Contents lists available at Science-Gate

International Journal of Advanced and Applied Sciences

Journal homepage: http://www.science-gate.com/IJAAS.html

# USG matrix analysis and power interest to improve community environmental awareness: A case study of mangrove land cover to support community and environmental education

Enggar Utari [1,*], Herlyn Herlyn [1], Mahrawi Mahrawi [1], Hartanto Sanjaya [2], Muhamad Iman Santoso [3]

[1]*Department of Biology Education, Universitas Sultan Ageng Tirtayasa, Serang, Indonesia*
[2]*Center for Geospatial Research, Badan Riset Dan Inovasi Nasional, Jakarta, Indonesia*
[3]*Department of Electrical Engineering, Universitas Sultan Ageng Tirtayasa, Cilegon, Indonesia*

A R T I C L E I N F O

*Article history:*
Received 21 July 2023
Received in revised form
27 February 2024
Accepted 15 June 2024

*Keywords:*
Mangrove forest composition
Remote sensing
Google Earth engine
Reforestation activities
Environmental education

A B S T R A C T

This study employed a mixed-method approach to analyze the composition of mangrove forests. The transect method and remote sensing through supervised classification using Google Earth Engine (GEE) were utilized to assess changes in mangrove areas in 2017, 2019, and 2021. The findings suggest that this study should be included in population and environmental education courses. The results revealed that Avicennia marina mangroves had the highest importance index (INP) values at three different locations. Between 2017 and 2019, mangrove areas decreased from 30.62 hectares to 27.98 hectares. However, from 2019 to 2021, the mangrove area increased from 27.98 hectares to 29.18 hectares, largely due to reforestation efforts in the Pulau Dua Nature Reserve. The NDVI (Normalized Difference Vegetation Index) values indicated "bushy" criteria, ranging from 0.43 to 1.00. The Normalized Difference Mangrove Index (NDMI) values fell into the "Rare" (-1.00 to 0.32) and "Medium" (0.33 to 0.43) categories. The Urgency, Seriousness, and Growth (USG) matrix analysis and Power Interest assessment identified illegal logging, erosion, and waste as significant causes of mangrove decline. Stakeholders, including village chiefs, religious leaders, traditional leaders, and youth leaders, must focus on preserving the mangrove ecosystem in the CAPD. The study's results are vital for educational purposes, particularly in population and environmental education courses. These courses should address environmental issues, prevention strategies, and conservation activities, which can be integrated into the curriculum. This will enable youth to contribute effectively to environmental awareness programs.



## 1. Introduction

Mangrove forests in Pulau Dua Nature Reserve (CAPD) have an essential ecological role in supporting the life and sustainability of marine resources. Mangroves play a crucial role in the life of aquatic biota; therefore, mangrove forest ecosystems are important to be preserved. One of the functions of mangroves is as a place to spawn aquatic biota (Li et al., 2019). For effective conservation, it is crucial to thoroughly understand the characteristics of the transition areas between land and sea. This knowledge helps in maintaining the dynamic environmental conditions essential for the growth and sustainability of mangroves (Khan et al., 2022; Singgalen, 2022). It is crucial to monitor changes or dynamics in mangrove ecosystems regularly (Nguyen et al., 2020; Wang et al., 2020).

Land cover stretches objects above the earth's surface (Dong et al., 2023; Ruijsch et al., 2023). Land cover analysis provides important information in understanding natural phenomena on the earth's surface (Baltodano et al., 2022; Ordóñez et al., 2023; Loukika et al., 2021). Several studies have been conducted on mangrove land cover using remote sensing on chlorophyll-a and mangrove habitats in coastal areas, looking at the influence of tides on the dynamics of mangrove forest land cover in the Banten Bay area (Baltodano et al., 2022; Li et al., 2021; Loukika et al., 2021; Mohd Razali et al., 2022). The research results by Anurogo et al. (2018)

* Corresponding Author.
Email Address: enggar.utari@untirta.ac.id (E. Utari)
https://doi.org/10.21833/ijaas.2024.07.002
Corresponding author's ORCID profile:
https://orcid.org/0009-0009-1756-1617

showed that the most extensive distribution of mangrove forests is found in the Tirtayasa District and Pontang District, with a percentage value of 29.75% and 28.46%, respectively. Vasquez et al. (2024) have also examined the dynamics of mangrove land covering the pond land of the Bangkala sub-district, Jeneponto Regency. The results showed a decrease in mangrove land in 2012-2017 from 25.57 to 20.78, caused by an economic crisis that made people choose to convert mangrove land into pond land. Furthermore, the results of the analysis of mangrove land cover with Landsat satellite images in the West Sumatra area showed a change in the vegetation index value (greenness level of vegetation) from 0.82 to 0.78 on Landsat satellite images in Sawahlunto City, West Sumatra, from 2000-2016.

Based on the results of satellite imagery with Google Earth Engine (GEE) combined with line transect techniques, data was obtained on a decrease in the number of mangrove areas (Li et al., 2019; Mandal and Hosaka, 2020; Taillie et al., 2020). The decrease in mangrove cover and density is caused by human and natural factors (Li et al., 2019; Mohd Razali et al., 2022; Taillie et al., 2020). One of the influencing natural factors is beach abrasion. Human activities are important in mangrove destruction (Gonçalves et al., 2019). Low community participation in maintaining mangrove sustainability is the cause (AlQahtany et al., 2022). In addition, policy owners' or community leaders' participation has not contributed much to mangrove land conservation (Garau et al., 2021; Taffuri et al., 2021). The community has used many methods to improve the condition of mangrove forests (Chai-Arayalert and Puttinaovarat, 2020). However, the current method used by the community in preserving mangroves is still limited. It is still limited to direct observation in the field without satellite images or using line transect to measure mangrove population density (AlQahtany et al., 2022; Del Toro and Más-López, 2019). In addition, local government policies are still limited in handling mangrove sustainability in CAPD without any basis through community interviews, questionnaires, or other techniques such as the USG (Urgency, Seriousness, and Growth) Matrix and Power Interest, so preservation activities are less effective.

This study will provide an overview of vegetation, mangrove density, and extent using satellite imagery and line transect. The results of satellite images and field observations with line transect combined with USG Matrix can be known as the level of damage and seriousness of the mangrove problem (Del Toro and Más-López, 2019; Nguyen et al., 2020). Community involvement is important because the community will maintain the sustainability of mangroves (Kollmuss and Agyeman, 2002). To find out community involvement can be obtained with power interest techniques to see community involvement and interest in mangrove problems, including stakeholders (Kollmuss and Agyeman, 2002; Taffuri et al., 2021). This study aimed to determine the composition of mangrove forests using the transect method and remote sensing methods through supervised classification to determine changes in mangrove areas with GEE (Li et al., 2019; Mandal and Hosaka, 2020). The measured changes were in 2017, 2019, and 2021. Then, it should be recommended to be included in the population and environmental education course.

Given that mangrove land plays a very important role in supporting marine life, research has been conducted to find out how the environmental concern attitude of the surrounding community in maintaining mangrove ecosystems through USG analysis and the Power Interest. In addition, this study has implications for the importance of environmental education as a vehicle for transforming human ecological beliefs, understanding, and behavior. Bergman (2016) explained that in environmental education, a person can increase cognitive, affective, and psychomotor capacities, affecting views and patterns of human relationships with nature. Through the educational process, ecological values captured by religion can be internalized by students. The main environmental education starts from the family and places more emphasis on the informal process. Interactions that are informal and emphasize substance will facilitate the formation of ecological character for students. In this context, environment-based education contributes to the future of ecology and human sustainability (Maghfur, 2010).

## 2. Method

This study used a mixed method where to determine the composition of mangrove forests using the transect method and remote sensing methods through supervised classification to determine changes in mangrove areas with GEE (Li et al., 2019; Mandal and Hosaka, 2020). The measured changes were in 2017, 2019, and 2021. Then, it should be recommended to be included in the population and environmental education course.

### 2.1. Field data collection

The sample in this study was taken at three stations; with each station, there were five plot points with a transect line length of 100 m2; on the transect line, five transect plot points were made with a size of 10 x 10 m2 with a distance between plots of 10 meters as shown in Fig. 1.

Satellite imagery data retrieval. Satellite imagery data retrieval is done using GEE. The satellite image data used is image collection data on Landsat 8 images in 2017, 2019, and 2021 image data. Landsat Eight imagery was chosen in this study because the Landsat 8 satellite is the latest Landsat system satellite and has advantages in good satellite archive data and more bands than previous Landsat images (Mandal and Hosaka, 2020; Singgalen, 2022).

Processing of satellite imagery data. Satellite image data is processed based on the period of years, namely 2017, 2019, and 2021 with several important stages (1) Determining the area to be processed and determining image collection variables, (2) Determining Cloud Masking to filter the best image and not covered by clouds, (3) Spectral indices are added in the script, to determine the value of vegetation index (NDVI) and mangrove particular vegetation index (NDMI) (Del Toro and Más-López, 2019; Gonçalves et al., 2019; Luo et al., 2020; Singgalen, 2022; Wang et al., 2020), (4) Satellite Imagery Data is filtered by period and (5) Image collection Landsat data and spectral indices data and (6) Making a Random Forest model aims to classify areas that are forest areas (Mangrove Area) and areas that are not included in forests (Non-Mangrove Area) (AlQahtany et al., 2022; Gonçalves et al., 2019; Li et al., 2021), (7) Random Forest model accuracy aims to curate training data with testing data on the Random Forest model.

Independent accuracy of Satellite Imagery data. Data accuracy is measured at this stage using the Stratified Random Sampling script Analysis of satellite imagery data. Image data results were processed and analyzed using GEE and literature studies in 2017, 2019, and 2021.

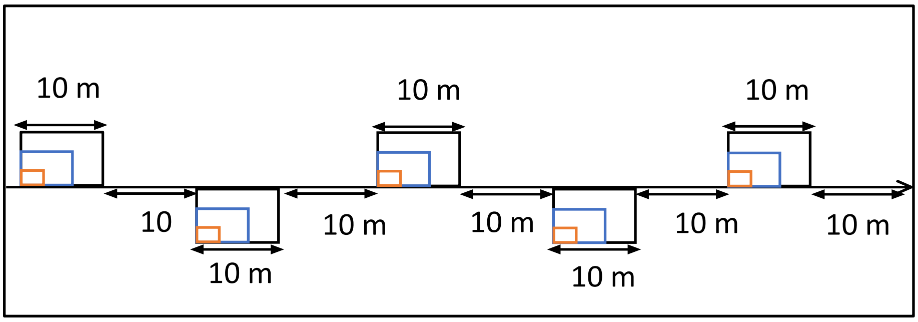



**Fig. 1:** Research design

## 2.2. Data analysis

### 2.2.1. Vegetation data calculation

Vegetation data processing involves calculating density, frequency, dominance, and important value indices at three stations. Density (K) and individual density (Di) are measured to determine the number of stands of each type per unit area. Relative density (RDi) is calculated to find the ratio between the number of individuals of a specific type (Ni) and the total number of individuals of all types (∑n). Frequency (F) is determined to understand the distribution of a tree species within the community. Dominance (D) is measured to assess the prevalence of plant species within a community. The Important Value Index (INP) is calculated to ascertain the role of dominant vegetation in the community.

### 2.2.2. NDVI and NDMI data calculation

Data processing uses GEE to calculate NDVI values in 2017, 2019, and 2021. Normalized Difference Vegetation Index (NDVI) is a commonly used method in comparing the level of greenness of vegetation (chlorophyll content) in plants (Singgalen, 2022) Header Density Level based on NDVI Value can be seen in Table 1.

**Table 1:** Header density level based on NDVI value

| No. | Header density level | NDVI value |
|---|---|---|
| 1. | Dense | 0.43 ≤ NDVI ≤ 1.00 |
| 2. | Keep | 0.33 ≤ NDVI ≤ 0.43 |
| 3. | Infrequently | -1.00 ≤ NDVI ≤ 0.32 |

The NDVI value ranges from -1 to 1. Clouds, water, and non-vegetated objects have NDVI values less than zero. Values representing vegetation are found in the range of 0.2 to 0.7.

### 2.2.3. The involvement of the community in maintaining the CAPD mangrove ecosystem

The Focus Group Discussion stakeholders are village heads, religious leaders, traditional leaders, youth leaders, environmental activists, and educators. The ranking used is a score of 1 to 5 according to needs, namely: Urgency (urgency issue): the problem must be solved immediately related to the availability of time. Seriousness: how serious a problem can lead to other, more serious problems. Growth: the likelihood of the problem developing worse if not addressed. The USG matrix results are then used to map stakeholder networks using Power Interest Quadrant analysis. This analysis is based on Power, Urgency, Legitimacy, and Proximity indicators and grouped by Power and Interest quadrants (Bulmer and Del Prado-Higuera, 2021; Taffuri et al., 2021).

## 3. Results and discussion

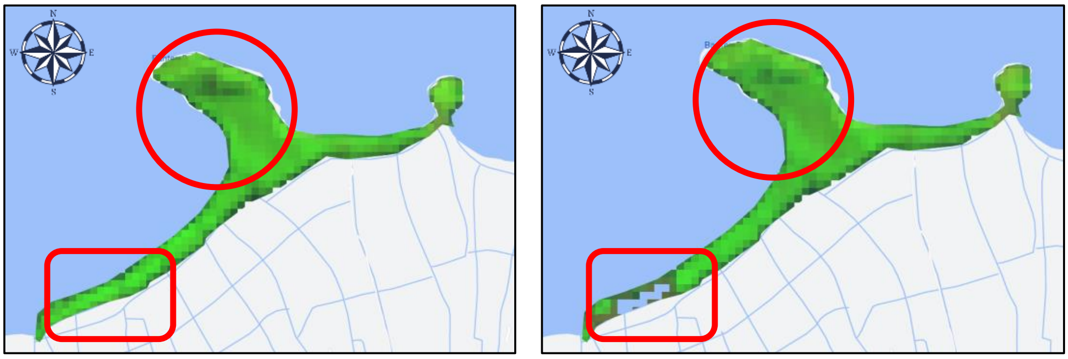
The results of the Mangrove Area Change data in CAPD can be seen in Table 2.

**Table 2:** Changes in the CAPD mangrove area

| Year | Luas area mangrove (Ha) | Percentage of mangrove area (%) |
|---|---|---|
| 2017 | 30.62 | 93.21 |
| 2019 | 27.98 | 85.17 |
| 2021 | 29.18 | 88.82 |

The total area of mangroves against the area of CAPD is 32.85 Ha (BPEFA, 2018). Table 2 shows that the value of the mangrove area in 2017 decreased by

2.64 Ha, and in 2019-2021, there was an increase in mangrove area by 1.20 Ha. The decrease in the mangrove area occurred due to illegal logging in 2017. The results of interviews with key persons, namely village heads, religious leaders, traditional leaders, youth leaders, environmental activists, and educators, generally stated that illegal logging occurred because residents of the Sawah Luhur area wanted to expand the pond area near the CAPD border. The area of damage caused by illegal logging can be seen in the southwest Fig. 2, marked with a box.



Landsat Composite 2017 Landsat Composite 2019

**Fig. 2:** Image of mangrove area change observed from Landsat 8 satellite in 2017 and 2019

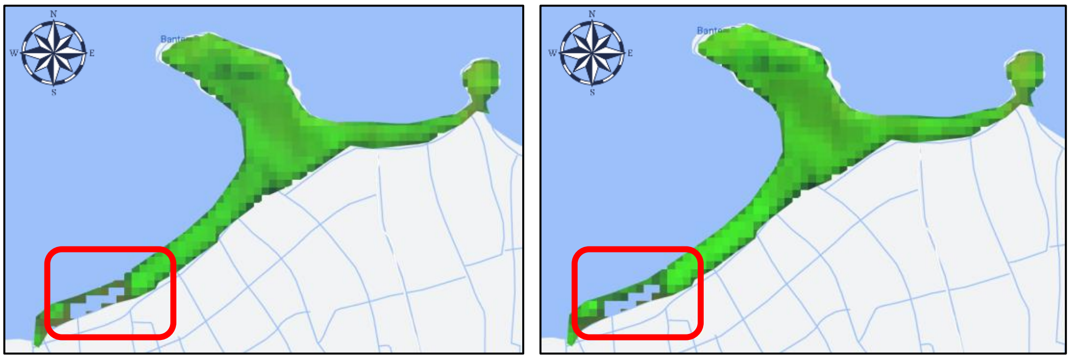
The damage is not only due to illegal logging. In other areas, such as circled areas, the damage that occurs is generally caused by beach abrasion. The results of the key person interview stated that within one year, at least one abrasion occurred, damaging the CAPD coastal area, especially in December when the wind direction blows from the north. Wind direction is one of the factors that can cause abrasion. Currents caused by wind are generally seasonal. Other abrasion factors can be hydro-oceanic processes from the sea, such as wave blows, changes in current patterns, and tidal phenomena.

Another environmental factor is the considerable waste found in CAPD, which can be seen in Fig. 3. The existence of waste found in CAPD is divided into organic waste (fruit dregs, dry leaves, bamboo branches) and inorganic waste (plastic beverage bottles, plastic bags, and plastic used food wrappers). Inorganic waste is a type of waste that is difficult for microorganisms to decompose. Inorganic waste that accumulates can make the roots of mangrove plants unable to penetrate the soil layer, resulting in disturbed respiration at the roots of mangrove breath. In addition, water, minerals, and other nutrients will be difficult to absorb by mangrove roots, resulting in less fertile soil to grow mangrove plants. The increase in mangrove areas in 2019 and 2021 occurred due to a reforestation program by the BKSDA in areas damaged by illegal logging, which can be seen in Fig. 4.

Reforestation occurs once in 2-3 months, with around 300-500 mangrove seedlings planted in damaged areas. Changes in the Landsat Composite in 2019 and 2021 can be seen in Fig. 5.

**Fig. 3:** Waste in the CAPD mangrove ecosystem


**Fig. 4:** Reforestation activities in areas experiencing illegal logging




Landsat Composite 2019 Landsat Composite 2021

**Fig. 5:** Image of changes in mangrove area observed from the Landsat 8 satellite in 2019 and 2021

### 3.1. NDVI change analysis from 2017, 2019, and 2021 in CAPD results

The analysis of changes in NDVI values is conducted to provide evidence of land cover changes in CAPD. Eight sample coordinate points were selected based on areas susceptible to land cover changes due to natural and human factors. The locations of these eight coordinate points are shown in Fig. 6. NDVI analysis was conducted to determine the value of green cover (chlorophyll color) in a land cover based on the reflection of the infrared channel (NIR) and red channel (RED) spectra received by satellites. The NDVI value is the number of vegetation indices that correlate with the density of vegetation in an area (Gonçalves et al., 2019; Li et al., 2021). NDVI uses reflected chlorophyll as the basis of indicators analyzed by satellites (Li et al., 2021; Mandal and Hosaka, 2020; Wang et al., 2020). The results of NDVI CAPD Value Analysis can be seen in Fig. 7.

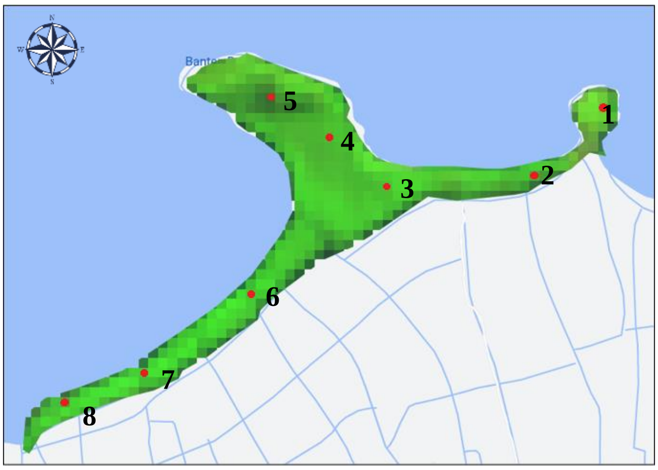



**Fig. 6:** Location of 8 sample point coordinates on GEE

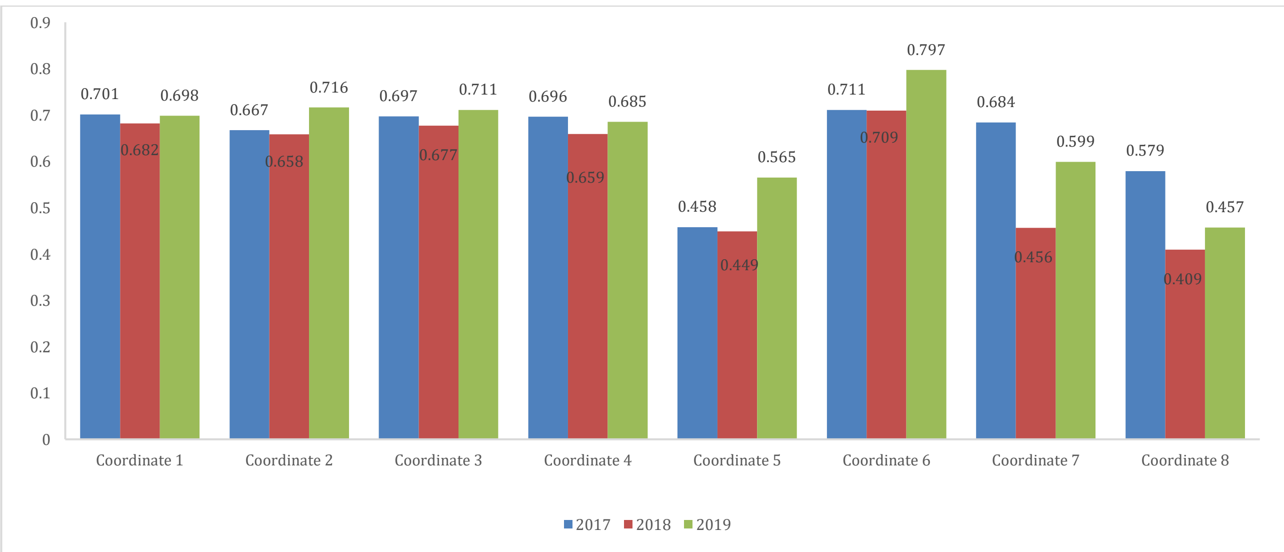



**Fig. 7:** Graph of changes in NDVI value in 2017, 2019 and 2021

Fig. 7 illustrates that the NDVI values decreased between 2017 and 2019 and increased between 2019 and 2021. Specifically, the NDVI value at coordinate point 7 decreased from 0.684 to 0.456 and at coordinate point 8 from 0.579 to 0.409 during 2017-2019. The increase in NDVI values during 2019-2021 can be observed at coordinate points 5, 6, 7, and 8. The changes in NDVI values across the eight sample points were not very significant. This is attributed to the dominance of the "Bushy" criterion, where the NDVI values remained within the range of 0.43 to 1.00. One factor influencing the decline in NDVI values is sunlight, which affects the reflectance of red and infrared rays, significantly impacting the NDVI values obtained from Landsat 8 satellite images.

### 3.2. USG matrix determination of priority-specific problems from criteria for mangrove forest destruction in CAPD

The matrix of USG analysis in Table 3 shows that the priority of the problem criteria for mangrove forest destruction cases is the high conversion of mangrove area functions. High population growth and increased coastal development for various designations led to the conversion of mangrove functions in CAPD. Increasing land use change and high amounts of waste impact the destruction of mangrove forests.

### 3.3. USG matrix determination of priority-specific problems from geographic criteria problems

The USG analysis matrix in Table 4 indicates that vulnerable areas are located near mangrove forests. This analysis considers the environment's capacity to supply energy resources, land, animals, and plants to enhance community welfare. The community is less likely to use these resources if the environment cannot meet their needs. Data from the community is categorized according to the Power (P) or Interest (I) matrix. Stakeholders are mapped to assess their current strength or potential to become influential. They are then scored on a scale from 1 to 10, with the average value calculated for each category (Ullah et al., 2021).

**Table 3:** USG matrix issue

| Specific issue | U | S | G | Total score | Rank |
|---|---|---|---|---|---|
| 1. Weak detection of mangrove forest damage | 3 | 4 | 2 | 9 | 3 |
| 2. High ecological pressure | 4 | 4 | 4 | 12 | 2 |
| 3. High conversion of mangrove area | 4 | 4 | 5 | 13 | 1 |

**Table 4:** USG matrix

| Specific issues | U | S | G | Score total | Ranking |
|---|---|---|---|---|---|
| 1. Natural resources are less | 1 | 1 | 1 | 3 | 3 |
| 2. Areas near vulnerable mangrove forest areas | 3 | 3 | 4 | 10 | 1 |
| 3. Areas outside the vulnerable mangrove forest area | 2 | 4 | 3 | 9 | 2 |

Stakeholders are categorized based on their power and interest in the issue of mangrove ecosystem conservation in CAPD. Some stakeholders have significant influence and can drive conservation efforts forward, while others show great interest in the potential of mangrove ecosystems but may not have the same level of power. Stakeholders with high power play a crucial role in conservation, whereas those with high interest need to be kept well-informed. When stakeholders possess both high power and high interest, it is essential to manage the conservation efforts in CAPD very carefully to ensure success.

Based on the mapping results in Fig. 8, the results of stakeholder categorization can be described in Tables 5 and 6.


**Fig. 8:** Power and interest grid

**Table 5:** Power and interest result

| Stakeholder | Village head | Religious leaders | Traditional figure | Youth leader | Environmental activist | Teacher |
|---|---|---|---|---|---|---|
| Power | 7 | 7 | 6 | 5 | 3 | 4 |
| Interest | 8 | 8 | 6 | 6 | 8 | 7 |

**Table 6:** Result in the description of power interest

| Stakeholder | High power high interest | High power low interest | Low power high interest | Low power low interest |
|---|---|---|---|---|
| Village head | √ | | | |
| Religious leaders | √ | | | |
| Traditional figure | √ | | | |
| Youth leader | √ | | | |
| Environmental activist | | | √ | |
| Teacher | | | √ | |

Stakeholders with high power and interest are village heads, religious leaders, traditional leaders, and youth leaders. In sub-districts like Ciwandan and Grogol, the average power level is relatively high (average score of 6), particularly in areas related to religious facilities, government facilities, and the number of government employees. On the other hand, environmental activists and educators have low power but high interest (average scores of 7 and 8). It is crucial to maintain constant communication with these stakeholders to prevent major issues from arising. Stakeholders at this level can be very helpful in the details of mangrove ecosystem conservation in CAPD. Besides power and interest, priority will also be given to stakeholders with high legitimacy, proximity, and urgency (Garau et al., 2021; Bulmer and Del Prado-Higuera, 2021; Guareschi et al., 2020). The scoring results for these factors are shown in Table 7.

**Table 7:** Power and interest quadrant result

| Stakeholder | Legitimacy | Proximity | Urgency |
|---|---|---|---|
| Village head | 7 | 7 | 7 |
| Religious leaders | 5 | 6 | 6 |
| Traditional figure | 5 | 5 | 7 |
| Youth leader | 5 | 7 | 6 |
| Environmental activist | 5 | 6 | 7 |
| Teacher | 6 | 5 | 5 |

## 4. Conclusions

The use of a mixed-method approach combining satellite imagery analysis (via GEE) and mangrove vegetation density measurement through line transects, along with USG Matrix and Power Interest analysis, represents an innovative method for addressing mangrove degradation. The study revealed a decline in mangrove land cover from 30.62 hectares in 2017 to 27.98 hectares in 2019, followed by an increase to 29.18 hectares in 2021. NDVI value analysis at eight coordinate points indicated a decrease between 2017-2019 and an increase between 2019-2021. The NDMI analysis showed varying trends across different points, with some increasing and others decreasing over the same periods. The primary factors contributing to the decline in mangrove areas include illegal logging around Sawah Luhur, abrasion, and waste accumulation in Pulau Dua Nature Reserve. Conversely, reforestation efforts in heavily damaged areas have driven the increase in mangrove cover. The USG Analysis and Power Interest Quadrant identify village heads, religious leaders, traditional leaders, and youth leaders as key stakeholders in mangrove conservation due to their high power, interest, and urgency.

Integrating these findings into Population and Environmental Education can enrich the curriculum with practical examples of environmental challenges and conservation strategies, specifically focusing on the mangrove ecosystems in CAPD. Future studies should further explore environmental issues such as air pollution to enhance the educational content, as highlighted by previous research (Ruhiat et al., 2016; 2017).

## Compliance with ethical standards

### Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## References

AlQahtany AM, Dano UL, Elhadi Abdalla EM, Mohammed WE, Abubakar IR, Al-Gehlani WAG, and Alshammari MS (2022). Land reclamation in a coastal metropolis of Saudi Arabia: Environmental sustainability implications. Water, 14(16): 2546. https://doi.org/10.3390/w14162546

Anurogo W, Lubis MZ, Khakhim N, Prihantarto WJ, and Cannagia LR (2018). Pengaruh pasang surut terhadap dinamika perubahan hutan mangrove di kawasan Teluk Banten. Jurnal Kelautan: Indonesian Journal of Marine Science and Technology, 11(2): 130-139. https://doi.org/10.21107/jk.v11i2.3804

Baltodano A, Agramont A, Reusen I, and van Griensven A (2022). Land cover change and water quality: How remote sensing can help understand driver–impact relations in the Lake Titicaca Basin. Water, 14(7): 1021. https://doi.org/10.3390/w14071021

Bergman BG (2016). Assessing impacts of locally designed environmental education projects on students' environmental attitudes, awareness, and intention to act. Environmental Education Research, 22(4): 480-503. https://doi.org/10.1080/13504622.2014.999225

BPEFA (2018). Data Sektoral LHK Provinsi Banten 2018. Banten Province Environment and Forestry Agency, Banten, Indonesia.

Bulmer E and Del Prado-Higuera C (2021). Revitalizing the global alliances for sustainable development: analyzing the viability of sustainable development goal 17-A multi-actor governance approach. Sustainability, 13(8): 4247. https://doi.org/10.3390/su13084247

Chai-Arayalert S and Puttinaovarat S (2020). Designing mangrove ecology self-learning application based on a micro-learning approach. International Journal of Emerging Technologies in Learning, 15(11): 29-41. https://doi.org/10.3991/ijet.v15i11.12585

Del Toro EMG and Más-López MI (2019). Changes in land cover in Cacheu River Mangroves Natural Park, Guinea-Bissau: The need for a more sustainable management. Sustainability, 11(22): 6247. https://doi.org/10.3390/su11226247

Dong Y, Zhou Y, Zhang L, Gu Y, and Sutrisno D (2023). Intensive land-use is associated with development status in port cities of Southeast Asia. Environmental Research Letters, 18(4): 044006. https://doi.org/10.1088/1748-9326/acc2d2

Garau E, Torralba M, and Pueyo-Ros J (2021). What is a river basin? Assessing and understanding the sociocultural mental constructs of landscapes from different stakeholders across a river basin. Landscape and Urban Planning, 214: 104192. https://doi.org/10.1016/j.landurbplan.2021.104192

Gonçalves RM, Saleem A, Queiroz HA, and Awange JL (2019). A fuzzy model integrating shoreline changes, NDVI and settlement influences for coastal zone human impact classification. Applied Geography, 113: 102093. https://doi.org/10.1016/j.apgeog.2019.102093

Guareschi M, Maccari M, Sciurano JP, Arfini F, and Pronti A (2020). A methodological approach to upscale toward an agroecology system in EU-LAFSs: The case of the Parma Bio-District. Sustainability, 12(13): 5398. https://doi.org/10.3390/su12135398

Khan MM, Siddique M, Yasir M, Qureshi MI, Khan N, and Safdar MZ (2022). The significance of digital marketing in shaping ecotourism behaviour through destination image. Sustainability, 14(12): 7395. https://doi.org/10.3390/su14127395

Kollmuss A and Agyeman J (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? Environmental Education Research, 8(3): 239-260. https://doi.org/10.1080/13504620220145401

Li S, Xu L, Jing Y, Yin H, Li X, and Guan X (2021). High-quality vegetation index product generation: A review of NDVI time series reconstruction techniques. International Journal of Applied Earth Observation and Geoinformation, 105: 102640. https://doi.org/10.1016/j.jag.2021.102640

Li W, El-Askary H, Qurban MA, Li J, ManiKandan KP, and Piechota T (2019). Using multi-indices approach to quantify mangrove changes over the Western Arabian Gulf along Saudi Arabia coast. Ecological Indicators, 102: 734-745. https://doi.org/10.1016/j.ecolind.2019.03.047

Loukika KN, Keesara VR, and Sridhar V (2021). Analysis of land use and land cover using machine learning algorithms on Google Earth engine for Munneru River Basin, India. Sustainability, 13(24): 13758. https://doi.org/10.3390/su132413758

Luo N, Mao D, Wen B, and Liu X (2020). Climate change affected vegetation dynamics in the northern Xinjiang of China: Evaluation by SPEI and NDVI. Land, 9(3): 90. https://doi.org/10.3390/land9030090

Maghfur M (2010). Pendidikan lingkungan hidup dan masa depan ekologi manusia. Forum Tarbiyah, 8(1): 57-71.

Mandal MSH and Hosaka T (2020). Assessing cyclone disturbances (1988–2016) in the Sundarbans mangrove forests using Landsat and Google Earth engine. Natural Hazards, 102: 133-150. https://doi.org/10.1007/s11069-020-03914-z

Mohd Razali S, Radzi MA, Marin A, and Samdin Z (2022). A bibliometric analysis of tropical mangrove forest land use change from 2010 to 2020. Environment, Development and Sustainability, 24: 11530–11547. https://doi.org/10.1007/s10668-021-01935-7 **PMid:34803478 PMCid:PMC8590627**

Nguyen HH, Tran LTN, Le AT, Nghia NH, Duong LVK, Nguyen HTT, and Premnath CFS (2020). Monitoring changes in coastal mangrove extents using multi-temporal satellite data in selected communes, Hai Phong City, Vietnam. Forest and Society, 4(1): 256-270. https://doi.org/10.24259/fs.v4i1.8486

Ordóñez PJ, Baylis K, and Ramírez I (2023). Land cover change effects from community forest management in Michoacán, Mexico. Environmental Research Letters, 18(6): 065008. https://doi.org/10.1088/1748-9326/accdef

Ruhiat Y, Sutisna S, Hasani A, Kuswantoro M, Widiastuti S, Fahrizal R, and Wibowo FC (2016). A formation model in distribution of sulfur dioxide ($SO_2$) concentrations in Cilegon city with the use of grid technique. International Journal of Interdisciplinary Environmental Studies, 11(3): 1-10. https://doi.org/10.18848/2329-1621/CGP/v11i03/1-10

Ruhiat Y, Wibowo FC, and Oktarisa Y (2017). Air pollutants minimalization of pollutant absorber with condensation system. Journal of Physics: Conference Series, 846: 1-7. https://doi.org/10.1088/1742-6596/846/1/012014

Ruijsch J, Teuling AJ, Verbesselt J, and Hutjes RW (2023). Landscape restoration and greening in Africa. Environmental Research Letters, 18(6): 064020. https://doi.org/10.1088/1748-9326/acd395

Singgalen YA (2022). Vegetation index and mangrove forest utilization through ecotourism development in Dodola and Guraping of North Maluku Province. Jurnal Manajemen Hutan Tropika, 28(2): 150-161. https://doi.org/10.7226/jtfm.28.2.150

Taffuri A, Sciullo A, Diemer A, and Nedelciu CE (2021). Integrating circular bioeconomy and urban dynamics to define an innovative management of bio-waste: The study case of Turin. Sustainability, 13(11): 6224. https://doi.org/10.3390/su13116224

Taillie PJ, Roman-Cuesta R, Lagomasino D, Cifuentes-Jara M, Fatoyinbo T, Ott LE, and Poulter B (2020). Widespread mangrove damage resulting from the 2017 Atlantic mega hurricane season. Environmental Research Letters, 15(6): 064010. https://doi.org/10.1088/1748-9326/ab82cf

Ullah S, Abid A, Aslam W, Noor RS, Waqas MM, and Gang T (2021). Predicting behavioral intention of rural inhabitants toward economic incentive for deforestation in Gilgit-Baltistan, Pakistan. Sustainability, 13(2): 617. https://doi.org/10.3390/su13020617

Vasquez J, Acevedo-Barrios R, Miranda-Castro W, Guerrero M, and Meneses-Ospina L (2024). Determining changes in mangrove cover using remote sensing with Landsat images: A review. Water, Air, and Soil Pollution, 235: 18. https://doi.org/10.1007/s11270-023-06788-6

Wang R, Xia H, Qin Y, Niu W, Pan L, Li R, and Fu P (2020). Dynamic monitoring of surface water area during 1989–2019 in the Hetao plain using Landsat data in Google Earth engine. Water, 12(11): 3010. https://doi.org/10.3390/w12113010