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Short Communication

Impact of climate change on runoff and potential evapotranspiration in Brahmani basin, Odisha, India

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Global warming resulting from the emission of greenhouse gases is the primary cause of climate change that has raised the average air temperature of the earth. The amount of reflected solar radiation decreases when these gases are present in higher quantities in the atmosphere that causes warming of the planet (Hansen, 2004; Ming *et al.,* 2014). The primary sign of climate change is deviation in rainfall behaviour and increase in air temperature (Box *et al.,* 2019). The water availability and the river discharge are impacted by these changes, which influences regional water balance. The magnitude of streamflow is affected by the changes in precipitation volume, intensity, and frequency, which have impact on the frequency as well as the intensity of severe events like flood and drought (Kundzewicz *et al*., 2008). There have been major changes in global average precipitation, surface temperature, floods and droughts, as stated by the Intergovernmental Panel on Climate Change (IPCC) and these changes are anticipated to continue in future. Developing nations like India are more vulnerable due to the adverse impact of climatic variability on water resources and agricultural sectors (Nath and Behera, 2011).

Therefore, a better knowledge on the changes in hydrological parameters arising from climate change is needed for sustainable agriculture and natural resources management. The two hydrological processes most important to take into account are runoff and potential evapotranspiration (PET). Runoff has an impact on river flow, water supply, hydropower generation, irrigation and soil erosion etc. (Mendoza *et al*., 2011). On the other hand, evapotranspiration (ET) has a wide range of applications like estimation of crop water and irrigation demand, irrigation scheduling, agricultural water allocation, and crop yield estimation etc. (Rank *et al*., 2023). Therefore, for assessing the sustainability of water resources and agricultural production system, it is essential to examine the effects of climate change on runoff production and ET of a catchment. It will be useful in taking up appropriate mitigation measures for sustainable management of water in the catchment.

Now-a-days, hydrological models have been popularly used for estimation of hydrological fluxes. These models are the simplified representations of the natural hydrologic processes (Gosain *et al***.**, 2006; Saharia and Sarma, 2018). In the last 10 years, the use of SWAT (Soil and Water Assessment Tool), a basin scale semi-physical agro-hydrological model, has been extensively used in the water resources and agricultural sectors (Uniyal *et al***.**, 2015). The SWAT model also helps in the future projection of agricultural water demand and supply using climate model inputs (Jha and Gassman, 2014). The current study employed the SWAT model to estimate future runoff production and PET in the Brahmani river basin of India and its changes with respect to the current situation.

Study area

The Brahmani basin is a prominent basin in the eastern India. It is the second longest river of Odisha. The major land use in the basin are agricultural and forest lands. The agricultural land use accounts for about 52% area of the basin. Brahmani River is generated by the confluence of the Sankh and South Koel Rivers. The basin lies between 20°28′ and 23°35′ N latitude and 83°52′ and 87°03′ E longitude that covers parts of Odisha, Jharkhand, and Chhattisgarh. The total area of the catchment is around 39,313 km^2. About 58% of the basin is located in Odisha. The mean annual rainfall of the basin is around 1305 mm. Tropical climatic conditions generally prevail in the basin. The maximum temperature reaches up to 47°C during summer and the minimum temperature falls to about 4°C in winter. The maximum elevation of the basin is nearly 1181 m. A map showing the location of Brahmani River basin is presented in Fig. 1.

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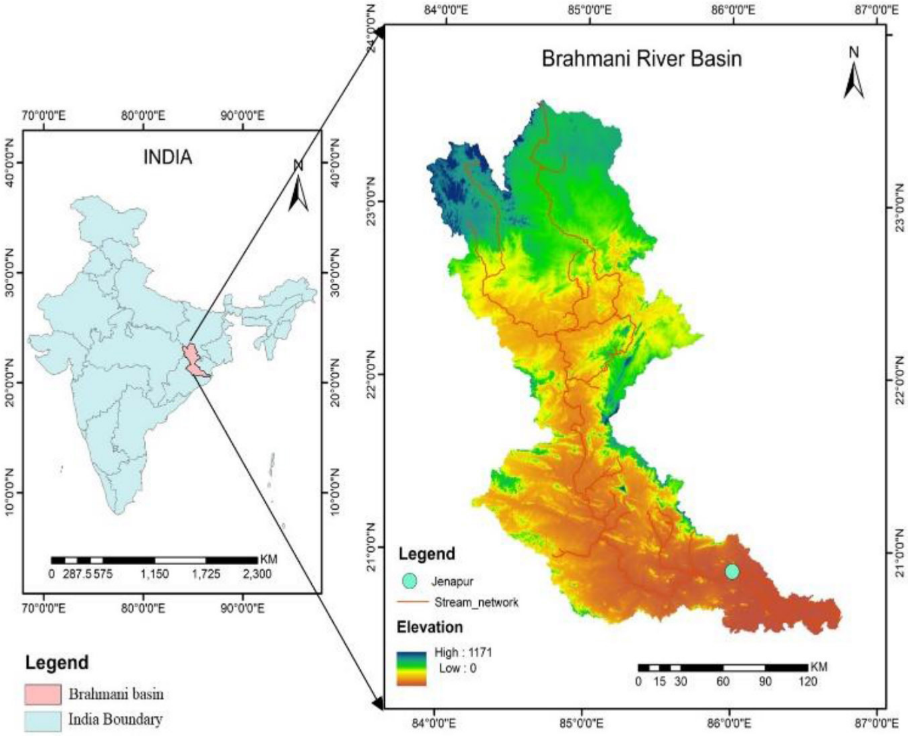

Fig. 1: Location map of the study area

Model simulation

Digital elevation model, soil, land use/land cover and climate are the essential inputs for the SWAT modeling. Around 135 hydrological response units (HRUs) were generated utilizing soil, slope and land use. The weather generator file of the SWAT model was built using the data of daily precipitation, minimum & maximum temperature, solar radiation, relative humidity and wind speed data of various gauging stations of the Brahmani basin for the period from 1990 to 2015 (26 years) taken from IMD. The model was simulated using the observed data of streamflow recorded at the Jenapur gauging station of the Brahmani basin for the period from 1997-2020. The first three years (1997–1999) of the model simulation was taken as the warm-up period. The data of streamflow for the years 2000 to 2012 were used for model calibration, while the rest eight years' data (2013-2020) was taken for validation. The performance indicators tested during the periods of calibration and validation are listed in Table 1. The highest and lowest temperatures as well as future precipitation in the basin was projected using the CanESM-2 Global Climate Model (GCM). Compared to hypothetical scenarios, climate change scenarios produced by the GCM outputs are more reasonable (Legesse *et al*., 2003). Although GCMs are the commonly used models to evaluate the impact of climate change, their course spatial resolution prevents them from being directly applied to local or regional studies (Araya-Osses *et al*., 2020).

Therefore, downscaling procedures are necessary to change the spatial resolution of the data from coarse to fine (Hamlet *et al*., 2020). The two most popular techniques for downscaling are dynamical downscaling and statistical downscaling. Without having the physical knowledge on the local location, statistical downscaling establishes a direct link between the observations, climatic factors and GCM output (Fowler *et al*., 2007; Ali *et al*., 2019). The Statistical Downscaling Method (SDSM), well-known as statistical model, was established by Wilby *et al.,* (2002) to downscale GCMs outputs. The future temperature and rainfall scenarios were projected using two typical RCP (Representative Concentration Pathway) scenarios such as RCP 4.5 and RCP 8.5, which reflects future medium and high carbon emissions, respectively (Pandey, 2023). A statistically downscaled GCM (Can-ESM) dataset has been used in the current study to analyze climate change impact under the RCP 4.5 and 8.5 scenarios up to the year 2085. Furthermore, the future runoff and PET were simulated using statistically downscaled GCM inputs. The study was conducted for two future time periods, 2050 and 2085 and was compared with the base period of 2001–2015.

Projection of future runoff and potential evapotranspiration

Comparing both RCP scenarios with the base period, it was observed that the SWAT model forecasted a rising trend in

Table 1: Summary statistics of model performance

Indices	Calibration	Validation
R^2	0.81	0.76
NSE	0.8	0.72
PBIAS	-0.08	-0.17
P-factor	0.77	0.86
R-factor	0.89	0.82

Table 2: Average monthly annual runoff and PET in the Brahmani basin

Month	Base Period	RCP 4.5		RCP 8.5	
	2001-2015	2050	2085	2050	2085
		Runoff (mm)			
January	2.8	3.8	6.8	2.3	1.9
February	4.3	0.9	3.9	1.9	1.7
March	3.8	2.3	1.3	2.2	0.9
April	2.1	0.9	0.6	0.4	0.0
May	6.7	7.9	15.2	8.7	6.3
June	52	41.9	45.1	47.3	62.2
July	81.7	109	121.6	124.4	137.6
August	101.9	123.6	127.5	130.1	144.3
September	72.6	134.9	142.4	147.7	162.3
October	39.5	68.6	78.2	45.1	25.3
November	6.2	37.7	22.8	10.1	9.9
December	1.9	1.3	8.9	2.3	1.9
Annual	375.5	532.8 (41.9%)	574.3 (52.9%)	522.5 (39.1%)	554.3 (47.6%)
		Potential evapotranspiration (mm)			
January	110.9	121.4	103.9	113.3	117.4
February	119.1	109.1	98.07	112.7	121.4
March	167.6	171.8	179.9	185.6	187.1
April	197.3	174.1	188.3	190.5	202.9
May	209.6	261.9	251.9	261.0	269.3
June	158.8	162.2	165.6	170.6	181.8
July	129.3	141.8	133.4	135.2	143.1
August	121.1	142.6	139.4	145.1	147.0
September	119.8	147.1	152.5	155.1	161.6
October	115.9	133.0	123.4	133.4	139.6
November	103.9	175.3	172.2	183.6	187.8
December	99.3	101.9	124	138.9	140.9
Annual	1652.6	1842.2 (11.5%)	1832.5 (10.9%)	1925 (16.5%)	1999.9 (21.0%)

both runoff and potential evapotranspiration (Table 2). The annual runoff from the basin showed a noticeable growing tendency under RCP 4.5 than 8.5. Interestingly, during the base period 2001–2015, the maximum runoff was in the month of August, but for the future periods (2050 and 2085) maximum runoff would be in the month of September under both the RCPs. The current practice of transplanting rice in the study basin starts from the end of July till mid-August, which is likely to shift towards September. Similarly, the estimated PET for both scenarios indicated a rising trend (Table 2). The highest PET for the base period was in the month of May, which was equivalent to the future scenarios as well, however the magnitude of PET would likely to increase in future. RCP 8.5 projected higher PET than RCP 4.5.

The annual variations in rainfall, runoff and PET from the base period under RCP scenarios 4.5 and RCP 8.5 are presented in Fig. 2. The runoff may increase by an amount of 41.9% under RCP 4.5 and 39.1% under RCP 8.5 by the end of 2050. Again, the runoff may increase up to 52.9% under RCP 4.5 and 47.6% under RCP 8.5 by the end of 2085. In both the scenarios, the percentage increase in the streamflow is found to be higher than the equivalent rise in rainfall. This suggests that during the next thirty years, there will be comparatively more intense rainfall events. In the upcoming years, the increased intensity of rainfall will be the primary factor increasing runoff, which may cause less groundwater recharge, less catchment storage and more soil loss from the watershed.

In the similar manner, the percentage increase in average annual potential evapotranspiration over the base period may reach up to 11.5% under RCP 4.5 and 16.5% under RCP 8.5 by the end of 2050. Towards the end of 2085, the annual PET demand may increase by 10.9% under RCP 4.5 and by 21.0% under RCP 8.5 as compared to the based period. Since PET is a climate-driven variable, rising ambient temperatures is the main cause of its increment. Therefore, it is anticipated that throughout the next 30 years, the trend of atmospheric temperature would most certainly continue to follow an increasing trajectory. The study depicts that the agricultural water demand is supposed to increase throughout the Brahmani River Basin in the upcoming years.

Study on land use changes indicated that the anthropogenic activities in the basin, deforestation and conversion of forest land to agricultural land in future supports generation of higher runoff and soil loss in the basin.

Overall, the loss of runoff is anticipated to aggravate the agriculture water availability. In addition to unexpected flooding from numerous flash floods brought on by the intense rainfall throughout the basin during the monsoon season, the crop may experience moisture stress as a result of frequent dry spells and

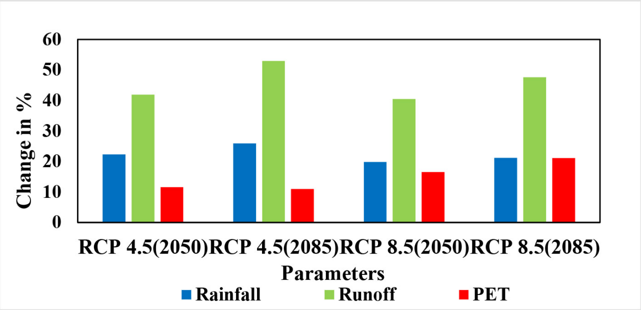

Fig. 2: Projections of changes in annual precipitation, runoff and PET compared to the base period under RCP 4.5 and 8.5

higher PET demand. Harvesting of the monsoon runoff in order to irrigate winter crops as well as supplement the water demand during the dry periods, creating the best crop plan possible in order to make the most of the monsoon rains. Light-duty short-duration crops may be preferred in place of the heavy-duty crops in order to reduce the higher irrigation requirement, which may aggravate in future by the rising trend of potential evapotranspiration. An emphasis should be given on establishing soil and water conservation measures and increasing afforestation, which would help to reduce runoff losses, increase in-situ soil moisture and recharge the groundwater.

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