Abstract

In sub-tropical agroforestry watersheds, where the hillslopes are characterized by high degree of soil macroporosity and the area receives extreme rainfall events frequently during the monsoon seasons, rapid overland and subsurface storm flow from the adjacent hilly areas often triggers devastating flash floods in the rivers. Soil erosion is a hazard traditionally associated with agriculture in sub-tropical and rainfed areas and is a threat to long-term soil productivity and sustainable agriculture. The soil loss associated with overland runoff and saturation excess overland flow affect several lives those depend on agriculture. Past efforts to reduce flooding and soil erosion in two agroforestry watersheds viz., Baronda and Kesinga, have been less successful mainly because many of the studies carried out, implemented hydrological and soil erosion models which are not well suited or developed for sub-tropical regions. The objective of this study was, therefore, to understand runoff and erosion processes by investigating plot as well as watershed scale observations and to use these relationships to model runoff and sediment yield. The investigations were carried out to represent the important components that relate hydrologic inputs to outputs. Runoff generation processes were investigated at six hillslope plots representing different land use / land cover. The observations of rainfall and runoff at hillslope plots located in part of Brahmaputra basin revealed that rainfall depth has major influence on runoff generation process. The rainfall depth above a threshold value which vary with land use / land cover, generates the surface runoff. It was also observed that threshold value of rainfall depth varies within a season and its variability can be characterized with the degree of vegetation and soil saturation. This new recognition of a clear threshold behaviour and its dependability on vegetation and soil moisture may be a way forward in collapsing the vast array of process complexities into an integrated hillslope behavioural description. However, in humid, upland regions dominated by agriculture and forests, detailed process-based studies that explore the interface between vegetation, soil moisture, runoff and sediment generation processes, have not been widely attempted. To examine the rainfall-runoff-sediment dynamics at watershed scale, two agroforestry watersheds in part of Mahanadi river basin were considered. The analysis of runoff response to rainfall at watershed scale revealed linearity between rainfall-runoff relationships during monsoon season. In addition, curve number at watershed scale was estimated by using SCS-CN method. The high curve number at both the watersheds indicated the flashiness behaviour. The threshold values of rainfall depth and soil saturation were also estimated by binary classification technique. The sediment concentration follows a power relationship with runoff and the relationship coefficient varies seasonally.

Besides this, the soil saturation and vegetation condition primarily control the runoff and sediment generation process at watershed scale. Therefore, the relationship between Normalized Difference Vegetation Index (NDVI) and sediment-runoff power relationship coefficients were established during pre-monsoon, monsoon and post-monsoon seasons. The results showed that sediment concentration and NDVI are inversely linear related during pre-monsoon and post-monsoon season. However, the opposite trend was depicted for the monsoon season. Therefore, it was argued that relationship between NDVI and Universal Soil Loss Equation (USLE) 'C' factor is only applicable for non-monsoon season.

A semi-distributed runoff and sediment yield model incorporating threshold behaviour of rainfall for runoff generation and effect of vegetation on sediment generation process, was developed based on process relationships from various investigations at hillslope plot and watershed scales. It was assumed that sediment concentration is transport limiting during pre-monsoon period and became source limited during rainy season. The model predicted daily runoff and sediment concentrations well in two agroforestry watersheds. The performance of developed model Rice Irrigation and System Evaluation (RISE) was evaluated and compared with Soil and Water Assessment Tool (SWAT) by measures of goodness-of-fit. The parameter sensitivity of the model was analyzed for threshold rainfall depth and degree of vegetation. The RISE hydrological and sediment model was simulated for the period from 1951 to 2060 for two agroforestry watersheds by using the historical as well as future projected meteorological dataset under RCP 4.5 and 8.5 obtained from National Aeronautics and Space Administration (NASA) Earth Exchange Global Daily Downscaled Projections (NEX-GDDP). To derive future NDVI time series, the historical NDVI and rainfall relationships were established. It was found that rainfall and NDVI are statistically significant correlated at monthly time scale. Wet and dry years were identified based on the temporal annual and monthly rainfall anomalies from 1951-2060. It was realized that the extreme wet and dry year follows a cycle of about 12-15 years. However, no significant trend in monthly or annual rainfall time series was observed. The simulated runoff and sediment yield were analyzed monthly during 1951-2060 for both the watersheds under both RCP's. It was predicted that the period around year 2043/2044 is likely to have extreme runoff and sediment concentration. In addition, seasonal upper envelope equations were applied to forecast the extreme runoff and sediment response to future rainfall events. The modelling approach presented here may be a way forward for the community having limited observed dataset for hydrological and sediment modelling under climate change scenarios.