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International Soil and Water Conservation Research ∎ (∎∎∎∎) ∎∎∎–∎∎∎

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Contents lists available at ScienceDirect

International Soil and Water Conservation Research

journal homepage: www.elsevier.com/locate/iswcr

Original Research Article

Evaluation of soil loss estimation using the RUSLE model and SCS-CN method in hillslope mining areas

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ARTICLE INFO

Article history:
Received 27 September 2016
Received in revised form
8 September 2017
Accepted 6 November 2017

Keywords:
Soil erosion
Runoff
RUSLE
SVM
Remote sensing
GIS

ABSTRACT

Mining operations result in the generation of barren land and spoil heaps which are subject to high erosion rate during the rainy season. The present study uses the Revised Universal Soil Loss Equation (RUSLE) and SCS-CN (Soil Conservation Service - Curve Number) process to estimate in Kiruburu and Meghahatuburu mining sites areas. The geospatial model of annual average soil loss rate was determined by integrating environmental variables parameters in a raster pixels-based GIS framework. GIS layers with, rainfall passivity and runoff erosivity (R), soil erodibility (K), slope length and steepness (LS), cover management(C) and conservation practice (P) factors were calculated to determine their effects on annual soil erosion in the study area. The coefficient of determination (r^2) was 0.834, which indicates a strong correlation of soil loss with runoff and rainfall. Sub -watersheds 5,9,10 and 2 experienced high level of highly runoff. Average annual soil loss was calculated (30*30 m raster grid cell) to determine the critical soil loss areas (Sub-watershed 9 and 5). Total soil erosion area was classified into five class, slight (10,025 ha), moderate (3125 ha), high (973 ha), very high (260 ha) and severe (53 ha). The resulting map shows greatest soil erosion of > 40 t h-1 y-1 (severe) through connection to grassland, degraded and open forestry on the erect mining side-escutcheon. The Landsat pan sharpening image and DGPS survey field data were used in the verification of soil erosion results.

1. Introduction

Soil loss is deliberated as a heavier real question as it incredibly threatens physical resources, agricultural, grassland, forest and environmental. Soil loss is a process of variables parameters rainfall, runoff, close relative element, soil features, terrain, plantation, and land cover. Soil loss is deeply fallen because of biophysical and socioeconomic factors, e.g., pasturage, agriculture system, and impoverishment (Hoffman & Todd, 2000).

The soil erosion procedure is adapted to the biophysical environment comprising soil, rainfall, topography, land cover and interactions between them. Important terrain characteristics influencing the mechanism of soil loss is length slope, shape and aspect. The impact of slope and aspect would play a significant role in runoff mechanism. More the slope, more the runoff and thus infiltration reduces. The runoff generated from slope will find a path nearby, and this would lead to erosion of soil as the velocity of the runoff increases. Rainfall simulation by slight portable rainfall simulators is deliberated to be a necessary method for consistent interrelated soil loss method for instance splash, basic runoff -precipitation processes, infiltration, losses sediment, nutrient movement (Arnaez, Lasanta, Ruiz-Flaño, & Ortigosa, 2007). Surface runoff and soil erosion are the two significant hydrologic reactions since the rainfall procedures on the sub watershed systems (Gajbhiye, Mishra, & Pandey, 2014). The sub watershed runoff and soil loss simulation technology (CREST) is a spatially circulated soil erosion model developed by the GIS- support approach with PC Raster (Lanuza & Paningbatan, 2010). This model was developed to create the preferred in sequence on surface runoff and soil loss by due to the regard of the geospatial hybridism and temporal allocation of the sub watershed. Extreme rainfall/runoff actions, erect slopes, intense soil tilt and soil texture property, have been narrated as the mainly relevant factor to analyze and reclassify new soil loss procedure in European grapery's (Biddoccu et al., 2013). Though squeezing out of the terrain factor becomes a significant matter, particularly the slope steepness and length. Though above the

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https://doi.org/10.1016/j.iswcr.2017.11.002

previous twenty years process have been exhibited which agree on the using GIS tools propagate together USLE and RUSLE-emerged justification of the algorithm applied to raise the slope length (Kayet, Pathak, Chakrabarty, & Sahoo, 2016a; Merritt, Letcher, & Jakeman, 2003).

In the last few decades, RS and GIS technology were used to precise calculation the soil erosion precisely on the sub watershed and sub basin scale rather at a field level (Gelagay & Minale, 2016a, 2016b). Soil loss in India has a main outcome on the agricultural land, siltation of reservoirs, erosion of soils, etc. The government has taken many actions for rectification of the problem and preventing further destruction of the soil layer. Soil loss in India has a primary payoff on the agricultural partition, siltation of basins, wasting of lands, etc. In India, nearly 130 million ha of land (Kothyari, 1996), i.e., 45% of the sum geographic surface area, is influenced by significant soil erosion by the gully, shifting agriculture, cultivated moorland, sandy areas, deserts, and water impede. The surface land area affected by soil wasting due to erosion is calculated at 1100 Mha through rainwater erosion and 550 Mha by wind erosion (Sammi Reddy, Singh, Tripathi, Singh, & Saha, 2003). A measurable appraisement (Kayet & Pathak, 2015; Mohammad, Pan, & Kennedy, 1995, Sahoo Dhar, Kayet, & Kar, 2016; Kayet and Chakrabarty, (2016)) is wanted towards concluding on the length and magnificence of soil loss rate trouble consequently that land legislation stratagem can be flourished on a provincialism basis with the helping of field appraisal. The Asia countries were particularly amenable to soil erosion, and forasmuch they are the focus to dry periods pursued by high depreciating rainfall on erect escutcheon distinguish by breakable soils (Grimm, Jones, & Montanarella, 2001).

The revised universal soil loss equation model can identify soil loss possibility on a pixel cell-by-cell method (Shinde, Tiwari, & Singh, 2010), which is effective as trying to recognize the spatial class of the soil erosion current time in a big area. Revised universal soil loss equation is the revised form of universal soil loss equation, which has been used at different geo-spatial scales by dividing a region of appeal keen into sub areas with similar parameters and connected with geographic information system framework (Renard, Foster, Weesies, McCool et al., 1997). These erosion models are presently included to put an environmental info system, which permits testing and evaluating of alternative management scenarios (Fistikoglu & Harmancioglu, 2002). The model propagates estimated soil loss through increasing the parameter of rainfall erosive, soil credibility, slope gradient and length, cover management and confirmation practice (Wischmeier & Smith, 1978) and PESERA (Pan-European Soil erosion risk assessment) (Kirkby et al., 2003). The consequence of topography on soil loss RUSLE is a consideration for by the dimensionless Slope length multiplier (Van Remortel, Hamilton, & Hickey, 2001). A new measurement of soil loss by water erosion in Europe has currently been expressed (Panagos et al., 2015), purposed at policy demiurge. This article by considers it should be done exercise a model founded on plot experiments to invoice the defeat of soil erosion. The visual validations of the RUSLE Model using PAN satellite image (Bosco, de Rigo, Dewitte, Poesen, & Panagos, 2015).

This article contributes to the way of the following facet of the study i) Detected and modeled to rate soil loss in the study region. ii) Assessment of soil loss through Runoff, RUSLE, SVM, and GIS framework. iii) Runoff model using SCS- Curve number method for soil erosion model and Modification of cover management factor using SVM algorithm. iv) Site selection for suitable erosion control structures. The proposed methodology is applied to Kiriburu (KIOM) and Megataburu (MION) Iron ore mines, Saranda forest.

2. Materials and methods

2.1. Study area

Most of the iron ore mines of Jharkhand lie in the Saranda forest. Kiriburu and Megataburu Iron ore mines were located in West Singhbhum district of Jharkhand (Fig. 1). The site of the study area is at latitude 22° 2′ 20.03″ − 22°10' 32.71' N and longitude 85° 8′ 13.6″ − 85°20'17.34″ E with the altitude of 850 m above the MSL. This area is located iron ore mining towns in clouding Gua, Chiria, Megataburu, and Kiriburu. Two famous Iron ore mines in Saranda forest are Kiriburu Iron ore mines (KIOM) and Megataburu Iron ore mines (MION). Kiriburu and Megataburu climate is hot, and there are two main seasons are found that is summer and winter. The average temperature is in summer is 25 °C. The temperature varies between 23 °C and 26 °C. The annual rainfall is around 1400 mm. The rainfall is mainly caused by the branch of monsoon from the Arabian Sea. The rainfall is mostly in between June to September. There is also variation in precipitation. In the west Kiriburu and Megataburu, the annual (2003–2012) rainfall varies from 800 to 2200 mm (Fig. 2). The district is of undulating terrain with hills alternating with valleys and steep mountains. Some stretches are comparatively flat in the river basins. The area is mainly covered by forest and falls into plateau region; many old rocks are there, and it is part of the ancient Gondwanaland. The soil of the region has been classified mainly into three groups' rocky soil, red soil, and black Soil. This study area high soil bulk density and low available water capacity (< 150 mm). The study area is having an undulating hilly terrain with high to moderate slope covered entirely with the tree as well as ground vegetation. The Saranda forest area is diverse in vegetation types. The vegetation types are broadly classified into tropical moist deciduous and tropical dry deciduous forests. The sub type of northern tropical moist deciduous forests in the area includes the moist peninsular Valley Sal (Singhbhum damp valley Sal and Saranda).

2.2. Data used

Landsat 7 ETM+ satellite data earned on 31st Dec 2015 was used in this work for generating the LULC map. Cartosat-1 image of 16th May 2014 was used for preparing Digital elevation model. The weather station (Kiriburu and Megataburu) based rainfall data for ten years (2003–2012) was collected from the IMD (India Meteorological Department) database using the runoff estimation. DGPS field survey data and field images were in use for LULC classification, DEM generation process, and result validation purpose.

2.3. RUSLE model

The USLE is a scientific model developed by W. Wischmeier, D. D. Smith (1978). The equation is informed of the innovative USLE. In RUSLE, the rainfall or runoff factor of the unique USLE was replaced by the rainfall erosivity factor (Millward & Mersey, 1999). The RUSLE was used for calculating the enduring average annual e soil erosion on a surface slope emerged on runoff model, soil category, crop process, and topography (slope) and supervision practices. The average annual soil erosion per unit region and the year were quantified as per the following formula (Eq. (1)) of RUSLE (Renard, Foster, Weesies, McCool & Yoder, 1997). The RUSLE is an empirical equation that enumerates the average annual soil erosion in tons /ha/year. The RUSLE formula-1 read.

$$A = R*K*LS*C*P \quad (1)$$

where, A estimated average annual soil erosion (ton/ha^{-1}/year^{-1}), R rainfall or runoff erosivity factor rainfall erosivity factor ((MJ mm ha-1 h^{-1} year^{-1}) or runoff (mm), K = soil erodibility factor (t MJ^{-1} ha-