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Hydrological modelling using SWAT

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Abstract

Land and Water are the two important natural resources as the entire life system is depend on it. Hence effective management of it is essential for optimum utilization. The hydrological modelling is effective tool for management of land and water resources as well as hydrologic behaviour of watershed. Soil and Water Assessment Tool (SWAT) is a physical based distributed parameter model having capability of prediction of runoff, erosion, sediment and nutrient transport from agricultural watersheds under different management scenario in conjunction of Arc GIS. The present study was undertaken for upper Godavari sub basin using SWAT (Soil and Water Assessment Tool) model, which has the capability to integrate GIS databases for estimation of runoff. In the catchment area has been delineated using the Digital Elevation Model (DEM). The Land Use Land Cover (LULC) map was prepared using IRS-P6 LISS-III image. The Slope maps also prepared using DEM. The hydro meteorological data from 1994 to 2014 was used for modelling. The upper sub basin was delineated into 2468 sub basin by taking flow accumulation threshold of 500 ha. It further sub divided into 10,594 HRUs. Each HRU was evaluated by multiple hydrologic response unit option by considering land used cover area of each sub catchments 20 per cent and soil class as 20 per cent and slope parameter 20 per cent. Using hydro-meteorological data runoff was simulated using SWAT model. The coefficient of determination for calibration period was 0.81 and for calibration period was 0.84 for upper Godavari basin. The results showed that model performance for simulating runoff during calibration and validation period was satisfactory for upper Godavari basin in Maharashtra. The results shows that properly validated SWAT model can be used effectively in testing management scenarios in watersheds. The SWAT model with GIS environment show very effective tool for hydrological modelling.

Keywords: SWAT, Runoff, Watershed, Simulation, Rainfall, Godavari.

Introduction

Land and Water are two important natural resources; as the entire life system is depend on it. Effective management of these natural is very much important. The natural resources are mostly managed on the basis of watershed as natural unit. Watershed is a natural hydro geological entity bounded by a ridge line having single outlet. The optimal management of water resources is the necessity of time in the wake of development and growing need of the Indian population. In hydrology, estimation of river runoff is a very important for a range of water management operations. It includes both real-time operational processes and offline uses for design and planning. Rainfall and equivalent runoff generated are most important hydrological processes which depend on the local physiographic, biotic and climatic factors[1]. For any river basin accurate forecasting of Rainfall-Runoff (R-R) through modeling is challenging task for scientists and engineers. The rainfall-runoff process is one of the non linear complex outcomes of different hydrologic parameters, viz. rainfall intensity, geomorphology of watershed, evaporation, infiltration rate of soil and depression storage and the interactions between surface water and groundwater flows which difficult to model by simple models[2]. To overcome such task hydrological modeling may play the significant role. All the hydrological models are simplified representation of the real word[3]. Different techniques had been employed, with various improvements, to get accurate runoff estimates. The Wiktionary defines model as a simplified representation (usually expressed in mathematical way) used to explain the workings of a real world system or event[4]. Model general form involves set of simultaneous equations as well as logical operations. Relationship among model and input data is the fundamental for hydrological modeling. Current advancement in technology and high computing power of computers provide powerful pre and post-processors for hydrological models through Geographic Information Systems (GIS), linking with digital spatial and non spatial data sets which provide user-friendly modelling environment[5].

Many simulation models and techniques are developed by researchers which gives higher and better degrees of accuracy. Now at present many physical based hydrological models are available. Among theses, the Soil Water Assessment Tool (SWAT) is one of the successfully used model in the simulation of sediment and runoff yield as well as water quality in small and larger watersheds[3]. Hence the presents study was under taken for hydrological modelling of upper Goodavari river basin using SWAT model. The Soil and Water Assessment Tool (SWAT) is a physical based distributed parameter model having capability of prediction of runoff, sediment, erosion, and nutrient transport from agricultural watersheds under different management scenario in conjunction of Arc GIS.

Study area: The Godavari river one of holy river in India, known as "Vridha Ganga" or "Dakshin Ganga"[6]. The Godavari river originates in Brahmagiri hills (Nashik, Maharashtra) at an elevation of 1,067 m[7]**.** The river basin extends over the state like Maharashtra, A.P., Chhattisgarh, Telangana and Odisha in addition to smaller parts in M.P., Karnataka and Union territory of Puducherry. The basin is roughly triangular in shape having an area of 3,12, 813 km^2 (approx. 10% of the total geographical area of India)[6]. The Pravara, Manjra, Maner, Purna, Penganga, Pranhita, Wardha, Indravati and Sabari are the major tributaries of Godavari. The Godavari basin is sub divided in to 8 sub basins viz. Upper, Middle, Lower, Indravati, Manjara, Wardha and Pranhita, Wainganga and other[8]. The Central Water Commission (CWC) assessed water resources potential in Godavari basin is about 110.54 km^3 out of that the utilizable surface water is approx. 76.3 km^3 and replenishable ground water is approx. 45 km^3. Considering the vast potential for irrigation and rainwater harvesting in upper sub basin the present study was under taken for upper sub basin.

Soil Water Assessment Tool (SWAT): The freely available SWAT model was developed by US Department of Agriculture (USDA)[9]. The SWAT is a physical based hydrological model which offers continuous time scale simulation. It is one of the proven very successful hydrology models in various applications. SWAT is a physically based hydrological model that offers continuous time stimulation. Various input data required for the SWAT model includes weather data, soil properties, topography, vegetation and land management of that catchment. SWAT model proven to be very useful tool for testing and forecasting of water circulation in soil, sediments of soil and crop rotation as well as sediments in the large basin. The SWAT model is proven to be useful hydrological tool for the design of large river basin.

Remote sensing and GIS are recent advanced spatial and effective technique for managing natural resource. The considering its advantages the SWAT model coupled with remote sensing and Geographic Information system (GIS) was used in this present study.

Methodology

In present study, the hydrological modelling of upper Godavari river basin was performed using SWAT model. The database creation of SWAT model needs compatible raster/vector datasets (viz. shape files and feature data) and database files of SWAT's standard formats. The SWAT model requires four type of dataset, viz. Land Use Land Cover (LULC), Soil, topographical and hydro-meteorological data for evaluating the hydrological processes. In the present study data were prepared as well as collected from various sources.

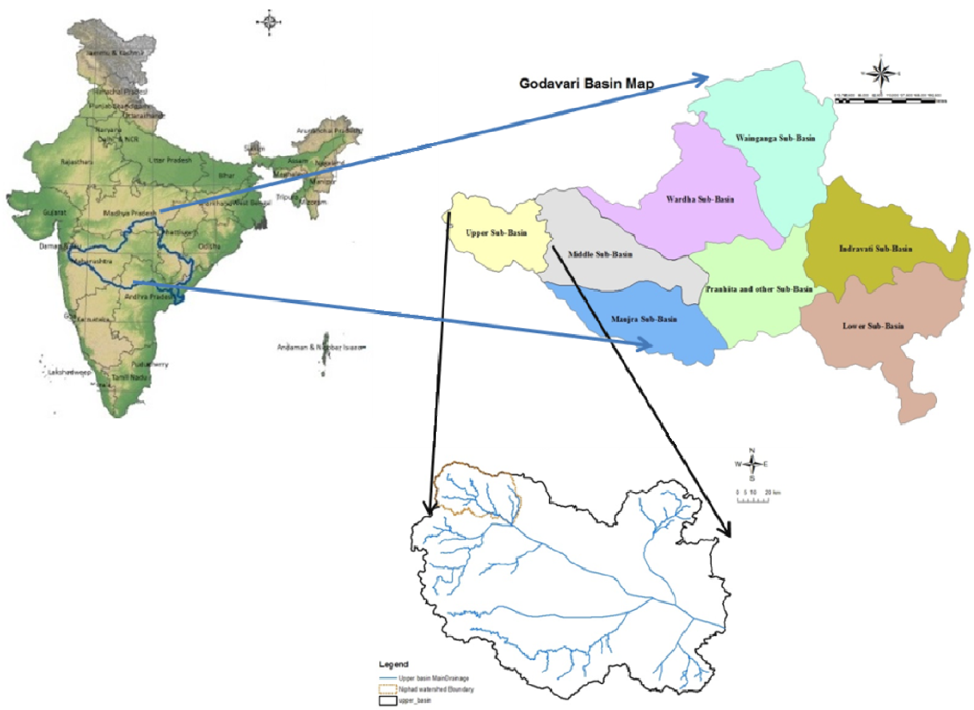

Figure-1: Location map of upper sub basin.

Land use Land Cover (LULC): Presently many sources of satellite images are available on free domain. The LULC map was prepared using the IRS-P6-LISS III images (23.5 m). The image was process using Arc GIS 10.1 and ERDAS Imagine 9.2 software. The LULC map of upper Godavari basin is shown in Figure-2.

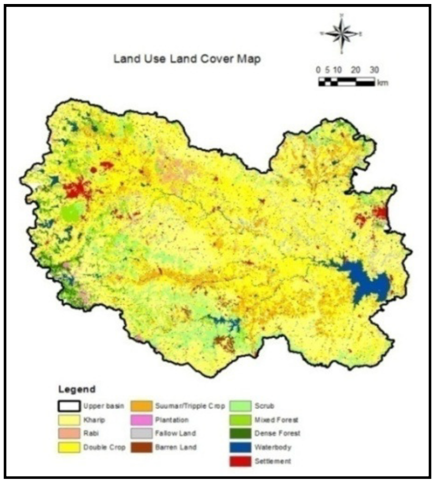

Figure-2: LULC map of upper Godavari basin.

Soil data: Soil data was collected from National Bureau Soil Survey and Land Use Planning (NBSS&LUP) and Maharashtra Remote Sensing Application Centre, Nagpur. The Soil database was grouped on the basis of Hydrological Soil Group (HSG).

Topographical data: The Digital Elevation Model (DEM) is topographical representation of the land surface. The slope map was prepared using the Thermal Emission Reflection Radiometer (ASTER) Digital Elevation Model (DEM) with 30 spatial resolutions. The same DEM was also used for SWAT input.

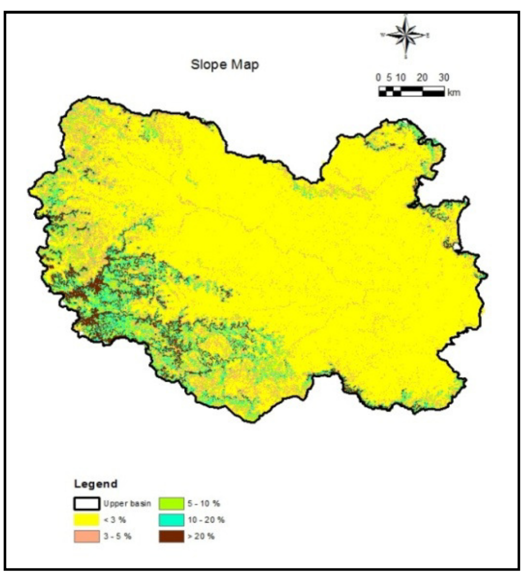

Figure-3: Slope map of upper sub basin.

Hydro-meteorological parameters: The hydro meteorological data was collected form Hydrology Data Users Group (HDUG) Nashik, Maharashtra, India on daily basis. It consists of rainfall, runoff, maximum and minimum temperature, Relative Humidity (RH), and wind speed. The methodology adopted in present research work is shown flow chart as Figure-4.

Results and discussion

The runoff production response in upper Godavari sub basins in Maharashtra was studied using SWAT 12.1 with Arc Info 10.2 interface. The SWAT model was used for runoff yield modeling considering its ability to characterize varied small to larger complex watershed explicitly accounting for spatial variability of rainfall pattern and distribution, soils, and vegetative cover heterogeneity. Also its ability to show effect of different land management practices on surface runoff.

HRU Analysis: Hydrological Response Unit (HRU) is a representation of the all the surface characteristics like land use, soil and slope in a single unit. In Each unit is all characteristics evenly distributed in order to improve the performance of the model. If the surface parameter is considered the separately we need to consider each and every properties of the parameters of the required area. It will increase the complexity of the model. Hence its better to combine all the parameters in to single unit which consists of lumped value of the all the parameter while simulation of it will consider the lumped value of the unit. Already prepared thematic layers like DEM, land use land cover, soil and slope were used for HRU analysis. The behavior of the model mainly depends up on the hydrological parameters of the database. The final output map of the HRU analysis will the input map for the simulation. The upper sub basin was delineated into 2,468 sub basins by model taking in to account suggested flow accumulation threshold of 500 ha. It was further sub divided into 10,594 HRUs. Each HRU was evaluated by multiple hydrologic response unit option considering land use cover area of each sub catchment 20 per cent, soil class as 20 per cent and slope parameter 20 per cent. The simulated runoff from upper sub basin was compared with runoff measured at Niphad hydrologic stations.

The hydro meteorological data of Niphad was used for runoff modeling for upper sub basin considering calibration period of January 1995 to December 2005 for upper basin and for validation period of January 2006 to December 2009 on daily basis. The land use land cover of upper basin was classified into eleven categories. The most dominating land use in upper sub basin was agriculture which includes kharif, rabi, double, tripple crop. The forest of scrub, mixed and dense type.

The SWAT models were run through GIS and windows interface to get desired output. The daily runoff simulated from model was compared with gauged outlet data using graphically and regression approaches. The daily observed rainfall and runoff is shown in Figure-5. The model performance were validated by using various standard statistical indices such as regression coefficient (r), Root Mean Square Error (RMSE), Nastch coefficient or coefficient of efficiency (CE), Mean Bias Error (MBE) and Index of Agreement (I.A.) for calibration and validation mode.

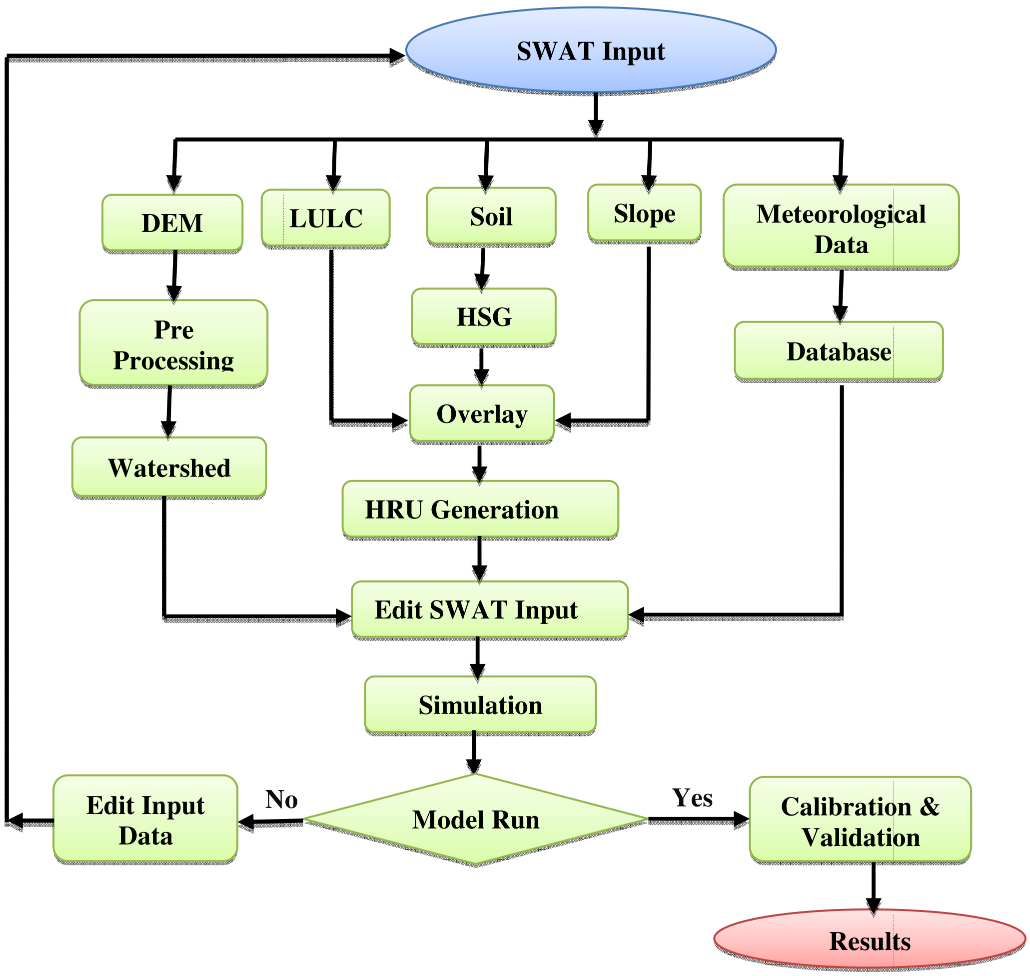

Figure-4: Methodology flow chart.

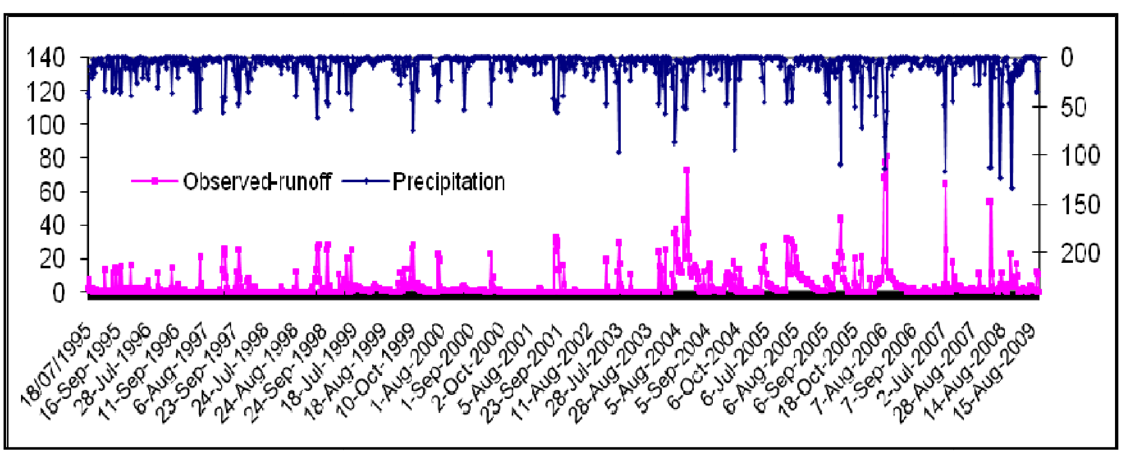

Figure-5: Daily observed rainfall and runoff for upper Godavari basin.

The results showed that coefficient of determination (R) was 0.81 for calibration and 0.84 for validation. The coefficient of correlation found to be less (0.81) as compared to validation (0.84). Even though model fund best in terms of MBE (0.72) and RMSE (5.58). During validation of SWAT model for upper sub basin RMSE was higher by 2.58 mm clearly indicates that during calibration mean square error was less. This clearly reveled that performance of SWAT model during calibration in terms of correlation was less but other statistical parameters such as RMSE, I.A. and M.B.E. showed significant performance.

Table-1: Statistical parameters of SWAT model for upper sub basin to predict runoff for calibration and validation.

SWAT Model	R	RMSE	IA	MBE
Calibration	0.81	5.58	0.82	0.72
Validation	0.84	8.16	0.86	2.23

The model results were also plotted in scatter plot and presented in Figure-6 for upper basin. From Figure-6, it was observed that model performance for simulating runoff during calibration and Validation period was satisfactory for Godavari upper basin in Maharashtra which receives rainfall during mid of June to October months. It was revealed from study that SWAT model predict runoff as compared to observed runoff for upper and middle basins in Maharashtra.

The results of SWAT model showed better performance in upper basin. The SWAT model considers physical conditions i.e. soil, slope, drainage network and other conditions. The results of SWAT showed that model can be used for prediction of runoff in Godavari basin as results were showed significant in runoff prediction.

Conclusion

SWAT model has capabilities of simulating surface runoff in small, medium and large watersheds. SWAT model for the upper Godavari river basin produced good simulation results for daily runoff data. The coefficient of determination for calibration period was 0.81 and 0.84 cross validation period. The RMSE, IA and MBE were 5.58, 0.82 and 0.72 for calibration and 8.16, 0.86 and 2.23 for validation in upper basin. These statistical indicators were found within desired range. The coefficient of determination approaching to 1 indicated better model performance during calibration and validation period. The other statistical indices RMSE and MBE were found in acceptable limit. The simulation results for watershed parameters were reliable. The model results showed that model performance for simulating runoff during calibration and validation period was satisfactory for upper Godavari basin in Maharashtra.

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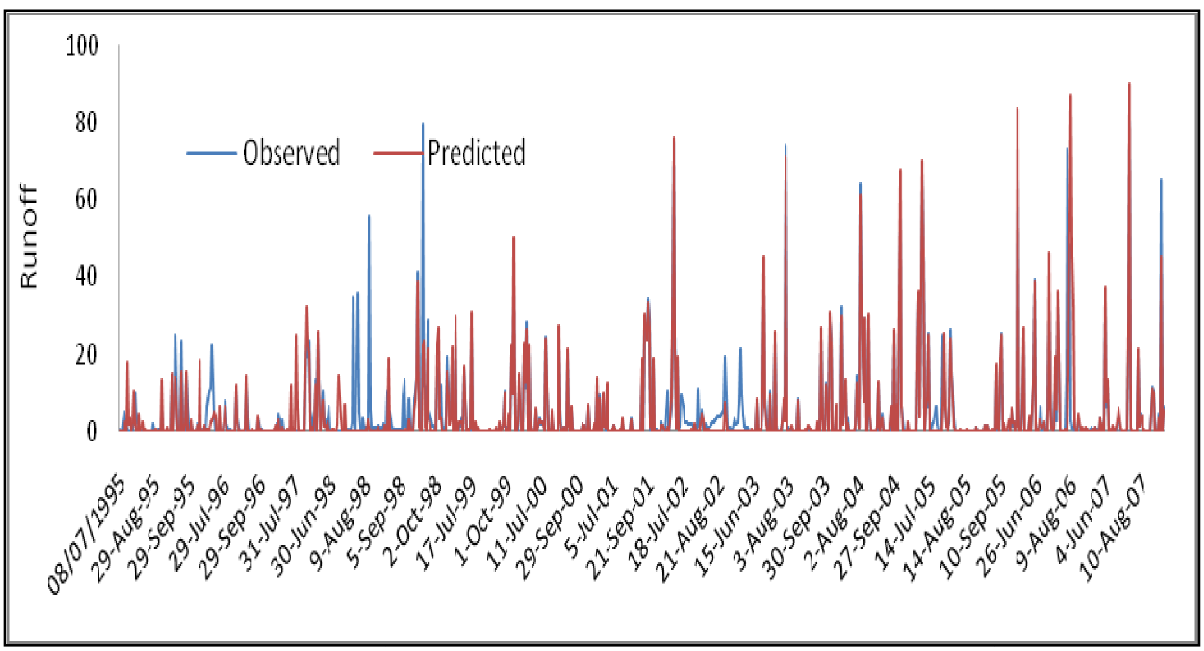

Figure-6: Daily observed and simulated runoff scatter plot for upper basin.

References

1. Chavan P.M. and Ukarande S.K. (2016). Soft Computing techniques for Rainfall-Runoff modeling: *A Review. International Journal of Recent Advances in Engineering & Technology* (IJRAET), 4(4), 2347-2812.

2. Ozgur K., Jalal S. and Tombul M. (2013). Modeling rainfall-runoff process using soft computing techniques. *Computers & Geosciences*. Volume.51, 108-117.

3. Tripathi M.P, Panda R.K. and Raghuwanshi N.S. (2003). Identification and Prioritisation of Critical Sub-watersheds for Soil Conservation Management using the SWAT Model. *Biosystems Engineering*, 85(3), 365-379.

4. Carranza E.J.M (2009). Chapter 1: Geochemical Anomaly and Mineral Prospectivity Mapping in GIS. Handbook of Exploration and Environmental Geochemistry, 11 (M. Hale, Editor) Elsevier.

5. Sharma K.D., Sorooshian S. and Wheater H. (2008). Hydrological Modelling in Arid and Semi-Arid Areas. International hydrology series. Modelling hydrological process in Arid and semi arid area. an introduction to workshop.1-18.ISBN 978-0-521-86918-8 handbook

6. Refsgaard (1997). Chapter 2: Terminology, modelling protocol and classification of hydrological model codes. Distributed hydrology model. Part of Water Science and technology book. Vol.22.

7. Jain S.K., Agarwal P.K. and Singh V.P. (2007). Krishna and Godavari Basins. Hydrology and Water Resources of India, Springer Netherlands, 641-699.

8. Anonymous (2012). River Basin Atlas of India-WRIS, RRSC-West, NRSC, ISRO, Jodhpur, India.

9. Arnold J.G., Srinivasan R., Muttiah R.S. and Williams J.R. (1998). Large area hydrologic modeling and assessment part I: model development. *Journal of American Water Resources Association,* 34, 73-89.