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Multi-Temporal Mapping of Seagrass Distribution by using Integrated Remote Sensing Data in Kung Kraben Bay (KKB), Chanthaburi Province, Thailand

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Abstract The seagrass beds are a unique marine productive ecosystem that provides a shelter, a food source for the marine community of animals and act as a biofilter in marine environments. The seagrass situation shows the current number of seagrass beds have been continuously decreasing in Thailand. The study presented the comparison of a high-resolution satellite imagery and aerial photograph by Unmanned Aerial Vehicle (UAV) to change detection in Kung Kraben Bay between 2011 and 2017. Study area was a 5.59 km^2, shallow (depth 2.5 m) and clear water in the Tha Mai district, Chanthaburi province, Thailand. The WorldView-2, GeoEye-1 and aerial photograph by UAV were composited to the Normalized Difference Vegetation Index (NDVI) image and classified to 3 classes such as a long seagrass leaves type (*Enhalus acoroides*), short seagrass leaves type (*Halodule pinifolia* and *Halodule uninervis*), and another object. The visual interpretation with *in situ* data and supervised classification technique assisted to seagrass detection in a very high-resolution image. The classification results showed that visual interpretation with *in situ* data that the overall accuracies and Kappa coefficients were higher than supervised classification with maximum likelihood such as 74.42% and 0.568, respectively. From 2011 to 2017, the total area of seagrass distribution had not changed, but the seagrass density had changed in some areas. The resultant maps provided a changing of landscape-scale seagrass dynamic data and the advantage of an aerial photograph by UAV for seagrass detection in a shallow water environment.

Keywords: Seagrass beds, Multi-temporal, Aerial photograph, UAV, NDVI, WorldView-2, GeoEye-1, Remote Sensing, Kung Kraben Bay

Introduction

Coastal ecosystems are the most important region of remarkable biological productivity, which is necessary for aquatic animal surviving. There are 3 coastal ecosystem formats including mangrove ecosystem, coral reef ecosystem, and the seagrass ecosystem. Especially seagrass ecosystem

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is a fertile coastal ecosystem which is necessary for marine creature's residence and high biodiversity. This area is a nursery ground for aquatic larvae, shelter, and food source of the marine animal. Including seagrass, boundary area can protect coastal erosion and reduce soil erosion as well (Marine National park Management, 2000). Seagrasses are flowering plants that can form dense in shallow salty and brackish waters in many parts of the world from the tropical to temperate zones. Seagrass ecosystem is one of the most productive ecosystems in the world which seagrasses provide shelter and food for the incredibly diverse community of animals from tiny invertebrates to large fish, crabs, turtles, marine mammals, and birds. Seagrasses provide many important services to people as economic value can be measured through other industries, such as commercial and recreational fisheries, nature and wildlife tourism, which rely on this habitat to survive.

The study of seagrass in Thailand shows the total of seagrass area is about 255.7 km^2, which there are three families 7 genera 12 species of seagrass in Thailand distribute in The gulf of Thailand and Andaman sea, including *Halophila ovalis, Halophila beccarii, Halophila decipiens, Halophila ovala*, *Thalassia hemprichii*, *Enhalus acoroides*, *Cymodocea rotundata, Cymodocea serrulata, Halodule uninervis, Halodule pinifolia, Syringodium soetifolium,* and *Ruppia maritima* (Green Peace, 2013; Department of Marine and Coastal Resource, 2016). The report of seagrass community in Kung Kraben bay in 1992, found 4 species of seagrass in descending order such as *Enhalus accroides, Halodule pinifolia*, *Halophila minor*, and *Halophila decipiens*, and found a lot of dugongs in the past (Aryuthaka, Sangthong, and Awaiwanont, 1992). There are a seagrass beds exploration and monitoring in 2015, that found the total seagrass area was 255.72 km^2, which spread in the Gulf of Thailand (96.31 km^2) and in the Andaman Sea (159.41 km^2) (Department of Marine and Coastal Resources, 2016).

The report of seagrasses situation in Thailand shows the current number of seagrass beds have been continuously decreasing because they are affected by human activities and coastal development problems, including anchoring, mining, coastal construction (breakwater or seawall), fishery (illegal tool), toxic waste releasing diseases *et al.* (Institute of Research and Development of Marine, Resources Coastal, and Mangrove, 2006). The seagrass degradation has been effective to growth, spawning, and living of marine animal in coastal marine ecology. This effects also make more current flow increasing which this cause is effects of coastal erosion increasing. Although the seagrass area remaining is still good condition. However, the anxiety of seagrass degradation, as a result, government agencies, coastal and marine resources conservation network and private organizations are working together to perform the conservation and restoration of seagrass area (Department of Marine and Coastal Resources, 2016).

The current technology of RS is the rapid development, such as data has changed from a low spatial resolution in the past become up to much higher spatial resolution detail of a centimeter. There is a study of seagrass observation by using multiple remote sensing sources found the seagrass surveying by comparing data from LANDSAT, SPOT satellite, and aerial photographs (Mumby, Green, Edwards, and Clark, 1997). The natural resources exploration by using a remote sensing technology based on 2 sources of data, including satellite imagery and aerial photography. The satellite image data that cover a wide area and the spatial resolution is very low level as LANDSAT8 (30 m.), Thaichote (15 m.), ALOS (10 m.), etc. to very high level as WorldView-3 (0.31m.), GeoEye (0.41 m.), QuickBird (0.61 m.) and IKONOS (1 m.), Deimos-2 (1m.), etc (Geo-Informatics and Space Technology Development Agency, 2016). The satellite imagery data was used to study a wide area, which does not want a very high spatial resolution. On the other hand, the aerial photograph covers a small area and there is a high spatial resolution more than satellite imagery which depending on consumer camera specification and altitude of aircraft.

The objective was to analyze the multi-temporal mapping of seagrass distribution by the high-resolution satellite imagery from WorldView-2, GeoEye-1 and Aerial photograph by UAV to the classification of seagrass species, boundaries, and compare the present seagrass distribution with the past of seagrass distribution. The expectation of this research was the benefits for management and planning of sustainable development for seagrass conservation in Thailand.

Problem statement

The high-resolution data of satellite image can be detected small seagrass beds but there is a problem of cloud covers, especially over the tropical areas. The GeoEye-1satellite imagery in 2016 encounter a cloud cover problem as well. The aerial photograph data by airplane is a high-resolution image same as satellite image but it is very expensive. The aerial photograph by UAV is a high-resolution image, but it is cheaper than airplane platform.

Objectives

1. To apply the Aerial photograph by UAV for solving the cloud cover for classify seagrass bed boundaries around Kung Kraben Bay.

2. To investigate the long-term changes in seagrass distribution around Kung Kraben Bay in 2011 and 2016.

Materials and methods

Site Description

Seagrass data was collected from the seagrass meadows occurring in Kung Kraben Bay, located in Tha Mai district, Chanthaburi province, Thailand (Figure1). This study site was in the eastern Thailand, under the responsibility of Kung Kraben Bay royal development study center. The total approximate area is about 5.5872 km2, covering latitude of 1,391,006.31 to 1,394,816.38 North and longitude of 811,664.24 to 816,909.16 East in WGS 84 / UTM Zone 47N.

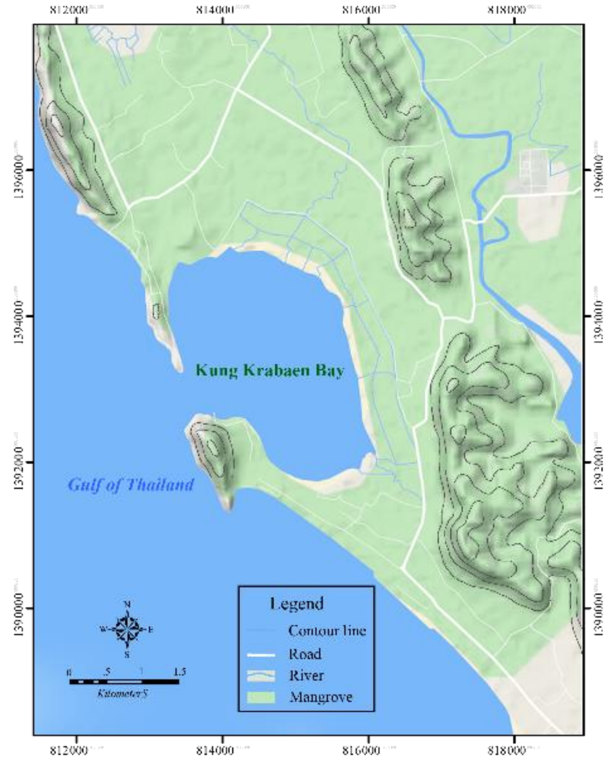
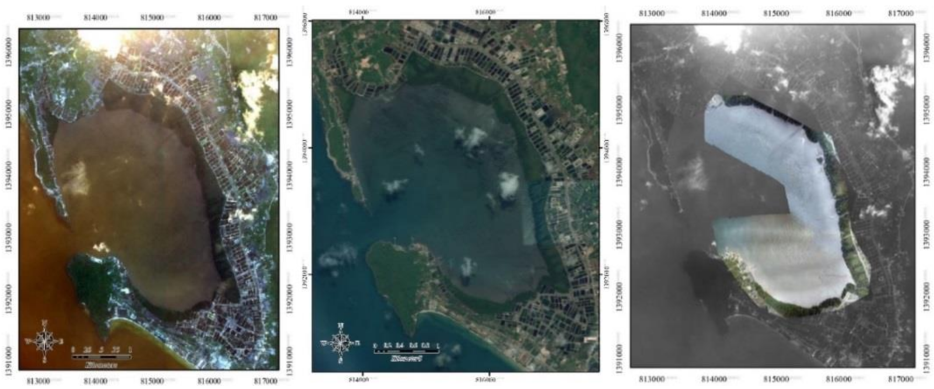


Figure 1. Field samples and location of Kung Kraben Bay in Chanthaburi, Thailand.

In this study, two main material sets were used in this study, namely the imagery data and field samples from *in situ* observations used for ground-truth data. The two imagery data sources are WorldView-2, GeoEye-1 and Aerial Photograph by UAV, which they have the high spatial and high spectral resolution image data. (as shown in Figure 2).



(a) (b) (c)

Figure 2. Study area viewed from (a) WorldView-2 (2 April 2011); (b) GeoEye-1 (2 May 2016); and Aerial Photograph by UAV (4 July 2017) in the natural-colour composite image.

The main steps are shown in Figure 3, consisting of five phases of data processing were involved in this study: (i) data pre-processing including geometric correction, radiometric correction, and water column correction; (ii) the pan-sharpening transformation and normalized difference vegetation index (NDVI) is a simple graphical indicator that can be used to analyze remote sensing measurements; (iii) detection and classification of seagrass distribution; (iv) the classification accuracy assessment by *in situ* data; (v) change detection analysis from the satellite data sets and multi-temporal mapping.

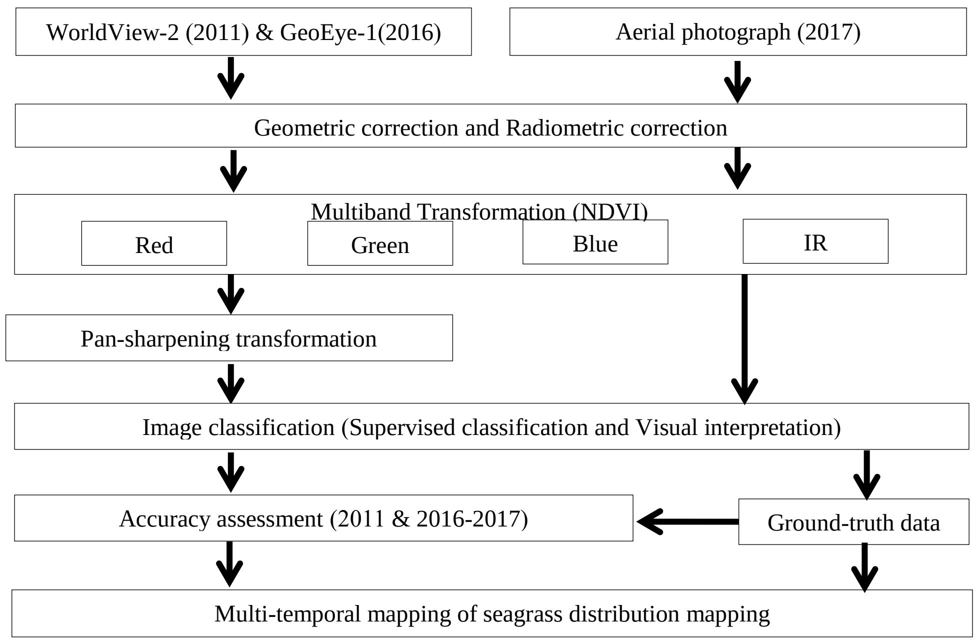


Figure 3. Workflow of multi-temporal analysis by using the high-resolution imagery data.

Geometric correction

Geometric correction was to avoid geometric distortions from an original image. The image was georeferenced to the UTM coordinate system, datum WGS-84 zone 47N using a total of 6 ground control points (GCP) which are linking to the aerial photograph and the satellite image of the study area. The aerial photograph is transformed to the geometry corrected image by 1st Order Polynomial transformation and the root mean square error (RMSE) value = 1.66917 so as to maintain the intensity of the pixels.

Radiometric correction

The radiometric correction models are the atmospheric correction and reduce the noise, such as compression of haze or enhance desired characteristics of an image. The atmospheric correction modifies Digital Number (DN) values based on the normalizing the sun's elevation angle in time series study which DN values are the difference in sun elevation angle throughout the year (United Nations Educational, Scientific, and Cultural Organization, 1999). The radiance image is then atmospherically corrected, resulting in a surface reflectance image. At this point, the reflectance image is ready to be used to extract quantitative information about features on the surface. In this case of WorldView-2 and GeoEye-1, they are radiometric corrected for standard satellite imagery package (level 2A).

Normalized Difference Vegetation Index (NDVI)

NDVI is a simple graphical indicator that can be used to analyze remote sensing measurements, typically but not necessarily from a space platform, and assess whether the target being observed contains live green vegetation or not (Verhulst N. and Govaerts B., 2010). In order to fully explore the useful information in hyperspectral, the red band reflectance of NDVI was replaced by the green and blue band reflectance. The equations are listed as follows:

$$NDVI = (NIR - RED) / (NIR + RED) \qquad (1)$$

Where NIR - Spectral reflectance measurements acquired in Near Infrared wavelength

RED - Spectral reflectance measurements acquired in red wavelength

The NDVI was used to detect seagrass information by the false color image. Calculations of NDVI for a given pixel always result in a digital number (DN) range.

Pan-sharpening

The pan-sharpening transformation is a process of merging high-resolution panchromatic data with lower-resolution multispectral data to create a multispectral image with high-resolution features. In this study, after the process of pan-sharpening, the both of satellite image resolutions are lower than the aerial photograph by UAV such as 0.5 meters and 0.15 meters, respectively.

Image Classification

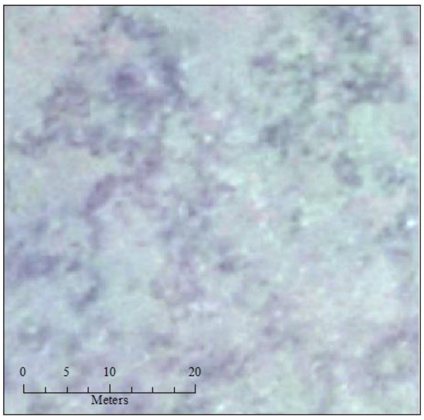
The process of image classification is supervised classification and visual interpretation with *in situ* data collection. The supervised classification based on maximum likelihood decision rule is realized by an operator who defines the spectral characteristics of the classes by identifying sample areas or training areas (Sagawa *et al.*, 2007). The researcher classifies the seagrass area in 2011 by WorldView-2 data and 2016-2017 by GeoEye-1 and Aerial photograph by UAV respectively. Three classes of seagrass distribution were classified such as a long leaves type (*E. acoroides*), short leaves type (*H. pinifolia* and *H. uninervis*), and another object.

Accuracy assessment

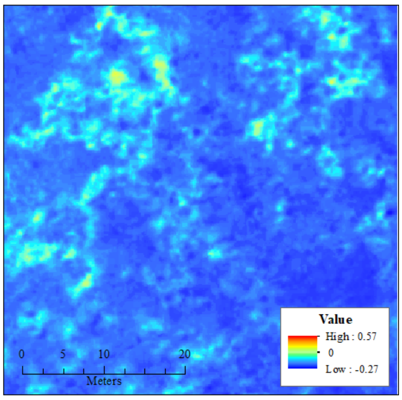
The Seagrass classification accuracy was calculated by comparing the pixels of classification data with *in situ* observations. The comparison is done by creating an error matrix from which different accuracy measures can be calculated. For each location, a score of the area match was assessed and summation of the scores was normalized as the detection accuracy (Dekker, Brando and Anstee, 2005).

Results

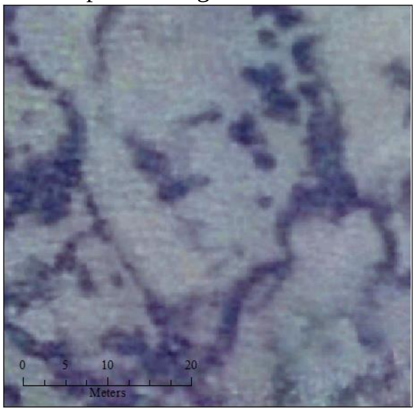
In order to seagrass classification, the relationship between leaves type reflectance value and the NDVI was correlated. Analysis indicated that a good relationship existed between NDVI and two classes of seagrass as shown in Figure 4. The NDVI technique is effective in detecting seagrass beds over water and shallow clear water but the technique is not effective in detecting seagrass beds in the deep-water area.



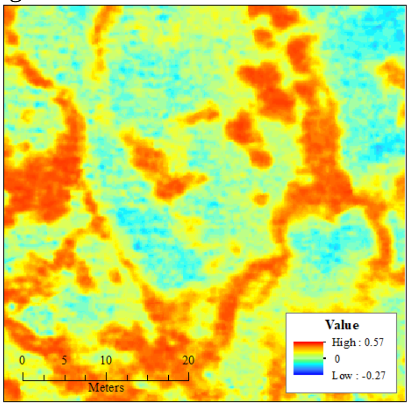
(a) short seagrass leaves type in Natural Color Composite image



(b) short seagrass leaves type in NDVI image



(c) long seagrass leaves type in Natural Color Composite image



(d) long seagrass leaves type in NDVI image

Figure 4. the relation of seagrass leaves type and NDVI image

The classification results show that the overall accuracies of visual interpretation with *in situ* data is *E. acoroides*, 2) *H. pinifolia* and *H. uninervis*, and 3) other objects are 82.61%, 100%, 50% respectively and overall accuracies of supervised classification with maximum likelihood are 60.87%, 50%, 85.7% respectively. The highest overall accuracy of classification method is visual interpretation at 74.42% and Kappa coefficients are 0.568. The supervised classification with maximum likelihood is 67.44% and Kappa coefficients are 0.481. From 2011 to 2017, the total area of seagrass distribution has not changed, but the seagrass density has changed in some areas.

Discussion

The aerial photograph by UAV detected the seagrass better than satellite image with pan-sharpening because the aerial photograph was taken a very low altitude about 100-500 meters, resulting in higher spatial-resolution than satellite imagery, no cloud cover problem (Dekker *et al*., 2006). Seagrass detection, the satellite imagery and aerial photograph can be detected only two types of seagrass: short leaves types and long leaves types because length and stem of seagrass leaves are so different (Department of Marine and Coastal Resources, 2016)**.** The length of *H. pinifolia* and *H. uninervis* stem are so similar approximately 5-24 cm. and a wide range of leaves is approximately 0.6-1.25 mm. but the length of *E. acoroides's* stem is approximately 30-150 cm. and a wide range of leaves is approximately 1.25-1.7 cm**.** Seagrass distribution, *H. pinifolia* and *H. uninervis* are distributed on sandy clay and seashells area but *E. acoroides* are distributed on the only sandy area. This other seagrass distribution studies in Kung Kraben Bay have reported similar findings (Paibulkichakul, *et al*., 2014; Paibulkichakul *et al*., 2016). The *H. pinifolia* had distributed at north and south part of Kung Kraben bay and the *E. acoroides* had distributed at south and center part of Kung Kraben Bay.

Recommendation

The aerial photograph has any problem by surface water reflections in any image. The Polarizing filters are a very useful addition to any camera kit for cut-off any water reflection. In addition, the researcher can avoid this problem by taking an aerial photograph in the morning about 8:00-9:00 AM. or evening about 4:00-5:00 PM. A new drone technology can increase the image resolution and shooting time. The data is recorded continuously and take less time to work. The many drone control technologies operate simultaneously in the same area. This technology can make operations faster and reduce mosaicking problems over time.

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