

Event-based rainfall-runoff modeling for a data-scarce semi-urban catchment using PC-SWMM: A case study for Vizianagaram town, Andhra Pradesh, India.

L K S V PRASAD SALLANGI^{1,2}, Venkatesh Kasi³, and Maheswaran Rathinasamy⁴

¹JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY

²JAWAHARLAL Nehru Technological University, kakina

³Indian Institute of Technology, Bhubaneswar

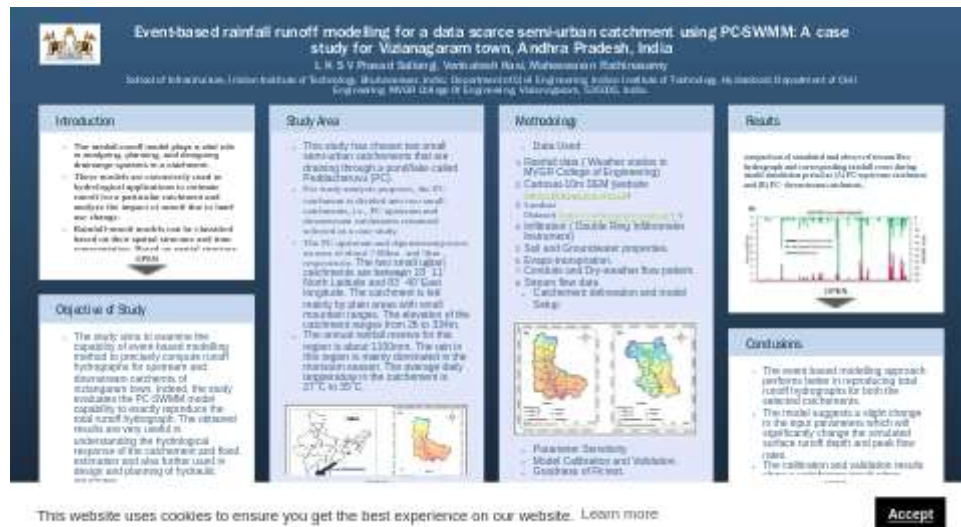
⁴Indian Institute of Technology, Hyderabad.

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Abstract

The rainfall-runoff model is essential to derive a relationship between Rainfall and Runoff, in which the hydrological response of the catchment can be derived. A real case study is chosen to simulate the rainfall-runoff modeling, in which small urban catchments are selected and are located in the center part of Vizianagaram Town. The present case study aims to develop an event-based rainfall-runoff model for upstream and downstream catchments of peddacheruvu catchment (PC). In this study, Cartosat-10mDEM, Hourly rainfall data are taken from (weather station), i.e., 1st July to 30th September, the Maximum and Minimum Infiltration rates, Evaporation data, soil data, Groundwater parameters, and dry weather flow patterns are used as in input for model simulation to know the wet weather flow and dry weather flow quantity contributing from the catchment. The model simulation is carried out by using the stormwater management model i.e., PC-SWMM version 5.7.1868. The model simulation is performed at two outlet points in the catchment. The upstream and downstream catchments are selected for computing the total runoff hydrographs. The model calibration is done for nine selected streamflow events from 1st July to 31st August 2019, and the remaining three streamflow events are chosen from 1st to 30th September 2019 are set for model validation. The model performance was checked by computing nine goodness of fit measures. The results of this study suggest that simulated runoff values have satisfactory results with the observed streamflow. In recent years, understanding the hydrological modeling and process has become more important in water resource management, especially in analyzing extreme hydrological events like floods or droughts. The availability of metrological and hydrological data is often scarce in a semi-urban catchment. Some of the significant issues are associated with obtaining reliable long-term hydrological data in the semi-urban region. This study investigates the performance of event-based modeling for data-scarce semi-urban catchments using PC-SWMM in computing the total runoff hydrograph. A real case study, i.e., Peddacheruvu (PC) Upstream and Downstream catchment, were selected, and model performance was examined using 12 streamflow events from 1 July 2019 to 31 September 2019. The model performances are evaluated using five goodness of fit measures like root mean square error (RMSE), Nash Sutcliffe efficiency (NSE), coefficient of determination (R²), RSR, and Kling Gupta efficiency (KGE). The model performance is acceptable throughout model calibration (1 July to 31 August 2019) as the NSE and R² varies between 0.75 to 0.77 and 0.76 to 0.78, respectively. Similarly, the model validation performances (1 September to 31 September 2019) revealed best fitted with the observed hydrograph for NSE and R² were 0.62 to 0.64 and 0.62 to 0.85. KGE for model calibration and validation model varies between 0.65 to 0.75 and 0.62 to 0.75.

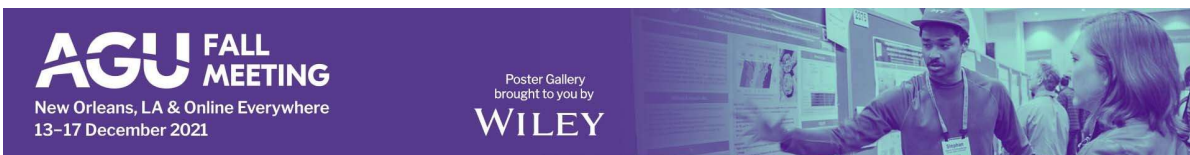
Event-based rainfall runoff modelling for a data scarce semi-urban catchment using PC-SWMM: A case study for Vizianagaram town, Andhra Pradesh, India



L K S V Prasad Sallangi, Venkatesh Kasi, Maheswaran Rathinasamy

School of Infrastructure, Indian Institute of Technology, Bhubaneswar, India; Department of Civil Engineering, Indian Institute of Technology, Hyderabad; Department of Civil Engineering, MVGR College Of Engineering, Vizianagaram, 535005, India.

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INTRODUCTION

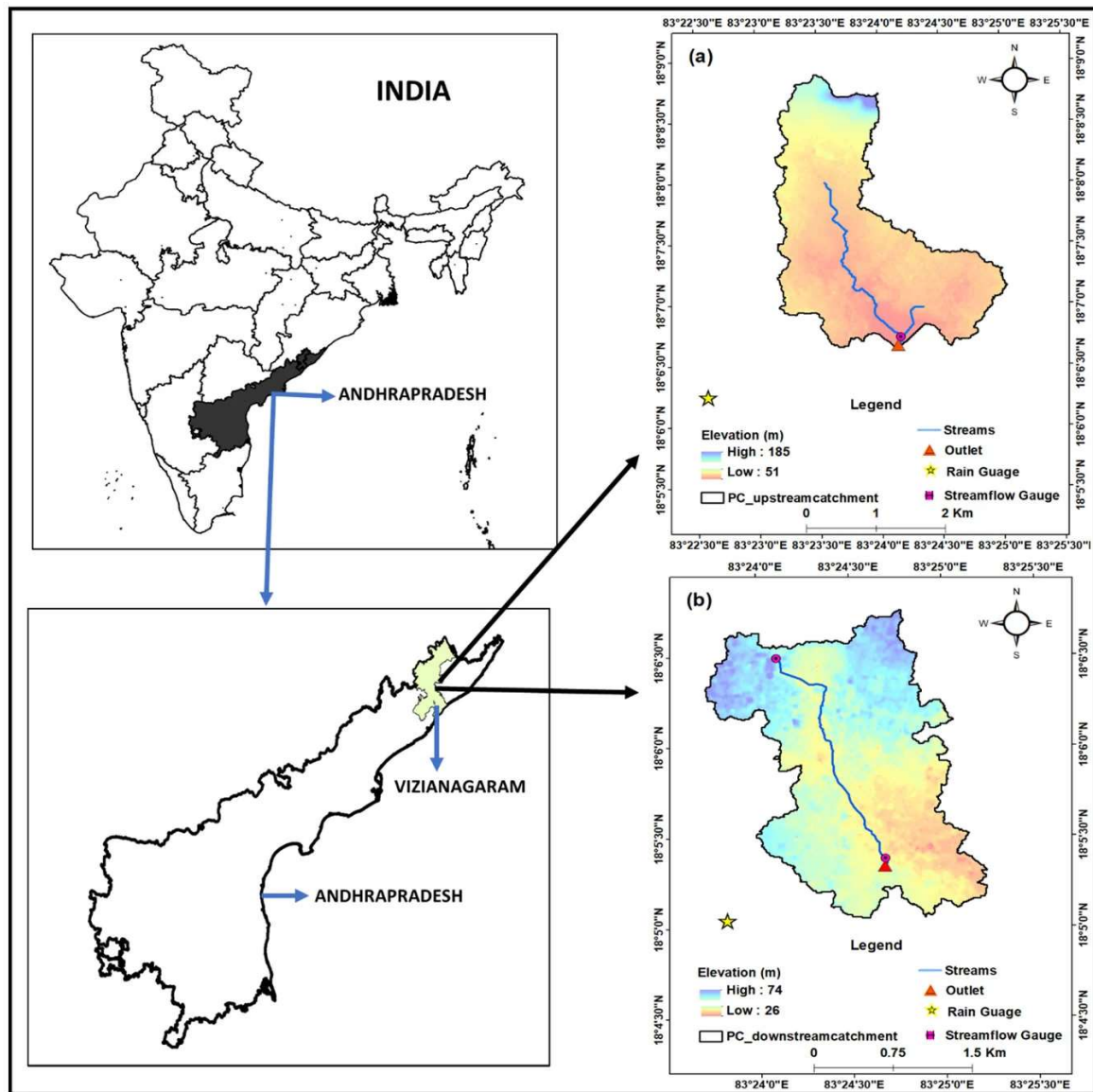
- The rainfall-runoff model plays a vital role in analyzing, planning, and designing drainage systems in a catchment.
- These models are extensively used in hydrological applications to estimate runoff for a particular catchment and analyze the impact of runoff due to land-use change.
- Rainfall-runoff models can be classified based on their spatial structure and time representation. Based on spatial structure, the models are further classified into lumped, semi-distributed and distributed models. Whereas in time representation, models are classified into event based and continuous based models.
- There are many advantages and limitations with event-based and continuous simulation models. In event-based modelling, only infiltration loss is taken into consideration, whereas in the continuous simulation modelling, only evapotranspiration loss is accounted.

OBJECTIVE OF STUDY

- The study aims to examine the capability of event-based modelling method to precisely compute runoff hydrographs for upstream and downstream catchments of viziangaram town. Indeed, the study evaluates the PC-SWMM model capability to exactly reproduce the total runoff hydrograph. The obtained results are very useful in understanding the hydrological response of the catchment and flood estimation and also further used in design and planning of hydraulic structures.

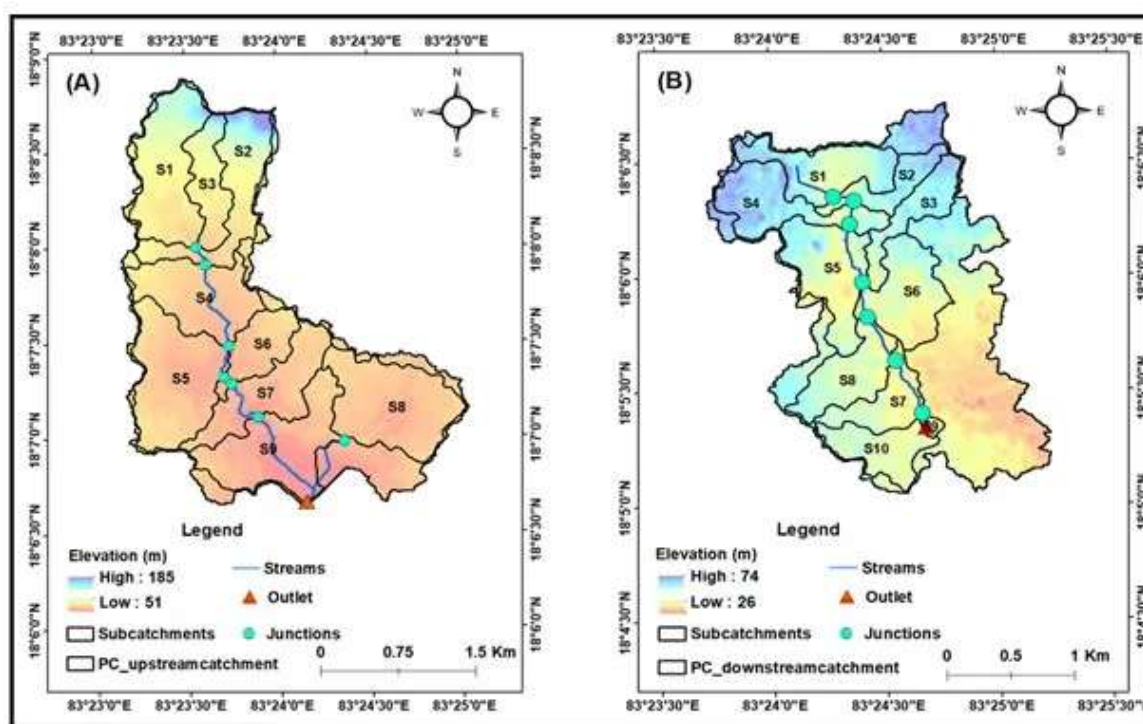
STUDY AREA

- This study has chosen two small semi-urban catchments that are draining through a pond/lake called Peddacheruvu (PC).
- For study analysis purposes, the PC catchment is divided into two small catchments, i.e., PC upstream and downstream catchments remained selected as a case study.
- The PC upstream and downstream covers an area of about 7.08km^2 and 5km^2 , respectively. The two small urban catchments are between $18^\circ 11'$ North Latitude and $83^\circ 40'$ East longitude. The catchment is led mainly by plain areas with small mountain ranges. The elevation of the catchment ranges from 26 to 334m.
- The annual rainfall receive for this region is about 1100mm. The rain in this region is mainly dominated in the monsoon season. The average daily temperature in the catchment is 27°C to 35°C .



METHODOLOGY

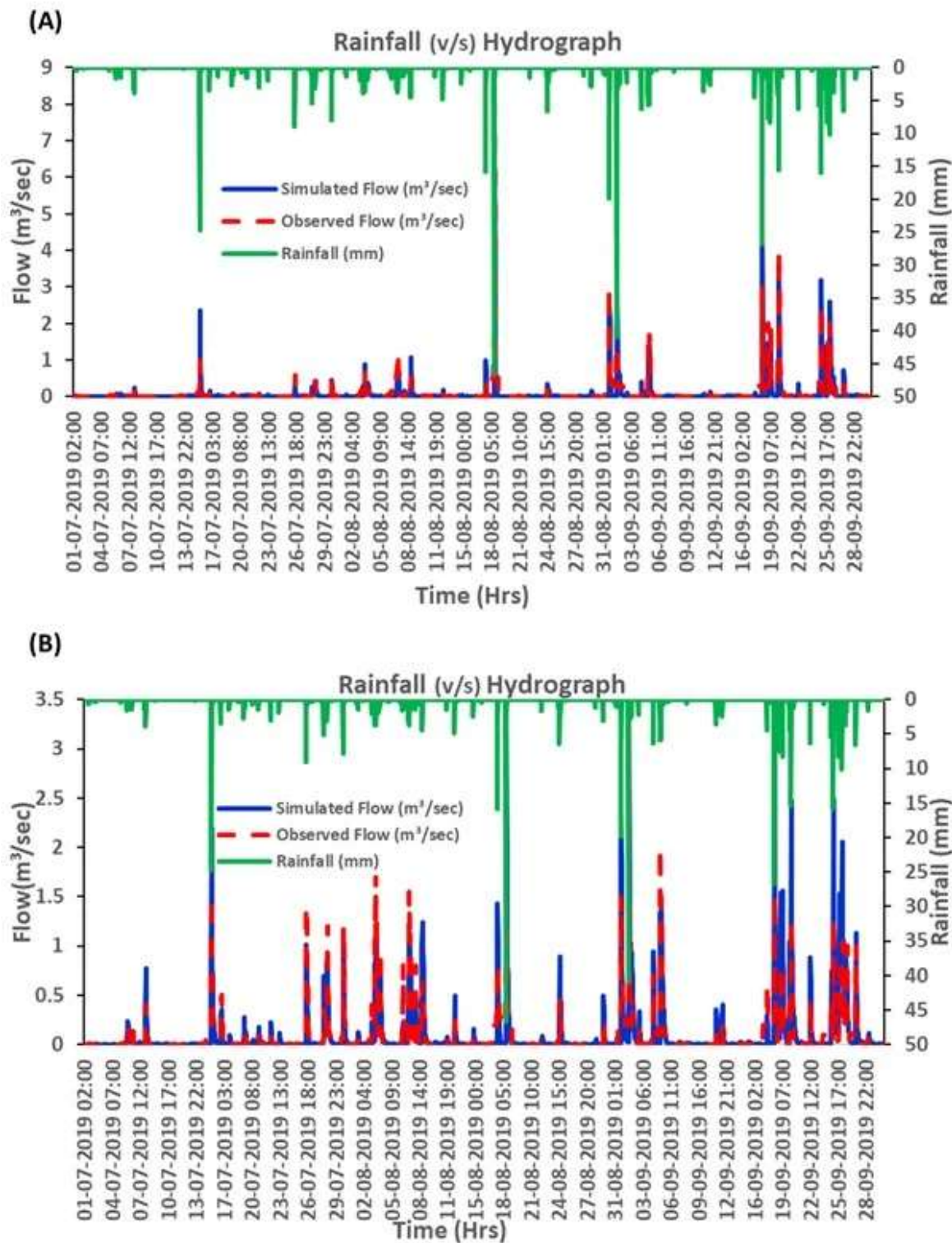
- Data Used:
 1. Rainfall data (Weather station in MVGR College of Engineering)
 2. Cartosat-10m DEM (website <https://bhuvan.nrsc.gov.in> (<https://bhuvan.nrsc.gov.in/>))
 3. Landsat Dataset(<https://earthexplorer.usgs.gov/> (<https://earthexplorer.usgs.gov/>))
 4. Infiltration (Double Ring Infiltrometer Instrument)
 5. Soil and Groundwater properties.
 6. Evapo-transpiration.
 7. Conduits and Dry-weather flow pattern.
 8. Stream flow data
- Catchement delineation and model Setup

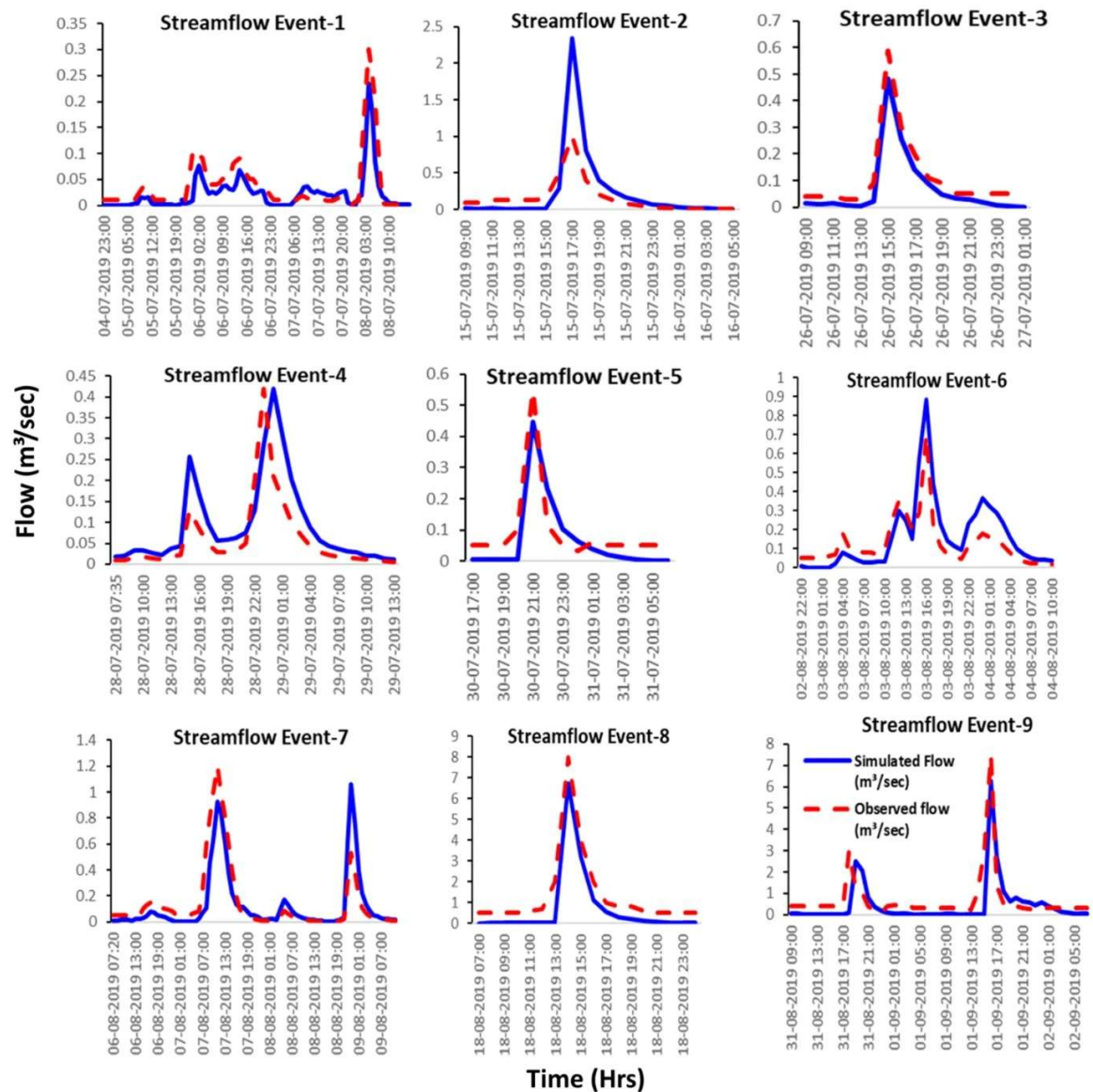


- Parameter Sensitivity
- Model Calibration and Validation.
- Goodness of Fit test.

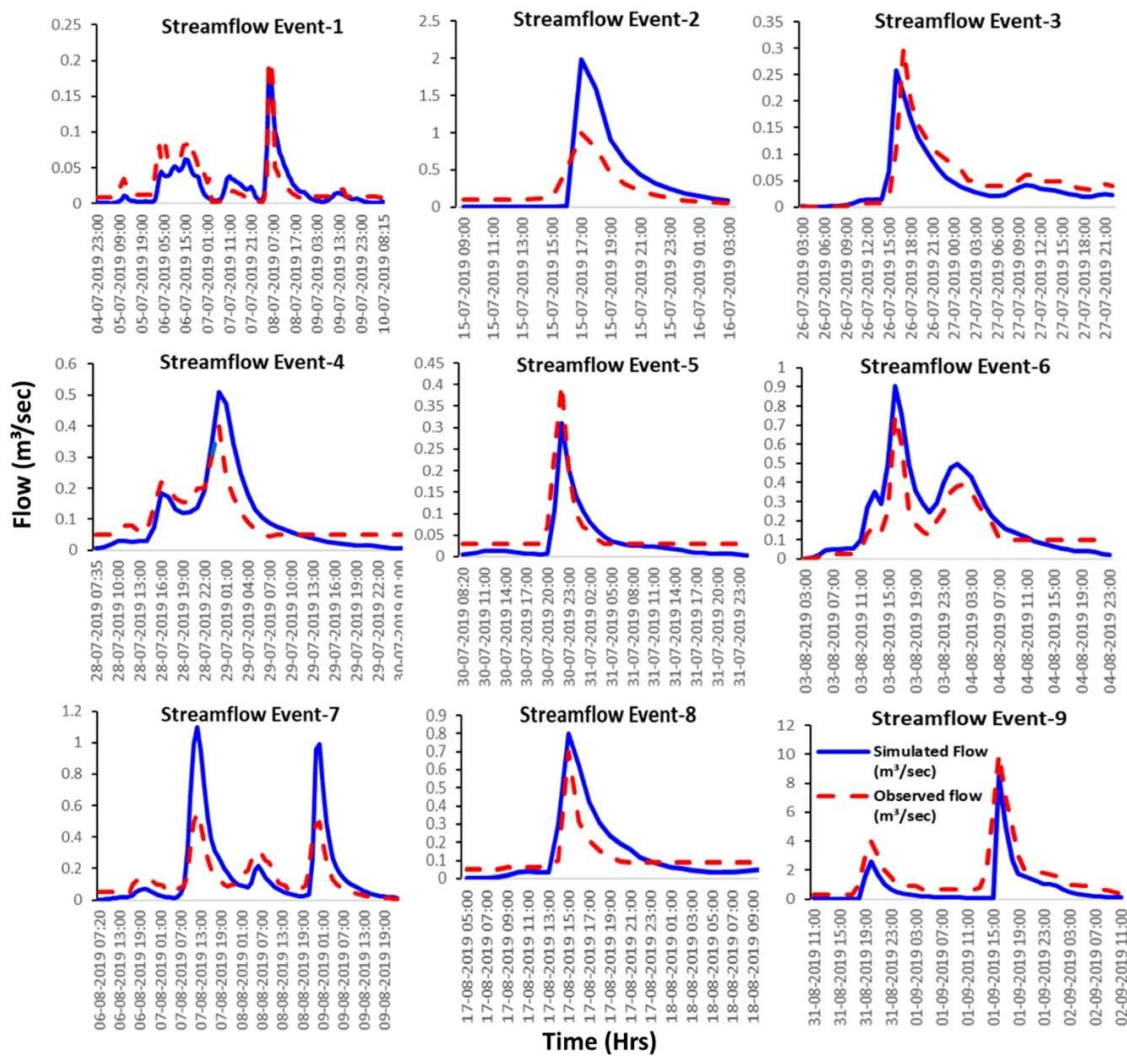
RESULTS

comparison of simulated and observed stream flow hydrograph and corresponding rainfall event during model simulation period at (A) PC-upstream catchment and (B) PC- downstream catchment.

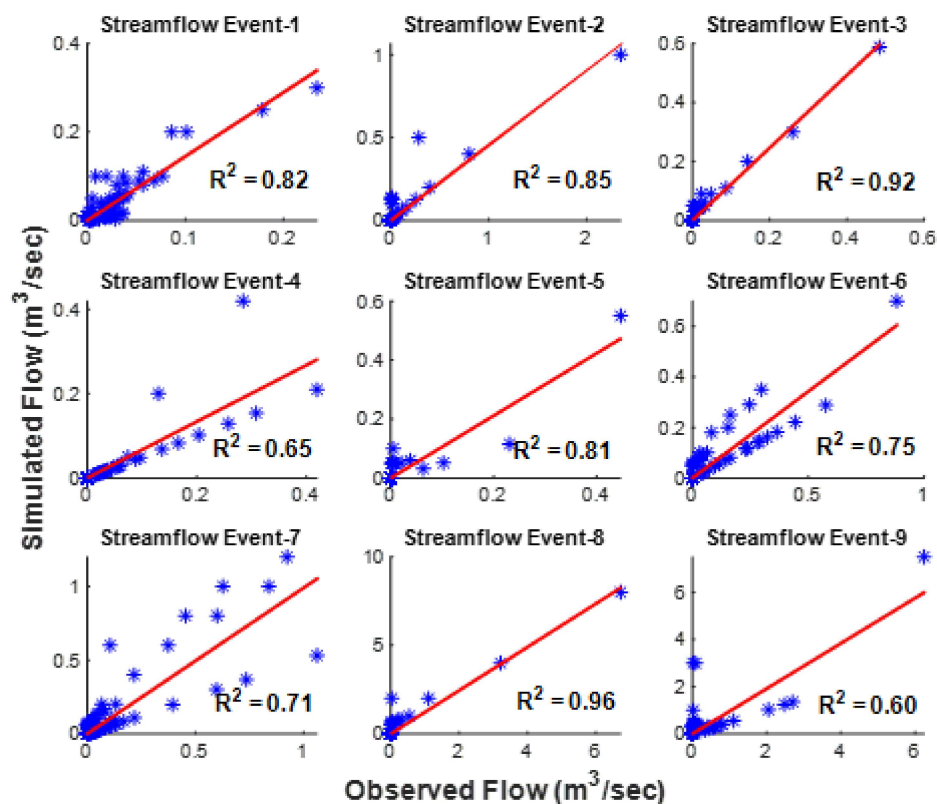




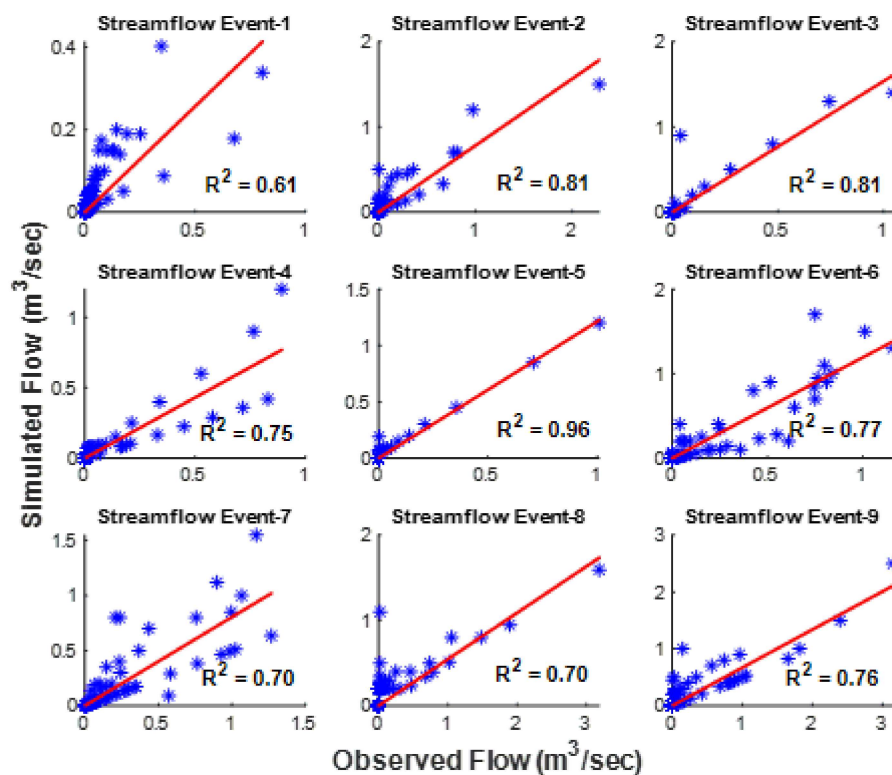
Comparison of event-based model with observed streamflow during the model calibration period for PC upstream catchment



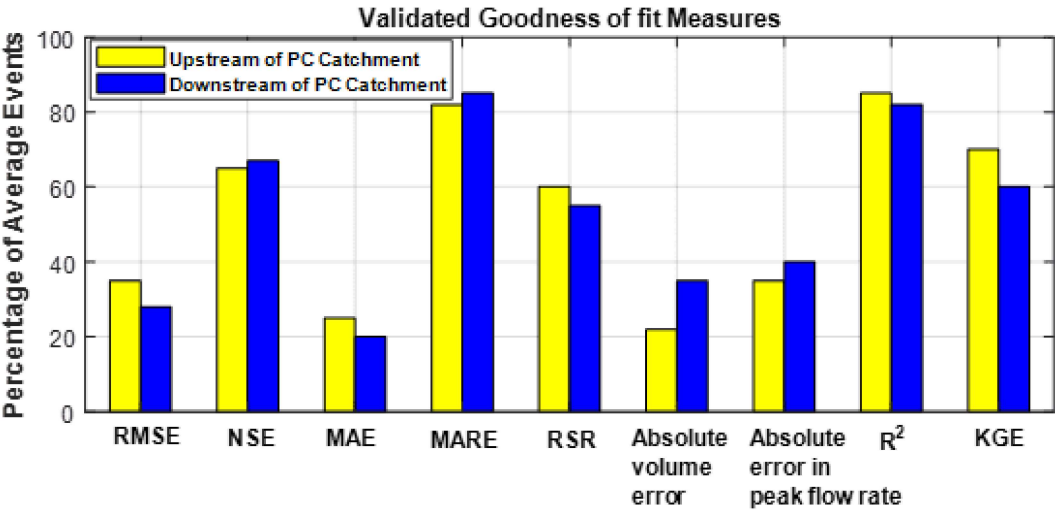
Comparison of event-based model with observed streamflow during the model calibration period for PC Downstream catchment



R^2 values for Upstream Catchment



R^2 values for Downstream Catchment



Validated Goodness of Fit tests measures for PC upstream and downstream catchment.

CONCLUSIONS

- The event based modelling approach performs better in reproducing total runoff hydrographs for both the selected catchments.
- The model suggests a slight change in the input parameters which will significantly change the simulated surface runoff depth and peak flow rates.
- The calibration and validation results show a satisfactory result when compared to goodness of fit measures for simulated and observed streamflow events.
- The event based modelling approach can highly be implemented on data scarce regions to quantify the runoff that permits the model with more reliable results.
- In conclusion, the event based modelling results can be used for future studies in analyzing the extreme hydrological events such as floods or droughts.

ABSTRACT

Rainfall runoff modelling in a data scarce region has always been challenge and is interest to hydrologist. With increasing flood disasters in urban clusters across the globe, it is pertinent to develop accurate rainfall runoff models for applications such as flood forecasting, inundation modelling. This study investigates the performance of event-based modelling for a data-scarce semi-urban catchment using PC-SWMM in computing the runoff hydrograph. For this purpose, a case study from Vizianagaram, South eastern India is presented. For the model development and calibration, the rainguage data, discharge data and the infiltration characteristics were estimated using simple measurement methods for the period from 1 July 2019 to 31 September 2019 for 12 different events. The model performances are evaluated using five goodness of fit measures like root mean square error (RMSE), Nash Sutcliffe efficiency (NSE), coefficient of determination (R^2), RSR, and Kling Gupta efficiency (KGE) for all the individual events. The model performance is acceptable throughout model calibration as the NSE and R^2 varies between 0.75 to 0.77 and 0.76 to 0.78, respectively. Similarly, the model validation performances (1 September 2019 to 31 September 2019) revealed best fitted with the observed hydrograph for NSE and R^2 were 0.62 to 0.64 and 0.62 to 0.85. KGE for model calibration and validation model varies between 0.65 to 0.75 and 0.62 to 0.75. The results of this study suggest that the PC-SWMM model along with simple methods of measurement can be reliably used for rainfall-runoff modelling in data scarce regions.