

Chapter 26

Runoff Estimation by Using Optimized Hydrological Parameters with Special Reference to Semi-arid Agriculture Watershed



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Abstract GIS technology is used to estimate the spatial heterogeneity of the hydrological parameters of a watershed. Hydrological models help to overcome the spatial variability and parameter uncertainties. Runoff is important parameter of hydrological cycle. Soil and Water Assessment Tool (SWAT) which is a physical distributed model developed to forecast runoff, sediment, erosion and nutrient transport from agricultural watershed helps to understand the hydrology of a watershed with rainfall, temperature, solar radiation, wind speed and relative humidity. SWAT simulates better results in both gauged and ungauged watersheds. In the present paper, Krishna river catchment area known as Jurala watershed in Mahabubnagar district, Telangana state of South India is taken to study surface runoff from agricultural areas as this area receives less annual rainfall and agriculture is mostly dependent on seasonal rainfall. Soil has less water infiltration capacity and bottom layer calcium carbonate deposits make soil alkaline due to bore well irrigation. To suggest proper water conservation methods, understanding hydrology of this watershed is important. To simulate runoff from this agriculture watershed SWAT model is used for 11 years from 2000 to 2010. The results are calibrated with observed values.

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Keywords Hydrological modeling · Agriculture watershed · Runoff
SWAT

1 Introduction

Sustainable development mainly depends on proper management of natural resources. Water resources management assures improvement in quality of ecosystems and human life standards. Watershed is defined as an area draining into a single water body or river. Spatial modelling of hydrology in a watershed helps to assess the total water yield within the basin [1]. Different hydrological models are available to study the processes running in a watershed. Watershed management is important as it serves as hydrological unit [2] which is closely associated with economical, agriculture, social security and life supporting processes for human life [3]. Data availability and accuracy plays major role in the final output. In remote and inaccessible areas hydrological parameter reliable data availability is uncertain. In many areas in India water stress is caused due to low or lack of rainfall, unpredictable rainfall pattern and also caused due to improper methods to conserve and manage in a sustainable method. This difficulty can be overcome by using mathematical models to calculate hydrological parameters of a watershed using remote sensing and GIS techniques to extract and evaluate different hydrological parameters. Increasing complexity of real world scenarios is becoming challenging for planning and decision making process. For planning and execution of projects, surface runoff estimation based on rainfall is necessary. In arid and semi arid regions rainwater harvesting plays important role for sustainable practice of agriculture. Modelling runoff is important for sustainable growth, where selection of suitable methods to quantify the hydrological parameters of watershed is essential [4]. SWAT model estimates runoff [5], sediment [6] and agricultural chemical quantities in watersheds with varying land use practices [7]. Hydrology parameters of SWAT are precipitation, evapotranspiration, infiltration, percolation and runoff. From recent past computer based hydrological modelling made it easy to estimate runoff in gauged and ungauged watersheds. Runoff is strongly influenced by vegetation cover and land use [8] as these two influence infiltration [9], erosion and evapotranspiration. Existing hydrological models require input parameters for the identification of similar areas with same hydrologic response [10]. SWAT is a continuous time model developed by United States Department of Agriculture's Agricultural Research Service (USDA-ARS) and Texas A&M university, to study the impact of land management/use practices on agricultural and forest watersheds with different soils, land use and slope [11]. Surface runoff directly influences the erosion process.

Better management practices in high runoff areas and steep slope areas are important for sustainable development [12]. Runoff production in a watershed depends upon process of infiltration, rainfall intensities and internal storage capacities. Rate of infiltration also influence by type of land use practice, slope,

vegetation cover and soil properties. Different researchers have been evaluated SWAT model across globe in gauged and ungauged watersheds [13]. Their findings reveal that SWAT model is capable of simulating hydrological processes with maximum accuracy. The SWAT model requires many hydrological parameters related to land use land cover, soil, and climate. These parameters need to be calibrated and validated before using in the model for more realistic values [14]. Calibration and validation of SWAT model is necessary for reducing uncertainties arising due to spatial variability of soil, land use land cover and slope parameters for more realistic and proficient examination [15, 16]. It can be better applied to ungauged basins. In this paper we attempted to test SWAT model capabilities to simulate runoff of the watershed.

2 Study Area and Significance

The Jurala watershed is part of Krishna basin in southern India. The watershed covering an area of 1857 km² lying in between Matkal, Narva, Kothakota, Atmakur, Gadwal, Dharur taluk of Mahboobnagar district in Telangana. This study area is drought-prone with a mean annual rainfall of 604 mm. Agriculture largely depends on rainfall and tank/well irrigation. Geographically the area extends between 77° 36' 3"E to 77° 55' 46" longitude and 16° 09' 43"N to 16° 40' 54"N latitude (Fig. 1). Major part is undulating plains with a gentle slope cover. Dominant soils are red sandy soils, black soils. Heavy black soils with rain fed conditions are cultivated with cotton, sunflower, chillies, maize, redgram, green gram (kharif season), jower, bengal gram, sunflower (rabi) season. Light soils (sandy red and sandy loamy soils) under rain fed conditions are cultivated with castor and maize (kharif), jower, cotton, ground nut, red gram, green gram (rabi). Another category of soils in this area are saline or alkaline soils (problematic soils). In present study area saline soils have canal water access and grown only paddy. Forty eight percent of the total area belongs to agricultural land. Sixty eight percent of the agriculture land belongs to kharif season that entirely depends on rainfall, wells/tanks. Southwest monsoon variability leads to failure in the crops. Agriculture area is mostly in low rainfall and less fertile soils. Current fallow land reflects low fertility of soils and non availability of farming. Nutrients in soils are nitrogen (low), phosphorous (medium), potash (high) amounts. Red sandy soils occupy largest part and are permeable and well drained. Major irrigation is of three types i.e. canals from Jurala project, tank irrigation, tube or bore well irrigation. Ground water plays major role in agriculture. Cropping pattern depends on local climatic conditions, soil type and type of irrigation. Paddy is mainly grown under canal, tanks and well irrigation. Rain fed area is cultivated with jower, bajra and grams. Commercial crops like chillies, cotton and ground nut are grown under canal irrigation.

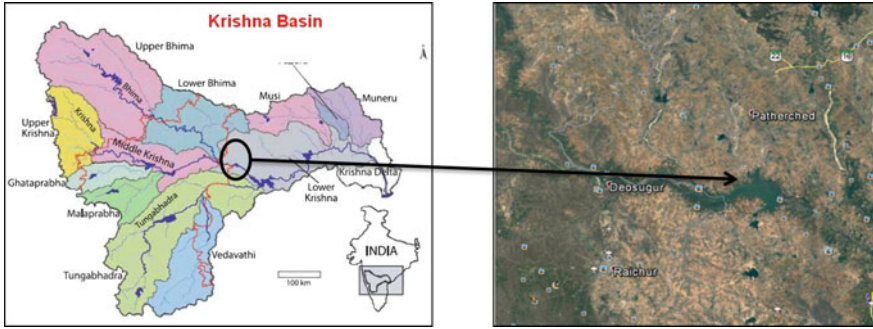


Fig. 1 Location of the study area

3 Data Used

3.1 Digital Elevation Model (DEM)

SRTM (Shuttle Radar Topography Mission) DEM of 90 m spatial resolution is used for watershed delineation. Information acquired and calculated from DEM are slope length, slope classes and elevation. Total 25 sub basins and streams are delineated from SRTM DEM using SWAT delineation process Fig. 2 and Table 1.

Fig. 2 Schematic diagram of Jurala watershed (Sub watershed and streams are delineated from SRTM DEM)



Table 1 Percentage of slope and area distribution of the Jurala watershed

Slope (%)	Area (km ²)	% of Total
0–10	1817.18	97.85
10–20	20.58	1.11
Above 20	19.34	1.01

3.2 Land Use Map

Land use map was obtained from National Remote Sensing Application Centre (NRSA), Hyderabad. Dominant type of land use is agriculture including kharif crop and Rabi crop. Kharif and Rabi crop accounting for 48.94%. Current fallow land occupies 32%, unused waste land 8.24%, forest 5.37% Figs. 3 and 4.

3.3 Soil Map and Database

Soil map is obtained from NBSS&LUP, Nagpur on 1:50000 scale. In case of lack of soil survey, soil information can be taken from, the FAO soil map of the world or ISRIC world soil information. Soil attributes for each soil type related to soil map should be added to user soil database in SWAT. Soil database includes different physiochemical and soil textural properties like water content, saturated hydraulic conductivity, bulk density, soil organic carbon content for each soil and different layers. Using SPAW which is a pedotransfer function soil properties like water content, and saturated hydraulic conductivity are calculated using soil physical properties like soil particle size (sand, silt, clay) and bulk density. Major soils found

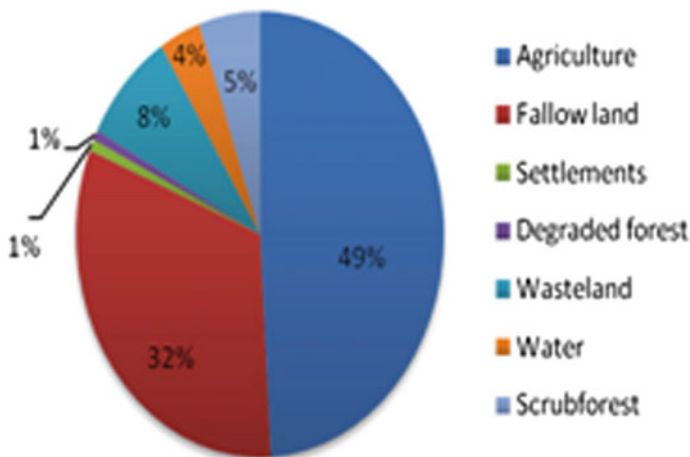


Fig. 3 Land use class distribution in the study area

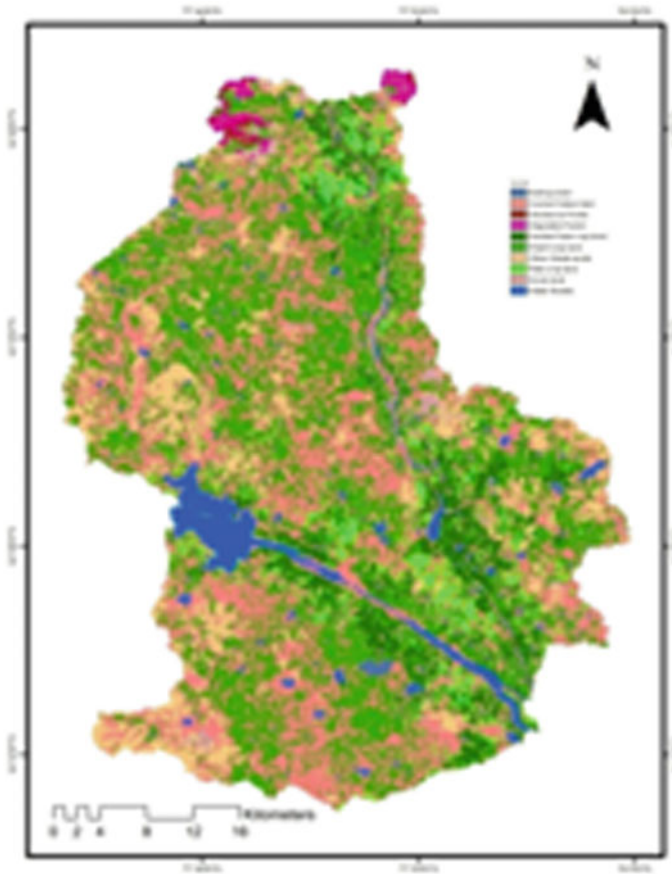


Fig. 4 LULC classes of Jurala watershed

in present study area are clay loam and sandy clay loam [17]. Depending on rate of infiltration soils are further classified into hydrological groups A, B, C, D Table 2.

The rate of transmission of water, nature of texture, structure and degree of swelling when saturated, yield similar runoff amounts. In our study area most of soils belong to group C and D with more runoff rate [18]. According to USDA soil classification these soils belongs to Vertisols. These are swelling and shrinking

Table 2 Classification of hydrological soil group based on soil texture

HSG	Infiltration	(mm/h)	Soil texture
A	High	>25	Sandy loam
B	Moderate	>12.5–25	Silt loam or loam
C	Low	2.5–12.5	Sandy clay loam
D	Very low	<2.5	Clay loam

heavy soils mostly found in river basins, lake bottoms and black swamps. CaCO_3 is present in calcic zone in diffuse form or discontinuous amounts. Often it occurs in surface horizon.

3.4 Weather Database

Rainfall data is obtained from CWC (Central Water Commission), Krishna Basin from automatic meteorological stations or rain gauges. Precipitation daily data is used for this area to calculate runoff. Temperature (minimum, maximum), solar radiation, relative humidity and wind speed data is used in weather input files. Using WXGEN stochastic weather generator model gaps in observed weather data were filled.

4 Model Description

SWAT was developed to study the impact of different land use practices on water, sediment and agricultural yields in watershed with various types of land use management practices and different soils, slopes. Land use change impact on runoff generation was analyzed by [19] in three different regions to demonstrate the long term impacts on runoff with varying soils, slope and vegetation cover. To simulate hydrological parameters in SWAT input data is required like weather data, land use map, soil map, topography, vegetation occurring in the watershed. In SWAT, watershed processes calculation is based on land phase and water phase. Processes that occur on land phase are calculated based on water balance Eq. (1).

$$SW_t = SW_o + \sum_{i=1}^t (PREC - SURQ - ET - PERCO - BF) \quad (1)$$

where:

SW_t = soil water content (mm), SW_o = soil water content available for plant uptake, t = time (days), $PREC$ = amount of precipitation, $SURQ$ = amount of surface runoff (mm), ET = amount of evaporation (mm), $PERCO$ = amount of percolation (mm), BF = amount of base flow (mm).

Surface runoff parameter is estimated by using modified Soil Conservation Service (SCS) curve number method. The SCS curve number is calculated using land use, soil permeability, and preceding moisture conditions. It calculates surface runoff as per the following Eq. (2).

$$Q_{surf} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)} \quad (2)$$

Q_{surf} is the surface runoff (mm), R_{day} is the rainfall for the day (mm), I_a is the initial abstractions.

SWAT is a spatially distributed hydrological model developed to calculate water, sediment, pesticide and nutrient transport from agricultural and forest watershed scale. SRTM DEM is used for watershed delineation as a first step in which watershed has been divided into different sub basins which allows assessing hydrologic processes in different sub basins within a watershed and analyzing localized land use management practice impacts on total yield. After giving soil map, land use land cover map as input HRU (Hydrological Response Units) are created which describe spatial variability in terms of slope class, soil type and land use cover within a watershed. Each HRU is a homogeneous unit area of land use and soil properties to quantify the relative impact of vegetation, soil and climate changes. SWAT uses a modified Soil Conservation Service-Curve Number (SCS CN) technique to calculate runoff.

5 Sensitivity Analysis

In present study watershed was divided into 25 sub-basins, number of HRU's 105 based on land use land cover, slope and soil type. The model was calibrated on monthly basis by comparing simulated runoff and measured runoff values. Initially the model was simulated for 2000–2003 period. Prior to model calibration, identifying and quantifying sensitivity parameters is an important step to address the quantity and quality of model output data to given parameter sensitivity.

Sensitivity analysis was performed to assess the parameter sensitivity to hydrological response. Selected parameters were given ranking based on relative sensitive values to calibrate and validate model based on SWAT user's manual [7] parameter range. The most sensitive parameters are ALPHA BF, CN2, SOL K, EPCO, SOL AWC, GW DELAY and ESCO which are important to simulate runoff in a semi arid basin. Selection of these parameters is dependent on field data which change spatially across the watershed. Optimized parameter values belong to site specific in terms of local soils, land use land cover and climate. If any change occur in these field conditions, the values of sensitive parameters also need to be changed otherwise it affects the best model results. The present sensitive parameter values are taken based on local soils, land use land cover and semi arid climate conditions (Table 3).

Curve Number (CN): Curve number gives the runoff potential in an area considering soil group, soil condition and type of land use. CN values range from 1 to 100. As CN number increases the runoff also increases. Below table shows

Table 3 List of sensitive parameters, ranking based on relative sensitivity and optimal values for SWAT calibration

Number	Parameter	Default value	Description	Optimal value
1	ALPHA BF	0.048	Base floe alpha factor (days)	0.524
2	CN2	68–89	SCS runoff curve number for moisture condition	Table 4
3	SOL K	14.2	Saturated hydraulic conductivity	1.22
4	EPKO	0.95	Plant uptake compensation factor	0.885
5	SOL AWC	0.12	Available water capacity of the soil layer	1.25
6	GW DELAY	31	Ground water delay time (days)	2
7	ESCO	0	Soil evaporation compensation factor	0.01

Table 4 Curve numbers for landuse land cover classes in Jurala watershed

S. no	Land use	Hydrological soil group			
		A	B	C	D
1	Cropland	72	81	88	91
2	Double crop	62	71	88	91
3	Scrub land	36	60	73	79
4	Fallow land	74	83	88	90
5	Waste land	96	96	96	96
6	Degraded forest	45	66	77	83
7	Water	100	100	100	100
8	Deciduous forest	36	60	73	79
9	Settlements	89	92	94	95

different curve numbers used for land uses according to Indian conditions like conservative tillage practices and land cover conditions of the watershed [20] Table 4.

6 Model Performance

Watershed models are defined as powerful tools for simulating different hydrological processes and their effect on watershed processes and management like water and soil conservation. The accuracy of simulated data compared to observed values and constituent values can be established by quantitative statistics [21]. Nash-Sutcliffe Efficiency (NSE) and Percent Bias (PBIAS). The simulated values using SWAT and observed values for Jurala watershed were compared monthly to analyze temporal distribution for the 2000–2010. The goodness of fit is evaluated

by statistical measures using co-efficient of determination (R^2) and Nash and Sutcliffe [21] between simulated values and observed values. Generally model efficiency of simulated values is judged satisfactory if $NSE > 0.50$, $RSR \leq 0.70$, $PBIAS \pm 25\%$. For calibration process identification of key parameters and parameter precision is needed. The range of NSE values is from 1 to negative 1. If value is zero, then the model result is no better than average annual runoff and between zero and one indicates model predictive ability as nearly true. If NSE value is one then it is said to be model is perfectly predicted simulated values with observed values.

7 Results and Discussion

The simulated runoff values for the year 2000–2003 were compared with measured runoff values for validation Fig. 5. Relationship between measured and simulated values is shown by the coefficient of determination R^2 as 0.72 and NSE as 0.84. According to the results SWAT simulated more realistic values (Fig. 6).

Results of the simulations shows that peak rate of runoff values are observed from August to October of each year. Annual rainfall of this area is 604 mm during monsoon season. Present study area has salt affected land of 34.22 km² of total area during 2005–2006 which is irrigated with canal water and grown only paddy. Area under not cultivation was 10.33 km² which is under barren area for the year 2005–2006. Makthal, Dharur, Dhanwada, and Ghatt talukas are affected with soil erosion. Most of the soils belong to hydrological group D in this area which is characterized with high runoff potential. They have very low infiltration rates during wet conditions and mainly constitute clay with high swelling potential. June and July months show low rates of runoff due to complete dry conditions of the top layers of

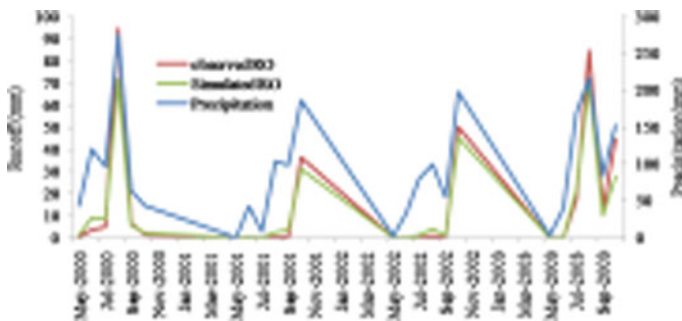


Fig. 5 Observed and simulated runoff values at Jurala watershed from 2000 to 2003

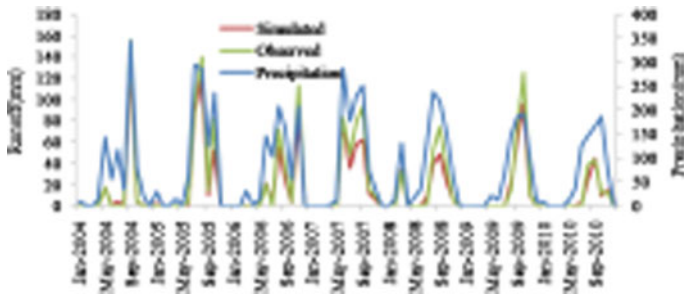


Fig. 6 Observed and simulated runoff values at Jurala watershed from 2004 to 2010

soil. Upon the saturation with water in the top layers from the month of August to October runoff volumes are high. This area is mainly under agriculture use. Dominant types of soils are shallow gravelly red soils next to calcareous moist clayey soils. Rate of runoff volume depends on type of land use and soil characteristics. Red sandy soils in Atmakur, Gadwal, Kothakota mandals are irrigated under Jurala project Table 5.

As irrigation from jurala project is assured paddy is main crop. Groundnut and sunflower are also grown under canal irrigation in some areas as commercial crops. Devarakadra, Dharur, Maldalkal mandals are majorly irrigated with tanks and rice is cultivated during kharif season and Bengal gram during rabi season. Red soils are dominant type with tank irrigation in present study area with rice grown in kharif and maize in rabi season. Black soils with tank irrigation spread in atmakur, devarakadra, dharur, ghatt, matkal, maldalkal mandals. Rice is grown in both Rabi and kharif season. Rain fed area constitutes 63% of total cropped area. These higher values reflect poor soil conservation practices. Agriculture and fallow land occupy highest percentage of land use may cause significant soil erosion. Soil erosion causes loss of soil nutrients making soil low fertile. Eroded sediment can absorb and transport pesticides, heavy metals, nitrogen, phosphates from agricultural runoff into downstream causing serious threat to aquatic life. Sub watershed wise land use land cover classes are shown in Table 6.

The temperatures are high during summer season which increases the rate of evapotranspiration. As major crop is rice which require more irrigation supply also adds increasing rate of evaporation. High rate of evapotranspiration is observed when compared with rate of runoff. Major area is under tube well irrigation which shows pre monsoon ground water levels are low during summer season. Sub watershed W04 shows low runoff and high infiltration volumes when compared with other sub watersheds. Agriculture is dominant land use and sandy loam soils that increases rate of infiltration thus reduces runoff. In watershed W05 deciduous

Table 5 Percentage area of soil classes of each sub watershed of Jurala watershed

WS	1	2	3	4	5	6	7	8	9	10
W01	0.00	0.00	0.00	2.40	0.00	61.46	0.00	13.12	0.00	23.02
W02	62.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.35
W03	18.53	0.00	0.00	0.00	0.00	4.66	0.00	33.57	0.00	43.25
W04	0.00	0.00	18.09	4.17	0.00	11.11	16.96	31.77	0.00	7.90
W05	0.11	0.00	0.00	2.61	0.00	0.00	20.20	77.07	0.00	0.00
W06	0.00	0.00	0.00	0.00	0.00	2.96	0.00	65.10	0.00	31.94
W07	31.90	7.55	0.00	6.83	0.00	0.00	0.00	11.40	0.00	42.32
W08	0.00	0.00	65.20	0.00	0.00	0.00	34.80	0.00	0.00	0.00
W09	0.33	45.00	0.00	0.00	0.00	20.17	0.00	0.00	0.00	34.49
W10	0.00	0.00	0.00	0.00	0.00	55.78	0.00	0.00	0.00	44.22
W11	0.00	0.00	20.29	0.00	0.00	0.00	35.28	44.43	0.00	0.00
W12	0.00	20.54	0.00	8.17	0.00	7.63	0.00	9.68	0.51	53.48
W13	0.00	0.00	0.00	0.56	0.00	0.31	0.00	59.47	0.00	39.66
W14	73.43	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	26.42
W15	0.00	0.00	0.00	10.93	0.00	59.62	0.00	0.00	0.00	29.46
W16	0.00	0.00	0.00	1.09	0.00	0.00	39.68	57.37	0.00	1.85
W17	0.00	0.00	0.00	0.00	0.00	22.26	0.00	37.92	0.00	39.92
W18	0.00	0.00	54.45	3.34	0.00	0.00	21.20	3.09	0.00	17.92
W19	46.02	4.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	49.41
W20	0.00	0.00	0.00	0.00	0.00	0.00	20.20	79.80	0.00	0.00
W21	0.00	0.00	0.00	0.00	0.00	19.20	0.00	49.48	0.00	31.31
W22	61.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	38.52
W23	0.46	0.00	0.00	0.66	0.91	7.92	56.22	0.00	0.00	33.84
W24	34.42	0.00	0.00	20.86	0.00	4.36	0.00	8.07	0.00	32.29
W25	0.00	62.84	0.00	0.00	0.00	10.52	0.00	0.00	0.00	26.64

Name of the soils: 1 loamy to clayey skeletal deep reddish brown soils; 2 moderately deep black clayey soils; 3 clayey to gravelly clayey moderately deep dark brown soils; 4 waterbodies; 5 moderately deep calcareous black soils; 6 loamy to gravelly clay deep dark reddish brown soils; 7 deep black clayey soils; 8 shallow gravelly red soils; 9 Settlements; 10 moderately deep calcareous moist clayey soils

forest, scrub forest and agriculture are major land uses that reduces amount of runoff. Soil infiltration rate is high in vegetated area. Sub watershed W12 also shows less runoff values as it receives low amount of rainfall. This watershed is irrigated with canal water and cultivated throughout year. Major crop in this area is rice. The sub watershed with clay soils results in high volumes of runoff water. Spatial variability of rainfall and runoff for each watershed is shown in Table 7, Fig. 7 for the period 2005–2009.

Table 6 Percentage area of LULC classes of sub watersheds of Jurala watershed (km²)

Subwatershed	Kharif	Rabi	Kharif + rabi	Fallowland	Deciduous forest	Degraded forest	Wasteland	Water	Scrubland	Builtupland
W01	34.73	4.99	2.05	32.68	0.00	0.00	17.28	3.95	3.81	0.51
W02	16.12	0.28	0.21	39.1	0.00	0.00	38.31	0.85	4.76	0.38
W03	45.71	4.12	1.29	36.74	0.00	0.00	6.75	0.75	4.01	1.25
W04	34.99	8.18	13.47	26.93	0.00	0.00	6.24	2.19	6.75	1.25
W05	21.06	14.09	16.34	19.08	3.11	10.79	4.75	0.96	9.35	0.47
W06	45.51	1.01	0.79	44.64	0.00	0.00	8.18	0.05	0	0.39
W07	37.1	6.79	13.31	33.4	0.00	0.00	2.53	2.57	0.07	0.74
W08	39.55	6.65	6.08	31.17	0.00	0.00	11.23	0.82	3.51	0.98
W09	32.82	5.55	4.38	51.72	0.00	0.00	0.68	1.02	3.56	0.28
W10	14.17	9.42	23.25	37.07	0.00	0.00	5.91	4.81	3.92	1.44
W11	29.24	9.04	7.00	33.15	0.00	0.00	15.48	1.68	3.74	0.67
W12	35.47	11.76	18.12	16.95	0.00	0.00	1.15	6.02	7.09	3.45
W13	61.12	1.6	0.87	27.22	0.00	0.00	4.5	0.85	3.02	0.82
W14	40.91	0.18	0.23	37.29	0.00	0.00	16.99	0	4.11	0.29
W15	23.29	11.71	17.33	24.15	0.00	0.00	6.95	8.83	7.5	0.24
W16	40.31	3.36	1.18	37.18	0.98	0.45	5.95	0.86	8.89	0.84
W17	36.8	2.01	0.96	34.57	0.00	0.00	20.37	0.36	4.41	0.52
W18	32.01	5.97	12.55	36.29	0.00	0.00	2.18	1.81	8.44	0.75
W19	41.36	0.89	0.91	46.25	0.00	0.00	5.1	2.14	2.71	0.64
W20	38.91	12.47	11.14	27.14	0.00	0.23	2.28	0.61	6.17	0.93
W21	38.13	5.47	1.49	47.63	0.00	0.00	3.87	0.5	2.21	0.7
W22	39.12	3.04	5.33	39.5	0.00	0.00	8.88	1.06	2.62	0.46
W23	34.39	2.97	0.74	37.23	0.00	0.00	18.99	1.77	3.59	0.13

(continued)

Table 6 (continued)

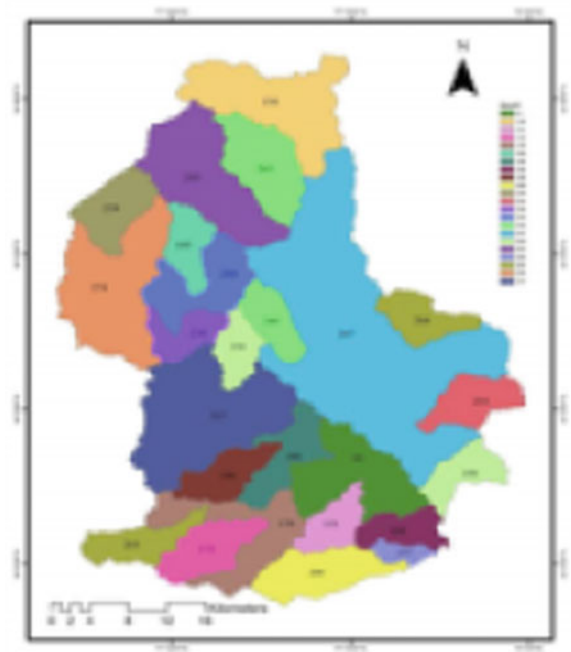
Subwatershed	Kharif	Rabi	Kharif + rabi	Fallowland	Deciduous forest	Degraded forest	Wasteland	Water	Scrubland	Builtupland
W24	18.77	8.69	9.54	31.51	0.00	0.00	7.22	21.12	2.89	0.26
W25	51.29	3.53	12.8	23.27	0.00	0.00	0.73	3.06	5.04	0.36

Table 7 Runoff values of Jurala sub watersheds from 2005 to 2009

SW	RF2005	RO2005	RF2006	RO2006	RF2007	RO2007	RF2008	RO2008	RF2009	RO2009	Area (km ²)
W01	1045	299	942	210	1105	294	1012	181	730	198	31.88
W02	1020	338	804	238	904	278	934	210	710	253	40.04
W03	1203	285	1162	249	1206	262	1097	137	867	209	48.75
W04	1045	310	942	222	1105	307	1012	191	730	207	403.27
W05	1045	195	942	109	1105	161	1012	69	730	136	119.38
W06	1045	308	942	219	1105	305	1012	191	730	204	34.5
W07	1045	244	942	167	1105	226	1012	124	730	166	47.08
W08	1045	295	942	208	1105	290	1012	181	730	196	44.36
W09	1020	282	804	169	904	207	934	179	710	200	61.42
W10	1020	340	804	214	904	261	934	219	710	239	12.36
W11	1045	328	942	236	1105	329	1012	212	730	216	38
W12	1020	103	804	42	904	39	934	31	710	88	90.78
W13	1045	243	942	159	1105	224	1012	128	730	164	35.14
W14	1020	228	804	153	904	172	934	126	710	180	47.41
W15	1020	265	804	158	904	189	934	164	710	190	32.539
W16	1045	316	942	225	1105	314	1012	199	730	209	119.7
W17	1045	302	942	214	1105	299	1012	184	730	201	63.99
W18	1045	312	942	223	1105	310	1012	202	730	204	35.1
W19	1020	237	804	154	904	176	934	135	710	181	75.73
W20	1045	309	942	217	1105	303	1012	187	730	206	69.61
W21	1045	313	942	224	1105	311	1012	197	730	207	30.33
W22	1045	256	942	178	1105	239	1012	131	730	174	40.24
W23	1203	336	1162	296	1206	318	1097	179	867	240	135.16
W24	1045	387	942	294	1105	402	1012	244	730	261	167.4
W25	1020	213	804	120	904	142	934	121	710	159	32.75

RF Rainfall; RO Runoff

Fig. 7 Annual mean runoff values for each watershed from 2005 to 2009 of Jurala watershed



8 Conclusions

The Jurala watershed with an aggregated area of 1857 km² is simulated for runoff volumes. Results indicated that model could adequately anticipate the runoff volumes with NSE of 0.95. Temporal changes in runoff volumes at 25 sub watersheds were adequately simulated by model. For sustainable development appropriate land management practices need to be developed to control runoff volumes. Results showed that runoff values are more from agriculture and fallow land uses. This results in low infiltration rates of rainwater and decreased levels of ground water during pre monsoon and post monsoon (NRSA-WRIS). This area is mainly dependent on rainfall hence suitable soil conservation practices must be adapted. Furthermore bore well irrigation is more than canal and tank/well irrigation for agriculture. Lower annual rainfall and increasing rate of ground water with drawl further result in low fertility of soil and loss of water through evaporation process. Such conditions may aggravate soil erosion lowering soil nutrients and sedimentation of reservoirs in the downstream area. Efforts should be made to increase ground water levels by artificial recharging wells/tanks. Identifying key parameters to improve soil fertility and water holding capacity using organic manure, drip irrigation, sprinklers to conserve water and nutrients in soil is important. Treating

saline soils with suitable chemicals to decrease salt content can improve soil conditions. Wasteland and barren land reclamation policies are recommended to address this problem. The present study proves that the SWAT model can better predict hydrological parameters.

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