ABSTRACT

In many river basins worldwide, the groundwater resources are depleting at an alarming rate due to the land use land cover (LULC) and climate change impacts, altering the basin-scale recharge dynamics. This, in turn, affects the surface water-groundwater interaction (SGI), a crucial flux component for managing the stressed aquifers and river restoration projects. Many of the SGI models available in the literature are very complex and data-intensive with limited applicability in semi-gauged and ungauged catchments. Moreover, limited studies investigate the synergistic impact of future LULC and climate change on the SGI dynamics. This calls for the development of a simplified physically-based SGI flux modelling approach for scantily-gauged catchments that can be used for assessing the impacts of future LULC and climate change. This thesis addresses these issues with the development of an enhanced hillslope-storage Boussinesq (ehsB) model accounting for all the hydrological process components for estimating the groundwater flux at hillslope and river basin-scales; development of an SGI model for data-limited river basins by fully coupling the ehsB sub-model with the physically-based variable parameter McCarthy-Muskingum (VPMML) streamflow routing sub-model accounting for distributed lateral flow along the river reach; benchmarking the developed VPMML-ehsB model with the popular SWAT-MODFLOW model in estimating the SGI flux; and assessment of the impacts of future LULC and climate changes on the SGI dynamics using the developed VPMML-ehsB model. The developed frameworks were validated in the Brahmani-Baitarani River basins in eastern India. Simulations considering all the water flux estimation approaches revealed that the developed ehsB model, requiring lesser hydro-geologic and river cross-section data, could predict the temporal variation of the subsurface water table in the experimental wells very well both at daily and 15-daily scales. The VPMML-ehsB model outperformed the SWAT-MODFLOW in predicting the average annual streamflow and the low flow. The simulation time of the VPMML-ehsB model is almost 60% less as compared to the SWAT-MODFLOW which makes it amenable as a suitable alternative for modeling the subsurface processes in earth system models. In the Baitarani basin, the predicted high and medium streamflow regimes with the exceedance probability, $P \leq 35\%$ are likely to increase in future (2021-2099); whereas the low streamflow regime ($P \geq 90\%$) would decrease by at least 50%. The proposed modelling approach has a future scope to be used in large-scale ungauged and data-scarce river basins for studying the stream–aquifer interaction process, management and evaluation of river bank filtration and river rejuvenation projects, and assessing the impact of climate and land use change on the high streamflow and baseflow.

Keywords: Baseflow; Climate change; Groundwater; Hillslope hydrology; Streamflow; Stream-aquifer interaction; Ungauged basin