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ASSESSMENT OF IMPACT ON SIMULATED WATERSHED RAINFALL-RUNOFF USING OPEN SOURCE REMOTE SENSING SATELLITE DIGITAL ELEVATION MODELS WITH GIS BASED HYDROLOGICAL 'SWAT' MODEL

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Abstract - *Digital Elevation Model (DEM) of a watershed forms key basis for hydrological modelling and essential in watershed delineation. DEM resolution plays a key role in accurate prediction of various hydrological processes. This study appraises the effect of different DEMs with varied spatial resolutions namely ALOS PALSAR-12.5m, ASTER Global DEM-30 m, CARTOsat-1 DEM-30m, SRTM-30m, and SRTM-90 m on hydrological responses of watershed using Remote Sensing (RS) & Geographical Information System (GIS) based public domain Soil and Water Assessment Tool (SWAT) model. This study investigates the impact of DEM resolution on topological attributes and simulated runoff in the 'Sina' river watershed, Maharashtra, India. From the results of case study, it was observed that reach length, longest flow path of stream network, average slope of watershed, minimum and maximum elevations, sub-watershed areas, number of HRUs, varied substantially due to DEM resolutions and consequently resulted in a considerable variability in estimated daily runoff. It was also observed that, daily runoff values have increased on low rainy days respectively with coarser resolution of DEM. The study found that the performance of SWAT model prediction was not influenced much for finer resolution DEMs upto 90m for estimation of runoff. The DEMs of ALOS-PALSAR provides better estimates of sub-watershed areas, runoff prediction values over other DEMs. Results showed that the watershed area, reach lengths, and elevations in watershed varied due to DEM resolutions. The sub-basin wise runoff estimation and month wise runoff predictions were varied from coarser resolution to finer resolution DEMs. The variation is not accountable and also negligible for consideration of resolution of DEM. The results of the study infer that there is no particular trend of increase or decrease in estimation in daily runoff values with temporal variations of DEM resolutions.*

***Key Words*: Digital Elevation Model, Runoff, Resolution, longest flow path, ArcGIS, Hydrologic Response Unit**

1. INTRODUCTION

Application of effective models in hydrological studies is vital to understand the natural processes occurring at the watershed scale. The ability of hydrological models in representing hydrological processes and estimating hydrological variables such as runoff and sediment yield greatly depends on the spatial resolution of input data. however, past studies have barely consider the impact of spatial resolution of input data on simulated hydrological variables, which necessitates a thorough investigation in diverse hydrological considerations [1], [2]. Model input data are actually the primary sources of errors in estimated hydrological variables ([3], [4], [5]). Recent studies also noted that the use of finer resolution spatial data does not necessarily improve the performance of hydrological model predictions [6]. Few studies also investigated the effect of spatial resolution of input datasets on hydrological response of watersheds in simulating runoff and sediments ([7], [8], [9])

Digital Elevation Model (DEM) of watershed constitutes an important input data for hydrological models in estimating various hydrological variables such as runoff and sediments ([10], [11] [12]). DEM is a digital (raster) dataset of elevations in 3D (x, y, z co-ordinates), which is useful in watershed modelling to find drainage structure [13]. It gives vital information for runoff analysis, sediment and nutrient transport studies. The DEM reflects abrupt changes in relief such as incised streams, ridge lines and slope breaks. In the past, studies also noted that DEM resolution has direct impact on the hydrologic model predictions from Topography based hydrological MODEL (TOPMODEL) ([14], [15]), another hydrological model based on the water balance simulation model (WASIM) [16], the Soil and Water Assessment Tool (SWAT) [17], the Areal Non-Point Source Watershed Environment Response Simulation (ANSWERS) [18] and the TOPographic Land Atmosphere Transfer Scheme (TOPLATS) model [19].

This study adopts SWAT (Soil and Water Assessment Tool) for hydrological modelling, which is a physically based semi-distributed hydrological model helps to estimate runoff, erosion, sediment and nutrient transport from agricultural watersheds under different management practices [20]. In the past, SWAT was used in watersheds of different sizes taking into account varying soils, land uses/covers and management conditions over long period of time in various regions and climatic conditions on daily, monthly and annual basis [21]. The SWAT model requires various input datasets such as DEM, soils, landuse–land cover (LU/LC), meteorological variables, etc. The DEM data plays a key role in watershed modelling and estimation of hydrological variables using SWAT. Several topographic attributes such as area, slope, length, channel slope, channel width, channel depth and field slope length, etc. are primarily derived from the DEM, and these attributes help in watershed delineation into multiple sub-watersheds. Each sub-watershed is delineated into a number of Hydrologic Response Units (HRUs), with unique combinations of land cover, soil type and slope. In SWAT, all the hydrological parameters are predicted at the HRU level within each sub-watershed and then routed at watershed level [22]. Different DEM resolutions may result in different number of HRUs and sub-watersheds, and subsequently may result in deviations of predicted values of hydrological variables. The SWAT model has the options to estimate watershed runoff using Soil Conservation Services Runoff equation (SCS-1972) [23]. The method of runoff estimation are functions of different parameters that are attributes of DEM and are sensitive to DEM resolutions. Thus, DEM dataset plays an important role in hydrological modelling of watersheds.

In the past, few studies have analyzed the effect of DEM resolution on the estimation of hydrological variables using SWAT. Cotter et al. [24] and Chaubey et al [12] evaluated the impact of resampled resolutions of DEM on the uncertainties of SWAT-predicted runoff. DEM resolution affects the watershed delineation, stream network and sub-basin classification in SWAT. A coarser DEM resolution resulted in decreased runoff, sediment, NO_a-N and TP load predictions with short-term fluctuations. Dixon and Earts (2009) [25] compared the SWAT predicted streamflow for three DEM resolutions of 30m, 90m and 300m in the Charlie Creek drainage basin (855 km^2), located in the Peace River drainage basin of central Florida, USA. While comparing the results of models that use DEM of 30 m resolution with 300 m resolution, the study indicated a large deviation in predicted streamflow, and also noted that models was sensitive to the resolutions of the DEM. the results were also compared with resampled DEMs and noted that the effects of DEM resolution could not be ignored and resampling to finer resolution might not improve the accuracy in predicting stream flows using SWAT model.

Lin et al. (2010) [14] studied the effect of DEM resolution on hydrological parameters considering 11 spatial resolutions (varying from 5 to 140 m) in the Xiekengxi river watershed (81.7 km) in Zhejiang Province of China. The study showed that runoff values were sensitive to coarser resolution of 100m, 120m and 140m but not much sensitive to finer resolutions of 5, 10 and 20 m. Slightly decreased trends were reported in the predicted sediments to coarser DEM resolutions. Peter et al (2013) [26] studied the effects of DEM resolution on sediment delivery estimates in a coastal watershed of South Carolina, USA with four DEMs of 90m, 30m, 10m and 3m resolutions. The finer-resolution DEM (i.e 3m) was derived from Light Detection and Ranging (LIDAR) data. The study noted that slope results were more accurate with finer resolution DEM, and thus increased consideration variability in sediment output.

Peipei et al (2014) [27] studied the impact of different resolution DEMs on SWAT model outputs of sediments and nutrient production in an agricultural watershed of Xiangxi river, Goarges Reservoir in China. They have used a range of 17 DEM spatial resolutions varying from 30m to 1000m and analyzed the results of the annual and monthly model outputs of sediments and nutrients for each resolution. The study noticed that sediment yield was greatly affected with DEM resolution and the predicted of dissolved oxygen load was significantly affected by DEM resolution coarser than 500 m. Total nitrogen (TN), NO_2 – N and total phosphorous (TP) loads were slightly affected with DEM resolution and ammonia nitrogen (NH_4-N) load was essentially unaffected by the DEM resolution.

Several studies also investigated the effects of DEMs (Digital Elevation Model) obtained from ground surveys and/or resampling/interpolation of digital contours on hydrological response of watersheds. In recent years, new DEMs of the earth's surface have become available. For example, CARTO DEM (cartosat-1 Digital Elevation Model) a National DEM developed by ISRO (Indian Space Research Organization) that has a high resolution of 30m, and a global elevation dataset, ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer) that has a spatial resolution of 30 m. The DEM data of CARTO and ASTER cover most of the regions of India and are publicly available at a spatial resolution of 30 m. Therefore, there is a need to evaluate the sensitivities of these DEMs on SWAT model performance and understand the hydrological response of watersheds in India. The objective of this study includes applying SWAT for hydrological modelling of 'Sina' watershed, Maharashtra in India, and analyzing the influence of different spatial resolution DEMs (ALOS-PALSAR 12.5m, CARTOsat-30m, ASTER-30 m, SRTM-30m, SRTM -90m) on runoff at a daily timescale.

2. METHODS AND MATERIALS

To apply SWAT for hydrological modelling, it requires spatial data inputs of Digital Elevation Model (DEM), soil map, LandUse/LandCover (LU/LC) map and temporal data of meteorological data. Based on the DEM information, the Soil and Water Assessment Tool (SWAT) is a continuous simulation macro scale hydrologic model that was developed by USDA-ARS for predicting runoff, sediment and nutrient transport from agricultural watersheds under different land management practices [20]. This study uses ArcSWAT 2009 version, which is an extension within the Environmental Systems Research Institute (ESRI) GIS software package Arc-Map. A detailed description of the SWAT model and its application can be found in the studies by Arnold and Fohrer (2005) [28] and Neitsch et al (2011) [22].

SWAT model divides the watershed into multiple sub-watersheds that are further subdivided into HRUs (Hydrologic Response Units). The HRUs are lumped units consisting of homogeneous land-use, management and soil characteristics [29]. In SWAT model, different parameters are calculated for each individual HRU. The HRUs facilitate to account for the impact of different land-use types, soil properties and management practices on the hydrological response of a basin. Most of the hydrological processes in SWAT (e.g. evapotranspiration, surface runoff, ground water flow and sediment yield, etc.) take place at the HRU level and the water balance is simulated at this level before runoff is routed to the reaches of the sub-basins and then to the basin channel. Surface runoff volumes were estimated using the modified SCS curve number method [30], which uses an empirical relationship between rainfall and runoff that provides a consistent basis for estimating the amount of runoff under varying land-use, soil types and antecedent soil moisture conditions

2.1 Brief of Study Area

Sina river is a large tributary of the Bhima river which is starting near Ahmednagar city, and it is one of the large left bank feeder of the Bhima rises 22 km West of Torna in Ahmadnagar district and runs south-east through Ahamdnagar and Solapur district to fall into the Bhima near Kudul about 25 km south of Solapur on the Maharashtra and Karnataka boundary. Sina river has two chief sources one near Jamgaon about 20 km west of the town of Ahmadnagar and the other near Jeur about 16 km to its north-east. The Sina is crossed by five ferries one in Madha at Kolgaon and four in Solapur at Lamboti, Tirha, Vaddukbai and Vangi. Of its entire length 180 km the river has a length of 17 km within the district. For a distance of 55 km roughly, the river forms boundary between Ahmadnagar district on the one hand and Beed district on the other. On the right, it receives the water of Mahekri, and ultimately joins the Bhima on the Karnataka state border. It has earth filled Sina Dam near Karjat in Ahmadnagar district.

'Sina' watershed was selected as a case study for evaluating the effect of spatial resolutions of DEM on hydrological response of watershed specifically for runoff. The Sina river watershed lies between latitudes 17°25′–19°15′N and longitudes 74°10′–76°05′E. The location map of study area is shown Fig.2. The areal extent of the study area is 12,304 km^2. The climate in the study area is semi-arid with an average annual rainfall of 715 mm and is a typical rain fed watershed characterized with dry land crops the average values of monthly minimum and maximum temperatures recorded in summer ranges from 26 to 42.5°C and the monthly average temperature recorded in winter ranges from 16 to 29°C.

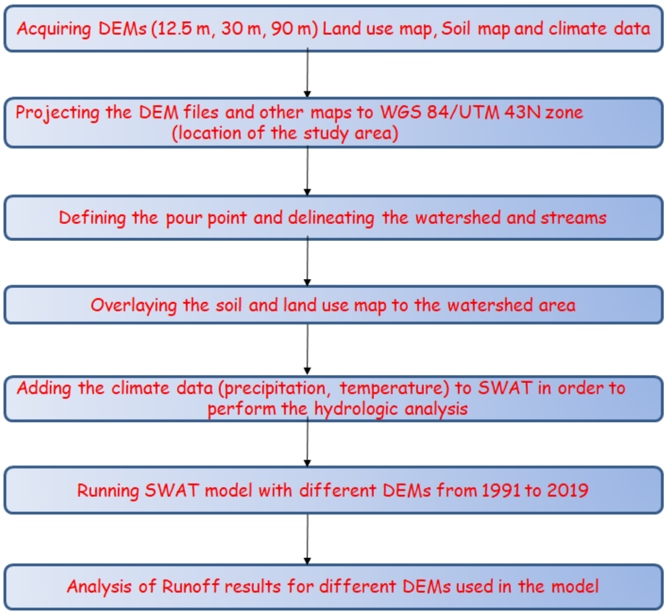


Fig-1: Flow chart of Method applied

2.2 Input Data utilized for SWAT Model

The input spatial data sets for the SWAT model are DEM, land use map, soil map and hydro-climatic data. The land use (2016) obtained from Bhuvan-ISRO web portal [31] and soil map from FAO-USGS [32]. Thirty-six years (1985-2020) of daily precipitation, maximum and minimum temperature data at 5 different locations were downloaded from NASA-POWER web portal [33]. The weather data from 5 different locations downloaded in and around the catchment namely (i)Solapur, (ii)Barshi, (iii)Karmala, (iv)Beed, (v)Ahamdnagar.

2.3 Digital Elevation Model

Digital Elevation Model (DEM) data plays an important role in SWAT modelling. The topographic attributes of the sub-basin, including area, slope, and field slope length are all derived from the DEM. So are channel length, channel slope, channel width, and channel depth, if the channel is automatically generated based on DEM but not previously defined. Five freely available global DEM products including Advanced Land Observing Satellite–Phased Array type L-band Synthetic Aperture Radar (ALOS-PALSAR) 12.5m, Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) Global DEM 30m, CARTOgraphy and SATellite (CARTOSAT-1) launched and maintenance by Indian Space Research Organization (ISRO) 30m and Shuttle Radar Topography Mission (SRTM) 30 m and 90 m resolution DEMs were considered for this study and details of these DEMs are shown in Table-1.

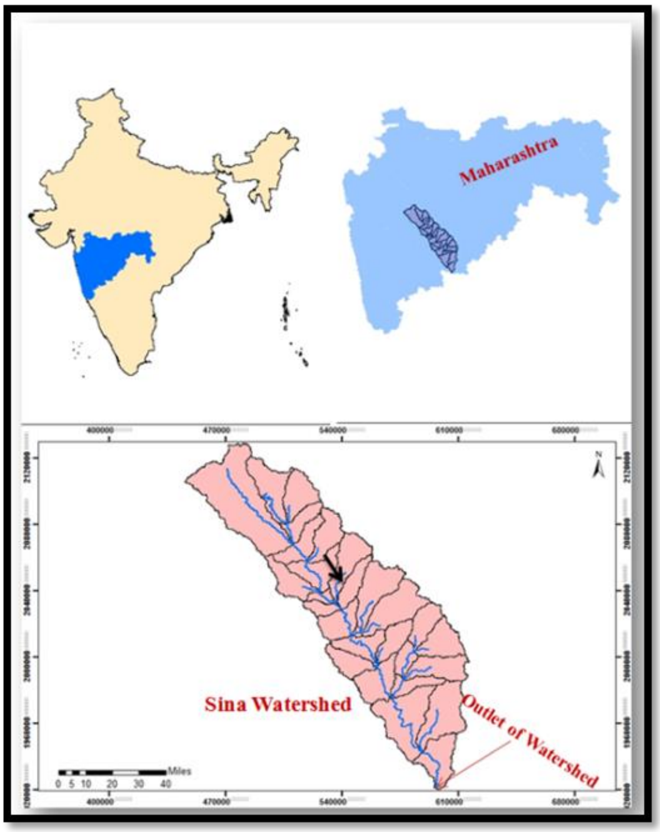


Fig-2: Location map of 'Sina'-Watershed

2.4 SWAT Model Application

The changes in hydrological response of watershed due to different DEM resolutions are assessed by running the SWAT model with five different DEMs of ALOS-PALSAR 12.5m, ASTER-30m, CARTO-30m, SRTM-30m and SRTM-90 m. Since, the calibration of SWAT model parameters can impact the uncertainty coming from input data [34], so the SWAT model is not calibrated in this study. The SWAT model is executed for each DEM keeping other simulation conditions constant, which include: (1) input data on LU/LC, soil, meteorological parameters and land management (2) the threshold drainage area of 10,000 ha for stream definitions to produce sub-basins (3) the same HRUs definition thresholds of land use (10%), soil (10%) and slope (5%) and (4) Hargreaves method of evapotranspiration (5) the default values were selected for other parameters.

Table.1 Details of different DEM's used

Sl.no	Name of DEM data set	Resolution, m	Source organization
1	Advanced Land observing Satellite Phased Array type L-band Synthetic Aperture Radar ALOS-PALSAR	12.5x12.5	Alaska Satellite Facility (ASF) Distributed Active Archive Center (DAAC)
2	CARTOgraphy and SATellite CARTOSAT-1	30 X 30	Indian space research organization (Bhuvan- ISRO)
3	ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer)	30x30	Ministry of economy Trade and Industry (METI) of Japan and the United States national Aeronautics and Space Administration (NASA)
4	Shuttle Radar Topography Mission (SRTM)	30x30	Consortium for Spatial Information (CSI) of the consultative Group of International Agricultural Research (CGIAR)
5	Shuttle Radar Topography Mission (SRTM)	90x90	Consortium for Spatial Information (CSI) of the consultative Group of International Agricultural Research (CGIAR)

3. RESULTS AND DISCUSSIONS

SWAT model run with all input data given with five different DEMs for 36 years of rainfall and temperature data, the results are discussed on the basis of spatial resolution variations predicted runoff. The next sections describe the impact of runoff on various aspects observed the results.

Table 2: Watershed characteristics of Different DEM resolutions

Description	Alos-12.5m	Aster-30m	Cartosat-30m	SRTM-30m	SRTM-90m
No of sub-basins	29	27	27	29	29
Area of watershed, km²	12,302	12,249	12,293	12,301	12,265
Longest flow path, m	296.48	307.252	312.711	316.396	316.998
Total reach Length, m	630.568	623.034	624.602	633.067	625.772
Min-Elevation	407	378	330	407	411
Max.-Elevation	966	967	897	966	964
Av. Slope of WSD	4.628	7.342	4.058	4.638	2.617
No. of HRU's	494	495	427	500	346
Av. Curve Number	84.99	84.98	84.98	84.99	84.97

3.1 Impact of DEM resolution on watershed delineation

The resolution of the DEM greatly impacts the watershed delineation, watershed size, and results in varying stream network system, number of sub-watersheds and HRUs. The details of the number of sub-watersheds and the number of HRUs that have resulted for different DEM resolution of ALOS-12.5m, ASTER-30m, CARTO-30m, SRTM-30m and SRTM-90m are given in Table-2.

While comparing all five DEMS, the ALOS-12.5m, SRTM-30m, SRTM-90m DEMs yielding large number of sub-watersheds. The coarser resolution of SRTM-90 DEM yielded lesser number of HRUs than finer resolution of ALSO-125m DEM. The minimum and maximum elevations of each DEM varied and the lesser values occurred for ASTER-30m resolution DEM. The lower longest flow path available for finer resolution DEM and the highest one available for coarser resolution DEMs. It was observed that, there was no particular increase or decrease trend in reach lengths for coarser and fine resolution DEMs. The average slope of watershed has no particular trend of increasing or decreasing order as the resolutions are coarser. The number of sub-watersheds and HRUs varied and decreased as the resolution become coarser.

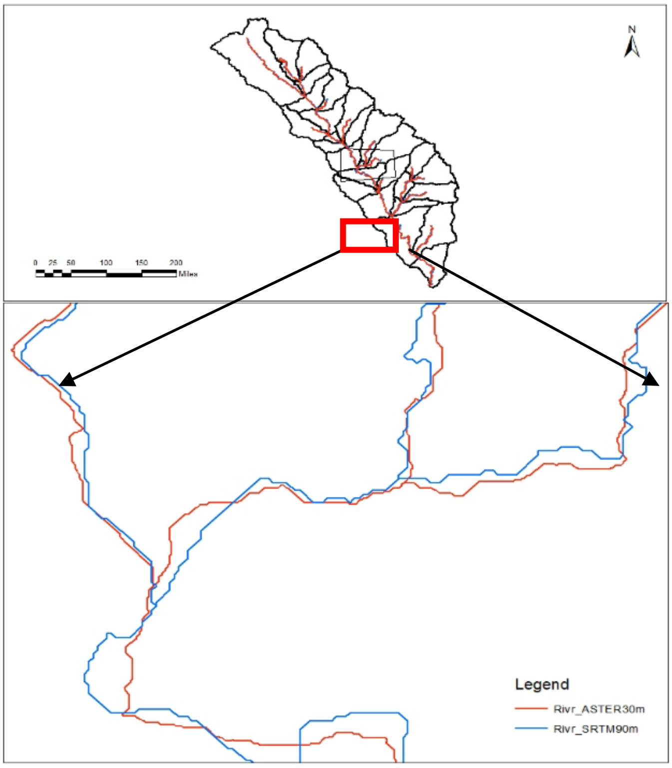
Here, it should be noted that runoff predicted at the HRU level within each sub-watershed and then routed to obtain total runoff yield for the watershed [22]. Hence, this difference in number of HRUs and sub-watersheds may result in loss of information on watershed heterogeneity and may result in increased variability of SWAT outputs.

3.2 Effects of DEM resolution on terrain and stream network characteristics

The DEMs of different resolutions influence the topographic representation and hierarchy of the stream networks of the watershed. The values of various topographic attributes for different DEM resolutions of ALOS-12.5m, ASTER-30m, CARTO-30m, SRTM-30m, and SRTM-90m are given in table-2. The results show that the mean slopes of sub-watersheds are sensitive to DEM resolution.

Change in the value of slopes could cause substantial variations in field slope lengths in ArcSWAT watershed delineations. From the results of Table-2, it is also noted that the reach lengths are varied substantially due to DEM resolutions, but no trend could be found. The resulted in major differences in the topographic features and stream network representation of watershed and sub-watersheds. Decreasing the resolution of a DEM tends to create a smoother, less defined landscape, with more moderate slope gradients and reduce curvatures. The most prominent differences among DEMs of varying resolutions are visible in the representation of the location of depression areas and drainage pathways. Fig.3 depicts disparity in the stream network directions and pathways that are delineated from

DEMs of CARTO-30m and SRTM-90m. The results indicated that there is a significant difference in the hierarchy order and segmentation of the stream networks in the watershed.



Fig– 3 Stream Network from CART-30m & SRTM-90m DEMs

Further, the results show that with decrease (coarser) in DEM resolution, it tends to overestimate the minimum altitude and underestimate the maximum altitude. This may be due to the loss of detailed topographic information at coarser resolution. In earlier studies by Lin et al (2010) [14] and Peipei et al (2014) [17] also noted that coarser DEM resolution increased the uncertainties of altitude and slope.

3.3 Simulation Results of all DEMs-Subbasin wise

First, the SWAT model was applied with ALOS-12.5m DEM to simulate surface runoff in 'Sina' watershed for daily time scale. The corresponding results of SWAT simulated daily runoff during 1985-2020 are present in Fig.4.

The SWAT model predicted the runoff well during the high flow period, i.e in the months of June-August, but tends to over predict the runoff during September-October months. Further, the SWAT model was executed by inputting different DEM resolutions of ASTER-30m, CARTO-30m, SRTM-30m, and SRTM-90m. The results of SWAT simulated runoff for the period 1985-2020 for five DEM resolutions are presented in figure 4, which shows low variability of simulated values among the different DEMs. Also, from Table-3, it can be inferred that the estimated runoff varied with both coarser and finer resolution.

The performance statistics also indicate that the accuracy of estimated daily runoff have decreased moderately with changes in DEM resolution. Results of SWAT simulated runoff according sub-basin wise for the period of 1985-2020 for five DEM resolutions are presented in Fig. 4. The results show that the daily runoff values have increased (decreased) for low (high) rainfall days with coarser resolution DEM. Sina watershed divided into 29 and 27 sub-watersheds based on the DEM resolution. Accordingly, ASTER-30m DEM predicted higher runoff in 15 sub-basins, the coarser resolution SRTM-90m DEM predicts higher runoff in 11 sub-watersheds. From ALOS-12.5 and SRTM-30m resolution DEMs predicts higher runoff in 2 and 1 number of sub-watersheds respectively. This result reveals that, there was no particular trend of increase or decrease in runoff resulted from 'Sina' watershed based on their resolutions of DEM. The tabular results are represented in the form of graph as shown in Fig. 3. The runoff values in all five DEMs not varied much and in the first 5 sub-basins the runoff predicted higher than the remaining sub-basins.

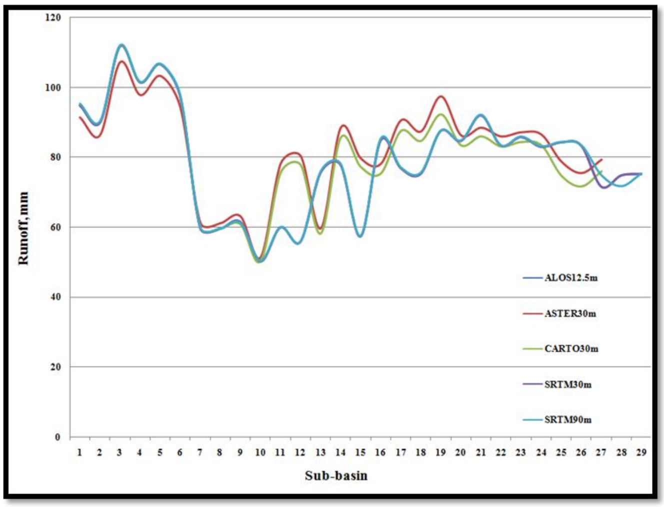


Fig-4 Runoff events for all DEMs, sub-basin wise

It is also noted that the SWAT model is very sensitive to SCS curve number values, which in turn very sensitive to land use. It is also observed that sub-watershed delineation varies with the DEM resolution and it directly affects the values of land use mapping areas within the watershed. The variation in runoff values for different resolutions can be attributed to the changes in sub-watershed areas and individual land use mapping units.

3.4 Simulation Results of all DEMs-Month wise

The Runoff predicted for all 5 categories of DEMs listed in table 4. The tabular values of runoff reveals that, ALOS-12.5m DEM has finer or high resolution not shows any high runoff prediction. The other 30m resolution DEMs of ASTER, CARTO and SRTM not showing any trend of either increase or decrease of runoff. The total runoff obtained for the entire year also not show any variation. The fine resolution DEM of ALOS-12.5m and coarser resolution of SRTM-90m DEM not followed any trend of variation in runoff prediction.

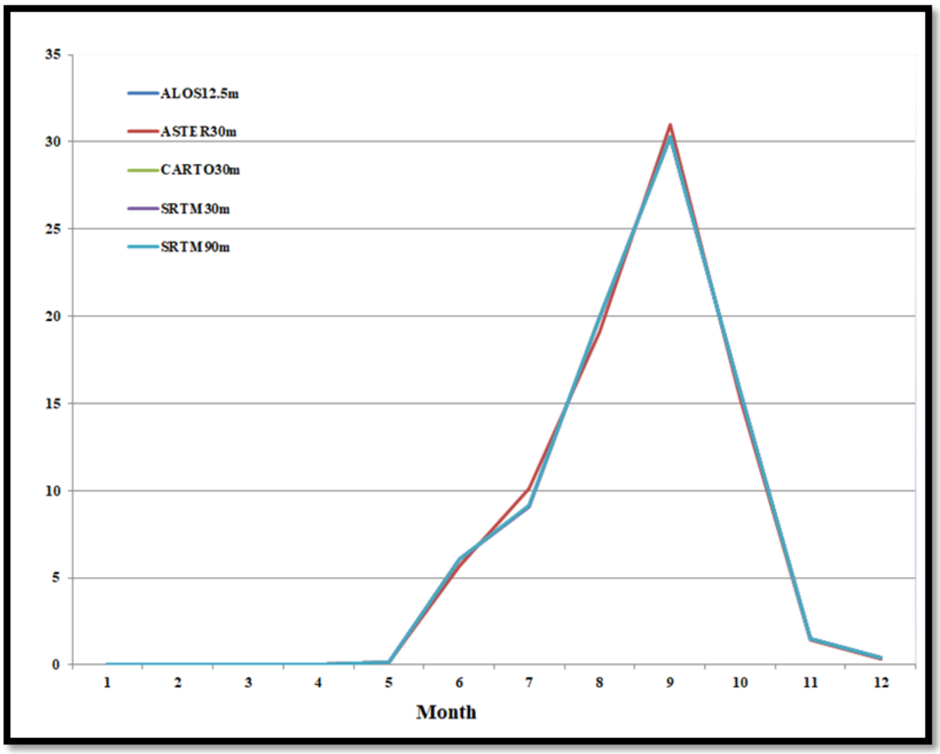


Fig-5 Runoff events for all DEMs –Month wise

From the table of results, it is observed that in monsoon season months of from June to October a little higher runoff predicted from SRTM 90m resolution DEM, whereas during non-monsoon season both DEMs delivered same amount of runoff. As a result, this may not be considered as the coarser resolution DEMs superior to predict higher runoff than fine resolution DEMs. In this study 2 different resolutions of 30m, 90m are consider for SWAT model simulation from SRTM fraternity. In the first 5 months of a year obtained same quantity of runoff for both DEMs and for next 5 months of June-October, SRTM-90 m resolution DEM predicted a very minute amount of higher runoff than 30m DEM. In the last 2 months of Nov-Dec, predicted same quantity of runoff for both DEMs. From this analysis it is also stated that, both DEMs not following any trend of increase or decrease of runoff. The percentage of runoff predicted from SRTM-90m higher by 0.168 than SRTM-30m DEM.

Similarly, the percentage of variation between SRTM-90m and ALOS-12.5m DEM obtained same as between SRTM-90 and SRTM-30m DEM resolutions. The percentage of variation may not be taken into account to state as increase in trend of runoff for coarser resolution DEMs. The other comparison between ALOS-12.5m DEM and ASTER-30m DEM, a little higher percentage of 0.204 obtained from ASTER-30m DEM.

This higher percentage of variation also not taken into account to stated that fine resolution DEMS predict lower runoff than coarser resolution DEMs. In this study, as a nutshell coarse resolution DEMs deliver a minute higher runoff than fine resolution DEMs. The month-wise runoff from different DEMs shown in the form of graph in Fig.5. The figure reveals that, the runoff predicted values have a minor variation between different resolutions of DEM. The runoff of all DEMs follows the same trend lines throughout the year according its seasonal variation. As per the hydrological cycle, the runoff starts rising during monsoon season and the peak obtained during the month of august and September, the fall of its intensity during non-monsoon months.

Table- 3: Average Annual Runoff in mm all DEM-Sina watershed

Sub-watershed No	ALOS 12.5 m	ASTER 30 m	CARTOsat 30 m	SRTM 30 m	SRTM 90 m
1	94.9118	91.4034	94.9975	94.945	95.3633
2	90.066	86.3326	90.0464	90.0677	90.362
3	111.9201	107.1987	111.883	111.9118	112.0637
4	101.5305	97.8077	101.4768	101.5341	101.605
5	106.7702	103.3066	106.8175	106.7876	106.8363
6	97.5517	94.3593	97.5733	97.5583	97.8273
7	59.8408	61.2785	59.9718	59.861	59.9965
8	59.6931	61.139	59.7275	59.6764	59.726
9	61.6168	63.125	60.9067	61.5576	61.3002
10	50.3023	51.361	50.2972	50.3097	50.4596
11	60.0626	78.1461	75.682	60.0771	60.1206
12	55.9687	80.3986	77.9226	55.9742	56.0178
13	75.722	59.6463	58.2569	75.7176	75.992
14	77.9521	88.4599	85.6991	77.9555	78.2034
15	57.4811	79.6561	77.2809	57.4784	57.6109
16	84.9778	78.129	75.4749	85.0111	85.3828
17	77.0223	90.5589	87.613	77.0179	77.2168
18	75.4219	87.4041	84.7821	75.4141	75.6686
19	87.7196	97.4223	92.346	87.7202	87.6878
20	84.7988	86.2693	83.4772	84.7912	84.8676
21	92.2309	88.4579	86.0589	92.0854	92.2141
22	83.4617	85.9625	83.1631	83.4633	83.4862
23	85.893	87.1498	84.4524	85.9043	86.0067
24	83.1101	86.5156	83.5367	83.0985	83.2226
25	84.3928	78.7494	74.7775	84.3833	84.4505
26	83.4925	75.4846	71.7532	83.484	83.5636
27	71.7121	79.3378	76.0633	71.7192	74.9941
28	74.9381			74.9347	71.8076
29	75.3129			75.3199	75.4077

Table- 4 Runoff predicted for all 5-DEMs according month-wise

Average monthly Runoff - Month wise					
	ALOS12.5m	ASTER30m	CARTO30m	SRTM 30m	SRTM 90m
Month	RO, mm	RO, mm	RO, mm	RO, mm	RO, mm
1-Jan	0.01	0.01	0.01	0.01	0.01
2-Feb	0	0	0	0	0
3-Mar	0	0.01	0	0	0
4-Apr	0.02	0.01	0.02	0.02	0.02
5-May	0.14	0.13	0.14	0.14	0.14
6-Jun	6.08	5.71	6.08	6.08	6.09
7-Jul	9.11	10.14	9.12	9.11	9.14
8-Aug	19.92	19.09	19.93	19.92	19.96
9-Sep	30.27	31.01	30.3	30.27	30.31
10-Oct	15.76	15.41	15.77	15.76	15.78
11-Nov	1.48	1.45	1.48	1.48	1.48
12-Dec	0.39	0.38	0.39	0.39	0.39

4. CONCLUSIONS

This study assessed the impact on simulated SWAT model runoff using of five DEM resolutions namely ALOS-12.5m, ASTER-30m, CARTO-30m, SRTM-30m and SRTM-90m. In the first stage of SWAT model derive the whole watershed into number of sub-watersheds, as a result of this operation the area of watershed and number of sub-basins are varied irrespective of DEM resolution. In case of longest flow path, coarser resolution DEMs derived higher value of longest flow path than finer resolution ALOS-12.5m DEM. Interestingly, the average slope of watershed has a trend of decrease in order of coarser resolution DEMs of ASTER-30m, CARTO-30m, SRTM-30m and SRTM-90m. It is observed that reach lengths, minimum and maximum elevations in the sub-watersheds varied substantially due to different DEM resolutions. In the process of SWAT modelling, Land use-Land cover map, soil groups map and slope of watershed used to derive HRUs. In this context, it is observed that there was no particular trend of increase or decrease of number of HRUs in the Sina watershed. Least number of HRUs derived in coarser resolution SRTM-90m DEM and highest number of HRUs from SRTM-30m DEM. The average curve number of Sina watershed not shown any variation for all different DEMs utilized in this study. In this study, the runoff results assessed according runoff sub-basin wise and runoff-month wise. The runoff results according sub-basin wise not followed any separate trend either increase or decrease based on DEM resolution. The runoff derived from Sina watershed, and the observation according month-wise runoff also not shown much variation from fine resolution to coarse resolution DEMs. The variation in runoff observed according season of the month as per theory of Hydrologic cycle. Results of this study indicate that the choice of input DEM resolution depends on the watershed response of interest. The results of the study infer that there is no particular trend of increase or decrease in estimation in daily runoff values with varying DEM resolutions.

REFERENCES

[1] Bormann H 2008 Sensitivity of a soil–vegetation–atmosphere transfer scheme to input data resolution and data classification; J. Hydrol. 351 154–169.

[2] Sharma A, Tiwari K N and Bhadoria P 2011 Determining the optimum cell size of digital elevation model for hydrologic application; J. Earth Syst. Sci. 120 573– 582.R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.

[3] Earls J and Dixon B 2005 A comparative study of the effects of input resolution on the SWAT model; River Basin Manag. III 83 213–222.

[4] Dixon B and Earls J 2012 Effects of urbanization on stream flow using SWAT with real and simulated meteorological data; Appl. Geogr. 35 174–190.

[5] Shen Z Y, Chen L and Chen T 2013 The influence of parameter distribution uncertainty on hydrological and sediment modelling: A case study of SWAT model applied to the Daning watershed of the three Gorges Reservoir Region, China; Stoch. Environ. Res. Risk Assess. 27 235–251.

[6] Ndomba P and Birhanu B 2008 Problems and prospects of SWAT model applications in Nilotic catchments: A review; Nile Basin; Water Eng. Sci. Mag. 1 41–52.

[7] Bruneau P, Gascuel-Odoux C, Robin P, Merot P and BevenK 1995 Sensitivity to space and time resolution of a hydrological model using digital elevation data; Hydrol.Process. 9 69–81.

[8] Li Z, Shao Q, Xu Z and Cai X 2010 Analysis of parameter uncertainty in semi-distributed hydrological models using bootstrap method: A case study of SWAT model applied to Yingluoxia watershed in northwest China; J. Hydrol.385 76–83.

[9] Shen Z Y, Chen L and Chen T 2013 The influence of parameter distribution uncertainty on hydrological and sediment modelling: A case study of SWAT model applied to the Daning watershed of the three Gorges Reservoir Region, China; Stoch. Environ. Res. Risk Assess. 27 235–251.

[10] Cotter A S, Chaubey I, Costello T A, Soerens T S and Nelson M A 2003Water quality model output uncertainty as affected by spatial resolution of input data; J. Am. WaterResour. Assoc. 39 977–986.

[11] Chaplot V 2005 Impact of DEM mesh size and soil map scale on SWAT runoff, sediment, and NO3–N loads predictions;J. Hydrol. 312 207–222.

[12] Chaubey I, Cotter A S, Costello T A and Soerens T S2005 Effect of DEM data resolution on SWAT output uncertainty; Hydrol. Process. 19 621–628.

[13] Freeman T G 1991 Calculating catchment area with divergent flow based on a regular grid; Comput. Geosci. 17(3)413–422.

[14] Lin S, Jing C, Chaplot V, Yu X, Zhang Z, Moore N and Wu J 2010 Effect of DEM resolution on SWAT outputs of runoff, sediment and nutrients; Hydrol. Earth Syst. Sci.Discuss. 7 4411–4435.

[15] Xu H, Taylor R G, Kingston D G, Jiang T, Thompson J R and Todd M C 2010 Hydrological modelling of River Xiangxi using SWAT2005: A comparison of model parameterizations using station and gridded meteorological observations; Quat. Int. 226 54–59.

[16] Bormann H, Breuer L, Graff T, Huisman J A and Croke B2009 Assessing the impact of land use change on hydrology by ensemble modelling (LUCHEM) IV: Model sensitivity to data aggregation and spatial (re) distribution; Adv. Water Resour. 32 171–192.

[17] Peipei Z, Ruimin L, Yimeng B, Jiawei W, Wenwen Y and Zhenyao S 2014 Uncertainty of SWAT model at different DEM resolutions in a large mountainous watershed; Water Res. 53(1) 132–144.

[18] Brown D G, Bian L and Walsh S J 1993 Response of a distributed watershed erosion model to variations in input data aggregation levels; Comput. Geosci. 19 499–509.

[19] Bormann H 2006 Impact of spatial data resolution on simulated catchment water balances and model performance of the multi-scale TOPLATS model; Hydrol. Earth Syst.Sci. 10 165–179.

[20] Arnold J G, Srinivasan R, Muttiah R S and Williams J R1998 Large area hydrologic modelling assessment. Part I:Model development; J. Am. Water Resour. Assoc. 34(1)73–89.

[21] Santhi C, Arnold J G, Williams J R, Dugas W A and HauckL 2001 Validation of the SWAT model on a large river basin with point and nonpoint sources; J. Am. Water Resour. Assoc. 37(5) 1169–1188.

[22] Neitsch S L, Arnold J G, Kiniry J R, Williams J R and King K W 2011 Soil and water assessment tool theoretical documentation version 2009; Texas Water Resources Institute, College Station, TWRI Report TR-191, Texas, USA.

[23] SCS 1972 Hydrology; National Engineering Hand Book, USDA–Soil Conservation Services, Washington DC, USA

[24] Cotter A S, Chaubey I, Costello T A, Soerens T S and Nelson M A 2003Water quality model output uncertainty as affected by spatial resolution of input data; J. Am.WaterResour. Assoc. 39 977–986.

[25] Dixon B and Earls J 2009 Resample or not?! Effects of resolution of DEMs in watershed modelling; Hydrol. Process.23 1714–1724.

[26] Peter C B, Ali M S, Megan W L, Mark D T and Craig S T D2013 Sediment delivery estimates in water quality models altered by resolution and source of topographic data; J. Environ. Quality 43(1) 26–36.

[27] Peipei Z, Ruimin L, Yimeng B, Jiawei W, Wenwen Y and Zhenyao S 2014 Uncertainty of SWAT model at different DEM resolutions in a large mountainous watershed; Water Res. 53(1) 132–144.

[28] Arnold J G and Fohrer N 2005 SWAT2000: Current capabilities and research opportunities in applied watershed modelling; Hydrol. Process. 19 563–572.

[29] Gassman P W, Reyes M R, Green C H and Arnold J G 2007The soil and water assessment tool: Historical development, applications, and future research directions; Trans. ASABE 50(4) 1211–1240.

[30] Arnold J G, Muttiah R S, Srinivasan R and Allen P M2000 Regional estimation of base flow and groundwater recharge in the Upper Mississippi river basin; J. Hydrol.227(1–4) 21–40.

[31] BhuvanISRO,https://bhuvanapp3.nrsc.gov.in/data/download/index.php, browsed on 02nd feb.2020

[32] FAO-USGS,http://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/faounesco-soil-map-of-the-world/en/

[33] NASA-POWER,https://power.larc.nasa.gov/data-access-viewer/, browsed on 12th Feb.2020

[34] Abbaspour K 2013 SWAT Model CUP; www.eawag.ch/forschung/siam/software/swat/index.