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Simulating water balance components Behavior to the climate change for Sasoi river basin

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Abstract
Climate has changed due to global warming worldwide and its impacts fluctuate in space and time. The climate change will affect on amount of rainfall, rainfall intensity, frequency of rainfall and evapotranspiration, etc. The investigation was evaluating the climate change effect on water resources. Water balance component is estimated by SWAT (soil and water assessment tool) and evaluate various statistical parameters along with Man-Kendal and Sen's slope statistics. The overall scenarios (1961-2100) give an idea about that the seasonal rainfall, seasonal runoff, seasonal groundwater recharge and seasonal evapotranspiration was found increasing at 69.66 mm/decade, 45.37 mm/decade, 8.36 mm/decade and 12.71 mm/decade respectively and seasonal potential evapotranspiration and annual potential evapotranspiration was found as decreasing at 4.19 mm/decade and 2.14 mm/decade respectively in Sasoi Basin.

Keywords: *Climate*, evapotranspiration, groundwater recharge, rainfall, runoff, *SWAT*

Introduction
Water is basic needs which play an important role in maintaining biodiversity, our health, social welfare and our economic development (Donald, 1968) [1]. Now a day's Shortage of water assets, water contamination and climate change will be the major rising issues. The global warming due to greenhouse gases is now a worldwide reality. The hydrological cycle is disturbed by the climate change. The climate change effects on water resources vary among different regions and river basins and cannot be generalized (Goyal and Surampalli) [4]. This investigation gives a general idea to understand the climate change impact on water resources. In the long run, rainfall Characteristics and evapotranspiration affect on runoff and groundwater recharge. Therefore, it required to assess the climate change impact on rainfall, runoff, evapotranspiration and groundwater recharge.
Sasoi River is located in Jamnagar district of Gujarat State. The length of Sasoi River is 50 km with 811 km2 catchment area. Pipli is the largest reservoir (18 sq. km) on Sasoi River in the area. (Das and Prakash) [7].

Materials and Methods
The required satellites data namely 90m SRTM DEM (Geotiff), Land use / Land Cover (raster data set) map and soil map (raster data set) were gathered from BISAG, Gandhinagar for the study. The chronological data of weather (1961-2000) were collected from the State Water data centre, Gandhinagar and Pearl Millet Research station, JAU, Jamnagar. The future weather data was acquired through Dile and Srinivasan (2014) [8] and Fuka *et al*. (2014) [2]. The collected weather data was bias corrected and used as input data for SWAT model.
For the investigation the data were analyzed using remote sensing and GIS software-Arc GIS V10.1, Arc SWAT 2012, WGEN maker 4.1 and SWAT model. SWAT can be used to simulate a single basin or a system of multiple basins that are hydrologically connected (Luzio *et al*. 2002) [3]. The investigation was carried out for three scenarios such as 1961-2000, 2046-2064 and 2081-2100. The climate change effect on water balance component was evaluated by standard method described by Kendall (1975) and Sen's (1968) [6] and compared with the best fit trend line.

Results and Discussions
The water balance components like rainfall, runoff, and evapotranspiration affecting ground water recharge were analyzed. The trend statistics of rainfall, SWAT simulated runoff; evaporation and ground water recharge are given in Table 1.

Rainfall and runoff

Control scenario (1961-2000)

The estimated mean rainy season rainfall and runoff for the basin are 427.68 mm and 180.15 mm respectively. The difference between mean, median and the value of skewness coefficient shows that the runoff data series are not normally distributed. The coefficient of variation in runoff was higher than that of rainfall indicating that runoff is affected by uncertainty in magnitude of rainfall, also its temporal distribution during the monsoon. Rainfall and runoff is increasing significantly at 10% and 5% level respectively. The slope of the best fit trend line of runoff and rainfall was observed as
13.65 mm and 7.36 mm per year while that of estimated by Sen's method was found as
7.32 mm and 1.25 mm.

Future Scenario (2046-2064)

The mean rainy seasonal rainfall and runoff was found 653 mm and 316.5 mm respectively. Runoff data series showed that runoff is decreasing non-significantly found as per Mann-Kendall statistics. The slope of the best fit trend line of runoff and rainfall was observed as -7.47 mm and -3.79 mm per year while that of estimated by Sen's method was found as -0.24 and -2.48 mm per year. There may be non-significant decreasing trend in runoff and rainfall.

Future Scenario (2081-2100)

The mean rainy season rainfall and runoff was found as 1269 mm and 731 mm respectively. Runoff is decreasing non-significantly as per Mann-Kendall statistics. The slope of the best fit trend line of runoff and rainfall was observed as -35.979 mm and -39.05 mm per year while that of estimated by Sen's method was found as -4.34 mm and -5.18 per year. There may be non- significant decreasing trend in runoff.

Evapotranspiration

Control scenario (1961-2000)

The mean potential and crop evapotranspiration during the rainy season was estimated as 1111 mm and 167.11 mm respectively. The tendency of potential evapotranspiration was descending and crop evapotranspiration was ascending. It is because of the high amount of monsoon rainfall increased the moisture status. Therefore the reduced stress resulted in increased crop evapotranspiration. The seasonal potential evapotranspiration (PET) declined significantly at 0.5% at the rate of -0.89 mm/year in rainy season and crop evapotranspiration (ET) is raised significantly at 0.5% the rate of 3.5 mm/year. The Sen's slope for potential evapotranspiration (PET) was found -0.88 mm/year and crop evapotranspiration (ET) 3.62 mm/year in rainy season.

Future Scenario (2046-2064)

The mean potential and crop evapotranspiration in rainy season was estimated as 1060 mm and 213 mm respectively. The potential evapotranspiration and crop evapotranspiration will increase. This may be because of increased temperature as a result of global warming. The seasonal potential evapotranspiration (PET) is insignificantly increasing at the rate of 0.49 mm/year and the crop evapotranspiration (ET) is insignificantly increasing at the rate of 3.49 mm/year by Man-Kendall in monsoon. The Sen's slope of potential evapotranspiration (PET) and seasonal crop evapotranspiration (ET) was 0.21 mm/year and 3.51 mm/year. The results of Man- Kendall and Sen's slope statistics are found comparable.

Future Scenario (2081-2100)

The mean potential and crop evapotranspiration during the rainy season was estimated as 1070 mm and 319.42 mm respectively. It is observed that the potential evapotranspiration and crop evapotranspiration will increase. The potential evapotranspiration (PET) is rising insignificantly at the rate of 1.74 mm/year and crop evapotranspiration (ET) is declining insignificantly at the rate of –1.35 mm/year during the rainy season. The Sen's slope for potential evapotranspiration (PET) was found 1.47 mm/year and crop evapotranspiration (ET) is declining insignificantly at the rate of -0.69 mm/year during the rainy season.

Groundwater Recharge

Control scenario (1961-2000)

The mean groundwater recharge was estimated as 44.73 mm during the rainy months. At 0.5% level, groundwater recharge is rising significantly. The slope of best fitted trend line and Sen's slope were found as 2.03 mm/year and 1.08 mm/year. The Sen's slope was also found insignificant. The mean groundwater recharge, minimum and maximum groundwater recharge was found as 41.36 mm, 0.0 mm and 289.69 mm respectively during the monsoon season.

Future Scenario (2046-2064)

The mean groundwater recharge was estimated as 64.20 mm during the rainy month. The groundwater recharge is rising insignificantly. The slope of best fitted trend line and Sen's slope were found as 0.243 mm/year and 0.00 mm/year. The Sen's slope was also found insignificant. That specifies the seasonal groundwater recharge during rainy season in the basin will slight change to 0.03mm/year. The mean groundwater recharge, minimum and maximum groundwater recharge was found as 64.20 mm, 0.0 mm and 230.65 mm respectively during the monsoon season.

Future Scenario (2081-2100)

The mean groundwater recharge was estimated as 64.20 mm during the rainy month. The groundwater recharge is stable. The slope of best fitted trend line and Sen's slope were found as -2.17 mm/year and 0.00 mm/year. The Sen's slope was also found insignificant. The mean groundwater recharge, minimum and maximum groundwater recharge was found as 143.54 mm, 0.5 mm and 529.27 mm respectively during the monsoon season.

Water Balance Component for Overall Scenario

Fig. 1 shows comparison of trend between scenario avg. of mean seasonal and annual water balance component and it give an idea about that the seasonal evapotranspiration, seasonal rainfall, seasonal runoff and seasonal groundwater recharge was found increasing at 12.71 mm/decade, 69.66 mm/decade, 45.37 mm/decade and 8.36 mm/decade respectively while seasonal potential evapotranspiration and annual potential evapotranspiration was found as decreasing at 4.19 mm/decade and 2.14 mm/decade respectively.

Table 1: Statistical and trend analysis of Water Balance Component for Sasoi 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 limit and Upper limit of Sen's slope (1%) (mm / year)		Lower limit and Upper limit of Sen's slope (5%) (mm / year)		Slope of best fit trend	R2	Mean (mm)	Median (mm)	CV
1961-2000	Seasonal Total runoff	1.64*	94.98	1.25	-0.084	7.213	-0.013	5.854	7.3626	0.0695	180.15	61.92	1.81
	Seasonal GWR	2.65***	99.59	1.08	0.000	2.514	0.000	2.203	2.0355	0.1584	41.37	23.97	1.45
	Seasonal ET	2.90***	99.81	3.62	0.411	6.445	1.106	5.990	3.5006	0.2089	167.11	154.10	0.54
	Seasonal PET	-2.62***	99.56	-0.88	-1.776	-0.013	-1.602	-0.190	-0.8895	0.1599	1111.06	1108.48	0.02
	Annual PET	-3.06***	99.89	-1.15	-2.281	-0.191	-1.99	-0.463	-1.5905	0.2541	1734.70	1738.91	0.02
	Seasonal RF	2.06**	98.04	7.32	-2.01	19.28	0.174	16.46	13.645	0.1057	427.68	310.99	1.15
2046-2064	Seasonal Total runoff	-0.21NS	58.31	-0.24	-48.79	34.35	-36.19	15.40	-7.477	0.010	316.47	147.07	1.31
	Seasonal GWR	0.14 NS	55.59	0.00	-6.95	8.43	-5.04	5.00	0.243	0.000	64.20	43.69	1.04
	Seasonal ET	1.19 NS	88.29	3.51	-6.61	15.95	-4.34	11.65	3.497	0.061	213.39	210.56	0.37
	Seasonal PET	0.21 NS	58.31	0.21	-3.50	3.60	-2.66	2.42	0.495	0.013	1060.07	1059.24	0.02
	Annual PET	1.05 NS	85.30	1.87	-2.47	5.34	-1.39	4.37	1.749	0.127	1723.77	1723.98	0.02
	Seasonal RF	-0.14 NS	55.56	-2.483	-62.21	61.77	-49.51	36.28	-3.792	0.001	653.06	384.40	0.90
2081-2100	Seasonal Total runoff	-0.16NS	56.44	-4.34	-100.35	51.17	-63.70	29.73	-35.979	0.0492	731.20	338.58	1.31
	Seasonal GWR	0.00NS	50.00	-0.09	-16.78	13.06	-9.66	9.07	-2.178	0.008	143.54	85.46	0.96
	Seasonal ET	-0.16NS	56.44	-0.69	-12.88	9.32	-9.95	6.54	-1.352	0.009	319.42	306.62	0.26
	Seasonal PET	0.55NS	70.94	1.47	-3.55	7.08	-2.23	5.68	1.746	0.0583	1070.16	1075.90	0.04
	Annual PET	-0.29NS	61.49	-1.15	-7.36	6.17	-4.34	4.96	-3.149	0.0522	1709.88	1733.11	0.05
	Seasonal RF	-0.23NS	58.98	-5.18	-129.10	77.14	-70.22	44.86	-39.05	0.0345	1269.46	686.20	0.94

**** 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.

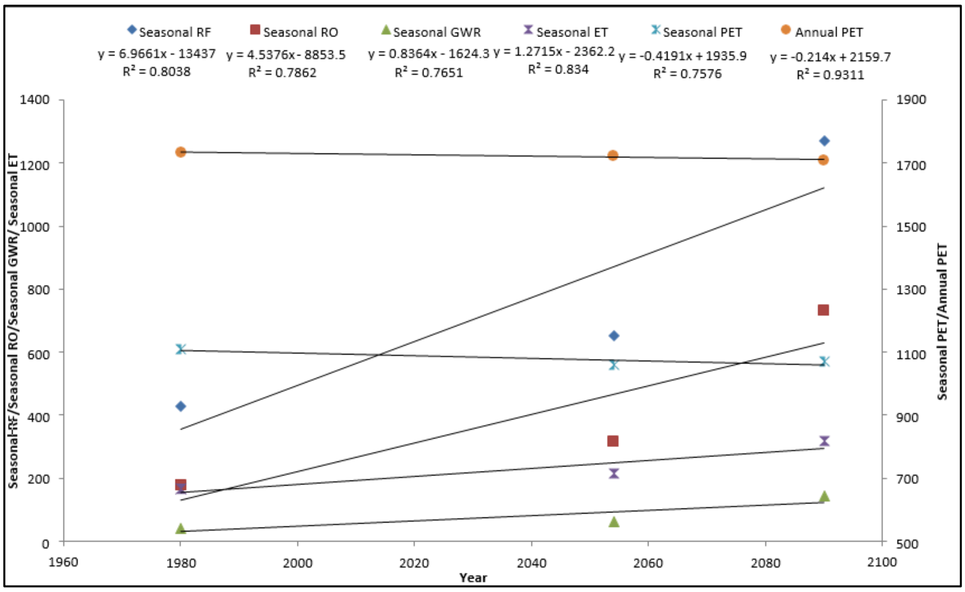

Fig 1: Comparison of trend between scenario avg. of mean seasonal and annual water balance component for Sasoi basin

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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