Assessment of infiltration process considering slope and diurnal temperature variation in humid subtropical region

ABSTRACT

The water infiltration into a soil system is a complex process dealing with oversimplified standard models by not considering important physical features like slope and temperature variation that govern the soil-water interaction and flow. Quantitative infiltration analysis of a soil surface becomes very complex when the collective impacts of slope and temperature are considered for micro-macro flow based on the land use and land type (LULC). This study focuses on the infiltration responses of the topsoil layer in the ponding condition for flat surface (0^o-4^o), gentle slope (5^o-15^o), and moderate slope (6^o-25^o) depending on the availability at the site incorporating the diurnal temperature variation by conducting Double-ring experiments in morning and afternoon session for each category of slope keeping all other factors similar. The influence of slope was investigated separately as well on the conceptually designed hillslope experimental set-up by analysing simulated rainfall and generated runoff on the soil samples extracted from the agriculture, landfill, and bare surfaces incorporating the effects of 10^o, 20^o, and 30^o slopes. The experimental study was emphasised four common LULC such as agricultural field, grassland, bare surfaces, and, from the environmental perspective, solid waste landfill for the impacts of slope and temperature variation on corresponding infiltrated volume. Three popular classical infiltration models, such as Kostiakov, Horton, and Philip models, were optimised to generate the parameters producing the closest outcomes to the observed cumulative infiltration in all slope and temperature variation conditions based on the field experimental data. Statistical tools- Coefficient of determination (R^2), Nash Sutcliffe Efficiency (NSE), Percentage Biased (PBIAS), and Root mean Square Error- observations standard deviation ratio (RSR) were engaged to evaluate the best performing model incorporating the slope and temperature impacts. Total 20 scenarios were studied to determine the quantitative impact of local topographical and local climatic conditions on cumulative infiltration. After the experimental studies, the physical-based analytical infiltration module was developed by combining the modified Green-Ampt model for micropores flow in the soil matrix and the Hagen Poiseuille-Manning equation for preferential flow from macropores incorporating the impacts of diurnal temperature variation on soil-water physical characteristics and inclination of surfaces. The model was calibrated by experimental data

observed from flat and gentle slope surfaces for all focused LULC in morning and afternoon sessions and validated the estimated cumulative infiltration for moderate slope in a higher temperature range. The results show that initial and final infiltration rates were not significantly correlated with temperature and slope; however, initial infiltration rates were majorly affected by the LULC and were found 2.56 times higher for harvested agricultural areas than grass areas. Cumulative infiltration was generally lowest in solid waste landfill and highest in bare surfaces among all selected (LULC). Cumulative infiltration volume has positively correlated with slope and temperature variation for all LULC under ponded conditions. The observations of the hillslope experimental set-up show that agricultural soil has experienced higher abstractions for all slopes and got saturated earlier than other-focused land uses. The infiltered volume was significantly affected by the slope of the surface when runoff was allowed and showed the average reduction in cumulative infiltration was analysed as 7.62% and 27.8% when the surface slope increased from 10^o to 20^o and $30^{o,}$ respectively. The mean rise in runoff was observed as 18.34% and 45.5% for the same increment of the slope. Overall, the Philip model showed the most efficient performance after the developed infiltration model (GIM) as per the statistical analysis.

The study is expected to be valuable for decision making in land management of focused land covers, irrigation management in terms of estimating field-scale runoff and infiltration by providing experimental supported data. The developed General Infiltration Model (GIM) proved to be more efficient and useful for better estimating the infiltration characteristics incorporating the combined impacts of slope and temperature. The results are expected to be useful for landfill management regarding the environmental aspects situated in the humid subtropical region of India.