Empirical Approach-Based Potential Impact Analysis of Climate Change and Land-Use Conversions on Streamflow Variations: A Case Study of the Brahmani Catchment

Sushree Swagatika Swain[1], Ashok Mishra[1], and Chandranath Chatterjee[1]

[1]Indian Institute of Technology Kharagpur

November 24, 2022

Abstract

Streamflow, the fundamental element of catchment-scale hydrology, is expressed as a complex response of many hydrological processes that includes atmospheric forcing (precipitation and temperature) and human activities (land-use change, reservoir/dam construction, and excessive water exploitation). Thus, change in climate variables and land-use alter a catchment's streamflow pattern, which is a critical concern to the researchers. In the present study, the potential contributions of Climate Change (CC) and Land-use Conversions (LC) on streamflow variations are quantified for the Brahmani catchment (36800 km2) of eastern India. The estimation procedure is followed by two empirical approaches, i.e. (i) the modified Double Mass Curve (m-DMC) method and (ii) the modified Slope Change Ratio of Accumulative Quantity (m-SCARQ) method. The abrupt changes in streamflow data series are checked by the sequential Mann-Kendall method. Multiple change points, including 1981, 1985, 1993, 1994, 2011, and 2013 are observed in streamflow data series in the study area. However, 1994 is selected as the break-point, which has the highest significance value, i.e. 1.92. Therefore, the entire analysis period (1979-2018) is divided into two sub-periods, i.e. the baseline period (1979-1994) and the assessment period (1995-2018). Further, the statistical characteristics (trend, slope, and significance) of hydro-climatic variables (precipitation, temperature, and streamflow) are analysed by applying the Mann-Kendall method followed by the Sen's slope estimator for all the periods. Using the m-DMC method, the potential contributions of CC (βCC) and LC (βLC) in the assessment period are quantified as 93.09% and 6.91%, respectively. However, from m-SCARQ, the contributions of precipitation (βP), temperature (βT), CC (βCC), and LC (βLC) on streamflow variations are 0.26%, 19.74%, 20%, and 80%, respectively. The outcomes of the m-DMC other than the m-SCARQ method showed that streamflow variation is more sensitive to climate change of the study area. Further, the m-SCARQ method is relatively strategic compared to the m-DMC method since it can signify the contributions of precipitation (βP) and temperature (βT) on the streamflow variations. Still, both the empirical approaches are attributed to different sources of errors and uncertainty with individual advantages. Accordingly, this study can provide new insights concerning the relative resistance of the Brahmani catchment's response to CC and LC that is vital for the prudent planning and management of future water resources. Keywords: Climate change; Land-use conversions; m-DMC method; m-SCARQ method; Brahmani

Empirical Approach-Based Potential Impact Analysis of Climate Change and Land-Use Conversions on Streamflow Variations: A Case Study of the Brahmani Catchment

Sushree Swagatika Swain [1], Ashok Mishra[2], Chandranath Chatterjee[2]

[1]School of Water Resources, Indian Institute of Technology Kharagpur

[2]Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur

Contact: sushreeswain1991@gmail.com

Streamflow, the fundamental element of catchment-scale hydrology, is expressed as a complex response of many hydrological processes that includes atmospheric forcing (precipitation and temperature) and human

activities (land-use change, reservoir/dam construction, and excessive water exploitation). Thus, change in climate variables and land-use alter a catchment's streamflow pattern, which is a critical concern to the researchers. In the present study, the potential contributions of Climate Change (CC) and Land-use Conversions (LC) on streamflow variations are quantified for the Brahmani catchment (36800 km^2) of eastern India. The estimation procedure is followed by two empirical approaches, i.e. (i) the modified Double Mass Curve (m-DMC) method and (ii) the modified Slope Change Ratio of Accumulative Quantity (m-SCARQ) method. The abrupt changes in streamflow data series are checked by the sequential Mann-Kendall method. Multiple change points, including 1981, 1985, 1993, 1994, 2011, and 2013 are observed in streamflow data series in the study area. However, 1994 is selected as the break-point, which has the highest significance value, i.e. 1.92. Therefore, the entire analysis period (1979-2018) is divided into two sub-periods, i.e. the baseline period (1979-1994) and the assessment period (1995-2018). Further, the statistical characteristics (trend, slope, and significance) of hydro-climatic variables (precipitation, temperature, and streamflow) are analysed by applying the Mann-Kendall method followed by the Sen's slope estimator for all the periods. Using the m-DMC method, the potential contributions of CC (β_{CC}) and LC (β_{LC}) in the assessment period are quantified as 93.09% and 6.91%, respectively. However, from m-SCARQ, the contributions of precipitation (β_P), temperature (β_T), CC (β_{CC}), and LC (β_{LC}) on streamflow variations are 0.26%, 19.74%, 20%, and 80%, respectively. The outcomes of the m-DMC other than the m-SCARQ method showed that streamflow variation is more sensitive to climate change of the study area. Further, the m-SCARQ method is relatively strategic compared to the m-DMC method since it can signify the contributions of precipitation (β_P) and temperature (β_T) on the streamflow variations. Still, both the empirical approaches are attributed to different sources of errors and uncertainty with individual advantages. Accordingly, this study can provide new insights concerning the relative resistance of the Brahmani catchment's response to CC and LC that is vital for the prudent planning and management of future water resources.

Keywords: Climate change; Land-use conversions; m-DMC method; m-SCARQ method; Brahmani

Empirical Approach-Based Potential Impact Analysis of Climate Change and Land-Use Conversions on Streamflow Variations: A Case Study of the Brahmani Catchment

Sushree Swagatika Swain[1], Ashok Mishra[2], Chandranath Chatterjee[2]

[1]School of Water Resources, Indian Institute of Technology Kharagpur

[2]Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur

Contact: sushreeswain1991@gmail.com

Streamflow, the fundamental element of catchment-scale hydrology, is expressed as a complex response of many hydrological processes that includes atmospheric forcing (precipitation and temperature) and human activities (land-use change, reservoir/dam construction, and excessive water exploitation). Thus, change in climate variables and land-use alter a catchment's streamflow pattern, which is a critical concern to the researchers. In the present study, the potential contributions of Climate Change (CC) and Land-use Conversions (LC) on streamflow variations are quantified for the Brahmani catchment (36800 km^2) of eastern India. The estimation procedure is followed by two empirical approaches, i.e. (i) the modified Double Mass Curve (m-DMC) method and (ii) the modified Slope Change Ratio of Accumulative Quantity (m-SCARQ) method. The abrupt changes in streamflow data series are checked by the sequential Mann-Kendall method. Multiple change points, including 1981, 1985, 1993, 1994, 2011, and 2013 are observed in streamflow data series in the study area. However, 1994 is selected as the break-point, which has the highest significance value, i.e. 1.92. Therefore, the entire analysis period (1979-2018) is divided into two sub-periods, i.e. the baseline period (1979-1994) and the assessment period (1995-2018). Further, the statistical characteristics (trend, slope, and significance) of hydro-climatic variables (precipitation, temperature, and streamflow) are analysed by applying the Mann-Kendall method followed by the Sen's slope estimator for all the periods. Using the m-DMC method, the potential contributions of CC ($_{CC}$) and LC ($_{LC}$) in the assessment period are quantified as 93.09% and 6.91%, respectively. However, from m-SCARQ, the contributions of precipitation ($_{P}$), temperature ($_{T}$), CC ($_{CC}$), and LC ($_{LC}$) on streamflow variations are 0.26%, 19.74%, 20%, and 80%, respectively. The outcomes of the m-DMC other than the m-SCARQ method showed that streamflow variation is more sensitive to climate change of the study area. Further, the m-SCARQ method is relatively strategic compared to the m-DMC method since it can signify the contributions of precipitation ($_{P}$) and temperature ($_{T}$) on the streamflow variations. Still, both the empirical approaches are attributed to different sources of errors and uncertainty with individual advantages. Accordingly, this study can provide new insights concerning the relative resistance of the Brahmani catchment's response to CC and LC that is vital for the prudent planning and management of future water resources.

Keywords: Climate change; Land-use conversions; m-DMC method; m-SCARQ

method; Brahmani