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Assessment of Rainfall Scenario in Determining Flood at Terengganu Watershed Malaysia

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Authors' contributions

This work was carried out in collaboration among all authors. Author IS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JIM and ATO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The future of climate lies on the hand of individual who is an active member that contributes input in the biosphere. The amount of climate change will largely influence the water flow in the river through the emission of solar radiation, increase in temperature, heat-trapping gases. There is a need to control pollution, flood hazard, check water quality and monitor sediments and water flow in the drainage basin. Soil and Water Assessment Tools SWAT is one of the best methods of the application being used for hydrologic assessment as well as monitoring events that occur in the catchment studies. Mitigation can simply determine how to reduce the human hazard, in controlling the climate change that affects water flow in river Terengganu. The Soil Water Assessment Tool (SWAT) provides the simulated rainfall from 1973 to 2017. The precipitation and other weather parameters were used for the purpose of this study and the resultant effect is the production of predictive flood hazard event within the catchment area of Kuala Terengganu.

Keywords: Climate change; rainfall; SWAT; flooding; modeling.

1. INTRODUCTION

The integrated networking of Soil Water Assessment Tool (SWAT) capabilities had for recent years help in predicting flood event and flood zoning in the hydrological modeling. The model among other things simulates water discharge from rivers and sub-basins within the

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watershed or catchment area. Planners use geographic information system (GIS) and remote sensing data to support the models for management, planning and decision making especially when comparing the hydrologic database of the different watershed McColl and Aggett [1] as allied by Kepner et al. [2].

Numerous researches and literature over the decades are available showing the significance of SWAT applications to water resources and the environment like in the work of Bingner and Theurer [3] and Lahlou et al. [4]. Most of the developed hydrologic modeling is in different scale-event that integrates base flow, direct runoff and predictive results using simulation and validation.

Javier et al. [5] in the work of Beighley and Moglen [6] developed an approach toward utilizing the HEC-HMS in determining peak river discharge in Baltimore Washington DC, metropolitan area. McColl and Aggett [1], also used the model for land use forecasting and future spatial distribution in the low-density population of residents.

Fig. 1. Map of Terengganu watershed

Flood forecast requires the estimation of spatial and temporal rainfall data within the catchment. One of the important meteorological events is rainfall data which is relevant for hydrologic studies. The relationship between atmosphere and terrestrial processes developed in time and space is considered during heavy rainfall while a hydrologic variable such as soil moisture content within the catchment most also is considered [7].

Simulated data related to flood frequency was described by Rahman et al. [8] in the catchment area of Monte Carlo. Changes in seasonality were also responsible for flood frequency in Europe and in broader ecological perspective [9,10]. It is easier to detect changes in seasonal changes signal in regional rainfall data than in flood data [11]. These are then related to regional climate model which is projected for 2070-2100 [12]. Investigates two methods to examine the changes in the frequency and the intensity of extreme rainfall events that uses Regional Frequency Analysis (RFA). Based on L-moments and Peak Over–Threshold (POT) analysis, climate model interpretation predicts an increase in heavy rainfall frequency and intensity in high latitude of the Northern Hemisphere due to enhanced greenhouse condition [13], Jones and [14,15,16].

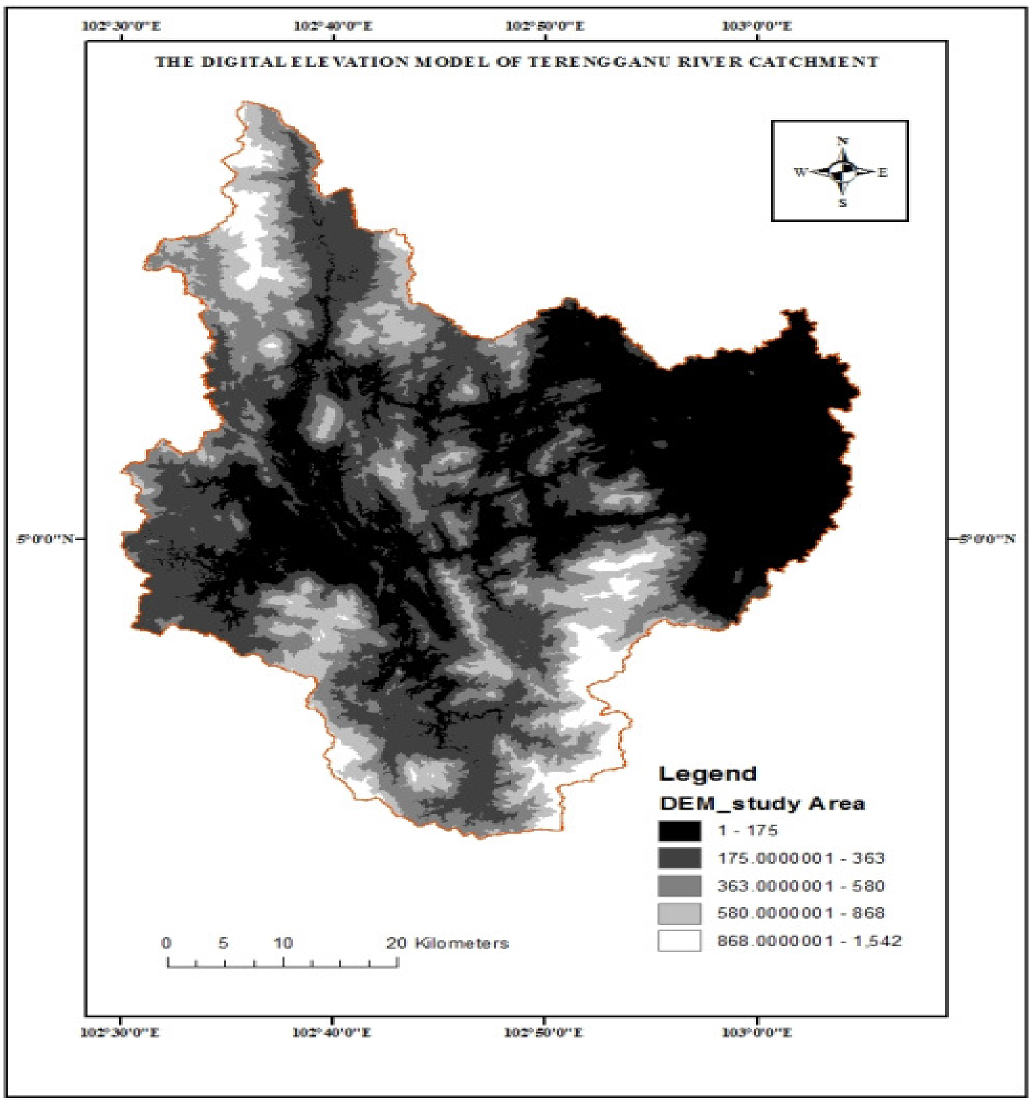

Fig. 2. Digital elevation model (DEM)

Miller et al. [17] Described the capability in Geographic Information System (GIS) and user interface for modeling watershed in Soil Water Assessment Tool (SWAT). The interface defined outlet point and delineate the watershed base on some parameter of Digital Elevation Model (DEM), soil, land-use and precipitation to derive a model parameter. The application of AGWA 2.0 was also a user-friendly tested in an arid region [17]. It also allows for evaluating flood impact assessment using alternative land use scenario across the international boundary. SWAT model uses hydrologic response unit (HRU) as a smallest homogeneous unit to calculate hydrological processes [18]. Many studies from different fields' use catchment hydrological modeling like SWAT and HEC-HMS to investigate the performance and best result of various management practices especially simulations [19] and [20] Geographic Information System (GIS) function to calculates the size of raster cells for both lands uses and soil types within the study area.

According to Arnold et al. [21], the raster delineation can simulate the impact of landscape position on management and runoff in explicit spatial analysis and detail accuracy. GIS provides various hydrological functions and raster spatial analysis such as flow direction, flow accumulation, flow travel time and zonal statistics to depict flow hydrograph. Topographic data or Digital Elevation Model (DEM) was used to delineate the catchment and to generate flow direction. Based on the Flow direction, Flow accumulation and rainfall data, the model calculated rainfall excess, flow velocity that produces a flood. The remote sensing and GIS data are paramount in the substantive development of spatial distributions of geographic events such as environment, man and water resources [22].

Terengganu watershed is experiencing a flood during the monsoon season. This study is aimed at assessing the menace of the flood using available meteorological data of rainfall. The objective is to identify the sub-basins parameters that are vulnerable to flood during the high rainfall (monsoon).

Table 1. Total amount of rainfall falling on the hydrologic response units (HRUs)

Sub-basins	1973 Rainfall mm	Sub-basins	2017 Rainfall mm
1	3776.822	1	3755.665
2	4302.678	2	4037.977
3	4470.667	3	4432.592
4	4480.933	4	4076.659
5	4137.642	5	4114.464
6	5402.017	6	4914.643
7	5405.78	7	4918.067
8	5402.604	8	4915.177
9	5401.226	9	4913.924
10	3507.391	10	3291.615
11	4617.462	11	4333.395
12	5410.604	12	4922.456
13	4621.722	13	4337.393
14	5582.505	14	5079.655
15	5410.606	15	4922.457
16	5583.743	16	5080.78
17	1962.296	17	1598.929
18	5529.638	18	5031.55
19	4384.619	19	3572.7
20	5579.321	20	5076.757
21	5582.772	21	5079.896
22	5574.478	22	5072.35
23	5583.743	23	5080.78
24	5521.302	24	5023.964
25	5533.999	25	5035.517

2. METHODOLOGY

2.1 Study Area

The study area is located at Lat 5°27'4.05"N, Long 103°2'47.04"E Lat 5°16'51.43"N, Long 103°10'39.30"E, with the total catchment area is 8822.4876 (Ha) occupying areas near the South China Sea [23].

2.2 Climate and Vegetation

The annual mean rainfall is approximately 3300 mm and the mean temperature ranges between 23°C to 32°C. The highest precipitation received by the catchment is during the North-East monsoon (October to December) and the South-West monsoon usually occurs during May to late September. Malaysia is full of evergreen forest and little or no grassland. It densely forested that give the opportunity to grow palm trees, rubber, and provision of timber. The flood usually occurs during the monsoon period [24]. The Digital Elevation Model (DEM) was clipped to the catchment areas shapefile boundary and the water level was recorded in the Soil Water Assessment Tool (SWAT).

The data collection was carried out in the Malaysia Drainage and Irrigation Department (DID). The study is simply summarized in the flow chart Fig. 3. The input data is from the satellite digital elevation model (DEM), AsterDEM. Soil Water Assessment Tool (SWAT) is combined with the simulated rainfall to produce flood risk model. The sub-basin parameters affected by the flood are identified in ArcGIS 10.3. The field survey was conducted using land cover types and local soil of Peninsular Malaysia. Image data was acquired by ASTER-DEM through satellite. The rainfall data are obtained from Meteorological Agency in Malaysia (MET-Malaysia).

3. RESULTS AND DISCUSSION

This approach is highly new in collaborating ArcSWAT-2012 with flood mapping. Using rainfall or precipitation input to develop flood scenario. The model not only useful for designing flood zoning, maps, and models but to included many more variable for sustainable agricultural uses of nutrient loss, plant growth and other hydrological analysis. The watershed was delineated with the total of 25 sub-basins Fig. 4 and every sub-basin is containing the Hydrologic Response Units (HRUs) with unique land cover, soil and slope.

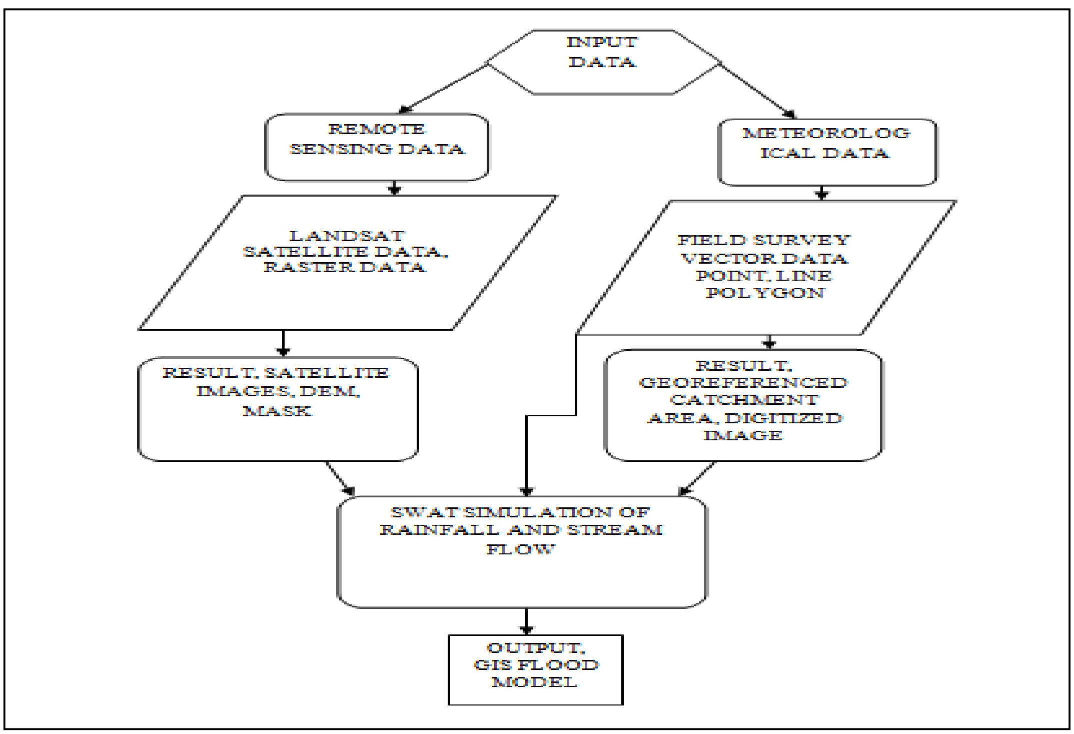

Fig. 3. Flow chart

The model requires daily rainfall data. Rainfall data can be used as an input in the catchment area of Kuala Terengganu. It is simply obtainable from the 6 different stations spread over the study area. In this study, the SWAT simulations produced the rainfall records from 1973 to 2017 as shown in Table 1. Average monthly precipitation over the year (rainfall) was used to determine the amount of water flow in the steam network of Kuala Terengganu, Malaysia as in Table 2.

The highest rainfall simulation in the year 1973 is 4340mm in sub-basin 21 and the lowest is found in sub-basin 17, refer to Fig. 5.

While in the year 2017 the highest rainfall amount is 4140 mm in sub-basin 20 and the lowest was found in sub-basin 17.

The streamflow and water level determined to the large extent the vulnerability of flood as indicated mostly in Kuala Terengganu Rivers. The flooded areas are found near to the mouth of the river where the slope gradient is low. Table 2 is the simulation result of the 25 sub-basins stream flow in meter cube per second (m^3/s).

The highest streamflow simulation out of the watershed is found in sub-basin 1 with 336.6 $m^3/2$, followed by sub-basin 5 with 295.6 m^3/s and sub-basin 9 with 262m^3/s. The y variables are the stream flow and the x variables are the number of sub-basins contained in the Terengganu watershed.

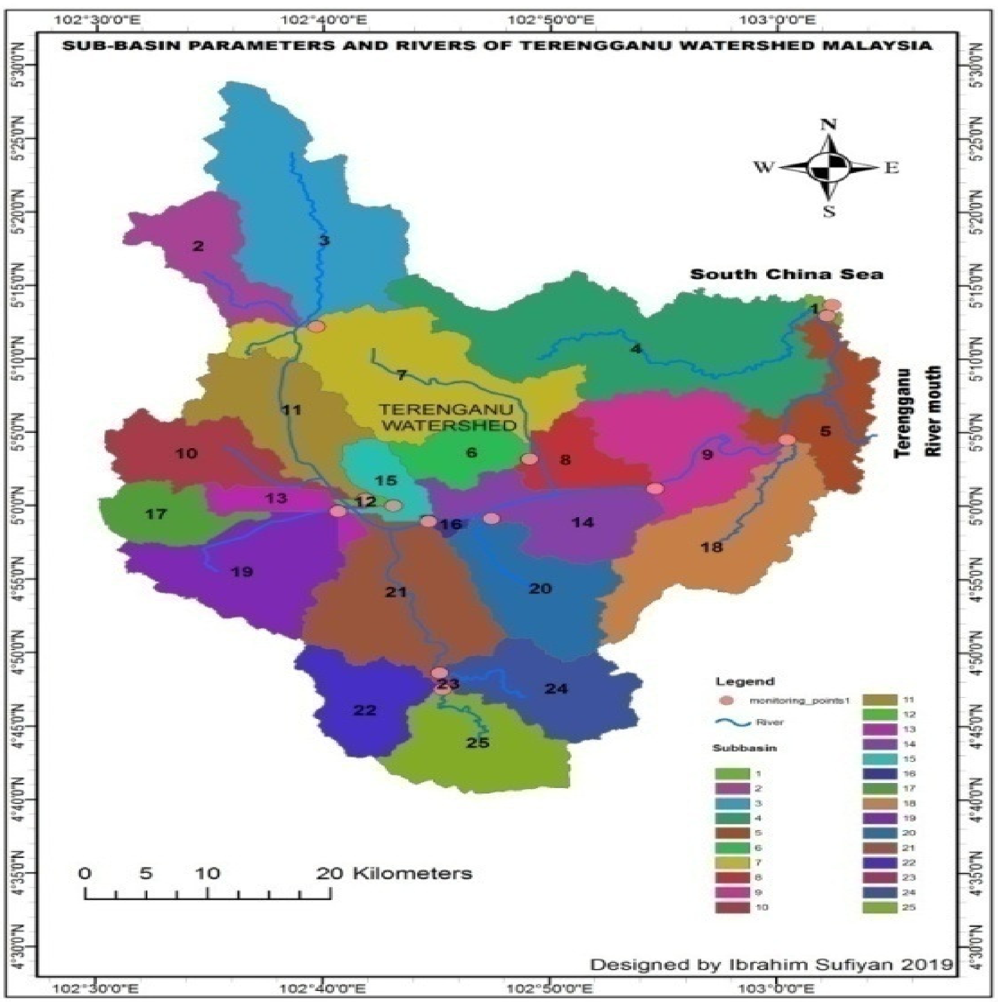

Fig. 4. Sub-basin parameter of Terengganu watershed

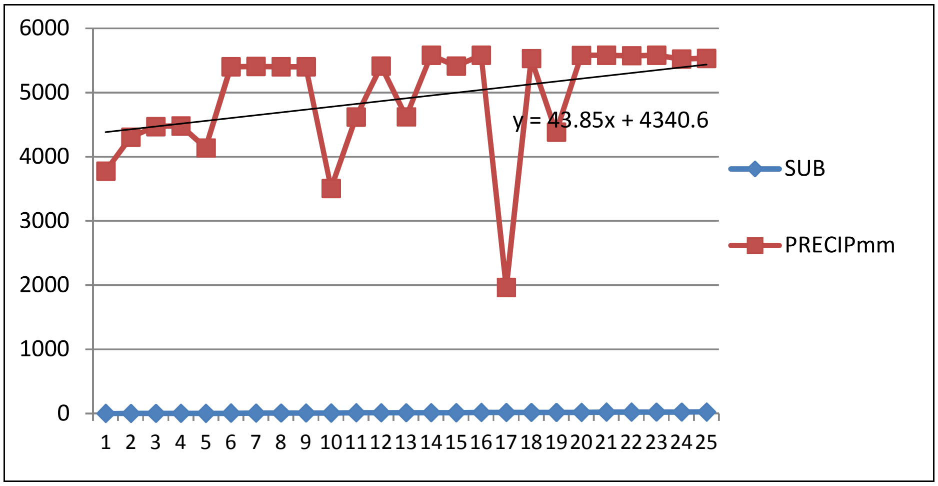

Fig. 5. 1973 rainfall simulation of Terengganu watershed

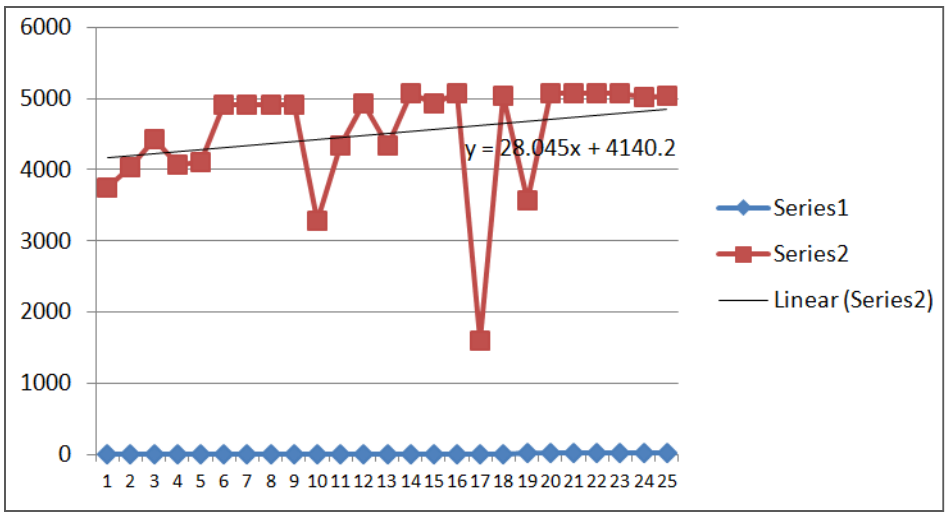

Fig. 6. 2017 rainfall simulation of Terengganu watershed

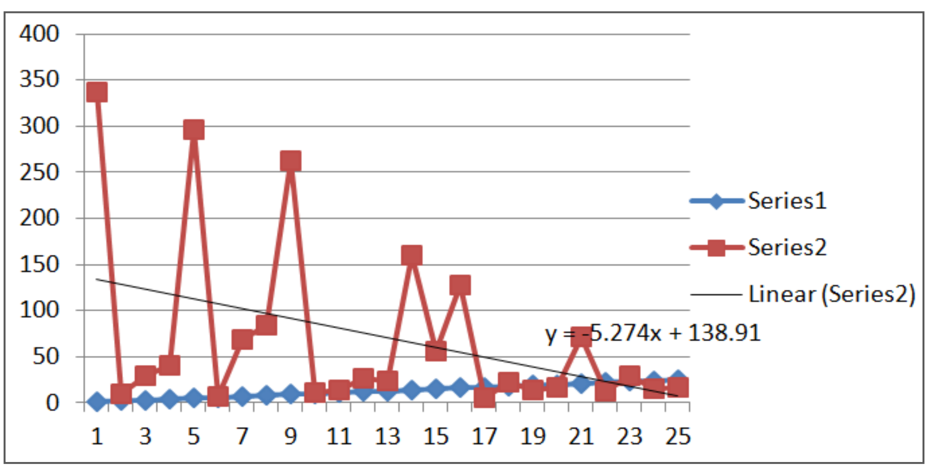

Fig. 7. 2017 streamflow simulation of Terengganu watershed

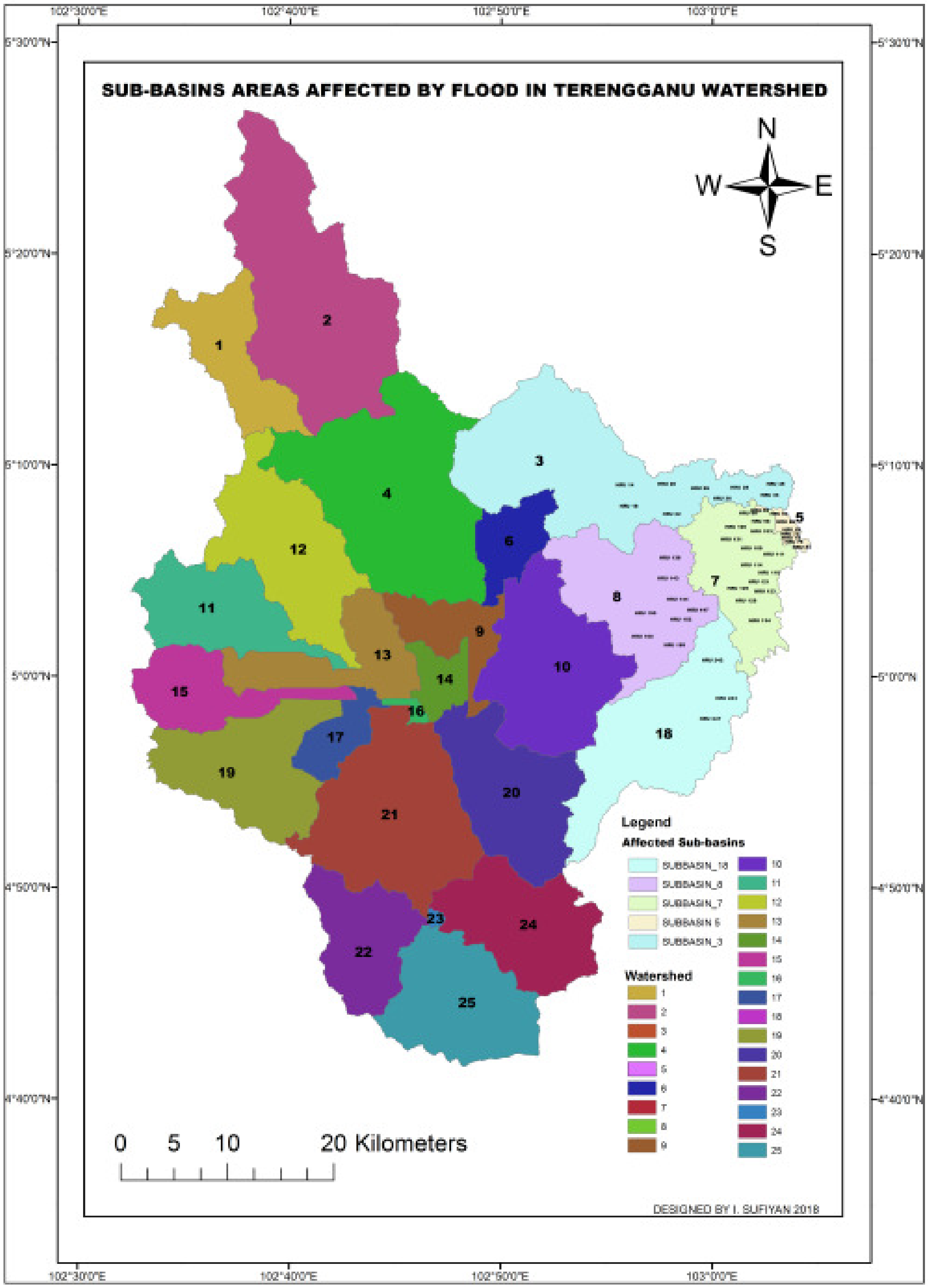

Fig. 8. Identified sub-basins flood risk zones of Terengganu watershed

The affected sub-basins by the flood is shown in model Fig. 7, includes sub-basin 3, 5, 7, 8 and 18. All of the affected sub-basins are located at the lower digital elevation model (DEM).

Table 2. Stream flow of Terengganu watershed for 2017

Sub-basins	Stream flow in m3/s
1	336.6
2	10.31
3	29.19
4	40.39
5	295.6
6	7.201
7	69.35
8	83.98
9	262
10	11.07
11	14.36
12	25.93
13	24.25
14	160.5
15	55.53
16	127.4
17	5.713
18	22.96
19	14.43
20	17.27
21	71.11
22	12.15
23	29.05
24	15.64
25	16.6

4. CONCLUSION

The study of the catchment area has really improved the situations of flood control by ascertaining the water level and the elevation data using digital elevation model DEM. The study among other things buttresses the climatic changes toward changing the environment by identifying flood vulnerability through rainfall simulation. Most of the settlements in Kuala Terengganu located near the river banks are subjected to flood menace and risk. The delineated watershed in Terengganu watershed has indicated vulnerability to flooding especially at the lower slope with 0 1 meter digital elevation model. This study is useful in decision making to urban planners, flood focus, simulation of future flooding within the sub-basin.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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