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Identification and Mapping of Lotus (*Nelumbo nucifera*) Distribution in a Shallow Lake Using Satte; Ite Imagery and Geographical Information System (GIS)

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Abstract: Tasik Chini is the 2nd largest freshwater lake of Peninsular Malaysia lately experienced diminishing population of lotus. Therefore, this study aims at mapping the distribution of lotus in two different seasons, August, 2004 (dry season) and April, 2007 (normal season) in this freshwater lake. Two IKONOS images dated August 26, 2004 (dry season) and April 07, 2006 (normal season) were acquired. Computerized analysis was carried out in image processing until the supervised classification stage by using ERDAS Imagine 8.7 and ArcGIS 9.0 software. IKONOS multispectral image acquired on both dates was geometrically corrected and a water mask was used based on strong absorption of Near Infrared (NIR) wavelengths by calm, clear and deep water. The water mask was applied using band reflectance values for a specific pixel satisfying the conditions of band decreasing property (green>red>NIR) and NIR<NIR threshold. Unsupervised classification was applied to the wetland-only image to identify submerged plant vegetation classes. Spectral similarity among the isodata classes was used to decrease the number of the classes to the available species in the lake. Classification of IKONOS satellite data with an unsupervised classification technique provided high accuracy for identification and mapping of submerged plant coverage and of different lotus, other submerged plant species and water classes (0.4, 27.1 and 72.5%, respectively for IKONOS image dated August, 2004). Image dated April, 2006 showed; 1.45 lotus, 18.74 of other submerged aquatic plants species and water classes 79.81%. IKONOS sensor data were found to be very useful for classifying submerged plants in large and shallow lakes.

Key words: Lotus, IKONOS satellite imageries, unsupervised classification, Tasik Chini, Geographical Information System (GIS), Malaysia

INTRODUCTION

The Tasik Chini basin includes a lush tropical secondary rainforest covering an area of 4975 ha from which many rivers and streams feeds the lake. Sungai Chini connects the lake to the main Sungai Pahang. In 1994, a barrage was erected across Sungai Chini making Tasik Chini a partial natural lake. The initial reason for building the barrage was to provide easy passage to the boating activities involved in tourism, especially during the drier season (Mushrifah and Ahmad, 2005). Shallow lake wetlands are known to switch between two alternative stable states; a macrophyte (aquatic plant) dominated clear-water state or a phytoplankton dominated turbid water state (Jeppesen *et al*., 1997). The macrophyte-dominated clear-water state tends to support high biodiversity and in turn high ecological and conservation values. In shallow lake wetlands, submerged and emergent aquatic plants have many important functions including suppression of phytoplankton, provision of habitat for invertebrates, fish and waterfowl, refuges for zooplankton and stabilization of sediment by their roots (Gulati and van Donk, 2002).

One of the main attractions of Tasik Chini is lotus (*Nelumbo nucifera*) which once upon a time covered almost the entire water surface of the lake. Nevertheless, regarding to observations and records, there is a significant decrease in term of percentage of the lotus

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coverage observed in one decade time. He also reported that this aquatic macrophyte is important inecotourism sector and acknowledged the possibility that the changes in percentage of lotus distribution in the lake were greatly influenced by the fluctuation of the water level. This may be due to a possible microclimatic changes taking place in the study area. While on the other hand, it is reported that the seasonal changes in the water level greatly influence the water quality of the lake (Shuhaimi-Othman *et al*., 2006). The use of high spatial resolution IKONOS satellite imageries (4 m multi-spectrum and 1 m panchromatic) is the most appropriate in monitoring the aquatic vegetation in lake and wetland (Olmanson *et al*., 2002). It is believed that this pan-sharpened and high resolution image allows the variation assessment of aquatic vegetation found in lake or wetland which may not be achieved by using Landsat satellite imageries.

A part of that the multispectrum data of the IKONOS imageries allowed the advanced classification which beyond the ability of normal aerial photograph. In a related study, IKONOS data was used to map emergent and submerged plants (Sawaya *et al*., 2003).

However, all density classes for submerged vegetation were merged into one class for accuracy assessment which yielded to the user and producer's accuracy of 54.2 and 92.9%, respectively (Ozge *et al*., 2008). This study aims to map the distribution of lotus (*Nelumbo nucifera*) using high spatial resolution IKONOS satellite data.

MATERIALS AND METHODS

Tasik Chini is located in the Southeast region of Pahang, Malaysia. The lake system lies at 3°15′40″N and 102°45′40″E and comprises 12 open water bodies, known as laut (sea) by local people. 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 Melai and Paya Merapuh at the South of the lake. Only one river, Sungai Chini drains the lake to the main river, Sungai Pahang. The area has a humid tropical climate with two monsoon periods, characterized by bimodal pattern: Southwest and Northeast monsoons bringing an annual rainfall which varies between 1488-3071 mm. This natural freshwater lake is made of 202 ha with 150 ha (dry season) of open surface water which may expand up to 350 ha during the wet season (Toriman *et al*., 2009). As Tasik Chini has unique seasonal changes, the field surveys were conducted in September, 2006 which represent the normal season. The coordinates for each cluster of lotus found on the lake surface were recorded by using DGPS with ±2 m accuracy. The sampling locations are shown in Fig. 1.

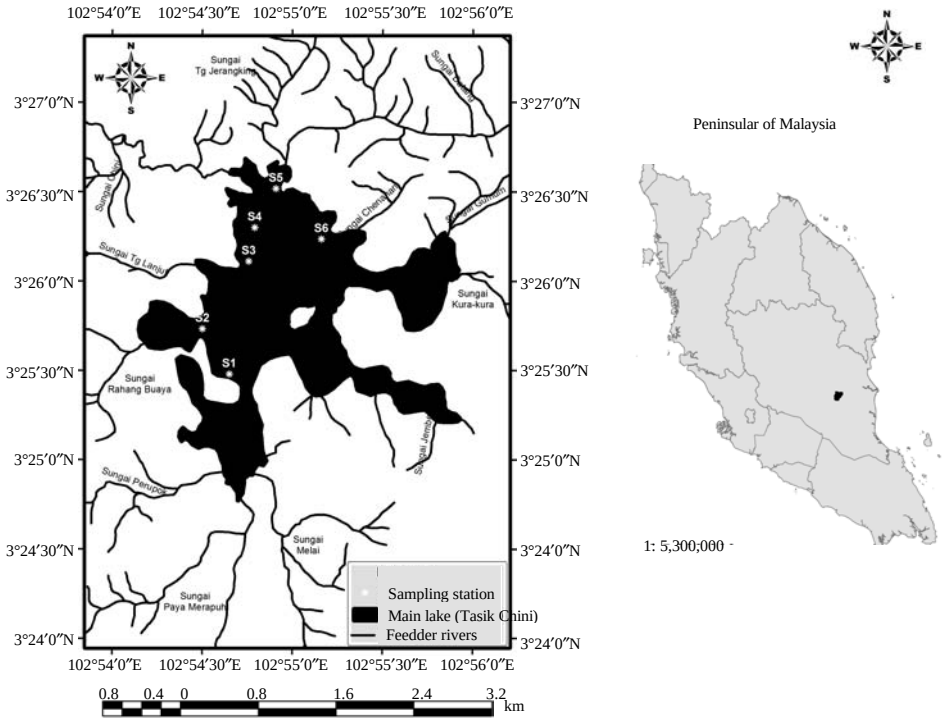


Fig. 1: Sampling stations at Tasik Chini, Pahang, Malaysia

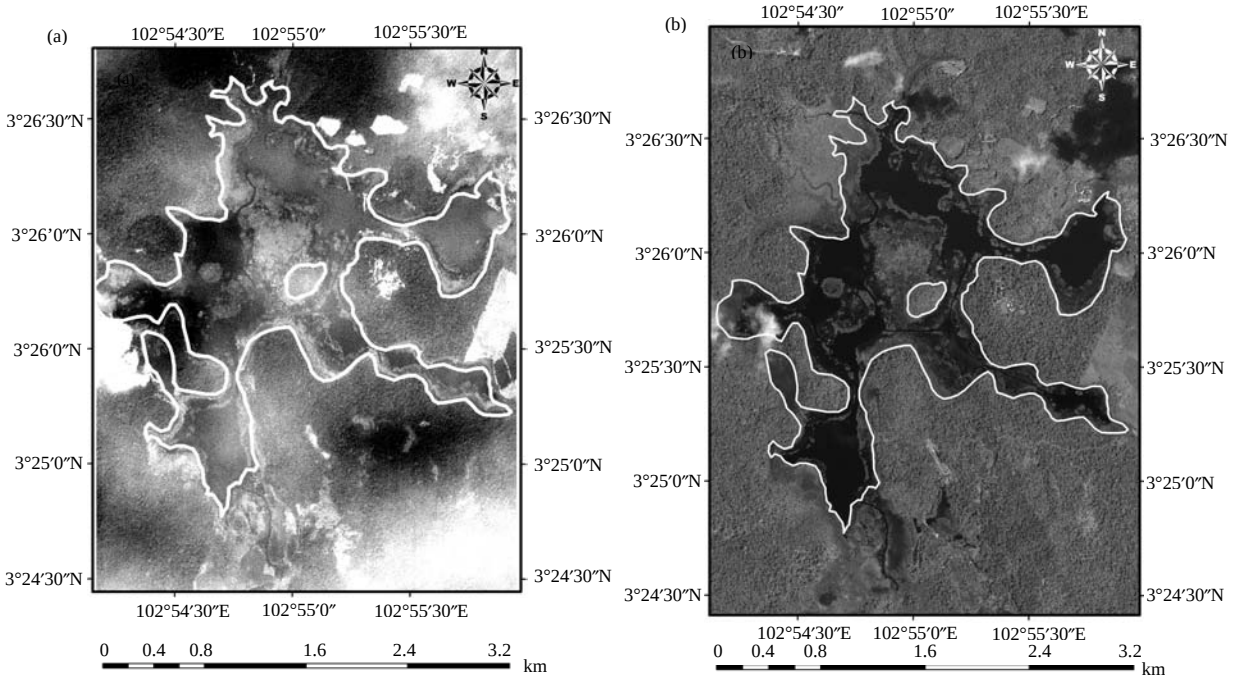


Fig. 2: IKONOS satellite images for Tasik Chini, Pahang, Malaysia (data acquisition: a) August 2004; b) April 2006)

Table 1: Description of the sampling stations

Station	Station name	DGPS coordinates	Note
S1	Pulau Besar	03°25'27.715"sU, 102°54'25.434"T	Near a small shed which has been used as a fishing spot by local people
S2	Laut Mempitih	03°26'05.787"U, 102°54'39.654"T	Near Bangau island. Lowest depth reading recorded (1.47 m) were fully covered by lotus
S3	Laut Mempitih (Genting Teratai)	03°26'07.539"U, 102°54'40.495"T	The famous tourist attraction spot for lotus watching
S4	Laut Tengkuk	03°26'13.145"U, 102°54'41.678"T	The most abundant lotus coverage observed
S5	Tg Jerangking (muara Sg. Chini)	03°26'25.000"U, 102°54'48.709"T	Lotus found at the river mouth of Sg Chini
S6	Laut Cenahan	03°26'15.639"U, 102°55'06.081"T	Near Orang Asli aborigine village

Submerged plant species collected from each sampling location were identified using identification keys for water plants (WIAP, 1998).

The classification were identified by lotus and non-lotus class and the secchi disc was used to indicate the water clarity and turbidity in order to define separate water classes in the classification.

It is assumed that when the depth of water is less than double of the Secchi disc depth, the diversity and heterogeneity of bottom reflective targets led to problems with a mixed pixel. ERDAS Imagine 8.7 was used to transfer the field data into raster environment Table 1. IKONOS images (acquired on August 26, 2004 and April 07, 2006) with spatial resolution of 4 m (multispectrum) and 1 m (panchromatic) as shown in Fig. 2 were used in this study. The image was minimum cloud spots and geometrically corrected based on 20 Ground Control Points (GCPs) collected in the field by the same DGPS device used in the field survey. The DGPS (Thales Model) accuracy was ±2 m, >0.5 m accuracy after pre-processing and the resulting total RMS errors were corrected <0.9. The methodology for the satellite data analysis is shown in Fig. 3.

Terrestrial and lake boundaries were digitized by visual interpretation. The constructed vector data for the terrestrial-lake boundary was used to create a bitmap which was used for masking the terrestrial area to produce a lake-only image.

Unsupervised classification was applied to the produced lake-only image to identify the lotus coverage. The distinct spectral classes analyzed from the images are shown in Fig. 4.

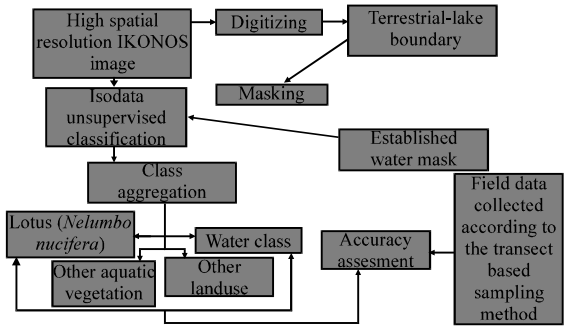


Fig. 3: Methodology for the satellite data analysis

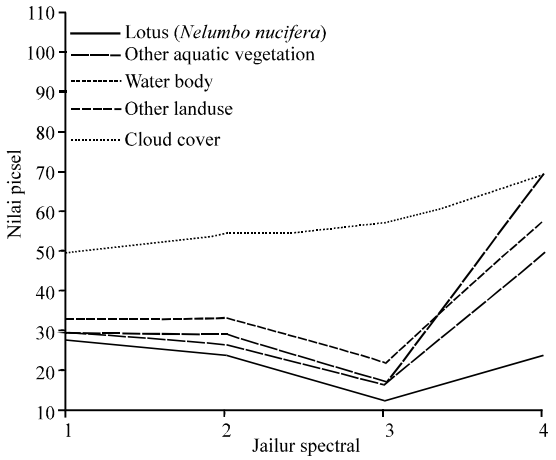


Fig. 4: Spectral reflection profile of IKONOS imageries

RESULTS AND DISCUSSION

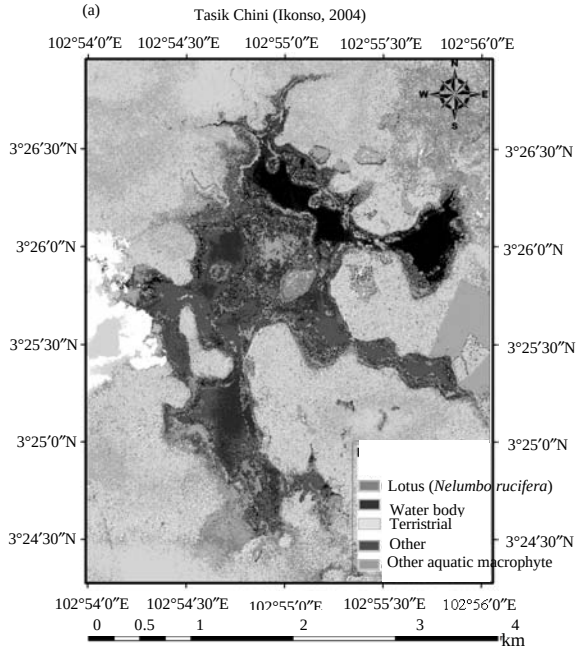
Stratification and unsupervised classification of two high spatial resolution multispectral IKONOS images was able to provide the map of lotus distribution of Tasik Chini of two different season; dry season (August 2004) and normal season (April, 2006).

The season were defined by referring to rainfall density of both date and based on annual rainfall pattern of the year. Figure 5 and 6 showed the final lotus distribution map of Tasik Chini for dry and normal season, respectively.

Figure 5 which shows the IKONOS image of Tasik Chini acquired in August 2004 in dry season shows the percentage of lotus distribution is only 0.40% out of the total lake size. This may be due to the water level during that period of dry season is slightly low.

The lotus mostly observed in the littoral zone of the lake at an average depth of ±1.6 m, this might be the favorable water level for optimum lotus growth. It is reported that lotus growth cycle begins in wet season where the seeds and vegetative propagules start to sprout as after the monsoon begins (Zonneveld, 1979).

The characteristics of this aquatic vegetation will be exhibited in a few weeks. As the water level increased, the water became cloudy caused by the sediment fluctuation.



(b)

Landuse/coverage	Area (km^2)	Percentage
Lotus	0.01931	0.40
Water body	3.47576	72.5
Other aquatic vegetation	1.29408	27.1
Total	4.78915	100

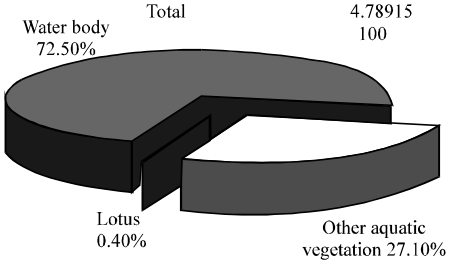


Fig. 5: Lotus (*Nelumbo nucifera*) distribution map for; a) IKONOS image (August, 2004); b) Land use coverage

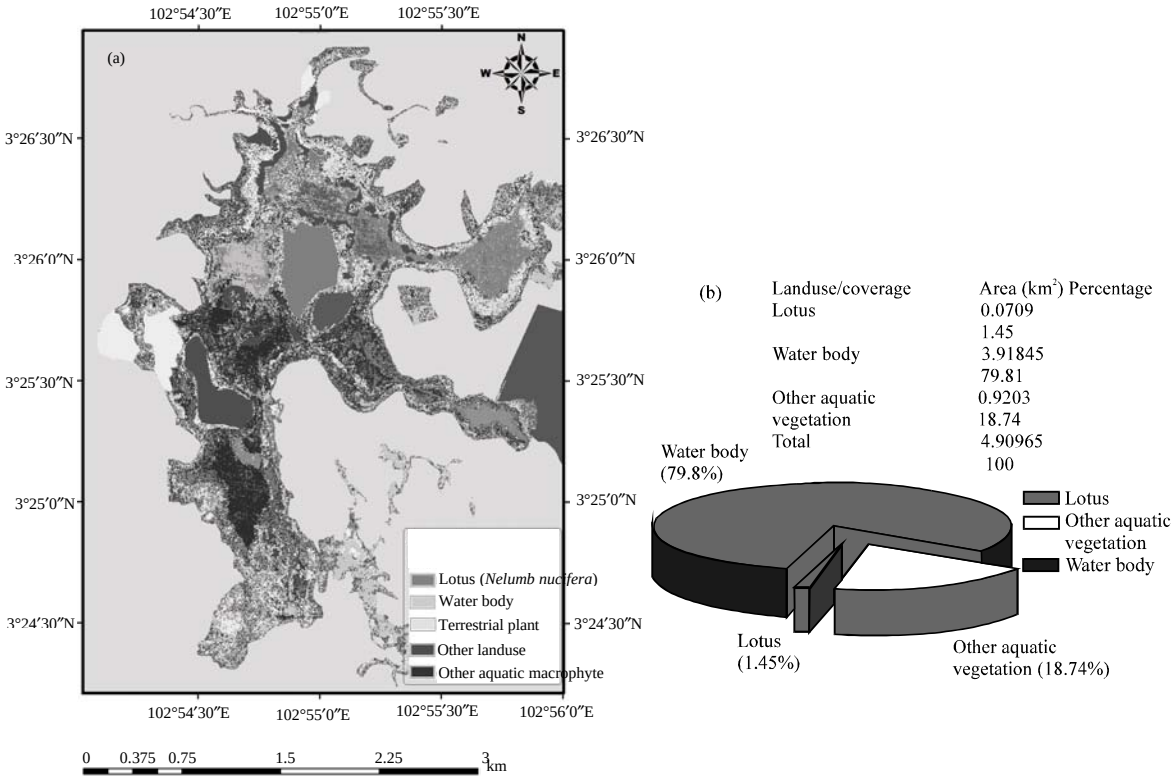


Fig. 6: Lotus (*Nelumbo nucifera*) distribution map for; a) IKONOS image (April, 2006); b) Land use coverage

CONCLUSION

With further research, additional field reference data and processing, it is expected to identify more specific aquatic plant types. Future plans also include application of appropriate accuracy assessments techniques (Idris *et al*., 2007; Toriman *et al*., 2010). This preliminary study has indicated that the use of IKONOS imageries for aquatic plant surveys is promising. The high spatial resolution of the IKONOS imagery enables the assessment of lotus distribution which is predominant at the lake and other aquatic vegetation variation at a reasonably fine scale (1 m) within lakes and wetlands that cannot be obtained from Landsat data and the multispectral data enable classification beyond what is commonly done with aerial photography.

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