Water Body Detection and Monitoring Due to Urbanization

Penetapan Badan Air dan Pemantauan Dengan Urbanisasi

Zuraihan Mohamad, Na'im Farhana Abdul Rahim, Masayu Norman,
Ashnita Rahim & Fazly Amri Mohd

Center of Studies for Surveying Science and Geomatics,
Faculty of Architecture, Planning & Surveying,
Universiti Teknologi MARA, 02600 Arau, Perlis

E-mail: zuraihan486@perlis.uitm.edu.my

Abstract

This study proposes water body detection using remote sensing techniques and monitoring the changes in water body due to urbanization. The monitoring timeline from 2013 until 2019, with acquisition of different satellite imagery dataset for both years. Project area of this study is Johor River in the region of Pulai, Johor. Satellite imageries used in this project are Landsat 8 acquired in 2013 and Sentinel-2 from 2019. There are two aspects in this project, to detect the presence of water body in project area using remote sensing technique and to monitor the changes of Johor River in Pulai region in 2013-2019. For detecting presence of water, multispectral bands combination and Normalized Difference Water Index techniques were used, mainly to distinguish water body and non-water body features. For river changes monitoring, image classification method was used to monitor the changes in those years.

Keywords: Remote Sensing, Urbanization, Normalized Differential Water Index

Abstrak

Kajian ini mencadangkan pengesanan badan air menggunakan teknik penderiaan jauh dan memantau perubahan badan air akibat pembangunan pembandaran. Pemantauan berlangsung selama dari 2013 hingga 2019 dengan pemerolehan set data satelit yang berbeza bagi tempoh tersebut. Kawasan projek kajian ini adalah Sungai Johor di wilayah Pulai, Johor. Imej satelit yang digunakan dalam projek ini adalah Landsat 8 yang diperoleh pada tahun 2013 dan Sentinel-2 pada tahun 2019. Terdapat dua aspek yang ditekankan di dalam projek ini iaitu untuk mengesan kehadiran badan air di kawasan projek menggunakan teknik penderiaan jauh dan untuk memantau perubahan Sungai Johor di wilayah Pulai pada 2013-2019. Untuk mengesan kehadiran air, digunakan gabungan jalur multispektral dan teknik Indeks Perbezaan Air Normalisasi terutamanya untuk membezakan ciri badan air dan badan bukan air. Untuk pemantauan perubahan sungai, kaedah pengkelasan gambar digunakan untuk memantau perubahan pada tahun-tahun tersebut.

Kata kunci: Remote Sensing, Pembandaran, Indeks Normalisasi Perbezaan Air

Introduction

Water is very important and vital for all people around the world. It is an important thing that is most needed for human life and activities. In recent years, water quality has been an enthusiastic issue to be debated by public. Various research conducted by scientists and researchers stated that data from the satellite like Landsat, IKONOS, SPOT, IRZ, ZCS and SeaWiFS may be applied in accessing water quality parameters including suspended matters, turbidity, phytoplankton and dissolved organic matter (Ang & Faradiella, 2016). For years, researchers have studied and monitored water quality using remote sensing application but there are still few obstacles on water quality monitoring using existing methods. This study explains the detection of water body using remote sensing techniques and application of remote sensing to monitor changes in water body. The remote sensing applications used in this report are multispectral bands combination and Normalized Differential Water Index (NDWI) to process the remote sensing data.

According to the report titled East Asia's Changing Urban Landscape: Measuring in a Decade of Spatial Growth, Malaysia is amongst the most urbanized countries in East Asia, and its urban population continues to increase rapidly (The World Bank, 2015). With range of 1 million to 5 million populations, Johor has the most rapid growth in 2000-2010 with its capital, Johor Bahru, grew from 270 km2 to 420 km2 in a decade (The World Bank, 2015). Given advantage of its location across the narrow strait from Singapore, the high-income country, Johor has become the second most urbanized city in Malaysia with steady growth of population each year, following suits Kuala Lumpur. However, with constant growth of urbanization, many other aspects have negatively affected, especially environmental degradation.

Water physique and clean water source are the ones of most implicated by urbanization and growth of population. Nowadays, the biggest environmental hazard of developing and developed countries is insufficient of clean water due to rapid increase of population (Muhammad Abo ul Hassan et al., 2018). Moreover, clear water has been contaminated by excrement through sewers, industrial effluent and agricultural excessive. Not to mention, the disposal of waste straight into rivers also has contributed to this issue. In March 2019, the whole nation has been shocked by river pollution news in Johor. The illegal dumping of toxic chemicals into Kim Kim River in Pasir Gudang has caused almost 1000 people including school children fell victim to gas poisoning (Eco-Business, 2019). This terrific incident shows how unorganized urbanization can badly effect the environment, clean water resource and next become danger to human's health.

Due to this incidence, further study of water body changes due to urbanization needs to be done in relative area to make sure any incident like river pollution in Pasir Gudang can be prevent next time in more effective ways. For this project, Johor River in Pulai region was selected as project area for the purpose of detecting presence of water body in Pulai and monitoring changes of water body due to urbanization.

Water is the most important source for all living things, also useful for non-living thing. Hence, water body changes have been analysed in several studies before. Factors of water body changes are influenced by rapid urbanization, industrialization and rural area conversion (Muhammad Abo ul Hassan et al., 2018). Unexpected population growth is related to water body and water quality degradation (Ghosh et al., 2014) that leads to insufficient sources of clean water. Furthermore, recently there are more news regarding the pollution of water and water physique, including rivers. In Johor, river pollution has been detected in early March 2019 caused by unorganized urbanization growth that lead to chemical waste dumping into Kim Kim River (New Strait Times, 2019). The health of many people nearby the polluted river was effect by the incident. Also, the source of clean water is limited and the ecosystem disturbed by the tragic incident. In response of this problem, this study proposes to show the importance of detecting water sources and monitoring the changes of water body due to urbanization.

Study Area

Located along Tebrau Strait, Pulai was chosen to be study area for this project. With coordinates of 1.4970˚N, 103.6131˚E, Pulai is located at south west area of Johor state. This project focused on the area along Johor River in the region of Pulai (area within red box). The area covered is 1063.53 hectares and the length of the river in the Pulai region is 7089.12m. Connected to Tebrau Strait, the river in the study area is the main feature to be analyzed in this project. The area covered by the river will be compare in 2013 and 2019 due to urbanization growth in Pulai region.

Historically, the location of Johor state along Tebrau Strait has become its key factor for the state's increasing rate of population growth. The increase of population leads to urbanization in the regions of the state, including Pulai. A significant growth of urbanization in certain area can be shown by obviously increasing area of township, populated areas (residentials), industrial area, roads and highways and other facilities. In this project, the areas covered by the river and urbanization studied to proven the change of the river affected by the urban growth in Pulai region (Figure 1).

Figure 1: Study area in Pulai, Johor Source: Google Earth (2019)

Data And Method

The study utilised the data from 2013 and 2019 of Pulai region to show the changes of water body in six years of time. From multispectral bands combination and Normalized Difference Water Index (NDWI) techniques, water features can be extracted from the satellite imagery for further processing with image classification technique.

There are two data used from two different datasets of different acquisition time. First image is Landsat 8 imagery of Johor, Malaysia, taken in January 2013 and another is Sentinel-2 imagery also of Johor region acquired in March 2019. Both images were downloaded from the United States Geological Survey (USGS) website with WGS84 UTM 48N projection (USGS, 2018a; 2018b). Cloud cover for these images under 10% which is suitable for image interpreting projects like this.

The data that had been downloaded in USGS explorer have different bands. Layer stack are needed to combine all bands into single multiband image. For Landsat 8, there are altogether eleven layers to be stacked and for Sentinel-2 there are twelve layers for layer stacking. A spectral band is a range of values the sensor is set to detect along the spectrum. In single satellite imagery, there might be teens of bands available depending on the sensor. These bands can be combined together to make the image more interpretable depending on the topic of study. R:8, G:11, B:4 bands combination was used to distinguish land and water features in this Sentinel-2 imagery while in Landsat 8, the bands used to differentiate water and land features are R:5, G:6, B:4.

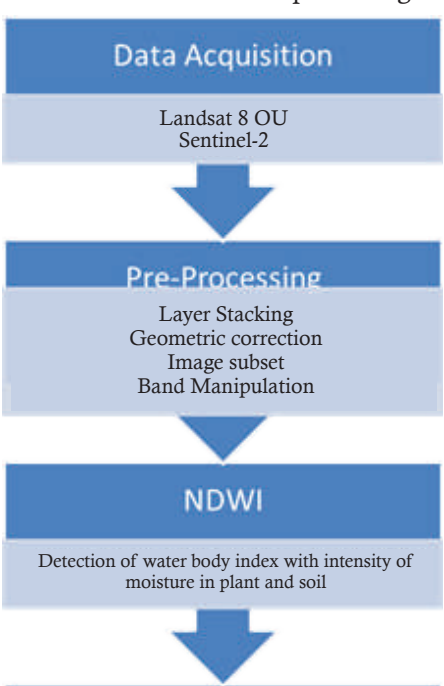
NDWI is the most appropriate index for water body mapping as the water body has strong absorbability and low radiation in the range from visible to infrared wavelengths. The index uses green and Near Infrared bands of remote sensing image. For Landsat 8 image, the NDWI formula is (Band 5- Band 6)/ (Band 5 + Band 6), while for Sentinel-2 the formula is (Band 8a - Band 11)/ (Band 8a + Band 11).

$$\mathbf{NDWI} = \frac{(NIR+SWIR)}{(NIR-SWIR)}$$

Where:

NDWI is the Normalized Difference Water Index
NIR is the near infra-red band
SWIR is the short wavelength infra-red band

Image classification technique is done to group pixels to represent land cover features, exist on the image. Unsupervised image classification is one of the common classification technique often used in digital image processing. Unsupervised classification on is a form of pixel based classification and it is essentially computer automated classification. User only specifies the number of classes and the spectral classes are created solely based on the numerical information in the data. The pixels are grouped together based on their spectral similarity. Figure 2 shows the flow of the data processing.



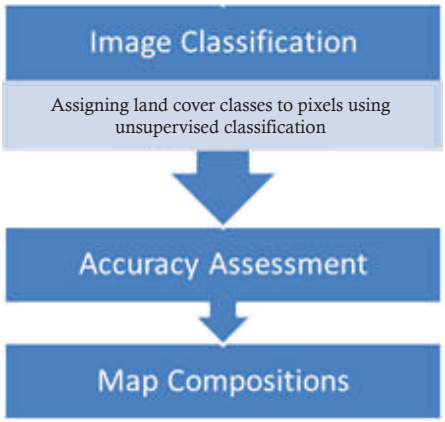


Figure 2: Flow of Study

Results And Discussions

Multispectral Bands Manipulations

From the output of multispectral bands combination from both Landsat 8 imagery and Sentinel-2 imagery in the next pages, the presence of water body can be identified by the dark blue-colored feature on the map. The non-water body features with water body feature distinguished clearly with multispectral band combination. Even though both imageries have different range of spectral bands, but both the output for both Landsat 8 and Sentinel-2 multispectral bands combination for land/water analysis are almost same to each other.

As for detecting presence of water feature, multispectral bands combination and NDWI techniques were used in this project. Based on the outputs for both techniques, it seems that application of remote sensing in detecting water body is really useful and reliable. Based on the image interpretation in Figure 3, water body of Johor River can be clearly identified in the image. The dark blue colour represents water feature while orange colour represent vegetation and green colour represent land cover. The objective of detecting presence of water body in the imagery is achieved successfully using multispectral bands combination technique. In this technique, actually there are other bands combinations that can be used to define and interpret the imagery based on the study topic and it is differs for different datasets.

Figure 3: Band Manipulation for Detecting Water Areas

Normalized Differential Water Index (NDWI)

From the output of NDWI for both Landsat 8 and Sentinel-2 imageries, water feature can be distinguished in the output map with white colour feature. NDWI value lies between -1 and 1. Water body in NDWI can be defined by pixels with more than 0.5 values. From both NDWI output, pixels with more than 0.5 values are considered water body and have been classified in white colour, while non-water body features with less than 0.5 value classed in black colour.

For NDWI technique, the output comes in grey scale image. This is more convenience in distinguishing water feature as the interpretation will be easier. The darker the area, the less moisture content reflected as in Figure 4. From the output of NDWI technique of remote sensing application, the objective of defining the presence of water body in the satellite imagery is a success. However, the bands used in applying NDWI may vary if other datasets is used but the application is still as same.

Figure 4: Distinguishing Water Areas from Non-Water Using NDWI

Area Comparison and Changes Rate

Table 1 shows that the comparison of area in hectare and percentage which is in 2013 and 2019. It can be seen that there are changes of the area cover which is in 2013 to 2019. In 7 years, vegetation area lessen from 166.68 hectares to 121.62 hectares while river area lessen by 2.67 hectares. Riverbank shows the biggest decrease of area which lessens by 4.22%. Meanwhile manmade features including urbanization and facilities have the biggest size increase from 677.61 hectares to 770.27 hectares. The result of change rate is get from the different value area of land use change between 2013 and 2019. The positive value means increasing trend from 2013 and 2019. The negative value means decreasing trend from 2013 and 2019 as indicated by Table 1.

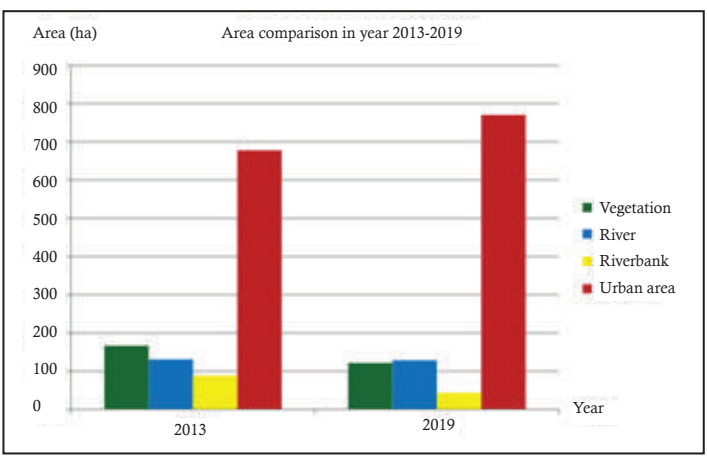
Table 1: Land Use Rate of Change Between 2013 To 2019

Land Use Class	Change Rate 2013-2019	
	Hectare	Percentage
Vegetation	-45.06	-4.16
Water body (River)	-2.67	-0.16
Water body (Riverbank)	-44.93	-4.22
Build-up (Urban)	92.66	8.72

As for monitoring the changes of Johor River and the effect of urbanization towards the size of the river, it can be shown in Table 2 and Figure 5. The difference in seven years is clearly shown in both tables, interpreted with digital analysis of remote sensing. It can be seen that the total area of this project is 1063.53 hectares with some features classed as river, riverbank, vegetation and manmade features mapped. In seven (7) years, it is clear that the embankment of the river is decreased by 44.93 hectares and the river also reduced by 2.67 hectares. The vegetation area, including plantation and forestation also decrease by 4.16 percent. Meanwhile, urbanization (manmade features) keep grading by 92.66 hectares until 2019.

Table 2: Comparison of Area of Land Use Coverage Between 2013 To 2019

Land Use Class	Area			
	2013		2019	
	Hectare	Percentage	Hectare	Percentage
Vegetation	166.68	15.67	121.62	11.44
Water body (River)	130.95	12.22	128.28	12.06
Water body (Riverbank)	88.29	8.30	43.36	4.08
Build-up (Urban)	677.61	63.71	770.27	72.43
Total	1063.53	100	1063.53	100



Conclusion

This project proved its reliability in representing of presence of water body in the region of Pulai, Johor and monitoring the changes of the river from 2013 until 2019 especially in aspect of degradation of river area. Multispectral bands combination and Normalized Differential Water Index (NDWI) techniques ran to determine the presence of water body in the study area worked very well. With application of remote sensing, the monitoring of water body changes can be done easily with reliable output. In conclusion from the result, the increase rate of urbanization resulting to the decreasing area of Johor River. It also can save time and manpower to monitor the changes of Johor River in times. Other than that, by the end of this project, it can be concluded that the aim and objectives of this report have been achieved successfully.

Throughout this study, there are some points that highly recommended which are the urbanization and development around the Johor River should be controlled to ensure the continuity of ecosystem and health issue including avoiding pollution of water along with safety issues. This problems need to be on focus to make sure the quality of water can be monitor and control.

Acknowledgements
The authors thank Geoprecision Tech Sdn Bhd for the knowledge and expertise sharing towards the completion of the study and the Center of Study for Surveying Science & Geomatics, Universiti Teknologi MARA, Perlis.

REFERENCES

Ang, K. H., & Faradiella, M. K. (2016). Remote sensing towards water quality study in Malacca River case study: A review perspective. *International Journal of Scientific Research in Science and Technology, 1*(2), 9-15.

Eco-Business. (2019). *Pasir Gudang dumping - What happened and who is responsible?.* Retrieved from https://www.eco-business.com/news/pasir-gudang-dumping-what-happened-and-who-is-responsible/

Ghosh, A.R., Qureshi, M.S., Kim, J.I., & Zalduendo, J. (2014). Surges. *Journal of International Economics, 92*(2), 266-285.

Muhammad Abo ul Hassan Rashid, Malik Maliha Manzoor, & Sana Mukhtar. (2018).Urbanization and its effects on water resources: An exploratory analysis. *Asian Journal of Water, Environment and Pollution, 15*(1), 67-74.

New Strait Times. (2019). *Toxic waste dumping going on for years.* Retrieved from https://www.nst.com.my/news/nation/2019/03/469368/toxic-waste-dumping-going-years

The World Bank. (2015). *Malaysia among most urbanized countries in East Asia.* Retrieved from https:// www. worldbank.org/en/news/feature/2015/01/26/ Malaysia-among-mosturbanized-countries-in-east-asia, June 17, 2019.

USGS Water Science School. (2018a). Where is earth's water? Retrieved from https://water.usgs.gov/edu/earthwherewater.html, April, 19, 2019.

USGS Water Science School. (2018b). Urbanization and water quality. Retrieved from https://www.usgs.gov/special-topic/water-science/ urbanization-and-water-quality, June 17, 2019.