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Application of aerial photography with visible atmospherically resistant index by using unmanned aerial vehicles for seagrass bed classification in Kung Krabaen Bay, Thailand

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Abstract The classification based on VARI resulted in three classes, namely (i) long-leaved species (*Enhalus acoroides*), (ii) short-leaved species (*Halodule pinifolia* and *Halodule uninervis*), and (iii) other objects. The aerial photographs showed clearly differentiation in seagrass species which different digital number value ranges with the VARI approach. The overall accuracy of visual interpretation was higher than supervised classification of 88.88% and 61.11%, respectively. The technique confirmed to be useful for seagrass species mapping in other areas. The results concluded that *H. pinifolia* and *H. uninervis* that distributing on sandy clay and seashell substrates, while *E. acoroides* distributed only on sandy areas.

Keywords: Aerial photography, Visible Atmospherically Resistant Index, Seagrass bed classification

Introduction

The seagrass bed is a fertile coastal ecosystem with high biodiversity, and is necessary habitat for many marine creatures (Paibulkichakul *et al*, 2016) eg *Enhalus acoroides*, *Halodule pinifolia* and *Halodule uninervis*. It is one of the most productive ecosystems, providing shelter and food for animal communities from tiny invertebrates to large fishes, crabs, turtles, marine mammals, and birds. Seagrasses provide many economically valuable services to people as well, such as commercial and recreational fisheries, nature and wildlife tourism (Duffy, 2006).

A study of the distribution of seagrass beds in the Gulf of Thailand found the most seagrass along the coastal zone and islands. The total seagrass area is about 55.2 km^2 which covers the provinces of Trat, Chanthaburi, Rayong, Chon Buri, Phetchaburi, Prachuap Khiri Khan, Chumphon, Surat Thani, Nakhon Si Thammarat, Phatthalung, Songkhla, Pattani, and Narathiwat (Department of marine and coastal resources, 2016).

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Reports on the seagrass situation in Thailand show that the current number of seagrass beds have been continuously decreasing (Waycott *et al.,* 2009) because of human activities including anchoring, mining, coastal construction (breakwaters or seawalls), fishing (using illegal gear) and toxic waste release. The seagrass degradation affects growth, spawning, and survival of marine animals in coastal marine ecosystems. Seagrass disappearance may increase the impact of currents and trigger coastal erosion in some areas. The growing concern about seagrass loss and degradation has made government agencies, coastal and marine resources conservation networks, and private organizations work together to perform the conservation and restoration of seagrass areas (Department of Marine and Coastal Resources, 2016).

Geo-informatic technology refers to the integration of Geographic Information System (GIS), Remote Sensing (RS), and Global Positioning System (GPS). RS technology has rapidly developed in terms of its abilities, such as very high spatial resolution (Kushwaha, 2008). Seagrass exploration using RS technology is based on two data sources, namely satellite imagery and aerial photography. Satellite imagery is suitable for study of a wide area that does not need high spatial resolution. On the other hand, aerial photography is appropriate for smaller areas where very high spatial resolution is required (Mumby *et al*., 1997).

Most vegetation indices combine information contained in two spectral bands, the red and near-infrared (NIR). The Normalized Difference Vegetation Index (NDVI) is one of the common techniques that uses the visible and NIR bands to analyze remote sensing images and assess live green vegetation (Lebourgeois *et al*., 2008). A limitation of NDVI indices is that this technique can't be used to classify objects under water, because NIR light is able to penetrate only a small distance into the water (Adi, 2015).

The Visible Atmospherically Resistant Index (VARI) was developed for the regional estimation of crop conditions. The VARI was more sensitive to the vegetation fraction due to the introduction of blue reflectance (Gitelson *et al.,* 2002a). This is the reason why VARI technique is more suitable for seagrass classification than NDVI technique. Furthermore, it is suitable with the consumer-grade cameras used on Unmanned Aerial Vehicles.

The objective of study was to apply the aerial photographs taken by an Unmanned Aerial Vehicle (UAV) for seagrass classification of *Enhalus acoroides*, *Halodule pinifolia* and *Halodule uninervis*.by using VARI.

Materials and Methods

The process of analyzing seagrass classification of *Enhalus acoroides*, *Halodule pinifolia* and *Halodule uninervis* and status consisted of five steps as shown in Figure.1, namely; (i) aerial photography by using UAV (DJI Mavic) with autonomous flight application on mobile device; (ii) image mosaicking; (iii) data pre-processing, including geometric correction; (iv) detection and classification of seagrass distribution; (v) accuracy assessment by using ground-truth data.

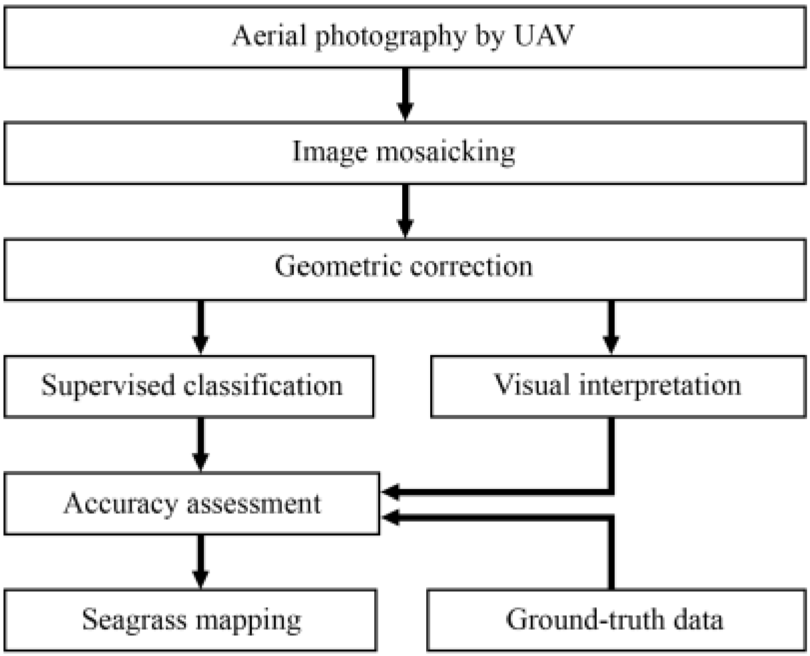

Figure 1. The process of analyzing seagrass classification and seagrass status

Flight planning

Aerial photographs were taken by using DJI Mavic (UAV) with DroneDeploy application software in a free explorer plan which this plan offer the unlimited flight, 500 photos/map, and 5 cm/pixel 2D resolution (DroneDeploy, 2018) at 10.00 a.m. – 3.00 p.m. on 4 July 2017. The UAV flies to take each photograph in each flight line or strip so it overlaps the preceding photograph. The amount of frontlap on each photograph is about 75% and sidelap on each photograph is about 65%. The aerial photos were taken at the altitude flight about 500 meters above the mean sea level. Four flights were made covering an area of about 7.02 km^2, and a total of 139 images (Figure 2). The resolution of a mosaicked image was 16.6 cm/pixel and the root-mean-square error (RMSE) was 5.4 meters. The aerial photograph was geometrically corrected by using 1^{st} order polynomial transformation with RMSE of 1.67 meters to maintain the intensity of the pixels.

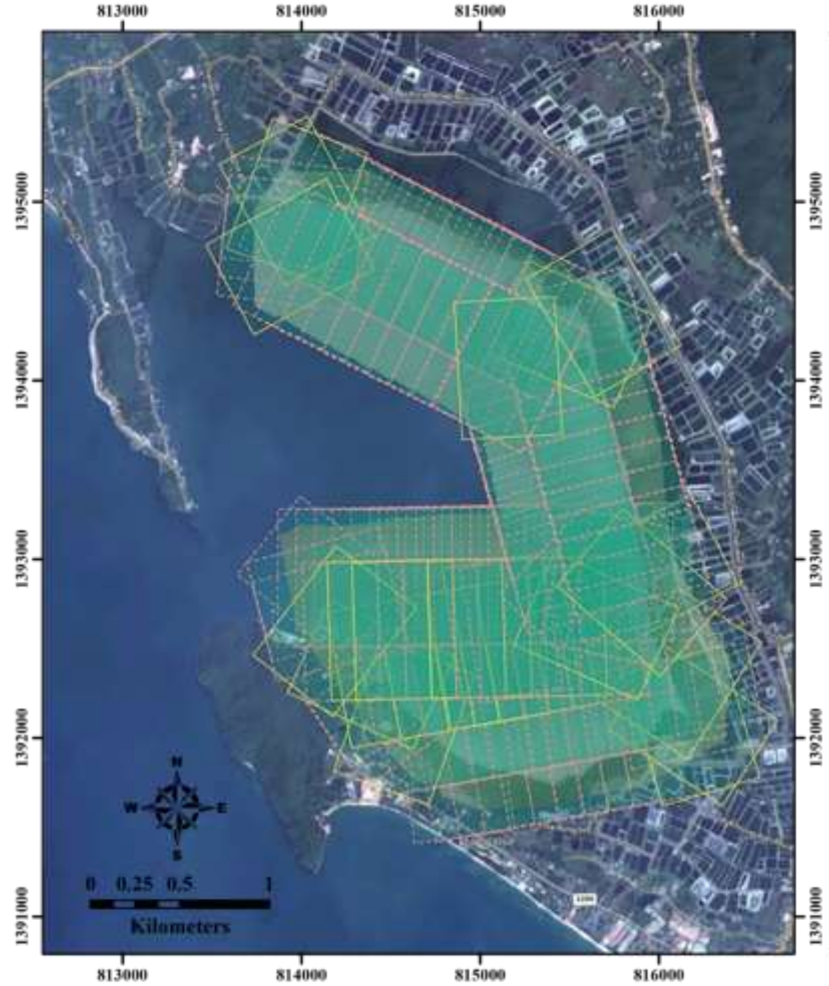

Figure 2. The flight planning in each flight line or strip covering Kung Krabaen Bay area

VARI algorithm

The VARI was developed for the regional estimation of crop conditions by the University of Nebraska. The VARI was more sensitive to vegetation fraction due to the introduction of blue reflectance (Gitelson *et al.*, 2002b). The aerial photograph uses the red, green, and blue channels to make a natural color composite image, and then calculate to make a VARI image which generates a value between -1 and +1 (Figure. 3). The equation for calculating VARI is:

$$VARI = (R_{green} - R_{red})/R_{green} + R_{red} - R_{blue}),$$

where R_x is the reflectance of the canopy for color x.

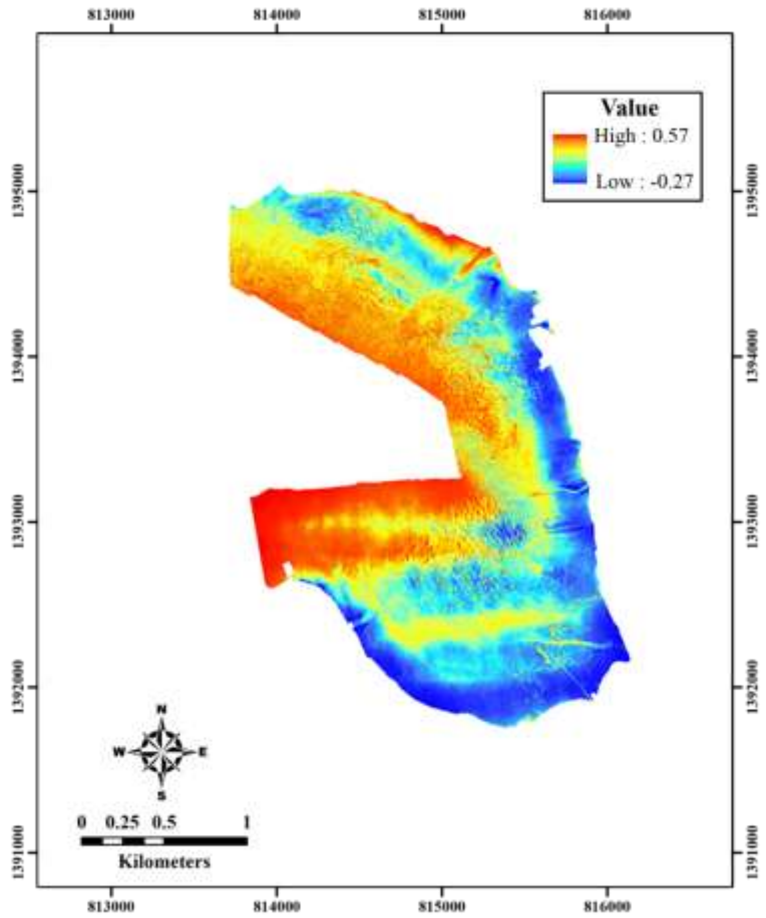

Figure 3. The result of a VARI image in Kung Krabaen Bay

Image classification

The processes of image classification applied in this study were supervised classification and visual interpretation. The visual interpretation is a complex process, including the meaning of the image content in order to classify spatial and landscape patterns (Albertz, 2007). Supervised classification based on the maximum likelihood decision rule, depended on the researcher who defined the spectral characteristics of the classes from selected training areas (Sagawa *et al.,* 2010) in VARI image, as shown in Figure. 4. Comparison of VARI images from the selected study areas were compared with the true color images by seagrass leaf type (short-leaved or long-leaved), such as (a) short leaves were shown in the natural color composite image, (b) short leaves were shown in the VARI image, (c) long leaves were shown in the natural color composite image, and (d) long leaves were shown in the VARI image.

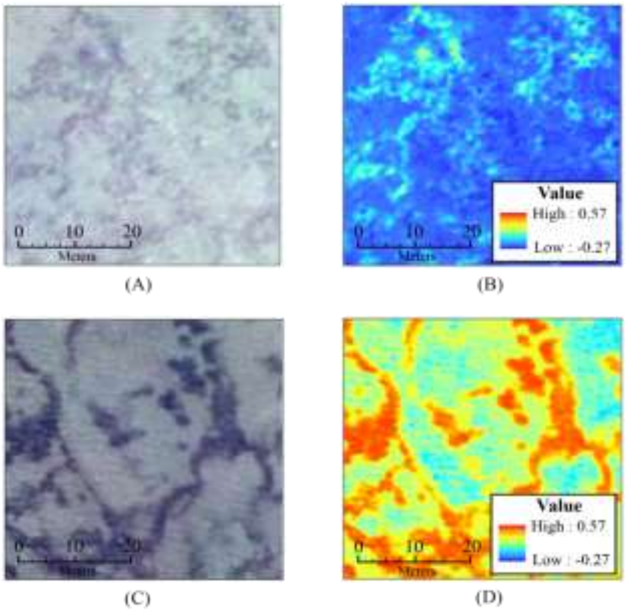

Figure 4. Comparison of VARI images from the selected study areas were compared with the true color images by seagrass leaf type (short-leaved or long-leaved)

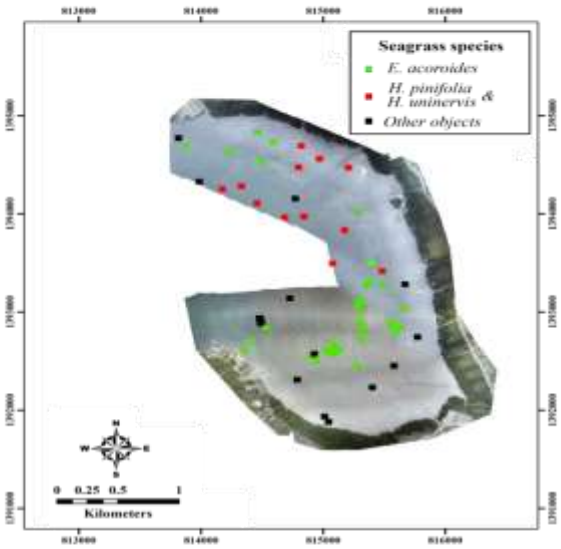

Figure 5. 43 sampling points were selected on random raster elements

Accuracy assessment

The accuracy assessment is a general term for comparing the classified image to reference sites that is considered to be accurate or ground-truth data. The 43 sampling points were selected on random raster elements in the classified image and the reference site (Figure. 5). The sampling point and reference data were compared for overall accuracy, producer's accuracy (omission errors), user's accuracy (commission error), and kappa coefficient. The comparison was done by creating an error matrix from which different accuracy measures were calculated (Dekker *et al*., 2005).

Results

The visual interpretation can be used to identify three classes of seagrass zones: long-leaved species (*E. acoroides*), short-leaved species (*H. pinifolia* and *H. uninervis*) and other objects. The resulting supervised classification image and visual interpretation image are shown in Figure. 6 and Figure.7, respectively). The accuracy assessment results are shown in Table 1. The classification results showed that the overall accuracy of visual interpretation of aerial photographs by using UAV for (i) *E. acoroides*, (ii) *H. pinifolia* and *H. uninervis*, and (iii) other objects is 88.88% and Kappa coefficient of this method is 0.809. The overall accuracy of supervised classification is 61.11% and Kappa coefficient of this method is 0.568. The results showed that aerial photograph images could clearly be used to classify the seagrass species by having different digital signatures with the VARI approach. The overall accuracy of visual interpretation was higher than that of supervised classification, which could be useful to estimate seagrass species mapping. The results also revealed that *H. pinifolia* and *H. uninervis* that were distributed on sandy clay and seashell substrates while *E. acoroides* was distributed only on sandy areas.

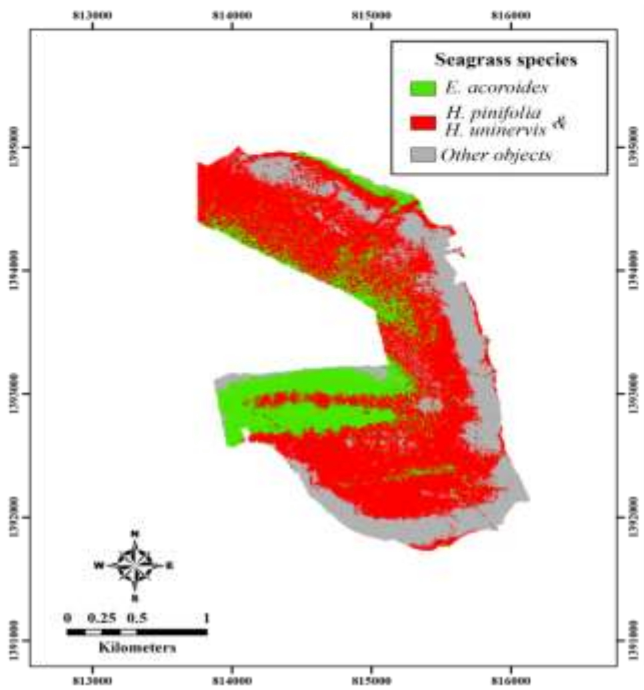

Figure 6. A supervised classification image in Kung Krabaen Bay

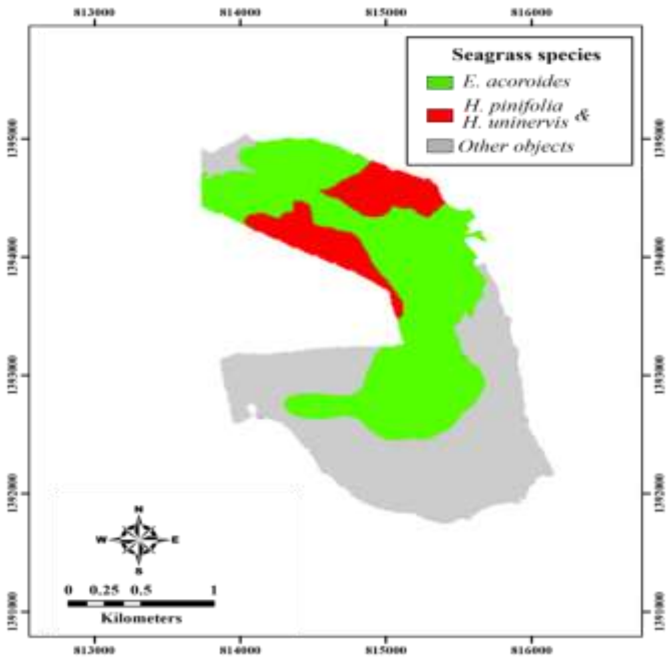

Figure 7. A visual interpretation image in Kung Krabaen Bay

Table 1. The accuracy assessment of supervised classification image and visual interpretation image results

Classification method	User's accuracy (%)			Producer's accuracy (%)			Overall accuracy (%)	Kappa Coefficient
	Long leaves	Short leaves	other	Long leaves	Short leaves	other		
Supervised Classification	41.03	83.33	33.33	80.00	26.32	62.50	46.97	0.438
Visual interpretation	89.74	83.33	80	92.11	90.91	70.59	86.36	0.809

Discussion

Aerial photography using UAV is suitable for seagrass detection in a small area. Aerial photographs taken from a very low altitude (less than 500 meters), result in higher spatial-resolution than satellite imagery and have no cloud-cover problems (Dekker *et al.*, 2007). A UAV, however, has a short flight time of about 20 minutes. Other limitations come from water reflection and surface waves that obscure underwater objects, including seagrass beds. Aerial photographs with VARI can be used to classify only two types of seagrass, namely short-leaved and long-leaved types due to the differences of their morphology (Marine and coastal resources research and development center the eastern gulf of Thailand, 2006). The stem length of *H. pinifolia* and *H. uninervis* (the short-leaved type) is approximately 5-24 cm and the leaves range in length from approximately 0.6-1.25 cm. However, the stem length of *E. acoroides* (the long-leaved type) is approximately 30-150 cm and the leaf length is approximately 1.25-1.7 cm. The overall accuracy of identifying seagrass by visual interpretation was better than by supervised classification. The results of supervised classification with VARI imagery were poor because some seagrass beds may have been concealed by coastal sediment. Visual interpretation can be more accurate because the eye of a human can detect a pattern and texture better than supervised classification. However, visual interpretation may be problematic for the classifier. The Object-based image analysis (OBIA) is a new classification technique. It was used to create objects by grouping pixels that had the same spectral characteristics together and extracting statistical features from them (Topouzelis *et al*., 2016). The OBIA may provide better results than both visual interpretation and supervised classification.

In the future, UAVs will be used for more mapping purposes. The first advantage of UAVs is that the researcher can plan the observation area for mapping and conduct aerial photography at any time, which is useful for survey frequency and continuity. Aerial photograph using UAV costs less than using satellite imagery (Perez *et al.*, 2013). In particular, the aerial photograph by using UAV was not affected by cloud cover problem which this technology can increased the data availability.

The aerial photograph images taken for this study could clearly be used to classify seagrass species having different digital scores using the VARI approach. The overall accuracy of visual interpretation result (VARI) was higher than that of supervised classification result (VARI), which visual interpretation (VARI) is useful for delineating seagrass beds, but not for identifying the short-leaved type species group. The supervised classification result was not useful in seagrass zone classification because there are limitations of water reflection and surface waves. This problem obscures any underwater objects and seagrass beds.

The problems of surface water reflection in aerial photography may be minimized by applying a polarizing filter to the camera or sensor. The newer drone (UAV) technology may increase image resolution and flight time, which will allow them to cover a larger area per flight and take less time for surveys. In case of windy days, the researcher must reduce the flight time because the UAV needs more energy to return to their home position.

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