

UTILIZATION OF ARTIFICIAL INTELLIGENCE TO ASSESS THE PERCENTAGE COVER OF SEAGRASS BEDS

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Abstract

Seagrass meadows are vital coastal ecosystems that play a crucial role in the survival of marine life and maintaining the balance of coastal ecosystems. Traditional assessments of seagrass meadow health are conducted through field survey methods that are intensive, time-consuming, and expensive. These methods are often limited in spatial and temporal coverage. This study aims to examine the conventional methods for assessing seagrass cover and describe the application of Artificial Intelligence in seagrass meadow cover analysis. Through a comprehensive literature review, this research analyzes various previous studies on conventional methods and the use of AI for assessing seagrass meadow cover. The results of the review show that conventional methods for assessing seagrass cover can provide accurate and detailed data on seagrass meadow conditions, including cover percentage, seagrass species, and seagrass health. These methods are flexible and can be adapted to various field conditions and research objectives. However, conventional methods also have several limitations. They require significant time and financial resources, especially for large areas. Additionally, their spatial coverage is limited, and the analysis results can be influenced by observer subjectivity. Artificial Intelligence (AI) has opened new opportunities in marine ecology, particularly in seagrass meadow monitoring. Deep learning techniques, a branch of AI, enable automated and accurate image analysis to identify and measure seagrass meadow cover. Thus, AI offers a more efficient, accurate, and objective solution compared to conventional methods. The ability of AI to process large and complex datasets allows for broader and more frequent seagrass meadow monitoring, providing more comprehensive information on the condition of seagrass ecosystems.

Keywords: Artificial intelligence, Conventional, Percentage, Seagrass beds.

INTRODUCTION

Seagrass meadows are crucial coastal ecosystems that play a vital role in supporting marine life and maintaining the balance of coastal ecosystems. These ecosystems provide a range of critical ecological functions, such as being primary producers, sediment stabilizers, habitats for various marine organisms, and filters for pollutants. However, seagrass meadows worldwide, including in Indonesia, are under serious threat due to human activities such as coastal development, pollution, and climate change.

Traditionally, the health assessment of seagrass meadows has been conducted through field surveys that are labor-intensive and time-consuming. These methods are often limited in spatial and temporal coverage, making it challenging to monitor changes in seagrass conditions comprehensively and sustainably. Therefore, more efficient and accurate methods are needed to monitor the health of seagrass meadows on a larger scale.

Artificial intelligence (AI) has rapidly advanced in recent years and has been applied across various fields, including marine science. AI offers significant potential to address challenges in monitoring and assessing the health of seagrass meadows. With its ability to process complex and large datasets, AI can be utilized to analyze high-resolution satellite imagery, oceanographic data,

and other *in-situ* data to generate more accurate and comprehensive information on the condition of seagrass meadows.

Seagrass meadows, as crucial coastal ecosystems, face various threats due to human activities and climate change. Traditionally, the health assessment of seagrass meadows has been conducted through intensive and time-consuming field survey methods. These methods are often limited in spatial and temporal scope, making it difficult to monitor changes in seagrass conditions comprehensively and sustainably. Additionally, the interpretation of field survey data is often subjective and prone to human error.

To address these limitations, this study aims to develop a more efficient and objective method for assessing the health of seagrass meadows. One promising approach is the utilization of artificial intelligence. However, the application of artificial intelligence in this context still faces several challenges, such as the lack of high-quality data, the complexity of algorithms, and the need for robust model validation. Therefore, this research will focus on developing an artificial intelligence model that can accurately and reliably estimate the percentage of seagrass cover as an indicator of ecosystem health.

LITERATURE REVIEW

Seagrass

Seagrasses are flowering plants that can thrive in shallow marine waters. In coastal areas, seagrasses can form seagrass meadows, which consist of one or several species of seagrass (Tangke & Faperta, 2010).

Seagrasses are flowering plants that grow underwater and are found on every continent except Antarctica, primarily along coastlines and estuaries. Seagrasses can be found from intertidal zones to depths of 90 meters. Extensive areas inhabited by seagrasses are often referred to as seagrass meadows or seagrass beds, and their size can vary from a few square meters to hundreds of square kilometers (Short *et al.*, 2016).



Figures 1. Seagrass illustration (Source: EcoNusa)

Benefit of Seagrass

Seagrasses have numerous important benefits for marine ecosystems and the surrounding environment. Below are some of the main benefits of seagrasses.

Philips & Menez (1988) stated that seagrasses have been utilized as a commodity by communities both traditionally and in modern times. Traditionally, seagrasses have been used for:

1. Compost and fertilizer

2. Cigarettes and children's toys
3. Woven baskets
4. Dikes for embankments
5. Mattress stuffing
6. Making fishing nets

In modern times, seagrasses have been utilized for:

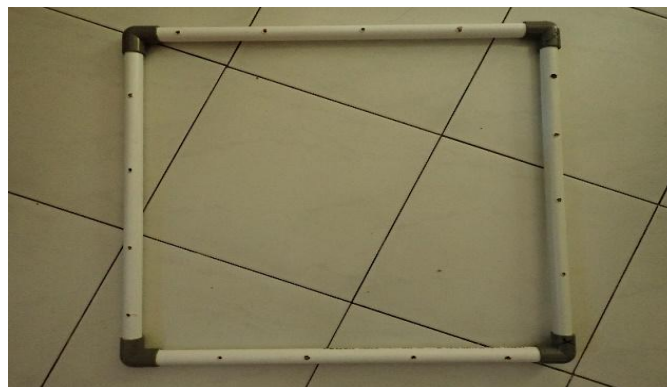
- | | |
|---------------------------------------|----------------------------------|
| 1. Waste filtration | 4. Food |
| 2. Coastal stabilization | 5. Medicine |
| 3. Raw materials for paper production | 6. Sources of chemical compounds |

Seagrasses sometimes form communities that serve as habitats for various types of marine animals. These seagrass communities can also slow water movement. Some species of seagrasses can even be consumed by coastal communities.

The existence of seagrass ecosystems is still not widely recognized, either among academics or the general public, compared to other ecosystems like coral reefs and mangroves. However, these ecosystems in coastal areas form an interconnected system that works together to perform ecological functions (Tangke, 2010).

Method for Calculating Seagrass Cover Percentage

To calculate the percentage of seagrass cover in aquatic environments, one commonly used approach is the **quadrant transect method**. This method involves the use of transects and square-shaped frames (quadrats). Data collection is conducted by setting up three transects, each 100 meters long, with a 50-meter distance between adjacent transects, resulting in a total area of $100 \times 100 \text{ m}^2$. Quadrats are placed 10 meters apart along each transect, resulting in a total of 11 quadrats per transect.



Figures 2. Transect Quadrat

The process begins by determining the geographic coordinates of the sampling location. The first step is to lay out a 100-meter transect line from the sea towards the shore. Next, $50 \times 50 \text{ cm}^2$ quadrats are placed along the transect, starting at the 0-meter point on the right side of the transect line.

Each quadrat is divided into four smaller sections to estimate the percentage of seagrass cover within it. This division helps to measure and calculate the coverage more accurately and systematically (Bongga *et al.*, 2021).

Artificial Intelligence (AI)

According to (M. Sobron & Yamin Lubis, 2021) Artificial Intelligence (AI) refers to computer systems capable of performing tasks that typically require human intelligence. This technology enables systems to make decisions by analyzing and utilizing the data available within them. The processes involved in AI include learning, reasoning, and self-improvement capabilities. These processes are comparable to how humans analyze before making decisions.

Advantages of Artificial Intelligence

The use of AI in assessing seagrass cover offers several advantages, including:

- **Efficiency:** Data analysis processes can be performed automatically and quickly, enabling more frequent and comprehensive monitoring.
- **Accuracy:** Well-trained deep learning models can achieve high levels of accuracy in identifying and classifying seagrass species and calculating cover percentages.
- **Wide Coverage:** Satellite imagery enables large-scale monitoring of seagrass beds, including in areas that are difficult to access.
- **Objectivity:** Decisions generated by AI models are more objective and have minimal bias compared to manual assessments.

AI-Based Software for Seagrass Cover Assessment

With advancements in AI technology, particularly in deep learning, we can utilize a variety of software and techniques to analyze satellite images, aerial photographs, and other data to map and monitor seagrass cover.

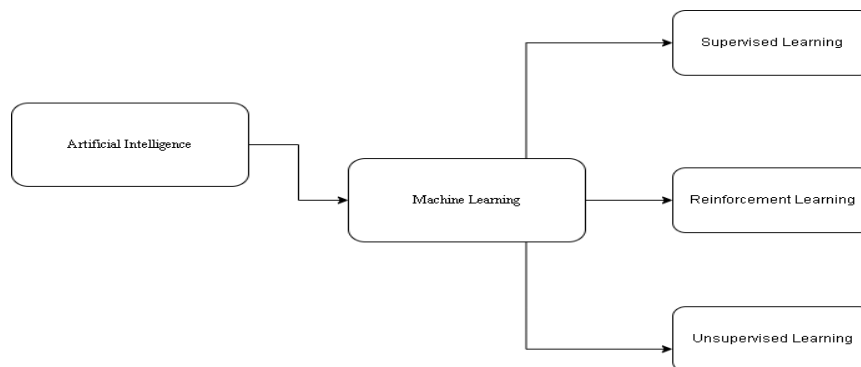
1. **Deep Learning Frameworks:**
 - a) **Tensor Flow and PyTorch:** The two most popular and flexible frameworks for building deep learning models. They provide a wide range of tools and libraries for creating complex models, such as convolutional neural networks (CNN) for image analysis.
 - b) **Keras:** A high-level API that runs on top of TensorFlow or Theano, making it more user-friendly for beginners.
2. **Image Processing Software:**
 - **ENVI, ERDAS Imagine, QGIS:** These tools are commonly used for image pre-processing, such as atmospheric correction, geo-referencing, and contrast enhancement. The pre-processed outputs can then be used as inputs for deep learning models.
3. **Integrated Development Environments (IDE):**
 - **Jupyter Notebook, Google Colab:** Interactive environments for writing, running, and visualizing Python code. They are highly suitable for experimentation and model development.

Examples of AI Applications in Seagrass Cover Assessment:

- **Automatic Seagrass Detection:** Utilizing CNNs to identify and highlight seagrass areas in satellite or aerial imagery.
- **Habitat Segmentation:** Dividing images into different classes (e.g., seagrass beds, seaweed, coral reefs) for further analysis.
- **Change Monitoring:** Comparing images over time to detect changes in seagrass cover caused by natural or human factors.
- **Biomass Estimation:** Using multispectral data to estimate seagrass biomass.

Machine Learning (ML)

According to (M. Sobron & Yamin Lubis, 2021) Artificial Intelligence (AI) refers to computer systems capable of performing tasks that typically require human intelligence. This technology enables systems to make decisions by analyzing and utilizing the data available within them. The processes involved in AI include learning, reasoning, and self-improvement capabilities. These processes are comparable to how humans analyze before making decisions (Cholissodin & Soebroto, 2019).



Figures 3. Artificial intelligence and machine learning scheme

In Machine Learning, there are three main categories commonly used to classify its methods and approaches. These categories are:

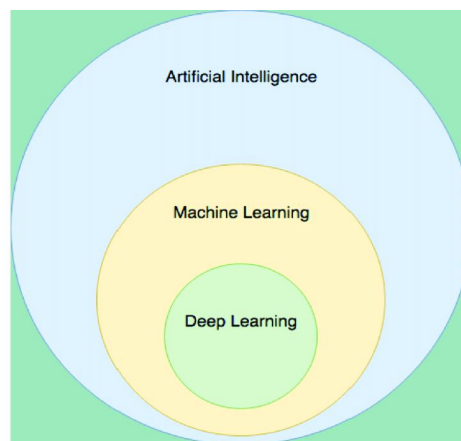
- **Supervised Learning:**
In supervised learning, Machine Learning (ML) models are trained using data that already has predefined categories or labels. The main focus of supervised learning is to identify patterns and relationships between features (inputs) and labels (outputs) that have been specified beforehand.
- **Unsupervised Learning:**
Unsupervised learning involves analyzing data that does not have predefined labels or categories. In this context, ML models learn to uncover hidden patterns, structures, and relationships in the data without prior knowledge of expected outcomes.
- **Reinforcement Learning:**
Reinforcement learning is a category where ML models learn through interaction with a dynamic environment. The goal of reinforcement learning is to maximize rewards by learning optimal decisions through interactive experiences.

Deep Learning (DL)

Deep Learning is an advanced branch of Machine Learning (ML) research that consists of multiple hidden layers in artificial neural networks. The Deep Learning approach employs nonlinear transformations and high-level abstraction models to handle large datasets effectively (Alam *et al.*, 2019).

Relevant Deep Learning Techniques:

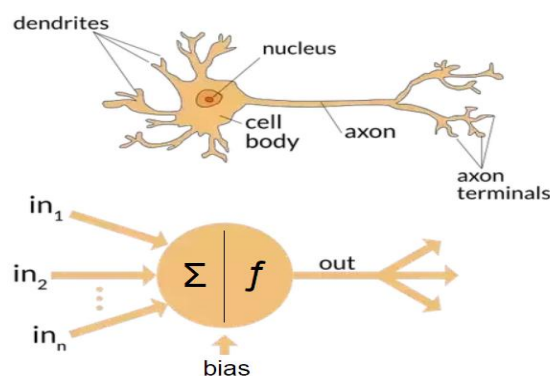
- **Convolutional Neural Networks (CNN):** Highly effective for analyzing image data, such as identifying and classifying types of seagrass meadows.
- **Semantic Segmentation:** A technique to classify each pixel in an image into specific classes (e.g., seagrass meadows, sand, water).
- **Object Detection:** Used to detect specific objects in images, such as individual seagrass or degraded seagrass meadow areas.



Figures 4. Subset (Set) in Deep Learning (Source: ResearchGate)

Neural Network (NN)

Artificial Neural Networks (NN) are a technique in Machine Learning (ML) that aims to mimic human neurons, which are the fundamental components of the brain. NN consists of an input layer and an output layer. Each layer comprises one or more neurons with an activation function that determines the output of each neuron. The capability of NN can be enhanced by adding hidden layers (Tarkus *et al.*, 2020).



Figures 5. Similarities between human nerves and neural networks
(Source: Towards Data Science)

Common Neural Network Architectures

There are several commonly used neural network architectures, including:

- **Multilayer Perceptron (MLP):**

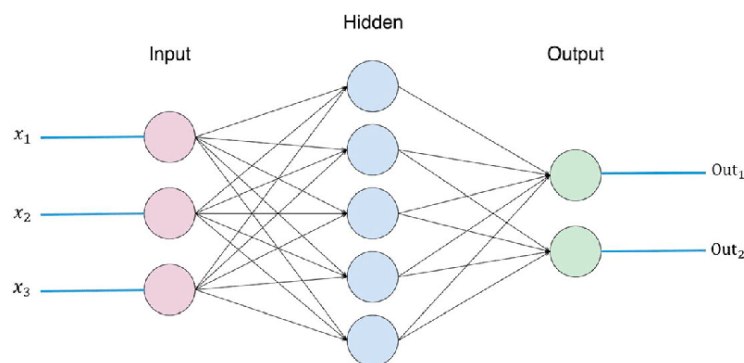
A Multilayer Perceptron is an artificial neural network consisting of multiple neurons connected by weights. These neurons are organized into layers, which include an input layer, one or more hidden layers, and an output layer (Navastara Adni Dini *et al.*, 2018).

- **Convolutional Neural Network (CNN):**

A Convolutional Neural Network (CNN) is an evolution of the Multilayer Perceptron (MLP) specifically designed to process two-dimensional data, such as images. CNN falls under the category of Deep Neural Networks due to its deep network structure and is often used in applications involving image data (I Wayan Suartika E.P *et al.*, 2016).

- **Recurrent Neural Network (RNN):**

A Recurrent Neural Network (RNN) is a type of artificial neural network with the capability to handle sequential data through recurrent processing. RNNs are often used to process sequential input data, where computations are performed repeatedly over time (Tarkus *et al.*, 2020).



Figures 6. Illustration of structure in neural networks (Source: ResearchGate))

RESEARCH METHOD

This study employs a literature review approach to examine various studies that have utilized artificial intelligence to assess the percentage of seagrass cover. The initial stage involves identifying relevant scientific databases, such as Scopus, Web of Science, and Google Scholar. Keywords used include "seagrass," "artificial intelligence," "image classification," "deep learning," and "remote sensing." Selected articles are critically analyzed to extract information on the methods employed, the types of artificial intelligence algorithms applied, and the results obtained. A comparative analysis is conducted to identify trends, gaps, and further development potential in this field.

The results of this literature review are expected to provide a comprehensive overview of the application of artificial intelligence in seagrass cover assessment. Additionally, this study aims to identify the most effective artificial intelligence algorithms, factors influencing result accuracy, and challenges faced in implementing this technology. The findings from this research could serve as a foundation for further studies, the development of seagrass management policies, and the broader application of artificial intelligence technology in marine fields.

RESULTS AND DISCUSSION

Challenges of Conventional Methods in Seagrass Cover Assessment

Seagrass cover assessment involves various methods, each with its own advantages and limitations. Visual methods, such as quadrat transects and quadrat photography, offer flexibility and relatively low costs but are prone to observer error and limited to small areas. Remote sensing, using satellite imagery, LiDAR, and drones, enables large-scale mapping (Fauzi & Kurniawan, 2020) but requires expensive equipment and is dependent on weather conditions. Other methods, such as underwater video (McKenzie & Yoshida, 2009), provide high morphological detail of seagrass, especially in hard-to-reach areas, while acoustic sensors like side-scan sonar (Short *et al.*, 2015) can map large areas, albeit with lower resolution. The choice of method depends on the research objectives, the scale of the area, and the availability of resources. Combining multiple methods is often necessary to achieve a comprehensive understanding of seagrass meadow distribution and condition.

Visual methods are classic approaches commonly used in assessing seagrass cover. These methods offer flexibility and are relatively easy to implement in the field. For instance, the quadrat transect method involves systematically placing quadrats to directly observe seagrass cover. Quadrat photography is a more advanced approach, where visual observations are replaced by digital image analysis. This allows for more objective measurements and enables data review at a later time. The line intercept method provides a simpler approach using a line as a measuring tool. The advantages of visual methods include relatively low costs, no need for specialized equipment, and the ability to provide detailed data at a local scale. However, their limitations include potential observation errors due to observer subjectivity, constraints in covering large areas, and difficulties in identifying similar seagrass species. Moreover, these methods are vulnerable to the effects of underwater lighting conditions, which can hinder observations.

Remote sensing methods offer an efficient and effective approach for mapping the distribution and cover of seagrass meadows on a large scale. Satellite remote sensing utilizes high-resolution satellite imagery to classify image pixels into various classes, including seagrass. A study by Fauzi and Kurniawan (2020) demonstrated that Sentinel-2 imagery can be used to map seagrass meadows in the waters of Pari Island with fairly good accuracy. LiDAR technology provides highly accurate data on underwater elevation, enabling the creation of detailed digital elevation models for seagrass distribution mapping. Drones equipped with high-resolution cameras can produce aerial images with high spatial resolution, offering flexibility in data acquisition. The main advantages of remote sensing methods are their ability to cover large areas, produce objective data, and enable periodic monitoring of seagrass cover changes. However, their drawbacks include high hardware and software costs, dependence on favorable weather conditions, and data processing complexity. Nonetheless, remote sensing has become an invaluable tool in seagrass ecosystem research and management.

Other methods also play a crucial role. Underwater video allows detailed observation of seagrass morphology in hard-to-reach areas, as demonstrated by McKenzie and Yoshida (2009). However, this method is limited to small areas and requires considerable time. Acoustic sensors, such as side-scan sonar, can map large areas, albeit at a lower resolution. Research by Short *et al.* (2015) showed that side-scan sonar can be used to identify seagrass habitats on a large scale. The choice of method depends on the research objectives, area scale, and resource availability.

Combining several methods is often necessary to gain a comprehensive understanding of seagrass distribution and condition.

CONCLUSION

Seagrass meadows are vital coastal ecosystems that play a crucial role in marine life and coastal balance. However, these ecosystems are facing significant threats from human activities and climate change. Traditional assessment methods are often time-consuming, labor-intensive, and limited in scope.

Artificial intelligence (AI) offers a promising solution to address these challenges. By leveraging AI techniques, such as machine learning and deep learning, we can develop more efficient and accurate methods for monitoring and assessing seagrass health. AI can analyze large datasets from satellite imagery, oceanographic data, and field surveys to identify seagrass cover, distribution, and health trends.

While AI presents significant potential, challenges such as data quality, model complexity, and validation remain. Integrating AI with traditional methods can provide a more comprehensive and reliable approach to seagrass monitoring. By combining the strengths of both approaches, we can better understand and protect these valuable ecosystems.

The future of seagrass bed coverage assessment lies in the continued development and application of AI technologies. As AI advances, we can expect more efficient and accurate monitoring methods, leading to better informed conservation and management decisions for seagrass meadows.

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