Biological Forum – An International Journal **13(4): 527-531(2021)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Soil Loss Estimation through MUSLE Equation using RS and GIS techniques in Neemahosalli sub-watershed

Tipperudramma N.[1*], Shrikant[2] and Ashoka H.G.[3]
[1]M.Tech (Agri Engg) Soil and Water Engineering, College of Agricultural engineering, UAS, Raichur-584101, (Karnataka), India.
[2]Ph.D. Scholar, College of Agricultural Engineering, UAS, GKVK, Bengaluru-560065, (Karnataka), India.
[3]Professor and Chief Scientific Officer, Directorate of Research, UAS, GKVK, Bengaluru -560065, (Karnataka), India.

(Corresponding author: Tipperudramma N.)*
(Received 31 August 2021, Accepted 01 November, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: The deterioration of soil and water resources in an area can be controlled effectively by adopting watershed approach. The objective of this study is to use the Modified Universal Soil Loss Equation (MUSLE) in conjunction with the Soil Conservation Service Curve Number (SCN-CN) approach to estimate runoff and soil loss using the Kirpich and Williams equations. The study was carried out for Neemahosalli sub-watershed of Kalaburgi district. The entire area of the sub watershed was estimated to be 1869.78 ha, and it is located between 77°15′53″ -77°20′01″E longitude and 17°28′0″ -17°31′13″N latitude. The thematic maps were prepared by using Landsat-8 satellite image in GIS software. The estimated data and parameters used in this study were aggregated and applied to the MUSLE model to estimate annual soil loss. Using Kirpich and Williams' time of concentration formulas, the data revealed that 92.80 t ha^{-1}yr^{-1} and 62.92 t ha^{-1}yr^{-1} soil loss occurred in the Neemahosalli sub-watershed, respectively.

Keywords: MUSLE, GIS, Soil Conservation Service Curve Number (SCN-CN), watershed

INTRODUCTION

Soil is one of the world's most precious natural resources, and it is necessary for life, as it provides the medium for plant growth as well as home for a variety of insects and other species. Soil creation is a long process that can take up to 500 years to complete, so we won't be able to replace them in our lifetimes, and it is particularly sensitive to climatic circumstances (Amutha and Porchelvan, 2009). Many of our soils are deteriorating and becoming endangered. Water is the most important natural resource for economic and social growth, along with soil.

Because it affects soil productivity, soil erosion caused by running water has been recognized as the most serious threat to soil protection. The most nutrient-dense top soil is removed. Loss of top soil and deformation due to soil erosion are the significance of deforestation, removal of natural vegetation, and overgrazing in mountainous regions, according to the globe map on the status of human-induced soil degradation (Shwetha *et al.,* 2020). Water erosion affects around 1.79 million hectares of land in China, accounting for 18.3% of the total area (Li *et al.*, 2010). The avoidance of soil erosion, which entails reducing the rate of soil erosion to that which would occur under natural conditions, is dependent on the implementation of appropriate soil conservation methods. Rainfall, runoff, soil, slope, plant cover, and the presence or lack of conservation measures are all factors that influence erosion rates. Erosion control necessitates a quantitative and qualitative assessment of possible soil erosion that takes these aspects into account.

Soil erosion affects around 175 million hectares of India's total land area of 329 million hectares, including almost 53% of the total land area (Upadhyay *et al.*, 2012). Soil erosion contributes for a total productivity loss of roughly 40 Mt in terms of yearly food grain output. Low productivity has been identified as a primary effect of soil degradation through soil erosion, as well as changes in important climate and ecosystem components. As a result, precise estimation of soil losses from agro-ecologically diverse locations is important for developing effective resource management or soil and water conservation strategies (Saleh and Ghobad, 2011).

To minimize all of these issues, remote sensing and GIS techniques were used to enhance sediment estimating simple. Remote sensing data from satellite-based platforms have allowed for the extraction of up-to-date information on land use and soil in a watershed, which may subsequently be used to identify significant soil erosion sites within the watershed. Collecting geographical data on input parameters has become easier and less expensive. Traditional approaches for generating this input data proven to be exceedingly costly and time-consuming. It is now possible to monitor the environment from afar because to the advancement of remote sensing technologies. Soil erosion modelling approaches have become more extensive and robust, thanks to GIS's powerful spatial processing capabilities and interoperability with remote sensing data. Researchers can use remote sensing to better understand factors including soil type, slope gradient, drainage, geology, and land cover, all of which can help optimise the process.

MATERIALS AND METHODS

A. Study area

The selected study area lies between 77°15′53″ - 77°20′01″ E longitudes and 17°28′0″ -17°31′13″N latitudes in Kalaburgi district of Karnataka. The climate is semi-arid and the region is characterized by high day temperature, low humidity and excessive evaporation during summer and pre-monsoon periods. The agricultural practices in study region are based on monsoon in major portion of watershed and very scarce on surface and ground water resources. Fig. 1 depicts the study area of Neemahosahalli sub-watershed.

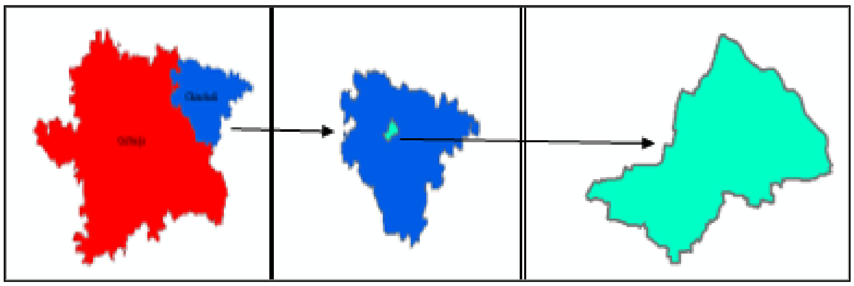

Fig. 1. Study area of Neemahosahalli sub-watershed.

B. Methodology

The annual soil loss was estimated by analysing various watershed parameters such as area, runoff, soil type, slope, cover and management factors from the satellite data and toposheets. These parameters are substituted in the various empirical formulae namely Modified Universal Soil Loss Equation (MUSLE), Kirpich and Williams' time of concentration to estimate the annual soil loss. Base map and thematic maps were prepared by using SoI toposheet and remotely sensed data. Table 1 shows the details of the data used in the investigation. Fig. 2 represents methodology followed in study.

Table 1: Basic data products used for the study in estimation of soil loss.

Sr. No.	Data collection	Source of data
1.	Toposheets (E43R6 and E43R7)	SoI, Bengaluru
2.	Digital Elevation Model (DEM)	Bhuvan website, (NRSC, Hyderabad) (http://bhuvan.nrsc.gov.in)
3.	Remote sensing image	Bhuvan website, (NRSC, Hyderabad)
4.	Soil map	KSRSAC, Bengaluru.
5.	Rainfall data	Karnataka State Natural Disaster Monitoring Center (KSNDMC), Bengaluru.

Sediment yield is computed for watershed as well as for each sub watershed using Modified Universal Soil Loss Equation (MUSLE) (Williams, 1975) as given below.

$$A = 11.8\,(Q \times Q_p)^{0.56}\, K \times LS \times C \times P$$

Where, A = Annual soil loss (t ha^{-1} yr^{-1}), Q = Runoff volume (mm), Q_p = Peak discharge in cubic meters per second (m^3 s^{-1}), K = Soil erodability factor, L = Slope length factor, S = Slope steepness factor, C = Cover and management factor and P = Supporting conservation practice factor.

C. SCS Curve Number model

The curve number approach, commonly known as the hydrologic soil cover complex method (Soil Conservation Service, 1972), is a versatile and widely used runoff estimation procedure. This technique considers a number of significant watershed features, including soil permeability, land use, and antecedent soil water conditions.

To estimate the curve number, depth of runoff the land use/land cover and hydrological soil group map showing hydrologic soil groups prepared from IRS satellite data were integrated.

The antecedent moisture condition and hydrological soil group are used to calculate the curve number. The acquired runoff value will be applied in the Modified Universal Soil Loss Equation, and the results will be compared by utilising the Kirpich and Williams' equations to calculate time of concentration.

The Soil Conservation Service Curve Number (SCS-CN) method**,** an event-based, lumped rainfall-runoff model incorporates the equation for water balance and two fundamental hypotheses that can be expressed respectively as

$$Q = \frac{(P-I_a)^2}{(P-I_a)+S} \qquad P \geq I_a$$

$$S = 254\left(\frac{100}{CN}\right) - 1$$

Where, P = total precipitation (mm), I_a = Initial abstraction (mm), F = Infiltration after time to ponding (mm), Q = Direct runoff (mm) & S = Potential maximum retention (mm).

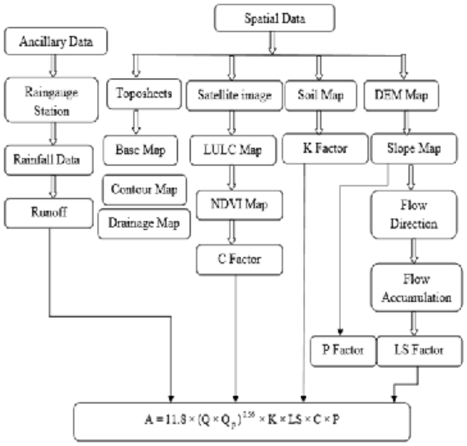

Fig. 2. Flow chart of methodology used for study in estimation of soil loss in Neemahosalli sub-watershed.

The watershed's antecedent moisture conditions and hydrological soil group were used to calculate CN values. The Curve Number values for AMC-I and AMC-II were calculated using the conservation approach from AMC-II (Chow *et al.,* 1988). Hydrologic soil cover complex runoff curve numbers (AMC II). The peak discharge (Q_p) was calculated through the equation

$$Q_p = \frac{(0.208 \times A \times Q)}{(0.5 \times D \times 0.6 \times Tc)}$$

Where, A = basin size (km^2), Q = Depth of runoff (mm), D = Duration of storm in hours, assumed as 24 hr, and T_c = Concentration time in hours calculated through standard formulae

Time of concentration was calculated with two well-known equations, the Kirpich equation and the Williams' equation.

Kirpich equation:

$$T_C = 0.0195 \times L^{0.77} \times S^{-0.385}$$

Williams' equation:

$$T_C = 14.6 \times A^{-0.1} \times S^{-0.2} \times L$$

Where, A = basin size, km^2, S = average channel slope, m m^{-1}, L = length of channel from divide to outlet, km & T_c = time of concentration, min

D. Soil erodibility factor (K)

Soil erodibility factor (K) in the MUSLE is an empirical measure which expresses the inherent susceptibility of a soil to water erosion as determined by intrinsic soil properties. The K factor is rated on a scale from zero to one, with zero indicating soils with the least susceptibility to erosion and one indicates soils which are highly susceptible to soil erosion by water. K factor map was created using the spatial analyst tool in ArcGIS 10.2 based on the soil information available in the soil map provided by KSRSAC, Bengaluru.

E. Slope length (L) and Slope steepness (S)

The topographical factor L factor, which is a function of slope length and slope steepness factor (slope steepness), is frequently abbreviated as LS factor. In comparison to slope length, the effect of slope steepness on soil loss is larger. The combined LS factor was calculated using the ArcGIS 10.2 spatial analyst extension, which included DEM, slope, flow direction, and flow accumulation maps. By adding the cell areas of all upslope cells draining into it, the flow accumulation, which signifies the accumulated upslope contributing area for a given cell, was computed. The watershed delineation tool in the hydrological modelling extension in arc view spatial analyst was used to compute from the DEM. The watershed's combined LS factor was determined, and its spatial distributions throughout the watershed were shown. For obtaining a LS factor map, the following equation was utilised in the map calculator application.

$$\begin{aligned} LS = \mathrm{Power}(\mathrm{fl} \quad \mathrm{accumulation} \\ \times \mathrm{cell\ size}/22.1, 0.4\ ) \times \mathrm{power}(\sin(\mathrm{slope})) \\ \times 0.01745/0.09, 0.4) \times 1.4 \end{aligned}$$

The total upslope contributing for a specific cell is denoted by flow accumulation, LS is the combined slope length and slope steepness factor, and cell size is the grid cell size.

F. Cover management factor (C)

The effect of vegetation and management on soil erosion rates is represented by the cover management factor (C) (Mc Dool *et al.,* 1989). It is the ratio of a certain crop's soil loss to soil loss under continuous bare fallow conditions. The quantity of protective cover provided by a crop for the soil's surface has an impact on the rate of soil erosion. When the land is continuously naked fallow and has no coverage, the C value is equal to 1. C value is lower when there is more coverage of a crop for the soil surface resulting in less soil erosion. The effect of vegetation cover as a control on soil erosion is well established. Vegetation is regarded as the second most critical factor after topography used to derive the NDVI by computing the ratio (Band 2 - Band 3) / (Band 2 + Band 3). The NDVI is highly correlated with the amount of green biomass, and can therefore be applied successfully to provide information relating to the green vegetation variability. Pandey *et al.,* (2011) use the NDVI to produce a more refined and realistic assessment of the C factor. In this study, the NDVI map of the study area was created in ArcGIS 10.2, and the following equation was used to calculate the C-factor using NDVI.

$$C = \exp\left[\alpha \frac{\mathrm{NDVI}}{\beta - \mathrm{NDVI}}\right]$$

Where α and β parameters determine the shape of the NDVI curve. Values of α = 2 and β= 1 were proved to be suitable to get reasonable results.

G. Support practice factor (P)

The support practise factor is the ratio of soil loss caused by a certain support practise to the loss caused by upslope and downslope tillage Shwetha *et al*., (2016) explain that support practice essentially affects soil erosion through altering the flow pattern, gradients, or direction of surface runoff and by reducing the amount and rate of runoff. Different P values were assigned according to the local slope and cultivation methods. Regarding the rural roads, only objects lying across the slope direction were mapped, considering only these as the roads having a protective character to erosion.

H. Soil loss estimation

(i) Peak discharge, runoff volume, and four potential and actual soil erosion-controlling data layers K, LS, C, and P were all integrated in MUSLE via the raster calculator option of the ArcGIS 10.2 spatial analyst tool in MUSLE. As a result, soil loss was estimated, yielding annual soil loss in tonnes per hectare per year.

RESULT AND DISCUSSION

A. SCS-CN

The SCS-CN approach was used to estimate the quantity of runoff generated in the watershed, also known as runoff volume, which is one of the most critical parameters in the MUSLE model (Williams, 1975). The peak discharge, or Q_p, is determined by the time of concentration. Time of concentration was calculated by using William′s formula (169.54 min) was found to be more as compared with the Kirpich formula (84.7 min). Soil loss estimation through MUSLE model using time of concentration from the Kirpich formula was found to be higher as compared with the time of concentration calculated by William′s formula. Arun *et al.,* (2012) also used the same method for obtaining time of concentration and obtained relevant results.

B. Soil erodibility factor (K)

To create the soil erodibility map, K factor values were assigned to different types of soil in the soil map. The K factor is found to have values ranging from 0.57 to 0.23. The lower the K factor, the lower the permeability and the lower the antecedent moisture content of the soil.

C. Slope length (L) and Slope steepness (S)

LS factor represents the influence of slope length and slope steepness on erosion process. LS factor was calculated by considering the flow accumulation and slope. From the analysis, it was observed that the value of LS increases in a range of 4.36-3.12 as the flow accumulation and slope increases.

D. Cover management factor (C)

Different land use patterns were given a crop management component. When the land is continuously bare fallow and has no coverage, the C value is equal to 1. When there is more crop coverage for the soil surface, the C value is lower, resulting in less soil erosion. The C factor values are found to range from 1.17 to 0.16.

E. Support practice factor (P)

The P factor depicts the environmental impact of techniques such as contouring, strip cropping, terraces, and subsurface drainage. The lower the P value, the more effective the conservation strategy is regarded to be at preventing soil erosion. The P-factor is 1.0 if there are no support practises. The P-factor values ranged from 0.78 to 0.50.

F. Average annual soil loss

Different catchment data such as area of watershed, land use patterns, runoff generation, peak rate of runoff, K, LS, C, and P components of the study region, as mentioned in methodology, are used to theoretically estimate soil loss by MUSLE. Shwetha *et al.,* (2016) discovered that using GIS and remote sensing approaches to generate MUSLE model factors was more accurate than using traditional methods. For estimating annual soil loss, the estimated parameters and data were used in the MUSLE model. The soil loss estimates using Kirpich and Williams' time of concentration were found to be 92.80 t ha^{-1} yr^{-1} and 62.92 t ha^{-1} yr^{-1}, respectively, in this study region. Sadeghi *et al.*, (2014) evaluated the model's accuracy in predicting sediment yield. Based on the four data layers such as K, LS, C and P were integrated in the raster calculation tool using ArcGIS 10.2.

CONCLUSION

Using existing conceptual methodologies and GIS techniques, this study attempts to quantify soil erosion in the Neemahosalli sub-watershed in Kalaburgi district. Geospatial approaches were used to investigate and map the geographic variance of erosion severity. In integrated investigations including a number of overlay analyses, remote sensing and GIS are successful. Some of the major elements in soil loss estimation utilising the MUSLE include the LU/LC, soil series, drainage length, and period of concentration (Arun *et al.,* 2012). The MUSLE model was used to calculate annual soil loss within the watershed. The raster calculator function in the ArcGIS spatial analyst tool was used to create the actual soil erosion-controlling layers K, LS, C, and P. The average values of factors K, LS, C and P were found to be 0.404, 3.740, 0.671 and 0.640 respectively. Annual soil loss was estimated to be 92.80 t ha^{-1} yr^{-1} and 62.917 t ha^{-1} yr^{-1} respectively, using Kirpich time of concentration (84.7 min) and Williams' time of concentration (169.54 min). It shows that the research site falls into the severe soil erosion category, with erosion rates ranging from 50 to 100 t ha^{-1} yr^{-1}.

FUTURE SCOPE

These results can also be used to inform the implementation of soil and water conservation, management and land use planning.

REFERENCES

Amutha, R., & Porchelvan, P. (2009). Estimation of surface runoff in Malattar sub-watershed using SCS-CN method. *Journal of the Indian Society of Remote Sensing*, *37*(2), 291-304.

Arun, M. K., Varuna, V. M., Dwarakishb, G. S., Kavyashreec, B., & Shwetha, H. R. (2012). Soil Loss Estimation through MUSLE using Kirpich and Williams Times of Concentration using RS and GIS Techniques: a case study. *Journal of Hydrological Engineering, 18*(1): 1-10.

Chow, V. T., Maidment, D. R., & Mays, L. W. (1988). Applied Hydrology. McGraw-Hill Publishing Company.

Li, H., Chen, X., Kyoung, J. L., Cai, X., & Myung, S. (2010). Assessment of Soil Erosion and Sediment Yield in Liao Watershed, Jiangxi Province, China, using USLE, GIS and RS. *Journal of Earth Science, 21*(6): 941-953.

McDool, D. K., Foster, G. R., Mutchler, C. K., & Meyer, L. D. (1989). Revised slope length factor for the universal soil loss equation. *Transaction of American society of Agricultural Engineering, 32*(1): 1571–1576.

Pandey, A., Chowdary, V. M., Mal, B. C., & Dabral, P. P. (2011). Remote Sensing and GIS for Identification of Suitable Sites for Soil and Water Conservation Structures. *Land Degradation and Development, 22*(3): 359-372.

Sadeghi, S. H. R., Gholami, L., Khaledi Darvishan, A., & Saeidi, P. (2014). A review of the Application of the MUSLE Model Worldwide. *Hydrological Science Journal, 59*(2): 365–375.

Saleh, A., & Ghobad, R. (2011). Sediment Yield Estimating from Three Micro Watersheds by integrated KW-GIUH and MUSLE Models. *Advanced Environmental Biology, 5*(6): 1346-1358.

Shwetha, G., Maheshwara, Babu, Srinivas Reddy, G. V., Aruna K. T., & Shanwad U. K. (2016). Soil Loss Estimation through Mathematical Models using GIS and RS Techniques. *International Journal of Agricultural Science and Research, 6*(3): 251-258.

Shwetha, G., S. S. Shirahatti & Shirahatti, M. S. (2020). MUSLE Model Approach for Soil Loss Studies in Tonshyal Micro Watershed. *Int. J. Curr. Microbiol. App. Sci., 9*(10): 2048-2051.

Soil Conservation Service (1972). SCS National Engineering Handbook, Section 4 (NEH4), Hydrology, U.S. Department of Agriculture, Washington, DC.

Upadhyay, R., Pandey, K., Upadhyay, S. K., & Bajpai, A. (2012). Annual Sedimentation Yield and Sediment Characteristics of Upper Lake, Bhopal, India. *Journal of Chemical. Sciences, 2*(2): 65-74.

Williams, J. R. (1975). Sediment – Yield Prediction with Universal Equation using Runoff Energy Factor. Proceedings of the sediment-yield workshop, USDA Sedimentation Laboratory, Oxford, Mississippi.

How to cite this article: Tipperudramma N.; Shrikant and Ashoka, H.G. (2021). Soil Loss Estimation Through MUSLE Equation Using RS and GIS Techniques in Neemahosalli sub-watershed. *Biological Forum – An International Journal, 13*(4): 527-531.