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ORIGINAL ARTICLE

A GIS-based water quality model for sustainable tourism planning of Bertam River in Cameron Highlands, Malaysia

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Abstract Cameron Highlands is experiencing rapid development as a popular tourist destination in Malaysia. This causes a rapid boost in construction and other tourism-related activities, such as the growth of vegetables, fruits and flowers. Due to that, the water quality of rivers in the highlands has been adversely affected. In this study, Bertam River, as one of the main streams in Cameron Highlands, was monitored to assess its suitability for recreational activities and conservation. Seven sampling points were selected in the river and tributaries: dissolved oxygen, biochemical and chemical oxygen demands (BOD and COD), total suspended solids (TSS), ammonia nitrate (NH_3–N) and pH were measured and the water quality index (WQI) was computed during high and average water flow. In addition, water quality surface data were generated from the sampling points using the interpolation technique of geographic information system to predict values of unknown locations. Results show that TSS, BOD and NH_3–N contribute most to the pollution of the waters. This is due to earthworks in the highlands as well as poorly treated sewage discharges from hotels, rest houses and apartments. WQI results indicate that Bertam River and its tributaries are classified as class II, III and IV, which require extensive treatment before utilization in most of the locations. Consequently, to improve the water quality of the rivers, recommendations have been made to ensure that some sampling points with potentials for recreational activities attain class II and subsequently class I in the near future.

Keywords River recreational use · Sustainable development · Water conservation · Water quality index (WQI)

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Introduction

Tourism relies on the use of fresh water resources. Recreational activities are often related to rivers, which also form an important element of the landscape visited by tourists (Gössling 2006; Hall and Härkönen 2006; Prideaux and Cooper 2009). Changes in the quality of water resources or its availability can therefore have a negative impact on tourism (UNESCO 2009).

Water quality studies have often been based on samples taken at specific locations and in restricted study areas. While these measurements provide useful information about the condition of water at or immediately around these locations, water quality analysis reveals little about the conditions further afield. As such, sustainable use of water resources entails the combined use of surface water assessment and monitoring programs with decision making and management tools (Ismail et al. 2012). This, therefore, warrants the need to expand from the conventional sample sites when wanting to produce a continuous map of the whole area. The use of GIS-based interpolation for

determining surface water quality will provide more detailed spatial information. GIS will provide benefits to spatially analyze water quality in areas where sampling does not exist. This will aid in developing a scientifically sound management plan that will improve the water quality (Meyer 2003) and reveal suitable areas for sustainable recreational activities as well as conservation areas even at un-sampled locations. As a result, it will be a useful tool for the decision makers, because they will be able to take action regarding tourism development at any point within the river. Furthermore, information to be derived from the GIS-based spatial interpolation will assist stakeholders to better understand the water quality distribution along the river course, thus leading to a more effective planning for tourism in Bertam River.

The Cameron Highlands is a hill resort located on the main mountain range of Peninsular Malaysia. It is situated in Pahang state at an altitude of 1,829 m. It covers an area of 712 km^2. The three townships of highlands are Brinchang, Tanah Rata and Ringlet. It is bordered by the State of Kelantan and Perak to the north and west, respectively, (Eisakhani et al. 2012a, b). Situated at the northwestern tip of Pahang, Cameron Highlands is approximately 85 km from Ipoh (Perak state) and about 200 km from Kuala Lumpur. During the day, its temperature seldom rises above 25 °C; at night, the temperature can sometimes drop to as low as 9 °C.

Cameron Highlands' forests are important water catchment areas providing water supply not only to the local residents but also to the rest of Malaysians living further downstream of the catchment forests (REACH 2009). Initially the rivers and streams of Cameron Highlands were categorized as fast flowing with cool, clean and clear water having high oxygen content and supporting sensitive aquatic invertebrates (Kumaran and Ainuddin 2004). However, over the last two decades, the highland has experienced rapid development as a popular tourist destination. The sensitive forest areas are being cleared for resort and condominium construction as well as land clearing for agro-tourism activities. This has led to uncontrolled development thereby causing water and habitat disruption (MNS 2000).

Bertam River is among the main streams in Cameron Highlands. It serves as a source for drinking water in downstream as well as irrigation and electricity generation purposes. Inclusion of pollution loads from point sources (sewage treatment plants, drains and channels) and non-point sources (runoff from roads, agricultural lands and construction sites) causes water quality deterioration of Bertam River (DID 2004).

Looking at the previous studies, the importance of river water quality and its relation to tourism activities have not been discussed completely (Table 1). Therefore, the aim of this study is to define potential areas for tourism development as well as areas that need to be conserved from tourism activities based on WQI and its prediction in un-sampled locations of Bertam River using GIS.

Table 1 Previous studies

GIS application	Study area	References
GIS models were used to define conservation areas, ecological research areas, and areas of residential and recreational development while, a fourth model was used for conflict resolution among competing uses	Virgin Islands, United States of America	Berry (1991)
GIS and AHP were used as instruments to evaluate the suitability of sustainable tourism destinations	Guilan Province coast of Iran	Abed et al. (2011)
GIS applications were demonstrated in the identification of areas suitable for ecotourism	Northern Ontario, Canada	Butler (1993)
GIS was used to locate areas suitable for tourism development	Lombok Island in Indonesia	Minagawa and Tanaka (1998)
GIS-based decision support system was developed for sound spatial planning for tourism	Mauritius	Beedasy and Whyatt (1999)
GIS and AHP were used to identify and prioritize potential ecotourism sites	SuratThani Province, Thailand	Bunruamkaew and Murayam (2011)
GIS-based spatial decision support system (SDSS) was used to help visitors choose and plan their activities more effectively to match their personal preferences and constraints	Great Smoky Mountains National Park, United States of America	Dye and Shaw (2005)
GIS was used as a regional tourism planning spatial decision support system in order to analyze, evaluate, predict and optimize tourism planning	Anhui Province, China	Zha and Wang (2010)
GIS was used for sustainable tourism infrastructure planning	Sinharaja Forest Reserve, Sri Lanka	Boers and Cottrell (2007)

Materials and methods

Sampling stations

In this study, seven sampling sites were selected based on an accurate and up-to-date procedure through investigations on current land uses and activities which threaten Bertam River. Furthermore, sampling events were chosen in dry as well as wet seasons to represent the condition of the river throughout the year and to show the effect of non-point sources of pollution which is largely significant during wet season. The existence of Bertam River tributaries was also considered; in other words, some of the sampling stations were chosen at the confluence of Bertam River to capture the variation in water quality due to the tributaries flowing into Bertam River. Sources of pollution were also considered when deciding the sampling stations and sampling points that were selected from different sources of pollution, both point and non-point sources. The geographic position of each sampling station was obtained using a handheld global positioning system (GPS) instrument (Garmin's GPSMAP 76CSx) (Table 2).

Sampling

Field samplings were conducted during high water flow and average water flow, in December 2012 and May 2013, respectively. DO and pH were measured in situ using multi-parameter display system (YSI 650 MDS, USA). Calibration of the field meters was conducted in the laboratory before the field sampling (Shuhaimi-Othman et al. 2007). River water from each sampling point was collected in a 1,000-mL sampling bottles. Bottles used for water sample collection were first thoroughly washed with the water being sampled and then were filled. After collection of the samples, they were preserved and analyzed in the laboratory in accordance with APHA 1992. Six water quality parameters, i.e., DO, BOD, COD, TSS, NH_3–N and pH were used in the calculation of the Department of Environment-Water Quality Index (DOE-WQI) (Shuhaimi et al. 2007). WQI provides a single number (like a grade) that expresses overall water quality at a certain location and time, based on several water quality parameters. The objective of an index is to turn complex water quality data into information that is understandable and useable by the public (Yogendra and Puttaiah 2008). The index was computed using Eq. 1.

$$\mathrm{WQI} = 0.22 \times \mathrm{SIDO} + 0.19 \times \mathrm{SIBOD} + 0.16 \times \mathrm{SICOD} + 0.15 \times \mathrm{SIAN} + 0.16 \times \mathrm{SISS} + 0.12 \times \mathrm{SIpH} \quad (1)$$

where;

- Sub-index for DO (In % saturation)

$$\mathrm{SIDO} = 0 \quad \text{for } x \leq 8$$
$$\mathrm{SIDO} = 100 \quad \text{for } x \geq 92$$
$$\mathrm{SIDO} = -0.395 + 0.030 \times 2 - 0.00020 \times 3 \quad \text{for } 8 < x < 92$$

- Sub-index for BOD

$$\mathrm{SIBOD} = 100.4 - 4.23x \quad \text{for } x \leq 5$$
$$\mathrm{SIBOD} = 108 \times \exp(-0.055x) - 0.1x \quad \text{for } x > 5$$

- Sub-index for COD

$$\mathrm{SICOD} = -1.33x + 99.1 \quad \text{for } x \leq 20$$
$$\mathrm{SICOD} = 103 \times \exp(-0.0157x) - 0.04x \quad \text{for } x > 20$$

- Sub-index for NH_3-N

$$\mathrm{SIAN} = 100.5 - 105x \quad \text{for } x \leq 0.3$$
$$\mathrm{SIAN} = 94 \times \exp(-0.573x) - 5 \times x - 2 \quad \text{for } 0.3 < x < 4$$
$$\mathrm{SIAN} = 0 \quad \text{for } x \geq 4$$

Sub-index for SS

$$\mathrm{SISS} = 97.5 \times \exp(-0.00676x) + 0.05x \quad \text{for } x \leq 100$$
$$\mathrm{SISS} = 71 \times \exp(-0.0061x) + 0.015x \quad \text{for } 100 < \mathrm{x} < 1,000$$
$$\mathrm{SISS} = 0 \quad \text{for } x \geq 1,000$$

- Sub-index for pH

$$\mathrm{SIpH} = 17.02 - 17.2x + 5.02 \times 2 \quad \text{for } x < 5.5$$
$$\mathrm{SIpH} = -242 + 95.5x - 6.67 \times 2 \quad \text{for } 5.5 \leq x < 7$$
$$\mathrm{SIpH} = -181 + 82.4x - 6.05 \times 2 \quad \text{for } 7 \leq x < 8.75$$
$$\mathrm{SIpH} = 536 - 77.0x + 2.76 \times 2 \quad \text{for } x \geq 8.75$$

Geographic information system (GIS) data capture and analysis

The Bertam River digital map including the GPS coordinates and the WQI was imported into the Environmental Systems Research Institute (ESRI) ArcGIS 9.3 software. ArcGIS shapefile was created by digitizing Bertam River digital map. The GPS coordinates were geocoded showing the geographic position of the seven sampling stations (Fig. 1). WQI values of the respective sampling stations were then inserted into the attribute table of the geocoded coordinates. Also point source of pollution (PSP) was

Table 2 Results of water quality parameters for Bertam River and its tributaries

	Sampling stations						
	SS1	SS2	SS3	SS4	SS5	SS6	SS7
High water flow							
Location	Brinchang, at army camp	Ruil River	Tanah ratah administrative area	Bisek River	Parang River	Habu Town	After Habu Town, before the dam
GPS position of the locations	101°23′39.237″E 4°29′19.001″N	101°22′48.717″E 4°29′4.826″N	101°22′56.903″E 4°28′12.609″N	101°23′40.356″E 4°27′5.044″N	101°23′13.411″E 4°26′33.584″N	101°23′25.481″E 4°26′12.926″N	101°23′21.375″E 4°25′54.39″N
pH	7.99	6.98	7.23	7.59	7.54	7.58	8.50
DO (mg/l)	7.14	5.07	7.39	6.07	7.22	6.73	7.59
BOD (mg/l)	1.33	1.21	0.18	0.90	0.81	2.03	5.60
COD (mg/l)	51	47	85	32	38	63	62
TSS (mg/l)	33	627.7	44.7	7.3	138.3	186.3	211.7
NH_3N (mg/l)	0.19	1.62	0.01	0.02	0.69	0.82	1.24
Average water flow							
pH	8.71	8.29	6.60	8.77	8.09	8.19	8.17
DO (mg/l)	8.52	8.45	8.53	8.34	7.90	8.30	8.28
BOD (mg/l)	1.00	1.66	0.75	0.93	1.24	2.15	4.60
COD (mg/l)	14	21	5	11	11	15	14
TSS (mg/l)	6.33	140.67	12.33	24.67	30.33	252.67	128.33
NH_3N (mg/l)	0.29	1.52	0.06	0.09	0.09	2.80	0.74

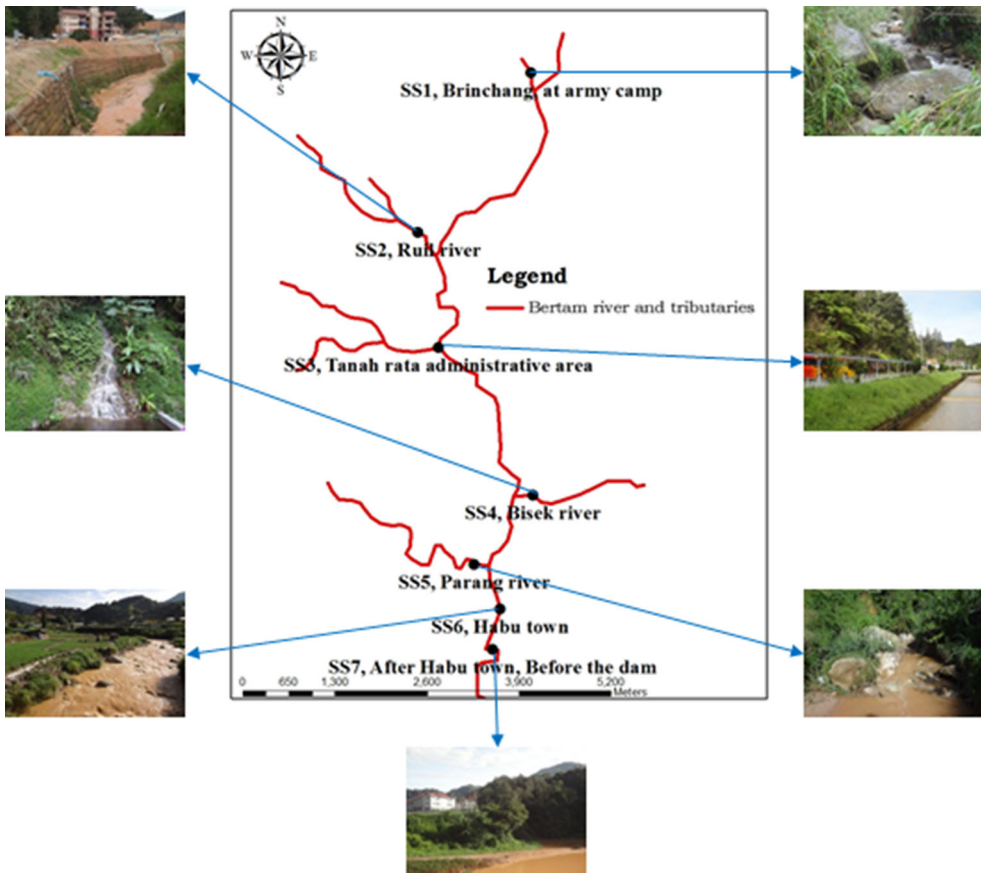

Fig. 1 Sampling stations for the study (source: field visit 2012)

obtained from a secondary source of data (Malakahmad 2008a, b). A Microsoft Excel file of PSP was created with the following fields: ID, Northing and Easting; the file was saved as xls file. 'Add XY data' tool was used to import the file into ArcGIS 9.3 software. A select query tool was used to extract point and non-point sources of pollution for the sampling stations. The result was then displayed as a digital map. The Bertam River shapefile and the geocoded coordinates were used in generating spatial interpolation map of WQI.

Spatial interpolation

Interpolation is referred as a method that estimates the values at locations where no measured values are available. Spatial interpolation assumes that attribute data are continuous over space. The method uses control points of known values and mathematical equations to estimate values between those points (Chang 2004). This allows the estimation of the attribute at any location within the data boundary (Azpurua and Ramos 2010).

The interpolation was based on the selected sampling stations described in part 2.1. Therefore, the spatial interpolation will provide an all-encompassing assessment of the entire river with regard to sustainable tourism. This is to ascertain the influence of land cover/land use types on the water quality even in sections of the river that are unapproachable.

Inverse Distance Weighted (IDW) method of spatial interpolation was used in the study. It is embedded in the spatial analyst extension of ArcGIS 9.3 software. IDW is based on the assumption that the nearby values contribute more to the interpolated values than distant observations. Thus, for this method, the influence of a known data point is inversely related to the distance from the unknown location that is being estimated. The advantage of IDW over other methods of interpolation is that it is intuitive and efficient (Azpurua and Ramos 2010). The general formula of IDW is given in Eq. 2.

$$\hat{Z}(S_0) = \sum_{\Sigma-1}^{N} \lambda i Z(S_i), \tag{2}$$

where $\hat{Z}(S_0)$ is the value being predicted for the target location s_0; N is the number of measured data points in the search window; λ_i are the weights assigned to each measured point; and $Z(s_i)$ is the observed value at location s_i. A feature dataset of the river network was used to mask only cells of the river that fall within the specified shape of the

river network, with the aid of extract by mask function of the software.

Results and discussion

Inferences from the sampling stations

Monitoring was carried out to provide the information needed for an assessment of the conditions of the water in relation to natural variability, human effects and intended uses. The results of the parameters measured from the seven sampling stations are shown in Table 2.

Sampling station 1 (SS1)

SS1 is located just before Brinchang Town, within the army camp. Water is not far from mount Brinchang, which is the source of Bertam River; as such, it has a clean background. Surrounding land uses at this location are forest and agricultural land.

SS1 depicts a higher concentration of COD during high water flow with a value of 51 mg/L. This is due to wide usage of chemical fertilizer (besides the organic fertilizer) as a result of farming activities around the sampling station (Malakahmad and Eisakhani 2008).

During high water flow, the water at SS1 falls under class III of WQI (Table 3). According to DOE-WQI, it means that the water is slightly polluted with extensive treatment required to attain the status of class II. The main cause for low WQI at this station is high concentration of COD. This is a result of farming activities at the station in which stormwater further washes particles from the farms into the river. However, during average water flow, the water at SS1 belongs to class II. This appears to have the best value of WQI among the sampling stations in all the seasons. According to DOE-WQI, it is suitable for recreational use with body contact (Table 3). Therefore, it will be categorized as a suitable area for tourism. Recreational activities will be carried out under certain guidelines to limit the impact of activities on water quality (UMN 2013). Table 3 shows the water quality index of the sampling stations at Bertam River.

An earlier study carried out at the same sampling station indicated a value of pH to be 6.7 and 6.3 during high and average water flow, respectively (Van der Ent and Termeer 2005). This portrays the water at the sampling station as more natural (undisturbed) than in the present situation, because natural river water is slightly acidic due to its origin from rain water as well as tannin and leaf acids released from the forest floors. Therefore, any significant increase in pH will likely be due to human influence. Van der Ent and Termeer (2005) in their findings portrayed the value of COD as 39 and 11 mg/L during high and average water flow, respectively. This depicts a better situation compared to what is obtained in this study. The condition could be explained by the wide usage of chemical fertilizer over time (Eisakhani et al. 2011). In the study done by Van der Ent and Termeer (2005), TSS value for SS1 appears to be 67 and 6.4 for high and average water flow, respectively. A much higher value of TSS appears during high water flow, which is attributed to human interference coming from agricultural practices in the sub catchment.

Another study carried out at SS1 has indicated the same pH value with that of the earlier study; the value is 6.7 and 6.32 during high and average water flow, respectively (Eisakhani and Malakahmad 2009; Van der Ent and Termeer 2005). COD also depicts a lower value of 19 and 11 mg/L during high and average water flow, respectively. The study also showed TSS to have a much lower value of 5 mg/L and 6.4 mg/L in high and average water flow, respectively. The pH, COD and TSS portray the water to be freer from anthropogenic activities than the present condition. This is because of expansion of agricultural activities which looks poised to grow further (Freeman 1999).

To curtail the effect of farming activities on the water quality, physical planning control such as the creation of riparian buffer zones along the river course should be enforced by the Land Office. Creating 2–5 m riparian buffer zones along the river system can divert sediments from farm catchments (Gray 2005). These buffer zones act as a filter to absorb excess nutrients, sediment and pesticides from agricultural runoff. Vegetation in these areas provides a multitude of barriers that slow and intercept runoff and pollutants. This stoppage enables a number of pollution reduction functions to occur.

As can be deduced from Fig. 2, SS1 and its interpolated surface have an index of 69.2 (class III) during high water flow. This sampling station has the best water quality in the sampling event. However, with the physical planning control proposed, that section of the river will most likely improve to class II of WQI. Subsequently, suitable areas for recreational activities where body contact is allowed (DOE 2002) will be ascertained. Higher water quality at the top and bottom of the reach running into SS3 is justified by the fact that such part of the river is in a forest area and only interacts with the natural environment. The water at that portion of the river is not disturbed by anthropogenic activities, thus, having a higher water quality. For the middle reaches of Ruil River, it encountered some human activities which explains deteriorating water quality. Again, the water quality at Ruil River can be seen to improve just before joining Bertam River, which is a result of the influence from that part of Bertam River that exhibits a higher water quality (Fig. 2).

Table 3 Water quality index (WQI) of Bertam River and its tributaries

Sampling sites	Location	WQI (HWF)	DOE CLASSES (HWF)	USES	WQI (AWF)	DOE CLASSES (AWF)	USES
SS1	Brinchang, at army camp	60.84	Class III (51.9–76.5)	Extensive treatment required. Fishery III-Economic value and tolerant species; livestock drinking.	78.72	Class II (76.5–92.7)	Conventional treatment required. Fishery II-Sensitive aquatic species. Recreational use with body contact
SS2	Ruil river	43.38	Class IV (32.0–51.9)	Irrigation	49.78	Class IV (32.0–51.9)	Irrigation
SS3	Tanah ratah administrative area	61.34	Class III (51.9–76.5)	Extensive treatment required. Fishery III-Economic value and tolerant species; livestock drinking	73.93	Class III (51.9–76.5)	Extensive treatment required. Fishery III-Economic value and tolerant species; livestock drinking
SS4	Bisek River	69.29	Class III (51.9–76.5)	Extensive treatment required. Fishery III-Economic value and tolerant species; livestock drinking	68.00	Class III (51.9–76.5)	Extensive treatment required. Fishery III-Economic value and tolerant species; livestock drinking
SS5	Parang river	52.71	Class III (51.9–76.5)	Extensive treatment required. fishery III-economic value and tolerant species; livestock drinking	68.95	Class III (51.9–76.5)	Extensive treatment required. Fishery III-Economic value and tolerant species; livestock drinking
SS6	Habu Town	46.67	Class IV (32.0–51.9)	Irrigation	44.41	Class IV (32.0–51.9)	Irrigation
SS7	After Habu Town, before the dam	40.00	Class IV (32.0–51.9)	Irrigation	53.07	Class III (51.9–76.5)	Extensive treatment required. Fishery III-economic value and tolerant species; livestock drinking

The area between SS3 and SS4 has a lower water quality than the two ends, because IDW spatial interpolation method assumes that each input point has a local influence that diminishes with distance away from it (ESRI 2007). Since the midpoint is closer to SS3, it is therefore influenced by it, which has a WQI value of about 61 and the midpoint having a WQI of about 58. Therefore, the WQI values in SS3 and the midpoint are virtually the same with only a WQI difference of 3. The WQI variation is due to the diminishing of influence from SS3 (Fig. 2).

Figure 3 shows the WQI of Bertam River during average water flow. SS1 and its interpolated surface portray the highest water quality having an index of 78.7 (class II). It can be noticed that the WQI at this part of the river during average water flow is much better than in high water flow. This is attributed to low rainfall, resulting in lower discharge from the tributaries (Ismail et al. 2012). As such, this part of the river is safe for recreational activities where body contact is allowed (DOE 2002). Therefore, primary contact recreation can be carried out at that location. This involves activities that are presumed to involve a significant risk of ingestion of water such as swimming, water skiing, kayaking and canoeing (TSWQS 2012).

Sampling station 2 (SS2)

SS2 is situated beside Tengkolok Road and the golf course. The sampling station is just before Tanah rata town when moving downstream. Surrounding land uses are residential and open space. Road construction activities were observed at this sampling station during high water flow.

Lower value of DO (5.07 mg/L) can be noticed at SS2 during high water flow. The main reason for low DO is the high concentration of TSS (627.7 mg/L) as a result of road construction next to the river. Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases level of DO necessary for aquatic life (Ginting and Mamo 2006). Photosynthesis also decreases as less light penetrates the water as less oxygen is produced by plants and algae, which leads to further drop in DO levels. Another reason could be explained by thermal discharges from the road construction activities during the sampling event, taking place next to the river. This increases the water temperature and subsequently leads to lowered DO.

High concentration of NH_3N during high and average water flow at SS2 is noticeable with a value of 1.62 mg/L and 1.52 mg/L, respectively. This could be explained by the discharge of effluents from the septic tanks around the sampling station, as well as decay of plant and animal material (Fig. 4).

The status of river water quality at SS2 during high water flow is class IV. This means the water at this station

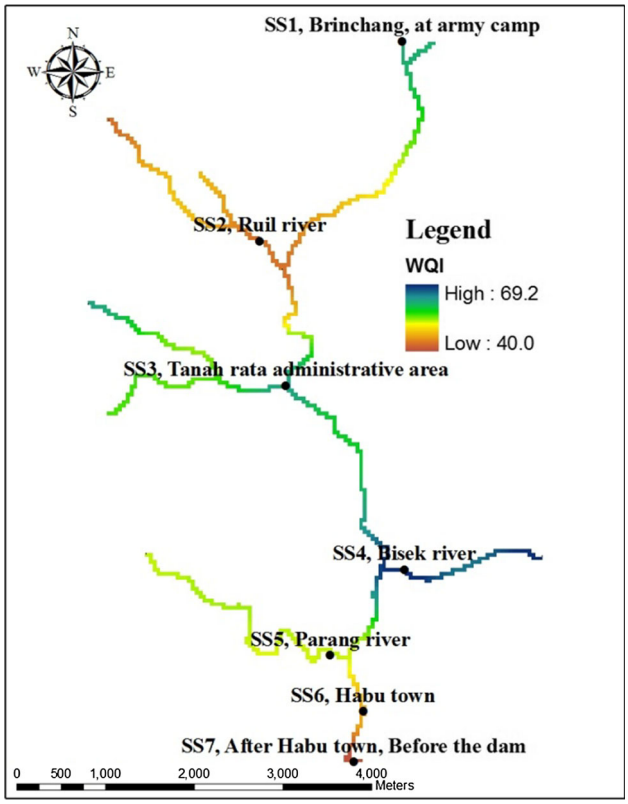

Fig. 2 Spatial interpolation of Bertam River WQI (HWF)

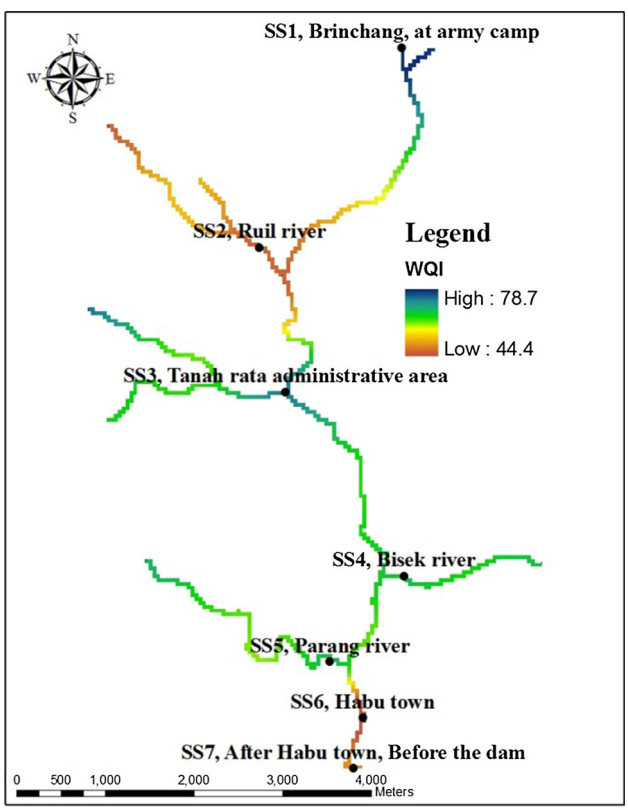

Fig. 3 Spatial interpolation of Bertam River WQI (AWF)

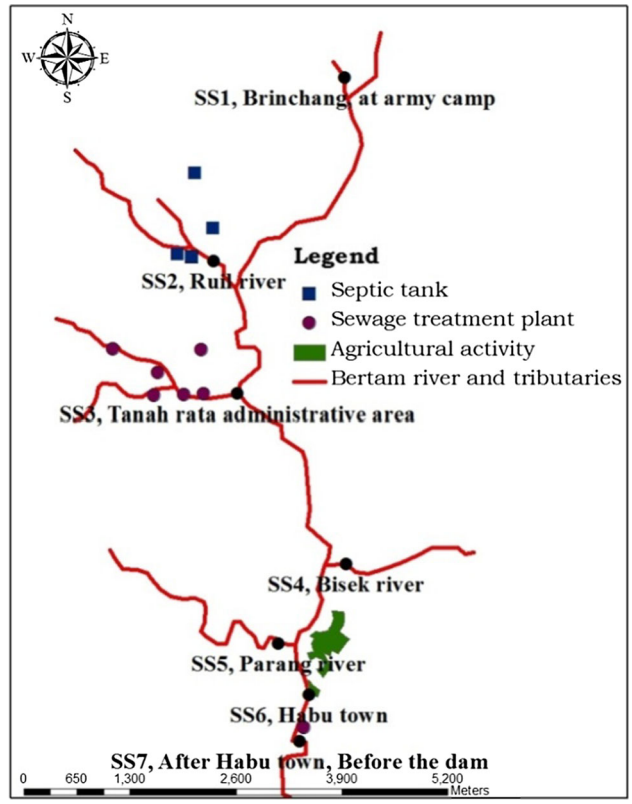

Fig. 4 Point and non-point sources of pollution around Bertam River and tributaries

is polluted and can be considered only for irrigation (DOE 2002). The pollution level at this station is highest in three parameters which are DO, TSS and ammonia nitrate. The picture remains largely the same during average water flow, except that there is little improvement because the road construction has reached an advanced stage coupled with the absence of high runoff.

To address issues associated with septic tanks, minimum requirements for septic system design, siting and installation should be set. This would include minimum setback distances from natural waterways. Another approach is to focus on the waters potentially at risk from pollution. This method identifies the water bodies at risk, and then attempts to calculate whether the waters can assimilate the pollutant load from the wastewater system without degrading water below acceptable levels. If not, the design approach requires alternatives like advanced treatment methods or not allowing the system to be installed at all (EPA 2002).

Sampling station 3 (SS3)

SS3 is located in Tanah rata town. Adjoining land uses at this sampling station are institutional and residential land. This sampling station has the highest concentration of

COD during high water flow with a value of 85 mg/L (Table 2). This is due to the discharge from the sewage treatment plants into the river (Fig. 4), as well as the presence of stormwater runoff. In urban and suburban areas, much of the land surface is covered by buildings as well as pavements; this does not allow rain to soak into the ground. Therefore, the stormwater runoff carries pollutants such as unearthed soil particles, oil, dirt, chemicals and fertilizers directly into natural waterways, where they harm water quality (EPA 2013).

SS3 belongs to class III during high water flow. The main parameter responsible for low water quality here is high concentration of COD. This is because the station is situated in the middle of an urban area where there is a large amount of domestic wastewater draining into the river because of high runoff (Eisakhani and Malakahmad 2009). During average water flow, SS3 also belongs to class III. However, the value appears very close to class II.

To protect surface water quality from stormwater runoff, development should be designed and built in such a way that it minimizes the increase in runoff. To decrease polluted runoff from paved surfaces, homeowners can be guided to develop alternatives to areas traditionally covered by impervious surfaces. Porous pavement materials could be used for driveways and walkways. Native vegetation and mulch can also be utilized to replace paved surfaces (EPA 2013).

Sampling station 4 (SS4)

SS4 is situated at the periphery of a forest land use. Water at this site was seen to be coming out from a rock. Some fish species were observed at the sampling station. A relatively lower value of DO (6.07 mg/L) can be noticed at this station during high water flow. The reason is that the sampling station is located next to the forest, which has led to the leaves of the adjoining vegetation falling into it and eventually decaying (Masters 1998). This, therefore, increases the amount of oxygen consumed by microorganisms in decomposing organic matter (dead leaves), leading to lowered DO. The status of river water quality at SS4 during high water flow is class III, though, the value of this station is close to class II of WQI. The same situation is obtained during average water flow at this sampling station.

To improve the water quality at this station, government at the local level, i.e., Cameron Highlands District Council (MDCH) should set up an integrated river basin management system in which various government departments and stakeholders will be brought together. This is because river management is placed under several departments with little coordination between them (Van der Ent and Termeer 2005). This will ensure that forest catchment areas and the rivers are viewed as an integrated living system.

Sampling station 5 (SS5)

SS5 is located around a small settlement; as such the surrounding land uses are residential and agricultural land. Toilet drains from residential neighborhoods were seen to flow into the river. At SS5, the water falls under class III during high water flow. The amount of pollution here is highest in TSS; this is as a result of agricultural activities in the hinterland (Fig. 4). However, during average water flow, the WQI has improved substantially. Though it is still in class III, the value here appears close to class II.

To improve on the water quality at this station there should be awareness and enlightenment programs on land owners to improve the water quality. This includes targeted media campaigns and developing environmental education programs that will help the land users understand how their actions affect water quality and ways of reducing such effects. Monitoring the state of the environment should be carried out by the local authority and other relevant agencies. The information obtained from the monitoring can be used to provide the land users with information about the state of their environment and the effects of their activities on water quality. This is aimed at instilling voluntary compliance through education and awareness enhancement, as well as increased commitment by the land users. According to UNISDR (2009), public awareness raising, educating land users, policies and laws are non-structural measures and do not include physical construction but the use of knowledge and practice to reduce impacts.

Sampling station 6 (SS6)

SS6 is situated at Habu Town; farming activities were observed around the sampling station, as well as earthwork as a result of the farming activities. Local toilets were seen to exist at the sampling station, discharging directly into the river. Higher concentration of COD was detected during high water flow with a value of 63 mg/L for this sampling station. This is due to the presence of agricultural runoff (Fig. 4). This is also an indication that non-point sources of pollution have tremendous impact on water quality (Eisakhani and Malakahmad 2009). Agricultural runoff is a major non-point source of nutrients and contaminants to Bertam River and its tributaries. The nutrients and contaminants come from agricultural activities (fertilizers, pesticides, manure). Improper agricultural activities raise nutrients concentrations, fecal matters, and sediment loads. Increased nutrient loading from animal waste

(manure) can result in eutrophication of water bodies, thereby harming the water quality (USU 2014).

Also a high concentration of TSS during high and average water flow can be observed at SS6 with TSS values of 186.3 and 252.67 mg/L, respectively. This is caused by hill cutting at this sampling station as a result of farming activities, thereby having more soil particles into the body of water. High concentration of NH_3N can also be noticed at SS6 during average water flow with a corresponding value of 2.80 mg/L. The reason for high ammonia is domestic and agricultural pollution as well as fecal matter (Zapanta et al. 2008).

Looking at SS6 during high and average water flow its WQI is in class IV. This depicts the lowest index of 44.41 during average water flow. According to DOE-WQI, it means that the water at this station is polluted; therefore, it is suitable for irrigation. The reason for the low value of WQI is because of increasing amount of COD, TSS and NH_3N at this station. This is because large parts of the station's hills are being cut down as a result of farming activities as well as pipes from toilets draining into the river. The condition of the water during average water flow remains largely the same.

To deal with the situation, farmers and ranchers can reduce sedimentation drastically by applying management practices that control the volume and flow rate of runoff water, keep the soil in place, and reduce soil transport (EPA 2005). Another strategy will be a legislation to withdraw license to any farmer who causes pollution. More so, plastic roofs should be enforced on agricultural produce like flowers to reduce pollution from fertilizers and pesticides. Proper agricultural methods proposed at the sampling station will aid in improving the water quality.

To curtail the effects of pipes draining into the river from the toilets, a septic tank should be installed at the station. A septic system is one way to treat wastewater on the property where it is generated. A septic system can be a cost-effective and convenient solution to wastewater treatment, but it must be regularly inspected and maintained to function properly and prevent contamination of the water body (Cornell-University 2013).

Sampling station 7 (SS7)

SS7 is located after Habu Town just before the dam. Earthwork was observed at this sampling station due to dam construction. The station has a presence of some residential quarters. A much higher value of 5.60 and 4.60 mg/L for BOD can be observed at sampling station 7 during high and average water flow, respectively. This is because the water at the sampling station is virtually stagnant with leaves of the adjoining vegetation falling into it and eventually decaying (Masters 1998). Also next to this sampling site is a sewage treatment plant discharging into the river. This, therefore, increases the amount of oxygen consumed by microorganisms in decomposing organic matter (dead leaves). This sampling station also depicts a higher concentration of COD during high water flow with a value of 62 mg/L. This is due to existence of a sewage treatment plant at the sampling station (Fig. 3). High concentration of TSS during high water flow can be observed at SS7 with TSS value of 211.7 mg/L. The reason for this is earthwork going on next to these sampling stations which has led to disturbance of the land surface. The eroded soil particles are then carried by stormwater into the river. SS7 also depicts a high concentration of NH_3N during high water flow with a value of 1.24 mg/L. The main reason for this is a sewage treatment plant around the sampling stations which discharges into the river, as well as decay of plant and animal material (Fig. 4).

The status of river water quality at SS7 during high water flow is class IV which means the water at this station is polluted and is only suitable for irrigation. This depicts the least WQI of 40.0 during high water flow. Low value of WQI at this station is attributed to high concentrations of BOD, COD and TSS. This is because of the stagnant water at this sampling station as well as leaves of the adjacent vegetation falling into it and eventually decaying. Also next to this sampling site there is a sewage treatment plant discharging into the river. More so, the sampling station is characterized by earthwork because of dam construction. This has also led to the disturbance of land surface, thereby having more soil particles into the body of water by stormwater. However, the situation at this sampling station has improved to class III during average water flow.

To minimize the effect of the dam construction on the water quality, developers should attempt to control the volume of runoff from new development using low impact development and pollution prevention strategies. Low impact development includes measures that conserve natural areas such as sensitive hydrologic areas (riparian buffers and infiltrate soils), reduction in development impacts, and reduction in site runoff rates by maximizing surface roughness and infiltration opportunities (EPA 2013).

Another means is institutional control, which involves the enforcement of local laws to improve erosion and landslide control on construction and agricultural sites. This involves the use of regulatory instruments such as environmental licenses to help manage premises likely to contaminate the river (Taylor and Wong 2002).

Spatial interpolation outcomes

GIS-based spatial interpolation has allowed for the creation of a surface data from points of sampling stations that are easy to understand. It has proved advantageous to spatially

analyze water quality index in areas where sampling does not exist (Figs. 2, 3). As data collection from numerous locations cannot be performed easily (Hoover 1997), selection of sampling stations from varying land cover/land use has resulted in spatial interpolation outcome that depicts the true picture of Bertam River water quality. Results of the spatial interpolation show the interaction between the neighboring points along the river line in a continuous manner. These interactions were reflected along the river course. Surface data derived from spatial interpolation has made it possible for a larger area of Bertam River to be ascertained as suitable tourism area, thereby helping to make an informed decision. Spatial interpolation has proved beneficial in parts of the river that are inaccessible due to either difficult terrain surface or thick rainforest which were analyzed for sustainable tourism development. Otherwise, it would have been virtually impossible to analyze most of the locations.

The results from the spatial interpolation clearly showed the hot spots in relation to the spatio-temporal characteristics of pollutants influx into the river (Figs. 5, 6). It has also revealed the pollution impaired areas in a more coherent way. Hence, a GIS-based spatial interpolation could strengthen monitoring and assessment capacity of river basin management systems toward a better pollution monitoring and control. Ultimately, it will allow for the implementation of the best management practices for the remediation of potentially impaired locations of the river, thus realizing more areas that are suitable for recreational activities.

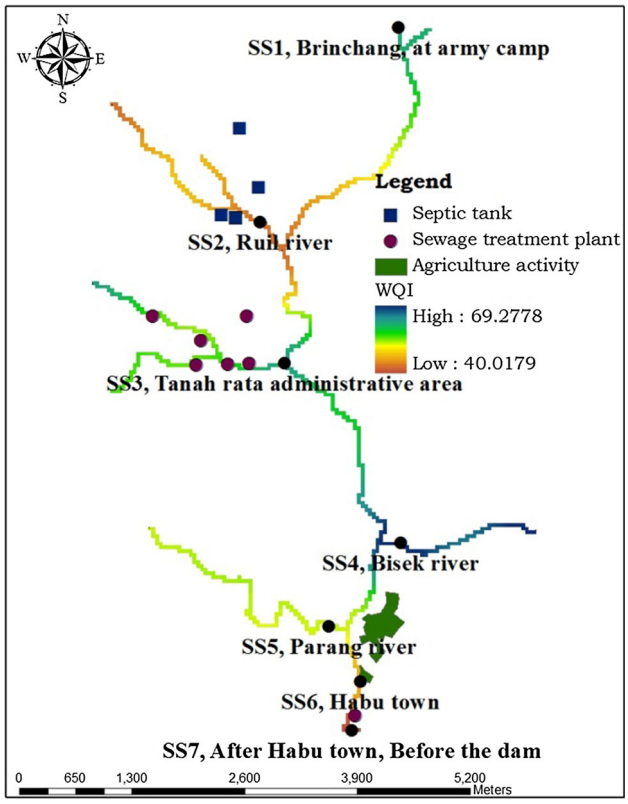

Fig. 5 Spatial interpolation of Bertam River WQI during HWF and pollution sources

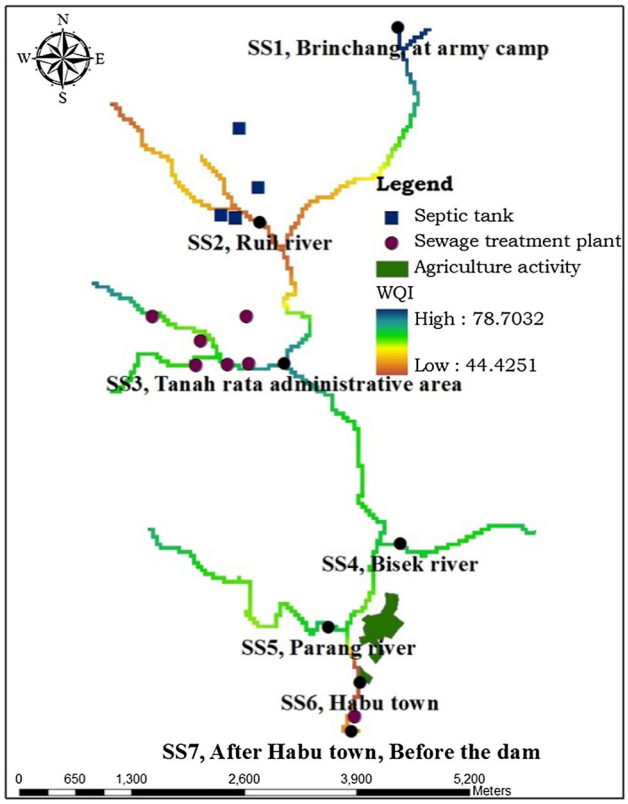

Fig. 6 Spatial interpolation of Bertam River WQI during AWF and pollution sources

Conclusion

Non-sustainable tourism and urbanization activities have had a negative effect on the water quality of Bertam River in Cameron Highlands. The deterioration of the water quality is because of the high amount of suspended solids and high concentrations of BOD and NH_3N. Overall, the water quality of Bertam River and its tributaries belongs to class II, III and IV of water quality index classification, which means that they are somewhat polluted. The study revealed that WQI was lower in the high water runoff than in the average water runoff. The maximum and minimum value of WQI during high water runoff has shown to be 60.84 and 40.00, respectively. For WQI during average water runoff its minimum and maximum value has shown to be 78.72 and 53.07, respectively. Lower value of WQI during high water runoff is an indication that non-point sources of pollution have a great impact on water quality.

Also, WQI of Bertam River has shown to vary with location of the sampling stations. SS1, SS3 and SS4 exhibit a relatively higher WQI value of 60.84, 61.34 and 69.29, respectively; while SS7 depicts the least WQI value of 40.00 during high water runoff. However, during average water runoff, SS1 and SS3 portray a much higher WQI value of 78.72 and 73.93, respectively; while SS6 exhibits a much lower WQI value of 44.41. The variation in the WQI value of the sampling stations is due to the type pollutants and its concentration. To enhance and use Bertam River for sustainable tourism development, short- and long-term strategies have been formulated. Measures suggested in the study will go a long way in improving the water quality of Bertam River and its tributaries. This is to ensure that the river reaches conservation status as well as the status of being used for recreational activities where body contact is allowed, according to DOE-WQI.

In addition, GIS has shown to be beneficial by providing a more flexible way to display and integrate a wide range of information such as sampling stations, WQI, land use, point and non-point sources of pollution. GIS has also shown its strength in predicting WQI in un-sampled locations, thereby helping to make informed decisions and thus attaining sustainable tourism development. Benefits derived from GIS would help the stakeholders to understand, assess and actively participate in issues that pertain to the water body, thereby leading to a holistic and more effective management of Bertam River and its tributaries.

Further efforts are required in a number of areas to extend this study. An area of research that needs further attention is the water quality assessment of other rivers (unstudied rivers) in Cameron Highlands. These rivers need to be carefully studied to determine their suitability for sustainable tourism development and decision making. In addition, water quality data obtained by the previous studies should be analyzed using spatial interpolation to determine the temporal changes of the water quality. This will help in revealing the spatial trend of water quality over the years and thus will lead to an informed judgment. Further studies should be able to suggest the various kinds of water recreational activities that could be carried out at the different parts of the river. This should include the type of facilities to be used by these activities. Such facilities are to be installed and used with great caution to ensure that there is a minimal impact on the water and surrounding area. Future studies should work on providing access to parts of Bertam River that were ascertained as suitable for tourism, but are inaccessible; this should ensure a minimum impact on the environment.

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