Abstract

Hilltop mining areas within the river basin have always been responsible for producing accelerated soil erosion. The present study is conducted for the hilltop mining region of Saranda forest in West Singhbhum district of Jharkhand state, India. The area has huge high-grade iron ore deposits and therefore, several active, close, and proposed mining areas are seen in this region. The ore excavation is carried out by surface mining method and then overburden material is dumped by the sidehill and valley fill processes. Eroded material from the mine sites can cause severe environmental issues such as aesthetic damage of biodiversity, sedimentation in the adjacent watersheds, water pollution, human health risk, etc. Assessment of soil erosion is an important aspect of erosion control planning under such detrimental circumstances. In the present study, a laboratory-based rainfall simulator setup is developed for the conduction of soil erosion experiments on the simulated mine site condition. The entire setup is divided into four major parts: (a) water supply system with a single spray nozzle, (b) supporting metal frame, (c) hydraulic jack attached container table for slope adjustment, and (d) sediment collection unit. It covers an area of 3 m^2, out of which 0.5 m^2 is the experimental plot, which can attain 40° slope. A setup is capable of simulating rainfall intensities of 65, 93, 112, and 148 mm/h. The drop distribution status is measured by the Christiansen coefficient (Cu), which varies from 81% to 88%. The rain droplet size ranges from roughly 1 mm to 5 mm and their corresponding terminal velocities range from 4.76 m/s to 10.64 m/s, striking velocities are found between 5.56 m/s and 9.63 m/s, and kinetic energies ranging from 0.0081 mJ to 3.0342 mJ. The total kinetic energy of the simulated rainfalls varies from 6 J to 12 J. The designed setup is capable of simulating rainfall with properties very close to natural rainfall.

Subsequently, erosion experiments are conducted using the developed rainfall simulator. There are four factors considered in the experimental work: slope, number of rainfall day, rainfall intensity, and available percentage of sand and silt in the plot. Experiments are conducted using the Taguchi's fractional factorial method and investigated the effects of selected factors on the soil erosion. Furthermore, statistical analysis of the experimental data is carried out and developed the new erosion prediction model. Further, the newly developed erosion model is applied in the hilltop mining areas of Saranda forest using remote sensing, and geographic information system (GIS) technology. The study area receives 80% precipitation of its total rainfall during the monsoon season. Hence, the present study is conducted for the monsoon season (June to September) of the year 2018 at erosion-sensitive sites of the mining area such as overburden dumps and mineral stockyards. These sites cover nearly 161 hectares of land in the Saranda forest. The required

thematic layers are prepared using various data sources. Slope factor is derived from the digital elevation model (DEM) using Cartoset-1 (2009) stereo satellite imagery. Available percentage of sand and silt in the mine sites is obtained by field survey. Thematic layers of rainfall intensity and the number of rainfall day factors are prepared from the Tropical Rainfall Measuring Mission (TRMM) data. In this study, the TRMM 3B42, 3-hourly, 0.25° × 0.25° product is used. A GIS integration of thematic layers is carried out by using ArcGIS 10.5 software.

The calculated erosion amount by the newly developed erosion model is around 4079 tons, and its annual rate of soil erosion is about 25 t/ha/year for the described area. Verification of the results is carried out by using the Revised Universal Soil Loss Equation (RUSLE) model. The calculated erosion amount by the RUSLE model is 5500 tons (43 t/ha/year) for the same year, which is 35% greater than the newly developed erosion model. Since the newly developed erosion model is established based on physical experiments, it shows erosion prediction more realistic. Moreover, the model required only four parameters, preparation of the factors is simple, and it is capable of providing soil erosion from every single rainstorm during the monsoon season. The uniqueness of this model is, it is not only compatible with GIS but also convenient for the manual soil erosion calculation in the field. The present study also identified the watersheds that can be affected by the mines and various erosion control practices are suggested to protect them.

Keywords: Soil erosion, Hilltop Mining, Rainfall simulation, Erosion prediction model, TRMM, Remote sensing and GIS, Erosion control practices