Sufiyan and Zakariya, J Pollut Eff Cont 2018, 6:1
DOI: 10.4172/2375-4397.1000216

Journal of Pollution Effects & Control
ISSN: 2375-4397

Research Article Open Access

Monitoring Simulation for Flood Risk Prediction Using 3D and Swat in Terengganu Watershed

Sufiyan I*, Zakariya RB

School of Marine and Environmental Sciences, University of Malaysia Terengganu, Terengganu, Malaysia

Abstract

For many years, the River (Sungai) Terengganu catchment in Malaysia has been flooding and causing great problems to the inhabitants as well as the environment. This study uses the real-time simulation in ArcGIS 10.3 and 3D in ArcScene 10.3, and the variables obtained from the soil and water assessment tool SWAT such as the land use, soil and slope are the parameters measured to induce the flood. When certain portions of the Hydrologic response unit HRU; land use, soil or slope is changed due to temporal adjustment and climate change, then the model can predict zones of low, moderate and high flood risk. The 3D simulations appear to produce a visual model for decision-making, planning, management, and mitigation. The simulation helps in determining the extent of the flood by using animation.

Keywords: Modeling; Flood; Simulation; 3D; GIS

Introduction

According to Lin et al. [1] flood can be defined as a high water flow naturally or artificially from the river bank that dominates the surrounding area to cause overflow. The high flow of the water may extend over the floodplain and generally become a hazard to the society. Flood is one of the devastating hazard or disasters that Malaysia had been experiencing over the decades, this includes the Sabah and Sarawak. There is a problem of flash flood in the Terengganu watershed particularly during monsoon period (November to January) every year, but more severe in 2014, 2015 and 2017 (Table 1).

According to Zhang et al. [2] SWAT is increasingly being used in the watershed hydrological processes widely accepted and understood for evaluation of modeling application Javier et al. [3] has explored the degree of complexity on spatial variables in the watershed on examination of parameters. This is because input data are not only affected by parameters but also modifies the inbuilt model structure. The Department of Irrigation and Drainage Malaysia (DID) is responsible for providing flood forecast and warning services to the public Mah et al. [4] land use affects land cover and vice-versa, but changes in land cover by land use do not explain the reason for degradation of land (Table 2). However, it denotes shifting land use pattern by various factors of social changes also result in land cover changes that affect ecosystem and biodiversity. Radiation budget and water trace gas emission and other processes which directly affect climate and biosphere Riebsame et al. [5] The application of SWAT and the 3D environment has contributed greatly in identifying areas or zones affected by flood in each sub-basin parameter within the Terengganu watershed. The 3D modeling and simulation using the 5m resolution from the ASTER DEM were converted into Arc Scene using ArcGIS-3D software. During the ancient times, people developed ways of monitoring flood level and this enables them to predict the water flow and the risk or hazard involved. The 3D visualization techniques include the remote sensing, such as satellite imageries, aerial photogrammetric, Geographic Information System (GIS) and LiDAR modeling. The recent application of 3D GIS had provided clear presentation and visualization of flood hazard event than the previously used of 2D maps [6].

Watershed-Number of Sub-basins	Area [ha]	Area [acres]	Number of HRUs
25	286,507.35	707,973.99	305

Table 1: Total area of the watershed.

Land use	Abbrevation	Area [ha]	Area [acres]	%wat.Area
water body	WATR	42,684.6541	105,475.9145	14.90
Residential-High Density	URHD	3,346.7332	8,269.9450	1.17
Orchard	ORCD	46.8465	115.7601	0.02
Rubber Trees	RUBR	11,981.4471	29,606.7548	4.18
Residential-Low Density	URLD	167.2060	413.1745	0.06
Oil Palm	OILP	13,251.0778	32,744.0757	4.63
Paddy	PADD	3,209.3467	7,930.4563	1.12
Grassland	GRSS	10.9008	26.9365	0.00
Forest-Evergreen	FRSE	211,809.1378	523,390.9698	73.93

Table 2: Land use result.

Geographic modeling and simulation are now considered to be fundamental in process and mining as well as dam- break flood. The dam is of benefit to people but there is a tendency to be broken due to flood hazard event [7,8].

The 3D model display information uses in Google Earth. The KML files will be read in ArcGIS. Google Earth Pro is more advanced than the standard version which allows high image resolution to be overlaid with other information included in GIS data. It is necessary to analyze water flow direction within 2 meters that can allow flood monitoring and change it from 2D to 3D [9]. The DEM was used to develop mesh in the system and the water mask was generated for simulation of flood and produce flood models. This can be successfully visualized in the realistic 3D environment [10].

Flood has been affecting human habitat and create the unsustainable environment. The current study about event in many cities, towns

***Corresponding author:** Ibrahim Sufiyan, School of Marine and Environmental Sciences, University of Malaysia Terengganu, 21030 Terengganu, Malaysia; Tel: +601137273688; Email: ibrahimsufiyan0@gmail.com

Received February 16, 2018; **Accepted** March 21, 2018; **Published** March 27, 2018

Citation: Sufiyan I, Zakariya RB (2018) Monitoring Simulation for Flood Risk Prediction Using 3D and Swat in Terengganu Watershed. J Pollut Eff Cont 6: 216. doi: 10.4172/2375-4397.1000216

Citation: Sufiyan I, Zakariya RB (2018) Monitoring Simulation for Flood Risk Prediction Using 3D and Swat in Terengganu Watershed. J Pollut Eff Cont 6: 216. doi: 10.4172/2375-4397.1000216

or villages can never be overemphasized due to the fact that climatic conditions are not static. The land covers as well as the geographical settings. The Geographic Information System (GIS) will be applied in acquiring spatial and non-spatial data. The river flows are quite high during the monsoon, and the water level becomes high, therefore we create the DEM to simulate the flow direction at regular interval to avoid the flood. We need to get informed or be informed about the aftermath of flood event that is the hazard and damages as quickly as possible, so as to assess the magnitude of losses and plan for the relief operation. Flood is most severe in hazard in Malaysia [11]. The issue of flood disaster is a global phenomenon that requires attention in other to control life and properties. There is need to monitor the activities of the flood by applying the modern technology of Geographic Information System [12].

Materials and Methods

Study area

The study focuses on the flood mitigation in one of the flood-prone regions in the Eastern part of Peninsula Malaysia called Kuala Terengganu Catchment area. The Kuala Terengganu catchment has a total area of 286507.3500 hectare or 707973.9872 acres and the catchment lies within the wet tropical climate that exhibits vital roles in manipulating weather, soil, organic matter sediment yield that drained into the South China Sea. It is located at upper left corner 50305.407N, 10202315.536E and the lower right corner is 403924.251N, 103011 6.211E respectively. The bottom has gentle slope gradually deepening toward the open sea as cited in (Figure 1) [13].

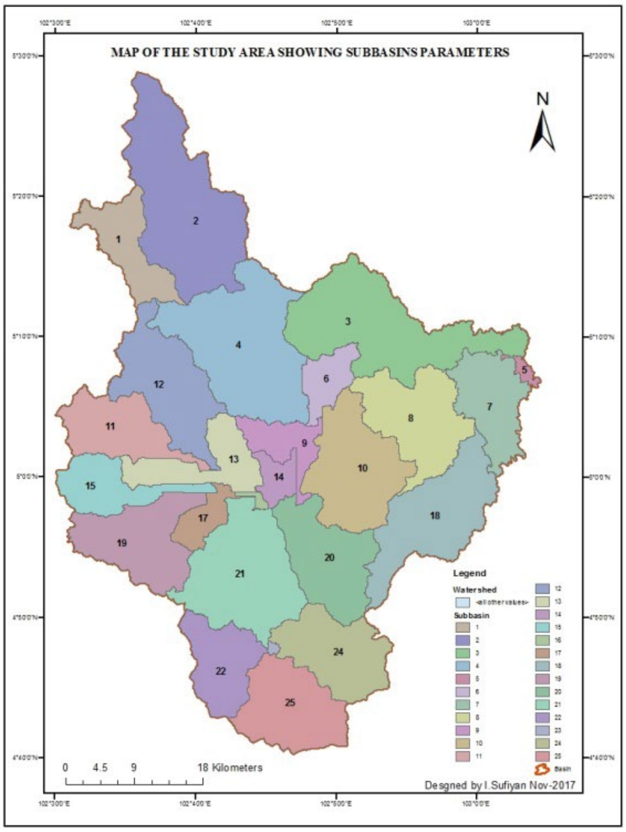

Figure 1: Study area map.

Methods

The SWAT Data Sources are obtained

- Department of Irrigation and Drainage (DID)
- Data of flood event in the study area (previously)
- Digital Elevation Model data (DEM)
- Stream flows data
- Land cover/land uses data
- Soil types

These are obtainable base on a different location of the stations

1. Climate data from Malaysian Meteorological Department (MET-Malaysia) from 2000-2015.
2. Land covers images from Malaysian Remote Sensing Agency (MRSA).
3. Malaysian soil map was obtainable from online source European Digital Archives of soil maps (EuDASM) named Reconnaissance soil map Peninsular Malaysia 1968.

Required spatial datasets and Optional spatial datasets

The required spatial datasets entail the following:

1. DEM
2. Land Cover
3. Soil map/data

The optional spatial datasets include:

1. Weather parameters
2. Daily rainfall data
3. Daily stream flow
4. Daily suspended-sediment

Results and Discussion

The result from the SWAT was obtained on 13th May 2017 at 05:29 pm with the total area of the watershed having 286507.3500 hectare or 707973.9872 acres. The total numbers of sub-basins are 25 characterized by 305 numbers of Hydrologic Response Units (HRUs). The threshold of 10/10/10 percent was chosen and selected. The flood risk event has been overcome by developing real-time simulation in the 3D scenario. This becomes apparent when the use of Geographic information system was employed to solve the problems of flood risk. This is done through visualization of selected zones affected by flood in Terengganu Malaysia (Figure 2).

The results from the SWAT watershed delineation was presented in Figures 3-5. Watershed is also known as a basin or catchment, or simply an area delineated with a specified outlet point that emptied in a large body of water. The Figure 6 represents the delineated watershed of Kuala Terengganu Catchment.

The stream links and reservoirs are developed through the stream network. 10 stream links are obtained from the Terengganu catchment. Each stream link had been connected with the defined sub-basins.

There are about 25 different sub-basins in the study area selected. Each of the sub-basins was characterized by a distinct parameter for

Citation: Sufiyan I, Zakariya RB (2018) Monitoring Simulation for Flood Risk Prediction Using 3D and Swat in Terengganu Watershed. J Pollut Eff Cont 6: 216. doi: 10.4172/2375-4397.1000216

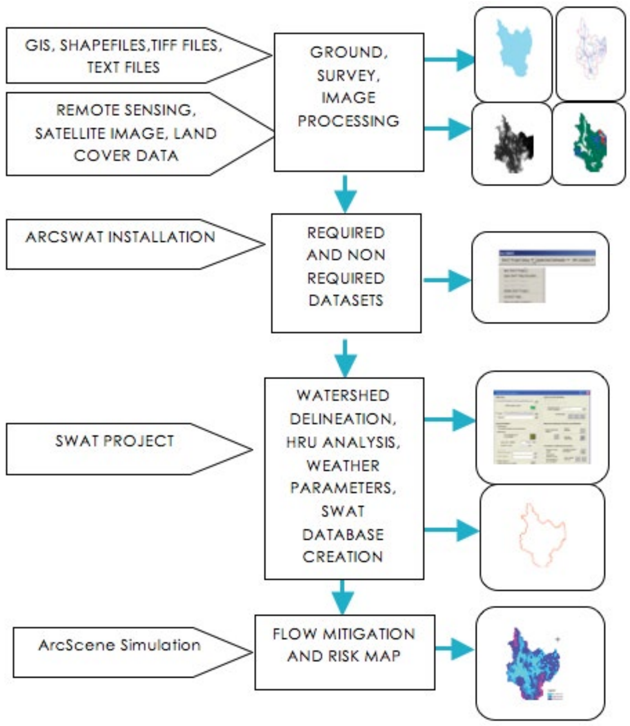

Figure 2: flow chart.

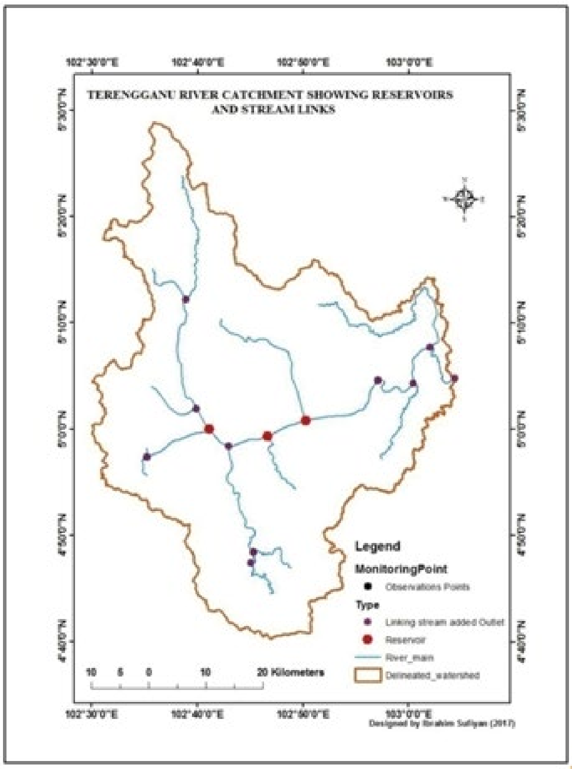

Figure 4: Stream network and reservoirs in Terengganu catchment.

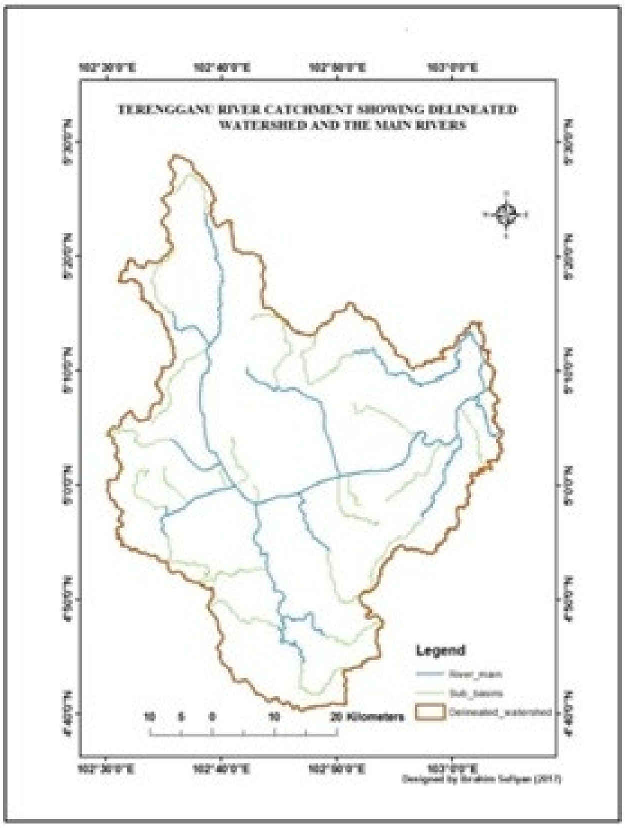

Figure 3: Watershed delineation in Terengganu catchment.

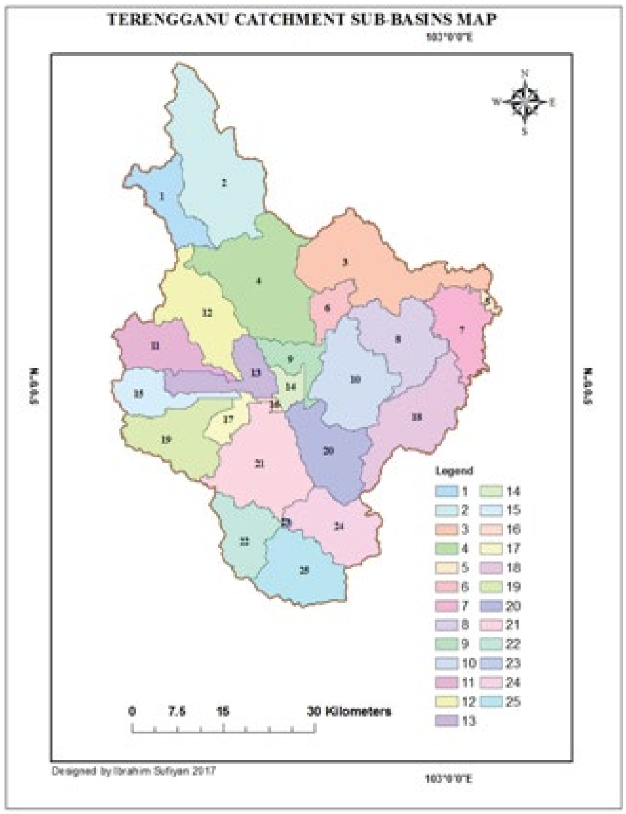

Figure 5: The main divisions of Terengganu catchment sub-basins.

classification and hydrologic analyses. Figure 6 shows the classified sub-basins in Kuala Terengganu catchment.

In the hydrologic response unit (HRU) analysis obtained from the SWAT, four major sub-basins were fully discussed. The sub-basins number 16 and 23 are selected as the smallest sub-basins in the Terengganu River catchment with 468.990 hectares SWAT area of 0.16%. The land covers characteristics include water and forest-evergreen. The soils found within the sub-basins are the local soils called Marang and Steepland then the lowest slope has 8.36% and the highest slope is 52.88% respectively. Furthermore, the sub-basins number 23 has 221.49 hectares with total SWAT area of 0.08% with a land cover of forest-evergreen and water and the local soil type called Marang. The lowest slope of 0-10 meters has 14.3% and the highest slope area have 27.46%. The largest sub-basins found in the catchment area of Terengganu are the sub-basins number 2 and 4. The total area in sub basin 2 is 27,019.53 hectares with SWAT area of 9.43%; the land covers include the water, oil palm, and the forest-evergreen. The local soils are Marang and Steepland and the lowest slope from 0-10 with 8.69& and the highest slope with 30.39% (Table 3).

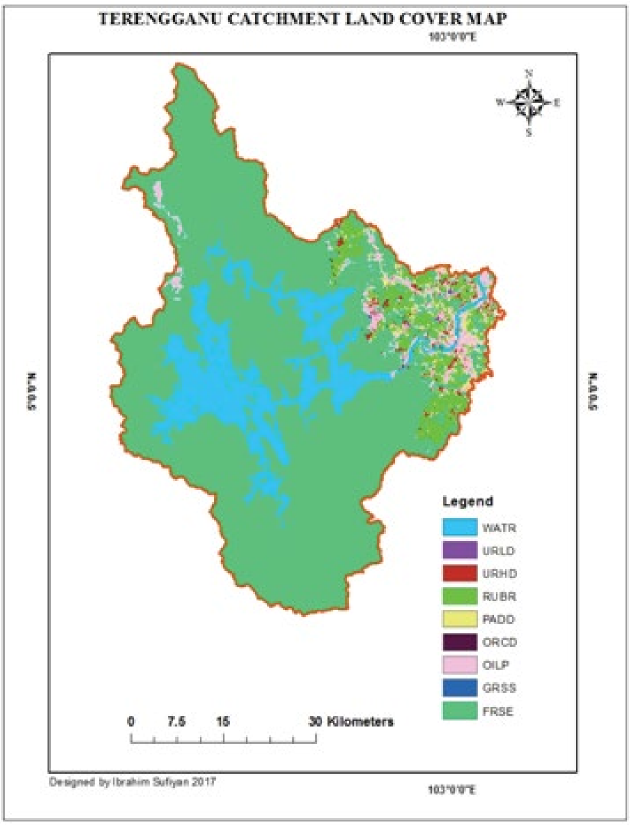

Figure 6: Land use classification of Kuala Terengganu catchment.

Soils	Area [ha]	Area [acres]	%wat.Area
Kuda Brang	35,604.8842	87,981.4491	12.43
Marang	26,762.6042	66,131.7330	9.34
Peat	47,32.3090	11,693.7721	1.65
Rudua	1,357.6481	3,354.8163	0.47
Steepland	200,117.6886	494,500.8145	69.85
Telemong	10,250.0178	25,328.3066	3.58
Tok Yong	7,682.1981	18,983.0956	2.68

Table 3: Soil types result.

The below explains the different pattern of the land cover which includes forest, water, urban land use, rubber paddy orchard oil palm, and grassland. The soils classification was based on the USGS with default SWAT soil database. The local soils in the study area are edited base on the SWAT update from the existing soils of the world. Table 4 shows the result of the soil classification with total areas in hectares, acres as well as the total percent obtained during the analysis (Figures 7 and 8).

The Soils has the ability to absorb moisture and get cooler and hotter quickly. Depending on the temperature, the water retention capacity varies from equatorial wet climate to monsoon as well as arid and semi-arid environment. The steep land has the highest percentage 69.85%. However, most likely to have less water retention capacity.

The slope data derived from the SWAT database was an inbuilt developed from the threshold of 10/10/10 percent from the HRU. Table 4 shows the result of total area from each category of slope in hectares and acres while taking cognizance of slope percent from 0-10 up to 40 meters above.

The elevation or slope map of the Kuala Terengganu catchment

Slope	Area [ha]	Area [acres]	%wat.Area
0-10	62,167.7600	153,619.6434	21.70
10-20	59,973.9917	48,198.7322	20.93
20-30	543,92.6797	134,407.0312	18.98
30-40	43,842.4838	108,336.9695	15.30
40-9999	66,130.4348	163,411.6109	23.08

Table 4: Slope result.

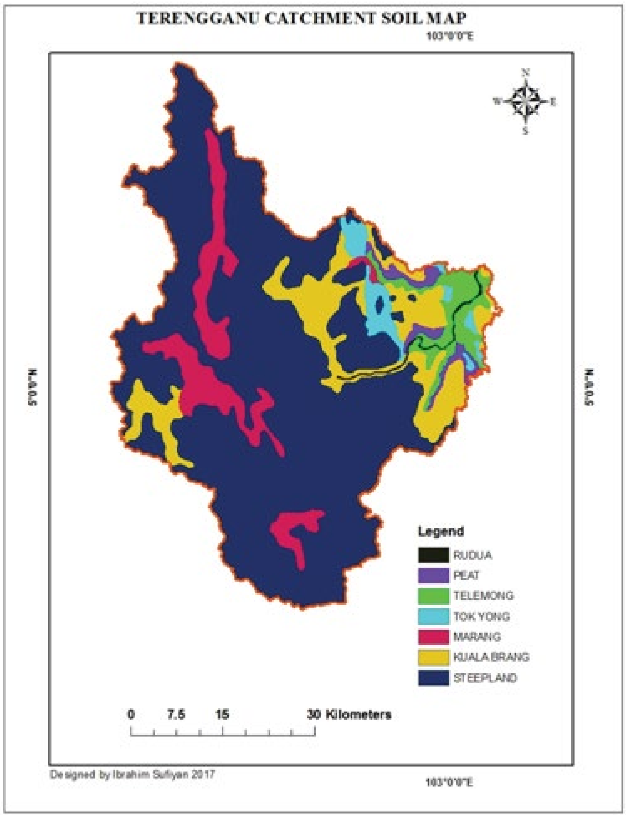

Figure 7: Soil map of Kuala Terengganu catchment area.

Citation: Sufiyan I, Zakariya RB (2018) Monitoring Simulation for Flood Risk Prediction Using 3D and Swat in Terengganu Watershed. J Pollut Eff Cont 6: 216. doi: 10.4172/2375-4397.1000216

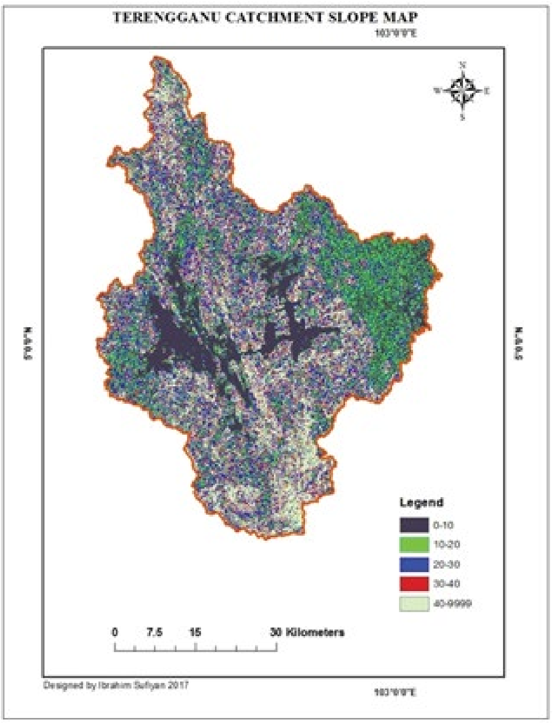

Figure 8: Slope map of Kuala Terengganu river catchment.

shows dark grey color depicts the lowest elevation that is 0-10 meters. The green color pattern is 10-20 meter slope, the blue color is between 20 -30 and lastly, the light grey color in the map represents the highest slope.

Flood risk and mitigation model was developed as shown in Figures 9 and 10. The yardstick is to measure the magnitude of the flood risk in the catchment area of Kuala Terengganu. Here we arrived at the categories of flood risk from the highest risk to moderate and no risk zones within the watershed. The flood risk map represents the risk zones which can be used for mitigation, planning, and a warning to the public.

The removal of major land cover such as forest land cover in Kuala Terengganu will significantly affect the zones which are predominantly occupied by evergreen forest. While both zones are at flood risk, the presence or absence of more land covers will ultimately change the water flow. The aftermath of flood event usually is associated with pollution. Dirty water with refuse and garbages, as well as blocked drainages, might cause an outbreak of epidermal disease, the risk of lives through broken cables can easily electrocute humans and live animals.

The 3D flood models were produced from the digital elevation model (DEM) of the study area was overlaid with the mask and the Terengganu river flow was considered as a base height. Figure 11 describes the 3D model developed from the ArcScene. At this point, the Z values are calculated in other to create the simulation. The real-time simulation is presented in Figure 11 while the simulation was displayed, the purpose is to create a quick alert or warning through animation

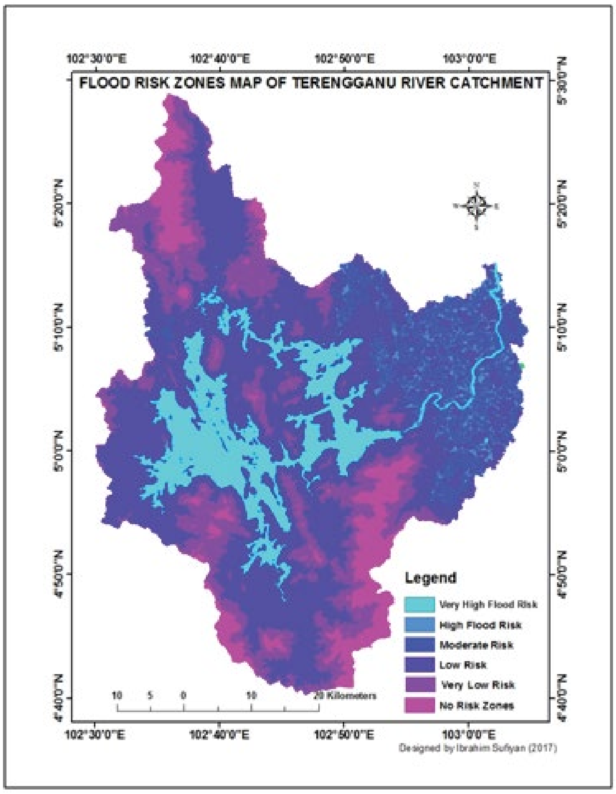

Figure 9: High and low flood risk map of river Terengganu.

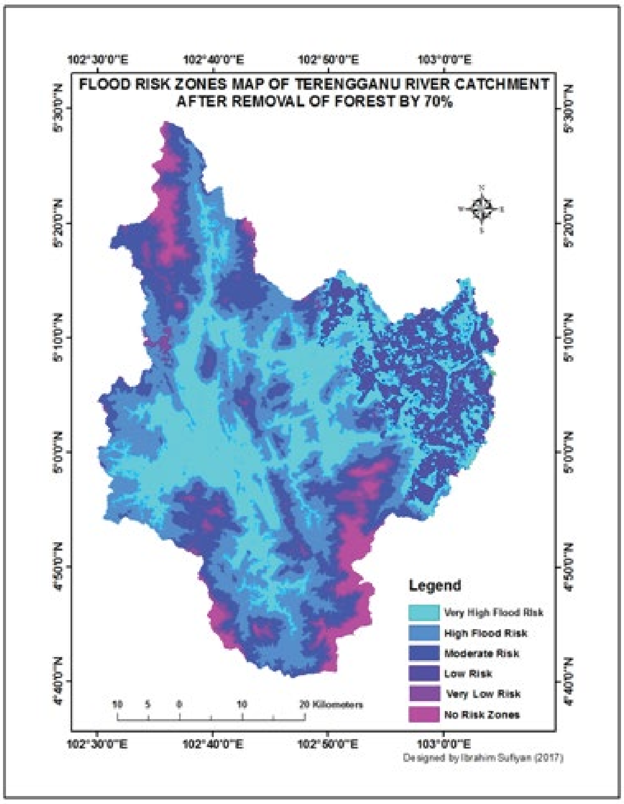

Figure 10: Removal of forest develop more flood risk in Terengganu river catchment.

Citation: Sufiyan I, Zakariya RB (2018) Monitoring Simulation for Flood Risk Prediction Using 3D and Swat in Terengganu Watershed. J Pollut Eff Cont 6: 216. doi: 10.4172/2375-4397.1000216

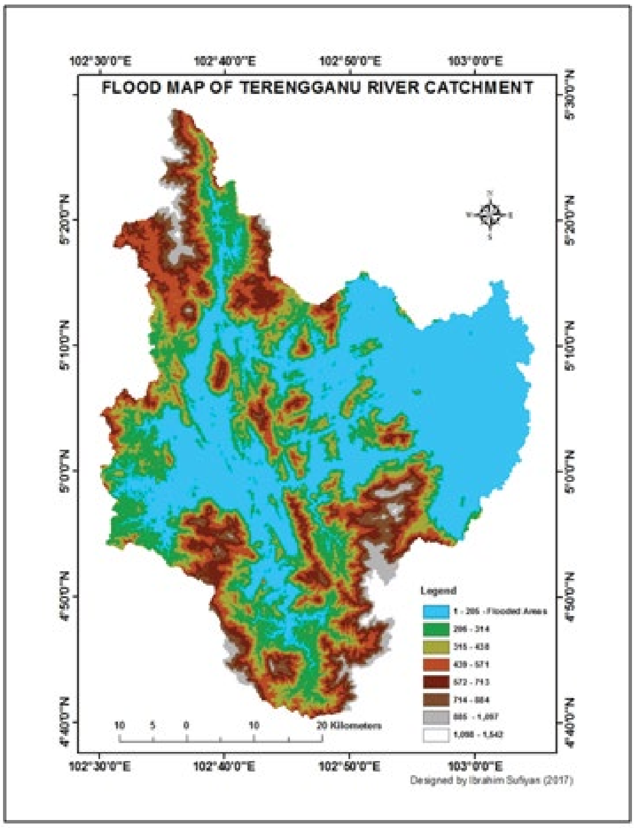

Figure 11: 3D flood simulation model of Terengganu river catchment.

video perhaps all the areas prone to flooding will be easily identified and mitigation action can be applied.

Flood simulation model of Terengganu catchment in Figure 11 presents the real-time 3D simulation with the blue color representing the flood event that ranges from 1 to 205 meters of elevation while other zones from 205 to 314 meter will be a flood if the water level increases. The model is also available in animated form.

Conclusion

The study of flood simulation become paramount in other to evaluate and provide information for decision making and flood control planning. At present, the two-dimensional (2D) visualizations are not sufficient in presenting real scene and therefore cannot make a full representation of data available. Today geographical 3D simulation and modeling are regarded as a fundamental approach to solving complex geographic problems. The SWAT has developed the scenario from the individual sub-basins for the Terengganu catchment where about 25 sub-basins parameter are obtained in the catchment. The watershed has been delineated creates sub-basins parameters where each sub-basin are having distinct characteristics of hydrologic response unit (HRU). The recent trend in flood monitoring was applied to 3D for the quick response, alert and warning, mitigation, planning, and management. Each time there is a flood in Terengganu we can visualize it base on the predicted simulation in 3D. The research is vital to urban planners, surveyors, environmentalist as well as engineers and geologist.

Acknowledgment

This research was fully supported by my able supervisor Dr. Razak Bin Zakariya from the faculty of Marine and Environmental Sciences Department of Remote Sensing and GIS, University Malaysia Terengganu.

References

1. Lin GF, Chou YC, Wu MC (2013) Typhoon flood forecasting using integrated two-stage support vector machine approach. J Hydrol 486: 334-342.
2. Zhang X, Srinivasan R, Hao F (2007) Predicting hydrologic response to climate change in the Luohe River basin using the SWAT model. Transactions of the ASABE 50: 901-910.
3. Javier JRN, Smith JA, Meierdiercks KL, Baeck ML, Miller AJ (2007) Flash flood forecasting for small urban watersheds in the Baltimore metropolitan region. Wea Forecast 22: 1331-1344.
4. Mah YS, Lai SH, Chan RA, Putuhena FJ (2012) Investigative modeling of the flood bypass channel in Kuching, Sarawak, by assessing its impact on the inundations of Kuching-Batu Kawa-Bau expressway. Struct infrastruct E 8: 705-714.
5. Riebsame WEWE, Meyer WB, Turner BL (1994) Modeling land use and cover as part of the global environmental change. Clim Change 28: 45-64.
6. Chan NW (2015) Impacts of disasters and disaster risk management in Malaysia: the case of floods. Resilien Recove Asian Disast 24: 239-265.
7. Forte F, Pennetta L, Strobl RO (2005) Historic records and GIS applications for flood risk analysis in the Salento peninsula (southern Italy). Nat Hazards Earth Syst Sci 5: 833-844.
8. Hossain AKMA, Jia Y, Ying X, Zhang Y, Zhu TT (2011) Visualization of urban area flood simulation in the realistic 3d environment. World environmental and water resources congress: 1: 1973-1980.
9. Kia MB, Pirasteh S, Pradhan B, Mahmud AR, Sulaiman WNA, et al. (2012) An artificial neural network model for flood simulation using GIS: Johor River Basin, Malaysia. Environ Earth Sci 67: 251-264.
10. Liu YB, Gebremeskel S, De Smedt F, Hoffmann L, Pfister L (2003) A diffusive transport approach for flow routing in GIS-based flood modeling. J Hydrol 283: 91-106.
11. Marghany M, Ibrahim Z, Van Genderen J (2002) Azimuth cut-off model for significant wave height investigation along the coastal water of Kuala Terengganu, Malaysia. Int J Appl Earth Obs Geoinf 4: 147-160.
12. Wang F, Xu YJ (2008) Development and application of a remote sensing-based salinity prediction model for a large estuarine lake in the US Gulf of Mexico coast. J Hydrol 360: 184-194.
13. Zhu Z, Woodcock CE (2012) Object-based cloud and cloud shadow detection in Landsat imagery. Remote Sens Environ 118: 83-94.