the research site was due to competition in each species for nutrients and sunlight. Apart from nutrients and the sun, the other factors that caused differences in the density of the mangrove vegetation were the substrate type and seawater tide.

3.1.2. Coral Reef Measurements

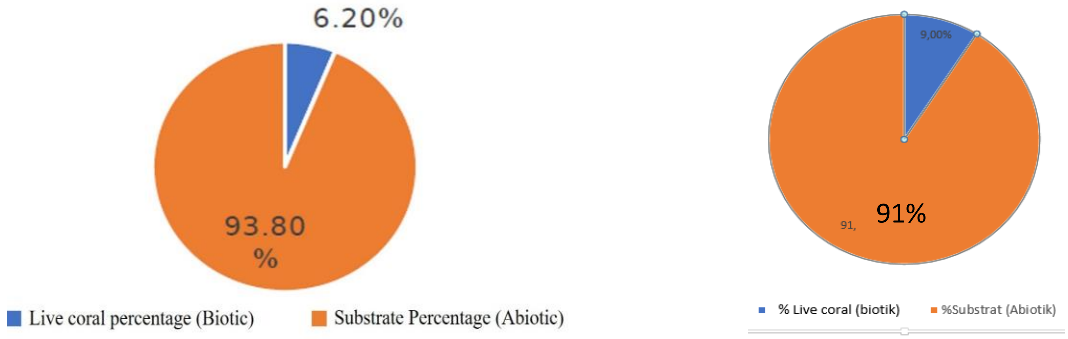
To determine the percentage of live coral cover in the study area, it was calculated based on the equation below (English *et al.*, 1997). This equation shows how to get information about the cover of coral life form species.

Ni = Li / L × 100%

Information: *Ni* was percentage of coral life form species – i coverage, *Li* was Length of the i-th coral life form (m), and *L* was Total line transect length (m).

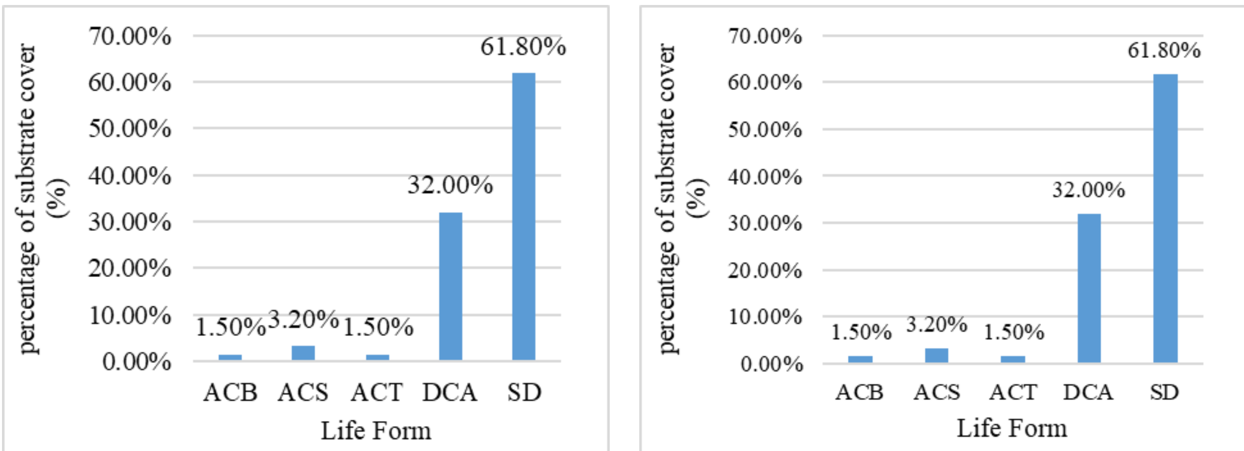
The percentages of substrate cover calculated using the Line Intercept Transect (LIT) method at Stations 1 and 2 in Tamban Coastal Waters belonged to the poor category, with an average biotic percentage of 6.20%. The percentage of substrate cover may belong to any of the following four categories, namely, damaged (0%–25%), moderate (26%–50%), good (51%–75%), and very good (76%–100%) (Giyanto *et al.*, 2017).

The results of observations and measurements of coral reefs at station 1 in these waters demonstrated that the predominant substrate was sand (SD), with a substrate cover percentage of 61.80%, followed by Dead Coral Algae (DCA), with a substrate cover percentage of 32.00%, Acropora Submassive (ACS), with a substrate cover percentage of 3.20%, Acropora Tabulate (ACT), with a substrate cover percentage of 1.50%, and Acropora Branching (ACB), with a substrate cover percentage of 1.50%. The low percentage of substrate cover was caused by high human



(a) (b)

Figure. 5. Percentage of Live Coral Cover by Category at Pond Water (a) Stations 1 and (b) Stations 2 (2022).



(a) (b)

Figure 6. Percentages of Substrate Cover at (a) Stations 1 and (b) Stations 2 in Tamban Waters (2022).

Table 6. The Mortality Index of Coral Reefs at Station 1

Total Percentage of Dead Coral (DC) Coverage	Total Percentage of Live Coral (LC) Coverage	Coral Mortality Index (MI)
938	62	0.938

Table 7. The Mortality Index of Coral Reefs at Station 2

Total Percentage of Dead Coral (DC) Coverage	Total Percentage of Live Coral (LC) Coverage	Coral Mortality Index (MI)
90	910	0.91

activities at this location. Meanwhile, the results of observations and measurements of coral reefs at station 2 in these waters demonstrated that the predominant substrate was sand (SD) too, with a substrate cover percentage of 69.90%, followed by Dead Coral Algae (DCA), with a substrate cover percentage of 21.10%, Coral Encrusting (CE), with a substrate cover percentage of 3.30%, Coral Branching (CB), with a substrate cover percentage of 2.50%, Acropora Branching (ACB), with a substrate cover percentage of 2.10%, and Acropora Submassive (ACS), with a substrate cover percentage of 1.10%. Similarly, the low percentage of substrate cover was caused by high human activities at this location. Table 6 shows the coral mortality index of 0.938. This means that the mortality index is very high.
Therefore,

$$MI = \frac{DC}{DC+LC} = \frac{938}{938+62} = 0.938.$$

Information: *MI* was Mortality Index, *DC* was Dead Coral, *LC* was live coral.

$$MI = \frac{DC}{DC+LC} = \frac{90}{910+90} = 0.91.$$

The Coral Mortality Index (MI) values obtained at Stations 1 and 2 were 0.938 and 0.91, respectively. These values indicated a high level of coral mortality. According to English *et al.* (1997), a Mortality Index value close to 0.0 indicates that coral mortality is almost non-existent, while a value close to 1.0 indicates a significant change from live coral to dead coral.

3.1.3. Water Quality

The water quality parameters measured were temperature, pH, salinity, and dissolved oxygen. Table 8 below shows that the parameters measurement in table 8 not too much affected the coral reeft condition

Parameter data retrieval was carried out *in situ*, including measurements of temperature, pH, salinity, and DO. Then, the water quality distribution data were processed using a surfer program. The measurements of the average water quality parameters obtained an average temperature value of 28.3 °C, an average pH value of 8, a salinity value of 25–33 ppt, and a DO value of 6.8–7.4 mg/L. These values showed that the water quality was still within the normal limits for coral reef life. This good condition must be maintained so that the water conditions do not change and will not threaten the life of the coral reef ecosystem on Tamban Beach in the future.

3.2. Partial Least Square (PLS) Modelling

The variables studied included Mangrove Ecosystem Assessment (A), Coral Reef Ecosystem Assessment (B), Seagrass Ecosystem Assessment (C), Climate Change Assessment (D), Mangrove, Coral Reef, and Seagrass Ecosystem Damage Assessment (E),

Table 8. Water quality parameters

	Temperature	pH	Salinity	DO
Station 1	28.3°	8	33 ppt	7.4 mg/L
Station 2	28.3°	8	25 ppt	6.8 mg/L

Assessment of Disaster Mitigation Efforts (F), and Efforts to Develop Coastal Ecosystem Management Strategies (G). The variables were established using a reflexive indicator type (i.e., arrow direction from a latent variable to a construct). Reflexive indicators were applied to the variables Mangrove Ecosystem Assessment (A), Coral Reef Ecosystem Assessment (B), Seagrass Ecosystem Assessment (C), Climate Change Assessment (D), Mangrove, Coral Reef, and Seagrass Ecosystem Damage Assessment (E), Assessment of Disaster Mitigation Efforts (F), and Efforts to Develop Coastal Ecosystem Management Strategies (G) because the indicators of some of these constructs were a reflection of the constructs (latent variables). This is in accordance with Fornell & Bookstein (1982) statement that if an indicator is a reflection of the construct or related to attitude and personality, it must use reflexive indicators.The PLS evaluation model is based on predictive measurements which have non-parametric properties. The measurement model, or the outer model with formative indicators, does not require evaluation with convergent and discriminant validity and composite reliability for block indicators because this model is evaluated based on its substantive content, namely, by comparing the relative weights and seeing the significance of the size of the weights (Dingemans *et al.*, 2020). The structural model, or the inner model, is evaluated by looking at the percentage of variance explained by looking at the R^2 value for the dependent latent construct using the Stone-Geisser Q-square test and by looking at the magnitude of the structural path coefficient. The stability of this estimate is evaluated using the t test obtained through the boostraping procedure.

3.2.1. Convergent Validity

Table 9 shows that convergent validity can be tested based on the assessment of the outer loading coefficient and the Average Variance Extracted (AVE) value. Table 9. The Outer Loading Value of the Mangrove Ecosystem Assessment Variable (A).

3.2.2. Discriminant Validity

One way to see the value of discriminant validity is to assess construct validity based on the AVE value, where a model is said to be good if the AVE of each construct is greater than 0.5. Table 10 below shows that constructed varibles related with disaster Mitigation Efforts has the value AVE.

A reflexive indicator is said to have a correlation with the measured variable if it has a loading factor coefficient > 0.7. According to Sarwono (2015), an outer loading value of 0.6 can be said to be sufficient.

The same conditions apply to the assessment of the indicator items for variable B. It was found that 10 indicators had outer loading values greater than 0.7, with p-values < 0.05. Therefore, it can be concluded that the 10 indicators of the variable Coral Reef Ecosystem Assessment (B) had convergent validity, meaning that they were good at measuring the variable Coral Reef Ecosystem Assessment (B). Indicator B.9 was found to have the highest outer loading value (0.936), and indicator B.7 had the lowest outer loading value (0.878). The 10 Seagrass Ecosystem Assessment (C) variable indicators were known to have outer loading values greater

Table 9. Convergent validity

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	t-statistic (|O/STDEV|)	p-values
A.1 <- Mangrove Ecosystem Assessment (A)	0.890	0.889	0.022	39.736	0.000
A.2 <- Mangrove Ecosystem Assessment (A)	0.827	0.828	0.034	24.623	0.000
A.3 <- Mangrove Ecosystem Assessment (A)	0.847	0.846	0.036	23.784	0.000
A.4 <- Mangrove Ecosystem Assessment (A)	0.734	0.729	0.059	12.504	0.000
A.5 <- Mangrove Ecosystem Assessment (A)	0.828	0.830	0.032	25.912	0.000
A.6 <- Mangrove Ecosystem Assessment (A)	0.884	0.881	0.026	34.313	0.000
A.7 <- Mangrove Ecosystem Assessment (A)	0.766	0.764	0.053	14.398	0.000
A.8 <- Mangrove Ecosystem Assessment (A)	0.912	0.912	0.024	37.300	0.000
A.9 <- Mangrove Ecosystem Assessment (A)	0.900	0.899	0.030	30.021	0.000
A.10 <- Mangrove Ecosystem Assessment (A)	0.893	0.891	0.028	31.613	0.000

Table 10. Average variance extracted

Construct Variables	Average Variance Extracted (AVE)
Mangrove Ecosystem Assessment (A)	0.722
Coral Reef Ecosystem Assessment (B)	0.825
Seagrass Ecosystem Assessment (C)	0.779
Climate Change Assessment (D)	0.809
Anthropogenic Activities (E)	0.764
Disaster Mitigation Efforts (F)	0.820
Management Efforts (G)	0.727

than 0.7, with p-values < 0.05. Therefore, it can be concluded that the 10 Seagrass Ecosystem Assessment (C) variable indicators had convergent validity, meaning that they were good at measuring the variable Seagrass Ecosystem Assessment (C). Indicator C.2 was known to have the highest outer loading value (0.926), and indicator C.4 had the lowest outer loading value (0.824). Furthermore, the outer loading values of the 12 indicators of the variable Climate Change Assessment (D) were greater than 0.7, with p-values < 0.05. Therefore, it can be concluded that the 12 indicators of the variable Climate Change Assessment (D) had convergent validity, meaning that they were good at measuring the variable Climate Change Assessment (D). Indicator D.10 was known to have the highest outer loading (0.927), and indicator D.7 had the lowest outer loading value (0.861). The outer loading values of the 12 indicators for assessing damage to mangrove, coral reef, and seagrass ecosystems (E) were known to be greater than 0.7, with p-value <0.05. Therefore, it

can be concluded that the 12 indicators of the variable Assessment of Damage to Mangrove, Coral Reef, and Seagrass Ecosystem Damage (E) had convergent validity, meaning that they were good at measuring the variable Assessment of Mangrove, Coral Reef, and Seagrass Ecosystem Damage (E). Indicator E.5 was known to have the highest outer loading value (0.911), and indicator E.8 had the lowest outer loading value (0.761). The outer loading values of the 12 indicators of the variable Disaster Mitigation Efforts Assessment (F) were greater than 0.7, with p-values <0.05. Therefore, it can be concluded that the 12 indicators of the variable Disaster Mitigation Efforts Assessment (F) had convergent validity, meaning that they were good at measuring the variable Disaster Mitigation Efforts Assessment (F). Indicator F.10 was known to have the highest outer loading value (0.935), and indicator F.7 had the lowest outer loading value (0.847).

The external loading values of the 11 indicators of the variable Efforts to Develop Coastal Ecosystem Management Strategies (G) were greater than 0.7, with p-values < 0.05. Therefore, it can be concluded that the 11 indicators of the variable Efforts to Develop Coastal Ecosystem Management Strategies (G) had convergent validity, meaning that they were good at measuring the variable Efforts to Develop Coastal Ecosystem Management Strategies (G). Indicator G.3 was known to have the highest outer loading value (0.901), and indicator G.4 had the lowest outer loading value (0.771).

3.2.3. Structural Model (Inner Model)

The output of the structural model (inner model) application after a bootstrap calculation process with 500 repetitions can be seen in Figure 7. The structural model shows below the relationship among the variables and they also show about the numbers of figure, based on the model above, it can be concluded that disaster mitigation efforts (F) had the most influence on management efforts (G). Disaster mitigation efforts (F) were strongly influenced by many factors, mostly by climate change study (D), coral reef ecosystem assessment (B), mangrove ecosystem assessment (A), seagrass ecosystem assessment (C), and e) anthropogenic activities (E).

Based on the above model, it can be concluded that disaster mitigation efforts (F) have the most influence on management efforts (G). Disaster mitigation efforts (F) are strongly influenced by many factors, mostly by climate change studies (D), coral reef ecosystem assessments (B), mangrove ecosystem assessments (A), and anthropogenic activities (E). Based on the concluded model, management measurement must cover tsunami mitigation not only in landscape management, but also in seascape management. Therefore the concept of disaster management at Tamban beach includes landscape and seascape aspects.

3.2.4. Landscape and Seascape relationship

The landscape and seascape relationship is generated from spatial patterns which include tides, spatial zoning of biotic communities, mangroves, rocky beaches, seagrass beds, coral reefs, and tidal swamps. Seascape patterns are perhaps most clearly seen in the coastal zone. They are not limited to nearshore ecosystems but also open ocean ecosystems, with dynamic multidimensional spatial structures such as water currents, eddies, temperature fronts, and plankton. Intertidal areas and mangrove forests represent critical transition zones that link the terrestrial and coastal environments and often control the flow of materials and energy across land into the sea. The causes of loss often involve multiple interacting stressors, including local impacts such as aquaculture, dredging, pollution, and species

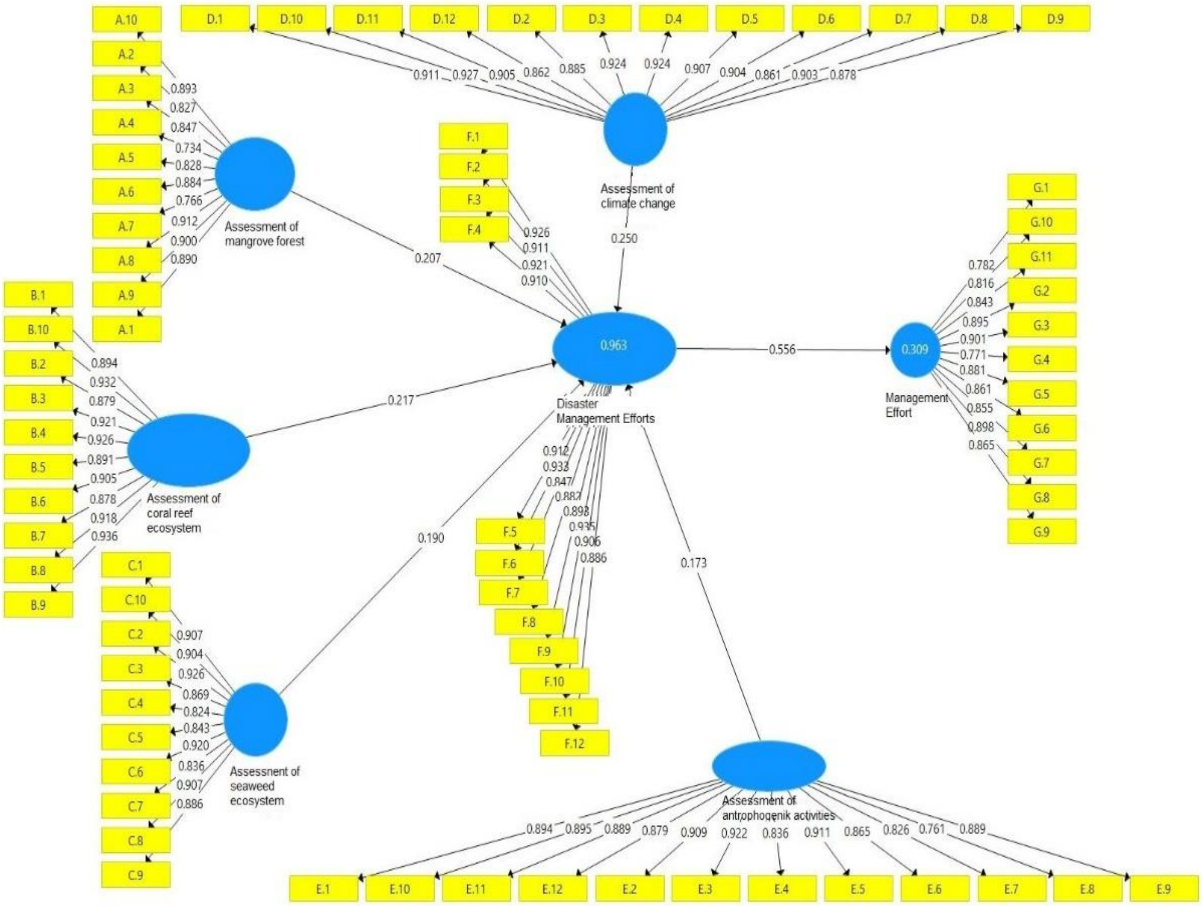


Figure 7. Structural Model (Path Analysis) Result of PLS Analysis.

invasion, as well as wider-scale impacts such as overharvesting, watershed development, and global climate change.

For conservation efforts to be successful, the abundance, proximity, and composition of different habitat types within the mosaic patch need to be considered. Coral reefs and mangroves exhibit complex spatial patterns over a wide range of spatial scales. Coral reefs and mangroves are in an interconnected and correlated relationship as an important factor that determines the structure and ecological function of this interconnected system. Identification of functionally integrated seascape types involves a shift in perception from a focus on single swath type to a consideration of the interrelated functions provided by the habitat type mosaic. This information can be used to help design restoration strategies or to ensure that resource sets are protected, so that seascapes function properly to support species, assemblages, and communities of interest. Although generally applied in terrestrial environments and known as 'conservation design', several coastal examples exist where restoration measures are strategically selected to increase fauna populations through ecologically functional seascape configurations. It is important to account for variability in the composition and configuration of the underlying seascape in explaining variability in performance and in describing the relative effect of compliance or enforcement or other factors.

IV. CONCLUSIONS

The strategy to formulate the tsunami mitigation management based on the findings of this study must consider:

first, the inundation area. It is indicated that the inundation area due to sea level rise due to the tsunami is increasingly widespread. It is estimated that the inundation area at Tamban Beach is based on measurements on the unmanned aerial vehicle (UAV) map of 62.7%. Most likely this inundation area will exceed 62.7%. Second, the strategy must consider the anthropogenic processes (human activities) that are very intense towards the ongoing changes in land use. The importance of increasing mangrove and coral reef cover for tsunami prevention is very important to note in tsunami disaster management. The construction of housing and the establishment of stalls and kiosks along Tamban beach continues to increase and is expected to continue intensively. Third, efforts to prevent people from becoming victims of the tsunami. Therefore, in the strategy it is necessary to have policies or guidelines for disaster management. Thus, the strategy that needs to be formulated is cooperation between the sub-district government. The Government of Malang Regency needs to immediately plan an ideal settlement location for the relocation of the Tamban coastal community which was affected by the tsunami. This research offers a novelty, namely managing coastal areas on a landscape-and-seascape basis as an important part of overcoming the impact of the tsunami. By using two methods that have been operationalized, namely the analysis of spatial-unmanned aerial vehicle (UAV) and partial least square (PLS) aspects, the results of developing a strategy using coastal management using landscape and seascape approaches for sustainable coastal area management.

ACKNOWLEDGMENTS

We would like to thank the Rector of Brawijaya University, Prof. Dr. Ir. Nuhfil Hanani A. R., who provided a chance to conduct this research. We also thank the head of Research Institute and the devotion community of Brawijaya University, who helped us accelerate the research.

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Submitted : 15 September 2022
Reviewed : 18 January 2023
Accepted : 18 April 2023