DOI: 10.15740/HAS/AU/12.TECHSEAR(7)2017/1788-1793 *Agriculture Update*
Volume **12** | TECHSEAR-7 | 2017 | 1788-1793
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RESEARCH ARTICLE :

Assessment of climate change impacts using SWAT

A. VALLIAMMAI, K. BALATHANDAYUTHAM AND B.J. PANDIAN

ARTICLE CHRONICLE :
Received :
19.07.2017;
Accepted :
03.08.2017

SUMMARY : Change in climate would alter the components of hydrological cycle including water availability, water demand, and water allocation at the global, regional, basin, and at local level. A study was undertaken using Soil and Water Assessment Tool (SWAT) to assess the impact of climate change on hydrology, focusing on trends of precipitation, evapotranspiration and water yield in Palar sub basin of Parambikulam Aliyar Project (PAP) Basin. From the model, for the current climate (1981-2000) it was observed that annual average rainfall of Palar sub basin is 830.13 mm, out of which 463.00 mm was used by the crops (*i.e.* evapotranspiration). Overall, the rate of precipitation is higher than evapotranspiration during monsoon and post monsoon periods (May to December). Future climate scenario over the Palar sub basin derived from 16 GCM ensemble at 60 % probability indicate that the annual rainfall, water yield, evapotranspiration would increase with the advancement of time, whereas soil water storage is expected to decrease. In the mid and end century, precipitation is expected to increase by 8.7 and 14.6 per cent and evapotranspiration by 4.6 and 5.2 per cent, respectively from the baseline. The annual soil water storage is predicted to decrease in mid and end century. In the mid century, the annual soil water storage would decrease by 2 per cent from the baseline. In end-century, it is expected to decrease by 4.1 per cent from the baseline. The evapotranspiration is expected to increase in all the seasons with varying magnitude towards mid and end century compared to current conditions indicating more water requirement for cultivation of crops. Hence, research towards economizing water to increase crop productivity is need of the hour.

KEY WORDS :
Watershed, Climate change, Hydrology SWAT

How to cite this article : Valliammai, A., Balathandayutham, K. and Pandian, B.J. (2017). Assessment of climate change impacts using SWAT. *Agric. Update,* **12**(TECHSEAR-7) : 1788-1793; **DOI: 10.15740/HAS/AU/12.TECHSEAR(7)2017/1788-1793.**

Author for correspondence :
A. VALLIAMMAI
Water Technology, Centre, Tamil Nadu Agricultural University, COIMBATORE (T.N.) INDIA
Email : vallimei@gmail.com

See end of the article for authors' affiliations

BACKGROUND AND OBJECTIVES

Water is one of the vital resources that is sensitive to climatic change (Gleick, 1986). Thus, climate change can have a profound impact on the water cycle and water availability at the global, regional, basin, and local levels.Most of the climate models predict lesser water availability for agriculture in coming decades (Ragab and Prudhomme, 2002). Changes in the amount, intensity and frequency of precipitation at regional levels might lead to change in runoff pattern or occurrence of drought. Hence, understanding and modeling hydrological processes within a river basin is important for assessing the environmental influence on river basin hydrology. Hydrological models can offer a sound scientific framework for river basin hydrology and provide reliable information on the behavior of the system and are extensively used for water resource management. SWAT (Soil and Water Assessment Tool) model offers continuous time simulation with high level of spatial details (Arnold *et al.*, 1998). SWAT has been used extensively worldwide (Gassman *et al.*, 2007) as evidenced by over 500 peer-reviewed publications on the model (http://swatmodel.tamu.edu/). In the current study, hydrology of Palar sub-basin of PAP was assessed using SWAT model.

RESOURCES AND METHODS

Description of study area :

Palar sub-basin of PAP is located in west part of Tamil Nadu that covers an area of 495 km^2 spread between $10^0 54'$ and $10^0 55'$ N latitudes and $77^0 07'$ and $77^0 12'$ E longitudes (Fig. A). In the Palar basin 31.78 per cent of the area is covered by forest. Agricultural crops occupy 57.00 per cent of the area and horticultural area is 5.42 per cent. Sizable area also is under range land. Palar basin has a variety of soils, majority of the area has sandy clay loam and sandy clay soils.

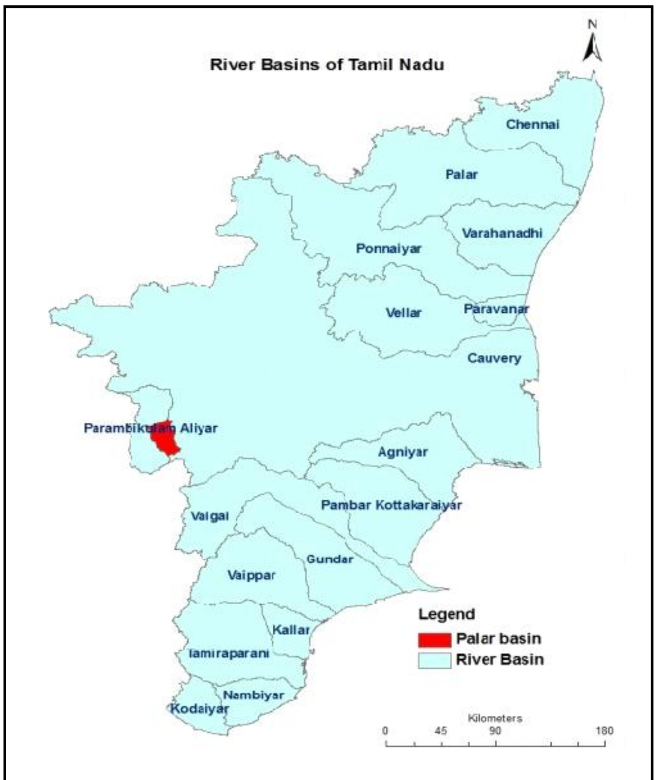

Fig. A : Location of Palar basin in India

Description of data sets used to setup SWAT Model:

The SWAT model requires a variety of detailed information describing the watershed *viz.*, information on elevation, slope, soil, land use and climate. The source of the Digital elevation model (DEM) used in the study is 90 m resolution (Fig. B) Shuttle Radar Topographic Mission (SRTM) (http://srtm.csi.cgiar.org/). Soil data from the FAO Digital Soil Map of the World (www.fao.org/geonetwork/srv/en/metadata) was used for defining the soils in the Palar basin (Fig. C). The attribute table includes Soil Texture, Depth, Drain, Nutrient content, AWC (Available water capacity) and hydraulic conductivity at different layers. The required soil properties (physical and hydraulic properties such

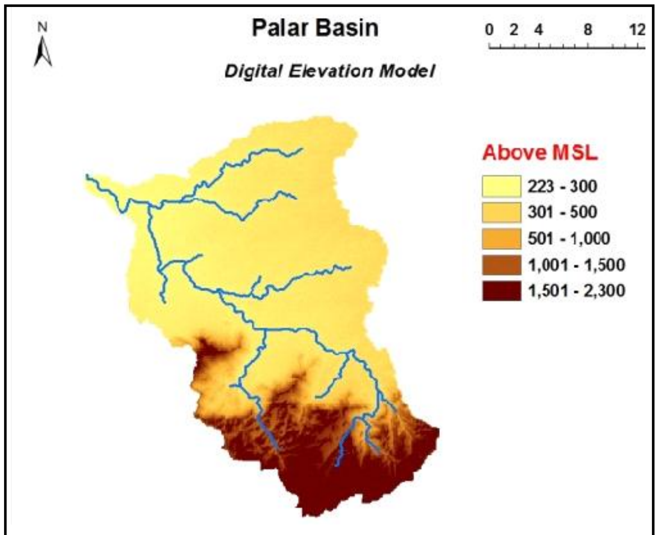

Fig. B : SRTM-Digital Elevation Map (DEM) of Palar sub basin

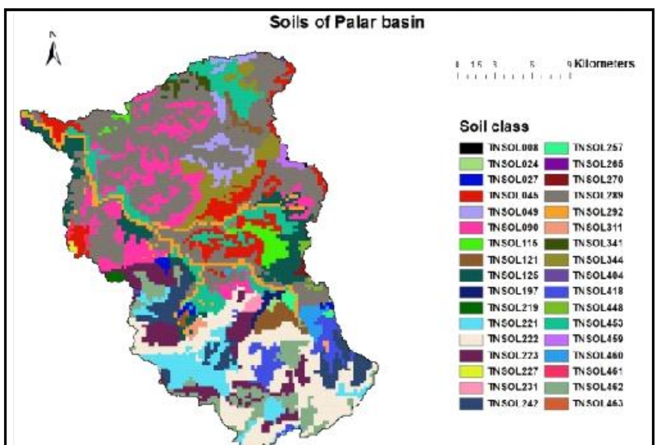

Fig. C : Soil map of Palar basin

as saturated hydraulic conductivity, bulk density and porosity) for simulating the water balance are derived based on the soil texture using the pedo-transfer functions developed by Saxton and Rawls (2006).

The Land use / Land cover data was prepared from Land use / Land cover map of National Remote sensing centre (NRSC), derived from Advanced Wide Field Sensor (AWiFS), 56m resolution data. The Land Use/ LandCover data at a spatial resolution of 56m obtained from the National Remote sensing Centre (NRSC) under the Bhoosampada initiativewas obtained for the year 2006-2007 (Fig. D). This was developed by NRSC using multi-temporal Resourcesat-1 AWiFS data acquired during August- May of the year (*Kharif*, *Rabi* and summer seasons).

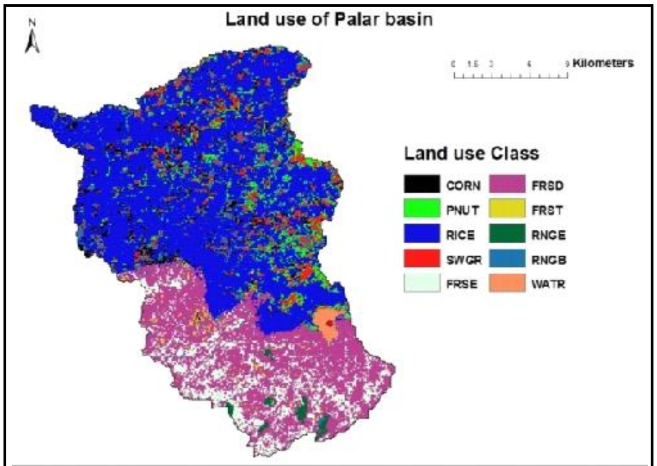

Fig. D : Land use / Land cover data from NRSC for Palar basin

Climatic data is one of the important components that drive the hydrologic model. The daily-observed gridded data of precipitation at 0.5^0 x 0.5^0 resolutions and maximum and minimum temperature at 1^0 by 1^0 resolutions obtained from the India Meteorological Department (IMD) was used for deriving the baseline (1981-2000) climate. Weather data on solar radiation, wind speed and relative humidity were generated using long-term statistics through the weather generator in built in the SWAT model. The future climate scenarios were extracted for Cauvery basin from 16 GCMs outputs (www.climatewizard.org), bias-corrected and spatially downscaled at 0.5 x 0.5 degree resolution, for A1B scenario with respect to two timelines *viz.*, i. mid (2041 -2060) and ii. end century (2071-2090).

SWAT model setup :

Using the SRTM DEM, the GIS interface ArcSWAT 2009 (Version 93.7f) generated the stream network . Palar basin was divide into 25 sub-basins (Fig. E) and each sub-basin was further subdivided into 1860 Hydrological Response units (HRUs) having unique soil and land use. SWAT model was executed by keeping all the SWAT input parameters constant except climate variables which were changed according to the period of simulation. The level of CO_2 maintained in the model was 350ppm for Baseline, 550ppm for Mid-century and 650ppm for end century. The future spatial and temporal rainfall scenarios over Palar basin from the ensemble of 16 Global Climate Models (GCMs) output for A1B scenario and the effect of climate change on the water yield, Potential evapotranspiration and soil water was assessed.

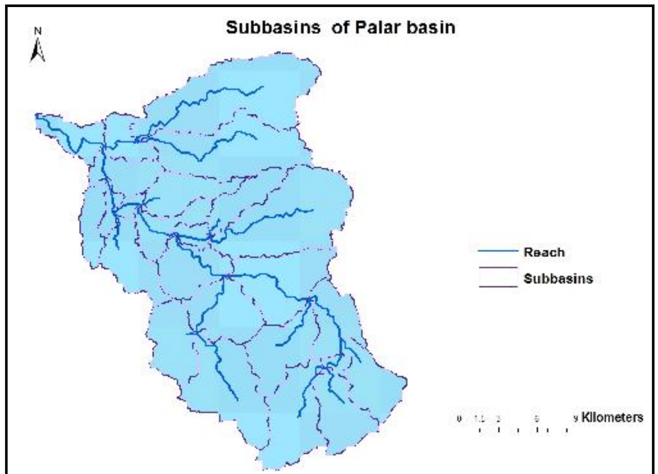

Fig. E : Delincated Palar basin

OBSERVATIONS AND ANALYSIS

The results obtained from the present study as well as discussions have been summarized under following heads:

Current hydrology of Palar basin :

The annual hydrological parameters simulated by SWAT (for 20 years from 1981 to 2000) are presented in Table 1. The inter annual rainfall variation in Palar basin is high which ranges between 421.2 mm and 1077.3 mm with a mean value of 830.1 mm. The mean annual soil water and water yield is 289 mm accounting for 35% of annual average rainfall. Mean annual Evapotranspiration

Table 1 : Current hydrology of Palar basin

Year	Precipitation (mm)	Surface flow (mm)	Lateral flow (mm)	Groundwater flow (mm)	Percolation (mm)	Soil water (mm)	ET (mm)	PET (mm)	Water yield (mm)	Sediment yield (t/ha)
1981	978	143.88	31.17	173.08	238.55	80.2	518.91	1752.58	347.19	0.07
1982	894.9	27.58	15.99	65.98	37.19	66.95	439.28	1783.05	109.27	0.02
1983	421.2	80.19	16.1	26.88	77.3	85.24	437.78	1818.01	122.64	0.15
1984	851	75.33	22.25	128.11	109.98	55.68	485.97	1916.46	225.31	0.19
1985	862.1	36.76	14.14	45.07	49.38	55.11	375.07	1916.64	95.65	0.06
1986	664.3	2.49	7.05	5.41	1.24	20.84	302.66	2011.16	14.93	0.01
1987	849.3	93.31	25.27	94.44	188.48	81.23	489.02	1914.75	211.9	0.16
1988	569.6	16.45	18.01	91.38	25.99	42.43	562.17	1978.59	125.56	0.01
1989	752.8	85.68	22.81	71.34	110.35	61.04	524.5	1852.96	179.33	0.08
1990	684.8	172.19	19.77	105.1	118.76	63.67	382.43	1951.49	296.53	0.32
1991	677.9	42.56	21.45	96.53	102.66	76.82	507.15	1714.13	160.06	0.04
1992	818.2	145.91	23.1	105.32	133.26	66.51	534.23	1708.91	273.88	0.22
1993	992.7	352.44	27	136.01	176.06	71.6	523.14	1778.57	514.84	0.46
1994	1077.3	103.64	23.29	152.96	159.29	50.48	438.46	1874.96	279	0.1
1995	958.1	33.93	13.92	66.36	39.43	56.56	377.84	1923.23	113.86	0.05
1996	879.2	149.31	24.13	70.48	153.14	75.34	541.9	2040.03	243.38	0.33
1997	995.7	191.01	23.92	149.71	152.76	67.29	460.84	1965.9	364.03	0.47
1998	987.8	146.04	22.37	113.85	145.23	74.46	445.79	1858.39	281.66	0.23
1999	856.6	159.17	21.07	136.15	127.91	77.7	424.81	1759.52	315.88	0.33
2000	831	115.19	18.09	62.92	67.8	96.29	488.08	1699.25	195.9	0.28
Mean	830.13	108.65	20.55	94.85	110.74	66.27	463.00	1860.93	223.54	0.18

Table 2 : Hydrology of Palar basin in the mid-century

Year	Precipitation (mm)	Surface flow (mm)	Lateral flow (mm)	Groundwater flow (mm)	Percolation (mm)	Soil water (mm)	ET (mm)	PET (mm)	Water yield (mm)	Sediment yield (t/ha)
2041	1083.87	195.93	34.3	205.07	275.04	77.53	535.26	1849.76	434.28	0.23
2042	938.07	37.88	16.93	73.59	45.8	58.46	468.5	1879.64	128.08	0.06
2043	666.5	88.66	17.52	37.03	87.57	84.48	455.14	1915.51	142.62	0.18
2044	896.44	87.36	23.42	132.4	117.54	57.78	497.92	2018.25	242.78	0.2
2045	998.76	42.24	15.53	55.92	61.06	48.42	402.07	2016.83	113.35	0.07
2046	786.59	2.74	7.72	6.83	2.01	23.32	314.35	2114.9	17.25	0.01
2047	913.75	107.19	27.07	108.36	203.36	80.66	525.91	2015.36	241.42	0.23
2048	625.01	28.07	19.88	102.9	41.78	49.14	580.87	2081.25	150.49	0.03
2049	818.82	105.81	24.9	86.1	127.3	57.33	561.68	1951.35	216.23	0.15
2050	701.02	171.21	20.96	109.73	129.29	66.27	381.68	2053.28	301.32	0.36
2051	748.71	61.8	23.68	121.62	127.25	73.11	538.19	1805.26	206.5	0.09
2052	889.81	176.48	25.85	130.26	162.2	68.1	537.99	1800.13	332.05	0.24
2053	1075	390.15	29.4	154.83	196.56	72.4	546.86	1872.31	573.7	0.62
2054	1161.07	131.37	25.25	173.08	183.46	50.79	445.89	1973.23	328.72	0.13
2055	999.6	41.46	15.23	75.48	46.55	47.47	412.88	2023.06	131.78	0.07
2056	939.48	159.39	26.49	87.01	168.41	74.5	566.1	2145.72	272.3	0.45
2057	1072.11	206.86	25.23	153.58	157.35	63.12	504.92	2067.74	385.03	0.6
2058	1009.9	157.44	23.81	120.11	157.44	73.88	460.11	1957.23	300.72	0.28
2059	876.74	182.55	22.45	147.74	140.88	76.85	437.43	1856.25	352.2	0.45
2060	843.43	119.08	19.51	76.03	81.65	95.93	510.89	1792.96	214.27	0.31
Mean	902.23	124.68	22.26	107.88	125.63	64.98	484.23	1959.50	254.25	0.24

Table 3 : Hydrology of Palar basin in the end-century

Year	Precipitation (mm)	Surface flow (mm)	Lateral flow (mm)	Groundwater flow (mm)	Percolation (mm)	Soil water (mm)	ET (mm)	PET (mm)	Water yield (mm)	Sediment yield (t/ha)
2071	1104.03	213.28	34.96	214.1	282.32	74.82	532.85	1896.61	461.32	0.38
2072	1046.77	42.92	17.2	74.21	50.48	51.97	471.07	1926.16	134	0.04
2073	765.48	92.56	17.6	41.93	91.78	84.17	440.14	1962.5	151.46	0.18
2074	937.64	72.56	21.51	112.52	96.42	58.2	486.58	2067.29	206.21	0.13
2075	1013.05	50.02	15.69	58.69	66.05	51.48	400.78	2064.92	124.04	0.09
2076	883.57	1.95	7.69	7.99	2.6	23.88	314.24	2164.39	17.59	0
2077	970.9	99.38	26.39	104.05	189.55	79.98	547.11	2063.59	228.63	0.23
2078	742.98	31.17	20.09	96.56	44.63	44.7	596.11	2130.3	147.46	0.04
2079	844.6	117.83	25.33	90.38	131.19	52.72	571.29	1998.46	232.95	0.21
2080	732.11	162.96	20.68	103.45	119.41	61.92	401.21	2101.86	286.53	0.39
2081	766.45	66.96	24.18	126.61	138.26	70.87	536.97	1849.03	217.09	0.12
2082	937.05	200.89	26.44	136.29	169.2	62.48	556.4	1843.92	363.03	0.46
2083	1202.61	434.69	29.48	164.24	206.69	77.61	522.64	1917.05	627.7	1.09
2084	1128.02	146.53	26.07	180.95	193.96	51.02	448.77	2020.07	352.53	0.24
2085	1011.32	44.78	15.68	79.03	48.35	45.5	421.35	2070.65	139.09	0.1
2086	993.02	143.74	26.43	88.9	165.55	74.07	567.1	2196.23	258.47	0.42
2087	911.51	235.58	25.88	156.53	169.11	63.79	501.72	2116.48	417.3	0.7
2088	1113.37	153.43	24.55	126.57	155.61	73.03	479.42	2004.67	303.89	0.31
2089	990.77	197.06	22.24	140.97	140.68	74.24	439.08	1902.59	359.75	0.32
2090	931.03	107.46	19.58	79.33	83.5	95.19	506.74	1837.96	206.02	0.31
Mean	951.31	130.79	22.38	109.17	127.27	63.58	487.08	2006.74	261.75	0.29

is 463 mm which is 55.78% of mean annual average precipitation. The atmospheric moisture demand (PET) of the basin is 1860 mm, indicating the need of water from external / underground sources for successful crop production.

Climate change and hydrology of Palar basin :

Hydrological components [Rainfall, atmospheric water demand (PET), crop water requirement (ET), water yield and soil water] derived from the SWAT model results for mid and end century are presented in Table 2 and 3, respectively.

From the Table 2 and 3, it could be seen that the all the above hydrological parameters except soil water storage are expected to increase during mid and end century compared to current condition. During mid century the Palar basin would receive 902 mm and it is expected to be 951mm in the end century. This might be due to the increased evaporation from the ocean surface due to increase in temperature which might result in high moisture content in the air leading to higher precipitation. These findings are in agreement with the conclusions of Rupakumar *et al.* (2003) and INCCA (2010). The mean annual water yield is 254 and 261 mm in mid and end century, respectively. Gosain *et al.* (2006) also have reported increased level of precipitation and a corresponding increase in water yield in future for Cauvery, Ganga, Brahmaputra and Pennar. Mean annual Evapotranspiration is 124 and 130 mm in the mid and end century respectively which shows higher crop water requirement in future climatic conditions.

Conclusion :

Hydrology of Palar basin would be greatly affected due to climate change. Rainfall and water yield are expected to increase in future as a result of changing climate. However, increase in intensity of extreme hydrologic events (flood and drought), crop water demand (ET) and decrease in soil water storage would pose serious challenges for sustainable crop production.

Authors' affiliations :

K. BALATHANDAYUTHAM, Department of Agronomy, Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Tamil Nadu Agricultural University, COIMBATORE (T.N.) INDIA

B.J. PANDIAN, Water Technology Centre, Tamil Nadu Agricultural University, COIMBATORE (T.N.) INDIA

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