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Effect of Dam Construction to Land Use and Land Cover Changes Using Remote Sensing: A Case of Hulu Terengganu Hydroelectric Dam

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***Abstract* – Increase demand of electricity has driven the exploration of Hulu Terengganu hydroelectricity dam as an option to generate electric power supply. Therefore, as a way to monitor the landscape changes, spectral indices were used to study on the spatial-temporal changes over the Hulu Terengganu catchment area. Spectral indices technique was applied on satellite images which acquired on three different years to describe the changes before the construction phase, during the construction phase and post-construction phase. Satellite images used in this study are SPOT-5 and Landsat 7 for year 2006, SPOT-5 and Landsat 8 for year 2014 and Spot-7 and Sentinel 2 for year 2018. Alteration of the land use and land cover has recorded degradation of the forest area by -5.53% during the dam construction phase (2014) and -8.35% during post-construction phase (2018). It also found that water body has remarkable change of 10,141% increase from 2014 to 2018. The result from this study would be useful as an overview for future planning, decision making and dam management activity related to the Hulu Terengganu hydroelectric dam operation.**

Keywords— LULC changes, spectral indices, land use classification, Hulu Terengganu hydroelectric dam

I. Introduction

Puah and Tembat hydroelectric dam was established in Hulu Terengganu catchment area as an additional electrical power generation in Malaysia. The dam has helped to generate an extra of 265MW electricity. However, the dam construction activity is closely related to alteration of the land use and land cover over the area which could impact to the environment, aquatic ecology and wildlife habitat [1]. Previous study related to land use in Hulu Terengganu catchment area has highlighted the importance of generating land use distribution mapping in wildlife management study especially for elephants habitat [2]. Therefore, to make a reliable prediction and decision for the catchment area, effort in generating frequent update on land use and land cover information is needed.

Remote sensing and GIS has been widely used to generate LULC spatial distribution in recent decades. Common techniques applied to map LULC distribution using remote sensing image are supervised and unsupervised classification [3, 4]. Supervised classification is a powerful technique for digital image processing with variety of algorithms available for classification task [5]. However, when dealing with multi-temporal LULC change detection, supervised classification has limitations especially for area with limited accessibility since the classification required user to identify training area or samples from ground-truth [6, 7].

Recently, spectral index classification technique has received great attention in mapping LULC distribution and change detection due to its simplicity and effectiveness [8, 9]. Well-established spectral index such as normalized difference vegetation index (NDVI) has widely used in remote sensing applications due to its effectiveness in identifying characteristics of vegetation [10, 11], while normalized difference water index (NDWI) and modified normalized water index were used to emphasize water feature in image [12, 13]. Few indices have been developed as well to identify bare land area such as normalized difference bare land index (NBLI) [14], normalized difference bareness index (NDBaI) [15] and bare soil index (BSI) from forest canopy density (FCD) measurement [16]. Generally, the spectral index classification technique could be applied to classify the LULC in cost-effective manner without having to identify the training samples. Hence, the technique is efficient especially for inaccessible area of interest such as Hulu Terengganu area and also when dealing with multi-temporal image.

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Understanding the LULC changes could help in further potential for the new established area to strengthen the ecological management, resources development and protection and other utilization within the area. This study aims to assess the spatial distribution of the Hulu Terengganu catchment area for year 2007, 2014 and 2018. Effect of the dam construction in Hulu Terengganu area especially changes of forest size would be analyzed based on the LULC changes assessment of the area.

II. STUDY AREA

The study was conducted at Hulu Terengganu catchment located in Terengganu state, Malaysia as shown in Fig. 1. The catchment is located within the forest reserves area and the main river for the area is Sungai Terengganu. The catchment consists of two dams which are Tembat Dam and Puah Dam. The scheme started its construction in year 2010 and started to operate in year 2015 for Puah and year 2017 for Tembat. With total installed capacity of 265MW.

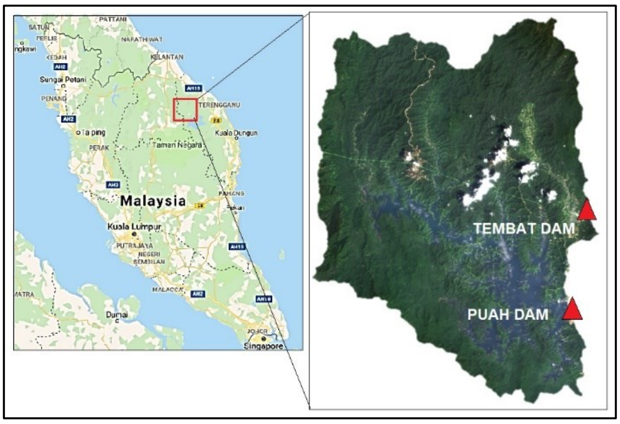

Fig.1. Hulu Terengganu catchment.

III. METHODOLOGY

Figure 2 shows overall process flow of this study.

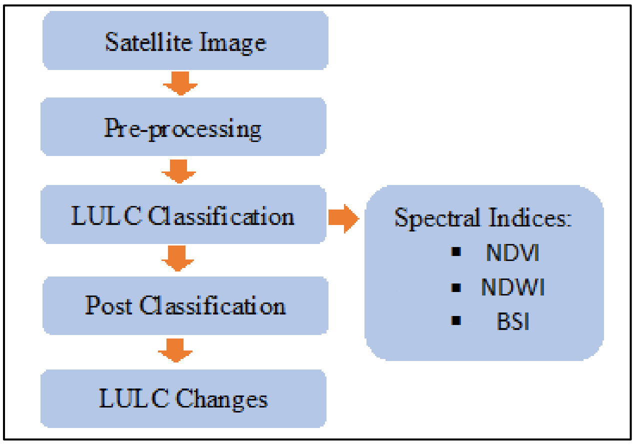

Fig. 2. Overall methodology.

A. Data Sets

Multi-sensor satellite images were used to produce LULC map for three different years of 2007, 2014 and 2018. Due to difficulty of finding images with cloud-free condition for the study area, SPOT images are mosaic with Landsat 7 for year 2007, Landsat 8 for year 2014 and Sentinel 2 for year 2018. Table I shows that each sensor have different spatial resolution. Therefore, image of Landsat 7, Landsat 8, SPOT-7 and Sentinel-2 were resample to 2.5 meter using nearest neighbour algorithm to standardize the pixel size.

Table I. Sensor specifications and information.

Year	Sensor	Spatial Resolution (Pixel size)	Date of Acquisition
2007	SPOT-5 Pan-sharp	2.5 meter	7th March 2007
	Landsat-7 Pan-sharp	15 meter	5th September 2007
2014	SPOT-5	2.5 meter	1st September 2014
	Landsat-8 Pan-sharp	15 meter	4th February 2014
2018	SPOT-7 Pan-sharp	1.5 meter	6th May 2018
	Sentinel-2 Pan-sharp	10 meter	18th February 2018

B. Pre-processing

Pre-processing is the initial task during processing. The datasets used in this study were obtained from Malaysia Remote Sensing Agency (ARSM) and USGS in level 1 form. Landsat 7, Landsat 8 and Sentinel-2 were pan sharpen to improve the spatial resolution. Atmospheric correction using ENVI QUAC module was applied to all the datasets.

C. Spectral Indices

Classification is the main task in identifying the land use and land cover classes. This study applied spectral indices as an approach to classify the LULC since it is fast and efficient. Spectral indices work by enhancing target feature characteristics through combination of multispectral bands [9]. The spectral indices used to produce the LULC classification for Hulu Terengganu catchment are Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Bare Soil Index (BSI).

NDVI is a simple index which widely used in remote sensing application to detect vegetation due to its sensitivity towards vegetation spectral curve [17]. The formula used to calculate the NDVI index is present in (1).

$$NDVI = \frac{(NIR\ Band - Red\ Band)}{(NIR\ Band + Red\ Band)} \quad (1)$$

NDWI is an indexes that could be used to detect water bodies developed by [18]. The index works by calculating the normalized difference between two spectral bands to enhance water bodies reflectance compared to other materials. The equation for NDWI is described in (2).

$$NDWI = (\lambda Green - \lambda NIR * \lambda Green) + \lambda NIR \quad (2)$$

Bare soil index was used to identify bare land by separating the barren land from other LULC features [19]. This study adopts the bare soil index algorithm to identify the bare land area. The formula for calculating bare soil index respectively are given in (3).

$$BSI = \frac{(SWIR\ Band - Red\ Band) - (NIR\ Band + Green\ Band)}{(SWIR\ Band + Red\ Band) + (NIR\ Band - Green\ Band)} \quad (3)$$

Reclassification of spectral indices value was then applied based on threshold obtained from image histogram to discriminate between LULC classes.

D. LULC Changes Assessment

LULC changes analysis was done based on the area changes for each classification class using 'from-to' analysis. The negative values represent the decline in the proportion of land use land cover categories during that particular time. Whereas, positive values correspond to the increased in the proportion of land covers class during that particular time of the study. The magnitude of change (K) for each land use class could be quantified by subtracting land use area for the second year (LA_{t2}) and the initial year (LA_{t1}) as expressed in (4).

$$K = LA_{t2} - LA_{t1} \quad (4)$$

Percentage trend of each land use could be quantified by dividing the changing rate of land use type with the total area of initial year (LAt1) and multiplied by 100 as expressed in (5) [20].

$$\text{Percentage change (\%)} = (K / LA_{t1}) * 100 \quad (5)$$

IV. RESULTS AND DISCUSSION

A. LULC Distribution

LULC distribution results using spectral indices for entire Hulu Terengganu catchment are presented in Fig. 3. Types of LULC classes identified are water bodies (including river and lake), forest and vegetation, and bare land. Comparison of LULC distribution area in hectare is shown in Figure 4 and the percentage of the distribution over the catchment area is tabulated in Table II. Result in Fig. 3 and Fig. 4 indicates that the catchment is majorly surrounded with forest and vegetation.

Quantification of LULC distribution for year 2007 describes that 98.50% of the total area is covered with forest and vegetation area, followed by bare land with 1.40% and water bodies 0.10%. However, LULC distribution for year 2014 indicates slight different with LULC distribution in 2007. In 2014, the catchment was covered by 93.05% of forest and vegetation, followed by bare land with 6.84%. However, percentage of water bodies remain similar with 0.10%. Whilst, the LULC distribution in year 2018 has shown significant difference percentage especially for water bodies class. Result has shown that forest and vegetation covered about 85.29% from total catchment area, followed by water bodies with 10.45% and bare land with 4.26%.

B. LULC Changes

Based on LULC classification in Fig. 3, LULC changes for year 2007, 2014 and 2018 were computed and tabulated in Table III. The LULC changes is explain based on two time period, first time period is between year 2007 to 2014 and second time period is between year 2014 to 2018.

2007 – 2014 time period: The land use changes for year 2007 to 2014 showed that LULC for Hulu Terengganu catchment has started to change especially for bare land area with an increase of 388.35%, which equal to addition of 2761.53 hectares of bare land area expansion. Meanwhile, reduction in hectare has been observed for forest and vegetation class, with decrease of 5.53% in year 2014. It is equivalent to loss of 2761.45 hectares of forest and vegetation

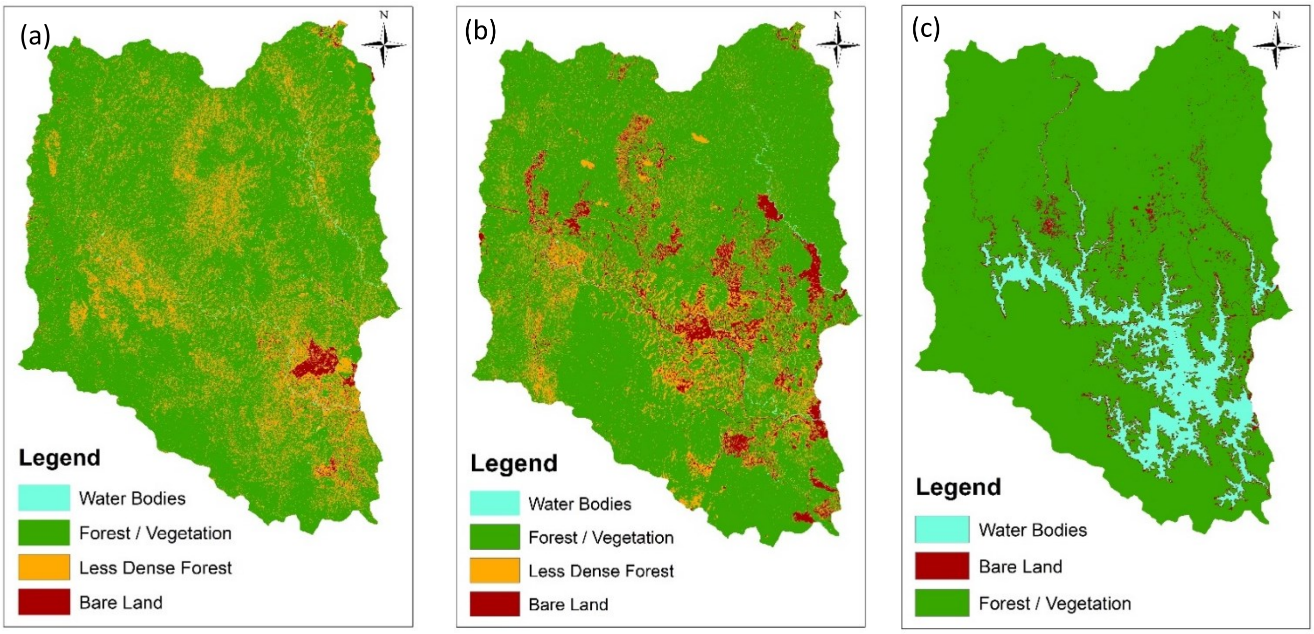

Fig. 3. (a) Land use map for year 2007, (b) Land use map for year 2014 and (c) Land use map for year 2018.

area. However, the water bodies class remain similar as presented in year 2007 with 51.80 hectares.

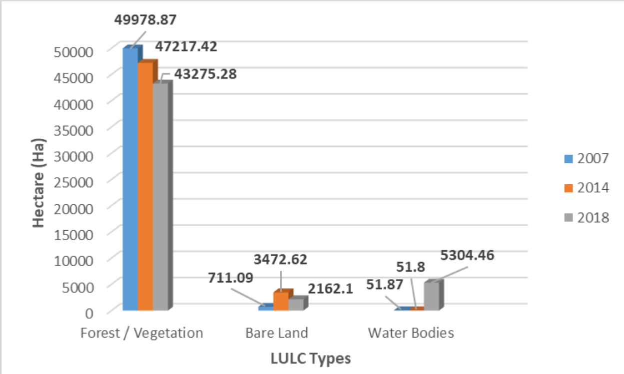

Fig. 4. Land Use Distribution of Hulu Terengganu catchment from 2007 to 2018.

2014 – 2018 time period: LULC changes have been quantified from year 2014 to 2018 and presented in Table III. Among all the LULC classes, water bodies have shown extreme changes with an increase of 10,141% which equal to addition of 5252.66 hectares from 51.80 hectare of water bodies in 2014. In 2018, forest and vegetation class is decreasing with negative change of -8.35%, which indicates loss of another 3942.14 hectares forest and vegetation area. Besides forest and vegetation class, the bare land class is decreasing as well with negative change of -37.74%, which equal to reduction of 1310.52 hectares of bare land area. The decrease in hectare for forest and bare land classes might be due to the completion of the dam construction activity in 2018, which the forest and bare land area have transformed into a reservoir.

C. Discussion

LULC changes result presented in Table III describes catchment landscape before Puah and Tembat dam construction, during dam construction and post dam construction. Relationship between the decrease of forest and vegetation with increase of bare land area during period from year 2007 to 2014 is closely related with land clearance activity during dam construction phase. Such for the case of LULC changes from year 2014 to 2018, it is mainly derived by Puah and Tembat reservoir formation. In 2018, the Puah and Tembat lake inundation has started, explaining the cause of drastic increment of water bodies class from 51.80 hectare to 5304.46 hectare. Additionally, comparison of LULC distribution for year 2007 and 2018 has illustrated the effect of dam construction towards the Hulu Terengganu catchment landscape especially forest and vegetation class. It is observed that the size of forest is reducing by 6703.59 hectare from the original size upon completion of the dam construction. Whereas, bare land coverage area is expanding by roughly 1451.01 hectare compared to year 2007.

V. CONCLUSION

The results of this study indicate that LULC in the Hulu Terengganu catchment area has a remarkable changes from year 2007 to 2018. The hydroelectric dam development activities taking place in Hulu Terengganu have led to land clearing and dam impoundment activities leading to changes in LULC classes. Hence, effect of environmental impact need to be assessed upon the alteration of the LULC over the catchment area. Therefore, the results of this project are important as inputs for future decision-making process involving the environment and wildlife aspect within the area. The result could also be expanded in the future by considering on prediction of future land use for comprehensive study of the LULC changes impact, which is key variable for annual dam management and operation activities, sediment transportation study and hydrological related study.

Table II. Land Use Distribution of Hulu Terengganu catchment from 2007 to 2018.

LU CLASS	2007		2014		2018	
	Hectare	%	Hectare	%	Hectare	%
Forest / Vegetation	49978.87	98.50	47217.42	93.05	43275.28	85.29
Bare Land	711.09	1.40	3472.62	6.84	2162.10	4.26
Water Bodies	51.87	0.10	51.80	0.10	5304.46	10.45
TOTAL	50741.83	100	50741.83	100	50741.83	100

Table III. LULC changes for Hulu Terengganu catchment for year 2007 – 2014 and 2014 – 2018.

LU CLASS	LULC Changes 2007-2014		LULC Changes 2014 - 2018	
	Magnitude of changes	Percentage of changes (%)	Magnitude of changes	Percentage of changes (%)
Forest / Vegetation	-2761.46	-5.53	-3942.14	-8.35
Bare Land	+2761.53	+388.35	-1310.52	-37.74
Water Bodies	-0.07	-0.14	+5252.66	+10141

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