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CLIMATE CHANGES IMPACTS TOWARDS SEDIMENTATION RATE AT TERENGGANU RIVER, TERENGGANU, MALAYSIA

N. A. Wahab[1], M. K. A. Kamarudin[1,*], M. E. Toriman[2], H. Juahir[1], M. B. Gasim[1], Z. I. Rizman[3], G. Adiana[1], A. S. M. Saudi[4], Sukono[5], B. Subartini[5], P. P. Damayanti[5], S. Supian[5], Y. Hidayat[6], T. Purwandari[6] and F. M. Ata[1]

[1]East Coast Environmental Research Institute (ESERI), Universiti Sultan Zainal Abidin, Gong Badak Campus, 21300 Kuala Terengganu, Terengganu, Malaysia

[2]School of Social, Development and Environmental Studies, Faculty of Social Sciences and Humanities, National University of Malaysia, 43600 Bangi, Selangor, Malaysia

[3]Faculty of Electrical Engineering, Universiti Teknologi MARA, 23000 Dungun, Terengganu, Malaysia

[4]Institute of Medical Science Technology, University Kuala Lumpur, 43000 Kajang, Selangor, Malaysia

[5]Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Bandung, Indonesia, 45363 Jawa Barat, Indonesia

[6]Department of Statistics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Bandung, Indonesia, 45363 Jawa Barat, Indonesia

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ABSTRACT

The climate changes caused by rainfall and stream flow are not the major contribution the changing of water level. This study was carried out at Terengganu River Basin in wet and dry season to assess the sedimentation problem and its relationship with hydrological characteristic. Three parameters analyzed based on in-situ and ex-situ analysis according to the correlation matrix and linear regression methods. The TSS (mg/L), Turbidity (NTU) and SSC (mg/L) were higher during dry season compared wet season caused by El Nino

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phenomenon (January 2016). There are higher positive correlation between SSC and TSS, R^2 = 0.924 (wet season) and R^2 = 0.841 (dry season), the correlation between the observation (Q) and the TSS is no significant R^2 = 0.057 (wet season) and R^2 = 0.001 (dry season). The main contributors of sedimentation problems in Terengganu River caused by the climate changes phenomenon.

Keywords: sedimentation; Terengganu River basin; hydrological characteristic; El Nino; communities.

Author Correspondence, e-mail: mkhairulamri@unisza.edu.my
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1. INTRODUCTION

River is one of the most important sources of water for all living things in addition to rivers, lakes, seas, water catchments and underground water. Rivers are very important to humans and other organisms as they are essential resources for living. River has many uses such as drinking water supply, agricultural, industrial and hydroelectric source and almost 60% of the rivers in Malaysia are regulated for domestic, agricultural, industrial fields, residential, sewage disposal and urbanization the major pollution sources influencing the river equilibrium in Malaysia [1-3]. The changes of development, industrial and agricultural activities, human population and sedimentation problems especially along the main of river and coastal area in Malaysia will increased the pollutant inputs and triggered the level of deteriorated the water quality [4-6]. The rivers deterioration in Malaysia has other environmental challenges. Some are man-made, others are not.

The country experienced its worst floods in 2014, especially at east peninsular Malaysia. They were blamed on deforestation and climate a change, which has also been termed the reason behind rising the sea levels. A number of processes influence the sedimentary content and quality of river water [7]. These include erosion, transport and deposition process. These processes mutually interact along the river, from the ridges up to the mouth of the river. It has been estimated that more than 80% of the suspended sediment load is caused by anthropogenic activities in the catchments.

Climate change could affect water resources in the Terengganu River Basin through alterations in the hydrologic cycle. The climate change also more frequent and intensity of rain events which increase erosion and caused greater production of sediment washing into rivers, lakes and streams. The El Nino phenomenon can decreased sediment loading from runoff, slower the stream velocity and decreased erosion and result in decreased suspended sediment in water bodies as well as affect normal distribution of sediment along river. These climate impacts can challenge efforts to maintain water quality through effective erosion and sediment control management efforts. Excessive levels of suspended stream sediment or a change in sediment distribution resulting from more frequent and intense storms can negatively ecosystem health. The impacts from changing levels of erosion and sedimentation threaten fish, invertebrates and aquatic vegetation, in particular.

Generally, the characteristics of pollutants of a river are unidirectional during different seasons. The river will exhibit different water levels, rates of flow and rates of erosion during different seasons. This situation is influenced by the frequency and intensity of rainfall in the area. When a river is dammed and reservoir is created, the sediments that used to flow along with relatively fast-moving river water are instead, deposited in the reservoir. This happens because the river water flowing through the reservoir moves too slowly to keep sediment suspended. Sedimentation is the process of bringing the material of erosion by water, wind or glaciers. Sedimentation is the main determinant for the level of water quality and environmental health of a river and natural lake catchment [8-11]. Sediments are a solid material that moved and deposited in a new location. Sediment or sedimentary can be defined as an eroded matter, which is carried through the water regime to the deposition location. Suspended sediment usually contains colloidal matter, which is microscopic and needs a low river velocity to be carried from one point to another.

The river affected higher sedimentation problem resulted in soil degradation, interference to the soil physics-chemical characteristics, weathering process, climate changes, soil erosion and many other impacts that have contributed to the increase of sediment [12-15]. There are four main indicator parameters to evaluate the sedimentation level; Total Suspended Solid

(TSS), Suspended Sediment Concentration (SSC), Turbidity and River Discharge (Q). SSC and TSS are predominantly used to quantify concentrations of suspended solid-phase material in surface waters. SSC is measurement the dry weight of all the sediment from a known volume of a water-sediment mixture. TSS is measuring the dry weight of sediment from a known volume of a subsample of the original. SSC, TSS, turbidity and river discharge are components to improve the understanding of fluvial sediment transport relations.

Turbidity is the measures of relative clarify of a liquid. It is an optical characteristic of water and is an expression of the amount of light that is scattered by material in the water when a light is shined through the water. Many factors can contribute to the turbidity of water. An increase in stream flow due to heavy rains or a decrease in stream-bank vegetation can speed up the process of soil erosion. This will add suspended particles such as clay and silt, to the water and this is one of the factors of turbidity. Water quality is measured by several factors such as the concentration of dissolved oxygen, bacteria levels, the amount of material suspended in the water.

2. METHODOLOGY

Terengganu River, Terengganu selected as research location. Terengganu River is the main river in the Terengganu which starting from Kenyir Dam, Hulu Terengganu in Malaysia and ending in Kuala Terengganu. This study was performed on wet season and dry season. Terengganu River basin is situated between a latitude of 4°40’-5°20’N and a longitude of 102°30’-103°09’E in the north eastern coastal region of Peninsular Malaysia. The main tributaries feeding the Terengganu River are the Nerus River, Tersat River, Berang River and Telemong River with a total catchment area of about 5000 km^2. These rivers pass through different socioeconomical activities area such as agricultural plantations, farming, aquacultures, commercial industries, urbanization, sand mining, rural settlements, reserves and forests. Population density is concentrated at the towns of Kuala Terengganu (downstream area) and Kuala Berang (middle stream). The annual mean air temperature varies between 26°C and 28°C and the annual rainfall is about 3300 mm. The northeast monsoon season (November to March) brings heavy rains to this basin.

This study involves 29 main sampling stations that has been determined using DGPS, which located around the Terengganu River catchment representing the length of the Terengganu River (upstream, middle stream and downstream) (Table 1 and Fig. 1) and the selection criteria of the sampling locations were based on TSS, SSC and turbidity between wet season and dry season.

Table 1. Location of sampling stations at the Terengganu River, Terengganu, Malaysia

Sampling Stations	Latitude	Longitude	Sampling Stations	Latitude	Longitude
Station 1	5°20'23.93"N	103° 8'21.92"E	Station 16	5° 2'26.86"N	102°55'46.47"E
Station 2	5°19'26.55"N	103° 6'20.14"E	Station 17	5° 1'55.10"N	102°55'37.24"E
Station 3	5°19'40.59"N	103° 5'56.80"E	Station 18	5° 3'54.70"N	102°56'28.08"E
Station 4	5°18'48.53"N	103° 5'12.22"E	Station 19	5° 4'37.88"N	102°57'4.74"E
Station 5	5°18'32.74"N	103° 5'12.42"E	Station 20	5° 3'43.35"N	102°58'16.48"E
Station 6	5°17'7.75"N	103° 5'50.67"E	Station 21	5° 4'8.88"N	103° 0'8.50"E
Station 7	5°16'14.99"N	103° 3'3.64"E	Station 22	5° 4'31.96"N	103° 0'25.47"E
Station 8	5°13'9.00"N	103° 1'32.70"E	Station 23	5° 8'2.35"N	103° 2'21.33"E
Station 9	5°12'42.04"N	103° 1'40.09"E	Station 24	5°11'2.74"N	103° 2'35.85"E
Station 10	5° 7'37.61"N	103° 2'9.46"E	Station 25	5°12'36.82"N	103° 1'50.56"E
Station 11	5° 4'8.14"N	103° 0'31.30"E	Station 26	5°13'26.72"N	103° 2'21.83"E
Station 12	5° 3'22.80"N	102°58'43.16"E	Station 27	5°16'37.05"N	103° 4'38.05"E
Station 13	5° 4'39.67"N	102°57'58.26"E	Station 28	5°17'37.90"N	103° 5'29.09"E
Station 14	5° 4'37.96"N	102°56'41.24"E	Station 29	5°18'57.56"N	103° 5'27.17"E
Station 15	5° 3'48.46"N	102°56'10.96"E			

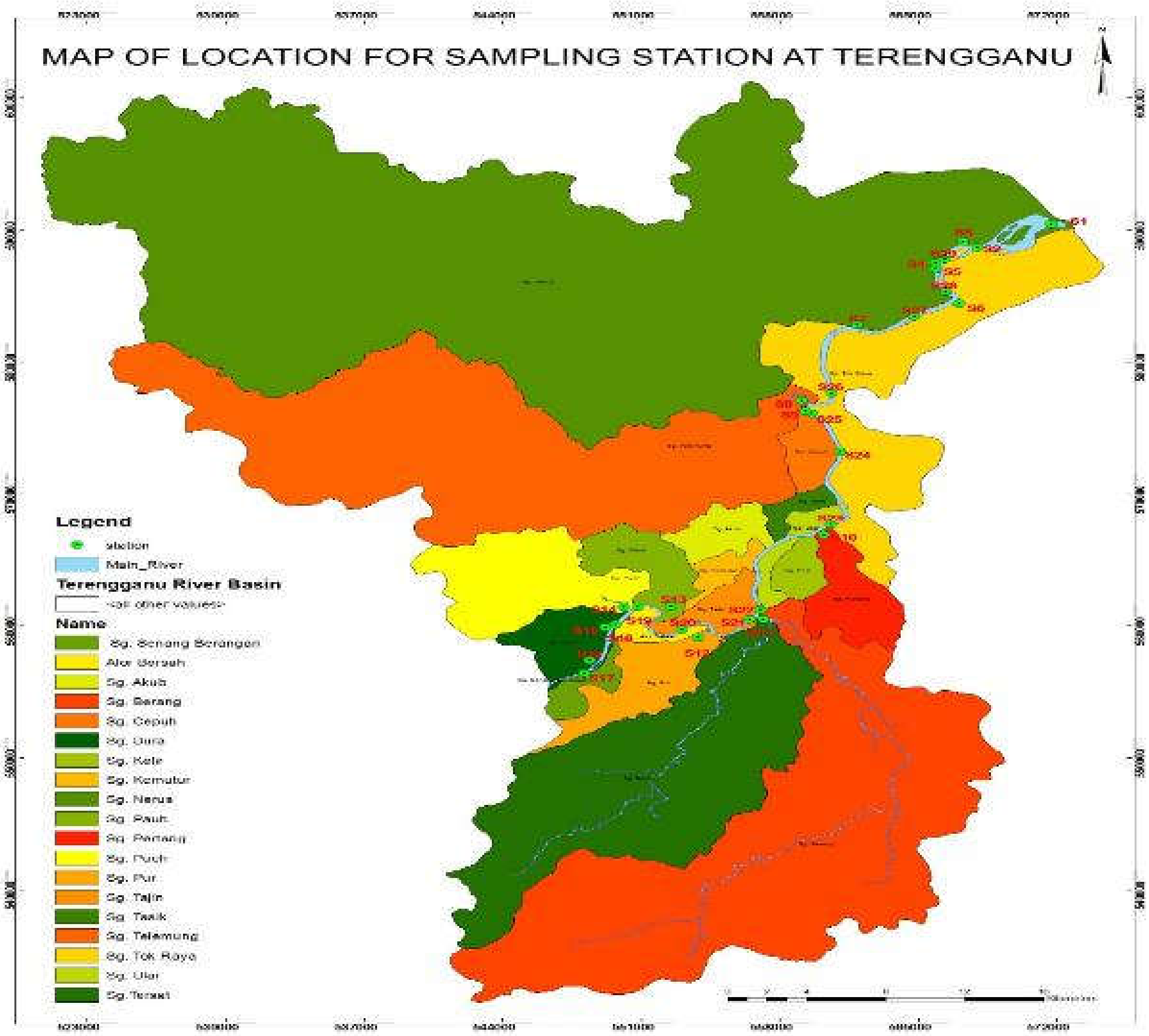

Fig.1. Map of sampling stations at the Terengganu River, Terengganu, Malaysia

The Gravimetric method used to analysis the SSC and TSS measured in mg/L. In lab analysis, about 250 ml water sample was needed for each study area (each station). This measurement was performed by weighing the membrane filter paper 0.45µm one by one and the reading was taken. Firstly, weighing the membrane filters using electronic weighing. Then, a membrane filter was placed onto a filtration apparatus (Nalgene, U.S.A) which connected to a vacuum pump and clipped in place. The 250ml river water sample lowly poured into the filtration jar, the membrane filter was removed and allowed to dry in the drying jar (Fig. 2 (a-e)). Once the membrane filter paper is dried, it is weighed to get the reading. SSC and TSS is measured by mg/L unit based on (Equation (1)). Precisely, precaution steps should be taken when the river water sample were taken. Interference of the river water flow should be minimum to avoid deposition of the measured suspended sediment [16-17].

The measurement of in situ parameter was turbidity. This parameter was determined by using the water-quality Multiprobe Model DO meter YSI 58. This multiprobe meter was calibrated before field sampling. Laboratory analysis for SSC and TSS based on the standard method of analysis (APHA 1998) procedure. Using SSC data to compute loads tends to produce estimates with smaller errors than those computed from TSS data. Loads computed from TSS data tend to be negatively biased as compared to those computed from traditional techniques. There does not appear to be a simple way to examine SSC and TSS paired data sets to determine if the TSS data will give as good as or better estimate of the suspended-sediment load than the estimates obtained using the SSC data. The fundamental difference between SSC (ASTM) and TSS (APHA and others) analytical methods arises during the preparation of the sample for subsequent filtering, drying, and weighing. The TSS analysis generally entails withdrawal of the original sample for subsequent analysis, although as determined in a previous study, there may be a lack of consistency in methods used in the sample preparation phase of the TSS analyses [18]. The SSC analytical method uses the entire water-sediment mixture to calculate SSC values.

Based on river formation concept presented in Fig. 3, a basic control on river size is the discharge, and the discharge measurement depends on the flow velocity measurement. The equation continuity relation Q = AV is based on the river flow measurement, water discharge (V), cross-sectional area (A) and flow velocity (V). The cross-section of the channel must be observed to determine the cross-sectional area (A), and the average of flow velocity (V) is determined by using a current meter.

(a) (b) (c) (d) (e)

Fig.2. a) Sample water b) Membrane filter c) Electronic weighing d) Filtration apparatus connected to a vacuum pump e) Dried membrane filter

TSS = {(WBF + DR) - WBF} (mg) x 1000 / VFW (mL) = mg/L (1)

where WBF = Weight of membrane filter, DR = Dry residue and VFW = Volume of filtered water.

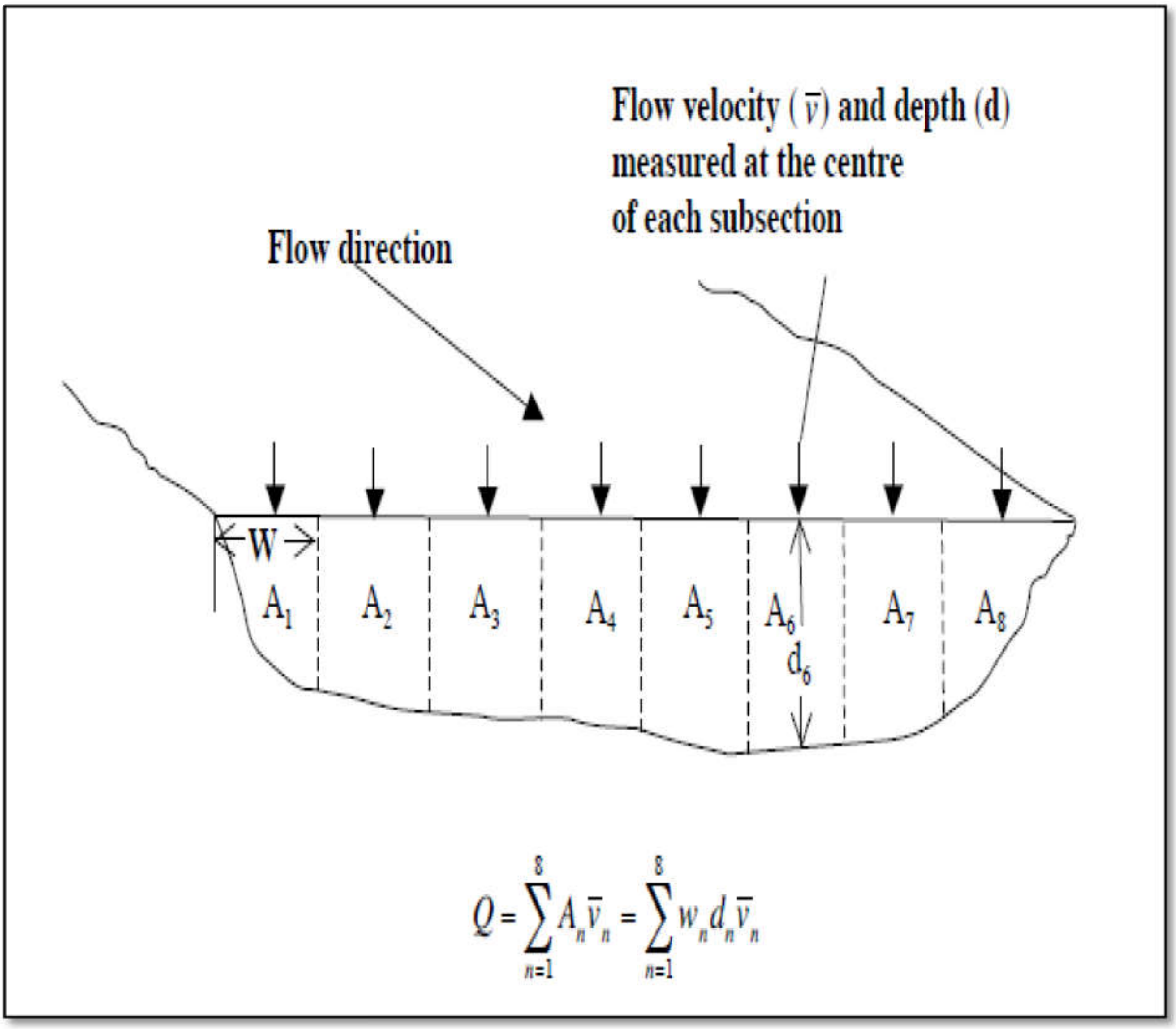

Fig.3. The theoretical of discharge measurement by cross section of the river

3. RESULTS AND DISCUSSION

On average (climatology), all regions in Terengganu contribute roughly equal rainfall percentages especially from October until December every year. The top three rainfall contributors during 2009 and 2011 followed by 2014. On long term average east coast Peninsular Malaysia shows the highest rainfall during the late to early withdrawal phase. This was observed during the late monsoon phase. However, a clear increase in percent rainfall contribution of twice the usual amount was noted for 2009, 2011 and 2014 compared 1990 until 1998. The Peninsular East Coast experienced the greatest drop from average rainfall during 2009 until 2014 affected by hydrology, anthropogenic and climate changes factors. Based on Department Irrigation and Drainage of Malaysia (DID), the distribution of rainfall intensity at Terengganu from 2300 mm until 4500 mm, the highest average of rainfall intensity on 2014, mostly area at east coast peninsular Malaysia (Pahang, Terengganu and Kelantan) effected heavy flooded during 2014 (Fig. 4). Fig. 5 showed the rainfall distribution (%) based on the areas of Malaysia in January 2015 and 2016. The East Coast of Peninsular Malaysia experienced a decline of average rainfall intensity in January at 13%, 2015 to 8% on 2016. This secondary rainfall data obtained from the Malaysian Meteorological Department (MMD) and the Ministry of Science, Technology and Innovation (MOSTI) proved the occurrence of El Nino phenomenon in January 2016.

The relative humidity in Kuala Terengganu is not very high, which is about 79.5 % to 86.8 %. The minimum relative humidity is usually in February and March. Maximum relative humidity is usually in November. The daily change in relative humidity is greater than the annual change. The daily minimum daily can reach as low as 70 % during the dry months and approaching as high as 89 % during the wet months. However, its maximum daily average does not change much from one place to another. The relative humidity in the study area varies because there are various human activities affecting the air [20]. Temperature level in Kuala Terengganu are high and constant throughout the year. The minimum daily temperatures of about 27°C, the annual temperature range is less than 3°C. Malaysia ranks close to the Equator Line resulting in relatively high temperatures impacting more solar rays. The temperatures level in January and February each year are relatively low temperatures compare other months. The relatively speed of wind ranged between 1.7 m/s and 2.7 m/s caused the Terengganu River Basin experienced the high levels of discharge and this contributes flood phenomenon each year, especially during the rainy season of November to January. Mean monthly evaporation values (mm) of the Kuala Terengganu for 15 years (2001 to 2015) was used to determine hydrological link between the earth's surface and the atmosphere. For the 15 years period, monthly evaporation ranged from 3.7 mm (December) to 5.3 mm (April) (Fig. 6).

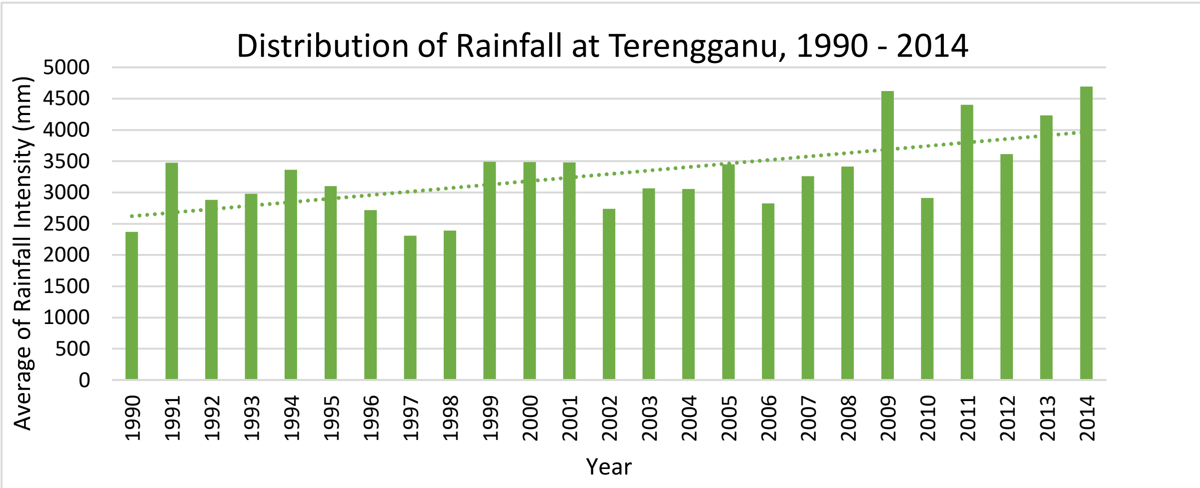

Fig.4. The distribution of rainfall at Terengganu from 1990-2014

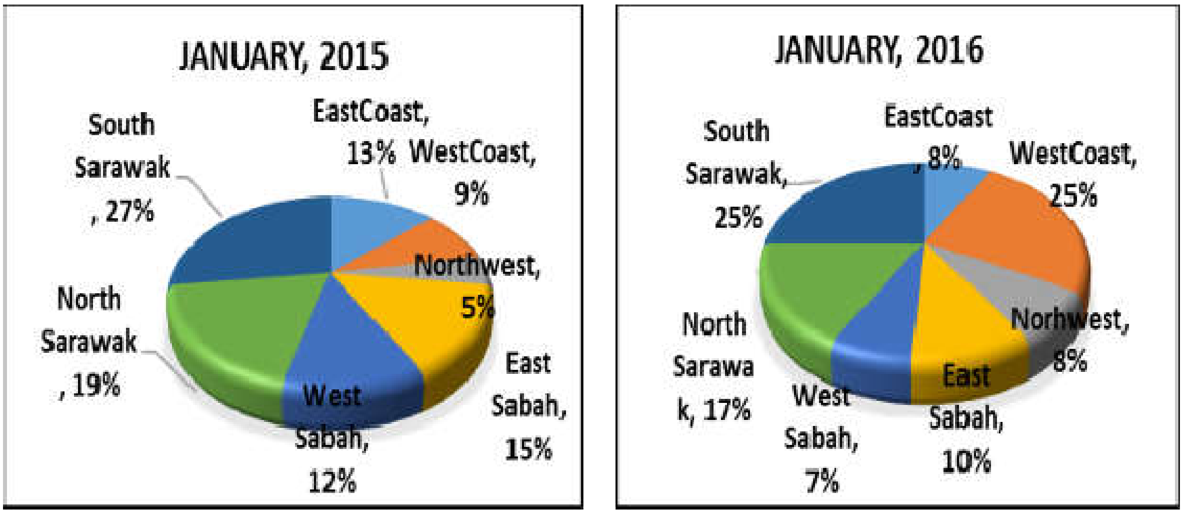

Fig.5. Rainfall distribution (%) based on the area of Malaysia, January 2015 and January 2016

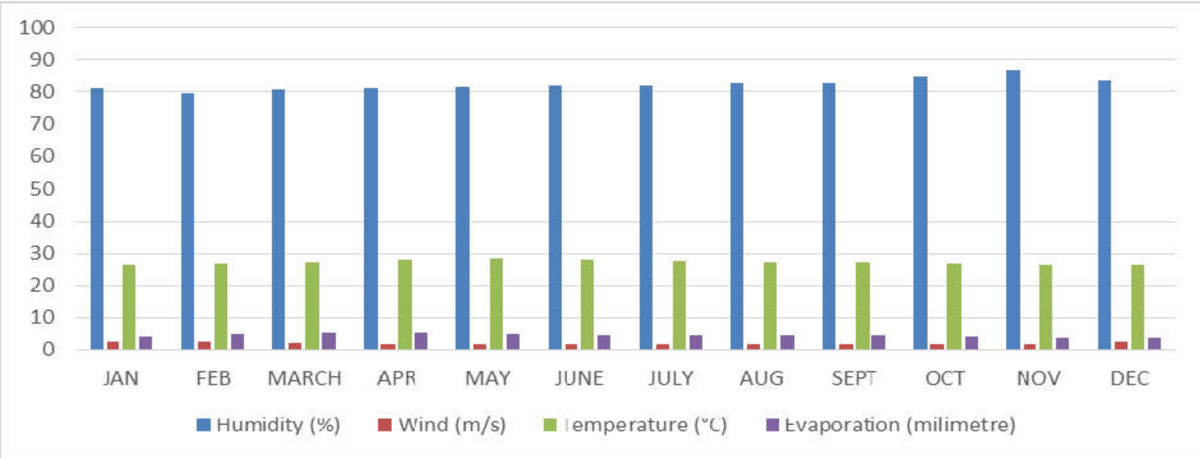

Fig.6. Distribution of humidity (%), wind (m/s), temperature (°C) and evaporation (millimeter) in Kuala Terengganu, 2001-2015

Fig. 7 and Fig. 8 showed the distribution of TSS (mg/L), turbidity (TUR) (NTU) and SSC (mg/L) during wet and dry season on 2016. TSS is one of important indicator of water quality whether clean, moderately polluted or contaminated, it's classified into Class I, II, III, IV or Class V based on the National Water Quality Standard (NWQS). The highest amount of TSS during wet season at Station 6 and Station 7 which 67.2 mg/L and 61.8mg/L respectively. The minimum level amount of TSS at Station 19, 0.4 mg/L during wet season. However, the value of TSS on dry season showed higher range compared wet season effected by El Nino phenomenon on January 2016, the TSS amount at S1 until Station 19 covered from upstream area to downstream areas were recorded 0.4 mg/L ± 128.2mg/L. From the result, the difference amount level of TSS at Terengganu River affected by the anthropogenic, geomorphology and hydrological cycle.

The 95% confidence interval of the below linear regression with the fixed intercept of 100% was additionally calculated. The lower and upper 95% confidence limits are also included in Fig. 9. The regression relationship obtained from this research project based on the measured particle size alone cannot be directly applied to predict the field TSS from the field-measured SSC. The variation in streamflow provides important information for the timing and changes in sediment concentrations and has widely been used to develop SSC prediction models. Turbidity, SSC and TSS inherently are related given that each principally is a measure of suspended sediment in streams. Although the relation between SSC and TSS is variable among sites. The overall fit of the data is fairly good and indicating that SSC consistently is larger than TSS concentrations for all sites. The coefficients of determination for the relation between SSC and TSS on wet season R^2 = 0.924 and dry season R^2 = 0.841 proved a significant relationship of between TSS and SSC values in the Terengganu River, indicating that an increase in TSS would cause an increase in SSC value, thus causing an increase in water turbidity.

The higher the velocity of water, the higher the rate of erosion and more suspended sediments are produced as a result. The primary advantages of using TSS to indirectly measure SSC are the continuous acquisition of data in real time and the low operating costs. Therefore, discharge value (Q) is a factor that could influence the mobility or TSS values. Fig. 10 showed the correlation between the observed value (Q) m^3/s and the estimated value mg/L sediment contained in Terengganu River was no correlation or insignificant, R^2 = 0.057 in wet season and R^2 = 0.001 in dry season due to El Nino phenomenon which occurred in January 2016. This shows that the discharge variable (Q) has a weak positive relation with the suspended sediment, which is the increase in the observation value (Q) was not the main factor that causes the concentration and increase in the value of suspended sediment in the Terengganu River Basin. Hence, other causes as a factor the increasing sediment production such as climatology factors, land use changes around the river basins and erosion.

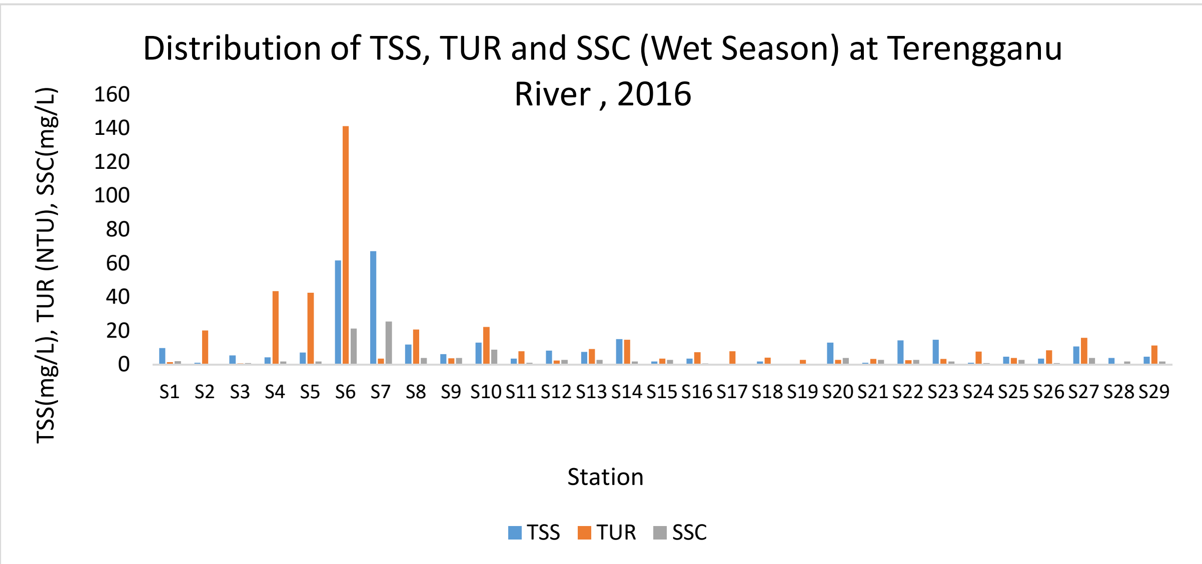

Fig.7. The distribution of TSS, TUR and SSC during Wet Season at Terengganu River Basin 2016

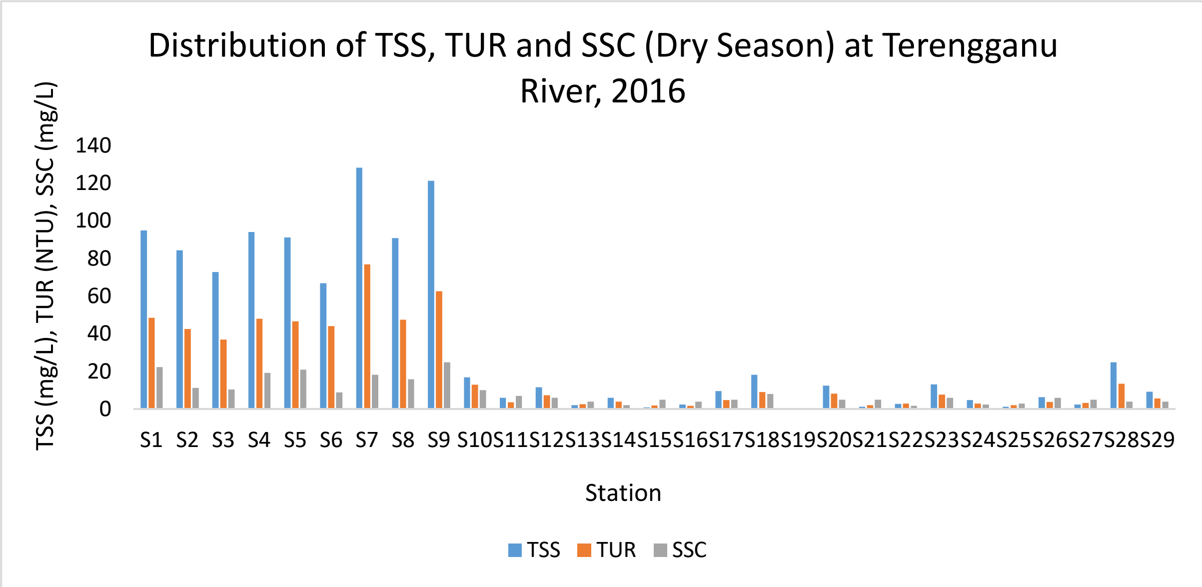

Fig.8. The distribution of TSS, TUR and SSC during Dry Season (January 2016) at Terengganu River Basin 2016

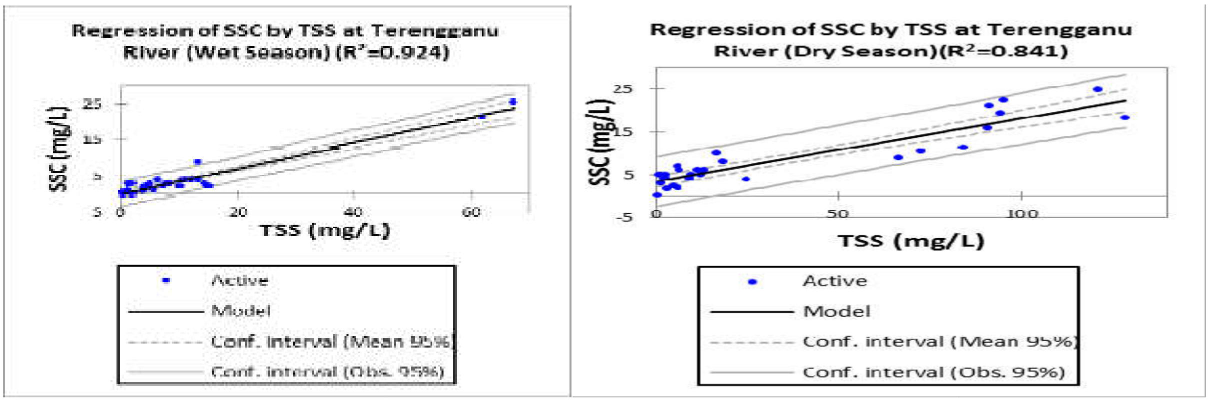

Fig.9. The regression of Total Suspended Sediment (TSS) and Suspended Sediment Concentration (SSC) during wet season and dry season

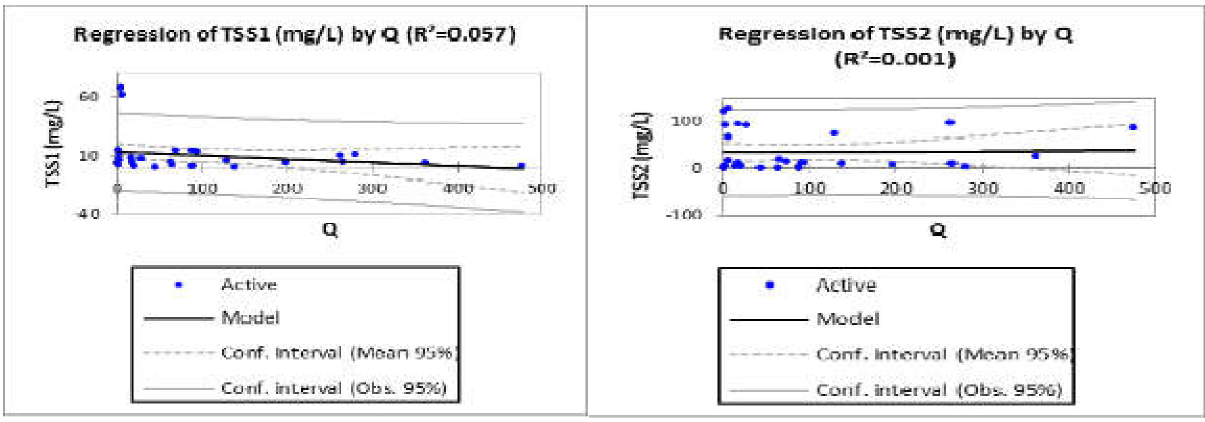

Fig.10. The regression of Total Suspended Sediment (TSS) and river discharge (Q) during wet season and dry season

A two-factor ANOVA test showed that the values were significantly different ($p < 0.05$) among the sampling stations and dates of sampling. Fig. 11 recorded the two-factor ANOVA test analysis in wet season, the F statistic value is 2.60 < F critical value is 3.11 and follows a distribution. The p-value is 0.080, which is > 0.05. The researcher accept the null hypothesis (Ho), rejecting the alternative hypothesis (Ha) that there is a no difference in the mean of these three parameter that observed along the Terengganu River. The density of rainfall plays an important role towards reducing surface erosion, which contributes to the sediment production and water quality status. In the ANOVA analysis (Fig. 12) showed the data from dry season, the F statistic value is 12.06 > F critical value is 3.11 and follows a distribution. The p-value is 0.0000248, which is < 0.05. The researcher reject the null hypothesis (Ho), accepting the alternative hypothesis (Ha) that there is a difference in the mean of these three parameter (TSS, SSC and Turbidity) that observed along the Terengganu River.

From the result, stream flow discharge from each feeder river into the river basin is directly related to the velocity of river water and seasons. In the wet season, the intensity of rainfall is low, so discharge from the Feeder Rivers is lower than that in dry season caused by El Nino Phenomenon. This study proved there difference in the mean of TSS, SSC and Turbidity during dry season compared to wet season. For all the survey during dry season, there was a general decreasing trend in the TSS, SSC and Turbidity concentrations from downstream to upstream. TSS, SSC and Turbidity are usually due to the introduction of external factors carried by runoff rain waters which can help increasing and contributions geomorphology, climate changes and anthropogenic factors such as municipal, industrial, agricultural and aquaculture [19].

Fig. 13 shows the result for sample mean and sample of standard deviation for wet season of three parameter (TUR, TSS and SSC), the mean of Turbidity is 14.6, TSS is 10.5 and SSC is 3.8. The standard deviation of Turbidity is 26.7, TSS is 15.7 and SSC is 5.8. Fig. 14 shows the result for sample mean and sample of standard deviation for wet season of three parameter (TUR, TSS and SSC), the mean of Turbidity is 5.0, TSS is 34.3 and SSC is 8.4. The standard deviation of Turbidity is 4.3, TSS is 42.3 and SSC is 6.8. The sample mean as an estimate of the mean for the whole population. The sample mean will vary from sample to sample and the way this variation occurs is described by the sampling distribution of the mean. While, the standard deviation is a measure of variability. The standard deviation of a sample used to estimate of the variability of the population from which the sample was drawn. From the result showed the values of mean and standard deviation for TSS and SSC higher during dry season compared to wet season. This study showed a strong correlation between TSS and SSC compared Turbidity in the Terengganu River Basin, indicating that an increase in TSS would cause an increase in SSC value, thus causing an increase of rainfall intensity. The increase in suspended sediment has a negative impact on the drainage system of rivers in the Terengganu River catchment area. While, if these problems not addressed will be an increasingly serious problem in the future. Furthermore, it will affect water quality and cause increasing shallowness of riverbeds and leading to flooding [22] within the surrounding area.

Anova: Single Factor

Sample average of each parameter

SUMMARY

Groups	Count	Sum	Average	Variance
TUR	29	423.3333	14.5977	715.224
TSS	29	305	10.51724	245.69
SSC	29	110.47	3.80931	33.07056

Sample variance for each parameter

No. of observations of each parameter

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1721.0134	2	860.5067	2.597143	0.080459	3.105157
Within Groups	27831.569	84	331.3282			
Total	29552.582	86				

Fig.11. Analysis of variance, one way ANOVA for Wet Season

Anova: Single Factor

Sample average of each parameter

SUMMARY

Groups	Count	Sum	Average	Variance
TUR	29	144.9633	4.998736	19.34938
TSS	29	996.4	34.35862	1792.544
SSC	29	244.84	8.442759	45.72244

Sample variance for each parameter

No. of observations of each parameter

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	14939.8	2	7469.898	12.06369	2.48E-05	3.105157
Within Groups	52013.24	84	619.2053			
Total	66953.04	86				

Fig.12. Analysis of variance, one way ANOVA for Dry Season

TUR		TSS		SSC	
Mean	14.59770115	Mean	10.5172414	Mean	3.809310345
Standard Error	4.966175252	Standard Erro	2.91068216	Standard Error	1.067878281
Median	7.4	Median	5.6	Median	2
Mode	#N/A	Mode	1.2	Mode	2
Standard Deviation	26.74367219	Standard Dev	15.6745032	Standard Deviation	5.750700536
Sample Variance	715.2240025	Sample Varia	245.690049	Sample Variance	33.07055665
Kurtosis	19.11232356	Kurtosis	9.34055458	Kurtosis	9.719337257
Skewness	4.127670075	Skewness	3.08191411	Skewness	3.147188875
Range	140.93	Range	66.8	Range	25.6
Minimum	0.403333333	Minimum	0.4	Minimum	0
Maximum	141.3333333	Maximum	67.2	Maximum	25.6
Sum	423.3333333	Sum	305	Sum	110.47
Count	29	Count	29	Count	29
Confidence Level(95.0%)	10.17274885	Confidence L	5.96226213	Confidence Level(9	2.187449497

WET Season	TUR	TSS	SSC
Sample mean	14.6	10.5	3.8
Sample std. deviation	26.7	15.7	5.8

Fig.13. Descriptive analysis for Wet Season

TUR		TSS		SSC	
Mean	4.998735632	Mean	34.3586207	Mean	8.442758621
Standard Error	0.816835451	Standard Error	7.8620519	Standard Error	1.255641643
Median	3.316666667	Median	11.6	Median	6
Mode	#N/A	Mode	6	Mode	5
Standard Deviation	4.398793523	Standard Deviation	42.3384452	Standard Deviation	6.761837185
Sample Variance	19.34938446	Sample Variance	1792.54394	Sample Variance	45.72244212
Kurtosis	6.354767845	Kurtosis	-0.539303	Kurtosis	0.297009145
Skewness	2.295307865	Skewness	1.03451171	Skewness	1.177188126
Range	20.75	Range	127.8	Range	24.73
Minimum	0.816666667	Minimum	0.4	Minimum	0.07
Maximum	21.56666667	Maximum	128.2	Maximum	24.8
Sum	144.9633333	Sum	996.4	Sum	244.84
Count	29	Count	29	Count	29
Confidence Level(95.0%)	1.673211571	Confidence Level(95.0%)	16.1046833	Confidence Level(95.0%)	2.572065309

DRY Season	TUR	TSS	SSC
Sample mean	5.0	34.3	8.4
Sample std. deviation	4.3	42.3	6.8

Fig.14. Descriptive analysis for Dry Season

4. CONCLUSION

In conclusion, water deterioration in Terengganu River Basin [21] caused by turbidity, TSS and SSC towards water quality status. By using the several statistical methods to organize the data collection such as descriptive statistics, ANOVA and correlation. The paper also explains about the correlation between the variables that stated in result section. Therefore, necessary steps towards its rehabilitation and prevention must be initiated and implemented immediately as suspended sediment load would affect water quality status. The increasing TSS and SSC consent in river basins could lead to increased turbidity, high alkali content in water, emission of unpleasant odours and water discolouration and reduced penetration of sunlight. The main sources of pollutants were possibly waste products and waste from development activities such as sand mining, farming, residential and agricultural. Stream flow from each feeder river into the river basin is directly related to the velocity of river water and seasons. In the dry season, the intensity of rainfall is higher than wet season caused by El Nino phenomenon during January 2016.

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