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Continuous Seagrass Density Estimation Using Sentinel-2 Imagery On An Intertidal Flat

Xuan Truong Trinh[1*], Wataru Takeuchi[2]

[1]*Institute of Industrial Science,*
4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, JAPAN, *xuantruongtrinh93@g.ecc.u-tokyo.ac.jp*

[2]*Institute of Industrial Science,*
4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, JAPAN, *wataru@iis.u-tokyo.ac.jp*

Abstract:

Seagrass ecosystems play important roles in supporting fishery, enhancing biodiversity, and sequestering carbon. However, seagrass ecosystems are being degraded, largely due to anthropogenic activities such as land reclamation and pollution. Therefore, quantifying and monitoring seagrass ecosystems and their services are crucial for conservation. There have been many efforts in quantifying seagrass distribution, yet we still lack measurements in terms of seagrass density. This limitation hinders the quantification of seagrass biomass and net primary productivity (NPP). As direct measurements with field surveys are costly, remote sensing-based estimation is a promising approach for such quantification. For those models, seagrass density is a crucial parameter to estimate biomass and NPP of seagrass. However, recent research could classify seagrass as two to five discrete levels of density, but not a continuous range, leading to gaps in estimation. There have been few attempts for continuous density estimation for monospecific seagrass beds, but not for seagrass beds with mixed or multiple species. To tackle that issue, this research aims to provide a continuous quantification of seagrass density through a combination of UAV and satellite images.

The study site is at an intertidal flat in Phu Quoc islands, Kien Giang Province, Vietnam. The estimation of density was done by spectrally unmixing a Sentinel-2 image acquired on 2020-02-05. Three classes that represent the land cover observed at the site are large seagrass (*Enhalus acoroides*), small seagrasses (*Thalassia hemprichii, Cymodocea rotundata, Cymodocea serrulata, Halophila ovalis*), and sand. Large seagrasses in satellite images are spectrally different from small seagrass as they create shade under their large leaves, hence differentiated from small seagrasses where self-shading is rare. Endmembers were selected as containing purely pixels of the same land cover, with minimal mixing of other classes. This was verified by examining the histogram of the reflectance of the indicated endmembers, which should show a normal distribution. Spectral unmixing was carried out with the assumption that the reflectance of each pixel is comprised of precisely three classes at a sub-pixel level. The result was an unmixed image where each pixel would have 3 values of the ratio of each of the three classes in the 10m pixel, representing the density of each class. The ground truth was obtained from 4cm resolution UAV images captured at low tide on the same day as the satellite image. The UAV orthomosaic underwent object-based image analysis, where it was first segmented using Simple Non-Iterative Clustering, followed by supervised

classification using the Random Forest classifier into the same three classes. The classified result was downsampled to 10m resolution to calculate the ratio of each of the three classes in the 10m pixel. The unmixed results from the Sentinel-2 image were compared with the UAV classified results in a Pearson correlation test with 1000 points randomly sampled at the study site.

The spectral unmixing results of the Sentinel-2 image are in general agreement with the UAV-derived results. The r values for correlation between pixel ratio estimated from satellite image and UAV image for large seagrass, small seagrass, and sand are: 0.67278 (p <<0.01), 0.55727 (p <<0.01) and 0.85981 (p<<0.01). The unmixing results correctly estimated the areas with the highest concentration of large seagrasses, and where there is only sand. Small seagrass composition is generally less correctly estimated than the other two classes. However, the unmixing results tend to overestimate large seagrass composition and underestimate small seagrass composition. Areas, where only small seagrass was found in the UAV images, were instead estimated to have varying degrees of large seagrass distribution. This discrepancy is especially prevalent at the edge of the seagrass beds where seagrass transition into sands.

The general correctness of the estimation means that there is potential for using spectral unmixing of satellite images to estimate the density of seagrass. However, the difference in estimation could be due to the spectral unmixing model assuming the contribution of only three land cover classes, while ignoring the effects of the water column on reflectance. Moreover, the model overestimation of large seagrass and underestimation of small seagrass ratio could be due to the similarity of their spectral responses, where small seagrass appear brighter green and large seagrass appear darker green. Especially at the edge of the seagrass beds, a higher pixel reflectance could be due to having a higher ratio of small seagrass, or due to having a higher ratio of both large seagrass and sand. In field observations, the transition zone between large seagrass and sand is likely to have small seagrasses. This supports the estimation of UAV-derived results and shows that spectral unmixing of Sentinel-2 images could overestimate the large seagrass at the edge. Spectral unmixing's robustness is still limited in this area, but the uncertainty could be reduced using higher spatial resolution data and more repetition with time series analysis. With the estimated percentage coverage of seagrass in each pixel, biomass estimation of the seagrass meadows could be enhanced. This could reveal spatial patterns concerning bathymetry and morphology or assess the impact of human activities such as fishing or water pollution.

To sum up, this research provided a novel attempt to estimate seagrass percentage cover by spectral unmixing of a Sentinel-2 image. Compared with the UAV derived results, the estimation is generally correct at 0.67278 (p <<0.01), 0.55727 (p <<0.01) and 0.85981 (p<<0.01). However, there is still a discrepancy in estimation, especially at the edge of the seagrass beds. This new approach could further enhance the quantification of seagrass biomass by remote sensing, which would lead to better conservation of the seagrass ecosystems.

Keywords: blue carbon, UAV, spectral unmixing, Object-based Image Analysis, ecosystem