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Land use changes and water quality in Bernam River basin 2008-2018

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ABSTRACT

Human exploration activities around river basin areas for development purposes have affected the river basin ecosystem, and especially the quality of river water. This study aims to assess the land use changes and Water Quality Index (WQI) in the Bernam River Basin. The secondary data sources used were land use maps of the Bernam River Basin in 2008, 2015 and 2018 as well as water quality data from 2008 to 2018. This study involved a mapping analysis and measurement of water quality based on the WQI set by the Department of Environment. The results of the study showed that there were relatively significant changes in land use, where forest and water body types of land use had decreased, while built-up and agricultural types of land use had increased. The findings also showed that the quality of water resources in the upstream area of the Bernam River Basin was still in Class II, which is a clean status. The implications of this study can help those responsible for planning the development around the Bernam River Basin to maintain the sustainability of the river basin so that the local people can still benefit from it in the future.

Key words : *Land use change, Water Quality Index, River basin.*

Introduction

Land use change is one of the major environmental changes occurring around the world and its effects have affected river water quality. In general, water quality is closely related to land use or land cover in river basin areas (Tong and Chen, 2002; Ahearn *et al.*, 2005; Tu and Xia, 2008; Liu *et al.*, 2009). This is because land use changes in river basin areas can have a negative impact on river water quality. Ngoye and Machiwa (2004) and Sliva and Williams (2001) explain that the quality of river water will decline due to changes in the pattern of land cover, especially as human activities increase in drainage basin areas. This statement is also supported by Giri and Qiu (2016), who mentioned that land use was one of the landscape components that played an important role in the issue of river water pollution. Thus, land use change in the process of urbanization, and industrial and agricultural activities can change the surface characteristics of river flow areas, which in turn affect the water quality and quantity (Camara *et al.*, 2019).

A study by Azyana *et al*. (2012) proved that the developing areas in river basins had a significant positive relationship with the pollution of the Kinta

River, especially for the conductivity, salinity, concentration of the total dissolved solids (TDS), nitrate (NO_3), phosphate (PO_4^{3-}) and biochemical oxygen demand (BOD) parameters. Additionally, a study by Mazlin *et al.* (2001) proved that the industrial activities in the Balakong industrial area contributed to the deterioration of river water quality in the Langat Basin, especially for the BOD, suspended solids (SS) and ammonia nitrogen (NH_3N) parameters.

A river at its source is not polluted, but the river water flowing from upstream to downstream carries with it various pollutants, resulting in the deterioration of the river water quality (Md. Sadek Uddin *et al.*, 2018). The presence of these pollutants comes from urbanisation, increased industrial activities, the use of fertilisers in agricultural activities, disposal of untreated waste, and sewage disposal pipes near the river areas. Human greed in reclaiming land for use near river areas without taking into account the environmental issues has had a negative impact on the river water quality.

Bernam River is no exception from such effects, meaning that the water quality status of the river needs to be examined. This is because the Bernam River Basin is a basin with two state borders, namely Selangor and Perak. This situation not only affects the quality of the river water but also causes flash floods when the river water overflows to the lower areas because the bottom of the river is becoming shallower. Therefore, the identification of the Water Quality Index (WQI) should be taken seriously, as the basin is at high risk of being polluted as a result of land use development activities inboth Perak and Selangor, such as the opening of new land areas for agricultural purposes, housing and new cities. Thus, the purpose of this study is to assess the land use changes and water quality in the Bernam River Basin from 2008 to 2018.

Materials and Methods

Study Area

The Bernam River Basin is one of the main basins in the State of Selangor, at the border between the State of Selangor and the State of Perak. The river flows from the eastern part of Bukit Liang Timur (part of the Titiwangsa Range) to the western part of Sabak Bernam town and into the Straits of Malacca. According to a report by Selangor Town and Country Planning Department (2018), in the eastern part of the basin is an agricultural area suitable for rubber and oil palm cultivation, while in the west is a swampy and lowland area, a large part of which has been converted into a paddy cultivation area with the implementation of the Integrated Agricultural Development Area (IADA) project in Northwest Selangor. The total length of this basin is 200 km with an average width of 50 m and it has a catchment area of 3,335 km² (Selangor Town and Country Planning Department, 2018).

However, this study only focuses on the upstream of the Bernam River Basin (Fig. 1). This is because the upstream of the basin is the area undergoing rapid development. According to Selangor Town and Country Planning Department (2018), this basin has high potential to be a source of raw water supply in Selangor in the future. However, human activities around the basin have caused pollution and affected the quality of raw water sources. To assess the water quality, a total of eight stations were selected in the upstream of Bernam River Basin. Table 1 shows the list of stations and coordinates.

Data Collection and Analysis

This study involved the collection of secondary data, namely the collection of data from available sources which are land use data of 2008, 2015 and 2018 and water quality data from 2008 to 2018. The land use data was obtained from the Malaysian Centre for Geospatial Data Infrastructure (MaCGDI) in the form of a GIS shapefile, while water quality data from 2008 to 2018 was obtained from the Department of Environment (DOE) Malaysia, which covers parameters such as dissolved oxygen (DO), BOD, chemical oxygen demand (COD), NH_3N, SS and pH.

The land use data were analysed using the Geographic Information System, ArcGIS Version 10.2 to identify changes in land use patterns in the upstream area of the Bernam River Basin. According to Popovici, Bălteanu and Kucsicsa (2013), GIS is the best method for studying spatial distribution and changes in geographical phenomena related to land use and land cover change, especially in the measurement of change. The mapping analysis used included overlay analysis, clip analysis, buffering zone analysis and topology.

The water quality assessment is measured using the WQI formula set by the DOE to classify the status of the water quality, determining whether it is in a clean, moderately polluted or polluted state. The

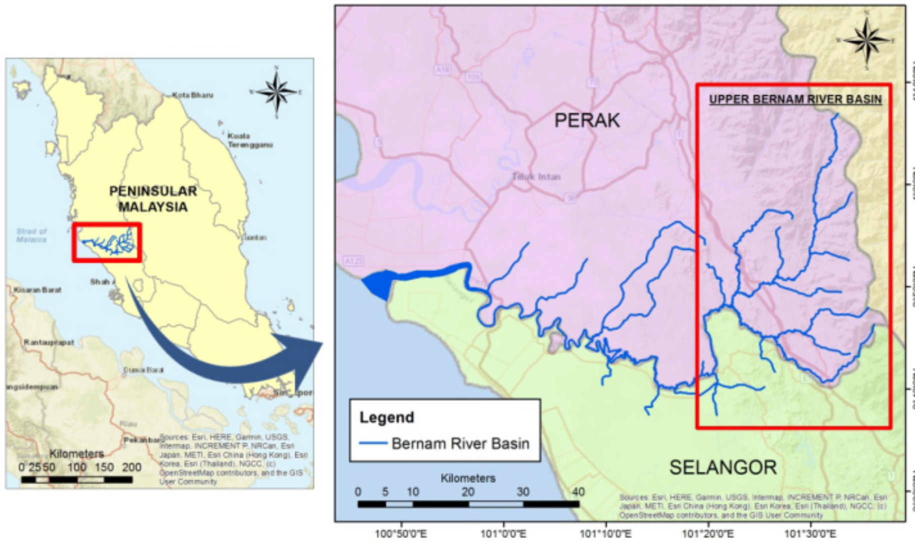

Fig. 1. Study area

WQI formula involves six main parameters, namely DO, BOD, COD, NH_3N, SS and pH. The following is the WQI formula used in this study.

WQI = (0.22 × SIDO) + (0.19 × SIBOD) + (0.16 × SICOD) +(0.15 × SIAN) + (0.16 × SISS) + (0.12 × SIpH)

where

SI_{DO}	= DO sub-index
SI_{BOD}	= BOD sub-index
SI_{COD}	= COD sub-index
SI_{AN}	= NH_3Nsub-index
SI_{SS}	= SS index
SI_{pH}	= pH sub-index
$0 \leq WQI \geq 100$	

Source: Department of Environment (2017)

To obtain the sub-index (SI) value of each parameter, the formulas in Table 2 were used in this study. With the WQI values obtained, the water quality classification and its usescan be identified (Table 3). The classification of the water quality and its uses consist of five main classes, namely Class I (very good), Class IIA/IIB (good), Class III (moderately polluted), Class IV (polluted) and Class V (very polluted).

Results and Discussion

2008-2018 Land Use Changes

Land use change refers to an increase or decrease in land use by humans that focuses on the purpose of specific land development. In assessing land use changes, categorisation of the types of land use is done. According to Nur Syabeera Begum and Firuza Begham (2019), the land use is categorised to see the change and loss of original land more clearly through visual and statistical calculations using cer-

Table 1. List of stations and coordinates

Station	Location	Latitude	Longitude
1	Trolak River Bridge	N 03° 52.792'	E 101° 23.075'
2	Kampung Balun Bridge	N 03° 49.549'	E 101° 24.556'
3	Kampung Slim Hanging Bridge	N 03° 48.631'	E 101° 22.324'
4	The bridge near UPSI Tanjong Malim	N 03° 40.908'	E 101° 31.823'
5	After Felda Soharto Heading towards Sabak Bernam	N 03° 40.885'	E 101° 20.930'
6	Tanjong Malim Town	N 03° 40.640'	E 101° 31.260'
7	Kampung Masjid	N 03° 44.350'	E 101° 26.733'
8	Kampung Kuala Slim Major Bridge	N 03° 48.251'	E 101° 21.698'

Table 2. SI formula for each parameter

SI parameter	SI formula	Value
SIDO	= 0	If ≤ 8
	= 100	If ≥ 92
	= -0.395 + 0.03 2 - 0.000198 3	If 8 < < 92
SIBOD	= 100.4 - 4.23	If ≤ 5
	= 108 × exp(-0.055) - 0.1	If > 5
SICOD	= -1.33 + 99.1	If ≤ 20
	= 103 × exp(-0.0157) - 0.04	If > 20
SIAN	= 100.5 - 105	If 0.3 < < 4
	= 94 × exp(-0.573) - 5 × (- 2)	If ≥ 4
	= 0	If ≥ 0.3
SISS	= 97.5 × exp(-0.00676) + 0.05	If 100 < < 1000
	= 71 × exp(-0.0061) - 0.015	If ≥ 1000
	= 0	If ≥ 100
SIpH	= 17.2 - 17.2 + 5.02 2	If < 5.5
	= -242 + 95.5 - 6.67 2	If 5.5 ≤ < 7
	= -181 + 82.4 - 6.05 2	If 7 ≤ < 8.75
	= 536 - 77.0 + 2.76 2	If ≥ 8.75

Source: Department of Environment (2017)

Table 3. Water Quality Classification and Its Uses

Class	WQI (%)	Water status	Use
I	> 92.7	Very good	Suitable for drinking water supply, water treatment is almost not required.
IIA/IIB	76.5 – 92.7	Good	Water source for drinking water supply, regular treatment is necessary. Water source for recreational use that involves body contact.
III	51.9 – 76.5	Moderate	Full treatment is required for drinking water source.
IV	31 – 51.9	Polluted	Suitable for drainage.
V	< 31	Very polluted	Not suitable for any use.

Source: Department of Environment (2017)

tain methods and systems. Therefore, the types of land use in this study have been divided into four main categories, namely water body, forest, agriculture and built-up (Table 4).

The areas of agricultural land use and built-up land use increased throughout the period from 2008 to 2018. For agricultural land use, the area increased by 3.12%, where in 2008 663.13 km^2 (46.08%), in 2015 672.50 km^2 (64.73%) and in 2018 683.83 km^2 (47.52%) were recorded. Built-up land use increased by 5.59%. This type of land use recorded 62.29 km^2 (4.33%) in 2008, 64.22 km^2 (4.46%) in 2015 and 65.77 km^2 (4.57%) in 2018. The land use changes in the upstream area of Bernam River Basin are shown in Table 5 and Fig. 6.

Table 4. Categorisation of types of land use

Land use category	Details
Water body	Rivers, lakes, former mines
Forest	Land forests, peat forests, wetlands
Agriculture	Livestock farming, mixed agriculture
Built-up	Industry, infrastructure and utilities, communal institutions and facilities, commercial, mixed development, transportation, housing, open space and recreation

Water Quality Index of Bernam River Basin

Water quality is an important indicator in determining whether a water body is clean or polluted. Fig. 7 shows the WQI value for each station in the upstream area of the Bernam River Basin. The highest WQI value of station 1 is 92.79%, while the lowest value is 85.46%. From 2008 to 2018, the value of the WQI percentage of station 1 is in Class II, which is good status, except in 2009, when it is in Class I with more than 92.7%, which is very good status. For station 2, the highest WQI value is 89.78% and the lowest value is 81.78%. This shows that station 2 recorded a good status of Class II every year,as the WQI percentage value for Class II ranges from 76.5% to 92.7%. Similarly, station 3 recorded Class II with clean status every year. The highest WQI value is 87.13%, while the lowest value is 81.59%. While the highest WQI percentage value of station 4 is 94.81%, the lowest value is 87.33%. The results of the study found that station 4 recorded Class I in most years, except in 2012, 2015, 2016, 2017 and 2018, which are in Class II.

In addition, station 5 recorded the highest WQI value of 86.94%, while the lowest value was 76.99%. The WQI value of this station was in Class II,for which the WQI percentage value was between 76.5% and 92.7%. For station 6, the highest value was 93.92% and the lowest value was 81.61%. Based on the standards set by DOE, the WQI values of station 6 for most years were in Class II, except in 2013 which was in Class I with very good status. In addition, the highest WQI percentage value for station 7 was 91.03% and the lowest value was 77.14%. While station 8 recorded the highest WQI percentage value with 87.39%, the lowest value was 78.31%. This shows that station 7 and station 8 recorded a Class II WQI every year.

Overall, it can be concluded that there was a significant change in land use, with a reduction in both the forest land use and water body areas, but with

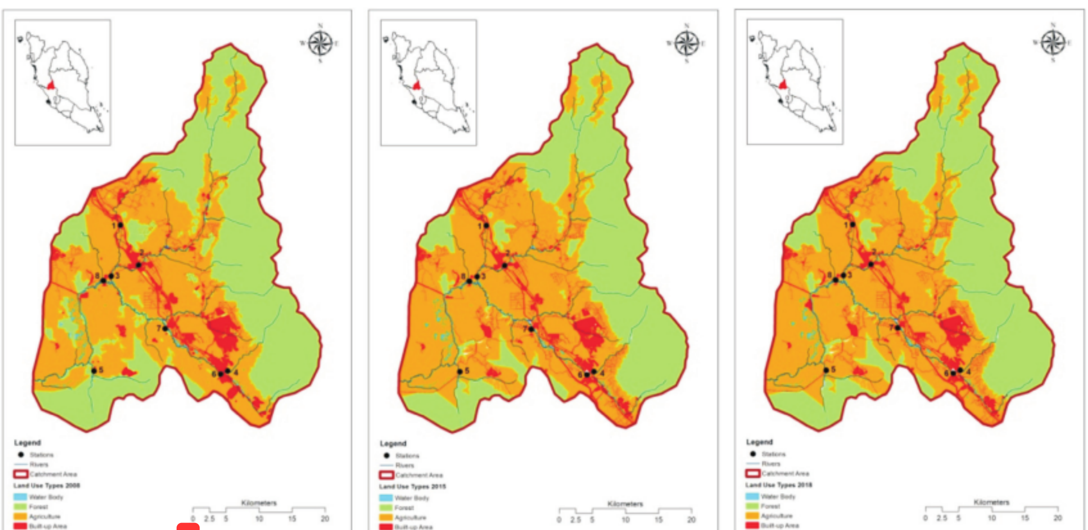

Fig. 6. Land use changes in the upstream area of Bernam River Basin in 2008, 2015 and 2018

Table 5. Land use changes in the upstream area of Bernam River Basin

Land use	2008		2015		2018	
	km^2	%	km^2	%	km^2	%
Water body	22.58	1.57	22.53	1.57	22.51	1.56
Forest	691.18	48.02	679.93	47.24	667.07	46.35
Agriculture	663.13	46.08	672.50	46.73	683.83	47.52
Built-up	62.29	4.33	64.22	4.46	65.77	4.57
	1439.18	100	1439.18	100	1439.18	100

the reduction in the size of the forest land use area being thegreater. This situation reflects the fact that the development in the upstream area of Bernam River Basin was more towards reclamation of forest areas than water bodies. Reduction in the size of the area of forest land use is often associated with land reclamation for development purposes, especially for built-up land use, and including increases in the size of agricultural and built-up land use areas. Nevertheless, the built-up land use type has a higher change rate than agriculture. This is due to population growth, which causes an increase in the need for development (Nur Syabeera Begum and Firuza Begham, 2019), subsequently leading to high demand and putting pressure on land use (Reis, 2008).

This situation resulted in forest land and water bodies in the upstream area of Bernam River Basin being reclaimed for development purposes to meet the demands of the growing population. The results of this study are similar to those reported by Prakasam (2010), where built-up and agricultural land uses increased and forest areas and water bodies decreased. According to Liyanage and Yamada (2017), land use changes such as large-scale agricultural activities, unplanned infrastructure development and sand mining around river basins can change the water quality and water balance. As Huang *et al.* (2013) explained in their study, a high population density and economic activities concentrated in built-up areas can lead to very serious river water pollution. The increase in river water pollution and changes in land use, especially agriculture and urbanisation, have a positive relationship, as reported in the studies by Hooda *et al*. (2000), Ahearn *et al.* (2005), Azyana *et al.* (2012), Donohue *et al.* (2006), Lee *et al.* (2009) and Effendi *et al.* (2018).

Meanwhile, the results of the WQI analysis showed that most stations in the upstream of Bernam River Basin were in the Class II clean status, with WQI percentage values ranging between 76.5–92.7%. This situation clearly shows that the land use changes around the river basin have to some extent caused a decrease in the water quality of the Bernam River. Thus, regular treatment should be implemented at the river water source to ensure its suitability to be used as a drinking water supply and meet the standards for recreational use involving body contact. The results of this study have similarities with the findings of a study by Irena *et al.* (2016), where the water quality in the upstream area of the river basin recorded good WQI values. However, measures to control human activities in the Bernam River Basin area need to be given attention so that the water quality of Bernam River will not be polluted in the future. This is because water quality is very sensitive to the landscape types in river basin areas (Xia *et al.*, 2012). Therefore, understanding the relationship between land use and water quality is very important to help in identifying the main cause of any decrease in water quality, and is useful in implementing effective water quality management so as to be able to apply relevant measures to

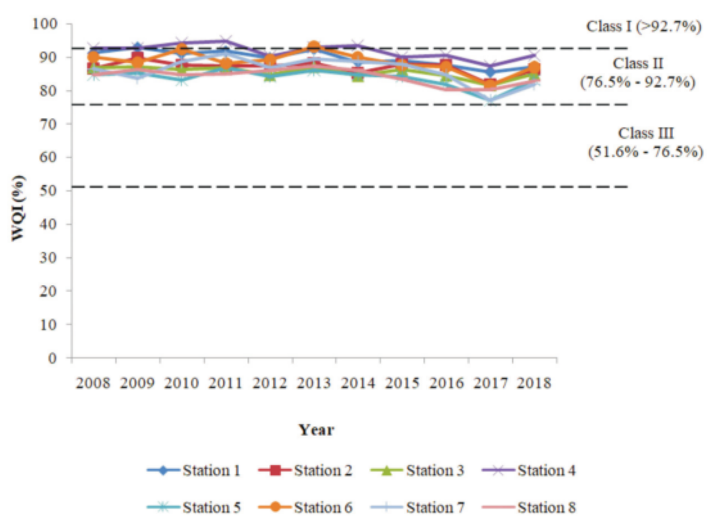

Fig. 7. The WQI value of each station

minimise the pollution burden (Abler *et al*., 2002).

Conclusion

River basins play an important role as a source of clean water to humans, flora and fauna. However, land use changes around the studied river basin area have influenced the quality of the river water, where rain is the main agent that transports pollutants from land use activities into the river. The presence of these pollutants has caused the quality of the river water to deteriorate, affecting the ecosystem in the river basin. Therefore, management to maintain the sustainability of the river is essential for every drainage basin, whether or not this is established in legal requirements. Indirectly, sustainable development can overcome the problem of river water pollution. Not only does such development benefit the locals, but the sustainability of the river basin can also be maintained, to remain useful for the local population in the future.

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