Asian Journal of Scientific Research

ISSN 1992-1454

OPEN ACCESS Asian Journal of Scientific Research

ISSN 1992-1454
DOI: 10.3923/ajsr.2020.197.204

CrossMark

Research Article
Satellite Imagery System in Water Resources Management: Impacts from the Land Use and Land Cover Change

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Abstract
Background and Objective: Water Resource is a critical requirement of human existence for all social and economic endeavors. The occurrence of high human activities, especially in agriculture, tourism and industry breaks the balance between water supply and demand that significantly increases the vulnerability of regions into more damaging impacts. The main objective of this study is to determine the increase in water demand by land-use changes and at the same time to assess the land use and land cover change in the region. **Materials and Methods:** The research was performed by remote sensing Landsat 8 Operational Land Imager/Thermal infrared Scanner (OLI/TIRS) 30 m Satellite Imagery analysis. **Results:** The findings show that the average rate of increase in water demand was estimated at 0.22% each year for domestic, commercial and industrial sector usage and 43.08% per year for the agricultural sector. **Conclusion:** This study shows how different water extraction by the society through land-use change has affected the water availability throughout the region.

Key words: Satellite imagery, land use change, land cover change, water resources, water demand, remote sensing, policy making

Citation: Carolyn Payus, Lim Ann Huey and F.A. Farrah Adnan, 2020. Satellite imagery system in water resources management: impacts from the land use and land cover change. Asian J. Sci. Res., 13: 197-204.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Land use and land cover change assigned to human activities involving land-use conversion for agriculture, business and residential which are seen to be the major factors that affecting the hydrology system that controls the availability of water resource[1,2]. According to Sun and Pratt[3] stated that the land use and land cover changes have four major effects on the hydrology of an area, including changes in peak flow characteristics of the water, total runoff, changes in the quality of water; and changes in the hydrologic amenities. The condition is exaggerated even more and triggered the worst when more over-extraction of water resources happened, which will change the water usage patterns and demand that will pose more pressure on the water scarcity[4]. The rapid growth of urbanization, especially in economic development for industrialization and over increasing population has led to the stress of the water demand that has exceeded the supply recovery rate of the resources that excruciating the problem even more due to the over-population and over-extraction from human activities[5]. It is being further added by Lele *et al.*[6] that increased rates of urbanization led to larger water yield and elevated the flow velocity that resulting in a more significant increase in river runoff peaks in the urbanized area. Urbanization also changes the surface of micro-climatic variables such as; surface moisture availability and radiant surface temperature[7], which are another contributing factor leading to hydrological changes that may negatively impact the water resource availability[8].

While, Northern part of Borneo is not one of the regions currently facing water scarcity, demand for water is continuously increasing and it has been plagued with problems and inefficiencies in water resource management, especially with regards to Non-Revenue Water (NRW), which reaches as high as 56.3% in the regions[9]. The effects of poor management and infrastructure, as well as wasteful consumption habits are now compounding to create an artificial scarcity that leaves many facing constant disruptions in water supply, particularly in high-density population areas[10,11]. Even though Southeast Asia nations, especially North Borneo is a region that has abundant with water resources, characterize as an equatorial part of the world with tropical rainforest climate, North Borneo experiences high temperatures and high humidity year-round and receives a high level of rainfall, at around 2400 mm of annual precipitation[12], with rainfall volume of around 950 km^3. This translates to significant amounts of runoff in rivers and streams which increases its reliability as a year-round water source. However, nevertheless it still facing a looming water crisis due to insufficient water supply, increasing demand due to growing population and ineffective water resource management[12,13].

The demand for water has been reported steadily increasing from 8.9 billion m^3 in 1980 to 15.5 billion m^3 in 2000 or an average increase of 3.7% per year in this region[12]. The agriculture sector accounts for the biggest demand for water that consuming 75-80% of total water demanded. The next-biggest demand for water came from the domestic and industrial sector, which accounted for 18-23% of water demand, while other sectors and uses constituted only around 2% of water demanded. Thus, the vast majority of water demand comes from agriculture as well as domestic and industrial sectors, where combined they constitute around 98% of all water demand[13]. The North Borneo of Sabah itself constitutes 22.37% of the land area in Malaysia[14] and contains a large portion of the ecologically megadiverse Bornean rainforest[15,16] that can be seen as the most important pit and water basin in the country. Thus, this research is important to obtain a view of the impacts and implications of economic development toward the water resources, thus to provide a picture of growth in water demand within the region by using remote sensing analysis on land use and land cover change.

MATERIALS AND METHODS

Study area: The study area is focused on the North Borneo case study of Kota Kinabalu district, which is the state's capital city of Sabah located at the North West Coast Division of Borneo faces the South China Sea. The study was carried out at the Geographic Information System and Remote Sensing Laboratory, Malaysia from March, 2018 to February, 2020. Figure 1 shows the location of the district in Sabah. The area is selected as it is the most rapidly urbanizing and fastest-growing region of Borneo and also where water demand is expected to increase the fastest[17].

Satellite image evaluation: The images that involved in land use and land cover change analysis were Landsat 8 OLI/TIRS (Operational Land Imager/Thermal Infrared Scanner) 30 m acquired from the United States Geological Survey (USGS) (https://earthexplorer.usgs.gov/). Images from two separate years were obtained, which are 2014 and 2019. The images were collected in the same order to obtain a more accurate average annual rate of change and minimize classification variations due to season, such as the same area classified as agriculture in one year but bare land in another due to

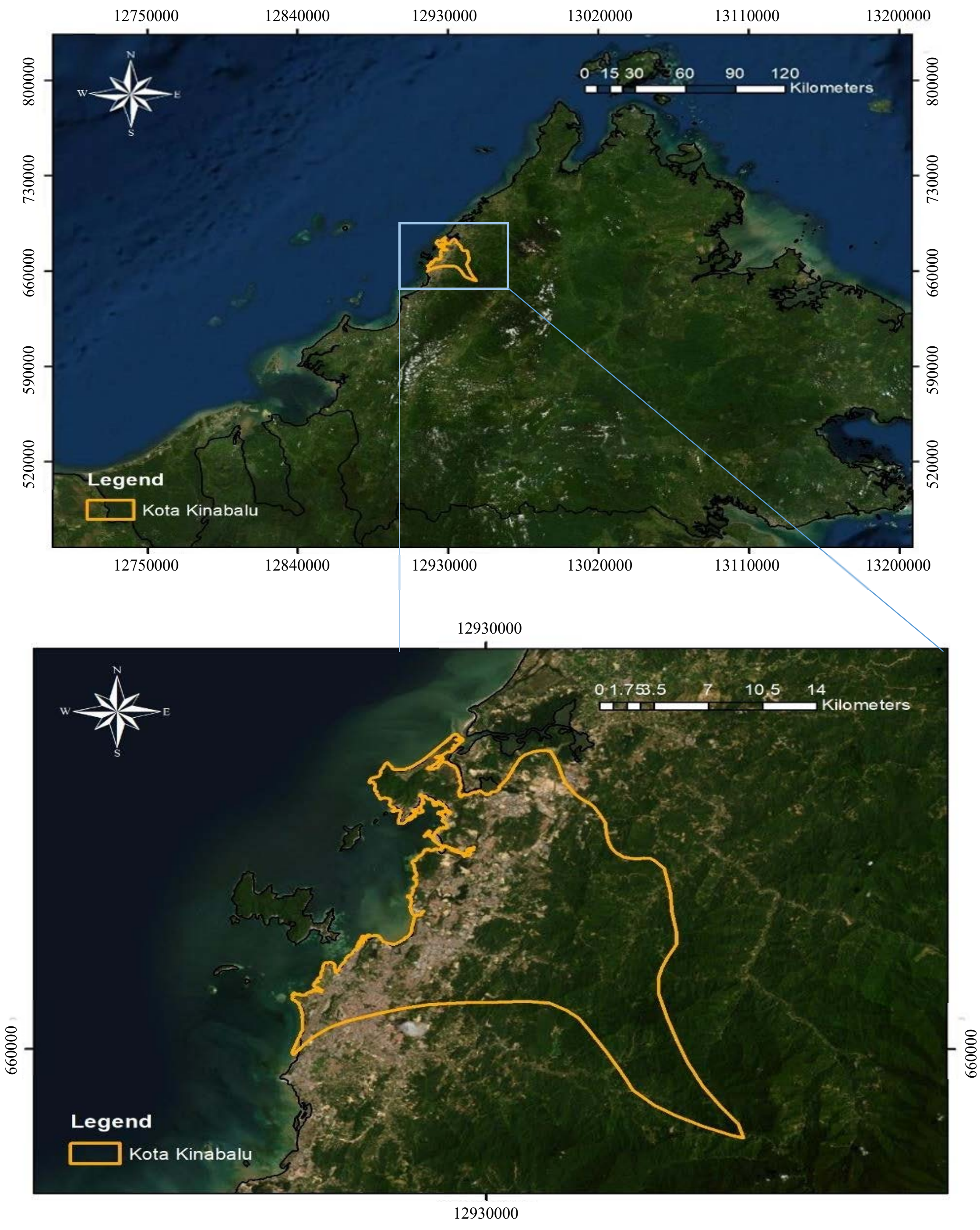

Fig. 1: North Borneo district of Kota Kinabalu study area by ArcGIS ArcMap 10.4.1

differences in the planting season. The Landsat 8 images obtained had already gone through Level 1 and Level 2 processing, which meant that they had already been orthometrically rectified, calibrated radiometrically and corrected for surface reflectance. Hence, these pre-processing steps were bypassed and processing went directly to band compositing. All image processing, classification and remote sensing analysis were done on ArcGIS ArcMap 10.4.1. By arranging particular band combinations to correspond to Red, Green and Blue, certain features can be highlighted or seen more clearly based on their spectral reflectance characteristics than those in an image with natural color and this is referred to as band compositing. Band compositing for this study was done with a 654 band combination, which is a false-color composite generally used for vegetation analysis[18], for a greater degree of discernment between vegetation types, which was useful for distinguishing agriculture and forest during classification later on. After the band compositing, cloud masking was performed to remove pixels that were obscured by clouds and shadows. This was done by manually digitizing the boundaries of the clouds and shadows using the classification toolbar in ArcGIS and designating the pixels inside those boundaries with no data values so that they would be omitted from the classification results.

Subsequently, masked was conducted to extract the area of study from the Landsat satellite images. This was done using the administrative border of the Kota Kinabalu district as the boundary. After the completion of pre-processing, classification was performed on the prepared image. The method of classification used was the supervised classification known as Maximum Likelihood Classification, that often provides good performance in land cover classification[19,20]. After the classification is completed and the land use map is generated and validation is performed on the classified maps via ground-truthing. Supervised classification was utilized to classify the LULC type and validation of the land-use maps using ground-truthing. Validation of classification accuracy was then performed by comparing the points on the classified map with an actual reference map, in this case, Google Earth and the ESRI base map.

Statistical analysis: After all the points have been ground-truthed, the assessment results are used to compute the confusion matrix for the given classification map to determine the accuracy of the classification. By using land use map in 2014 from the Geospatial Information Agency, LULC classification for 2014 was verified with kappa coefficient 0.90 and land classification for 2019 was verified with kappa coefficient of 0.86, which translates both with a satisfactory performance level of accuracy[21].

RESULTS AND DISCUSSION

From Kota Kinabalu's status as the fastest-growing city in Sabah, while good for the economy, comes with certain drawbacks-when one of the main ones being the increased demand for resources, especially water. Land Use and Land Cover (LULC) change analysis is done in the Kota Kinabalu region to determine changes in land use between the years of 2014 and 2019. The focus is to study changes in 2 classes of land cover: built-up land (urban, residential and industrial buildings, etc.) and agricultural land. The agricultural and domestic as well as industrial sectors account for almost all demand for conventional water supply and these industries can be represented in the land classes of agricultural land and built-up land respectively. Thus, it can infer that an increase or decrease in these land classes will exert a corresponding increase or decrease of demand on the water supply system. The aim is to obtain a percentage value of annual change in these land classes, for example rate of development to obtain an idea for the expected annual percentage of the increase in water demand. Limitations present in the resolution of the Landsat 8 imagery used (at 30x30 m per pixel) means that the image resolution is too coarse to be able to distinguish between the different sub-classes of built-up land such as commercial, industrial and residential buildings. Thus, all sub-classes are grouped under the main class.

The two base maps for land use classification in this analysis were obtained after the application of pre-processing methods such as band compositing and cloud masking. Analysis of LULC change in Kota Kinabalu was then performed using the supervised classification method known as Maximum Likelihood Classification on ArcGIS, on the maps from the years 2014 and 2019. The land cover maps created are shown in Fig. 2, while further results of the analysis are shown in Table 1 and 2, respectively. LULC in Kota Kinabalu was classified into 5 classes: water body, built-up land, forest, bare land and agriculture, as can be seen in Fig. 2. By comparing the two classified map images, it showed that there is a dramatic decrease in forest area, which is replaced

Table 1: Area of LULC classes represented in classified land cover map

	2014		2019	
Land use category	Area (km^2)	Percentage	Area (km^2)	Percentage
Built-up land	37.2564	10.940	37.6632	11.06
Agricultural land	20.6649	6.070	65.1762	19.14
Forest	212.5917	62.440	183.9771	54.03
Bare land	61.9920	18.210	43.5978	12.80
Water body	7.9533	2.340	10.0692	2.96

Table 2: Changes in built-up land and agricultural land in KK between 2014 and 2019

	Area in year				
Land use category	2014	2019	Area change (km^2)	Percentage change	Mean change per annum (%)
Built-up land	37.2564	37.663	0.4068	+1.09	+0.22
Agricultural land	20.6649	65.176	44.5113	+215.40	+43.08

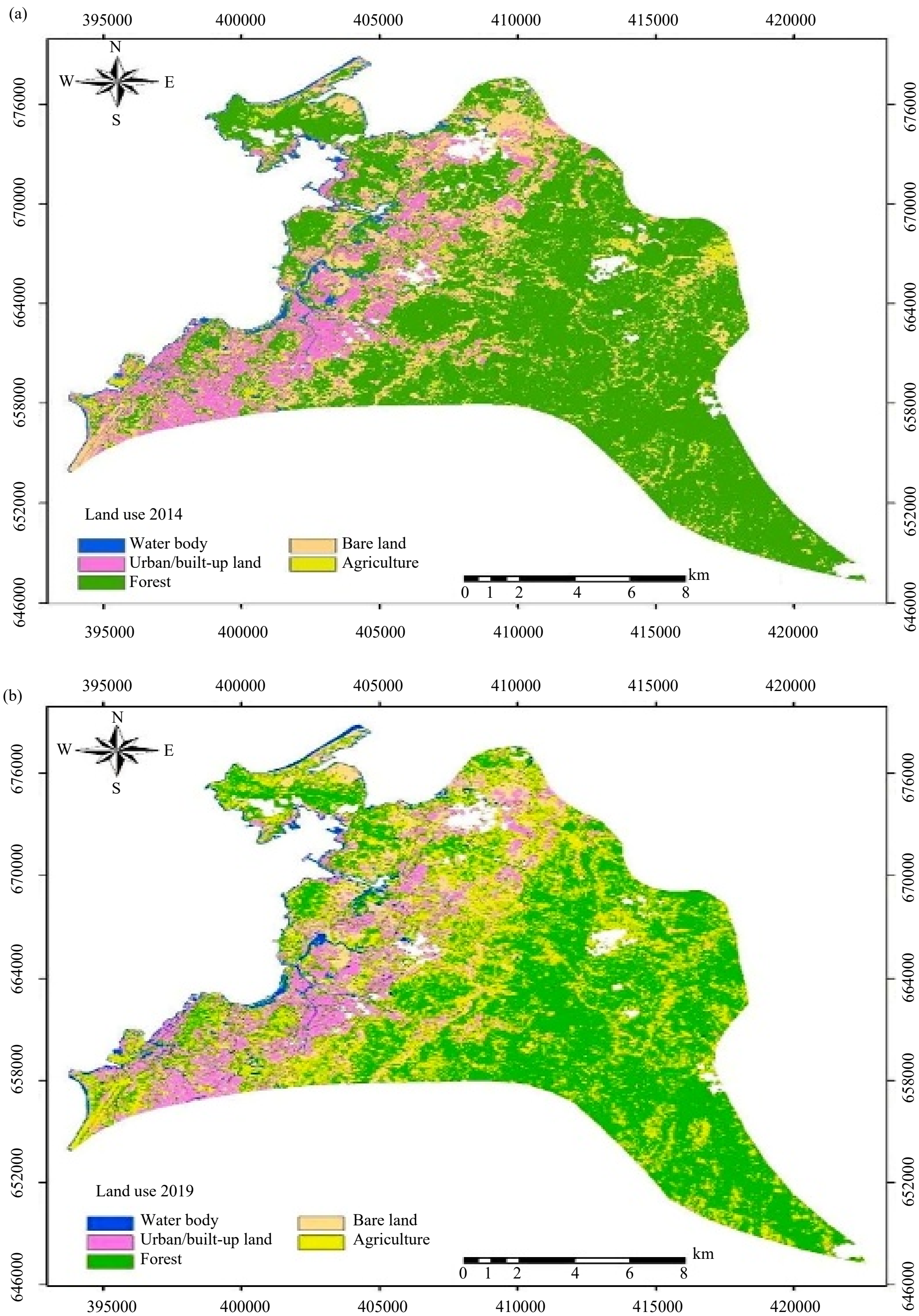

Fig. 2(a-b): LULC changes maps of Kota Kinabalu for the 2 years (a) LULC in 2014 and (b) LULC in 2019

mostly by agriculture and bare land. This trend is corroborated by the observations of Reynolds *et al.*[22], who noted that significant fractions of forest-covered state lands in Sabah are constantly being converted to agricultural plantations and almost all Class II (Commercial) Forest Reserves has been re-logged at least once since 1990.

Understanding the patterns of land use and land cover change are important for the efficiency of environmental management, including effective water management practice. By using the remote sensing patterns, the results from the change-detection analysis can be done to show the extent of LULC changes occurring in different LULC classes resulting from population growth and socio-economic activity. Referring to Table 1, in 2014 the area represented by built-up land constituted 37.25 km^2, 10.94% of the total area in Kota Kinabalu. Agricultural land took up 20.66 km^2 or 6.07% of the total area, while forest comprised 212.59 km^2 or 62.44%. Bare land took up 61.99 km^2 or 18.21% and finally, the water body constituted 7.95 km^2 or 2.34%. In 2019, built-up land took up 37.66 km^2 or 11.06% of the total area, while agricultural land was composed of 65.17 km^2 or 19.14%. Forest accounted for 183.98 km^2 or 54.03% of the land and bare land covered 43.59 km^2 or 12.80%. Water body constituted 10.06 km^2 or 2.96%.

In both years, the forest was the largest land class within Kota Kinabalu, but had declined significantly, from 62.44% coverage in 2014 to 54.03% in 2019. In 2014, the second-highest land class was bare land at 18.21% followed by built-up land (10.94%), agricultural land (6.07%) and lastly water body (2.34%). In 2019, however, the second-most populous land class was agricultural land (19.14%) followed by bare land (12.80%), built-up land (11.06%) and water body (2.96%), respectively. For this study, the focus is primarily on studying changes in these two land classes: built-up land and agricultural land due to their significance to local water demand. The built-up land also can be seen enlarged over the year 2019 that may have converted into a touristy area such as eco-tourism or rural destinations including hotels and home stays. A more detailed breakdown of the changes in these two land classes is shown in Table 2. From Table 2, the total change in the area that occurred in built-up land-which covers residential, commercial and industrial buildings-is an increase of 0.4068 km^2 (1.09%) between 2014 and 2019. Assuming that the rate of development is constant for each year, the mean change per annum or rate of change of built-up land in KK is an increase of 0.22% per year.

Thus, from where it can be extrapolated that the water demand from domestic, commercial and industrial sectors are increasing at an average rate of roughly 0.22% each year. Agricultural land, on the other hand, is experiencing a major expansion in the total land cover area having expanded 44.51 km^2 in 5 years. Taken as a percentage, this is a 215.40% increase of its initial area in 2014, more than doubling its land area within 5 years. Assuming a constant rate of growth, the mean change per annum of agricultural land in KK is a 43.08% development rate, which may lead to a commensurate increase in water demand for irrigation. The results of this analysis indicate that Kota Kinabalu is facing extremely rapid growth in its agricultural sector, which leads to commensurate increases in water supply-demand that may place a significant amount of stress on existing water supply systems within the region. This is notable as the agriculture sector already uses 75-80% of all water demanded in Malaysia[23]. Sabah has historically been reliant on agriculture exports as a major contributor to GDP, with the agriculture sector contributing some 24% to the state's GDP in the years 2010 to 2017, the second-highest contributing sector after the services sector, which includes tourism[24]. The state government is extremely supportive of agricultural activities and has greatly encouraged its growth over the past few decades, which may lead to further expansions.

In 1983 and 1984, the Sabah State Government decided to allocate most lands identified as of good potential for agriculture to private ownership for agricultural development[25]. This subsequently laid the groundwork for the general long-term pattern of forest and agricultural land use. Within the framework of this legislative approach, the main driver of land-use change and agricultural growth is fuelled by the demand and increasing profitability of oil palm cultivation[22]. Altogether, the total area planted with oil palm in Sabah increased by 377.35 km^2 in the 4 years between 2014 and 2018. With a total planted area of 15492.45 km^2 in 2018, this made Sabah the second-largest producer of palm oil in Malaysia next to Sarawak, producing a quarter of Malaysia's palm oil (26.5%)[26]. In October 2019, the state government unveiled the Sabah Agriculture Blueprint 2021-2030, which aims to nearly double the agricultural sector's contribution to the state's GDP from 24-40%[27]. This will undoubtedly affect further boosting the development of agricultural land within Kota Kinabalu. In light of this, caution should be exercised by the state government and local authorities when zoning land for agriculture or approving plantation licenses to not place excessive stress on existing water supply systems, particularly in more water- insecure regions.

CONCLUSION

In conclusion, it was found that in the North Borneo case study of Kota Kinabalu, the obtained average rate of increase in water demand is approximately recorded the highest at 43.08% per year for agricultural consumption and 0.22% per year for domestic and industrial use. This indicates the most expansion of land use resulting from the population growth and socio-economic activity. Agriculture accounts as the majority of water demanded and thus, the rate of development in the agricultural sector should be placed under closer scrutiny when it comes to planning for water resources management within the region. A low-cost change analysis using remote sensing satellite imagery made it possible to quantify and map the changing pattern in LULC that provides a basis for strategic land-use planning, managing and protection in decision making.

SIGNIFICANCE STATEMENT

This study discovers an average rate of increase in water demand recorded the highest at 43.08% per year for agriculture consumption and 0.22% per year for domestic and industrial use. This indicates mostly an expansion of land use resulting from the population growth and socio-economic activity. This important to give an overview of the implications of economic development toward the water resources, to start taking an appropriate planning decisions, to minimize ecological and sociological impact especially from the land use and land cover change point of view.

ACKNOWLEDGMENT

This research was supported by the Japan Society for the Promotion of Science (JSPS). Water Database was provided by Sabah State Water Department, Malaysia. This research is part of Water for Sustainable Development (WSD) Project of United Nations University-Institute for the Advanced Study of Sustainability (UNU-IAS), collaboration with the University of Tokyo (UTokyo) and Universiti Malaysia Sabah (UMS).

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