MAPPING OF LOTUS DISTRIBUTIONS USING SENTINEL-2 SATELLITE IMAGERY IN TASIK CHINI

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ABSTRACT

Mapping and monitoring of wetland as one of the most valuable natural resource has gained importance with the developed of the geospatial technology. The recent deployment of European Space Agency (ESA) Sentinel operational satellites has established a new paradigm for remote sensing applications including mapping the wetland species. As one of the attractions in Tasik Chini, an understanding of the Lotus distributions is necessary to ensure the sustainability of this species population in their habitat. This study aims to explore the capabilities of 10-meter resolution Sentinel-2 satellite imagery for mapping the distributions of Lotus (Nelumbo nucifera) in freshwater lake of Tasik Chini. For this purpose, two different approaches were used namely pixel based classification and object based classification. Sentinel-2 data during the monsoon season is used to map the lake boundaries based on the rising of water level. Accurate information on the extent of water bodies is important to facilitate the landuse classification activity. The classification of the landuse classes are identified into five classes, which are forest, shrub, water, Lotus and other aquatic plant. These classes were determined based on the discriminating capability of the Sentinel-2 satellite data. The performance of classification result has been identified using the accuracy assessment contingency table. The overall accuracies of pixel based and object based classification result were 89% and 94%, and Kappa coefficient are 0.81 and 0.9 respectively, indicating a strong agreement or accuracy between the classification map and the ground reference information. From the result, Lotus distribution has been successfully identified and mapped using Sentinel-2 imagery in Tasik Chini with the extent of 57.94 ha or 12.39% of the study area.

1. Introduction

Wetlands is a transitional between terrestrial and open water aquatic ecosystems include mangroves, freshwater and peat swamp forests, lakes, rivers and marshes, are important features in the landscape that provide numerous beneficial functions for ecosystems (Kavyashree M.P., 2016). Some of these functions include improving water quality, habitats, storing floodwaters and maintaining surface water level. Tasik Chini, the second largest freshwater lake in Malaysia covered by 467 ha of water body. As a tourists' attraction, Tasik Chini has been declared as one of the eco-tourism sites in Pahang, received high volume of domestic and international tourist every year (Khairil et al., 2011). One of the main attractions of Tasik Chini is lotus (*Nelumbo nucifera*) which once upon a time covered almost the entire water surface. However, the disappearance of this attractive iconic flower due to the massive floods had contributed to the slowing down in numbers of tourist to Tasik Chini (Alagesh., 2017). Monitoring the lotus growth is a challenge because its germination process is quite fast. This exotic wetland plant is an emergent aquatic that produces individual leaves and flowers directly from the root system. The rehabilitation efforts have been carried out by the Forest Research Institute of Malaysia (FRIM) and the Pahang Forestry Department to ensure the sustainability of this species population in Tasik Chini (Hussin., 2015). As an attraction to the tourist, lotus populations can spread aggressively and need to be well managed so that the distribution can be controlled properly.

With the development of geospatial technologies such as the use of satellite data, the monitoring of lotus populations will become more efficient and comprehensive. Since the first launch of the satellite in the 1970s, the remote sensing has been growing widely. Remote sensing technology has proven to be a successful tool in monitoring terrestrial features. This technology is often less costly and time consuming for large geographic areas compared to conventional field mapping. Remote Sensing has been used to classify landuse with different techniques and data sets (Butt et al., 2015; Olokeoguna et al., 2014; Vittek et al., 2014; Baker et al., 2006). High-resolution satellite imaging with spatial resolution less than 5 meter such as QuickBird, IKONOS, and WorldView is required for details landuse classification. It is believed that this high resolution imagery will enhance the features variations which may not be achieved by using medium resolution satellite imageries such as Landsat ETM (Toriman et al., 2012). However the use of high-resolution satellite imagery is very costly especially in more frequent management and monitoring activities.

This study aims to explore the capabilities of open access Sentinel-2 satellite imagery with 10-meter resolution for mapping the distributions of Lotus in the study area.Sentinel-2, a new satellite for earth observation, comes with 13 bands provide high quality radiometric images is considered to be the follow-up mission to the SPOT and Landsat instruments. Sentinel-2 images in particular has served a great deal in the classification of different landscape at a larger scale. In comparison with Landsat images, Sentinel-2 has a better spatial and spectral resolution in the near infrared region with three vegetation red edge bands.

A variety of classification methods have been applied extensively for the landuse classification and analysis throughout the world. In this study, two different classification approaches were used, pixel based, and object based classification. The most commonly used pixel based classification is maximum likelihood classification (MLC) (Rokni et al., 2014; John Hogland et al., 2013; Ahmad et al., 2012;), which assumes that each of spectral class in satellite images can be described by a multivariate normal distribution. MCL takes advantage of both the mean vectors and the multivariate spreads of each class. The effectiveness of maximum likelihood classification depends on reasonably accurate estimation of the mean vector and the covariance matrix for each spectral class data. An object based image classification is an alternative framework that can mitigate the deficiency associated with the pixel-based approach. This method has attracted significant attention in recent years (Amalisana B. et al., 2017; Lei A., 2017; Li X. et al., 2014). The classification begins with a segmentation of neighbouring pixels into homogenous objects. In this study, the multi-resolution segmentation technique was used to build up a hierarchical network of image objects that allowed the definition of relations between neighbouring objects based on the chosen scale, colour and shape parameters. To ensure more accurate classification, lotus and other landuse class distribution data in the study area was also collected through ground field surveys activity.

2. Methodology

2.1 Study Area

Tasik Chini is the second largest natural freshwater lake in Malaysia located in the southern east part of Pahang state, comprises 12 open water bodies known as 'laut' by local people (Figure 1). There are seven active rivers feeding the lake including Sungai Datang at the Northwest of the lake, Sungai Gumum at the Northeast, Sungai Perupok at the West and Sungai Paya Merapuh and Sungai Melai at the South of the lake. There is a diverse range of ecosystem within the Tasik Chini area. The main attraction of Tasik Chini is its lotus populations. Lotus have wide disc shaped leaves and can reach up to 36 inches in diameter, which float easily on water.

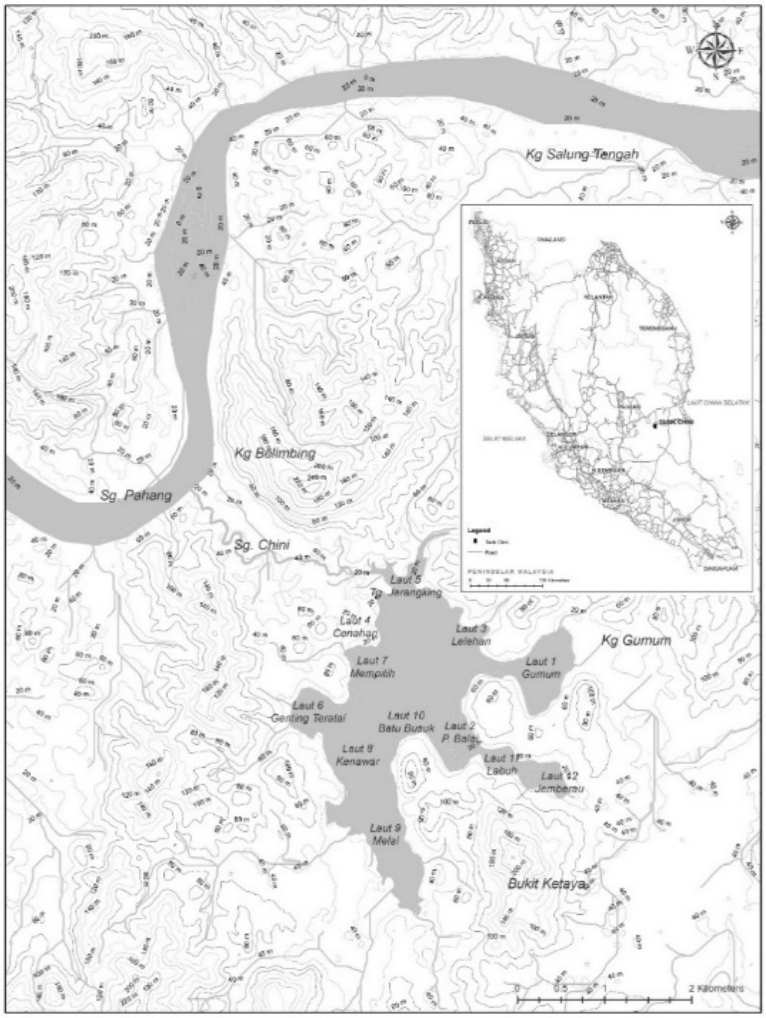

Figure 1. Tasik Chini, Pahang, Malaysia

Increasing of water level during the raining season greatly influence the distribution of lotus in Tasik Chini. To improve the lotus classification accuracy in this study, Sentinel-2 data during the monsoon season on 20 February 2017 is used to map the terrestrial and lake boundaries due the rising of water level at this time.

2.2 Method

Sentinel-2 is an earth observation satellite by European Space Agency launched on 23 June 2015 and as part of the Copernicus Programme to perform terrestrial observations in support of services such as forest monitoring, landuse changes detection, and natural disaster management. Sentinel-2 satellite at an altitude of 786 km is a polar orbiting multi-spectral imaging mission with 13 spectral bands in the visible, near infrared, and short wave infrared. The 13 spectral bands cover a range of the spectrum from 43 nm to 2190 nm with a swath width of 290 km. It has a spatial resolution of 10m (4 visible and near-infrared bands), 20m (6 shortwave infrared bands) and 60m (3 atmospheric correction bands). The satellite images can be downloaded free from the Copernicus Open Access Hub. In this study, satellite images were downloaded as Level-1C which means that those products are ortho-images in UTM/WGS84 projection, with per-pixel radiometric measurements provided in Top of the Atmosphere (TOA) reflectance. In this study, Sentinel-2 data on 23 September 2016 were used for mapping the lotus distributions in Tasik Chini. The workflow applied in this study is shown in Figure 2.

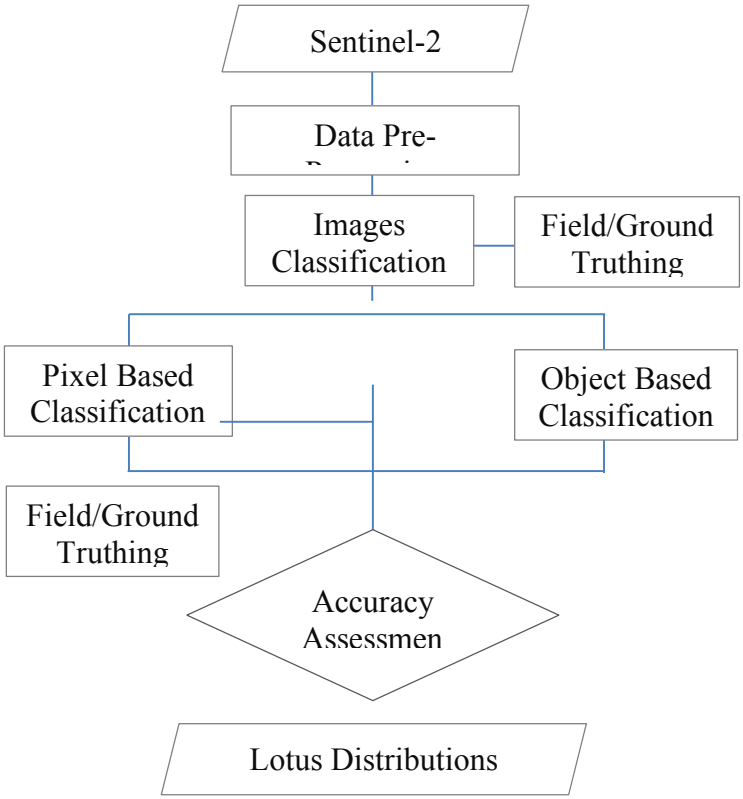

Figure 2. Workflow

All the Sentinel-2 imagery, as well as additional datasets, are referenced in a projected coordinate system. The geographic coordinate system used is the Rectified Skew Orthomorphic (RSO) and the selected datum is Kertau 1948. Pre-processing of remote sensing images is necessary to increase the interpretability of information especially when conducting vegetation studies (Sivasena R.A, 2013). The data processing starts by cropping the stack images to the size of the study area. Cropped images is then resampled depending on its original spatial resolution. The pixel size of the new raster is set to 10m. Afterward, pixel based classification; classification and object-based classification were performed.

Image classification is a process of sorting pixels into a number of data categories based on their data file values and reducing images to information classes. Similar features will have similar spectral responses. The spectral response of a feature is unique with respect to all other features of interest. The most common pixel based supervised classification technique is the maximum likelihood. It touches a probability density function where the classifier guesses the probability which a specific pixel belongs to a specific class. Pixel based classification need to be done by selecting representative samples for each landuse class. The most important part of the object based classification is the segmentation where pixels are grouped into objects using an interactive algorithm. After the multiresolution segmentation, all of the objects created within the study area were observed as a training data and their spectral characteristic were determined. According to this observation and additional information from ground sampling activity, a tree decision rules were set to separating the lotus from the other landuse objects.

Once the classification is finished, it is necessary to know the accuracy of the output. For this purpose, a validation dataset is created from ground truthing activity. In addition, interpretations of high resolution satellite image from Google Earth also assist to get a sample of landuse type in the study area. It consists, as the training dataset, 30 random points selected for each class. Some of this sample data information will be used as a reference in satellite data classification process and some of the data are being used for the assessment of classification results. The accuracy evaluation performs a cross-validation at those point locations comparing the class value from the reference data versus the class obtained by the classification algorithm (Rwanga S.S., 2017). This comparison produces an accuracy percentage and the kappa statistic.

3. Results and Discussion

Digital classification of landuse from satellite images data is widely used because of less time consuming and provide a high spatial and temporal resolution. In this study, Sentinel-2 data during the monsoon season is used to map the lake boundaries based on the rising of water level at this time. Accurate information on the extent of water bodies is important to facilitate the landuse classification activity. In this study, supervised classification using Maximum Likelihood method are performed. The classification of the landuse classes are identified into five classes, which are forest, shrub, water, lotus and other aquatic plant. These classes were determined based on the discriminating capability of the Sentinel-2 satellite data. The result from the classification are presented in Figure 3.

The object based classification method separating images into homogeneous regions, which may have particular common attributes, such as grey levels, mean values, shapes, and textures. The field work data within the study areas helped for classifying landuse with the same characteristic in Sentinel-2 images. The entire process of object based classification can be described according to this sequential steps: (a) segmentation of the image; (b) compared each segment with its neighbours to determine the similarity; (c) the segment continues growing by comparing it with all the neighbours until there is no remaining joinable region; and (d) the process moves to the next uncompleted segment, repeating the entire process until all segment are labelled. Nearest Neighbours classification was applying to the segmented images by selecting representative samples for each landuse class based on field data observations. In this study, the result from the object-based classification showed good result in term of boundary extraction (Figure 4).

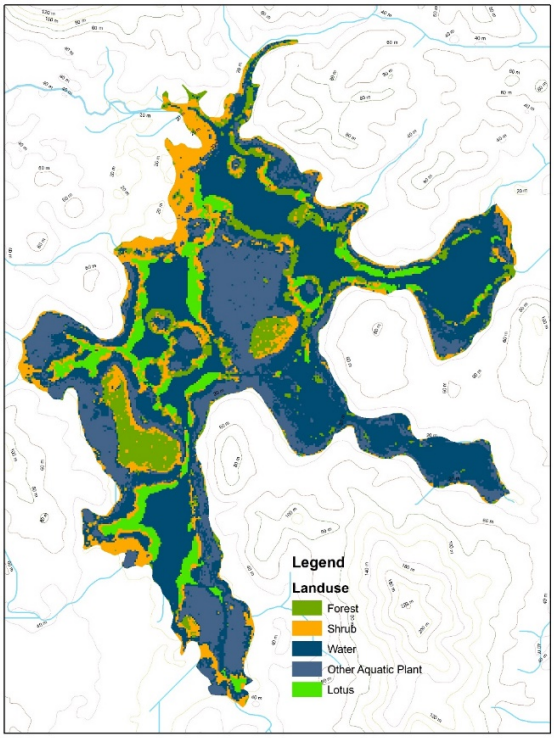

Figure 3. Pixel-based classification results

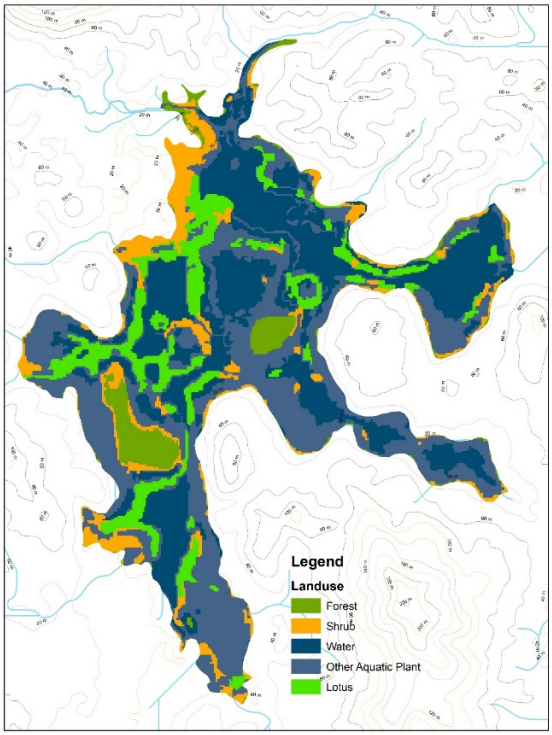

Figure 4. Object-based classification results

From the result of landuse classification using pixel based method, its shows that the study area are dominated by the water body with the extent of 213.48 ha or 45.6% of the study area. Figure 3 shows that water body is appears in most area of study site. Other aquatic plant is also the major landuse class that can be found in the study area with the total extent of 111.29 ha. Another landuse class that occupied a large extent of areas is shrub and forest that covering about 13.5 % and 9.6 % of the study area or about 63.33 ha and 44.92 ha respectively. Lotus distributions has successfully mapped with the extent area of 34.70 ha or 7.4 % of the study area. Slightly different with classification result by pixel based classification, the result from object based classification technique shows that the study area is dominated by other aquatic plant with the extend of 178.31 ha or 38.1 %. Another landuse class that occupied a large of areas is water body that covering about 158.33 ha or 33.9 % of the study area. Followed by lotus, shrub and forest with the extent of 57.4 ha, 48.30 ha and 24.84 ha or about 12.4%, 10.3% and 5.3% respectively. The statistic of the results is shown in Table 2.

Table 2. Landuse extent in the study area

Landuse	Pixel based classification		Object based classification	
	Area (ha)	(%)	Area (ha)	(%)
Forest	44.92	9.60	24.84	5.31
Water	213.48	45.64	158.33	33.85
Shrub	63.33	13.54	48.3	10.33
Other Aquatic Plant	111.29	23.79	178.31	38.12
Lotus	34.7	7.42	57.94	12.39
Total area	467.71	100.00	467.71	100.00

The visual interpretation and comparison of results of pixel based versus object based classification of the Sentinel-2 image revealed some differences between the landuse classes. To assess the quality of landuse classification, a random sampling scheme was adopted to collect a testing sample set over the study area. One of the most important final step at classification process is accuracy assessment. The aim of accuracy assessment is to quantitatively assess how effectively the pixels were sampled into the correct landuse classes. Moreover, the key emphasis for accuracy assessment pixel selection was on areas that could be clearly identified on both Sentinel-2, and Google Earth. A total of 279 points (locations) were created in the classified image of the study area.

In this study, the performance of classification result has been identified using the accuracy assessment contingency table (Table 3) or error matrix. Error matrix is an array of numbers set out in rows and columns corresponding to a particular classification unit relative to the actual landuse type as verified on the ground. The column headings represent the landuse classification as determined in the field and the row headings represent the landuse classification taken from the classification result. The highlighted diagonal indicates the number of points assessed in the field and Google Earth interpretation that agree with the classification result. Conversely, the inaccuracies of each landuse class are described as both errors of inclusion (user's or commission errors) and errors of exclusion (producer's or omission errors). The overall accuracies of pixel based and object based classification result were 89% and 94%, and Kappa coefficient are 0.81 and 0.9 respectively.

Table 3 Accuracy assessment of land cover classification result

	References													
	Pixel based classification							**Object based classification**						
Result	Forest	Water	Shrub	Other Aquatic Plant	Lotus	Total	User Accuracy	Forest	Water	Shrub	Other Aquatic Plant	Lotus	Total	User Accuracy
Forest	25	2	1	0	0	28	0.89	26	0	2	0	0	28	0.93
Water	1	11	0	2	0	14	0.79	0	12	0	2	0	14	0.86
Shrub	0	0	93	2	0	95	0.98	0	0	91	4	0	95	0.96
Other Aquatic Plant	0	1	26	49	0	76	0.64	0	1	3	68	4	76	0.89
Lotus	0	2	1	0	63	66	0.95	0	0	0	2	64	66	0.97
Total	26	16	121	53	63	279		26	13	96	76	68	279	
Producer Accuracy	0.96	0.69	0.77	0.92	1.00			1.00	0.92	0.95	0.89	0.94		

Overall Accuracy :	0.89	Overall Accuracy :	0.94
Kappa Coefficient :	0.81	Kappa Coefficient :	0.91

4. Conclusion

Sentinel-2 imageries have a capability for mapping wetland aquatic plant. In this study, we use pixels based and object based classifications technique to map lotus and other landuse type in Tasik Chini. From the accuracy assessment analysis, the overall accuracies of pixel based classification and object based classification result were above 85%, and Kappa coefficient are well above 0.8, indicating a strong agreement or accuracy between the classification map and the ground reference information. Lotus distribution has been successfully identified and mapped using Sentinel-2 imagery in Tasik Chini with the extent of 57.94 ha or 12.39% of the study area. Thus, the present study illustrates that the geospatial technology are important technologies for quantification of spatial distribution of Lotus which is otherwise not possible to attempt through conventional mapping techniques. Wetland mapping is made possible by these technologies in less time, at low cost and with better accuracy.

Acknowledgments

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