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Research paper

Evaluation of Annual Sediment Load Production in Kenyir Lake Reservoir, Malaysia

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Abstract

Kenyir Lake's natural environment experienced significant changes over the past 20 years. Pressure from anthropogenic activities such as deforestation, construction, and sand mining around Sungai Terengganu, tourism, farming and agricultural has creating imbalance between environmental processes and response in Kenyir Lake. The aim of the study is to estimate the production of sediment yield (*Muatan Sedimen*) (MS) (tonnes/km^2/year) in Kenyir Lake Basin. 21 sampling stations were chosen along Kenyir Lake to represent the upstream and downstream. The statistical analysis proved that the correlation and regression relationship between Total Suspended Solid (TSS), MS and area of catchment. MS showed a weak correlation and insignificant relationship of regression caused by the anthropogenic factors and uncertain climate changes. These sedimentation problems due to unsustainable land use changes, river bank erosion problems and active construction activity around the Kenyir Lake Basin. This study suggests the sedimentation management methods including land use settlement, cliff erosion problems, settlement and negotiable of uncontrolled development operations in Kenyir Lake and the integrated of river and lake management methods based on Integrated River Basin Management (IRBM) in Kenyir Lake Basin is recommended.

Keywords: *Sedimentation; anthropogenic; deforestation; Kenyir Lake Basin; Total Suspended Solid (TSS)*

1. Introduction

In recent event of Cameron Highland, the lack of governing body and proper jurisdiction on lake management made it difficult to manage a lake and eventually to avoid disaster from happening. Currently, Kenyir Lake and its catchment are mostly in its original natural condition and preservation has to begin immediately to avoid future disaster due to human activities. At the same time, it is important to ensure activities and interest of different parties on Kenyir Lake and its catchment is well managed and while at the same time preserving the nature. The construction of the dam around Kenyir Lake started from 1978 and was completed in 1985. The wide variations in climatic and land use impacts whereas others are much more sensitive to any environmental change. In addition, the accidental or deliberate introduction of invasive non-native species can also severely impact communities of indigenous species in Kenyir Lake [1-5].
The wide variations in climatic and land use impacts whereas others are much more sensitive to any environmental change. Natural events can also precipitate sudden changes. Increasingly, however, the anthropogenic effects of human activity such as intensive agriculture, deforestation, urbanization and tourism are causing specialized habitats to change, shrink and become fragmented to the extent that they may no longer be self-sustainable [24–26]. In addition, the accidental or deliberate introduction of invasive non-native species can also severely impact communities of indigenous species in Kenyir Lake. In protecting the existing fragile natural environment are of fundamental significance in interactions between humankind and the environment, this study has identified its key objective to address and promote the sustainable development towards preserve, protect and enhance biodiversity in Kenyir Lake. The management implications of this characteristic of incremental development of degradation problems and the potentially long time for lakes to respond to management interventions include the need for long term involvement of relevant lake basin management institutions and their activities. The potential for long term impacts also suggest a need for a precautionary approach in developing and implementing lake management interventions [6-8].
The collaborative research to understand the levels of resilience of such specialized environments is critical to protecting them and making informed policy decisions about land use planning and natural resource extraction. This section focuses specifically on the major existing environment in Kenyir Lake and it's basin including the climate characteristics, hydrological characteristic, air quality, topography and geomorphology of the lake and river system. Based on the isohyet map has been develop, the high rainfall intensity in December 2014 was focused at the Terengganu and Kelantan border with the range of rainfall intensity was 2300 mm to 1600 mm [27]. The rainfall cumulative intensity still pouring

down in few area that heavily effected by flood such as National Park, Jerantut, Temerloh, Cameron highland especially in Brinchang and Chini in capacity range about 120 mm to 60 m. Based on the isohyet map in January 2015, high intensity if rain was poured at Kuala Rompin area at the range of 800 mm to 700 mm. Other places such as central area of Pahang state and upstream area of Pahang River, the rainfall intensity has dropped to the range of 120 mm to 40 mm in the blue area (Figure 1) [5, 9-10]. Figure 2 showed the estimated flow direction based on Digital Elevation Model (DEM) hydrodynamic model using XP – SWMM which represent the hydraulic elements of flow in the system and the model offered many different types of conduits for simulation such as sewer pipes, channel reaches or culvert, and nodes represented as ponds or lake, junctions, outfalls or other physical transition points along the link. Based on the cross-section data obtained from the study area, XP SWMM used a node-link concept to represent the drainage system [11, 12].

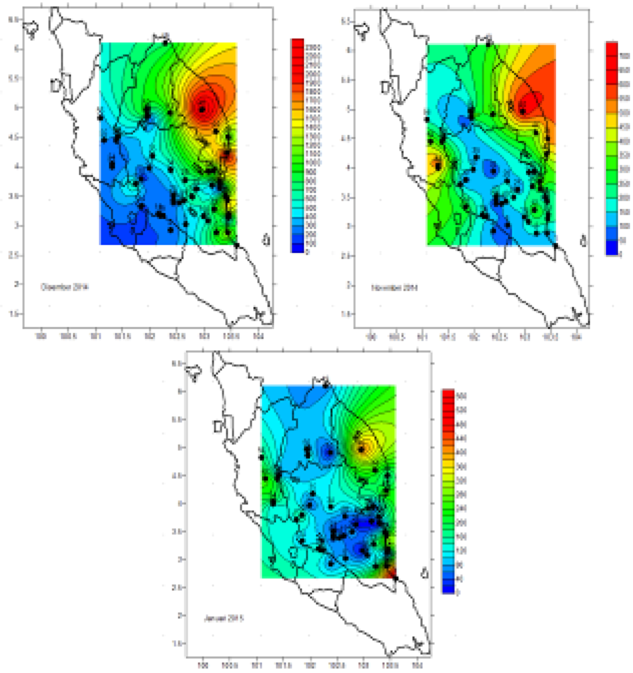


Fig. 1: Cumulative Rainfall distribution of from (a) November of Terengganu boarder for 2014 (b) December 2014 and (c) January 2015

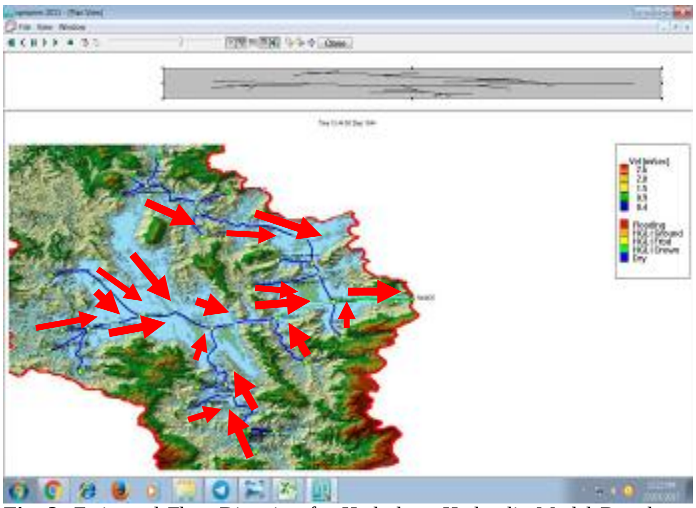


Fig. 2: Estimated Flow Direction for Hydrology Hydraulic Model Based on Digital Elevation Model (DEM) at Kenyir Lake Basin, Hulu Terengganu, Terengganu

2. Methodology

2.1. Study Area

Kenyir Lake is the biggest man-made lake in Southeast Asia. It's covered by more than 340 islands spread out in water catchments area of 260,000 hectares within almost 90 percent natural environment. Kenyir Lake is a one of famous lake in Terengganu and Peninsular Malaysia which fascinating tourist spot. The topography of the Kenyir Lake catchment area varies from 50' to a spot height of 1,210' above mean sea level (MSL), but for about 80% of the area, the topography is well below 250' MSL. Areas above the 250' contour area mainly confining to the south west where Taman Negara National Park.

The main water sources contributing to the main lake body comprises firstly, the natural tributaries of Sungai Terengganu and a few rivers along the Kenyir Lake Basin. Hydrological analysis was carried out to evaluate the water level characteristics of the water body as well as the river systems. In this study, field work on hydrographic survey was carry out from 15th to 18th May 2017 (Dry season) and 10th to 13th December 2017 (Wet season) where covering almost 95% of the all main tributary in Kenyir Lake.

This study included 19 sampling stations during dry season and 21 sampling stations during wet season which are Sungai Siput (Station 1), Sungai Petuang (Station 2), Sungai Tembat (Station 3), Sungai Terengganu (Station 4), Sungai Ketiar (Station 5), Sungai Besar (Station 6), Sungai Lepar (Station 7), Sungai Lawit (Station 8), Sungai Cenan (Station 9), Sungai Bewah (Station 10), Sungai Cicir (Staion 11),Sungai Perepek (Station 12), Sungai Terenggan (Station 13), Sungai Cacing (Station 14), Sungai Pertang (Station 15), Sungai Lasir (Station 16), Sungai Leban Terengganu (Station 17), Sungai Sauk (Station 18), Sungai Mandak (Station 19), Sungai kenyir (Station 20) and Sungai Berangan (Station 21) (Table 2 and Figure 3).

Table 1: The Sampling Stations for Dry Season (July 2017) and Wet Season (December 2017) at Kenyir Basin, Hulu Terengganu, Terengganu, Malaysia, 2017

Stations	Location	River Name
Station 1	102° 42'42.602"E 05°11'01.064"N	Sungai Siput
Station 2	102°39'49.705"E 5° 17'42.360"N	Sungai Petuang
Station 3	102°38'19.879"E 5° 12'57.393"N	Sungai Tembat
Station 4	102°37'46.486"E 5° 11'24.258"N	Sungai Terengganu
Station 5	102°33'17.735"E 5° 03'30.462"N	Sungai Ketiar
Station 6	102° 34'15.044"E 04°58'03.613"N	Sungai Besar
Station 7	102° 33'09.379"E 04°56'16.506"N	Sungai Lepar
Station 8	102°35'13.374"E 4° 54'38.067"N	Sungai Lawit
Station 9	102° 42'04.9"E 04°52'32.0"N	Sungai Cenana
Station 10	102°41'24.427"E 04° 50'36.340"N	Sungai Bewah
Station 11	102°44'30.707"E 04° 47'42.302"N	Sungai Cicir
Station 12	102°44'31.9"E 04° 47'16.9"N	Sungai Perepek
Station 13	102°45'00.244"E 04° 46'28.235"N	Sungai Terenggan
Station 14	102°42'32.595"E 04° 48'17.089"N	Sungai Cacing
Station 15	102°48'00.5"E 04° 55'26.2"N	Sungai Pertang
Station 16	102°50'22.510"E 04°57'54.633"N	Sungai Lasir
Station 17	102°45'03.621"E 05° 02'21.528"N	Sungai Leban Terengganu
Station 18	102° 46'42.443"E 05°04'58.079"N	Sungai Sauk
Station 19	102° 20'6.25"E 05°07'34.463"N	Sungai Mandak
Station 20	102°54'5.18"E 05° 0'40.01"N	Sungai Kenyir
Station 21	102°54'40.34"E 05° 1'2.36"N	Sungai Berangan
*Sungai = River		

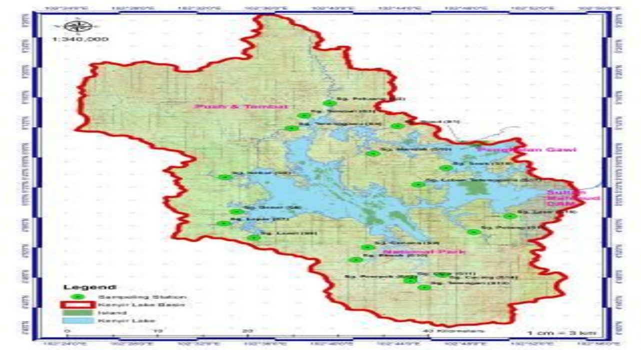


Fig. 3: The Map of Location at Kenyir Lake Basin, Hulu Terengganu, Terengganu, Malaysia.

2.2. Research Methodology

TSS was measured using filtration methods with membrane filter 45 mm and vacuum pump (Gravimetric Method) (Figure 4) which measured in mg/L. TSS is described the concentration of solid-phase material suspended in a water sediment mixture which usually expressed in milligrams per liter (mg/L) [13-15]. 250 ml water sample were needed for each study area (each station). The readings of TSS were taken and calculated using the Equation (1).

TSS ={(WBF+ DR) - WBF} (mg) x 1000 / VFW (mL) = mg/L (1) [11, 15]

*WBF = Weight of membrane filter; DR = Dry residue; VFW = Volume of filtered water

Fig. 4: The Gravimetric Method to analyses the Total Suspended Solid (TSS)

Stream gaging is a technique used to measure the discharge, or the volume of water moving through a channel per unit time, of a stream. The discharge value (Q) is the product of velocity and cross section area (A). The cross section area is derived from the product of depth (d) and width (w), the cross section area is trapezium or triangular shaped and the value is half the product, which are due to imprecision of the current meter, variability of the river flow velocity over the cross section and uncertainty in the estimation of the cross section geometry (Figure 5) [10, 16].

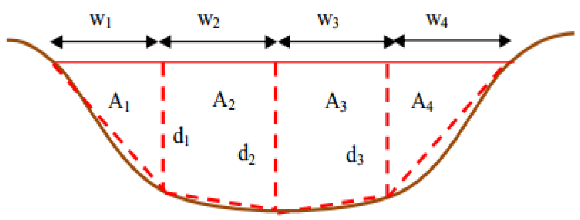


Fig. 5: The theoretical of discharge measurement by cross-section of the river

The annual sediment load production (MS) basically used in the sedimentation studies to determine the level of sedimentation level in a basin. The process of sediment deposition depends on river discharge and velocity of river water. The speed of water flows in river plays an important part in determining its capacity to carry away sediments production. Besides that, the area of sub basin also one of factors in determining the estimate sediment production in a year. The calculation of annual sediment load production (MS) based on the discharge value (Q) (m^3/s), TSS value (mg/L) and area of sampling basin (km^2). The data to be analysed would be used to determine the changes in the concentration of suspended sediment and its relationship with hydrological and geomorphological factors and other variables. Equation (2) showed the following formula used in the measurement of MS (tonnes/km^2/year). Figure 6 showed the Fundamental of Georeferencing of ArcGIS method to determine the area of each sub catchments (area sampling basin) [17-20].

Annual sediment load production (MS)
= (Q x TSS)/ Area of sampling basin
= (L/day x tonnes/day) / km^2
= tonnes/km^2/365 days
= tonnes/km^2/days (2)

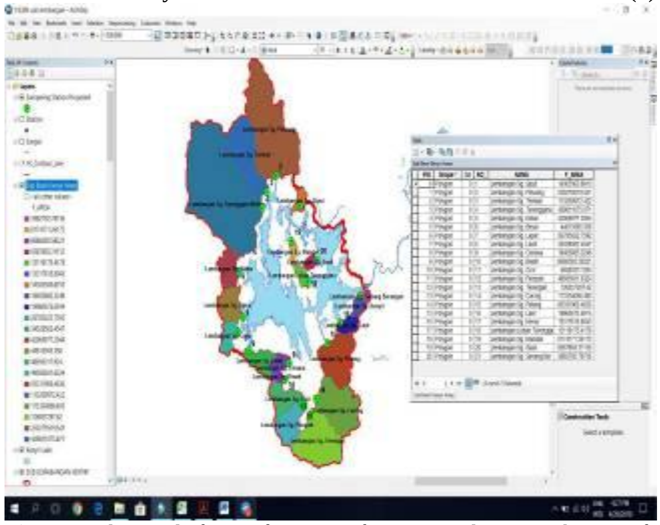


Fig. 6: Fundamental of Georeferencing of ArcGIS to determine the area of each sub catchments in Kenyir Lake Basin, Hulu Terengganu, Malaysia

Table 2: The Area of Sub Basins in Kenyir Lake Basin, Hulu Terengganu, Terengganu

Sub Basin	Area of Sub Basin (km^2)
Sungai Siput	14.306
Sungai Petuang	250.280
Sungai Tembat	113.261
Sungai Terengganu	429.811
Sungai Ketiar	42.070
Sungai Besar	44.614
Sungai Lepar	26.786
Sungai Lawit	34.529
Sungai Cenana	18.406
Sungai Bewah	8.688
Sungai Cicir	48.593
Sungai Perepek	49.586
Sungai Terenggan	126.057
Sungai Cacing	113.334
Sungai Pertang	93.332
Sungai Lasir	19.961
Sungai Leban Terengganu	13.119
Sungai.Sauk	9.588
Sungai Mandak	8.174
Sungai Kenyir	13.318
Sungai Berangan	3.983

3. Results and Discussion

In the normal follow by the hydrological theory, where the discharge value (Q) in the elevated downstream is higher than the upstream but in Table 3 and Table 4 showed the discharge value (Q) at Sungai Petuang showed the highest values at 10.48 m^3/s (Dry Season) and 29.59 m^3/s (Wet Season), the lowest values at Sungai Bewah with 0.07 m^3/s (Dry Season) and 0.917 m^3/s (Wet Season). The daily suspended sediment production was calculated to estimate the Total Suspended Solid (TSS) tonnes per day (tonnes/day). The highest daily suspended sediment production in a river basin (Kenyir Lake) was caused by highest discharge value and the highest TSS, the highest value of estimated TSS (tonnes/day) or suspended sediment load at Sungai Tembat (Dry Season), 12.483 tonnes/day and 14.741 tonnes/day at Sungai Terengganu (Wet Season). In the normal reading through the hydrological theory, where the discharge value (Q) or water velocity in the elevated downstream is higher than upstream and the TSS production higher during the water flow in a basin increased because the higher flow contains the strong energy to move the higher concentrated the suspended sediment load compared to the low flow. The density of water at forest canopy is the main role towards reducing the surface erosion which contributes to sediment load production in river basin.

When the water flow in a basin increased, the TSS will also increase because the higher flow contains the strong energy to move the higher concentrated the suspended sediment load compared to the low flow level and the high water flow also increased the rate of erosion. TSS is also to determine whether the status of water quality clean, moderately polluted or contaminated and to estimate the suspended sediment load production in the Sungai Terengganu, TSS is an indicator to classify the river in Class I, II, III, IV or Class V, based on NWQS.

The highest amount of TSS at Sungai Lepar and Sungai Cenana recorded 18 mg/L respectively. The minimum level amount of TSS at Sungai Besar, 4.4 mg/L during dry season. The value of TSS on dry season showed higher range compared wet season effected by climate changes and anthropogenic factors, the TSS amount for all sampling stations were recorded 4.4 mg/L ± 18.00 mg/L during dry season and 1.6 mg/L ± 15.00 mg/L during wet season. From the result, the difference amount level of TSS at Kenyir Lake Basin effected by the anthropogenic and geomorphology factors, climate changes and hydrological cycle. This study proved the wet season (higher density of rainfall) caused the higher level of soil loss. From Department of Environment (DOE) 2005 stated the WQI Class of Kenyir Lake Basin for TSS in class II during wets season, the river water needs to be treated and still suitable to protect aquatic species and recreational activities.

Table 3: Estimated suspended load in the Kenyir Lake, Hulu Terengganu, Terengganu during Dry Season (July 2017)

Stations	TSS (mg/L)	Q (m^3/s)	Estimated TSS tonne per day (tonnes/day)
Sg.Siput	16.00	0.22	0.304
Sg Petuang	8.40	10.48	7.606
Sg. Tembat	16.00	9.03	12.483
Sg Terengganu	17.60	4.8	7.299
Sg. Ketiar	16.40	1.04	1.474
Sg. Besar	4.40	0.61	0.232
Sg. Lepar	**18.00**	0.33	0.513
Sg Lawit	7.20	1.91	1.188
Sg. Cenana	**18.00**	0.92	1.431
Sg. Bewah	7.20	0.07	0.044
Sg. Cicir	10.00	3.53	3.050
Sg. Perepek	17.60	2.13	3.239
Sg. Terenggan	15.60	2.17	2.925
Sg. Cacing	15.20	2.80	3.677
Sg Pertang	10.00	5.16	0.458
Sg. Lasir	15.20	6.35	8.339
Sg. Leban Terengganu	8.00	2.9	2.004
Sg.Sauk	6.40	0.54	0.299
Sg. Mandak	12.80	0.22	0.2433024

Table 4: Estimated suspended load in the Kenyir Lake, Hulu Terengganu, Terengganu during Wet Season (December 2017)

Stations	TSS (mg/L)	Q (m^3/s)	Estimated TSS tonne per day (tonnes/day)
Sg.Siput	1.22	1..571	0.166
Sg Petuang	3.60	29.59	8.271
Sg. Tembat	10.00	9.72	8.398
Sg Terengganu	6.00	28.436	14.741
Sg. Ketiar	12.00	1.145	1.187
Sg. Besar	5.90	0.833	0.425
Sg. Lepar	15.00	0.33	0.428
Sg Lawit	8.90	4.778	3.674
Sg. Cenana	3.60	2.475	0.770
Sg. Bewah	9.60	0.917	0.761
Sg. Cicir	1.60	3.604	0.498
Sg. Perepek	2.80	5.923	1.433
Sg. Terenggan	6.80	8.485	4.985
Sg. Cacing	2.80	10.436	2.525
Sg Pertang	1.60	8.149	1.127
Sg. Lasir	2.00	3.66	0.632
Sg. Leban Terengganu	5.20	1.478	0.664
Sg.Sauk	2.40	3.222	0.668
Sg. Mandak	2.80	2.041	0.494
Sg. Kenyir	2.0	9.447	1.632
Sg. Berangan	3.2	3.293	

The estimate annual sediment load for Station 1 to Station 21 representing 21 sub catchment around Kenyir Lake such as Sungai Siput, Sungai Petuang, Sungai Tembat, Sungai Terengganu, Sungai Ketiar, Sungai Besar, Sungai Lepar, Sungai Lawit, Sungai Cenana, Sungai Bewah, Sungai Cicir, Sungai Perepek, Sungai Terenggan, Sungai Cacing, Sungai Pertang, Sungai Lasir, Sungai Leban Terengganu, Sungai Sauk, Sungai Mandak, Sungai Kenyir dan Sungai Berangan. The highest annual suspended sediment load during dry season is 152.493 tonnes/km^2/year (Station 16) (Sub catchment Sungai Lasir) and the lowest MS value at Station 10 (Sub catchment Sungai Bewah) is 1.829 tonnes/km^2/year. Meanwhile, the highest MS during wet season was recorded at Station 21 (sub catchment Sungai Berangan) is 83.437 tonnes/km^2 /year and the lowest at Station 15 (sub catchment Sungai Besar) is 3.474 tonnes/km^2/year. Overall, the annual average estimation for annual sediment load production flow out from the tributary rivers into Kenyir Lake is 83.437 tonnes/km^2/year (sub catchment Sungai Berangan) the lowest in the sub catchment Sungai Besar is 2.686 tonnes/ km^2/year (Figure 7). The value of sediment load at downstream and mid-stream of Kenyir Lake higher than upstream. This study proved the impact by the geomorphology, hydrological, development of anthropogenic factors and climate changes such as sand mining activities in Sungai Terengganu Basin and bank erosion along the sub river basin in Kenyir Lake Basin.

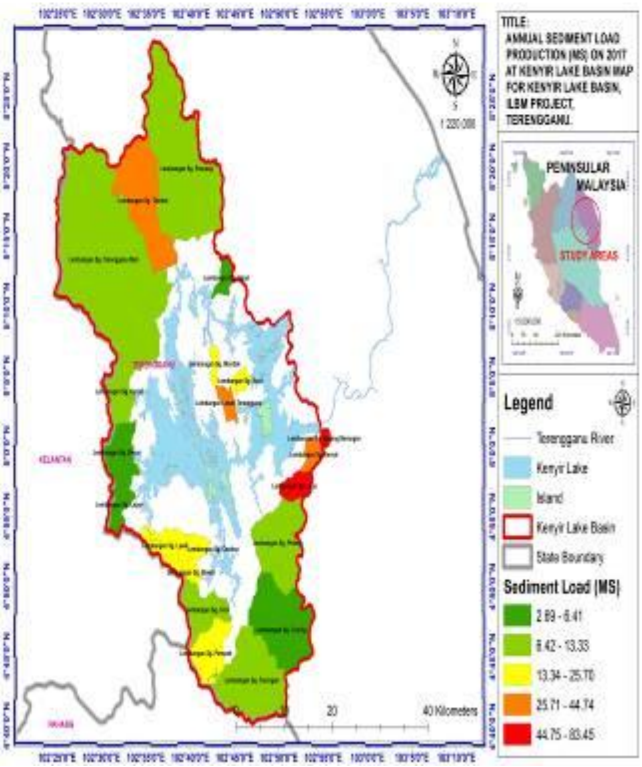
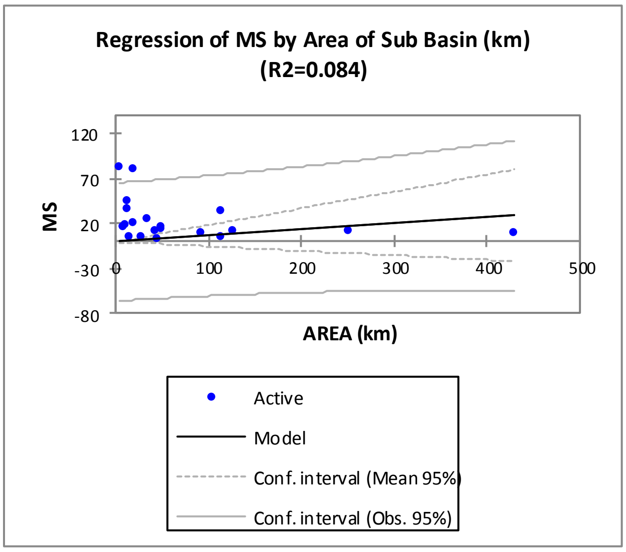
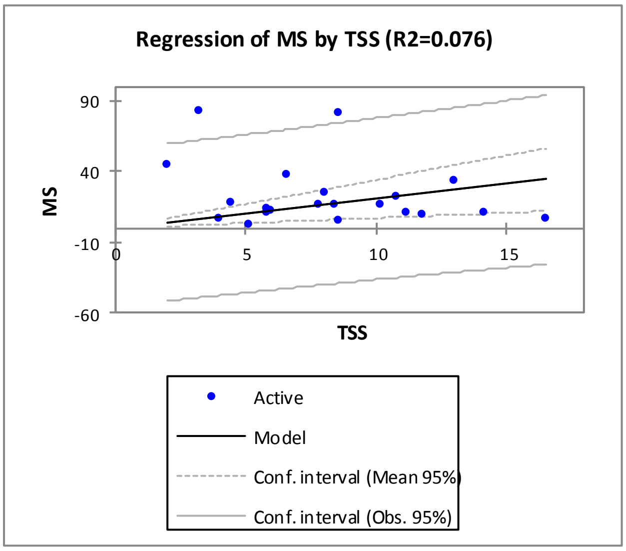


Fig. 7: The average of annual sediment load production (MS) at Kenyir Lake, Hulu Tereangganu, Terengganu

Figure 8 (a) (b) showed the regression analysis of coefficient relationship was not significant, R^2 = 0.084 and R^2 = 0.076. The results of this study showed that the area of the river catchment and production of TSS was not the major factor in the production of sediment loads. The abundance of sediment production will certainly have many impacts on the surrounding basin. Sungai Terengganu one of a major river in the state that is directly connected to Kenyir Lake in Hulu Terengganu, if without control of the strategic will be disrupt the river ecosystem in the long term and it will give a negative impact on the environment and society [29-31]. The increasing the sedimentation could lead to increase the turbidity and the odours of water. The values of river discharge (Q) at the Terengganu River are the primary factor that effected the sediment mobility. The increased rate of water flow triggers the sediment production. From this research proved the sedimentation problem in the Kenyir Lake not only caused by the geomorphology, hydrological characteristic but also depends on the others anthropogenic and climate changes factors. The sedimentation problem level in the Kenyir Lake Basin is not in critically stage like Chini Lake and Telom Lake but the flow rate of water and land use activities (development around basin) will be contributed to the increasing levels of sedimentation in Kenyir Lake Basin [21- 23].



(a)



(b)

Fig. 8: Regression relationship between (a) annual sediment load production (MS) and sub basin area (b) Total Suspended Solid (TSS) and MS at Kenyir Lake Basin, Hulu Terengganu, Terengganu

4. Conclusion

High suspended sediment concentrations flows into tributaries are flow out to the Kenyir Lake can inhibit light penetration, increase costs of water treatment and detract aesthetically from the water body. Increase in TSS and turbidity levels due to surface run-off during rainfall periods to receiving watercourses. Sedimentation issues have to be taken into account when implementing the landuse and development plan surrounding the reservoir area in order to control sedimentation in Kenyir Lake Basin. Advisable to develop buffer zone areas act for all tributary and water body areas and construct bank protection project with soft engineering method at erosion potential areas to decrease the erosion problem which will lead to deposited sediment. Flow conditions in the reservoir also need to be created and stabilized to control the deposition of sediment. Monitor the current reservoir sedimentation, future sediment inflow and also the deposition analysis. Result from the survey is beneficial for planning future reservoir. The sedimentation problem level in the Kenyir Lake Basin is not in critically stage but the flow rate of water and land use activities (development around basin) will be contributed to the increasing levels of sedimentation.

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