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# Tourism Infrastructure Development and Transformation of Vegetation Index in Dodola Island of Morotai Island Regency

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**Abstract**

The development of tourism infrastructure without control can cause changes in the environmental vegetation index and harm a tourism destination. This study aims to analyze changes in the vegetation index on Dodola Island from 2013-to 2021 to develop tourism infrastructure. The approach used is remote sensing, namely the Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI) using Landsat 8 Operational Land Imager (OLI). NDVI is an index of the greenery or photosynthetic activity of vegetation. Vegetation actively carrying out photosynthesis will absorb most of the red waves of sunlight and reflect higher near-infrared waves. In addition, SAVI is a soil vegetation index adjusted for soil pixels' effect using a vegetation density function. The results of this study indicate a perfect correlation between the NDVI average value and the SAVI average value of 0.996 so that it can be used as data to analyze changes in the vegetation index value on Dodola Island from 2013-to 2021. The average NDVI value of Dodola Island in 2017 showed a significant decrease to 0.16 from 0.35 in 2016. Likewise, the average SAVI value of Dodola Island in 2017 showed a reduction of 0.12 from 0 .27 in 2016. Although in 2021, the average NDVI value will increase to 0.32 and the average SAVI value to 0.27, stakeholders need to form institutions and establish policies as a preventive measure for the decline in the vegetation index worse than in 2017. Based on the Decree of the State Minister of the Environment No. 201 of 2004 concerning the damage to mangrove forests, the condition of the mangrove area of Dodola Island in 2017 is categorized as damaged, and sparse mangrove rehabilitation is necessary. Based on the results of this study, a community-based mangrove ecotourism approach is recommended as an alternative method of sustainable tourism development on Dodola Island.

**Keywords**: Mangrove, NDVI, Dodola Island, SAVI

## 1. INTRODUCTION

The development of tourism infrastructure in a tourist destination influences the existing conditions of the environment. [1] show that tourism development in Indonesia impacts the environment, economy, and socio-culture. To optimize accessibility and accommodation support facilities, infrastructure development causes land conversion from green open spaces into essential economic areas. The

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tourism development approach has to be planned to balance the financial benefits, socio-cultural and environmental sustainability. In addition, [2] argues that the management and protection of the environment in Indonesia have been regulated by Law Number 32 of 2009 related to integrated handling in the use, improvement, and development of the domain. It means that the use of natural resources for tourism development needs to be carried out with due regard to environmental conditions.[3] show that changes in land conversion in an area can be identified and analyzed using remote sensing through Landsat 8 Operational Land Imager (OLI) with the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Soil Adjusted methods. Vegetation Index (SAVI). It shows that changes in the vegetation index in an area due to infrastructure development can be identified and analyzed using remote sensing using NDVI and SAVI methods.

Researchers have widely used the Normalized Difference Vegetation Index (NDVI) since 1980 [4]. The NDVI approach is very effective in identifying changes in the vegetation index. [5] used NDVI to identify changes in vegetation cover using Landsat 8 OLI. NDVI describes the greenness of plants due to the photosynthetic activity of vegetation; therefore, damaged plants can be identified using the NDVI approach. On the other hand, NDVI can also estimate wheat crop yields, where the interpretation of meteorological data is continued to the decision-making stage, especially for wheat farmers [6]. Meanwhile, [7] used the NDVI approach to estimate tree canopy cover to classify dense, moderate, or sparse areas. It shows that the NDVI approach has limitations on research problems. Thus, the NDVI approach needs to be limited based on the objectives and issues of this research, namely to identify changes in the vegetation index of the built-up area, green open space area, and the mangrove area Dodola Island from 2013-2021.

The Soil Adjusted Vegetation Index (SAVI) can be collaborated with the Normalized Difference Vegetation Index (NDVI) to obtain the results of adequate identification of vegetation conditions. [8] show that SAVI uses a background canopy adjustment factor L (0,5) to account for first-order soil background variation, so SAVI is most widely used in areas with relatively sparse vegetation where the soil is seen through the canopy. On the other hand, [9] modified the SAVI approach to obtain optimal results. Several previous studies used the NDVI and SAVI approaches to monitor the distribution of mangroves [10], [11]. The NDVI and SAVI approach used to watch mangroves in an area will show optimal results.

In developing mangrove ecotourism, the results of the NDVI and SAVI interpretations can be used to optimize the management of tourist destinations, especially in built-up areas, green open areas, and mangrove areas to obtain economic and social benefits. [12] argue that mangrove ecotourism can be

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sustainable if a formal management process is carried out by legal institutions and supported by government policies. [13] show that an evaluation of the condition of the mangrove ecosystem needs to be carried out to provide contextual management recommendations for mangrove ecotourism destinations by considering the socio-cultural conditions of the surrounding community that ecotourism development is supported by various stakeholders and can be sustainable. It shows that the identification and analysis of the distribution of mangroves on Dodola Island can recommend a contextual mangrove ecotourism development approach to local governments and managers of Dodola Island destinations to be sustainable.

This study aims to identify and analyze changes in the vegetation index value due to the development of tourism infrastructure on Dodola Island, Morotai Island Regency, North Maluku Province, Indonesia. Morotai Island, as one of the priority tourism destinations in Indonesia, makes Dodola Island a priority in infrastructure development and becoming a tourism icon at the provincial level. The land use classification on Dodola Island is divided into three parts: the built-up area for the resort area, the Green Open Space (RTH) area of Dodola Besar Island, and Dodola Kecil Island, the mangrove area, which is divided into three zones. The vegetation index changes were analyzed using remote sensing by interpreting Landsat 8 OLI 2013-2021 satellite image data based on the NDVI, and SAVI approaches. [14] show that NDVI and SAVI of mangrove conditions can be compared with the regulation of the state minister of the environment number 201 of 2004 concerning the requirements for mangrove damage. On the other hand, [15] show that mangrove conditions will be used as evidence to formulate policies for mangrove forest rehabilitation by involving local communities. It indicates that the research context with the method used is relevant to this study's objectives.

Previous research that implemented remote sensing methods using Landsat 8 OLI through NDVI and SAVI approaches was limited to testing the model's accuracy [16]. In addition, analysis of the distribution and condition of mangrove vegetation using remote sensing through NDVI and SAVI approaches is contextual. The structure and composition of mangroves in each Zone or region have significant differences, and it is essential to monitor regularly [17]. It shows that the context of this research has an urgency to be carried out to watch the sustainability of mangrove vegetation along with the intensity of tourism infrastructure development on Dodola Island, Morotai Island Regency, North Maluku Province, Indonesia.

## 2. METHOD

This study uses remote sensing methods, namely the Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI), to identify

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changes in the vegetation index of Dodola Island in 2013-2021. Specifically, the process of calculating raster data using NDVI and SAVI can be seen in Figure 1.

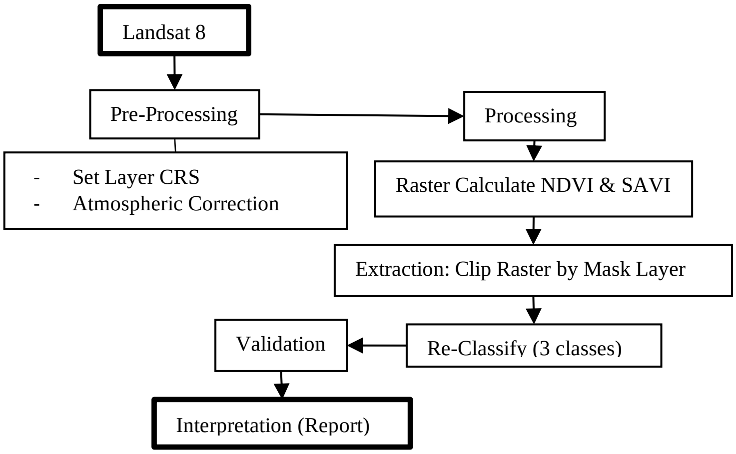


**Figure 1.** Data Processing Using NDVI and SAVI in QGIS 3.20

Figure 1 is a data processing stage divided into two phases: pre-processing and data processing. In the pre-processing data stage, Transverse Mercator (UTM) on the Landsat 8 Operational Land Imager (OLI) is set based on the 1984 World Geodetic System (WGS) datum with Zone 52 N. Also, the pre-processing data in this QGIS 3.20 application use the Semi-Automatic Classification plugin to correct the atmosphere on Landsat bands 3, 4, 5, and 6 by applying DOS 1 atmospheric correction. Furthermore, raster data calculations are carried out in the data processing stage based on each approach. In the NDVI approach, bands 4 and 5 are calculated as follows:

$$NDVI = \frac{\rho 5 - \rho 4}{\rho 5 + \rho 4} \text{.....................} (1)$$

Description,

ρ5 = NIR

ρ4 = RED

Furthermore, in the SAVI approach, the bands used are band 5and band 4 using the following equation:

$$SAVI = (1 + L)\frac{\rho 5 - \rho 4}{\rho 5 + \rho 4 + L} \text{.............} (2)$$

Description,

L = Soil Brighness Correction factor (0,5)

ρ5 = NIR

ρ4 = RED

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The Soil Adjusted Vegetation Index (SAVI) is generally used to analyze the availability of green open space. [8] combine the NDVI technique with SAVI to investigate the availability of public green open space and private green open space. The importance of analyzing the availability of open space is to balance the infrastructure development plan by considering environmental conditions. It shows the relevance of using the SAVI and NDVI approaches for this study. 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 addition, the area to be analyzed can be seen in Table 1.

**Tabel 1.** Characteristics of an Area in Dodola Island

| Land-use in Dodola | Description | Area (Ha) |
|---|---|---|
| Built-Up Area | Area Resort | 5,6 |
| Green Open Space Area | Big Dodola | 65,6 |
| | Small Dodola | 3,1 |
| Mangrove Area | Zone 1 | 5,6 |
| | Zone 2 | 5,6 |
| | Zone 3 | 5,6 |

Source : [18]

Table 1 shows that the characteristics of the green open space area on Dodola Island are divided into two parts, namely Dodola Besar Island and Dodola Kecil Island. In addition, the mangrove area of Dodola Island is divided into three parts, namely Zone 1, Zone 2, and Zone 3. [18] show that the water conditions in each Zone in the mangrove area of Dodola Island are in the range of 27,3-30,1$^{o}$C. Meanwhile, the Ph values ranged from 4,88 to 5,07. Meanwhile, salinity ranges from 29-30%, and Dissolved Oxygen (DO) on water concentrations ranging from 6.3 to 6.7. Suppose it is related to the Decree of the State Minister of the Environment Number 51 of 2004. In that case, it can be seen that the natural and suitable temperature for the development of mangrove ecology is in the range of 28-31$^{o}$C. Meanwhile, the standard pH of water for marine tourism is around 6,5-8,5, and for marine life, it is approximately 7-8,5. Salinity that supports the existence of mangrove species is in the range of 2-22% for brackish and salty water to 38%. Meanwhile, the dissolved oxygen concentration in the standard is >5 mg/L. Meanwhile, the types of mangroves on Dodola Island are Ceriops decandra, Bruguiera gymnorhiza, Sonneratia alba, Phempis acidulant, Rhizophora mucronata, Rhizophora apiculate, and Lumnitzera racemose. It shows that changes in the average values of NDVI and SAVI in 2013-2021 affect the growth of mangroves on Dodola Island, so it is essential to identify and analyze them to recommend contextual mangrove rehabilitation programs.

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## 3. RESULT AND DISCUSSION

### 3.1 Normalized Difference Vegetation Index (NDVI) of Dodola Island 2013-2021: Built-Up Area and Mangrove Are

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. Likewise, [19] uses Landsat 8 OLI satellite imagery and NDVI and Normalized Difference Built-Up Index (NDBI) models to identify land use or land-use change and classify the differences between vacant land use and buildings. In addition, [20] combines the NDVI approach with the LAI approach to evaluate biomass in reforestation sites based on area. It shows that the NVDI approach can identify or analyze changes in the vegetation index value. This research uses the NDVI approach to identify changes in the built area of Dodola Island in 2013-2021, as shown in Figure 2.

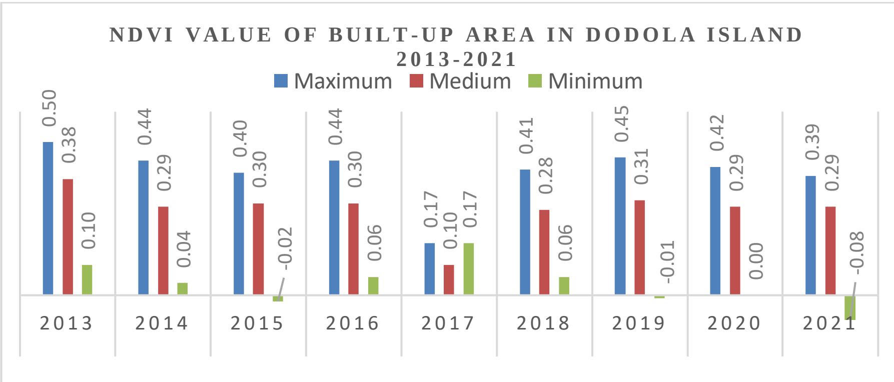


**Figure 2.** NDVI Value of Built-Up area in Dodola Island 2013
Source: NDVI calculation result using QGIS 3.20

Figure 2 shows that in 2017 there was a decrease in the average NDVI value in the built area of Dodola Island. On the other hand, the tourism infrastructure development program was realized in 2017 as a follow-up to the Nawacita program. The Morotai Island Regency was designated as one of the priority tourism destinations [21]. Based on the calculation results of Landsat 8 OLI raster data using the NDVI 2013-2021 approach, the average NDVI value in the built-up area in 2016 was 0,30 (moderate-damaged), which decreased significantly in 2017 to 0,10 (sparse-damaged). Although in 2018-2021, the average NDVI value of the built area increased to 0.28-0.31 (moderate-damaged), a significant decline in 2017 has threatened environmental sustainability for resort accommodation development. The development of tourism infrastructure to provide accommodation services for tourists impacts the environment [22]. [23] shows

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the negative impact of tourism activities on the environment. It shows that tourism development is beneficial and negatively affects the environment and local communities [24]. Therefore, a participatory approach is needed to anticipate the occurrence of economic and social disparities in tourism, which also impact environmental sustainability, especially in mangrove areas, as shown in Figure 3.

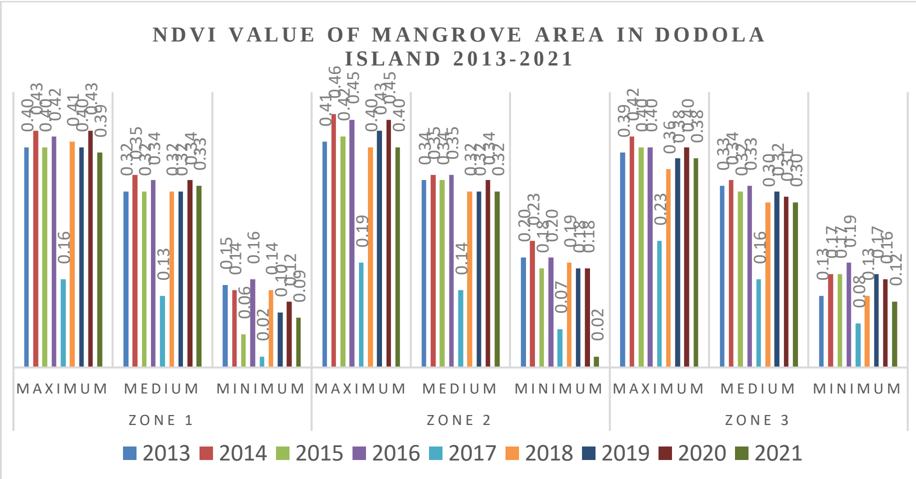


**Figure 3.** NDVI value of mangrove area in Dodola Island 2013
Source: NDVI calculation result using QGIS 3.20

Figure 3 shows that the 2013-2021 average NDVI value in mangrove areas showed an extreme decline in 2017. Although the average NDVI value of mangrove areas in 2021 was around 0,30-0,32 (moderate-damaged), the maintenance program of 16,8 hectares needs to be managed professionally. The results of the NDVI calculation of the mangrove area of Dodola Island show that the most extreme decline in the vegetation index is Zone 1 of the mangrove area of Dodola Island, where the average NDVI value in 2017 is 0,13. Furthermore, the average NDVI value in Zone 2 of the mangrove area of Dodola Island is 0,14. Meanwhile, the average NDVI value in Zone 3 of the mangrove area of Dodola Island is 0,16. Based on the Decree of the State Minister of the Environment No. 201 of 2004 regarding the criteria for damage to mangrove forests, the mangrove area of Dodola Island is in the category of sparse-damaged. Such conditions need to be anticipated and accommodated institutionally by establishing participatory management of mangrove rehabilitation.

Meanwhile, the participatory approach in developing tourist destinations is part of community empowerment to obtain economic and social benefits from the tourism sector. [25] show that a partnership program for community-based tourism development has been implemented on Kolorai Island, using the concept of a tourist village. Their livelihood dominates the livelihood of the Kolorai community as fishermen. The Kolorai community has access to Dodola Island,

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which is closer, so the involvement of the Kolorai community in the mangrove rehabilitation management program becomes effective in controlling or monitoring the condition of mangroves in each Zone.

### 3.2 Dodola Soil Adjusted Vegetation Index (SAVI) of Dodola Island 2013-2021: Built-Up Area and Mangrove Area

The Soil Adjusted Vegetation Index (SAVI) is generally used to analyze the availability of green open space. Sinaga *et al.* [8] combine the NDVI technique with SAVI to investigate the availability of public green open space and private green open space. Due to NDVI value, validation of vegetation condition used SAVI. Based on the correlation test results, it can be seen that there is a perfect correlation between NDVI and SAVI of 0,996. It shows that changes in the average value of the vegetation index based on the SAVI approach in the built area of Dodola Island in 2013-2021 can be analyzed contextually, as shown in Figure 4.

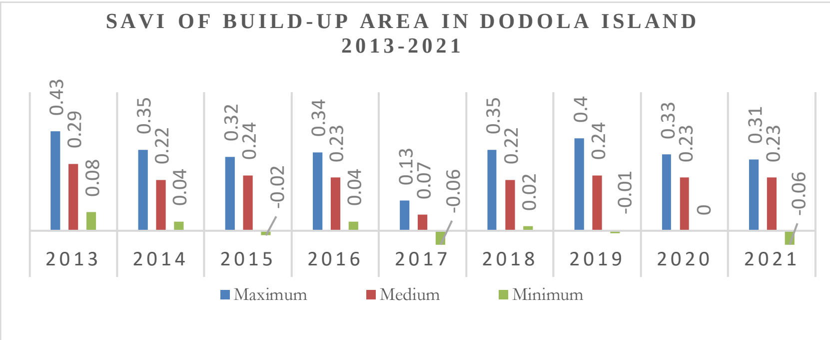


**Figure 4**. SAVI Value of Built-Up area in Dodola Island 2013
Source: SAVI calculation result using QGIS 3.20

Figure 4 shows that the average SAVI value for the built-up area in 2017 experienced a significant decline due to the development of tourism supporting infrastructure. The average value of SAVI in built-up areas in 2016 was 0.23 (Low Density), which decreased in 2017 to 0.07 (Very Low Density). In its development, the average value of SAVI in the built area in 2021 has increased to 0.23 (Low Density). The built area of Dodola Island has an area of 5.6 Ha (8.52%) of the size of Big Dodola Island of 65.6 Ha (100%). In general, the average value of SAVI in the Green Open Space (RTH) area of Dodola Besar Island in 2016 was 0.27 (Low Density), which decreased in 2017 to 0.12 (Low Density). Furthermore, in 2021, the average SAVI value of Dodola Island will gradually improve to 0.25 (Low Density). It shows that the density level of the green open space area in Big Dodola Island needs to be maintained through land-use control policies. It will optimize the eco-friendly Dodola Island tourism economic area, especially by considering the density of the Dodola Island mangrove area, as shown in Figure 5.

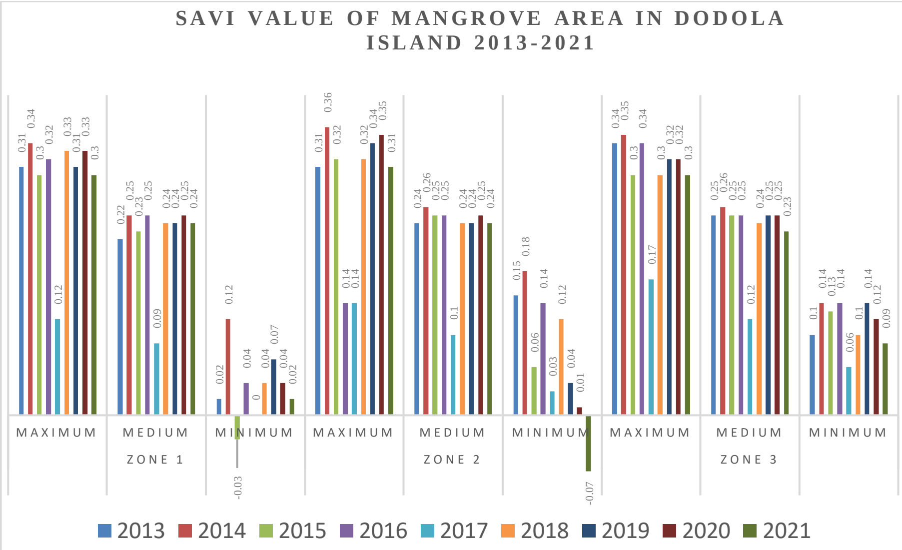


**Figure 5**. SAVI Value of Built-Up area in Dodola Island 2013
Source: SAVI calculation result using QGIS 3.20

Figure 5 shows that the average value of SAVI in the mangrove area of Dodola Island experienced a significant decrease in 2017. The mangrove area of Dodola Besar Island has an area of 16,8 Ha (25.6%) of the total area of Dodola Besar Island, which is 65,6 Ha ( 100%). In this study, the mangrove area of Dodola Island is divided into three zones. Based on the average SAVI value, it can be seen that the most drastic decline in Zone 2 of the mangrove area of Dodola Island, where the average SAVI value in 2017 was 0,03 (Very Low Density). Furthermore, the average value of SAVI in Zone 1 of the mangrove area of Dodola Island in 2017 is 0,09 (Very Low Density). Then, the average value of SAVI in Zone 3 of the mangrove area of Dodola Island in 2017 is 0,12 (Low Density). In 2021, the average value of SAVI in Zone 1, Zone 2, and Zone 3 will increase in the range of 0,23-0,24 (Low Density). Nevertheless, the mangrove density level in the mangrove area is optimized through a mangrove rehabilitation program that involves local communities.

### 3.3 Dodola Soil Adjusted Vegetation Index (SAVI) of Dodola Island 2013-2021: Built-Up Area and Mangrove Area

The approach to developing ecotourism in Indonesia is very dynamic. [26] argues that the existing condition of tourism destinations in Indonesia is optimizing natural resources into a source of community income managed based on the socio-cultural context. Indonesia has a variety of languages, cultures, and ethnicities. Therefore, the approach to tourism development is holistic and contextual. Sustainable ecotourism development in Indonesia relies on education about the importance of the environment, which needs to be balanced with economic and social interests [27]. Meanwhile, [28] emphasizes that Indonesia's ecotourism needs to involve local communities as subjects, not as objects. It shows that in developing mangrove ecotourism on Dodola Island, community involvement in the mangrove management process is needed to obtain optimal results. People on Kolorai Island have convenient access and mobility to participate in the Dodola Island ecotourism development program. Thus, the community can receive economic, socio-cultural, and environmental benefits as a subject of development to achieve sustainable tourism.

An approach to eco-friendly tourism development is ecotourism. Ecotourism can be identified through the form and level of community participation and adapting natural resources such as mangroves as a means of environmental education and a marine tourism attraction with environmentally friendly activities [29]. In the context of the Covid-19 pandemic, restrictions on mobility and tourism activities in various countries and regions have greatly helped the environmental recovery process [30]. In the context of the Covid-19 pandemic in Indonesia, [31] show that tourism business actors experience losses due to limited mobility and activities that the government formally stipulates in the form of policies. However, environmental ecosystems benefit from the recovery process. In the context of research on Dodola Island, the increase in the average value of NDVI and SAVI in 2020 and 2021 is also supported by government policies to limit mobility and accessibility to tourist destinations on Dodola Island. Controlling tourist visits is an effective form of destination management to anticipate damage to facilities and the environment due to vandalism related to tourist behavior.

The participatory approach in ecotourism development is conceptually known as a community-based tourism approach [32]. The involvement of local communities in ecotourism development is considered effective as a strategy for empowerment, preservation of the natural and cultural environment [33]. In addition, [34] show that community involvement in ecotourism development in Indonesia is one approach to resolving land resource conflicts, water crises, and security and comfort threats caused by the tourism sector. In mangrove ecotourism on Dodola Island, community involvement is essential. Therefore, through the Tourism Office as a facilitator in the development, the local government needs to mobilize the people of the island of Kolorai through outreach programs and assistance in managing the mangrove rehabilitation program as an initiation to ignite local community participation. Thus, the challenges and economic, socio-cultural, and environmental benefits of the tourism sector on Dodola Island are the burdens of all stakeholders (community, government, and private). The urgency of

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participatory ecotourism development prevents a significant decrease in the average NDVI value as in 2017 in figure 6.

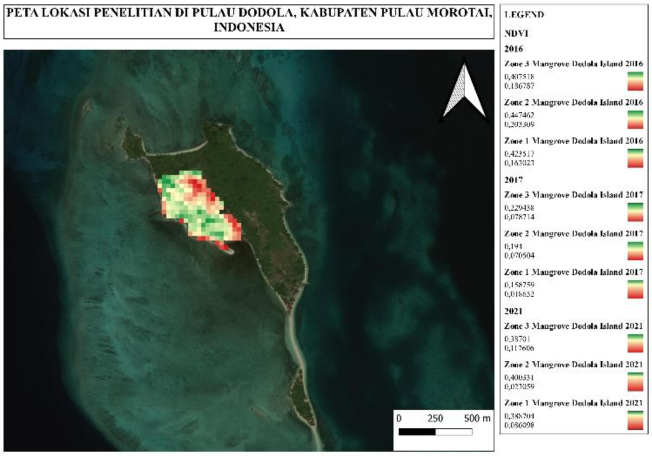


**Figure 7.** NDVI of mangrove area in Dodola Island 2016, 2017, and 2021
Source: NDVI calculation result using QGIS 3.20

Figure 6 shows a significant decrease in the average NDVI value in 2017, requiring optimizing the tourism infrastructure development program. The involvement of local communities in controlling land use for tourism purposes is a practical partnership approach to support the sustainability of the tourism sector [35]. Community involvement in the ecotourism development process also helps mobility information on Morotai Island tourism destinations campaigning massively on various technology platforms [36]. As well, [37] shows that local communities have high intentions in marketing tourism products by utilizing supporting information technology. Thus, the involvement of local communities in the development of mangrove ecotourism can optimize the management of tourist destinations and support sustainable tourism.

## 4. CONCLUSION

Based on this research, it can be seen that there is a perfect correlation between the average value of NDVI and SAVI of 0,996. The average NDVI value of Dodola Island in 2017 showed a significant decrease to 0,16 from 0,35 in 2016. Likewise, the average SAVI value of Dodola Island in 2017 showed a reduction of 0,12 from 0,27 in 2016. Specifically, the average NDVI value in the built area of Dodola Island also decreased in 2017 to 0,10 from 0,30 in 2016. Dodola also reduced in 2017 to 0,14 from 0,34 in 2016. Meanwhile, the average NDVI value in each Zone in the mangrove area of Dodola Island also decreased in 2017 as follows: Zone 1, 2016 by 0,34 decreased in 2017 to 0,13; Zone 2, in 2016 of 0,35

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decreased in 2017 to 0,14; Zone 3, in 2016 of 0,33 decreased in 2017 to 0,16. Meanwhile, the average value of SAVI in the built area of Dodola Island also reduced in 2017 to 0,07 from 0,23 in 2016. The average weight of SAVI in the mangrove area also decreased in 2017 to 0,10 from 0,25 in 2016. The average value of SAVI in each Zone in the mangrove area also reduced in 2017 as follows: Zone 1, in 2016 was 0,25, decreased in 2017 to 0,09; Zone 2, in 2016 of 0,25 decreased in 2017 to 0,10; Zone 3, in 2016 of 0,25, declined in 2017 to 0,12. Although in 2021, the average NDVI value will increase to 0,32 and the average SAVI value to 0,27, stakeholders need to establish a particular institution for monitoring the mangrove vegetation of Dodola Island and establish a policy for the rehabilitation of mangrove areas as a preventive measure. A decrease in the vegetation index caused environmental degradation of the mangrove area to be worse than in 2017. Based on the Decree of the State Minister of the Environment No. 201 of 2004 concerning the characteristics of mangrove forest damage, the condition of the mangrove area of Dodola Island in 2017 was categorized as sparse-damaged, which gradually recovered in 2021 and can be classified as damaged -moderate. Based on the results of this study, a community-based mangrove ecotourism approach is recommended as an alternative method of sustainable tourism development on Dodola Island.

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