

## Mangrove-based Ecotourism Sustainability Analysis using NDVI and AHP Approach

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### Abstrak

Artikel ini bertujuan menganalisis keberlanjutan ekowisata mangrove menggunakan pendekatan *Normalized Difference Vegetation Index (NDVI)* dan *Analytical Hierarchy Process (AHP)*. Berdasarkan hasil kalkulasi data citra satelit Landsat 8 OLI menggunakan teknik NDVI, dapat diketahui terjadinya penurunan nilai vegetasi Pulau Dodola di tahun 2017. Kondisi ini perlu dianalisis secara ilmiah mempertimbangkan eksistensi kawasan mangrove Pulau Dodola yang perlu dilestarikan selain kepentingan pembangunan infrastruktur pariwisata. Metode penelitian yang digunakan ialah metode penelitian campuran melalui pendekatan studi kasus di Pulau Dodola, Kabupaten Pulau Morotai, Provinsi Maluku Utara, Indonesia. Penelitian ini mengadopsi teknik penginderaan jarak jauh dan sistem pendukung keputusan dalam menguraikan hasil analisis ekowisata mangrove yang keberlanjutan. Hasil penelitian ini menunjukkan bahwa hasil kalkulasi data spasial Landsat 8 OLI dari tahun 2013-2021 menunjukkan adanya penurunan nilai vegetasi secara signifikan di tahun 2017 dimana nilai maksimum 0.30 dan nilai minimum 0.11. Secara spesifik, kawasan mangrove juga mengalami penurunan nilai vegetasi dengan nilai maksimum 0.23 dan nilai minimum 0.02. Sebagai upaya mengantisipasi terjadinya kerusakan lingkungan di area mangrove, penelitian ini merekomendasikan program pelestarian mangrove yakni rehabilitasi, restorasi, reklamasi, dan konservasi kawasan mangrove. Selain itu, hasil analisis prioritas menggunakan pendekatan AHP menunjukkan bahwa program rehabilitasi merupakan program yang perlu diprioritaskan karena sesuai dengan kondisi eksisting dan kapabilitas pengelola Pulau Dodola.

**Kata kunci**—Mangrove, Ekowisata, Keberlanjutan, NDVI, AHP

### Abstract

This article aims to analyze the sustainability of mangrove ecotourism using the *Normalized Difference Vegetation Index (NDVI)* and *Analytical Hierarchy Process (AHP)* approaches. Based on Landsat 8 OLI satellite imagery calculation using the NDVI technique, there has been a decrease in vegetation value on Dodola Island in 2017. This condition needs to be analyzed scientifically, considering the Dodola Island mangrove area to be preserved. In addition to the interests of tourism infrastructure development. The research method used is a mixed research method through a case study approach in Dodola Island, Morotai Island Regency, North Maluku Province, Indonesia. This study adopts remote sensing techniques and decision support systems to describe the results of sustainable mangrove ecotourism analysis. This study indicates that the calculation results of Landsat 8 OLI spatial data from 2013-to 2021 show a significant decrease in vegetation value in 2017, where the maximum NDVI value is 0.30, and the minimum NDVI value is 0.11. Specifically, the mangrove area also experienced a decrease in vegetation value with a maximum NDVI value is 0.23 and a minimum NDVI value is 0.02. To anticipate environmental damage in mangrove areas, this study recommends mangrove conservation programs, namely rehabilitation, restoration, reclamation, and conservation of mangrove areas. In addition, the results of the priority analysis using the AHP approach show

*that the rehabilitation program is a program that needs to be prioritized because it follows the existing conditions and capabilities of the Dodola Island managers.*

**Keywords**—*Mangrove, Ecotourism, Sustainability, NDVI, AHP*

## 1. INTRODUCTION

Ecotourism in Indonesia can be discussed using socio-cultural, political, policy, economic, and education perspectives [1]. From a socio-cultural perspective, the sustainability of mangrove ecotourism is driven by a participatory development approach, namely community-based tourism development [2]. Specifically, aspects of community livelihoods in terms of accumulation of financial capital, natural capital, human capital, physical capital, and social capital also play an essential role in mobilizing the successful implementation of community-based tourism development programs [3]. From a political and policy perspective, protecting mangrove forest areas and aquatic resources is essential in supporting sustainable tourism. Regulations on conserving the mangrove environment have become prevalent in using non-environmentally friendly resources by certain elements. From an economic and educational perspective, environmentally friendly business processes and the support of human resources with capabilities in the tourism sector play an essential role in maintaining financial stability without damaging the environment. From an environmental and technological perspective, the Geographic Information System (GIS) and Decision Support System (DSS) methods are analytical approaches based on spatial data that can describe the existing conditions and changes in mangrove areas. Thus, policymakers can prioritize appropriate reclamation, restoration, rehabilitation, and conservation programs.

Morotai Island Regency has been designated one of Indonesia's priority national tourism destinations. Also, the attraction of Morotai Island is the historical tour of World War II, the culture of the local community, and the sea. Local governments seek to develop infrastructure to support accessibility and mobility related to tourism activities programs to help accessibility and mobility in the tourism sector develop airports to increase foreign and domestic tourist visits to Morotai Island. The local government also optimizes land and sea transportation that connects various tourism destinations on Morotai Island. In addition, the tourism destination marketing program is also optimized to reach a broader tourism market. Otherwise, the approach to tourism development on Morotai Island is guided by the principle of sustainable development, thus emphasizing the involvement of local communities as well as preserving the environment. To optimize tourism destinations on Morotai Island, the regional government cooperates with various business actors in the tourism sector. It indicates that Morotai Island tourism has superior competitiveness, and the prospect of economic tourism development benefits all parties [4]. Nevertheless, the portrait of tourism development on Morotai Island needs to be supported by scientific studies that contextually identify and analyze sustainable development issues, both in the economic, socio-cultural, political, educational, environmental, and information technology fields.

The intensity of the tourism development program in Pulau Morotai Regency needs to be balanced with the quantity of research that contextually offers constructive theoretical and empirical ideas for developing tourism science [5]. Based on the results of scientific searches, the scope of the discussion in tourism studies on Morotai Island is holistic, namely the convergence of topics between tourism science and other scientific groups in the realm of policy [6], education [7], the livelihoods of coastal communities [8], gender issues [9], as well as the potential and conditions of the natural environment [10]. The popularity of research topics on Morotai Island is dominated by the central issue of community livelihoods in coastal areas, fisheries potential,

mangrove ecosystems, coral reefs, and matters related to maritime affairs [11]. The scope of the discussion of tourism and information technology has the same urgency and needs to be carried out on an ongoing basis. The content of the debate and the context of this research focus on National Tourism Destination. Popular research topics related to Morotai Island are dominated by studies related to education [12] and the potential of marine resources [13]. In addition, studies on socio-economics [14], history and culture [15], [16], policy, bureaucracy, and politics [17], as well as information technology [18], still show the quantity aspect.

Furthermore, research on tourism and technology leads to a novelty in contextual discussions, especially the description of changes in the mangrove vegetation index on Morotai Island, in this case, the implementation of ecotourism development on Dodola Island, a tourism icon in North Maluku Province. It indicates that the intensity of the Morotai Island tourism development program needs to be supported by the results of scientific studies in the fields of tourism, technology, and ecology. Scientific studies that show the importance of the mangrove environment for the sustainability of community livelihoods need to be improved to be used as a reference for stakeholders in making environmental, economic, and socio-cultural policies [19]. Thus, research-based development is embodied in policies and the planning and implementation of regional development programs [20].

The mangrove ecosystem on Morotai Island has an essential role in supporting the sustainability of people's livelihoods [21]. Community settlements on Morotai Island are more dominant in coastal areas and archipelagic areas. Hence, these activities as subsistence fishers are a form of strategy to meet the needs of clothing, shelter, and food [8]. In the socio-cultural context of the people of Morotai Island, the existence of the mangrove area has a relationship with the cultural dimension [22]. The value of sustainability should integrate with tourism development policies and programs on Morotai Island [23]. This study offers constructive critical ideas by analyzing the sustainability of mangrove ecotourism on Dodola Island through a Geographic Information System (GIS) and Decision Support System (DSS) approach. Also, the programs need to be prioritized by destination managers based on the existing condition of mangroves on Dodola Island. Meanwhile, the programs analyzed based on importance are reclamation, restoration, rehabilitation, and conservation.

This study aims to analyze the sustainability of mangrove ecotourism on Dodola Island using the Geographic Information System (GIS) method by implementing a remote sensing approach to process spatial data (Landsat 8 OLI) from 2013 to 2021 through the Normalized Difference Vegetation Index (NDVI). Furthermore, the results of the NDVI will be classified based on the standard criteria for mangrove damage in the Decree of the State Minister of the Environment Number 201 of 2004. The reclamation, restoration, rehabilitation, and conservation will be analyzed using a Decision Support System (DSS) known as the Analytical Hierarchy Process (AHP) approach to recommend priority programs for developing mangrove ecotourism in Dodola Island, according to the principles of sustainable development. The urgency of this research departs from the results of previous studies that discuss the effect of climate change on the sustainability of small islands in Indonesia. Rising sea levels, abrasion, and erosion can threaten the sustainability of small islands in Indonesia. In addition, the mangrove ecosystem can prevent abrasion and environmental degradation in coastal areas and small islands. In the context of Morotai Island, the scope of discussion regarding mangrove ecosystems is more dominant in carrying capacity, structure, and composition. On the other hand, there is a literature gap in the study of tourism sustainability, namely the analysis of the sustainability of the mangrove ecosystem as an ecotourism attraction using the Geographic Information System (GIS) and Decision Support System (DSS) methods on Dodola Island, Morotai Island Regency, North Maluku Province, Indonesia.

## 2. METHODS

The research methodology used in this study is the mixed method. The consideration for choosing a mixed research method is the elaboration of qualitative and quantitative approaches in the data processing and analysis of research problems [24]. In addition, mixed methods are also the right approach to testing the validity and credibility of the data and maintaining the coherence and relevance of the theory used in the research context. Previous researchers have widely used mixed methods to test the validity of information based on research problems in their respective fields of science [25]. In this research, diverse research methods are used to test the credibility of the analysis results using a Geographic Information System (GIS) approach with a Decision Support System (DSS) approach.

The location of this research is Dodola Island, Morotai Island Regency, North Maluku Province, Indonesia. Morotai Regency, selected as a National Tourism Destinations priority, became a North Maluku Province tourism icon. The mangrove ecosystem in Dodola is categorized as a natural resource developed. Otherwise, the development of mangrove ecotourism on Dodola Island needs to be balanced with scientific studies. The government builds wood bridges as access to travel among the mangrove area using pedal bicycles. Daloha resort also provides accommodation with two rooms and one bathroom so that four to six tourists can use one place. It indicates that the local government and tourism stakeholders paid attention to the intensity of tourist visits by establishing various supporting infrastructures. In the future, infrastructure development and travel activity might negatively impact the environment. Thus it is necessary to conduct a comprehensive study on Dodola Island. For this research, it might be essential to identify and analyze the changes in the vegetation index caused by the development of tourism infrastructure on Dodola Island and the various consequences that threaten the sustainability of ecotourism on Dodola Island.

### 2.1 Normalized Difference Vegetation (NDVI)

*Normalized Difference Vegetation Technique* (NDVI) is part of the Geographic Information System (GIS) method, a remote sensing process using spatial data to identify changes in the earth's surface [26]. This study focuses on identifying the vegetation value of the mangrove area on Dodola Island using the NDVI technique and the processing flow of Landsat 8 OLI satellite imagery in the QGIS 3.20 application in Figure 1.

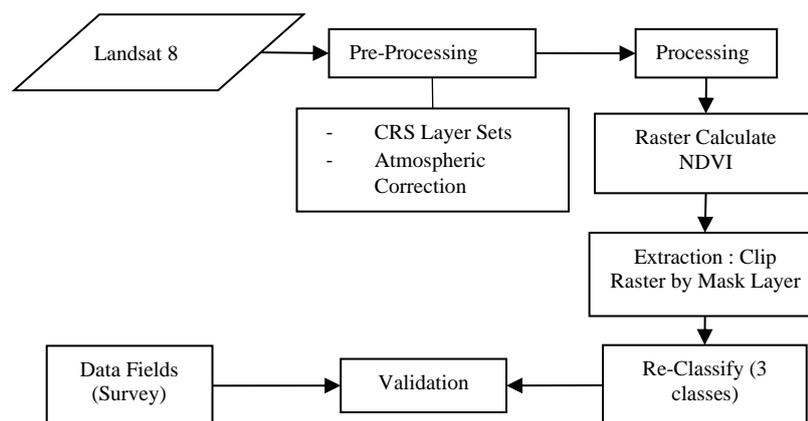


Figure 1. Data Processing Using Normalized Difference Vegetation (NDVI)

Figure 1 shows that data processing using the Normalized Difference Vegetation Index (NDVI) is divided into pre-processing and data processing. The first step is pre-processing data stage. Universal Transverse Mercator (UTM) on the Landsat 8 Operational Land Imager (OLI) satellite image data was applied based on the 1984 World Geodetic System (WGS) datum in Zone

52 N. Furthermore, Pre-processing data in this research use QGIS 3.20 application. In addition, the processing data stage uses the Semi-Automatic Classification plugin to correct the atmosphere on Landsat bands 4 and 5 by applying DOS 1 atmospheric correction. Studies on the analysis of satellite imagery data using NDVI have been widely used before [27]. However, the results of NDVI related to AHP still need to be improved to contribute theoretically and practically to each scientific domain, both in the tourism and environmental sectors. Furthermore, in the data processing stage, the results of the atmospheric correction for Landsat bands 4 and 5 will be calculated using the following equations (1) :

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad (1)$$

NDVI = Normalized Difference Vegetation (NDVI)

NIR = Near-Infrared Band (Band 5)

RED = Red Band (Band 4)

After the NDVI calculation process, the raster data according to the range of the year the satellite image was taken will be classified and extracted according to the research location using Clip Raster By Layer Mask. In the context of this study, the satellite image data displayed is limited to annual data, which shows the degradation of the mangrove area on Dodola Island due to the development of tourism infrastructure. The output of the raster data classification results will be discussed comprehensively using standard criteria for mangrove damage based on the State Minister of the Environment Number 201 of 2004.

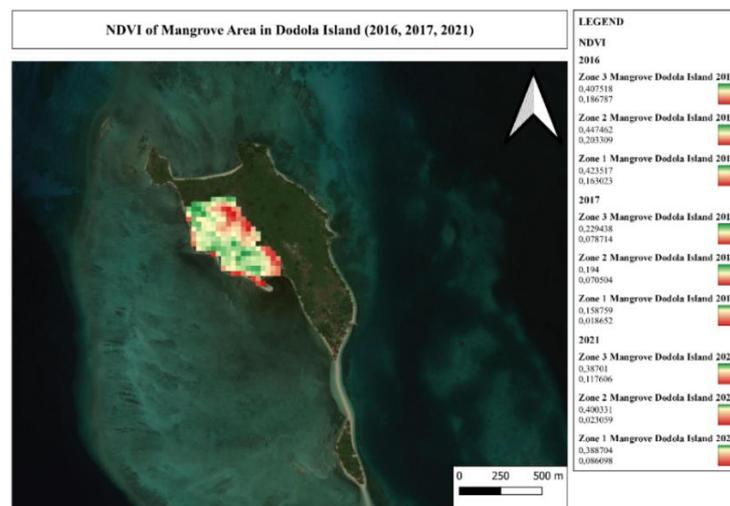


Figure 2. Results of 2016, 2017, 2021 Dodola Island NDVI Process.

Source: Raster Calculation of Landsat 8 OLI in QGIS 3.20

Figure 2 illustrates the outputs of the Dodola Island NDVI process from 2013-to 2021 and notices the drastic changes in 2016, 2017, and 2021 data. The changes of NDVI in the maximum and minimum values represent mangrove conditions on Dodola Island. The mangrove index on Dodola Island needs to be interpreted based on the standard criteria for mangrove damage as stated in the Decree of the State Minister of the Environment Number 201 of 2004 in Table 1.

Table 1. Standard Criteria for Mangrove Damage

Criteria		Coverage (%)	Density (Trees/ha)	NDVI
Healthy Mangrove	Dense	75%	> 1500	0.43 - 1.00
	Moderate	50 < 75	1000 < 1500	0.33 - 0.42
Damaged	Sparse	< 50	< 1000	-1.0 - 0.32

Source : [28]

Based on the results of the NDVI process on Dodola Island, the maximum value for the Dodola Island vegetation index changes each year. It indicates that the dense canopy of mangroves in Dodola also changes each year. Hence, it needs to be preserved by several programs such as conservation, reclamation, restoration, or rehabilitation, according to the existing condition. The declining value of the mangrove vegetation index on Dodola Island is due to logging for tourism infrastructure development programs in 2017. Furthermore, the mangrove vegetation index's increased value on Dodola Island is assumed due to nurseries and replanting of mangrove trees based on the type of composition and structure. The NDVI concept is relevant and can be adapted to identify the mangrove vegetation index. Thus, the NDVI technique can interpret the condition of mangroves according to the standard criteria for mangrove damage in the Decree of the State Minister of the Environment Number 201 of 2004.

## 2. 2 Analytical Hierarchy Process

The NDVI value of the mangrove area will be used as empirical facts to recommend an appropriate program, such as a reclamation program, rehabilitation program, conservation program, and restoration program. The Analytical Hierarchy Process (AHP) technique can determine the program's priority [29]. The AHP model was pioneered by [30] through the following process: The first stage, describing the program in a comparison matrix; The second stage, assigning value weights based on the importance scale; The third stage, adding up the consequences of the criteria to obtain priority critical success factors; The fourth stage, identify the consistency ratio and eigenvalues. Several researchers have used the AHP approach to analyze the program's priorities based on the weight of the stakeholders' interests. [31] shows that AHP is used in setting development strategies tailored to the availability of tourism resources. Otherwise, the various alternatives in the program are also analyzed based on stakeholders' interest to be implemented based on the development program. Meanwhile, the equations of AHP used are as follows:

$$a. \text{ Calculating Criterion Weights} \quad Wi = \frac{1}{n} \sum_{j=0}^n \frac{a_{ij}}{\sum_{k=1}^n a_{kj}} \quad (2)$$

$$b. \text{ Calling Consistency Ratio} \quad CI = \frac{\lambda_{\max} - n}{n - 1} \quad (3)$$

$$c. \text{ Maximum Eigenvalue} \quad \sum_{j=i}^n a_{ij} W_j = \lambda_{\max} W_i \quad (4)$$

$$d. \text{ Consistency Ratio} \quad CR = \frac{CI}{RI} \quad (5)$$

It also shows that the Consistency Ratio (CR) value can be obtained from the result of dividing the Consistency Index (CI) deal with the Random Index (RI) value. If the CR value is equal to or less than 0.10, then the level of consistency is considered satisfactory, as shown in Table 2.

Table 2. Random Index Value

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

In weighing the importance level of each criterion, the stakeholders who have the authority to determine priority programs are the manager of the Dodola Island destination and the Dodola Island Regency Tourism Office. The resource persons were also interviewed to assess the importance of programs that need to be prioritized. The weighting of the degree of importance is divided based on the program and alternative zones. In weighting the program, stakeholders are given a choice of conservation, reclamation, rehabilitation, and restoration programs. Stakeholders can provide value based on existing conditions by considering various aspects of the environment, economy, and socio-culture. Furthermore, stakeholders can provide a value based on the mangrove zone divided into three areas. The outputs of the AHP analysis are program priorities and zone priorities.

### 3. RESULTS AND DISCUSSION

#### 3.1 Normalized Difference Vegetation (NDVI) of Mangrove Area in Dodola Island

The land area and distribution of mangroves in coastal areas and islands can be identified and classified using the Normalized Difference Vegetation Index (NDVI) vegetation index model. Several previous researchers adopted the NDVI model with other models to make land-use maps. [32] using Landsat 8 OLI satellite imagery and NDVI and Normalized Difference Built-Up Index (NDBI) models to identify land use and classify the differences between vacant land use and buildings. Besides that, [33] adopted NDVI and LAI to evaluate biomass in reforestation sites based on area. The NDVI model is adopted to identify land use or vegetation areas on the surface. Meanwhile, the LAI model was used to identify leaf density based on plant characteristics on the surface. Thus, NDVI can determine the distribution and percentage of mangrove density in coastal areas and islands. Based on the results of processing satellite image data, the vegetation index value of Dodola Island has fluctuated from 2013-to 2021. Likewise, the vegetation index value of the mangrove area on Dodola Island has changed from 2013-to 2021. Furthermore, Changes in the vegetation index can be caused by tree felling activities for the benefit of developing tourism supporting facilities and infrastructure or due to abrasion or erosion of seawater. The value of the Mangrove Vegetation Index on Dodola Island has changed from 2013 to 2021. It shows that the ecological conditions are vulnerable to changes due to various human activities such as logging mangrove trees for local communities and development. The following is a description of the mangrove vegetation index value from 2013 to 2021.

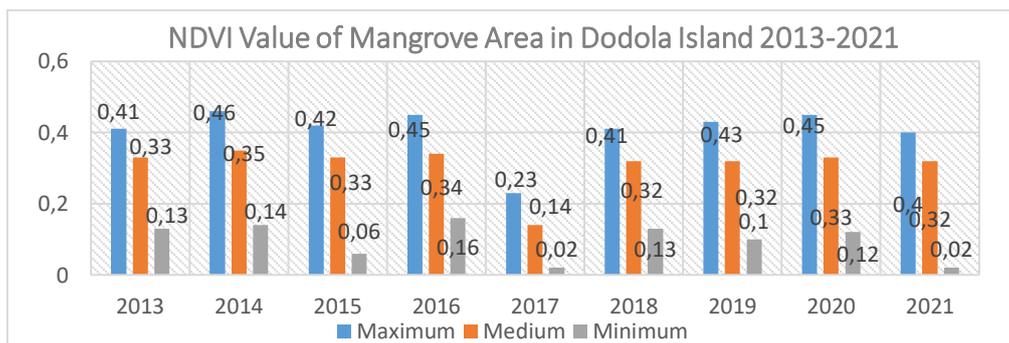


Figure 3. NDVI Value of Dodola Island 2013-2021  
Source: Raster Calculation of Landsat 8 OLI in QGIS 3.20

Based on the results of the calculation of raster data using the NDVI technique in the mangrove area of Dodola Island, the decline in the value of the vegetation index in 2017 reflects the threat to mangrove sustainability due to the development of tourism supporting infrastructure. [34] argues that mangroves have a high level of vulnerability to degradation and are influenced by many factors such as the threat of waves, strong currents, and the absence of barrier coral reefs. The exposure of mangrove areas is a threat to the sustainability of small islands. Suppose the mangrove area is used as a tourist attraction. In that case, the government and various stakeholders in the tourism economic sector must establish an environmental conservation program following the characteristics of the local ecosystem.

Changes in the mangrove vegetation index value on Dodola Island in 2016-2017 indicate an extreme intervention on mangrove vegetation. It could be in the form of land conversion of mangrove areas for tourism infrastructure development in the form of wooden bridges. Although the existing condition of Dodola Island's mangrove vegetation in 2020-2021 is improving, the current situation is supported by mobility access to tourism and development restrictions during the Covid-19 pandemic. The current situation is essential to be taken seriously, so it is necessary to apply prevention, care, and management of mangrove areas through the concept of community-based ecotourism to bring economic, socio-cultural, and environmental benefits sustainably.

Therefore, a decision support system is needed through the AHP approach to determine programs and areas that need to be prioritized.

### 3.2 Analytical Hierarchy Process for Mangrove-based Ecotourism Sustainability Programs

Previous research suggests a mangrove conservation program for environmental sustainability. [35] emphasized the mangrove rehabilitation program, where the government and all stakeholders related to the tourism economy sector on Dodola Island. Furthermore, local communities or managers of mangrove ecotourism destinations are willing to actively participate in the rehabilitation process (planning, implementation, monitoring, and evaluation). In addition, there are locations for rehabilitation, tillers, and seedlings based on species and family. The success rate of mangrove rehabilitation is measured by the life of the saplings, the growth rate of tillers, and the addition of leaves. Meanwhile, the rehabilitation site's substrate location, salinity, and temperature support mangrove growth. Mangrove restoration programs are also recommended to provide suitable conditions for mangroves to grow naturally. [36] argues that mangrove restoration can be carried out institutionally by establishing an extraordinary institution that maps restoration areas based on the structure and composition of previous mangroves to be planted according to species and families. Cross-sectoral collaboration is critical to the success of mangrove restoration programs due to the complexity of monitoring and regularly evaluating. Active community participation is needed in mangrove restoration programs. In addition, other factors that support the success of the mangrove restoration program are the mapping of planting locations based on temperature, salinity, and light intensity.

In addition to the rehabilitation and restoration program for mangroves, [37] showed that reclamation of mangrove forests is also needed to renew mangrove areas that have changed due to development or natural disasters. Mangrove forest reclamation aims to restore ecosystem functions that have undergone significant differences. In addition, [38] argues that reclamation of mangrove forests is needed to restore the balance of ecosystems in coastal areas. In addition, conservation of mangrove areas is required to maintain ecological and economic sustainability by selecting and determining core zones and utilization zone. [39] argue that the conservation of mangroves needs collaboration between various stakeholders. Otherwise, [40] argues that good communication between the government and the community is precisely the determinant of the success of mangrove conservation programs. Based on the conservation program proposed by previous researchers, the rehabilitation, restoration, reclamation, and conservation program is a practical approach to preserving mangroves' sustainability as a tourist attraction and needs to be divided into three zones (zone 1, zone 2, zone 3).

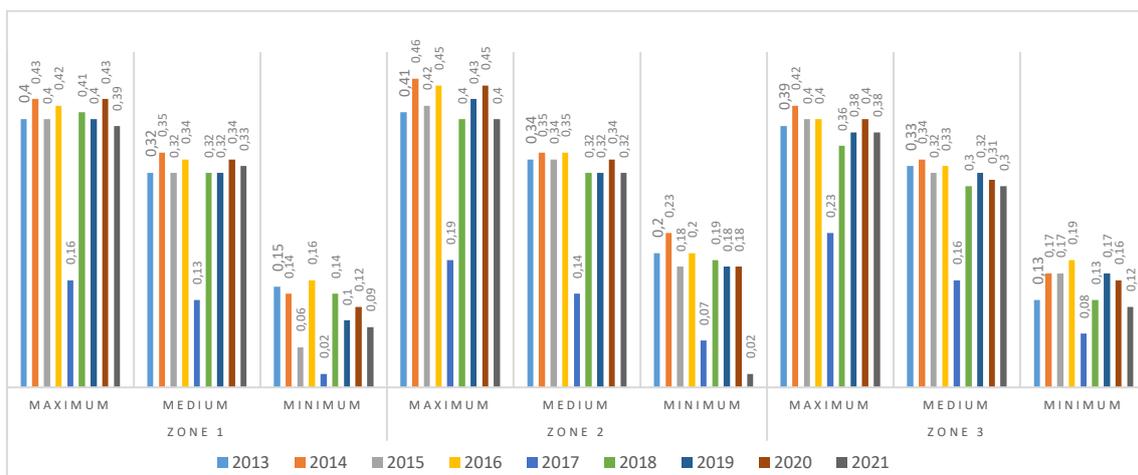


Figure 4. NDVI Value of Mangrove Area in Dodola Island 2013-2021  
Source: Raster Calculation of Landsat 8 OLI in QGIS 3.20

Figure 4 is the result of the calculation of the NDVI value based on the division of the mangrove area on Dodola Island into three zones. Each zone becomes an alternative that will be analyzed on a priority scale based on predetermined criteria, namely Mangrove Rehabilitation, Mangrove Restoration, Mangrove Reclamation, and Mangrove Conservation, as shown in Figure 5.

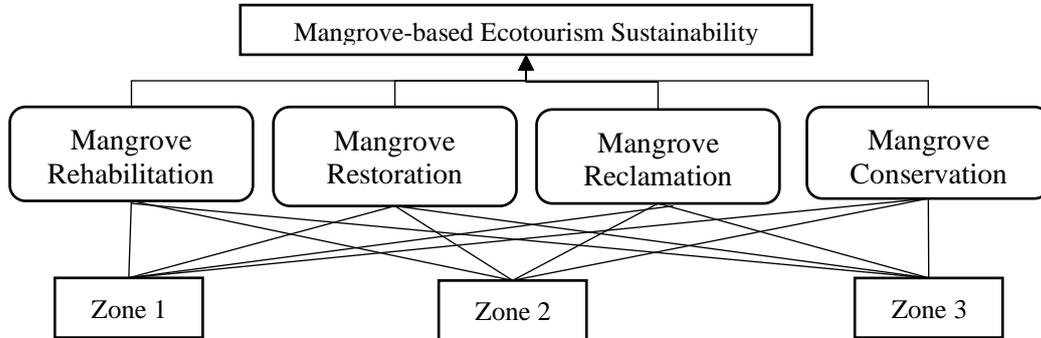


Figure 5. Hierarchy Structure of Criteria

Figure 5 is a hierarchical structure that describes the objectives of the rehabilitation, restoration, reclamation, and conservation programs to achieve the sustainability of mangrove-based ecotourism. Furthermore, the comparative judgment stage for each program will be assessed based on the level of importance. The pairwise comparison of each stakeholder toward programs and areas that need to be prioritized with different weights. Each program has advantages and disadvantages that can benefit or harm the economic and socio-cultural dimensions. When adjusted to the raster data from the Lansat 8 OLI satellite image processing, the previously designed programs have met the qualifications to protect environmental sustainability. Considering the importance of optimizing mangrove natural resources as a tourist attraction that also brings economic and social benefits, the ecotourism approach becomes an alternative tourism development strategy relevant to Dodola Island's context. In Addition, the normalization results of the weight of the degree of importance in the previous table are as follows.

Table 3. Normalized Result of Pairwise Comparison

Goals	REH	RES	REC	CON	Eigen Value	$\lambda$ max	CI	CR
Rehabilitation	0.49	0.52	0.38	0.53	0.4787	4.2291	0.0764	0.0849
Restoration	0.25	0.26	0.25	0.32	0.2681			
Reclamation	0.16	0.13	0.13	0.05	0.1180			
Conservation	0.10	0.09	0.25	0.11	0.1351			
Total	1.00	1.00	1.00	1.00	1.00			

Table 3 shows that normalization is performed to get the eigenvalue. In addition, the data was calculated to obtain the consistency ratio value. After that, to test the consistency, the acquisition is made by dividing the consistency ratio value by the index ratio based on the criteria. If the Consistency ratio value is less than 0.10, then the weighting based on the degree of importance is consistent. Similar calculations were also applied to calculate the degree of significance for each alternative based on the criteria. The weight of priority from the overall estimate using AHP for the requirements of Mangrove Rehabilitation, Mangrove Restoration, Mangrove Reclamation, and Mangrove Conservation, as well as the alternative Zone 1, Zone 2, and Zone 3, can be seen in table 4 below.

Table 4 AHP of Mangrove Ecotourism Program and Zone in Dodola Island

Zone 1	0.6330	Rehabilitation
Zone 2	0.2419	Restoration
Zone 3	0.1250	Conservation

Table 4 is the summation result using a process hierarchy analysis approach, showing that Zone 1 needs to be prioritized over Zone 2 and Zone 3. In addition, the program that needs to be prioritized is the mangrove rehabilitation program. Thus, it is necessary to support the government and various stakeholders related to the economic sector on Dodola Island. It is essential to encourage the community to be actively involved in the program's planning, implementation, monitoring, and evaluation stages. Also, It is necessary to prepare land and mangrove seedlings based on species and families. Otherwise, it is required to support the success of the mangrove rehabilitation program in Zone 1 of the mangrove area of Dodola Island.

#### 4. CONCLUSIONS

The results of this study indicate that the average NDVI value of Dodola Island from 2013 to 2021 is in the range of 0.32-0.37, which suggests that the vegetation characteristics of Dodola Island and Small Dodola Island are moderate. In 2017, the NDVI value of Dodola Island decreased. The maximum NDVI value is 0.30, and the minimum NDVI value is 0.11 due to the development of tourism infrastructure in the mangrove area. At the same time, the NDVI value of the mangrove area of Dodola Island also decreased. The maximum NDVI value is 0.23, and the minimum NDVI value is 0.02. Responding to the extreme changes in NDVI values, several programs are recommended to increase the value of the vegetation index, namely rehabilitation, restoration, reclamation, and conservation. Based on the expert's assessment according to the AHP approach, the priority program following the existing conditions of the mangrove area of Dodola Island is a mangrove rehabilitation program that is supported by the availability of land for nurseries, nurseries, planting, and maintenance of mangroves. Mangrove rehabilitation is one of the programs that support the sustainability of the ecosystem on Dodola Island, including the sustainability of eco-based tourism activities. Thus, mangrove-based ecotourism on Dodola Island can be sustainable.

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