

Spatial distribution of benthic habitat derived from Planetscope image in shallow water of Kahyapu Village, Enggano Island

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Abstract. The shallow waters of Kahyapu Village has an essential benthic habitat which is important to monitor due to the dynamic influenced by the Indian Ocean and anthropogenic activities. Benthic habitat monitoring can be used through utilize the Planetscope image, which is a high-resolution satellite image that provides a daily image acquired and detailed information, such as benthic habitat. This research aims to map the spatial distribution of benthic habitats using Planetscope images derived from three different set of bands processed differently: Principal Component Analysis transformed surface reflectance (SR-PC band), PC-transformed sunglint-corrected bands (Deglint-PC band) and PC-transformed depth invariant index bands (CII-PC band). A field survey was carried out using an Underwater Photo Transect based on variation of benthic habitat in the field. Maximum likelihood image classification was used to train the benthic habitat map using model samples from field surveys. A major benthic habitat class was determined, which consisted of coral reefs, seagrass, macroalgae, and substrate. Seagrass reached approximately 48% (911.46 hectares), substrate covered 37% (705.12 hectares), coral reefs closed nearly 13% (249.63 hectares), and macroalgae just got 2% (39.78 hectares) of the total of benthic habitat distribution. The benthic habitat spatial distribution illustrated that seagrass and substrate class dominated the benthic habitat spatial distribution, while the macroalgae class was challenging to map.

1 Introduction

Enggano Island is the outer island on the west side of Sumatera, which borders directly on the Indian Ocean and has the most complete coastal resources consisting of coral reefs, macroalgae, mangrove, and seagrass beds. However, the dynamics of marine oceanography in the Indian Ocean will impact the sustainability of coastal ecosystems, including rising sea levels, rising sea surface temperatures, increasing frequency of tidal waves, and coastal erosion [1]. Land use change and coastal development in Enggano Island will influence the coastal disaster and loss of endemic flora and fauna due to coastal habitat degradation [2].

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Monitoring the coastal habitat periodically is essential and can be used as baseline data to monitor its sustainability in the future. Coastal habitats can be monitored using remote sensing technology that is more effective and efficient and covers wide areas [3]. Remote sensing can detect coastal environment indicators so coastal habitat conditions and trends can be monitored [4].

Planetscope image is one of the consistent high-resolution satellite images and performs well for benthic habitat mapping in different benthic habitat classes [5, 6, 7]. It produced good accuracy for using Maximum Likelihood, Minimum Distance, and Support Vector Machine to obtain five benthic habitat classes [8]. Daily acquisition of Planetscope images can improve accuracy and consistency in numerous characteristics and a complex benthic cover [9]. Frequently acquiring high-temporal Planetscope images ensures effective monitoring of benthic habitat changes and seagrass cover changes in limited accessibility of coastal areas [10].

The application of the principal component PC-transformed in assessing the benthic habitat in Labuan Bajo shallow waters using machine learning classification on Planetscope image has yielded promising results. It produced 63.57% on PC-transformed SR band, 67.05% on Deglint PC-transformed band, and 72.09% water column PC-transformed band [11]. Benthic habitat mapping in Enggano has been reported, with a notable study on Dua Island using Sentinel-2 and maximum likelihood classification, which produced an overall accuracy of 85.45% for coral reefs, seagrass, sand, and rubble class [12]. However, the utilization of Planetscope image using PC-transformed on maximum likelihood classifier for benthic habitat mapping in the complex shallow waters of Kahyapu remains unexplored. This research aims to fill this gap and map benthic habitat spatial variation using Planetscope images in Kahyapu shallow waters.

2 Methods

Planetscope 3B level, acquired on 12 September 2023, was used to derive benthic habitat variation. It is a surface reflectance and top-of-atmospheric correction level product with four optical bands, which consist of blue, green, red, and near-infrared. A Planetscope image is a surface reflectance product that the digital number still needs to be converted using reflectance coefficient from each spectral band [13, 14]. In this study, a digital number from each band on the Planetscope image was converted using each spectral band's coefficient to obtain the corrected surface reflectance level.

Field samples were designed according to benthic habitat variation on the true color image. A field survey was conducted from 31 July to 3 August 2023 in the shallow waters of Kahyapu village. Benthic habitat field data were collected using an underwater photo transect with interval 2 m of transect [15]. Then, it is divided into two groups: model samples and validation samples. Field model and validation sample distribution of benthic habitat variation illustrated in Figure 1 which represents sample point distribution of each pixel size (3 x 3 m) on Planetscope image. Benthic samples are distribute on the eastern Kahyapu shallow waters and the southern Dua Island, which can be seen on the left side of Figure 1. The upper right side shows the model sample points in a zoomed view, while the lower right side shows the model points sample, which distributed in a pixel size of 3 x 3 m on the Planetscope image.

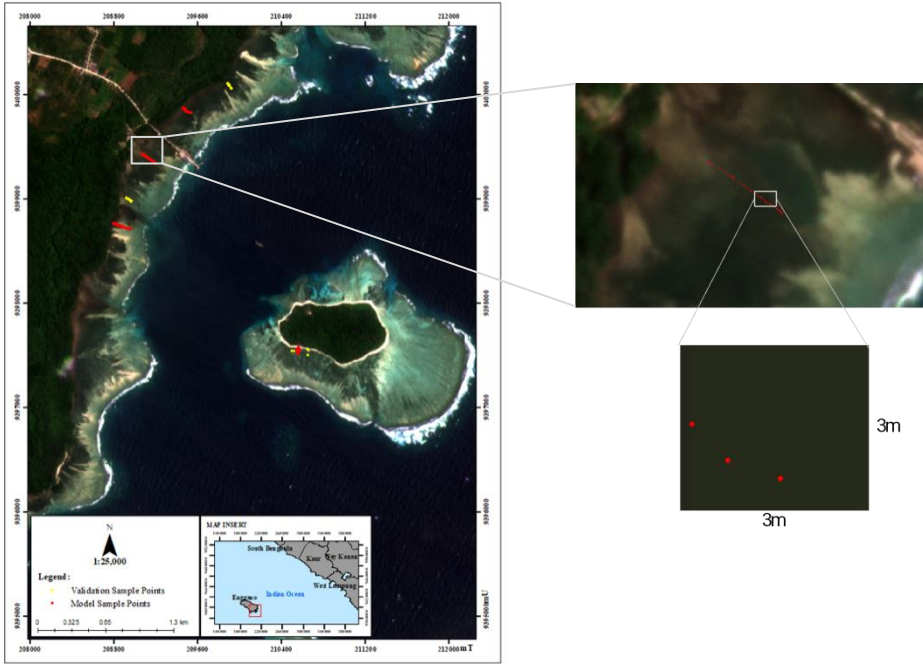


Fig. 1. Field samples distribution in Kahyapu shallow waters: field survey samples distribution on the left side, model samples of benthic habitat on the upper right side, and point samples of each pixel size on Planetscope image on the lower right side.

Sunglint correction was applied to the surface reflectance image using a correlation between each visible and near-infrared band [16]. The depth-water invariant index (DII) was applied to the decline-corrected image using the Lyzenga transformation to remove the water column effect and maximize the spectral reflectance of the benthic habitat [17]. Image masking was applied to separate shallow waters from deep waters and land objects. Principle Component Analysis (PCA) transformation was applied to three different data sets: surface reflectance bands (SR-PC band), sunglint-corrected bands (Deglint-PC band), and depth invariant index bands (DII-PC band). These final transformed three data sets were subsequently used as inputs to the image classification using a maximum likelihood classifier on the image. PCA is a transformation technique of the original remote sensed dataset into smaller datasets to optimize the potential information. PCA transformation can be used using the formula [18]:

$$R_{kp} = \frac{a_{kp}x\sqrt{\gamma_p}}{\sqrt{var_k}} \quad (1)$$

Where : a_{kp} = eigenvector for band k and component p , γ_p = p th eigenvalue, var_k = variance of band k in the covariance matrix.

A total of 288 points of training samples from the field survey, 60% of the points sample is used to train the model and 40% of the points sample is used to validate the benthic habitat map. Each photo transect was interpreted and analyzed using Coral Point Count with Excel extensions (CPCe) to obtain benthic habitat variation from the field. The benthic habitat maps were constructed using the benthic habitat major class, which were determined into coral reefs (live coral and dead coral), seagrass, macroalgae, and substrate (sand, mud, rubble, and rock). Validation sample points were selected to assess the benthic habitat map using the Confusion Matrix post-classification [19].

3 Results

The study area on the eastern side of Kahyapu Village has moderate turbidity due to the muddy sand substrate type, approximately less than five meters deep, and near human activities such as port activities, settlements, and a small river. This site was dominated by seagrass beds and hard corals distributed along the shallow waters. Site characteristic of the southern Dua Island has clear waters with a sand substrate and less than five meters deep. This site is a small island that used to be a local tourism destination, so it has spotless and clear water. However, rubble was still dominant in this area as strong winds and tides from the Indian Ocean directly influence this site.

Due to high tides and strong wind conditions, field surveys were limited in the southeast of Kahyapu village and the south of Dua island. Regarding benthic habitat variation in the shallow waters of Kahyapu village can be generated from photo transect analysis, which is evaluated into four major benthic habitat classes: coral reefs, seagrass, macroalgae, and substrate. All benthic habitat major classes can be found in the shallow waters of Kahyapu village.

Figure 2 provides the spatial distribution information of benthic habitat according to three different corrected level band inputs. Coral reefs are classified along the shallow waters after seagrass beds. However, it is still classified as seagrass on the southeast side of Dua Island and as macroalgae in the northeast of Kahyapu village. Coral reefs were associated with seagrass, macroalgae, and rubble or rock as substrate.

Seagrass class can be found along the shallow waters, mainly in the southeast of Kahyapu village, southern Dua Island, and Merbau Island. However, seagrass was misclassified as macroalgae from the northeast to the east of Kahyapu. Moreover, it was classified as a coral reef on the northwest side of Merbau Island. Seagrass classification was also overestimated on the southeast side of Dua Island and Merbau Island.

Macroalgae were rarely found in the shallow water of Kahyapu, which makes them difficult to map. They were overestimated on the northeast side of Kahyapu Island and classified as seagrass. Furthermore, they are misclassified as substrates on the east side of the sandbar in the Kahyapu waters. In the actual field, macroalgae was associated with coral reefs and rubble. Substrate was the second dominant object found in the shallow water of Kahyapu. It was also misclassified as seagrass and macroalgae in the southern part of Kahyapu waters. Substrate from sand type was associated with seagrass, while rubble was associated with macroalgae in the field.

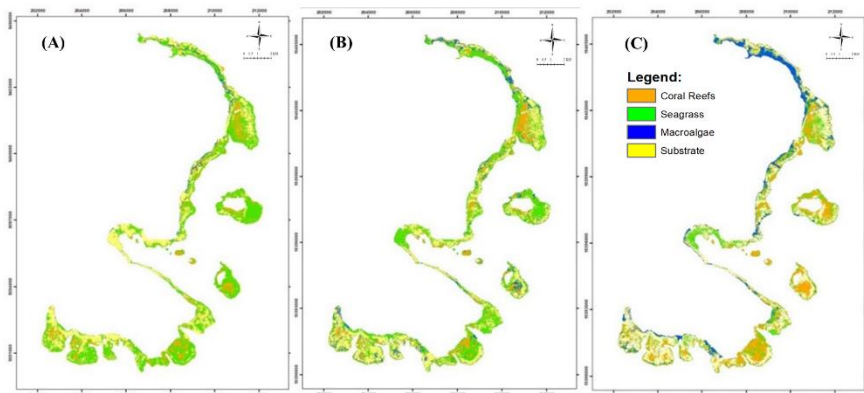


Fig. 2. Map of benthic habitat map from different band input (a) Surface reflectance PC band; (b) Glint PC band, and (c) DII PC band

Benthic habitat distribution in Figure 3 showed that seagrass beds and substrat were the dominant benthic habitat type from SR-PC and Glint-PC band. At the same time, substrate is a dominant benthic habitat from DII-PC band. In contrast, macroalgae was the smallest habitat covered benthic area in Kahyapu village among three input bands. The highest area cover of coral reefs was produced from DII-PC band (520.76 hectares), while the smallest area was produced from SR-PC band (249.63 hectares). The seagrass beds has the highest coverage area produced from SR-PC band (911.46 hectares), while DII-PC band obtained the lowest coverage area of seagrass beds (399.36 hectares). Although macroalga was the smallest benthic cover, the highest value with 224.56 hectares produced DII-PC band, while the lowest value reached 39.77 hectares of macroalgae cover. Substrate cover gradually increase from SR-PC band to DII-PC band with 705.12 hectares, 731.50 hectares, and 761.31 hectares, respectively.

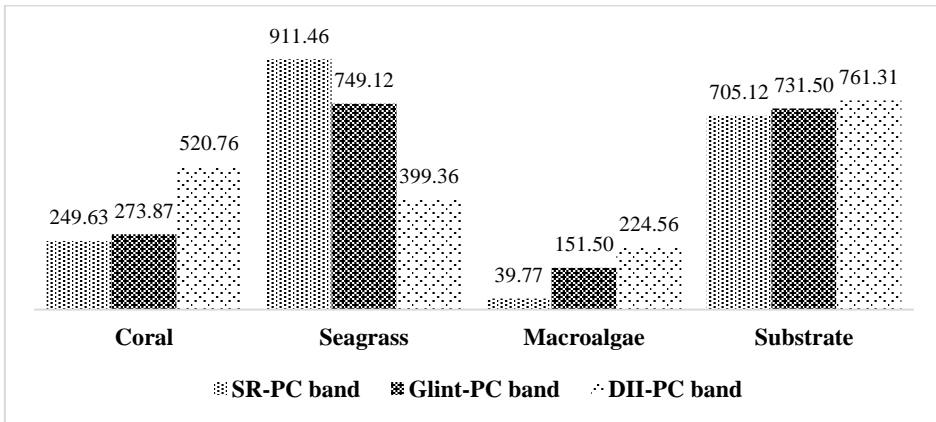


Fig. 3. Benthic habitat area in the shallow waters of Kahyapu village from SR-PC, Glint-PC, and DII-PC band

4 Discussion

Coral is identified as being associated with macroalgae and seagrass. Brown macroalgae, related to hard corals in the field, have similar pigments to coral lifeforms [11]. Coral is also identified as seagrass, especially on the southern side of Dua Island. Misclassification is still produced in benthic habitat classification due to similar spectral signatures among benthic habitat communities [8]. Coral reefs in the shallow waters of Kahyapu are categorized into hard corals and dead corals. Hard corals are dominated by coral branching and massive coral. In contrast, other corals are identified as acropora, encrusting, foliose, heliopora, and submassive. Hard coral lifeforms, namely Acropora branching, Acropora digitate, Acropora tabulate, coral branching, coral encrusting, coral submassive, coral mushroom, and coral millipore, have covered the benthic habitat in Enggano Island [20].

Benthic habitat distribution in the shallow water of Kahyapu is dominated by seagrass. Five seagrass genera were identified: Cymodocea, Halophila, Halodule, Thalassia, and Enhalus. Some of the seagrass classes found along the shallow waters are identified as being coral reefs and substrates. Seagrass is associated with sand as a substrate in the southeastern Kahyapu while it is associated with corals in the southern Dua Island. *Enhalus acoroides* was a dominant seagrass species on the coast of Kahyapu because it lived near mangroves with smooth substrate [21].

Macroalgae is the most difficult object to map because it is not abundant and is associated with other benthic habitats such as seagrass and substrate. However, macroalga can be found in the shallow water of Kahyapu, namely *Halimeda* sp., *Padina* sp., coralline algae, and turf

algae. These macroalgae are associated with rubble in the field. The limited number of samples and low cover distribution in the field affected the classification performance of macroalgae in the satellite image [22].

The substrate also dominates the benthic habitat variation, which is dominated by rubble and sand, while a rock is slightly found in the shallow water of Kahyapu. However, some substrate classes are identified as seagrass and macroalgae. Seagrass cover in Dua Island is categorized into moderate to low density [23, 24]. Strong sand reflectance near low-density seagrass contributes to the pixel classification [24].

5 Conclusion

Kahyapu shallow waters are dominated by seagrass habitat, encompassing 48% of the total benthic habitat mapped in this study, followed by substrate coverage with 37%. Coral reefs and macroalgae covered less than 15% of the total benthic habitat coverage. PCA transformation was proven to improve the accuracy of the benthic habitat map when applying a maximum likelihood classifier for major benthic habitat classification schemes in complex shallow waters.

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