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Impact of Climate Change on Hydrology of Cauvery Basin

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A study was taken up to assess the hydrological response of Cauvery basin, India under current and future climatic conditions using Soil and Water Assessment Tool (SWAT). Future climate predictions indicated the increase in rainfall ranged between 7 and 21 per cent towards mid century (2040 -2069) while this that increase was projected to be between 10 and 33per cent in end century (2070-2099) compared to baseline (1971-2005). In the mid century, the predicted increase in annual Potential Evapotranspiration (PET) varyed from 3 to 4.5 per cent whereas it is 8.4 to 9.3 per cent for end century scenario. Annual water yield is expected to increase by 14 to 21 per cent during mid century and is projected to increase further by 20 to 27 per cent towards end century. The annual soil water storage was also predicted to increase by 5 to 14 per cent and 7 to 18 per cent in the mid and end century respectively.

Key words: Climate change, hydrology, SWAT, Cauvery basin

The impact of climate change is likely to have serious influences on agriculture and water sectors and eventually on the food security and livelihoods of a large section of the rural population in developing countries. Hydrology of most of the river basins is expected to get altered due to changing climate and most of the models predict lesser water availability for agriculture in the coming decades (Ragab and Prudghomme, 2002). River Cauvery is the fourth largest river in southern India in terms of agriculture and ensuring food security that covers 5.8 Million ha of cultivable area, which contributes to 40 per cent of the total food grain production of Tamil Nadu. Climate change induced variations in precipitation pattern (onset and withdrawal, amount, intensity, distribution), frequent extreme weather events (flood and drought) in Cauvery basin is a threat to agriculture production in Tamil Nadu. Hence, assessing the climate change impact on hydrology is the need of hour for developing suitable adaptations strategies that could help the farmers to sustain the crop production and income in the context of changing climate and increasing water scarcity. Understanding the fundamental relationship between natural variables namely soil, climate, terrain parameters and crop management practices is required to cope with water scarcity. This warrants employing a spatially distributed and physically based hydrologic model such as Soil and Water Assessment Tool (SWAT), which incorporates each of these interrelated functions. In the current study, impact of climate change on hydrology of Cauvery basin was assessed using SWAT model.

Materials and Methods

Description of the study area

The Cauvery basin has a drainage area of around 81,155 km_2 spread between $10_0$7' and 13 $_0$ 28' N latitudes and 75 $_0$ 28' and 79 $_0$ 52' E longitudes (Fig.1) over the states of Karnataka, Tamil Nadu, Kerala and Union Territory of Pondicherry. Cauvery basin receives an annual average rainfall of 1129 mm and of which, about 50 per cent is received during the south-west monsoon (June-September), 33 per cent in the northeast monsoon (October – January) and the rest in the summer months (February - March).

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SWAT model description and model setup

The Soil and Water Assessment Tool (SWAT) is a conceptual watershed scale simulation model that was developed by Arnold *et al*. (1998) and Srinivasan *et al.* (1998) as a decision support tool to assess the impact of land management practices on the water resources of United States. Currently, SWAT is applied worldwide and is considered as a versatile model that can be used to integrate multiple environmental processes, enabling more effective watershed management and better informed policy decision. SWAT can be used to study the long term effects of natural variations in climate as well as the manmade interventions on water yields in un-gauged catchments. The model can be used for the assessment of existing and anticipated water uses and water shortages (Gosain *et al*., 2005).

The SWAT model requires a variety of detailed information describing the watershed viz., information on elevation, slope, soil, land use and climate. Digital Elevation Map (DEM) derived from 90 m SRTM (Shuttle Radar Topography Mission) dataset was used to provide the topographic information for delineating the watershed. A digital soil map obtained from FAO to drive the Karnataka soil information and soil map at 1:50,000 scales obtained from the Remote Sensing Unit of Tamil Nadu Agricultural University was used to define the Tamil Nadu soil of the basin.

The Cauvery basin has 38 % clay loam, 26 % sandy clay loam and 13 % sandy loam soils (Fig. 2). Land use and land cover data (Fig. 3) was obtained from National Remote Sensing Centre (NRSC), Hyderabad to derive the information on agricultural areas and this data was merged with the irrigation source information (Fig. 4) acquired from Global irrigated area map (GIAM) developed by International Water Management Institute (IWMI), Hyderabad to create a map on land cover with irrigation sources. In the Cauvery basin 24.8% of the area is covered by forest and 73.2% by agriculture. Twenty three percent of the basin is irrigated from surface water sources, 22 % from ground water and 19 % with conjunctive use of surface and ground water. Rainfed agriculture occupies about 9 % of the area in the 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 (1971-2005) 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 (2040 -2069) and ii. end century (2070-2099).

For ease of modelling and handling the data, the entire Cauvery basin was divided into five smaller basins viz., Basin1 (Upper Cauvery upto Mettur reservoir), Basin 2 (Mettur to Upper Anicut), Basin 3 (Amaravathy basin), Basin 4 (Upper Anicut to Grand Anicut) and Basin 5 (Downstream of Grand Anicut, including lower Anicut and the delta region) (Fig. 5). Each basin was modelled separately and then integrated all the 5 small basins by linking and routing procedure.

Using 90 M SRTM DEM and digitised stream network from google earth, the GIS interface ArcSWAT 2009 (Version 93.7f) was used to accurately delineate the streams. Each of the five basins was subdivided into many sub-basins (Fig. 6) and on the whole the entire Cauvery basin was divided into 704 subbasins. Each sub-basin was further sub divided into Hydrological Response units (HRUs) having unique soil and land use. The sub-basins of basin1, basin2, basin3, basin4 and basin5 were divided into 2561, 3431, 1807, 1585 and 2434 HRU's respectively. The model was executed by keeping all the SWAT input parameters constant except climate variables which were changed according to the period of simulation.

Results and Discussion

Changes in the precipitation pattern due to climate change

Annual rainfall is expected to be more in the mid century compared to the baseline (Fig. 7). The rate of increase is expected to be higher in the upper Cauvery region i.e., Karnataka part of Cauvery) where the rainfall is expected to be 21 % higher than the baseline, while in the middle Cauvery and delta region, there is a possibility for 11 % and 7 % increase than the baseline condition respectively. The end century shows significant increase in precipitation compared to midcentury and baseline. In the Upper Cauvery region, the precipitation would be higher by 33% than the current quantity. In the middle Cauvery region and in the delta region the annual rainfall is expected to increase by 15 % and 10% respectively. The increase in rainfall 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).

Hydrological response to Climate change

The spatial and temporal effects on hydrological response to climate change in terms of PET, Soil water content and water yield is estimated and analysed for baseline (current condition), mid century and end century.

Climate change and Water yield

Average annual and seasonal water yield (sum of surface flow, lateral flow, and ground water flow contribution to stream flow) are expected to increase in mid and end century times (Fig. 8). As per model prediction, the annual water yield is expected to increase by 21, 15 and 14% in the Upper Cauvery, middle Cauvery and delta region respectively in the mid century than the current levels. In the end century, it is expected to increase by 27, 20 and 21% respectively for Upper Cauvery, middle Cauvery and delta region compared to current conditions. Increase in precipitation would lead to increased water yield as result of increase in the surface flow, lateral flow and ground water flow. Gosain *et al*. (2011) also have reported increased level of precipitation and a corresponding increase in water yield in future for Cauvery, Ganga, Brahmaputra and Pennar.

Climate change and Potential evapotranspiration

In the end-century the increase is expected to be higher whereas slight increase is expected in annual PET in the mid century (Fig. 9). In the upper Cauvery, the annual PET is expected to increase by 4.3% in the mid century and by 8.4 % in the end century compared to baseline. The predicted change ranges from 3 to 3.7 % during mid century and from 5 to 8.7 % in the end century over mid Cauvery. The increase is expected at delta region by 4.5 and 9.3 % in mid and end century respectively. The magnitude of changes in PET in the mid century, is lesser than the end century, which is obviously due to increase in temperature. However, PET is not only affected by the temperature but also by the CO_2 concentration and it is a known fact that any increase in CO_2 would tend to increase the water use efficiency due to decrease

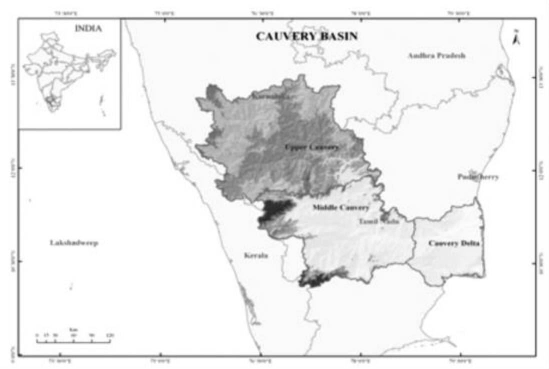

Fig. 1. Location of Cauvery basin in India

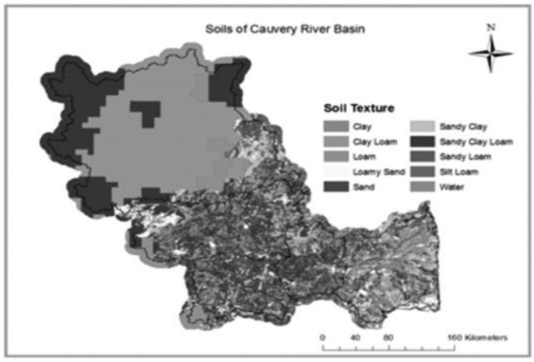

Fig. 2. Soil map of Cauvery basin

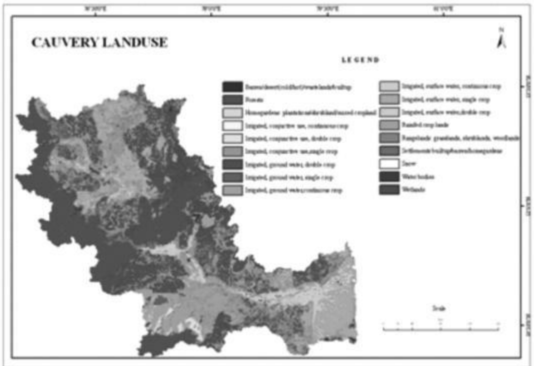

Fig. 3. GIAM data for Cauvery basin

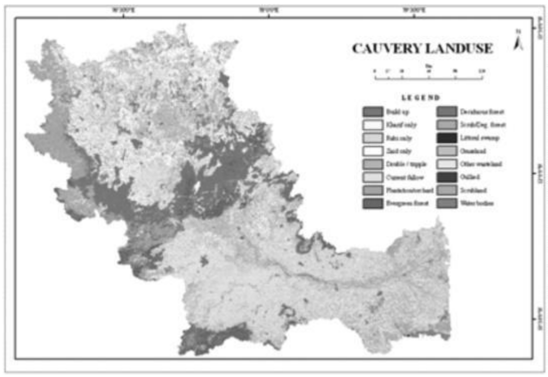

Fig. 4. Land use / Land Cover data from NRSC for Cauvery basin

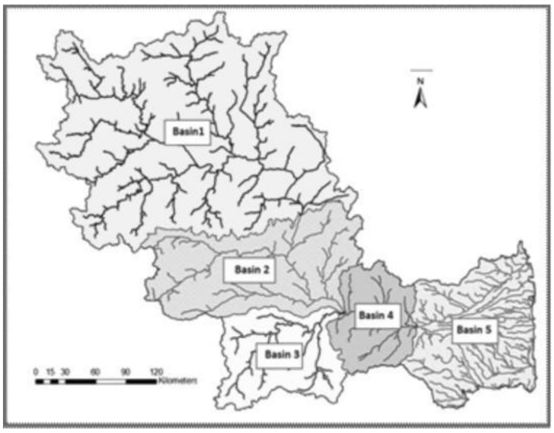

Fig. 5. Stream network generated from the DEM

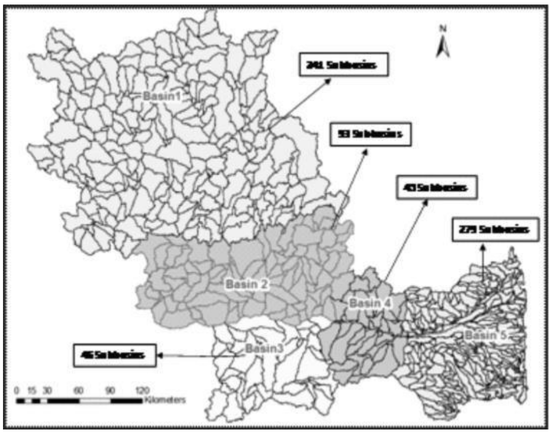

Fig. 6. Delineated Cauvery Basin

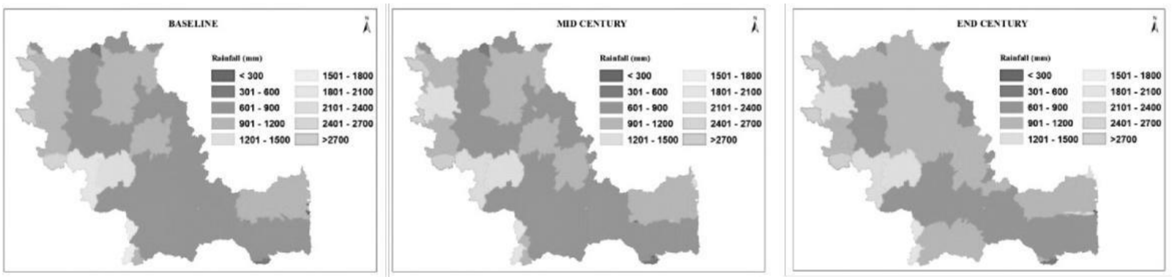

Fig. 7. Spatial distribution of annual rainfall in Cauvery basin

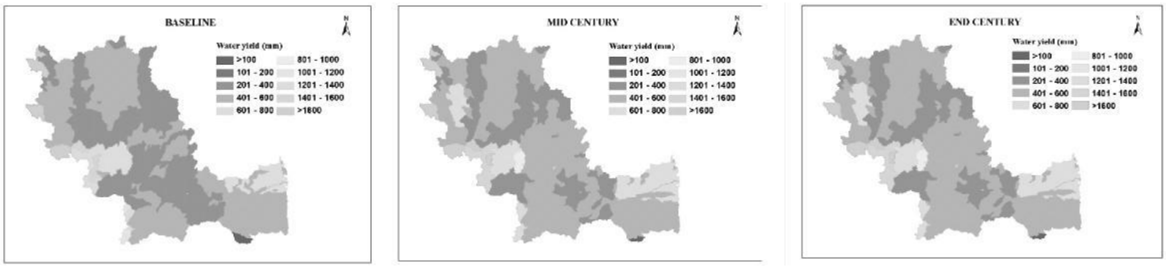

Fig. 8. Spatial and temporal variation of annual average water yield in Cauvery basin

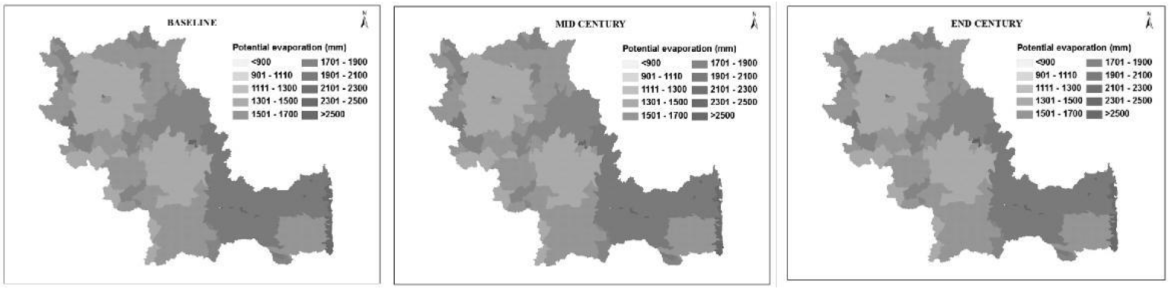

Fig. 9. Spatial and temporal variation of annual Potential evapotranspiration in Cauvery

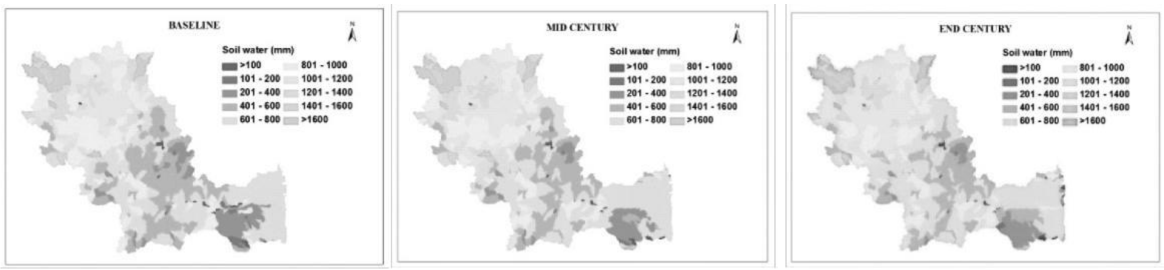

Fig. 10. Spatial distribution of annual soil water storage

in stomatal conductance of the leaves which would reduce the rate of transpiration. Morison (1987) and Rosenberg (1988) found a positive relationship between elevated CO_2 and stomatal resistance and the resultant decrease in transpiration. During the mid century, the temperatures are expected to increase by around 1.8 $_{0}$ C and the impact of this might get nullified due to the simultaneous increase in CO_2 concentration in the atmosphere. Islam *et al*. (2012) also reported a decrease in ETo demand with increases in CO_2 levels which has moderated the increase in ETo due to increasing temperature. However, in the end century, PET is expected to increase even with higher CO_2 concentration which may not have sufficient offsetting the impact of increase in temperature by more than 3.5 $_{0}$ C.

Climate change and soil water storage

The annual soil water storage is also predicted to increase in mid and end century (Fig. 10). In the mid century, the annual soil water storage would increase by 14, 7 and 5 % in upper Cauvery, mid Cauvery and delta region respectively. In end-century, it is expected to increase by 18, 10 and 7 % in upper Cauvery, mid Cauvery and delta region respectively. Increase in soil water storage with increasing precipitation as simulated in the present study is also in line with the result of Christensen *et al*. (2007) and Meehl *et al*. (2007).

To conclude, hydrology of Cauvery basin is expected to be greatly affected by climate change by climate variability and change. Rainfall, water yield and soil water storage are expected to increase in future time which would have marked implications on agricultural production and the regional food security.

Acknowledgement

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