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ANALYSIS OF ECOTOURISM AND DISASTER MITIGATION DATA AT THE KUALA LANGSA MANGROVE FOREST BY USING THE ANALYTIC HIERARCHY PROCESS

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ABSTRACT

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The problem in the management of a public area is to determine aspects that contribute most as its best practices. This paper explores the contributions of the Kuala Langsa Mangrove Forest located in Langsa City, Aceh Province, for ecotourism and disaster mitigation. This research was intended to analyze the aspects of forest management that has successfully reformed dry coast into an ecotourism site. The Analytic Hierarchy Process (AHP) as a multicriteria decision making method was used to analyze the best indicators data. This method was selected as the suitable method since it utilizes the objectivity of mathematics in comparing some subjective criteria to obtain the best indicators. The implementation of the AHP method consists of three stages: the development of the criteria's hierarchy table; the development of pairwise matrix related to the intention of giving weights for the criterion's elements; the logical concistency verification of the matrix. Indicators were written on a five point scale related to a value judgement. The results of the research show that as an ecotourism site, the activities of the mangrove forest are motivated and based on the existing rules which attract people to become interested. The role of the local government has resulted: developed the programs according to the existing mangrove management law that reached 67% among other law related indicators; budget allocation priority by self-generating which get priority of 59% among budget indicators; oriented on the increasing of fishermen, obtained 49% of economical function elements; encouraged the involvement and partnership of the local resources around the mangrove forest which reached 31% among other programs offered and sustainability approach by considering ecological functions aspect. For physical contribution for disaster mitigation, the largest dissipation is given by Rhizophora mucronata due to its height compared to the other types.

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1. INTRODUCTION

The mangrove (*Rhizoporaceae*) condition in Aceh is severe, because there are many illegal logging activities that have been done to produce charcoals, and open oil palm plantations and fishpond constructions. However, there exist one of the biggest mangrove forests with the most complete species in Aceh, namely the Kuala Langsa Mangrove Forest located in Langsa City with the total area of 6.014 ha containing 38 species, or about 0.04% worldwide [1].

Besides serving as an ecological function and the nutrients provider for water biotas, breeding and nursing place for various biotas, mangrove also acts as a barrier of abrations, wind storms, and tsunamis. It functions also to absorb waste water, to hold sea water intrusion, as well as economical functions such as woods, leaves, and raw material for medicine sources, etc. Technology have been tried to be utilized to defend the coastal areas. These solutions are quite expensive, often harmful for the ecosystems, and unsustainable. Mangrove forests serve as the natural coastal defences.

The prediction of mangroves' contributions for coastal protection is still hard to be done even though researches have been devoted to do this investigation. Without being able to do so, it is difficult to use mangroves as an element for the coastal defence system. Without knowing the exact effects, it will be hard then to ensure the local population about the actual importance of mangroves [2]. Aiming at the advantages that will be governed, this study is trying to identify the aspects that local government uses to preserve and rebuild the mangrove forest for its ecological function, and to identify the government's best choice of practices for the socio-economical functions, and to also determine the potency of the mangroves for disaster mitigation, particularly the wave attenuation they cause.

Some researches regarding various aspects of the Kuala Langsa Mangrove Forest have been conducted, but not especially related to the disaster mitigation. They investigated the management of ecosystem potential of the forest, covering its potential of fishery, carbon sequestration, and tourism [3]. The research study about the land suitability of mangrove rehabilitation in Langsa City has also done [4]. Therefore some conditions as well as results of the studies were refered.

To perform the analysis for the best indicators among the programs related to the best practices, the Analytic Hierarchy Process (AHP) was used as the method to overview the managerial work of the forest. This method was selected to utilize the objectivity of mathematics in comparing some subjective criteria to obtain the best indicators. Besides, it was also chosen due to its hierarchical procedure that can break down the complex system into simple ones. In the present case-study, the local government's best practices were analyzed considering the assessment of management aspects according to different criteria and indicators. For the hierarchy of the method, three level of criteria and indicators were included. The indicators were obtained based on the mangrove forest performance [5].

Similar works have been done from several related researches using the same method in various areas recently. AHP was also used to identify the priority factors to prevent change in mangrove cover in Medan City [6]. The research of mangrove management using AHP method performed in Riau Province, containing the hierarchy which included the actors involved, one level of criteria, and alternatives. The community involvement became the priority in the result of the research [7].

Regarding the contribution of mangroves for disaster mitigation in general, the wave dissipation formulation due to a plant where the drag force and its coefficient are the main quantities [8]. This paper refers to this method of calculation by using the data of Kuala Langsa Mangrove Forest. Three kinds of mangroves were chosen due to their domination growing in the area, namely for *Rhizophora mucronata*, *Sonneratia alba*, and *Rhizophora apiculata* [3]. Results of the research are expected to give some references and clear examples for either local goverments of other districts in Aceh or the communities in general. It will also give an overview regarding the importances and the advantages of preserving, maintaining, and developing the mangrove forest in each area.

2. RESEARCH METHODS

2.1 The Method to Find Best Practices

AHP is a multicriteria method for decision making introduced by Prof. Thomas L. Saaty in the 1970s [5]. In this method, the subjective beliefs are quantified according to a mathematical procedure to help making informed decisions [9]. The implementation of the AHP method consists of three stages:

1) The development of the criteria's hierarchy table which is based on the recognitions of concepts and objects by human mind when processing information. To construct the suitable hierarchies, a logical process is applied to help breaking down the complex system into simple structures;
2) The development of pairwise matrix related to the intention of giving weights for the criterion's elements. This is done by comparing elements in pairs respected to the corresponding elements in the next level;
3) The logical concistency verification of the matrix to avoid the inconsistency in comparing elements which were done in step 2). The consistency ratio of each matrix is computed to evaluate this degree of inconsistency.

Indicators were written on a five point scale related to a value judgement. These indicators were associated with the criteria of the third hierarchy level: highly implemented (score 5); medium to highly implemented (score 4); medium implemented (score 3); medium to low implemented (score 2); low implemented (score 1). The scores are determined by experts in the related problem. The application of AHP also evaluated consistency of the matrix through Consistency Ratio (CR), ranges from 0 to 1. If the value of CR was 0.10 or less, it was considered acceptable [9].

To evaluate the pairwise matrix consistency, we define the maximum eigenvalue as λ_{max} and n as the element numbers of the eigenvector, then the Consistency Index (CI) to measure the consistency of decisions in the data is given by **Equation (1)** as in [9],

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{1}$$

The computed Random Index (RI_n) as the average of CI of very large sample for $n \leq 10$ is given as in **Table 1**,

Table 1. Random Index

Order	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Data source: [9]

The Consistency Ratio (CR) is defined as the ratio of CI and the related RI from the table [9] as in **Equation (2)**,

$$CR = \frac{CI}{RI} \tag{2}$$

2.2 Data of Criteria and Indicators

In the present case-study, the ecotourism management was analyzed considering the assessment of best practices according to different criteria and indicators. The secondary data used were obtained from various references as presented in **Table 2**, which have been organized as the evaluation criteria according to a three-tiered hierarchical structure. The pairwise comparison matrices for the data Criterion Level I and II can be developed by using these data. These matrices are intended to reduce the difficulty in doing the comparison for several indicators at a time [5]. The the first pairwise comparison matrix contains the criteria of the first hierarchical level of **Table 2** (legal and managerial aspects; ecological function; and economical functions).

Table 2. **Hierarchical Structure Data of Criteria and Indicators for The Best Practices**

Criterion level I	Criterion level II	Criterion level III	Indicators	Implementation	Scores
Legal and managerial aspects	Law	Open space in residential areas law	City space management law No. 12, 2013	Medium to high	4
			Green space 30% UU No. 26, 2007	Medium	3
			UU No.41, 1999	Medium	3
		Mangrove management law	Restriction of opening fish ponds, charcoal production, and palm oil plants	Medium	3
	Management programs	Local based	Involving local resource around the mangrove forest	Medium	3
		Welfare oriented	Involving surrounding community	Medium to high	4
		Collaborations	Collaboration between stakeholders	Medium to high	4
		Holistic approach	Management of socio-ecological system	Medium	3
		Sustainability	Mangrove nursery	Medium to high	4
			Feeding ground for marine/coastal biota	Medium to high	4
	Budget allocation	APBN	Promotions and event activities for tourists	Medium to low	2
		APBD and special autonomy	Rehabilitation project of tourism	Medium to high	4
		Self-generating	Good management of ecotourism	Medium to high	4
Ecological functions	Nutrients providers	Human	Resident around mangrove forest and city	Medium	3
		Macaca	Existence of *Macaca* in mangrove forest	Medium	3
		Fishes and shrimps	*Periophthalmus* genus, *Mugilidae*, familia, and *Exocietidae Penaeus* genus	High	5
		Crabs and shells	*Anadara granosa, Scylla serata and Pincatada margaritifera*	Medium to high	4
	Carbon absorbant	Weather	28-32^{0} C degrees and about 75% humidity	Medium	3
		Plants	*Sonneratia alba, Bruguriera gymnorrhiza, Avicennia* genus, and *Rhizophora* genus	High	5
		Animals and new species	Existence of coastal biota, birds, *Macaca*, migrated birds and dolphines	Medium to high	4
	Waste water absorbent	Organic provider	Number of mangroves	Medium to high	4
		Mangrove types	*Sonneratia alba, Bruguriera gymnorrhiza, Avicennia* genus, and *Rhizophora* genus	High	5
Economical functions	Physical constructions	Economic values	Wood sources	Low	1
			Leaves sources	Medium	3
			Raw material for medicine	Medium	3
			Carbon trading	Medium to low	2
		Construction materials	Use of wood as raw materials on boardwalk	Medium to high	4
		Pedestrian sidewalk	Maintenance of broad walk	Medium	3
			Increased length of broad walk	Medium to low	2
		Fishermen	Significant benefits	Medium	3

Criterion level I	Criterion level II	Criterion level III	Indicators	Implementation	Scores
Economical functions	Community involvement	Achievements	Nominated for API in ecotourism	Medium to high	4
		Ecotourism workers	Availability of food kiosk, boat rental, and tour guides	Medium to high	4
	Public and tourists	Ecotourism and Education	Tourist visits for ecotourism (coastal tourism)	Medium to high	4
		Sport	Sport activity and facility	Medium	3

2.3 The Physical Contribution for Disaster Mitigation

The physical contribution of mangroves for disaster mitigation was observed by a direct calculation method of the energy dissipation. The data needed for the computation are mangrove heights and densities of several types that grow in the Kuala Langsa Mangrove forest.

Let $\boldsymbol{x}$ set as the on-off shore axis and the depth of the water is defined as $\boldsymbol{h} = \boldsymbol{h}(\boldsymbol{x})$, $\boldsymbol{g}$ is the acceleration of gravity, and ρ is the fluid density. Moreover, let $\boldsymbol{H} = \boldsymbol{H}(\boldsymbol{x})$ be the wave height, $\boldsymbol{t_0}$the wave period, and $\boldsymbol{k}$ the wave number. The plant's quantities are the drag coefficient C_d, the diameter of stem $\boldsymbol{d}$, spacing between plants $\boldsymbol{b}$, and the height of the canopy $\boldsymbol{s_v}$ [8]. Here the time averaged energy dissipation caused by the vegetations in water $\boldsymbol{D_v}$ is refered to Arif (2019) which is defined as Equation (3).

$$D_{\mathrm{v}} = \tfrac{1}{4}\, \rho C_{\mathrm{d}} d (3\pi k)^{-1} b^{-2} (gk/\omega)^{3} \left(3k \cosh^{3} kh\right)^{-1} \left(\sinh^{3} k s_{\mathrm{v}} + 3 \sinh k s_{\mathrm{v}}\right) H^{3} \tag{3}$$

The acceleration of gravity is taken as $g = 9.8\ m\ sec^{-2}$, while other data quantities needed for the computation are assumed as: the water depth $h = 1.8\ m$, the water density $\rho = 1$, the wave height $H = 0.1\ m$, and the wave period $t_0 = 4\ sec$. The drag coefficient $C_d = 0.2$, and the average plants' diameter $d = 0.11\ m$.

Table 3. Morphology Data of The Mangrove Dominant Types in The Research Area

Kinds of Mangroves	Vegetation Density	Vegetation Height (m)
Rhizophora mucronata	416.67	20
Sonneratia alba	400	15
Rhizophora apiculata	277.78	15

Data source: [3]

As the samples for the wave dissipation computation, three kinds of mangroves are chosen due to their domination growing in the area, namely for *Rhizophora mucronata*, *Sonneratia alba*, and *Rhizophora apiculata*, for which their density data are provided [3]. Their average values of vegetation height [3] are also applied, as given in Table 3.

3. RESULTS AND DISCUSSION

3.1 The Development of Pairwise Comparison Matrices

The pairwise comparison matrices for the data Criterion Level I in Table 2 have been developed as shown in Table 4.

Table 4. Pairwise Comparison Matrix for The Data Criterion Level I

Variables	Legal and managerial aspects	Ecological function	Economical functions
Legal and managerial aspects	1	2	3
Ecological function	1/2	1	2
Economical functions	1/3	1/2	1

This step was carried out through comparing elements in pairs with respect to a given criterion. The pairwise matrices are used for establishing weights among elements to the same hierarchical level. Then the pairwise comparison matrices for the data Criterion Level II have also been developed.

For the second hierarchical level, three comparison matrices are necessary: law, management programs, and budget allocations as presented in Table 5 for legal and managerial aspects; nutrients providers, carbon absorbent, and waste water absorbent as presented in Table 6 for ecological function; and physical constructions, community involvement, and public and tourists as presented in Table 7 for economical functions [11].

Table 5. Pairwise Comparison Matrices for The Legal and Managerial Aspects Data Criterion Level II

Variables	Laws	Management Programs	Budget Allocation
Law	1	2	2
Management programs	1/2	1	2
Budget allocation	1/2	1/2	1

Table 6. Pairwise Comparison Matrices for The Ecological Function Data Criterion Level II

Variables	Nutrients Providers	Carbon Absorbant	Waste water Absorbant
Nutrients providers	1	3	3
Carbon absorbant	1/3	1	2
Waste water absorbant	1/3	1/2	1

Table 7. Pairwise Comparison Matrices for The Economical Functions Data Criterion Level II

Variables	Physical Constructions	Community Involvement	Public and Tourists
Physical constructions	1	1/2	2
Community involvement	2	1	2
Public and tourists	1/2	1/2	1

In the same way, for the third hierarchical level, nine comparison matrices are necessary: open space in residential areas law, and mangrove management law; local based, welfare oriented, collaborations, holistic approach, and sustainability; APBN, APBD and special autonomy, and self-generating; human, *Macaca*, fishes and shrimps, and crabs and shells; weather, plants, animals and new species; organic provider, and mangrove types; economic values, construction materials, and pedestrian sidewalk; and fishermen, achievements, and ecotourism workers; and ecotourism and education, and sport [12].

3.2 The Priority Aspects as an Ecotourism

The AHP provides a priority of decision indicators, and the weights of the criteria were calculated from the eigenvector of the largest eigenvalue λ_{max}. As an example, the weights of these criteria preference for matrix in Table 2 is given in Table 8.

Table 8. The Weights of The Criteria Resulting from Pairwise Matrix

Criterion	Weight
Legal and managerial aspects	1.63
Ecological function	0.90
Economical functions	0.49

The similar computation procedures of maximum eigenvalues were carried out for Criterion Level II for the pairwise matrices in Table 5, Table 6, and Table 7 which results are presented in Table 9.

Table 9. The eigenvalues of the Criteria Level II

Criterion Level II	Eigenvalue (λ_{max})	CR
Pairwise matrix for legal and managerial aspects	3.054	0.052
Pairwise matrix for ecological function	3.047	0.045
Pairwise matrix for economical function	3.054	0.052

From **Table 9** we obtained that the three maximum eigenvalues give the consistency ratio number for the matrix $CR < 0.1$ which means that the pairwise matrices are consistent **[5]**. This conclude that the data for these pairwise matrices from **Table 5**, **Table 6** and **Table 7** can be utilized further to find the priority aspects for ecotourism.

The hierarchical structure of all the ecotourism criteria that local government used to preserve and rebuild the mangrove forest is illustrated as the pie charts in **Figure 1**. The chart shows the proportion of each element in the Criterion Level I. Three main mangrove ecotourism elements percentages in Kuala Langsa Mangrove Forest were identified and plotted based on the descending order, namely "Legal and managerial aspects" which got the highest value of 54%; "Ecological functions" which got the second highest value of 30%; and "Economical functions" got the lowest value of 16%. This means that the "Legal and managerial aspects" was considered the most important aspects of the mangrove forest management.

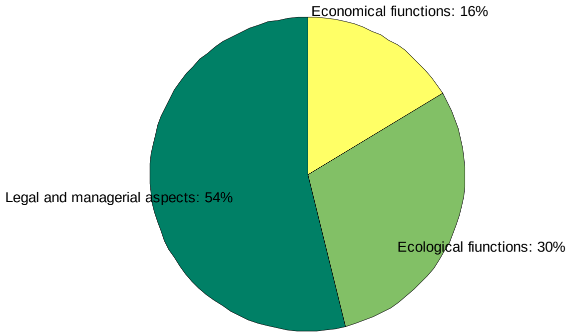
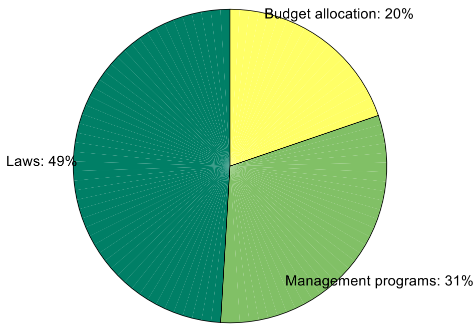


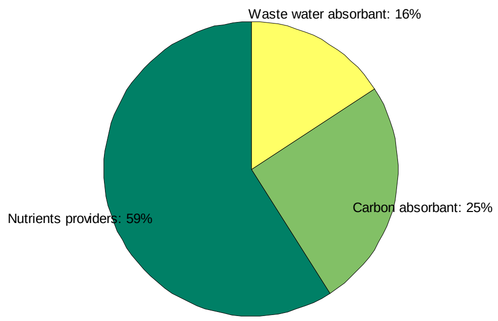
Figure 1. Hierarchical Structure of Criteria Level I for The Ecotourism Management

Each element consists of three sub-elements which percentages can be seen in **Figure 2(a)** at the top chart, the best implementation element from the first pairwise matrix is "Law" which obtained the highest value of 49%; in **Figure 2(b)** at the bottom left hand side from the second pairwise matrix, the best element is "Nutrient provider" which reached the highest value of 56%; and in **Figure 2(c)** at the bottom right hand charts from the third pairwise matrix the best element is "Community involvement" which got the highest value of 49%.

Each figure shows the proportion of each element in the Criterion Level II which consists of nine elements altogether. Therefore, all the three elements mentioned above were considered as the most important aspects of the mangrove forest management. However, a better investigation should be put at the "Budget allocation" element, since in this research the data of the year 2019 are used, which are much different from the budget data of the previous years that might also give different results **[13]**.



(a)



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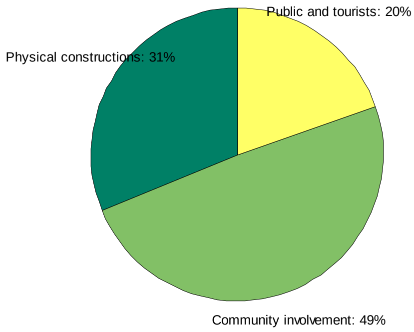
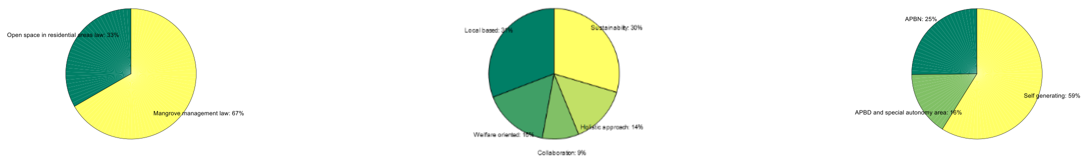
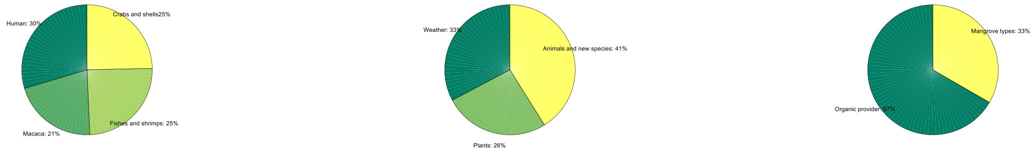


(c)

Figure 2. Hierarchical Structure of Criteria Level II for The Ecotourism Management



(a)



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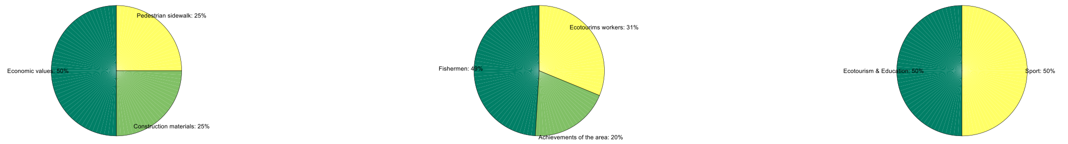

(c)

Figure 3. Hierarchical Structure of Criteria Level III for The Ecotourism Management
(a) Priority elements for legal and managerial aspects, (b) Priority elements for ecological functions, (c) Priority elements for economical functions

For the third hierarchical level, the priority charts were drawn in terms of percentages for the nine comparison matrices obtained from each element in Criteria Level II, and shown in Figure 3. In Figure 3(a), the priority elements for legal and managerial aspects are: mangrove management law, local based, and self-generating. In Figure 3(b), the priority elements for ecological functions are: human, animals and new species, and organic provider. In Figure 3(c), the priority elements for economical functions are: economic values, fishermen, ecotourism & education, and sport.

The indicators of Table 2 relative to these three criteria were used to combine their related weights and scores to calculate the priority vector in the AHP method in order to obtain the results in Table 10. Best practices governed from the other two elements of ecotourism implementation, i.e. “Ecological functions” and “Economical functions”, are also presented in the Table 10.

Table 10. The best Practices in the Kuala Langsa Mangrove Forest

Criterion level I	Criterion level II	Criterion level III	Indicators	Implementation	Scores
Legal and managerial aspects	Law	Mangrove management law	Restriction of opening fish ponds, charcoal production, and palm oil plants	Medium	3

Criterion level I	Criterion level II	Criterion level III	Indicators	Implementation	Scores
	Management program	Local based	Involving local resource around the mangrove forest	Medium	3
	Budget allocation	Self-generating	Good management of ecotourism	Medium to high	4
Ecological functions	Nutrients providers	Human	Resident around mangrove forest and city	Medium	3
	Carbon absorbent	Animals and new species	Existence of coastal biota, birds, *Macaca*, migrated birds and dolphines	Medium to high	4
	Waste water absorbent	Organic provider	Number of mangroves	Medium to high	4
Economical functions	Physical construction	Economic values	Leaves sources Raw materials for medicine	Medium Medium	3 3
	Community involvement	Fishermen	Significant benefits	Medium	3
	Public and tourist	Ecotourism & education	Maintenance of boardwalk	Medium	3
		Sport	Sport activity and facility	Medium	3

3.3 The Potency of Mangroves for Disaster Mitigation

We determined the quantity of wave dissipation fluxes given by the three dominant types of mangroves that grow in the research area, with the data which were shown in **Table 3**. By implementing **Equation (3)** through a computer program calculation, the wave dissipation of a plant resulted is presented as a prevention

facility of abrations, wind storms, and tsunamis, as shown in **Table 11**. The dissipation flux unit is Joule per meter square area. The canopy configuration **[14]** is not considered in this equation.

The largest dissipation is given by *Rhizophora mucronata* due to its height which is about 5 m difference in the average with the other two types. As can be seen from **Equation (3)** where cube power is involved, the higher the plant is, the more amount of dissipation is resulted.

Table 11. Wave Dissipation of Mangroves in the Area

	Space between plants (m)	Wave dissipation (Jm^{-2})
Rhizophora mucronata	23.89	1702.30
Sonneratia alba	24.89	0.37
Rhizophora apiculata	35.89	0.18

3.4 The Local Government's Best Practices in Managing Mangroves Related to Disaster Mitigation

Related to the disaster mitigation, from the research result is also inferred that the local government's best practice of maintaining the law references should prevent the area from the target of exploitation activities, such as cutting the mangrove trees to be converted for opening fish ponds. This also prevent the ponds from becoming critical areas since they usually only productive for the first five years period.

For its ecological functions, the research shows that human will get the best benefits from the existence of the forest as nutrient providers, but at the same time people are also prevented from the flood disaster. Not only for human, the mangrove ecosystem also acts as living place for animals such as *Macaca*, crabs, fishes, shells, and shrimps. New foreign species have come to this forest which gave signs to the better environmental achievements of the area, such as migrated birds and dolphines.

A pedestrian sidewalk inside the forest in the form of a long and circular bridge was built and open for public as well as tourists. The bridge was made of natural materials, which can be sustained by selective maintainance. The community surrounding the forest who live mostly as fishermen also get benefits from it, not only to get the opportunity as ecotourims workers, but also due to the presence of the forest itself. The plan for the development and management of mangrove forest is also conducted due to its service function as a recreational area for community. This finding also relevant with the similar research that was done in Riau Province [7] and in *Seribu Islands*, Jakarta [15].

The hot and humid weather of Langsa which half of the area located on the coast facing Malacca Strait, also encouraged the local government to built several other forests in the city. Since the forests restoration in 2012, the open spaces have served the public to provide fresher air. In fact, these works of local government has won the *API* (*Anugerah Pesona Indonesia*) award from the Ministry of Tourism and Creative Economy of Indonesia in 2019 [10].

4. CONCLUSIONS

This study has succeeded to identify the aspects that local government uses to preserve and rebuild the mangrove forest as the government's best practices for the socio-economical functions. The role of the local government of Langsa becomes important to keep the strict policy regarding the building and maintaining the forest. The results of the research recommend that the activities of the mangrove forest should be based on the rules which attract people as an ecotourism site. Due to the rich resources of the forest area, it has been attracting many parties to be exploited. Regarding the ecological function, the best practice is the sustainability approach indicated by human activities in maintaining the forest, the existence of animals and new species, and organic provider.

The existence of mangrove forest is very important to be sustained because of its clear function as a disaster mitigation area. The research has determined the potency of the mangroves for disaster mitigation, particularly wave attenuation they cause. Regarding the mangrove type which is recommended to grow, the largest dissipation is given by *Rhizophora mucronata* due to its height compared to the other types. The higher the plant, the more amount of dissipation is resulted. In Aceh, the mangrove management is still not well performed. So, it is important to replicate what the Langsa's local government has done in the city to other areas in order to help reducing severe damages.

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