Assessment of Sedimentation in the Hirakud Reservoir

Abstract

Soil erosion and sediment yield from the catchment are matters of great concern for the designers and managers of reservoirs, as it is responsible for supplying the sediment load that gets transported to the reservoir, resulting in the reduction of its operational life. The present study considers the Hirakud Dam on the River Mahanadi in eastern India as a test case and using past data of sedimentation predicts the projected life of the reservoir, when it is likely to get nearly completely silted, using existing empirical techniques. Simultaneously, a physics based approach is also adopted to predict the sediment load arriving at the reservoir using a catchment flow and erosion simulation model (SWAT), which coupled with another numerical simulation model (TELEMAC-SISYPHE), is used for computing the sedimentation and morphological changes in the reservoir. Using past rainfall as the primary input, the SWAT model is used to recreate the sediment load inflow history for the Hirakud Reservoir. On using this time-series as input to the TELEMAC-SISYPHE model, the sedimentation buildup in the reservoir is recreated from its inception till date and matched with field observations obtained from reservoir surveys. Once the numerical models are validated, they are used in conjunction with projected rainfall in future as predicted by GCM, suitably adapted to the local scale by the SDSM, for predicting future sedimentation in the reservoir. Wilcoxson Signed Rank test and Bootstrap confidence interval re-sampling techniques are used to perform uncertainty analysis and multiplicative change factor methodology is used to perform the bias correction on the downscaled climate parameters. The study involves sensitivity analysis of simulated data (discharge: 15, sediment load: 6), 5-years calibration and 3-years validation of SWAT simulated results. The results show that the prediction of sediment yield is highly sensitive to the sizes of different sub-basins due to the sensitivity of topographic factors used in the MUSLE and about 34% area of total catchment falls under high or above soil erosion zones with combination of coarse loamy soil and agricultural land. Precipitation rates are satisfactorily downscaled from predictors of CGCM3. The most compelling observation is that the peak value of rainfall is likely to shift consistently from July to April as a result of climate change. A decreasing trend of monsoon streamflow of Mahanadi River is observed with CGCM3 data due to high surface warming in future. The simulated results of TELEMAC-SISYPHE demonstrate that in the Mahanadi River, the upstream delta forms finger-like projected sediment mounds in the reservoir instead of spreading laterally. In the Ib River, the upstream delta occupies the full valley width from bank to bank. The simulations also successfully demonstrate the advancement of sediment mounds from the two inlets towards the Hirakud Dam. Historical trend analysis is also performed to predict the trap efficiency, rise of the reservoir bed level and capacities of different storage zones in the different projected years. The predictions of the life of the Hirakud Reservoir using empirical techniques and that by the numerical simulation models (considering no change in future climate) are similar. Unlike the empirical techniques, although the numerical simulations consider the rainfall as one of the input parameter, the climate change effects do not affect the sedimentation rate due to the constant median value of the annual streamflow over the future time period. The study also established generic trends between the reservoir geometry variables and the sediment distribution patterns in a reservoir through a series of numerical experimentations. Further, these trends are also used for determining the sedimentation patterns for the Mahanadi and Ib River branches of the Hirakud Reservoir.

Keywords: Erosion; Climate change impact; Sedimentation; Storage capacity