Water Conservation And Management (WCM)

DOI: http://doi.org/10.26480/wcm.01.2020.01.06

ZIBELINE INTERNATIONAL PUBLISHING

ISSN: 2523-5664 (Print)
ISSN: 2523-5672 (Online)
CODEN: WCMABD

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RESEARCH ARTICLE

SIMULATION OF SEDIMENT YIELD AND SUPPLY ON WATER FLOW IN DIFFERENT SUBBASINS OF TERENGGANU WATERSHED FROM 1973-2017

Ibrahim Sufiyan[a], Magaji J.I[a], Isa Zaharadeed[b]

[a]Department of Geography, Nasarawa State University Keffi, Nasarawa State Nigeria
[b]Department of Geography, Kaduna State University, Kaduna State Nigeria
**Corresponding Author Email: ibrahimsufiyan0@gmail.com*

ARTICLE DETAILS

Article History:

Received 21 November 2019
Accepted 26 December 2019
Available online 20 January 2020

ABSTRACT

The catchment area of Terengganu has to be flooding during the monsoon season. The reason is climate change that increases water flow in most of the rivers. The analysis using ArSWAT2012 has simulated the whole watershed and the result as proven to have about 25 different sub-basins. Each sub-basin has its peculiar characteristics of Hydrologic Response Units (HRUs). Base on the morphological classification, the river has accumulated a lot of sediments. The sediment yield and concentration has been analyzed from 1973-2017 through simulation. The study compared the simulations and found out the slide differences in the sediment loads that come in and the sediment that goes out. The sediment concentration also varies with the temporal morphological changes of the Terengganu watershed especially the river mouth.

KEYWORDS

Climate change, Sub-basins, Sedimentation, watershed.

1. INTRODUCTION

Water is supplied to rivers from precipitation in the drainage basin (catchment area). Some of the precipitation is returned to the atmosphere by evaporation and evapotranspiration, but the remaining stream flow can move down the slope due to the force of gravity to the surface or through ground due to the slope toward rivers. Overland flows are commonly subdivided into infiltration- excess overland flows (due to a precipitation rate exceeding infiltration). The relevant coarse weathered material tends to be most common in cold climate and steep slope. Clay (produced by chemical weathering) is numerous in humid climates. The organic material or content made its maximum contribution to the sediment supply in a moist environment (Leopold et al., 2012). The rate of mass wasting (downslope movement) of loosed materials under the influence of gravity) depends on the composition and texture of the loose materials, the water contains availability, the presence of vegetation, slope angle and ground motion associated with the earthquake. The concentration of dissolved material decreases as water discharge increases, because of the decreasing quantities of groundwater flow.

However, the total suspended load or sediment increases with discharge. If there is N year of record, and the maximum annual discharge are ranked, the most substantial having rank m-1 and the smallest having rank m=N, then the probability of an annual flood of magnitude m is express as:

$$P(x) = m / (N-1)$$

The mean return period of the flood event is

$$T = 1 / P(x)$$

And the cumulative probability is

$$f(x) = 1 - P(x).$$

Frequency distribution of extreme events such as the annual maximum discharge of a river is normally positively skewed. River flow data are fundamentally essential in the management of water resources. Hydrometric data are required for river management and assessment. According a study, the issue of global warming and climate change is one of the driving forces that affect river flows patterns (Blake et al., 2000). For proper drainage basin or river, basin analysis required the utility of a hydrometric database which depends on mainly readily available data and accuracy. The two relevant variables to be considered in the hydrometric survey are rainfall and streamflow. Climate change can be predicted and expected to play a vital role in changes the precipitation and streamflow. In the arid and semi-arid regions, water supply is very unusual and sensitive to changes in rainfall and evaporation. In the runoff scenario, it is believed that doubling carbon dioxide might increase river flows by up to 40 % and 80% in a specific part of the world (Bates & De Roo, 2000).

1.1 Drainage Density

Drainage density is defined as the total channel length (drainage basin area) or a measure of the degree of accuracy of the drainage basin. The drainage density increases directly when the average height or distance of the adjacent channels decreases. Therefore, the closer the team heads to the drainage divide, the higher the density increase. Drainage density depended on the amount of precipitation rate (minus-evaporate rate

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	Website: www.www.watconman.org	**DOI:** 10.26480/wcm.01.2020.01.06

Cite the Article: Ibrahim Sufiyan, Magaji J.I, Isa Zaharadeed (2020). Simulation Of Sediment Yield And Supply On Water Flow In Different Subbasins Of Terengganu Watershed From 1973-2017. *Water Conservation And Management, 4(1): 01-06.*

capacity of the ground) and saturated- excess overland flow (because the earth is saturated with water. The relative essential of these two types of overland flow depends on the precipitation rate corresponding to the permeability of the soil. Water can also flow through the field or relatively near the surface called through flow or subsurface storm flow) or more profound slowly downward movement (groundwater flow). As water flows down the slope, the potential energy of the water can be converted to kinetic energy. Moreover, kinetic energy does not necessarily increase with the loss of elevation, because the water flow is resisted by friction at Boundaries (Bridge, 2003).

1.2 Sediment Supply

Sediment is matter dregs, less precipitate, deposits, sometimes known as residue or remains of silt and alluvium (residuum), which settle at the bottom of the liquid that is water in a river catchment. Sediment is supplied by weathering of exposed rocks and by the down-slope movement of the loose material. Physical weathering due to excess temperature may lead to frost action; a different study concludes that climate change had produced more sediment deposits and control in large rivers (Van Griensven et al., 2006). The rate of weathering and the texture coupled with the composition of weathered material are controlled by:

1. the nature of the exposed rocks (their form and structure)
2. the amount of precipitation
3. the presence of vegetation
4. temperature
5. The above factors were in turn controlled by topography and climate.

According to a study, the sediment supply to rivers and floodplain varies in space and time purposely due to the quantity of water (Hooke, 2000). There is a more significant difference in the case of the amount of sediment because of discrete mass movements such as landslide, mudflow, and debris flow. Deposit requires threshold gravity or fluid force to activate downslope movement and residue travels more slowly than the fluid (unless it is suspended load). Consequently, sediment from mass wasting is commonly stored temporarily at the mouth or edge of the floodplain. Sediment yield from catchment or drainage basin has been estimated based on the measurement of suspended load and dissolved load in rivers.

1.3 Sediment Yield in the Catchment

Sediment yield can be viewed as the amount of sediment passing or reaching a point within a given period. The estimation of sediment yield is given as kilogram or tons per annum. Changes in sediment yield can determine changes in the ecosystem which include climatic factors, erosion, weathering processes and human activities. Sediment yield also affects the rate of soil structure by influencing the downslope movement of deposit of sediments. The result of sediment deposition, the transportation as well as the erosion is significant issues that affect human inhabitance intensified by floods and water pollution (de Moel, et al., 2014; Abril and Knight, 2004). According to a study, sediment yield is defined as the discharge of sediment through a section per unit catchment per unit area (Chaplot, 2005). The calculation of sediment yield involved the measurement of the drained, the mass or volume of the sediment removed and required time upon which the deposition had occurred. The drainage basin can be calculated using GPS coordinates recorded along the river boundaries of the basin. The volume of the sediment deposits in the reservoir can be sampled using soil augur at 1 to 2 meters regular intervals across the reservoir. Sediment yield estimation is required for studies concerning sedimentation and river morphology, water and soil conservation, planning and modeling of flood hazards, measuring water quality and structural design for erosion control. Another contribution is the study undertaken about sediment yield and discharge relationship (Asselman and Jonkman, 2003).

The impact of land-use changes because of sediment yield is estimated base on the concentration of water discharge. There are also recent publications and reports on sediment depositional changes or return due to climate and flow accumulation in reservoirs as pointed out, and respectively (Lang et al., 2003; Zhu et al., 2003). Some researchers calculates the yield in some denudation rates on the order of 0.01 to 1mm annually (Patel and Srivastava, 2013). The average global denudation rate is 0.055mm per annum based on the suspended solid and 0.01 mm per annum based on dissolved materials: however, these vary significantly across the globe (Knighton, 2014). For sediment yield, the estimation is likely to be accurate partly because bed-load considered. Mostly, sediment load is very variable in time and space, the accuracy of the estimate is substantially dependent on the sampling frequency and extent of time and space. Anthropogenic factor had a the emendous impact on sediment yield in some region, as a result of deforestation, agriculture, construction, and mining.

Sediment yield can underestimate denudation rates of hillsides because much-eroded sediment may be stored on the floodplain. Therefore, considerable attention should be drawn to exercise extrapolation on both sediment yield and derived denudation rate to geological past. The wet climate has dense vegetation or forest to protect the surface material from erosion. However, other factors are affecting the sediment yield that is the adequate precipitation and temperature, topographic, seismicity, soil types and land use are expected to influence sediment yield. All of these factors affect weathering rates to hillslope erosion and river transport (Hooke, 2000). According to a study discussed that among the different types of natural disasters, the flood is considered to be one of the devastating hazards with huge damage (Youssef et al., 2011). The Department of Irrigation and Drainage (DID) stated that about 9% of the land area of Malaysia is prone to flood occurrence with damage of around 0.3 billion USD yearly (Pradhan, 2010).

2. Material and Methods

2.1 Study area

The study area is in the catchment of the Terengganu River, Malaysia. The area is always experiencing the monsoonal rainfall and high river flow which is suitable for simulation of the river flow and sediment on transit.

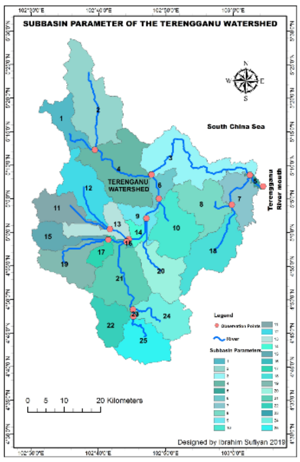

Figure 1: 25 sub-basins of the Terengganu watershed

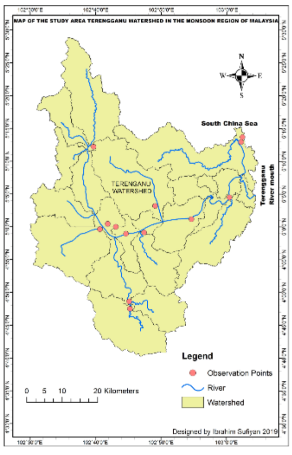

Figure 2: The river network and flow to estimate the Sediment yield

The system extracts each input data from the database created, after that, it will directly delineate the watershed and categorized them into hydrologic response units (HRUs) which have unique combinations of land cover and soil types and slope for each sub-basin. The flood model also requires daily climatic information such as the rainfall amount, the wind, solar radiation, temperature (maxi and mini) and relative humidity. The flood mapping generally will consider the geographical references for the much-needed data as it occurs in different formats. For the purpose of this study, the emphasis is given on the requirement of optional data input from both the Geographic Information System (GIS) and Remote Sensing. The ground survey will be carried out in other to obtain recent and up-to-date information about the land cover pattern, soil types and the slope classes. The output data is expecting to produce predictable results for simulation in ArcScene10.3. The 3D simulation will apply to visualize the flood risk zones in the Terengganu River catchment. This study also focused on the specific methods so that each stage of the processing and analysis of the data can produce results independently based on the criteria assigned to it.

2.2 Method of Data Collection in Soil Water Assessment Tool (SWAT)

1. Department of Irrigation and Drainage (DID)
    a) Data for a flood event in the study area (previously)
    b) The stream flows data, these are obtainable base on a different location of the stations
2. Climate data from the Malaysian Meteorological Department (MET Malaysia) from 2000-2015
3. Land cover images from the Malaysian Remote Sensing Agency (MRSA)
4. Malaysian soil map was obtainable from online source European Digital Archives of soil maps (EuDASM) named Reconnaissance soil map Peninsular Malaysia 1968.

The input data for ArcSWAT2012 includes the following: Required spatial datasets and Optional spatial datasets

The required spatial datasets entail the following;

i. Satellite-DEM
ii. Land Cover/land use map
iii. Soil map/data

The optional spatial datasets include:

i. Weather parameters
ii. Daily rainfall data
iii. Daily streamflow
iv. Daily suspended-sediment

3. Results and Discussion

The Swat analysis simulates the sediment deposit that comes in from the entire 25 sub-basin in 1973. As indicated in Table 1, the highest sediment simulation is found in sub-basin number 1 with 4903000 tonnes of sediment load and the less sediment load is found in sub-basin 25.

3.1 Simulation from 1973

Table 1: SEDIMENT _IN (the Sediment Load that comes in the sub-basin)

SUB	YEAR	SED_INtons
1	1973	4903000
2	1973	169800
3	1973	49420
4	1973	3670000
5	1973	8103000
6	1973	346700
7	1973	1557000
8	1973	1182000
9	1973	4263000
10	1973	211600
11	1973	671400
12	1973	914600
13	1973	872900
14	1973	1243000
15	1973	606700
16	1973	834100
17	1973	191300
18	1973	1612000
19	1973	522600
20	1973	99220
21	1973	923600
22	1973	25.81
23	1973	2923
24	1973	283
25	1973	14.83

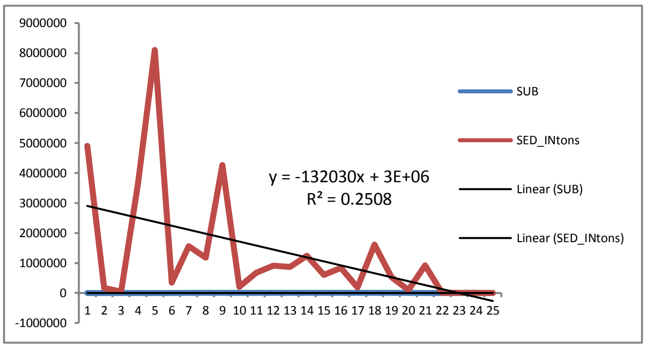

Figure 3: Showing the highest Sediment Load in 25 Sub-basins 1973

The simulation in Table 2 is presented showing the individual sediment loads carried out of the 25 sub-basins. The year 1973 has the highest simulation of the sediment loads that are going out of the watershed from the individual sub-basins. The sub-basin 9 has yielded more sediment at the mouth of the river, while the smallest simulation is recorded in sub-basin 25.

Table 2: SEDIMENT_OUT (the sediment yield out of the 25 Sub-basins)

SUB	YEAR	SED_OUTtons
1	1973	2996000
2	1973	169800
3	1973	49420
4	1973	3670000
5	1973	1168000
6	1973	346700
7	1973	457200
8	1973	573100
9	1973	3950000
10	1973	211600
11	1973	671400
12	1973	138800
13	1973	150100
14	1973	1297000
15	1973	377700
16	1973	834000
17	1973	191300
18	1973	1612000
19	1973	522600
20	1973	99220
21	1973	424700
22	1973	25.81
23	1973	2923
24	1973	283
25	1973	14.83

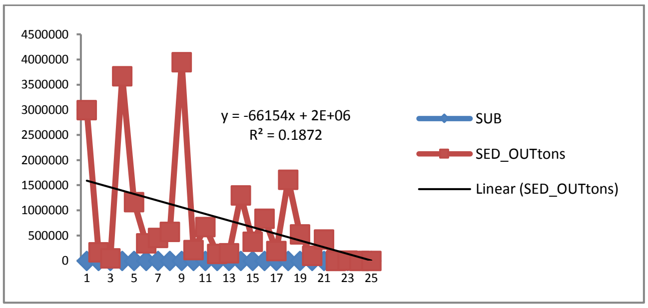

Figure 4: The frequency of simulation indicating the Sediment Load and the Sub-Basin

The amount of sediment concentration is a gradual one that it takes years of accumulation. This is simulated using the weight of individual sub-basin in the catchment area within the 25 sub-basins. The highest result of the sediment concentration in 1973 is found in sub-basin 4 with 1273 mg/L, while the smallest sediment concentration is found in sub-basin 25 with 0.014 mg/L as shown in Table 3.

Table 3: Simulation of Sediment Concentration of 25 Sub-basins in 1973

SUB	YEAR	SEDCONCmg_kg
1	1973	229.9
2	1973	229.7
3	1973	17.7
4	1973	1273
5	1973	107.6
6	1973	640.7
7	1973	172.6
8	1973	178.9
9	1973	395.2
10	1973	237.8
11	1973	598.1
12	1973	138.7
13	1973	139.2
14	1973	204.2
15	1973	164
16	1973	167.9
17	1973	202.3
18	1973	1107
19	1973	226.9
20	1973	83.82
21	1973	157.6
22	1973	0.03074
23	1973	1.385
24	1973	0.2613
25	1973	0.01472

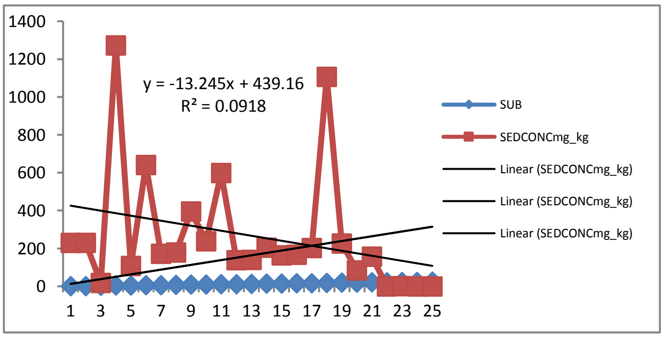

Figure 5: The frequency distribution of Sediment Concentration in the 25 sub-basins

3.2 Simulation from 2017

Table 4 presents the simulation by the SWAT and automatically projected to 2017 with little adjustment in the final results of the sediment loads that come into the watershed at different sub-basins parameters. The highest sediment load that comes in is found in sub-basin 1 with 4164000 tonnes of sediment loads. The smallest sediment loads were recorded in the simulation with 44.83 tonnes in sub-basin 22.

Table 4: SEDIMENT _IN Sediment transported with water into reach during the time step (metric tons)

SUB	YEAR	SED_INtons
1	2017	4164000
2	2017	137300
3	2017	86900
4	2017	3109000
5	2017	7569000
6	2017	431800
7	2017	1842000
8	2017	1298000
9	2017	3672000
10	2017	266000
11	2017	786000
12	2017	1091000
13	2017	825900
14	2017	1432000
15	2017	633900
16	2017	724000
17	2017	168500
18	2017	1748000
19	2017	459100
20	2017	165800
21	2017	1578000
22	2017	44.83
23	2017	4935
24	2017	478.6
25	2017	12.53

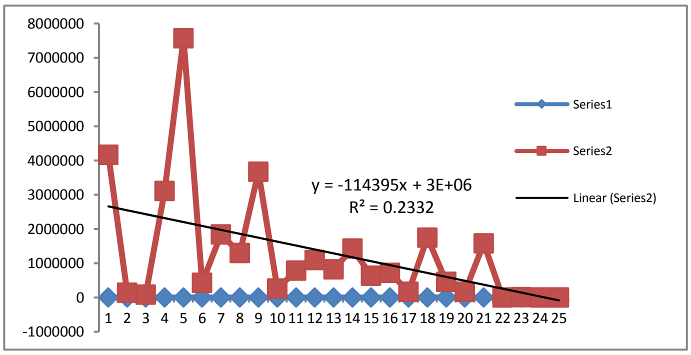

Figure 6: Simulation of the Sediment Loads transported in 2017

Table 5 presents the sediment that comes out from the 25 sub-basins in 2017. The highest discharge of the accumulated sediment is found in sub-basin 9 with about 3348000 tonnes, and the lowest sediment yield that is transported is found in sub-basin 25.

Table 5: SEDIMENT_OUT Sediment transported with water out of reach during the time step (metric tons)

SUB	YEAR	SEDIMENT _OUT
1	2017	2544000
2	2017	137300
3	2017	86900
4	2017	3109000
5	2017	993500
6	2017	431800
7	2017	410500
8	2017	505300
9	2017	3348000

10	2017	266000
11	2017	786000
12	2017	123600
13	2017	116100
14	2017	1076000
15	2017	305400
16	2017	746500
17	2017	168500
18	2017	1748000
19	``2017	459100
20	2017	165800
21	2017	365300
22	2017	44.83
23	2017	4935
24	2017	478.6
25	2017	12.53

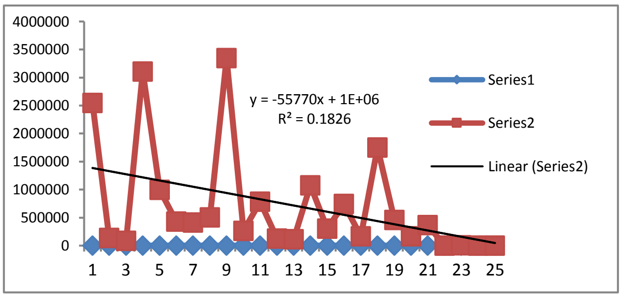

Figure 7: Simulation of the Sediment out of the 25 Sub-basin

The amount of sediment concentration is presented in Table 6. The highest value of the sediment concentration is found in sub-basin 4 with 1242 mg/L and the lowest is found in sub-basin 25 with 0.012 mg/L.

Table 6: SEDIMENT CONCENTRATION (Concentration of sediment in reach during time step (mg/L)

SUB	YEAR	SEDIMENT CONCENTRATION
1	2017	218.1
2	2017	186.1
3	2017	29.44
4	2017	1242
5	2017	102.6
6	2017	899.7
7	2017	165.9
8	2017	171.5
9	2017	375.7
10	2017	347.1
11	2017	794.6
12	2017	134.7
13	2017	131.3
14	2017	193.2
15	2017	155.2
16	2017	168.6
17	2017	262.1
18	2017	1163
19	2017	292.1
20	2017	137.6
21	2017	151.3
22	2017	0.05163
23	2017	2.289
24	2017	0.4352
25	2017	0.01262

The graph in figure 7 indicates the simulated sediment concentration The flow of the sediment is control by the gradient force downstream of the river. The Terengganu River has seriously affected the deposit of the sediments at the mouth of the river. This has created jobs sich sand mining for building and construction.

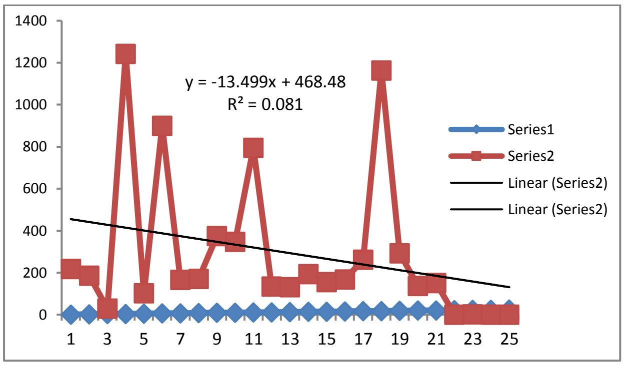

Figure 8: Simulation of Sediment Concentration in 2017

Summary of the statistical analysis from the 25 sub-basins

Table 7: Summary of the Analysis

Amount of Sediments	R^2 1973	R^2 2017
Sediment coming -in	0.250	0.233
Sediment going-out	0.187	0.182
Sediment Concentration	0.091	0.081

Table 8: Summary of the Sediment Analysis 1973-2017

Sediment Deposits	Sub-basins	1973	Sub-basin	2017
Highest Sediment Deposits- In	1	4903000	1	4164000
Lowest Sediment Deposits- In	25	14.83	22	44.83
Highest Sediment Deposits-Out	9	395000	4	1242
Lowest Sediment Deposits-Out	25	14.83	25	0.012
Highest Sediment concentration	4	1273	9	3348000
lowest Sediment concentration	25	0.014	25	12.53

4. Conclusion

There is a greater difference in the sediment that comes in the catchment in 1973 and that which comes in 2017. The graph in figure 2 and 5 displays an almost similar result of R^2 (0.250) and (0.233), the linear graph has cut across the temporal sediments that came-in and carried along by the river. The most important aspect of this study is the determination of the sediment load and supply which disturb river flow and block most of the river channels and cause a flood. It is important to study the sediment yield that will determine the carrying capacity of the river and as such most streams change their courses due to the blockage by accumulation and deposition of sand particle. The sediment yield also determines the navigation safety in marine science as well as the overflow of the riverbanks in most of the sub-basins.

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