SIMULATING THE CLIMATE CHANGE IMPACT ON WATER RESOURCES SYSTEM IN UND RIVER BASIN USING SWAT MODEL

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ABSTRACT

The assessment of climate change impact on water resources will help to prepare a future plan for the water resources development and management for the basin. Therefore, the quantifications of the different components like rainfall, runoff, ground water recharge and evapotranspiration of the water balance at basin scale and the impact of climate change on them are required. The study was planned for estimating the runoff, evapotranspiration and groundwater recharge by SWAT model and assessing the impacts of climate change on potential surface and ground water resources of basin. The overall scenarios (1961-2100) showed that the seasonal rainfall, seasonal runoff, seasonal groundwater recharge and seasonal groundwater recharge was found increasing at 79.12 mm/decade, 52.54 mm/decade, 10.29 mm/decade and 13.13 mm/decade, respectively, while seasonal potential evapotranspiration and annual potential evapotranspiration was found as decreasing at 1.2 mm/decade and 2.97 mm/decade, respectively, in Und Basin.

KEY WORDS: Climate change, SWAT model, Und river

INTRODUCTION

India has great diversity and variety of climates and extremes of weather conditions. The climate ranges from continental to oceanic, from extremes of heat and cold, and from aridity and negligible rainfall to excessive humidity and heavy rainfall. This steadily increases the temperature of the earth’s surface and drives global warming. The United Nations Intergovernmental Panel on Climate Change (IPCC) predicts the global temperatures to rise an additional 3 to 10 degrees Fahrenheit (1.6 to 5.5 degree Celsius) by the centuries’ end (Chandiok, 2009). The climatic factors influence the availability and utilization of water resources. Due to continuous fluctuations in climatic factors, the entire world is facing the same problem is called global warming. The global warming has changed the climate worldwide. However, the climate change and its impacts vary in space as well as time. The climate change will have different impacts in different places on rainfall amount, its intensity, frequency, rainy days, evapotranspiration, etc. These rainfall characteristics and evapotranspiration ultimately impacts on runoff and groundwater recharge also. Therefore, the location specific studies on basin scale are required to assess the impact of climate change on rainfall, runoff, evapotranspiration and groundwater recharge.

Und river originates from Lodhika Ridge near Mota Vadala and meets in Arebian Sea. Its length is 80 km with 1615 km^2 catchment area. Und-I and Und-II dams are located on this river having 769 km^2 and 381 km^2 catchment area, respectively. Bavni is right bank tributary and Fulzaras well as Manvar are left bank tributary of Und river.

MATERIALS AND METHODS

Remote sensing and GIS software- Arc GIS V10.1, Arc SWAT 2012, WGEN maker 4.1 were used during the studies. The Soil and Water Assessment Tool (SWAT) model is a medium- to large-scale river basin model that was developed to predict the impact of climate changes on water resources system components of the basin over long periods of time (Neitsch *et al.*, 2005). SWAT is a physically based, spatially semi-distributed and computationally efficient model that can be used to simulate a single basin or a system of multiple basins that are hydrologically connected (Luzio *et al*., 2002). It is a continuous time series model with a GIS interface and that uses readily available input data.

The satellite data for area of interest were collected from BISAG, Gandhinagar. The input data was in the form of raster dataset. The dataset used namely 90m SRTM DEM (Geotiff), Land use / Land Cover (raster data set) map and soil map (raster data set). These three are imagery data and others input data. The historical hydro-metrological data (1961-2000) were collected from the State Water data centre, Gandhinagar and Pearl Millet Research station, JAU, Jamnagar. The future weather data was obtained through Dile and Srinivasan (2014) and Fuka *et al.* (2014). The collected data was bias corrected developing programme in excel spreadsheet.

As an input file, SWAT required text file for each and every weather parameter. The weather parameters used for SWAT are rainfall (.txt), temperature (maximum and minimum) (.txt). The study analysis was for three period scenarios *viz*., 1961-2000, 2046-2064 and 2081-2100.

The time series of seasonal and annual rainfall, runoff, evapotranspiration and groundwater recharge were analysed. The climate change impacts were assessed by the trend analysis of the time series of rainfall, runoff, evapotranspiration and groundwater recharge using the standard method as described by Kendall (1975) and Sen's (1968) and compared with the best fit trend line.

RESULTS AND DISCUSSSION

The rainfall, runoff and evapotranspiration are the three most influencing water balance components on the groundwater recharge. Therefore, the trend analyses of the bias corrected rainfall, runoff, evapotranspiration and groundwater recharge were assessed. The trend statics of time series of rainfall along with SWAT simulated runoff, evaporation and ground water recharge are given in Table 1 for control and future scenario.

Control scenario (1961-2000)

Rainfall and runoff

The average rainy season rainfall and runoff estimated for the basin are 453.8 mm and 183.56 mm, respectively. The difference between mean and median indicated that the runoff data series are not normally distributed. The coefficient of variation in runoff was found higher as compared to that of rainfall indicating that runoff is influenced by uncertainty in rainfall magnitude as well as its temporal distribution during the monsoon period.

The Kendall statistics for the runoff data series showed that rainfall and runoff is increasing significantly (5% level). The result is also supported by the slope of best fitted line and Sen's slope method. However, the slope of the best fit trend line of rainfall and runoff was observed as 14.19 mm and 7.6 mm per year, while that of estimated by Sen's method was found as 9.54 mm/year and 1.52 mm/year and found significant (5% significant level). It seems that the climate change impact on rainfall may not be same for different regions of India during different seasons. However, the catchment hydrology of Karjan reservoir of Gujarat, India is significantly affected by the climate change over reference scenario of 2000. They found that the frequency of occurrence of given rainfall and runoff is increased in climate change scenario in comparison to reference scenario. Also the impact of climate change (after 2000) in the basin has increased the runoff potential of the basin (Joshi and Joshi, 2012).

Evapotranspiration

The average potential and crop evapotranspiration during the rainy season was found as 1072 mm 191.33 mm, respectively. This indicated that the temporal distribution of the rainfall during the rainy season is poor and the crops are facing the water stress during the season. The potential evapotranspiration has decreasing trend, while crop evapotranspiration is increasing. The reason is that the amount of rainy season rainfall is found in increasing trend, which increased the moisture status during the monsoon season. The increase in the moisture status could reduce the stress (i.e. increased stress coefficient) during the monsoon season, which resulted into increased crop evapotranspiration.

The seasonal potential evapotranspiration (PET) during rainy season is decreasing significantly at 5 per cent and the rate of evapotranspiration is 1.055 mm/year during the rainy season, while the crop evapotranspiration (ET) is increasing significantly at 0.5 per cent with the rate of 3.494 mm/year. The Sen's slope for the time series potential evapotranspiration (PET) were found –0.88 mm/year during the rainy season, while the crop evapotranspiration (ET) was 3.31 mm/year during the rainy season. Many evidences showed that PET decreased over the last decade in the world, such as in India (Golubev *et al.*, 2001)

Groundwater recharge

The average groundwater recharge during the rainy season was found as 42.77 mm. The ground water recharge for the entire basin by SWAT was found varying from 0.0 to 14.80 per cent (1961-2000) with mean of 5.63 per cent of the rainfall. However, Saghravani *et al.* (2013) reported that the estimation of mean annual recharge using empirical model during 2000-2010 was 326.39 mm per annum with the mean of the recharge coefficient as 18 per cent for Selangor, Malaysia in tropical zone. The differences may be due to the rainfall pattern, soil types and topography of the area. Estimation of recharge, by whatever method, is normally subject to large uncertainties and errors (Kumar and Seethapathi, 2002). Also as per Oke *et al.* (2013), the aquifer recharge is one of the most difficult factors to measure in the evaluation of groundwater resources.

The groundwater recharge is increasing with 0.5 per cent significant level. The slope of best fitted trend line and Sen's slope were found as 2.25 mm/year and 1.12 mm/year. The Sen's slope was also found non-nsignificant. That indicated that the seasonal groundwater recharge during monsoon in basin has stable trend. The mean groundwater recharge during rainy season is 42.77 mm. The minimum and maximum groundwater recharge during the rainy season was found as 0.0 mm and 364.42 mm, respectively.

Future Scenario (2046-2064)

Rainfall and runoff

The average rainy season rainfall and runoff estimated are 769.95 mm and 395.12 mm, respectively. The Kendall statistics for the runoff data series showed that runoff is decreasing non-significantly. The result is also supported by the slope of best fitted line and Sen's slope method. However, the slope of the best fit trend line of rainfall and runoff was observed as -1.05 mm and -6.33 mm per year, while that of estimated by Sen's method was found as -0.71 mm and -0.013mm per year. There may be non-significant decreasing trend in runoff.

Evapotranspiration

The average potential and crop evapotranspiration during the rainy season was found as 1058 mm and 240.66 mm, respectively. It can be seen that the potential evapotranspiration will be stable and crop evapotranspiration will be increasing during the future scenario of 2046-2064. This may be due the increased temperature due to global warming.

The rainy season potential evapotranspiration (PET) is stable and the crop evapotranspiration (ET) is insignificantly increasing at the rate of 4.604 mm/year. The Sen's slope for the time series (2046-2064) of seasonal crop evapotranspiration (ET) and potential evapotranspiration (PET) were found as 4.04 mm/year and -0.089 mm/year. The results of Kendall and Sen's slope statistics are found comparable.

Groundwater recharge

The average groundwater recharge during the rainy season was found as 73.66 mm by SWAT model. The groundwater recharge is increasing insignificantly. The slope of best fitted trend line and Sen's slope were found as 0.687 mm/year and 0.0 mm/year. The mean groundwater recharge during rainy season is 73.66 mm. The minimum and maximum groundwater recharge during the rainy season was found as 0.0 mm and 269.62 mm, respectively.

Future Scenario (2081-2100)

Rainfall and runoff

The average rainy season rainfall and runoff estimated for the basin are 1394.33 mm and 807.63 mm, respectively. The Kendall statistics for the runoff data series showed that runoff is decreasing non-significantly. The result is also supported by the slope of best fitted line and Sen's slope method. However, the slope of the best fit trend line of runoff was observed as -37.21 mm per year, while that of estimated by Sen's method was found as -9.64 mm per year and for rainfall -38.61 and -6.25 mm per year, respectively. There may be non-significant decreasing trend in runoff.

Evapotranspiration

The average potential and crop evapotranspiration during the rainy season was found as 1060.12 mm and 348.31 mm, respectively. It can be seen that the potential evapotranspiration and crop evapotranspiration will be increased and decreased respectively in the future may be due the global warming and increasing rainfall trend.

The seasonal potential evapotranspiration (PET) during rainy season is increasing non-significantly at the rate of 1.014 mm/year during the rainy season, while the crop evapotranspiration (ET) is decreasing non-significantly at the rate of -1.19 mm/year. The Sen's slope for the time series(2081-2100) of seasonal crop evapotranspiration (ET) and potential evapotranspiration (PET) were found as -0.21 mm/year and 0.96 mm/year. The results of Kendall and Sen's slope statistics are found comparable.

Groundwater recharge

The average groundwater recharge during the rainy season was found as 167.76 mm. The groundwater recharge is in decreasing non-significantly. The slope of best fitted trend line and Sen's slope were found as -2.38 mm/year and -0.23 mm/year. The mean groundwater recharge during rainy season is 167.76 mm. The minimum and maximum groundwater recharge during the rainy season was found as 3.45 mm and 635.38 mm, respectively.

Water balance component trend for overall scenario

The average of mean seasonal and annual water balance component presented in Figure 1 and it showed that the seasonal rainfall, seasonal runoff, seasonal groundwater recharge and seasonal ground water recharge was found increasing at 79.12 mm/decade, 52.54 mm/decade, 10.29 mm/decade and 13.13 mm/decade, respectively, while seasonal potential evapotranspiration and annual potential evapotranspiration was found as decreasing at 1.2 mm/decade and 2.97 mm/decade, respectively.

CONCLUSION

The warming trend was found in the study area. The average rainy seasonal rainfall, runoff, evapotranspiration, potential evapotranspiration, groundwater recharge and annual potential evapotranspiration was also found increasing, while annual and rainy seasonal average potential evapotranspiration was found decreasing in study area.

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Table 1: Statistical and trend analysis of Water Balance Component for Und Basin during rainy season

scenario	Water resources system components during rainy season	Mann Kendal (z)	Confi. Level in M-K (Z)	Sen's Slope (mm/year)	Lower and Upper limit of Sen's slope (1%) (mm/year)		Lower and Upper limit of Sen's slope (5 %) (mm/year)		Slope of best fit trend	R^2	Mean (mm)	Median (mm)	CV
1961-2000	Seasonal Total runoff	2.14**	98.39	1.52	-0.004	7.483	0.000	6.043	7.633	0.069	183.57	47.24	1.84
	Seasonal GWR	2.57***	99.48	1.12	0.000	2.411	0.000	1.958	2.250	0.141	42.77	21.75	1.63
	Seasonal ET	2.53***	99.43	3.31	-0.078	6.98	0.796	6.07	3.493	0.161	191.34	171.39	0.53
	Seasonal PET	-2.09**	98.15	-0.88	-1.942	0.21	-1.788	-0.047	1.055	0.004	1072.32	1110.50	0.18
	Annual PET	-3.13****	99.91	-1.31	-2.574	-0.195	-2.224	-0.509	-1.734	0.266	1739.05	1744.36	0.02
	Seasonal RF	2.25**	98.77	9.54	-1.48	19.92	0.81	16.95	14.19	0.102	453.81	323.20	1.14
2046-2064	Seasonal Total runoff	-0.04NS	51.40	-0.013	-62.56	45.77	-44.34	20.83	-6.333	0.005	395.13	196.82	1.24
	Seasonal GWR	0.07NS	52.80	0.000	-6.33	11.34	-5.00	6.29	0.687	0.002	73.66	48.83	1.08
	Seasonal ET	1.12NS	86.85	4.049	-7.83	18.64	-3.09	13.69	4.604	0.095	240.66	235.60	0.35
	Seasonal PET	0.00NS	50.00	-0.089	-4.14	4.02	-2.79	2.69	0.376	0.006	1058.13	1058.62	0.03
	Annual PET	1.19NS	88.29	1.585	-2.97	5.52	-1.74	4.71	1.705	0.104	1723.31	1724.68	0.02
	Seasonal RF	-0.14NS	55.56	-0.718	-80.07	80.45	-63.91	45.92	-1.055	0.0	769.95	509.13	0.88
2081-2100	Seasonal Total runoff	-0.55NS	70.94	-9.64	-116.27	50.54	-64.13	24.83	-37.21	0.050	807.64	352.17	1.22
	Seasonal GWR	-0.16NS	56.44	-0.23	-19.57	14.88	-12.23	9.92	-2.381	0.007	167.76	95.82	0.98
	Seasonal ET	-0.10NS	53.88	-0.21	-10.87	8.00	-7.88	5.91	-1.19	0.008	348.31	333.47	0.22
	Seasonal PET	0.23NS	58.98	0.96	-5.88	7.41	-3.67	5.69	1.014	0.014	1060.13	1070.01	0.05
	Annual PET	-0.29NS	61.49	-1.26	-8.01	7.23	-4.59	5.54	-3.034	0.045	1704.74	1726.84	0.05
	Seasonal RF	-0.23NS	58.98	-6.25	-143.29	79.057	-76.812	41.784	-38.91	0.035	1394.33	730.52	0.87

******* Significant at 0.1%, *** Significant at 0.5%, ** Significant at 5%, * Significant at 10 %, NS = Non Significant, RO=Runoff, GWR=groundwater Recharge, ET=evapotranspiration PET= Potential evapotranspiration, RF=Rainfall, Annual PET all are in mm.***

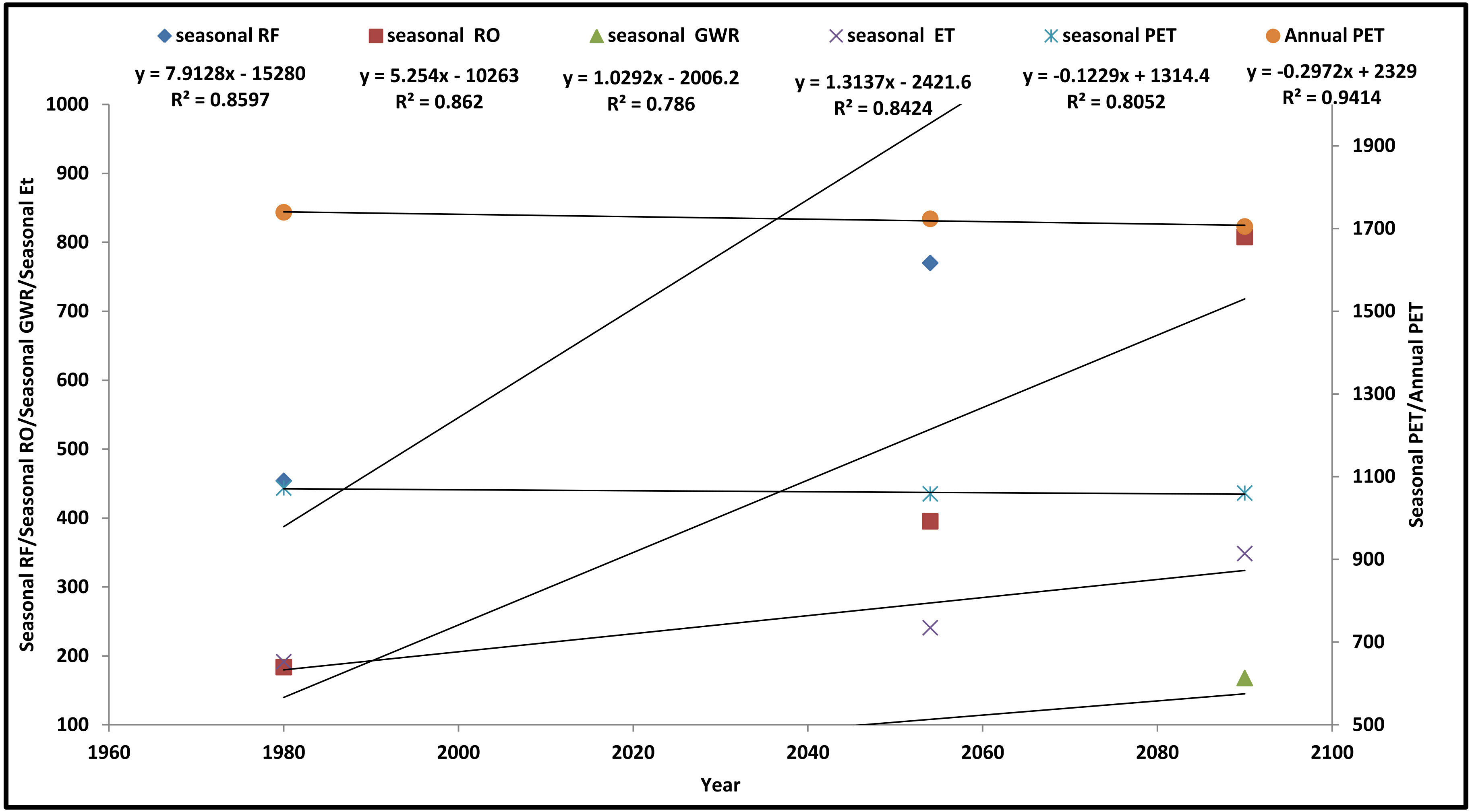

Fig.1 comparison of trend of scenario avg. of mean seasonal and annual water balance component for und basin

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