Research Article

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

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ABSTRACT
Climate change is expected to create many challenges (water availability) worldwide and projecting its impacts at regional scale allows communities to water resources planning, development and management requires assessment of different components of hydrological cycle, like rainfall, runoff, ground water recharge and evapotranspiration. Each of these components should be quantified and water balance should be made on basin scale. 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 of 1961--2100 shows that the monsoon seasonal rainfall, runoff and crop evapotranspiration are increasing at 24.12 mm/decade, 11.55 mm/decade and 2.52 mm/decade while annual and monsoon seasonal potential evapotranspiration are decreasing at 14.20 mm/decade and 5.46 mm/decade respectively. The groundwater recharge by SWAT model indicated stable trend in aji basin.

INTRODUCTION

Climate change is expected to create many challenges (including water availability) worldwide and projecting the impacts of climate change at regional scale allows communities to be proactive in planning for the future. Impacts of climate change and climate variability on the water resources are likely to affect irrigated agriculture, installed power capacity, environmental flows in the dry season and higher flows during the wet season, thereby causing severe droughts and floods in urban and rural areas. India accounts for about 17.5 percent of the world's population and roughly 4 percent of the total available fresh water resources. Ground water resources provide for more than 60 percent of the irrigated land which has already depleted to large extent in many pockets of the country (Patel and Gajera, 2013). Water is the basic need of life for the human beings and any alteration in its availability is directly going to impact them through various means. Regions having renewable fresh water resources falling below 1667 m^3/person/year are classified as "water stress" regions. Furthermore, regions whose water availability falls below 1000 m^3/person/year can be categorized as chronic 'water scarcity' experiencing region (Kole, 2005). Another major player emerging as potent factor for water security in India is the global climate change. The impacts of climate change on glacial recession, decreasing rainfall pattern in some parts of India, greater but variable rainfall pattern in other parts of the country can lead to drought and flood like situations. Increased evapo-transpiration and reduced soil moisture may increase land degradation and desertification. Above mentioned arguments coupled to the scenario that the water utilization rate in India is 59 percent, much ahead of the 40 percent standard, clearly point to an urgent need to better adopt water management practices in the country to increase the water security for proper transition into a green economy (Kumar *et al.*, 2013). While climate change and global warming is a global phenomenon, its effect varies regionally or on basin scale. It has been observed that an increase in the average temperatures is usually accompanied with reduced precipitation in the catchment of Germany (Goludev *et al*., 2001).

Adaptation is response to climate change to seek possibilities and/or capabilities to impacts (Joshi *et al.*, 2012). It is also required to include all the climate change vulnerability drivers to respond to the impacts (Kendall, 1975). The Regional Circulation Models (RCMs) is essentially identical to the GCM in the formulation of the grid-scale dynamics and the subgrid-scale physics differing only in horizontal resolution (50 km -300 km) and time step. Its performance in simulations for Europe and India has been documented in (Kumar and Seethpathi, 2002).

Aji is the most important river of Saurashtra. The Aji river passes through the city of Rajkot. The Aji-I project is built for the water supply to Rajkot city. It is situated between latitude 21º to 22ºN and longitude of 70º to 71º E. Aji river length is 164 km with 2130 km^2 catchment area. . Some of the major tributaries of Aji are the Nyari, Lalapari, Khokaldadi, Banked and the Dondi. The River originating from hills of sardhar near Atkot, to its mouth at the Gulf of Kutch in Ranjitpara of Jamnagar district .There are four dams on Aji River. Aji-I, Aji-II, Aji-III, &Aji-IV dams are situated on Aji River having catchment area 142 km^2, 452 km^2, 1378 km^2 and 1772 km^2 respectively.

January is the coldest month with mean monthly temperature varying from 4ºC to 15ºC and maximum monthly temperature varies between 40ºC to 46ºC in the month of May. Agriculture is the main occupation in the area. Groundwater is the main source of irrigation in study area. Major area falls under irrigated agriculture with groundnut, cotton and pulses as main kharif crop and wheat, garlic and onion as Rabi crop.

MATERIALS AND METHODS

SWAT is a basin scale continuous time model that operates on a daily time step and is designed to predict the impact of management on water, sediment, and agricultural chemical yields in ungauged watersheds. In SWAT a watershed was divided into multiple sub-watersheds, which were then further subdivided into hydrologic response units (HRUs) that consist of homogenous land use, management, and soil characteristics. Alternatively, a watershed could be subdivided into only sub watersheds that are characterized by dominate land use, soil type and management (Arnold *et al.,* 1996; Arnold *et al.,* 2005; Neitsch *et al.*, 2001; Gassman *et al.,* 2007). The procedure followed for the SWAT modelling was given in fig. 2. 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 hydro logically 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 Meteorological Observatory of Main Dry land Agricultural Research Station, JAU, Targhadiya. 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.

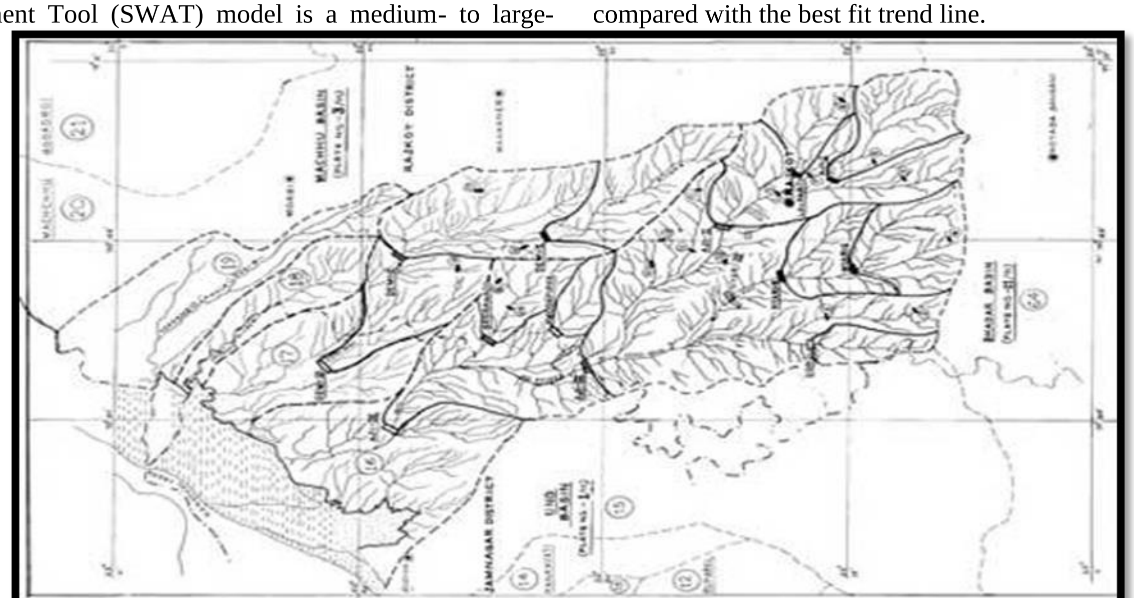

Fig. 1. Location map of the study area

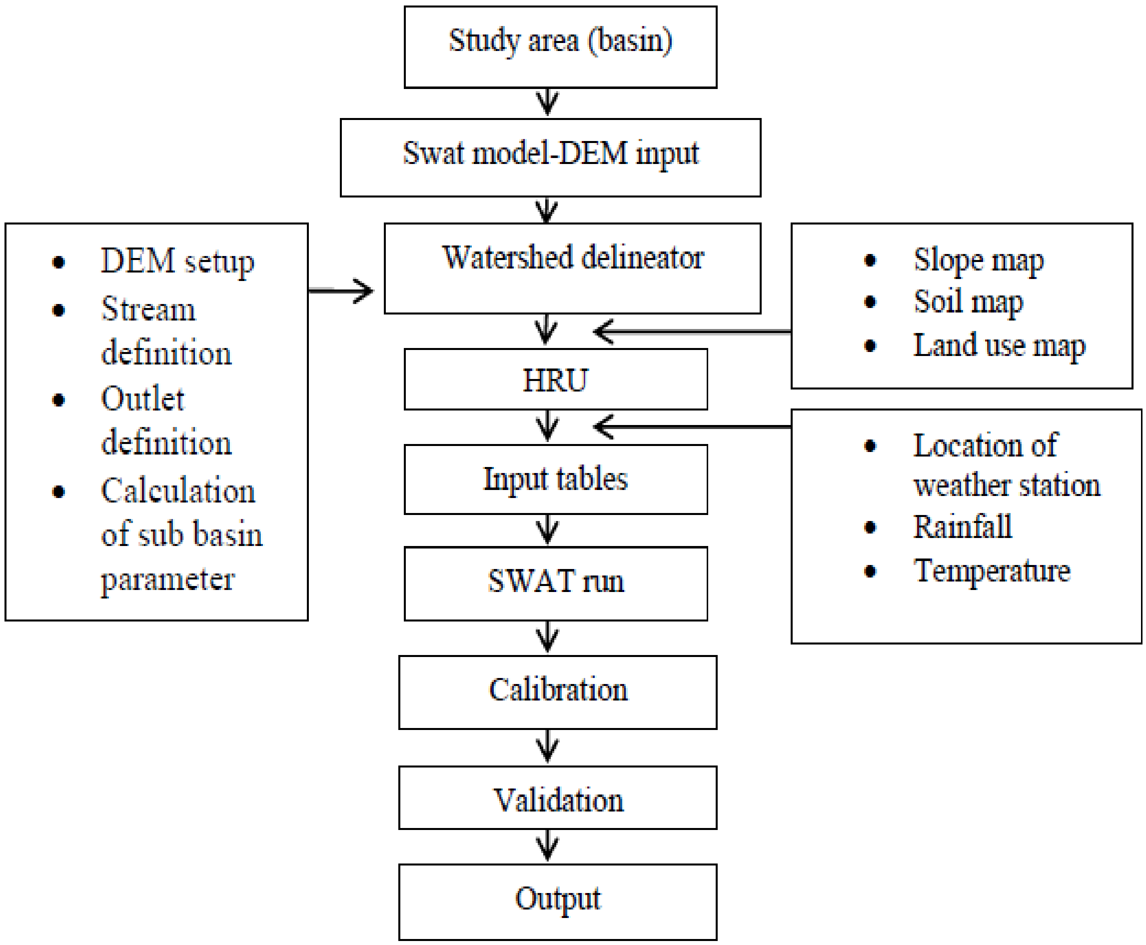

Fig. 2. Procedure followed for the SWAT modeling

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)

Runoff

The average rainy season runoff estimated for the basin are 94.80 mm. 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 (Fig. 3.).

The Kendall statistics for the runoff data series showed that rainfall and runoff are increasing significantly (5% and 10% 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 3.86 and 11.18 mm per year, while that of estimated by Sen's method was found as 6.143 mm/year and 0.328 mm/year and found significant. 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 climatechange 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).

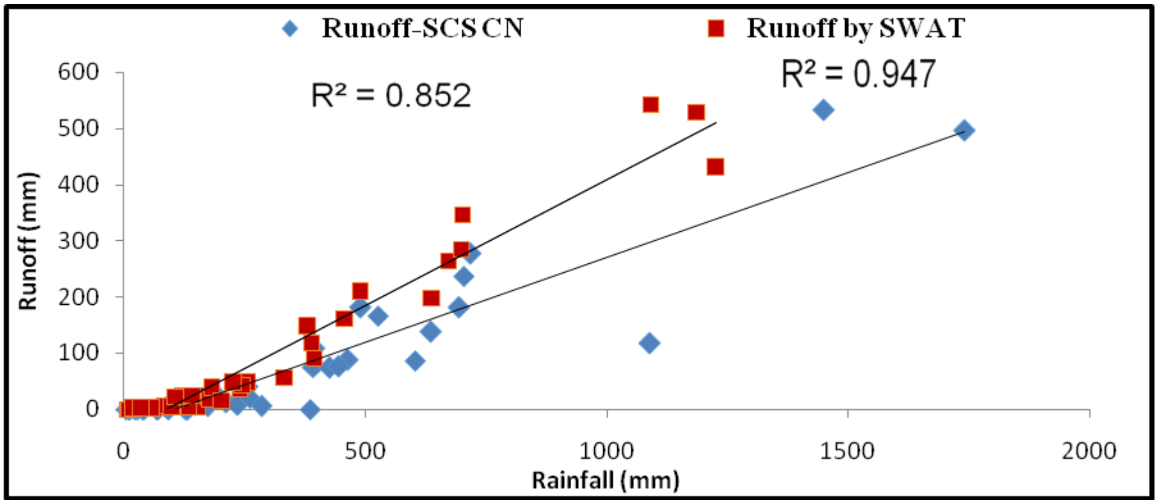

Fig. 3. Comparison of runoff estimation by different methods (1961-2000)

Evapotranspiration

The average potential and crop evapotranspiration during the rainy season was found as 650.23 mm 113.23 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 (Fig. 4.).

The seasonal potential evapotranspiration (PET) during rainy season is decreasing significantly at 5 per cent and the rate of evapotranspiration is -2.06 mm/year during the rainy season, while the crop evapotranspiration (ET) is increasing significantly at 5 per cent with the rate of 2.11 mm/year. The Sen's slope for the time series (1961-2000) of seasonal crop evapotranspiration (ET) and potential evapotranspiration (PET) were found as 1.59 mm/year and -0.96 mm/year. Many evidences showed that PET decreased over the last decade in the world, such as in India (Golubev *et al.*, 2001).

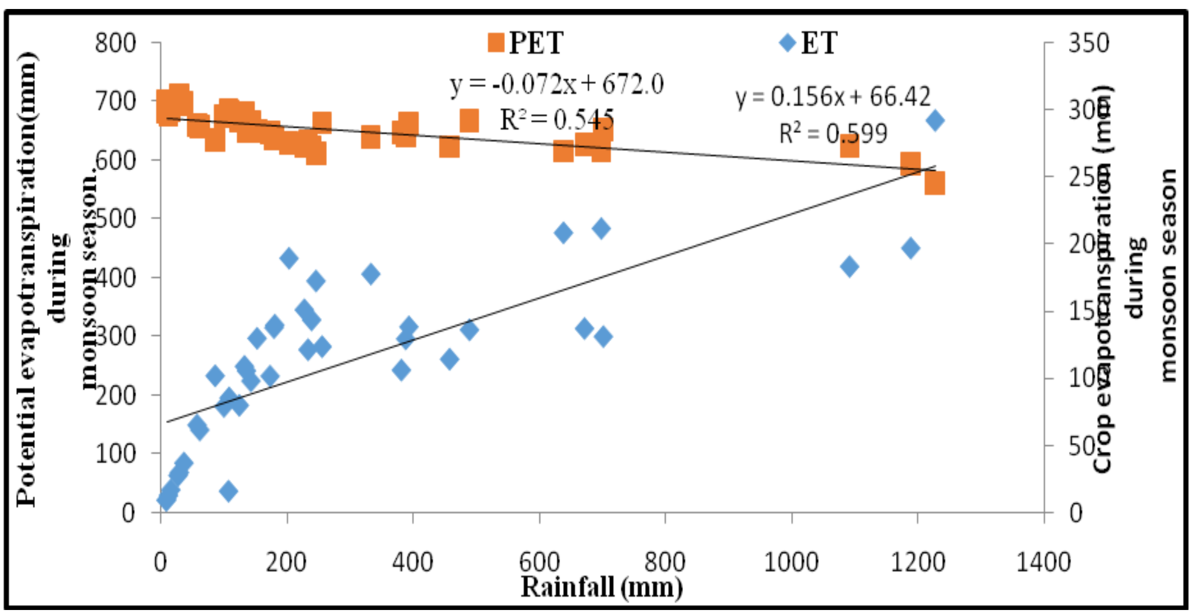

Fig. 4. Estimated potential evapotranspiration by SWAT model in Aji basin (1961-2000)

Groundwater recharge

The average groundwater recharge during the rainy season was found as 30.47 mm. The ground water recharge for the entire basin by SWAT was found varying from 0.00 to 26.54% (1961-2000) with mean of 7.9 % 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 (Fig. 5.).

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 -0.35 mm/year and 0.0 mm/year. The Sen's slope was also found decreasing non-significant. That indicated that the seasonal groundwater recharge during monsoon in basin has stable trend. The mean groundwater recharge during rainy season is 30.47 mm. The minimum and maximum groundwater recharge during the rainy season was found as 0.0 mm and 158.62 mm, respectively.

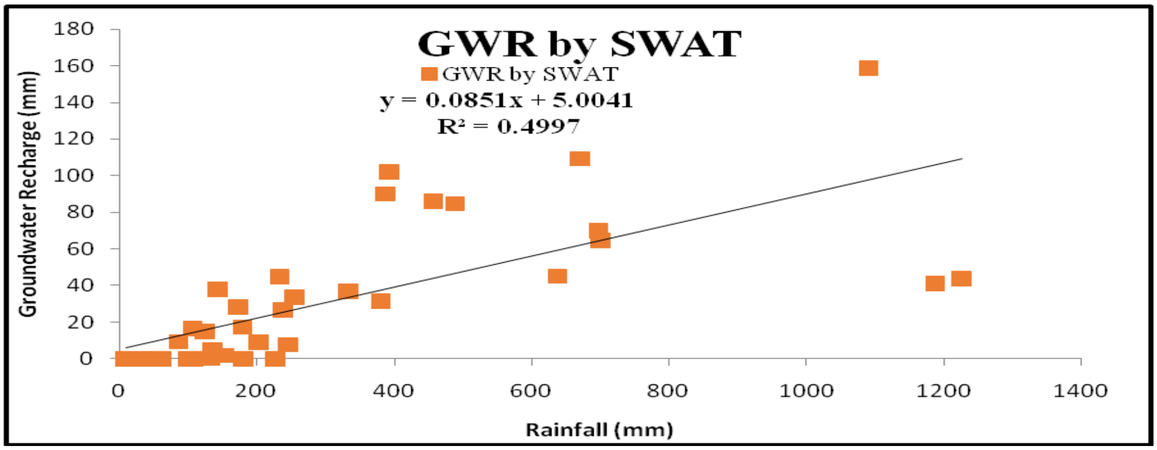

Fig. 5. Estimated Ground Water recharge by SWAT model in Aji basin (1961-2000)

Future Scenario (2046-2064)

Rainfall and runoff

The average rainy season runoff estimated is215.40mm, respectively. The Kendall statistics for the runoff data series showed that runoff is decreasing non-the slope of the best fit trend lineof runoff was observed as -3.019 mm peryear while that of estimated by Sen'smethod was found as -0.001 mm per year. There may be non-significant decreasing trend in runoff (Fig. 6.).

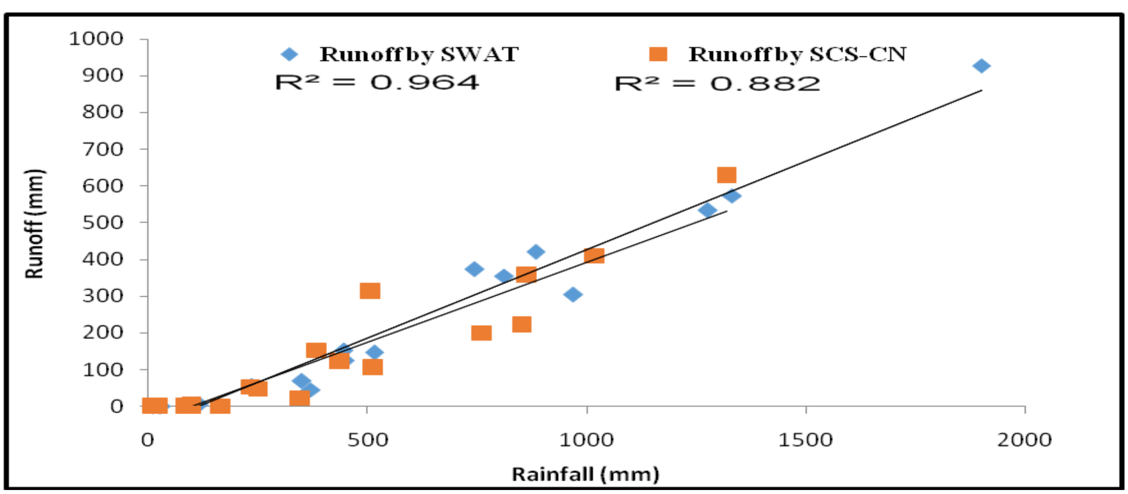

Fig. 6. Comparison of runoff estimation by different methods (2046-64)

Evapotranspiration

The average potential and crop evapotranspiration during the rainy season was found as 649.31 mm and 139.58 mm, respectively. It can be seen that the potential and crop evapotranspiration will be increasing during the future scenario-2046-64. This may be due the increased temperature due to global warming.

The rainy season potential evapotranspiration (PET) is insignificantly increasing at the rate of 0.35 mm/year and the crop evapotranspiration (ET) is insignificantly increasing at the rate of 0.84 mm/year. The Sen's slope for the time series (2046-64) of seasonal crop evapotranspiration (ET) and potential evapotranspiration were found as 3.01 mm/year and 0.774 mm/year. The results of Kendall and Sen's slope statistics are found comparable (Fig. 7.).

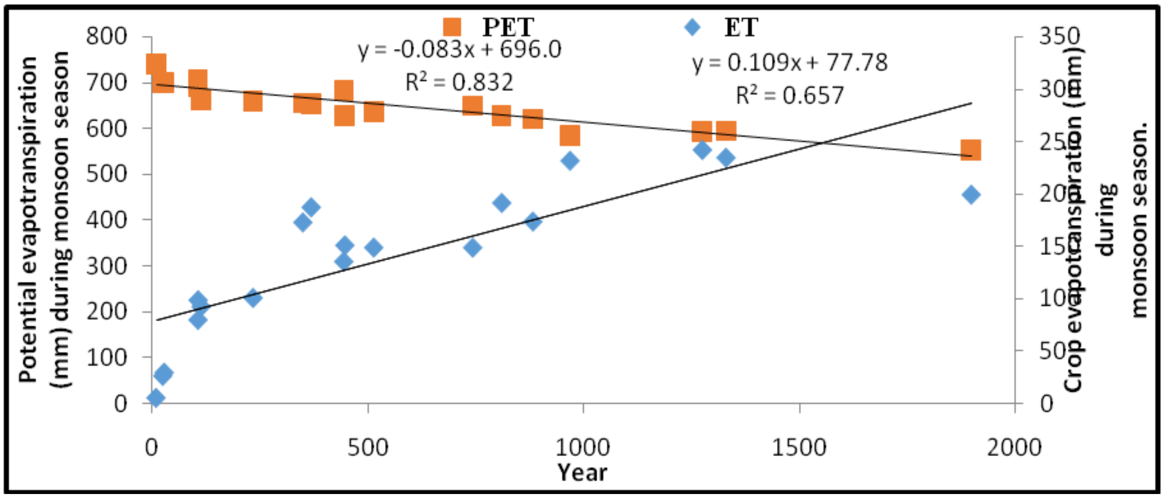

Fig. 7. Estimated potential evapotranspiration by SWAT model in Aji basin (2046-64)

Groundwater recharge

The average groundwater recharge during the rainy season was found as 55.93 mm by SWAT model. The groundwater recharge is increasing insignificantly. The slope of best fitted trend line and Sen's slope were found as 0.131 mm/year and 0.175 mm/year. The mean groundwater recharge during rainy season is 55.93 mm. The minimum and maximum groundwater recharge during the rainy season was found as 0.0 mm and 195.8 mm, respectively (Fig. 8.).

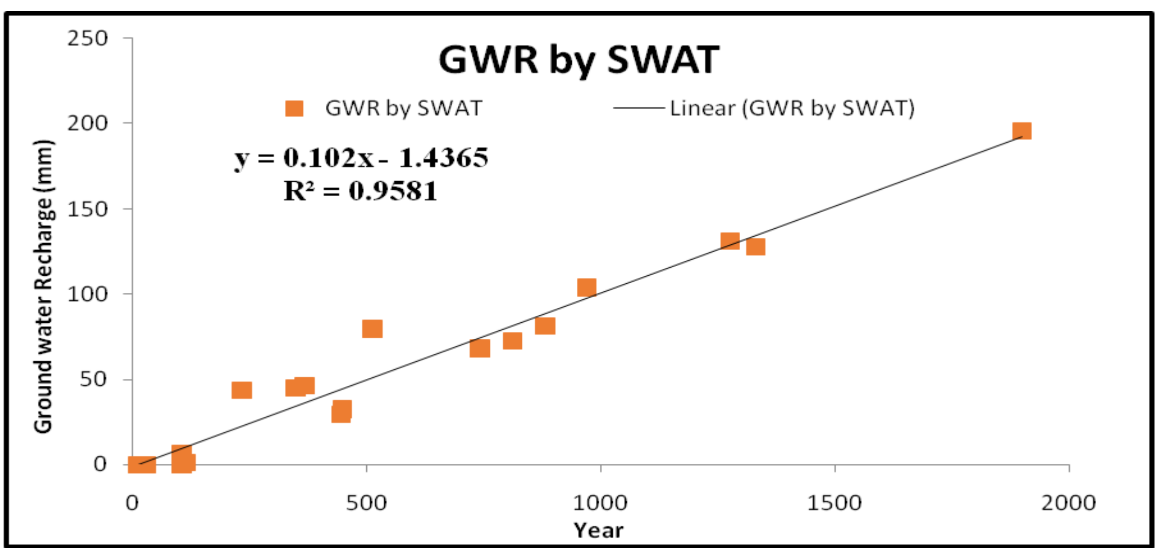

Fig. 8. Estimated Potential evapotranspiration by SWAT model in Aji basin (2046-64)

Future Scenario (2081-2100)

Rainfall and runoff

The average rainy season runoff is estimated for the basin are 204.49 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 5.78 mm per year while that of estimated by Sen'smethod was found as -0.158 mm per year (Fig. 9.).

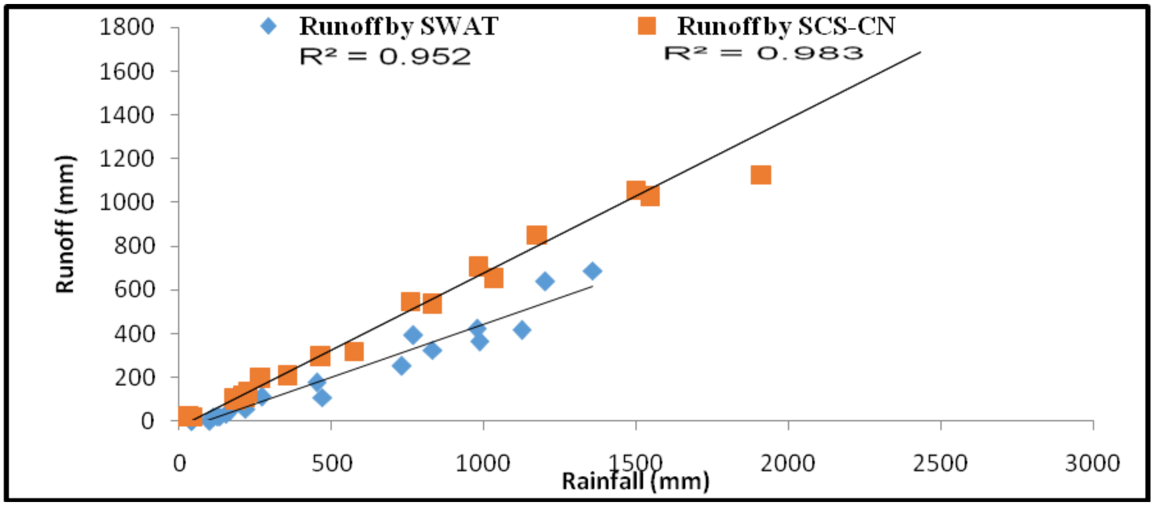

Fig. 9. Potential evapotranspiration estimated by SWAT model in Aji basin (2081-2100)

Evapotranspiration

The average potential and crop evapotranspiration during the rainy season was found as 539.64 mm and 129.12 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 1.20 mm/year during the rainy season, while the crop evapotranspiration (ET) is increasing non-significantly at the rate of 1.07 mm/year. The results of Man-Kendall and Sen's slope statistics are found comparable. The slope of the best fit trend line of annual PET showed that it is also increasing insignificantly at the rate 4.698 mm/year (Fig. 10.)

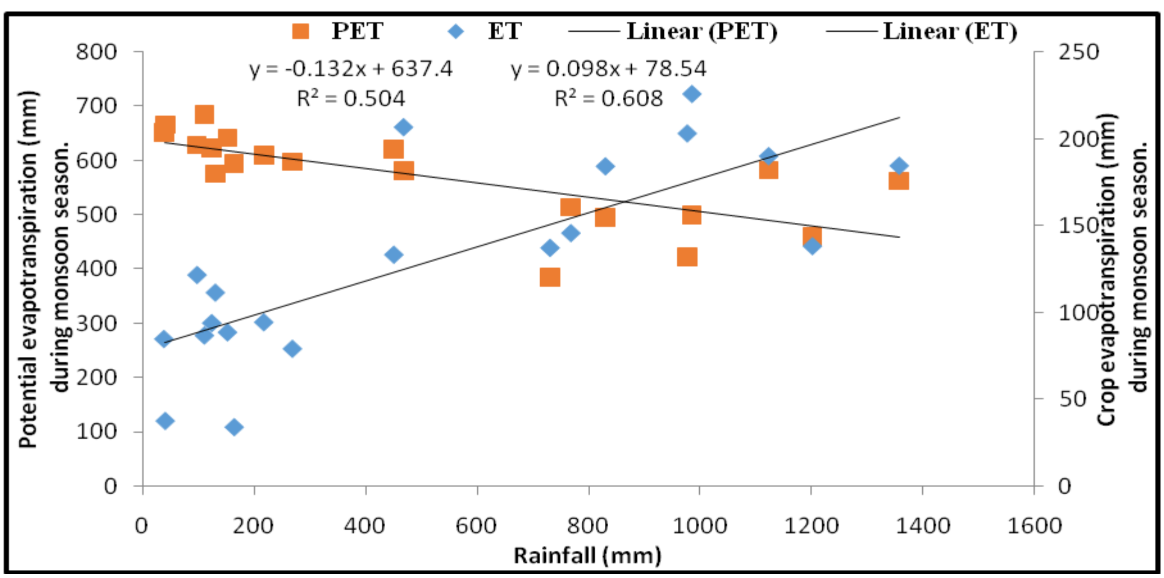

Fig. 10. Potential evapotranspiration estimated by SWAT model in Aji basin (2081-2100)

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 19.45 mm. The minimum and maximum groundwater recharge during the rainy season was found as 0.00 mm and 95.7 mm, respectively (Fig. 11.).

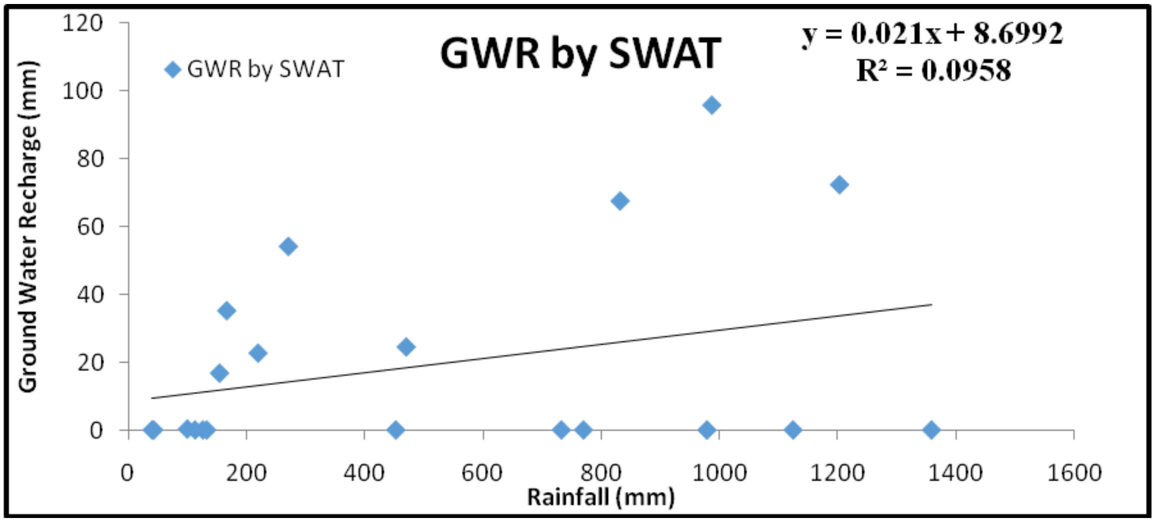

Fig. 11. Estimated Ground Water Recharge by SWAT model in Aji basin (20181-2100)

CONCLUSION

The overall scenarios of 1961-2000, 2046-64 and 2081-2100 shows that the monsoon seasonal rainfall, runoff and crop evapotranspiration are increasing at 24.12mm/decade, 11.55 mm/decade and 2.52 mm/decade while annual and monsoon seasonal potential evapotranspiration are decreasing at 14.20mm/decade and 5.46mm/decade respectively. The groundwater recharge by SWAT model indicated stable trend while.

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