# ABSTRACT


IMPACT OF CLIMATE VARIABILITY AND HUMAN ACTIVITIES ON ALTERATION OF RUNOFF IN SOUTH KOEL RIVER BASIN, EASTERN INDIA

The present work was carried out to trace the impact of climate variability and human activities on the alteration of the runoff in the South Koel River basin in Eastern India under the tropical monsoon climate. The whole work was designed in view to achieve three specific objectives. The first objective was to assess the temporal variability of rainfall and runoff since 1973 in terms of trend and step change in the South Koel River Basin. The second one was to assess the relative contribution of climate variability and human activities to cause the alteration of runoff in the study area. The third objective was to capture the runoff sensitivity to changes in individual land use land cover classes with special reference to forest cover, agricultural land use, and urban built-up area in the concerned river basin.

The required databases include weather parameters which were collected from NASA Power Data Access; Land use and land cover (LULC) data which were prepared by classifying Landsat TM and OLI images; Soil data that was collected from ISRIC-WDC; and runoff data that was collected from Central Water Commission, Govt. of India.

As per the first objective, rainfall and runoff are two separate response variables which were analyzed separately against time to detect step change and trend. Buishand U test, Buishand Range test, and Standard Normal Homogeneity test were applied for step change analysis of normally distributed series; otherwise, Pettitt's test and Sequential Mann-Kendall test were applied. Mann-Kendal test was applied for detecting trends in the series having no autocorrelation; otherwise, the Modified Mann-Kendal test was applied for capturing the trend. The magnitude of the trend was measured by Sen's slope estimator. The normality was checked by the Kolmogorov-Smirnov test and Shapiro-Wilk test, while the lag1 autocorrelation was checked by Pearson's correlation coefficient *(r)*.

To achieve the second objective, the whole study period (1981-2018) was divided into the reference period and the interference period based on the change point detected in the step change analysis. The SWAT model was calibrated to LULC of the reference period, and the model was run with meteorological data of the same period designated as 'Sim 1'. Another SWAT model was calibrated to LULC of the interference period, and the model was run using meteorological data of the interference period called 'Sim 2'. So, the mean runoff difference between Sim 2 and Sim 1 was supposed to be the total runoff change caused by climate variation and human intervention. On the other hand, the SWAT model calibrated to LULC of the reference period was again run with meteorological data of the interference period, known as 'Sim 3'. Any difference in mean runoff between Sim 3 and Sim 1 would be due to climate variation, and the difference between Sim 2 and Sim 3 reflects the change due to human interference. The significance of the mean runoff difference was evaluated by t-Test, and the effect size was also computed by Cohen's *d*.

To achieve the third objective, the whole basin was divided, based on uniformity in LULC class, into homogeneous units, what is technically called Hydrologic Response Unit (HRU). Each HRU of forest cover, agricultural land, and built-up area were separately classified into four categories based on their areal coverage, and runoff was simulated for

them. Then ANCOVA model was run to judge whether the mean runoff of each of the three LULC classes varied across their respective size groups. Any significant difference reflects the runoff sensitivity to the size group of the respective LULC class.

As per the results, no significant change points and trends were found in the rainfall series. The monsoon and annual runoff series, on the other hand, showed significant step change and decreasing trend. Buishand tests detected 2001 as a change point, while the Standard Normal Homogeneity test identified 2008. The rate of decrease in monsoon runoff was 4.731-5.29 mm/yr., whereas that of annual runoff was 5.126-5.292 mm/yr. The trendless rainfall and decreasing runoff tendency imply that rainfall is not the driving force for the alteration of runoff; rather, human intervention is playing an effective role in such change.

The SWAT model output and t-Test show that rainfall caused the increase in runoff from the reference period to the interference period, although its contribution was not statistically significant at all at a 5% significance level, whereas LULC was found to have caused a decrease in runoff significantly at the same significance level. Their combined effect caused an overall decrease in the runoff by 195.87 and 224.64 mm based on change points 2001 and 2008, respectively. The respective contribution of rainfall on runoff increase was 84.29 mm (43.03%) and 58.13 mm (25.88%), while that of LULC on decreasing runoff was 280.15 mm (143.03%) and 282.77 mm (125.88%). The respective effect size of LULC impact was huge (Cohen's $d = 2.27$) and very large (Cohen's $d = 1.95$).

The interesting feature that was deduced is the forest cover decreased by 7.04% from reference to the interference period while the agricultural land increased by 4.25% during the same period; this kind of LULC change is supposed to increase runoff, but instead of increase, the runoff was reduced. It was substantiated by facts collected through field investigation. Through field survey, it was known that in the last 15-20 years, the local farmers have been cultivating more water-consuming high-yielding crop varieties, and the canal was commissioned in 2008-2009 for diverting flow for irrigation, which together effectively reduced the runoff in the basin.

ANCOVA results, in which rainfall was controlled, showed that runoff was sensitive to the size class of forest and that of agricultural land, whereas runoff was not sensitive to built-up areas. This might be due to the limited areal coverage of urban built-up and its scattered distribution within the basin. However, a similar result was produced by ANOVA, which did not eliminate the rainfall effect. This similarity in both results also implies that human intervention is more important than rainfall for causing alteration in runoff. However, the threshold value beyond which runoff changes is determined to be 1.35 $km^2$ for forest cover and 1.30 $km^2$ for agricultural land.

So, the evidences are strong enough to conclude that the climate of the South Koel River basin remains stationary over time, whereas runoff is getting reduced day by day, and human intervention is playing a pivotal role over here. The reorientation of agricultural technology may be an effective strategy to stop the runoff reduction and to get sustainable stream flow. The present study did not incorporate the variability of rain intensity and its impact on stream flow which needs further investigation to gain a comprehensive understanding of the basin hydrologic system. However, it is expected that the findings may provide the relevant database and guiding principle in formulating a strategic plan for making stability in the runoff yield of the basin.