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Monitoring mangrove forest cover declination at kilim karst geoforest park, Langkawi from 2005 to 2017 using geospatial technology

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Abstract. Mangrove forests are commonly found in the coastlines and estuaries of tropical and subtropical regions. Besides having commercial values, mangroves play major roles as coastal protection, buffer zone, and nursery grounds for various types of marine organisms. Since this forest ecosystem has face problems like degradation, there are increasing efforts to monitor and assess this ecosystem for better conservation and management. Conventional mangrove mapping and field survey requires labour intensive, expensive and takes long time to complete. However, geospatial techniques comprising of Remote Sensing (RS) and Geographical Information System (GIS) today become an alternative method that can be used to access the mangrove area, especially for the difficult area. Therefore, this study aims to use geospatial approach to monitor the mangrove area at Kilim Karst Geoforest Park (KKGP), Langkawi. Object-based image analysis (OBIA) method which is involved multi-resolution and classification steps is used to extract and delineate mangrove area from very high resolution (VHR) satellite imagery from 2005 to 2017. Both segmentation and classification processes were conducted using e-Cognition software. The mangrove area from 2005 to 2017 were assessed using overlay technique in ArcGIS software to determine and evaluate the degraded area. The overall degraded mangrove area was approximately 5.632 ha. Factors affecting the decline of the mangrove cover in this study area are also determined. As conclusion, the results indicated the applicability of geospatial technique to be used to monitor and assess mangrove extent for better management and conservation proposes.

1. Introduction

Mangrove forest is a unique ecosystem which is concentrated in tropical and sub-tropical regions [1]. Mangroves live in the coastline area, estuary, around the island and areas which are influenced by tidal. Mangrove forest provides benefit to human life and wildlife inhabiting mangrove forests where they play essential roles in the ecosystem especially in terms of ecological, environmental, biological, medical and economical values. They are not only important as habitats for diverse flora and fauna

including rare species but also react as high-yielding nurseries that provide breeding grounds for marine life and its communities [2]. Besides, mangroves react as essential resources in order to export organic matter to the marine environment, producing nutrients for fauna in both the mangroves themselves and adjacent marine and estuarine ecosystems. The survival of mangrove ecosystems and the productivity of fish and marine life in coastal areas shown a strong correlation to each other [3-5].

About 115,108.60 ha of mangrove are recorded in Peninsular Malaysia for 2010 [6]. In Langkawi, the mangrove forest covers approximately 3,142 ha, and the largest area is at the Kisap Forest Reserve with 1,336 ha [7]. There are some factors that affect the mangrove forests especially in Langkawi. For example, aquaculture, coastal development, socio-economic and logging activities. Impacts from these activities are degradation in forest quality and ecosystem function, disruption of forest sustainability and mangrove areas conversion occurred and resulted in the loss of a huge number of individuals of mangrove species [8]. Since mangrove provides many advantages to human and also other communities, the preservation of mangrove forest ecosystems is very compulsory. Since the increasing needs to monitor and assess the dynamics of mangrove forest structure, there are various ways that have been done in order to have a better understanding of the basic biology and ecology of mangrove ecosystems and indirectly will aid to guide attempts of conservation and restoration, and better management of the ecosystems [9]. In order to preserve and monitor mangrove ecosystems, an accurate spatial information is required. The usual conventional method used is field survey, however it is very difficult to access all areas of mangroves besides it will take long time and this is not an effective way.

In addition, an efficient tool need to be used for monitoring temporal changes of mangrove areas with huge extent. Mapping of coastal habitat using remote sensing technique has been widely used and is frequently a reliable alternative compared to ground-survey methods of mapping, mostly in remote or inaccessible regions [10]. Since the details and monitoring of the dynamic structure of mangrove forests are performed by using satellite sensors which are beyond human capability, this technology has been widely applied to mangrove study for some applications for instance management purposes, inventorying and mapping as well as change detection. In addition, the detail characteristics of land use land cover (LULC) at different scales to put into practice for various coastal regulation measures can be done nowadays by developing of higher resolution of satellite data which is below than 1 meter. High and medium-resolution optical satellite data are practically proved for the mapping of mangrove extent and change [11-12]. Because of the rapid anthropogenic development often occurring in coastal zones, the requirements for high resolution maps in the management of tropical environments is dramatically increase [13]. Furthermore, these types of tropical coastal ecosystems such as seagrass beds, mangroves and coral reef are geographically complex, high resolution data might be used to accurately restore these features [14] .

In Malaysia, especially northern part of Langkawi, only a few of mangrove studies using geospatial technique have been conducted. For instance, research done by [15] using medium resolution of SPOT imagery to classify mangrove species at Kilim River. However, research conducted by [8, 16] regarding mangrove in this area does not involved the use of geospatial technology. Therefore, this study aims to assess the capability of geospatial technology in monitoring long-term mangrove cover decline occurred in KKGP. There are two objectives of this study. Firstly, to monitor long-term mangrove decline by using multi-temporal very high resolution (VHR) satellite imageries and second, to identify the locations of mangrove area decline and factors affected. Results generated from this study can provide an additional opportunity for a better understanding of mangrove forests towards their sustainable management. Besides, the results can serve as a guideline in choosing the appropriate tools in the development of management plans for the mangrove forests in KKGP.

2. Materials and methodology

Kilim is situated in the northeast part of Langkawi Island (Figure 1). From a rural region which was comprises of traditional villages, mangrove forest, limestone hills and flora and fauna, Kilim turns to a well-known tourist destination in Langkawi after designated as Geoforest Park by UNESCO on July 2007. About 47,800 hectares of total land area designated as Kilim Karst Geoforest Park, Langkawi, Kedah [16]. The temperature in Kilim ranges from 22.50 to 34.50 degree Celsius and the monthly rainfall varies from 69.0mm to 870.0 mm. Figure 1 shows Langkawi Island in Malaysia.

Figure 1. Location of study area.

2.1 Data descriptions

The primary data used in this study are VHR satellite imageries with different date of acquisitions. All data specifications are shown in Table 1.

Table 1. Satellites data specifications.

Satellites	Year	Bands	Source
Quickbird	2005	Multispectral bands (2.4m) Panchromatic band (0.6m)	Digital Globe
Worldview-2	2012	Multispectral bands (2.0m) Panchromatic band (0.5m)	Digital Globe
Pleiades 1B	2017	Multispectral bands (2.0m) Panchromatic band (0.5m)	AIRBUS Defence & Space

2.2 Methodology

Figure 2 shows the flowchart of this study. The satellite imageries are used as primary data while topographic map is used as secondary data. Before the satellites data can be used, all these data need to be corrected through pre-processing stage. In pre-processing stage, atmospheric corrections, geometric correction and pan-sharpened of satellite image steps need to be applied to satellite images. Then, extraction of mangrove area from satellite images were done using object-based image analysis (OBIA) technique in e-Cognition 8.7 before running the change detection analysis.
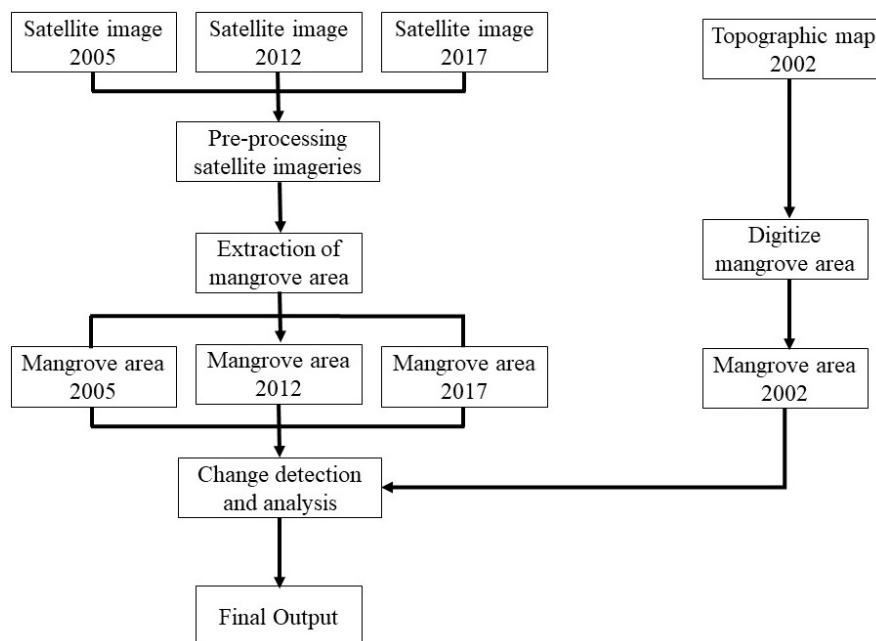
Figure 2. Flowchart of this study.

2.3 Mangrove delineation and change detection
The extraction and delineation of mangrove area from VHR satellite imageries in this study was done by using OBIA technique. Through this technique, Nearest Neighbor's algorithm (NN) found in OBIA techniques is selected to classify the types of land use/land cover (LULC) in satellite images such as water bodies, urban areas and vegetation. This technique is a very effective technique in OBIA where the NN classification found in OBIA has the capability and compatibility to classify remote sensing data that has higher spatial resolution [17]. This technique is very unique in which users can create objects through multi-resolution segmentation (MRS) along with the supervised classification using Sample Editor. NN classification allows users to select samples for each class or type of LULC. Users can define criteria (statistics) for the classification process and this software will classify the rest of the images. There are four main steps to perform object-based extraction of mangrove area from satellite images using NN standard. Firstly performing MRS, choosing training area, define statistic and run classification. Next, Overlay tool in ArcGIS software is used to perform change detection analysis on extracted mangrove area of different dates. The overlay technique is applied on mangrove area for three epoch (2005 to 2012), (2012 to 2017) and (2005 to 2017) in order to obtain the changed area.

3. Results and discussions
The mangrove area in this study has been extracted from VHR satellite imageries for further studies. Figure 3 shows the mangrove area (green area) that has been successfully extracted from VHR satellite imageries for year A) 2005, B) 2012 and C) 2017.
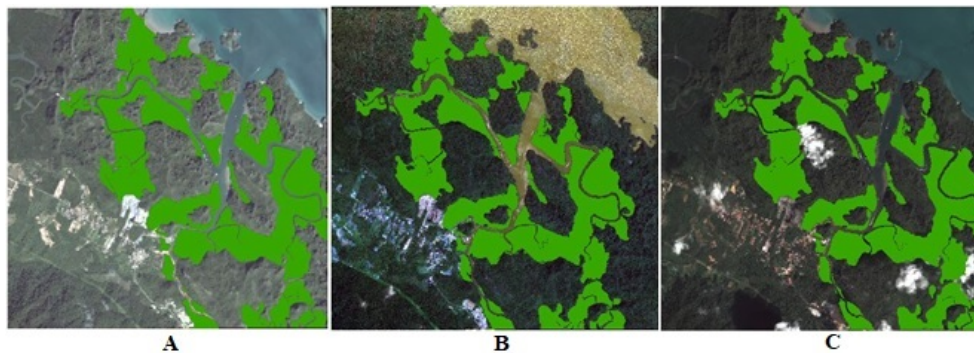
Figure 3. Extraction of mangrove area from VHR satellite imageries for year (A) 2005, (B) 2012 and (C) 2017.
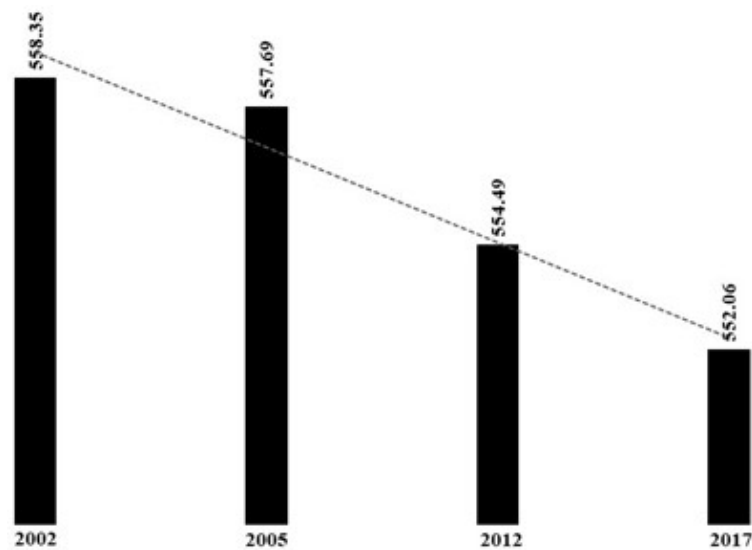
Based on Figure 3, the extracted mangrove area from different satellite imageries show similar patterns for all three different dates. The mangrove area have been extracted from non-mangroves using OBIA method. This method was used since it provides high accuracy and suitable to be used with VHR satellite imageries. In order to validate and ensure that the extracted mangrove areas from these satellite images are correct, qualitative comparisons have been carried out to assess these extracted mangrove areas with manually digitized mangrove area from the topographic map of year 2002. In this study, the comparison of patterns of extracted mangrove area from satellite imageries with the pattern of digitized mangrove area from topographic map has been performed. The comparison shows that the patterns of mangrove area which are extracted digitally using OBIA method from VHR satellite imageries for all of the years show the same pattern when qualitatively compared with the mangrove area that has been manually digitized from the topographic map as shown in Figure 4.
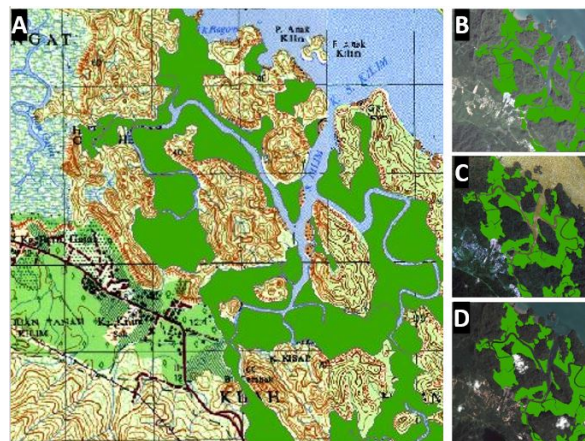
Figure 4. Comparison of delineation of mangrove area from satellite (B:2005, C:2012, D: 2017) and topographic map (A).

This results suggested that the delineation or extraction process of mangroves from VHR satellite images are satisfactory and acceptable. The delineation of mangrove area from VHR satellite imageries are very important step because this process need to be done as accurate as possible since these extracted mangrove area will be used in determining the extent and decline of mangrove area within certain periods of time. Next, Figure 5 shows the total area of mangrove that has been extracted from topographic maps and satellite imageries.

**Figure 5.** Total mangrove area extracted from 2002, 2005, 2012 and 2017.

Based on Figure 5, the highest mangrove area was 558.35 ha in year 2002 followed by mangrove area in 2005 and 2012 of 557.69 ha and 554.49 ha respectively, while the mangrove area in 2017 was the lowest which was approximately 552.06 ha. Overall, the extent of mangrove area in Kilim from year 2002 to 2017 showed a decline.
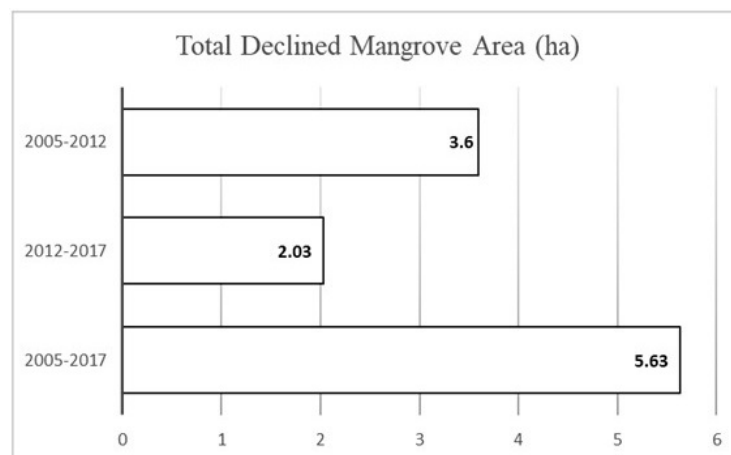
Fig. 6. Total declined area in hectares based on satellite epochs.

The assessment of the decline of mangrove area in Kilim within a period of 12 years was carried out by comparing the extent of mangrove area for different years. A total of three (3) periods represent each satellite data were used in this study together with the extent of extracted mangrove area were compared to quantify the total loss of mangrove area. Figure 6 shows total declined mangrove area in hectares based on satellite epochs. Total declined area from 2005 to 2017 is 5.63 hectares where the highest loss of mangrove area in Kilim happened in 2005 to 2012 epoch which is about 3.6 hectares followed by epoch 2012 to 2017 which is 2.03 hectares. The deterioration of the mangroves in this area is related to several factors such as land use/land cover (LULC) development/changes, tourism activities and natural influences such as sea level rise (SLR). These three factors have been identified based on several studies conducted by previous researchers [8,15,18-19]. Figure 7 shows the areas experiencing mangrove reduction.
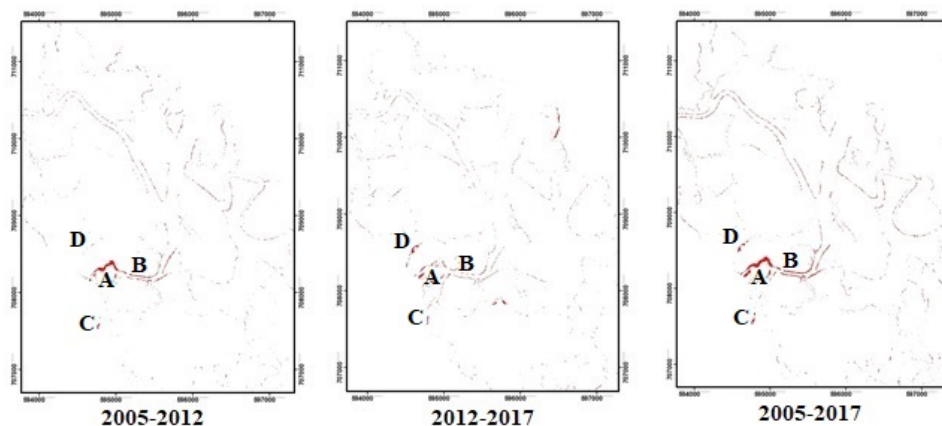
Figure 7. Declined areas in Kilim detected using satellite imageries.

Figure 7 shows the mangrove area experiencing a decline within 12-year period for three epochs which are epoch 1 (2005 to 2012), epoch 2 (2012 to 2017) and epoch 3 (2005 to 2017). The maps of mangrove forest degradation in this area are published using the overlay technique found in ArcGIS software [2]. Extracted vector of mangrove area for each satellite images are used to produce maps which are show the areas that experiencing mangrove degradation. There are some areas experiencing a highly critical mangrove decline. The most significant mangrove decline occurred around the fisherman jetty (Area A) as well as the area being the main route of tourist boats coming to the KKGP (Area B). In addition, agricultural areas (Area C) and mangrove area which is located nearby to the quarry area (Area D) also experience mangrove degradation. Meanwhile, other areas showed a slight change especially for areas along the edge of the Kilim River. Table 2 shows the highest change of mangroves in Kilim area according to the factors that previously mentioned.

Table 2. Summary of highest mangrove area decline.

Change to	Area (ha)	Highest Change	Location	Specification
Water	0.81	Before 2012	Tourist"s main route for ecotourism activity (Area B)	Riverbank erosion due to boating activity
Water	0.3	After 2012	Near quarry	Quarry activity
Fisherman jetty	1.42	Before 2012	Fisherman jetty at Kilim (Area A)	Mangrove clearing for jetty construction
Aquaculture	0.15	After 2012	In front of Bat Cave	Agriculture activity

4. Conclusion

As conclusion, this study shows that geospatial technology which is the combination of remote sensing technique and GIS can be used efficiently in determining mangrove area decline in Kilim Karst Geoforest Park, Langkawi. The use of VHR satellite imageries and sophisticated OBIA combined with GIS can delineate mangrove area and determine the decline of mangrove area successfully. This results show that geospatial technology has great potential and advantage in assessing and monitoring environmental issues notably the decline of mangrove cover. Therefore, this

technology can be applied by the relevant agencies in managing their mangroves for protection and sustainable purposes.

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