J. Agric. Res. Technol., 51 (2) : 139-147 (2026) https://doi.org/10.56228/JART.2026.51201

Estimation and Mapping of Soil Erodibility Factor for Kolhapur District

M. P. Sawant[1], B. K. Gavit[2], S. S. Shinde[3], M. R. Patil[4], S. M. Todma[5]
Department of Soil and Water Conservation Engineering, Dr. ASCAE & T, MPKV, Rahuri - 413 722 (India)
Corresponding author E-mail : bhaugavit@gmail.com
(Received : 02.10.2025 Accepted : 07.01.2026)

Abstract

This research examines the soil erodibility factor (K) in the Kolhapur district of Maharashtra, which is susceptible to soil erosion due to its mountainous terrain, significant rainfall and varied soil characteristics. The study evaluated key soil attributes influencing erosion across 897 soil samples, consisting of 109 collected from the field and 788 from existing laboratory data. K values were calculated utilizing the Wischmeier and Smith (1978) formula after analyzing factors such as the proportions of sand, silt, and clay, as well as organic carbon content, soil structure, and permeability. The K values varied from 0.17 to 0.66 t ha h/(ha MJ mm), with an average of 0.28, suggesting that the soils have a moderate level of erodibility. The Inverse Distance Weighted (IDW) interpolation technique was employed to develop spatial distribution maps. Tehsils with coarser textures and lower organic matter, including Gaganbawada, Radhanagari, and Shahuwadi, exhibited higher K values. These findings will aid in the formulation of targeted conservation strategies and promote sustainable land management practices in Kolhapur.

Key words : Soil erodibility factor, K-value, GIS, Soil texture, Organic matter, IDW interpolation, Kolhapur.

Soil erosion poses a significant challenge to environmental sustainability and agriculture, negatively impacting land productivity, water availability, and the health of ecosystems. It is driven by both natural elements like rainfall intensity, landscape features, and soil characteristics, as well as human activities such as deforestation and poor land management. This process results in the erosion of the nutrient-rich topsoil layer, which leads to soil deterioration and reduced crop yields (Imani *et al*., 2014). The soil erodibility factor (K), an essential element in erosion models such as USLE and RUSLE, measures the natural vulnerability of soil to being detached and carried away by water. This factor is influenced by physical soil characteristics, including texture, structure, organic matter and permeability (Wischmeier *et al*., 1971; Renard *et al*., 1997).

On a global scale, soil erosion results in the loss of about 24 billion tonnes of fertile soil each year, causing economic damages that exceed $400 billion (UNCCD, 2020; FAO, 2020). In India, erosion affects approximately 92.4 million hectares of agricultural land, resulting in considerable yield losses, sediment buildup in reservoirs and decreased groundwater recharge (CSWCRTI, 2015; Narayan and Babu, 1983). Maharashtra is particularly at risk due to its varied landscape and inconsistent rainfall patterns. The state reportedly loses an estimated 775 million tonnes of topsoil annually, with around 94% of its land vulnerable to erosion caused by water (NBSS&LUP, 2021; MRSAC, 2019). Soil loss rates differ across the state, often surpassing 20 t ha^{-1} $year^{-1}$ in high-rainfall areas such as the Western Ghats (Patil and Ingle, 2018; IIT Bombay, 2020).

The K-factor is greatly affected by the soil's texture and organic matter content. Soils with a coarse texture generally exhibit greater resistance to erosion due to improved infiltration, while finer-textured soils are more likely to erode (Peter *et al.*, 2008; Essien, 2013). Research indicates a negative relationship between soil organic carbon levels and erodibility, highlighting the supportive function of organic matter (Nandgude *et al.*, 2014; Stanchi *et al.*, 2015). Advanced geospatial technologies, including GIS and remote sensing, have improved the accuracy of K-factor mapping, allowing for better identification of areas at risk of erosion (Imani *et al.*, 2014; Das *et al.*, 2019).

Kolhapur district, located in the Western Ghats of Maharashtra, is particularly vulnerable to erosion due to its steep slopes, deforestation, varied soil textures and high annual rainfall, especially in regions like Gaganbawada, Radhanagari and Shahuwadi. Nevertheless, previous erosion evaluations in this area have mostly depended on generalized information, lacking specific data at the tehsil level. This limitation hinders the development of effective, targeted soil conservation measures. The current study aims to fill this gap by calculating and spatially analyzing the soil erodibility factor (K) for Kolhapur district through field-based soil assessments and GIS technologies.

Materials and Methodology

Study Area : The research was carried out in the Kolhapur district, situated in the southern region of Maharashtra, India, between the latitudes of 15°45 N and 17°10 N, and longitudes of 73°40 E and 74°42 E. Kolhapur, which falls under the Western Maharashtra region, covers an area of 8,047 km², making up 2.64% of the total geographical area of the state. The district is administratively organized into 12 tehsils, which include Gadhinglaj, Karveer, Bhudargad, Panhala, Kagal, Shirol, Hatkanangale, Ajara, Chandgad, Gaganbawada, Radhanagari, and Shahuwadi. The principal occupation in the area is agriculture, supported by several rivers-namely, the Panchganga, Krishna, Warana, and Vedganga-that aid in irrigation and soil formation. The district experiences a tropical monsoon climate, with annual rainfall ranging from 1500 to 5000 mm, predominantly occurring from June to September. The distribution of rainfall is uneven; the western tehsils, which are closer to the Western Ghats, receive considerably more precipitation compared to the eastern plains.

The dominant soil type in Kolhapur is black soil, formed from basaltic parent material and categorized into coarse shallow, medium, and deep black soils. These soil types differ in their capacity for moisture retention and fertility, with deep black soils being conducive to high-yield crops such as sugarcane, paddy, soybean, and maize, while the shallower soils are more reliant on rainfall, especially in dryland conditions. The topography of the district is characterized by significant diversity. The western part, which is part of the Sahyadri hill ranges, features rugged hills, lateritic plateaus, and dense forests, with elevation levels between 500 and 1000 meters. Conversely, the eastern region consists of flat to gently undulating plateaus and plains, which are

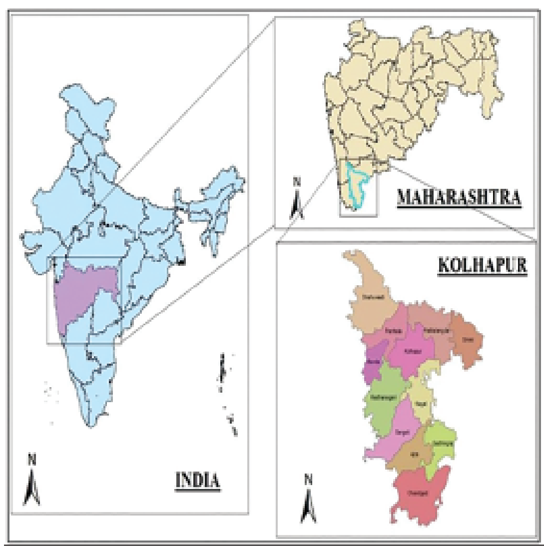

Fig. 1. Location map of the study area

more amenable to intensive agriculture and urban expansion. This variation in terrain and elevation from west to east affects not only land use and cropping patterns but also the distribution of areas prone to erosion, making Kolhapur an excellent location for assessing soil erodibility.

Data Collection : In this research, a total of 897 soil samples were evaluated to determine the soil erodibility factor (K). This total included 788 secondary samples obtained from the District Soil Testing Laboratory in Kolhapur and 109 primary samples gathered from actual field. The laboratory analysis encompassed eight tehsils, showcasing a range of soil types and conditions and incorporated parameters such as particle size distribution, organic carbon content and soil permeability.

To achieve thorough spatial representation, field sampling took place in grid areas lacking coverage in the laboratory dataset. A grid-based method measuring 7.5 km x 7.5 km was used to collect 109 samples from different land use categories, which comprised agricultural land, barren areas, hilly terrains and forest regions.

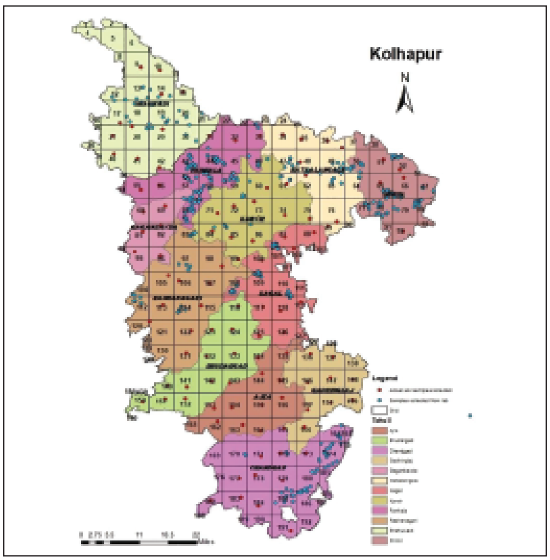

Fig. 2. Spatial Distribution of Sampling Grids and Soil Samples

The samples were extracted from the topsoil layer, specifically from 0-30 cm, using a soil auger and GPS coordinates were logged at each location for precise spatial identification. Each field sample was air-dried and subsequently analyzed in the lab to determine the essential physical and chemical properties of the soil needed for K-factor calculation.

Soil Texture : The texture of soil, which is defined by the relative amounts of sand, silt and clay, significantly affects its susceptibility to erosion. Soils that contain higher levels of silt and very fine sand are more likely to experience erosion due to their weaker cohesion, whereas clay-dominated soils are better at resisting erosion because of their stronger particle bonds (Nandgude *et al*., 2014; Olaniya *et al*., 2020). Consequently, the erodibility factor (K) is closely related to the textural composition. For this research, we employed the International Pipette Method to analyze soil particle size distribution, which is a dependable and accurate approach for classifying soil texture and aiding in erosion evaluations (Jadhav *et al*., 2024). Understanding soil texture was essential for establishing structure codes and permeability codes. The USDA triangular textural classification chart was utilized to classify the textural category.

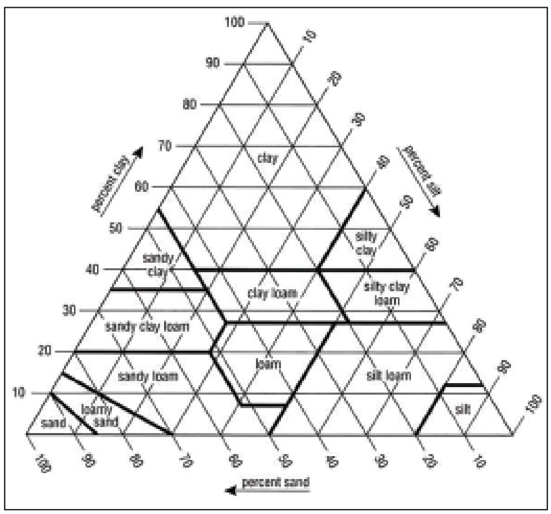

Fig. 3. USDA Textural classification chart

Soil Organic Carbon : Soil organic carbon (SOC) is a crucial element of soil organic matter, significantly contributing to enhancements in soil structure, fertility and erosion resistance. It improves soil aggregation and stability, thus decreasing the likelihood of erosion (Murphy, 2014). Studies show that soils with organic carbon levels below 2% face a higher risk of erosion, especially sandy and loamy soils, which generally contain lower carbon amounts (Nandgude *et al*., 2014; Shinde *et al*., 2020; Peter *et al*., 2008). In this research, the Walkley-Black titration method was utilized to assess the organic carbon content in the collected soil samples, offering a crucial input for determining the soil erodibility factor (K).

To determine the soil organic matter content in various soil samples, the recorded soil organic carbon (SOC) values were employed. A standard conversion factor of 1.724, as suggested by Nelson and Sommers (1996), was applied to compute organic matter using the following formula:

Organic matter = Organic carbon x 1.724…(1)

Soil Structure : Soil structure refers to how soil particles are arranged into aggregates of various shapes and sizes, which significantly influences water absorption, retention and erosion resistance. Soils with good aggregation are more stable and less vulnerable to erosion due to improved permeability and decreased runoff (Shinde *et al*., 2020; Olaniya *et al*., 2020). Structural forms such as blocky, granular, prismatic and platy are created through the physical and chemical bonding of sand, silt, and clay particles (Tesfaye *et al*., 2021). The classification of soil structure includes platy, granular, prismatic, or blocky types. The soil's textural class determines its structural code (NBSS and LUP, Nagpur, 1988). In this research, structure codes were assigned following the soil textural pyramid created by the United States Geological Survey (USGS).

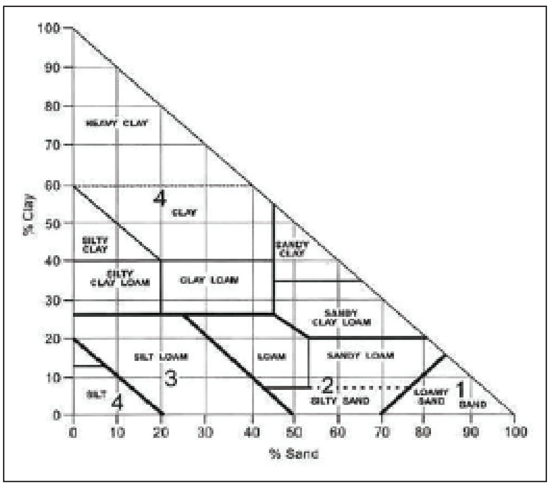

Fig. 4. Soil structure code based on soil textural classification

Table 1. Structure code for different types of soils

Code	Structure	Size (mm)
1	Very fine granular	<1
2	Fine granular	1 – 2
3	Moderate or Coarse granular	2 – 10
4	Blocky, platy or massive	>10

(NBSS & LUP, 1988)

Soil Permeability : Permeability refers to the capacity of soil to permit water to flow through its interconnected voids, affecting both infiltration and drainage. The absorption of water into the soil is maximized when the soil is relatively dry; however, as the pore spaces become saturated, swelling takes place, which decreases the infiltration rate to a consistent level (Shinde *et al*., 2020). The permeability of soil varies according to its type and is generally associated with its grain size distribution or texture. Therefore, the permeability classifications for the study area were established based on the classification of soil texture. The soil permeability classifications derived from soil texture are presented in Table 2, as outlined by the National Soil Handbook, USDA (1983).

Table 2. Permeability code from soil texture class

Soil texture	Permeability code
Heavy clay, Clay	6
Silty clay loam, Sandy clay	5
Sandy clay loam, Clay loam	4
Loam, Silt loam	3
Loamy sand, Sandy loam	2
Sand	1

(National soil handbook, USDA, 1983)

Computation of Soil Erodibility Factor (K) : Soil erodibility, commonly referred to as the K-factor, indicates how resistant soil is to being detached and transported by factors such as rainfall and surface runoff. Its determination is influenced by essential physical characteristics including texture, organic matter content, structure and permeability, which together affect the ease with which soil particles can be moved (Shinde *et al*., 2020; Stanchi *et al*., 2015). Soils that are high in silt and fine sand typically demonstrate greater erodibility, while those with a high clay content display reduced susceptibility due to the stronger cohesion among particles (Olaniya *et al*., 2020).

The direct assessment of K-values through field runoff studies can often be resource-demanding. For this reason, empirical models like the Universal Soil Loss Equation (USLE) and the nomograph developed by Wischmeier and Smith (1978) are frequently utilized. These models derive the K factor using five quantifiable parameters: the percentage of silt and very fine sand, the percentage of clay, organic matter content, the soil structure code and the permeability code (Imani *et al*., 2014; Nandgude *et al*., 2014). Their accuracy has been corroborated by comparisons with field observations (Das *et al*., 2019).

In this research, the K-factor was calculated using the equation established by Wischmeier and Smith (1978):

$$K = \{2.1\times 10\text{-}4 \text{ x } M1.14\ (12\ \text{-}a) + 3.25 \text{ x } (b\text{-}2) + 2.5\times (c\text{-}3)\}\ /100 \qquad \ldots(2)$$

Where, K = Soil erodibility factor, t ha h ha^{-1} MJ mm, M = (per cent silt + per cent very fine sand) x (100- per cent clay), a = Per cent organic matter content, b = Structure code used in soil classification and c = Soil permeability code.

Classification of Soil Erodibility : The values of the soil erodibility factor (K) were categorized into six classes, each with intervals of 0.10, as suggested by Manrique in 1988, as displayed in Table 3.

Table 3. Classification of soil erodibility

Class	Soil erodibility	K values (t ha h ha^{-1} MJ mm)
1	Very low	0.00-0.10
2	Low	0.10-0.20
3	Moderate	0.20-0.30
4	Moderate high	0.30-0.40
5	High	0.40-0.50
6	Very high	>0.50

(Manrique, 1988)

Preparation of Soil Erodibility Map : To depict the spatial distribution of soil erodibility (K values) across Kolhapur district, all processed soil datasets were integrated into a Geographic Information System (GIS). The mapping was performed using ArcGIS 10.2 software, which facilitated efficient overlay, interpolation, and visualization of spatial data. Among the various spatial interpolation methods available like Kriging, Spline, and Trend Surface Analysis, the Inverse Distance Weighted (IDW) technique was chosen for its computational ease and effectiveness in areas with gradual spatial changes.

The IDW interpolation method approximates unknown values based on the premise that samples nearer to a point exert a greater influence than those that are farther away, relying solely on the known z-values (K values) and their spatial distances. This technique was implemented using the latitude, longitude, and calculated K values from each sample location as input parameters. The IDW method has been effectively utilized in earlier soil studies, particularly in regions where the terrain is fairly uniform and the data points are reasonably distributed (Munyati *et al*., 2021).

The generated soil erodibility maps clearly indicate areas with differing levels of erosion risk and are a valuable resource for land-use planning, watershed management, and executing targeted soil conservation strategies in the Kolhapur area.

Results and Discussions

Physico-Chemical Properties of Soils : Soil samples taken from 12 tehsils in Kolhapur displayed a significant range in textural composition, with sand content varying from 5.47% to 73.80%, silt from 1.62% to 75.90% and clay from 2.59% to 69.09%. The main textural classes identified included clay, clay loam, sandy clay loam, silty loam, loam, and loamy sand. In hilly tehsils such as Ajra, Gaganbawada, and Shahuwadi, clay and sandy clay loam were found to be the most common. The structure codes across the region ranged from 1 (very fine granular) to 4 (massive blocky), with the latter being prevalent in hilly areas. These blocky structures limit infiltration and increase runoff potential, making the soil more susceptible to erosion. Permeability codes varied from 2 (moderate) to 6 (very slow). Tehsils situated in rugged terrains, like Radhanagari and Gaganbawada, mainly exhibited slow to very slow permeability, leading to inadequate water percolation and a greater risk of erosion. The organic matter (OM) content in the district ranged from 0.0862% to 10.6888%, with lower OM levels often recorded in hilly regions, further increasing their susceptibility to erosion.

Soil Erodibility Factor (K) : The soil erodibility factor (K) calculated using the Wischmeier and Smith (1978) formula in the district varies from 0.1665 to 0.6614 t ha h/ha MJ mm, with an overall average of 0.2765, placing most soils within the moderate to high erodibility range. Based on Manrique's (1988) classification, the soils within Kolhapur district fall into five categories. Regions such as Chandgad (0.2622), Gagan Bavda (0.2552), Hatkanangale (0.2733), Kagal (0.2519), Shirol (0.2581), and Shahuwadi (0.2778) exhibited lower K values (0.20-0.30), characterized by greater clay content and reduced silt fractions. In contrast, higher K values (0.30–0.40) were observed in Ajra (0.3324), Gadhinglaj (0.3674), Bhudargad, Karveer (0.3173), Panhala (0.2871), and Radhanagari (0.2890). Gargoti (0.3733) in the Bhudargad tehsil showed the highest erodibility, primarily due to its sandy-silty texture and lower clay content. In the western Kolhapur tehsils like Ajara, Chandgad, Radhanagari, Gagan Bavda, and Panhala, which are situated in the Sahyadri ranges, K-factor values tend to be moderate (0.25–0.35) because of dense vegetation and minimal disruption. Nevertheless, some localized areas exceed a K value of 0.5 due to deforestation and uncontrolled land use, indicating an elevated risk of soil erosion.

Spatial Distribution and Mapping of K-Factor : The spatial distribution of K-values was depicted using IDW interpolation in ArcGIS 10.2. The resulting soil erodibility maps clearly outlined zones at risk of erosion throughout the Kolhapur district. Significantly, the western hill ranges, such as Gaganbawada, Radhanagari, and Shahuwadi, were identified as critical hotspots for erosion due to their physical features and indicators of poor soil quality. Conversely, the central and eastern plains showed relatively low to moderate levels of erodibility, indicating a lesser immediate need for intervention. Nevertheless, these regions could still experience long-term degradation if intensive agricultural practices are maintained without appropriate soil management. These maps function as tools for decision support, allowing land managers and policymakers to focus erosion control efforts in the areas where they are most needed.

Table 4. Tehsil wise soil erodibility factor values of Kolhapur district

Tehsil	Sand (%)	Silt (%)	Clay (%)	OM	c	b	K (t ha h/ ha MJ mm)
Ajra	38.69	33.56	20.56	2.24	3	4	0.3324
Chandgad	25.16	22.49	42.87	1.79	6	4	0.2622
Gadhinglaj	35.18	38.31	21.08	1.30	3	3	0.3674
Gagan Bavda	33.69	26.58	37.79	2.16	4	4	0.2552
Gargoti	38.15	38.33	17.17	1.61	3	3	0.3733
Hatkanangale	31.92	17.91	40.29	1.08	6	4	0.2733
Kagal	25.15	18.79	48.83	1.36	6	4	0.2519
Karveer	29.63	26.98	37.97	1.22	6	4	0.3173
Panhala	28.63	21.43	41.29	1.77	6	4	0.2871
Radhanagari	20.86	30.86	42.17	1.73	6	4	0.2890
Shahuwadi	26.67	24.06	41.72	1.44	6	4	0.2778
Shirol	19.36	19.98	51.83	1.12	6	4	0.2581

Table 5. Soil erodibility factor K value of Kolhapur district

Tehsil	Sand (%)	Silt (%)	Clay (%)	OM	c	b	K (t ha h/ ha MJ mm)
Kolhapur	26.55	22.35	42.92	1.52	6	4	0.2764

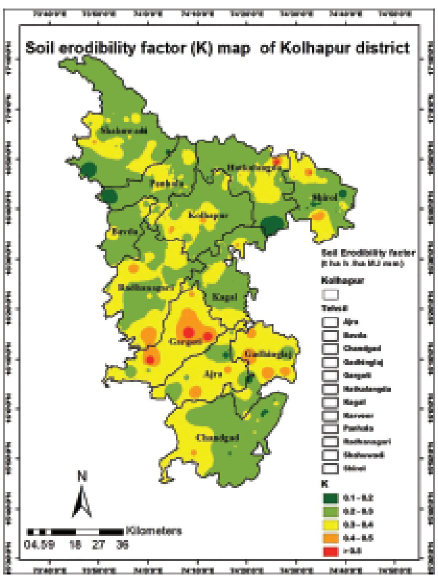

Fig. 5. Soil erodibility factor (K) map of Kolhapur district

Conclusions

The detailed analysis of the soil erodibility factor in the Kolhapur district led to the following findings:

1. The investigation demonstrated that the soil erodibility factor shows considerable spatial variability throughout the Kolhapur district, with values spanning from 0.1665 to 0.6614 t ha h ha^{-1} MJ mm, and an average of approximately 0.2765, indicating that most soils fall into the moderate to high erodibility categories.

2. The hilly tehsils, including Gaganbawada, Shahuwadi, Panhala, Ajra, and Radhanagari, were identified as particularly vulnerable to erosion, even in regions with forest cover. The combination of steep gradients, low organic matter content, blocky soil structure, and very slow permeability contributes to increased surface runoff and the detachment of topsoil.

3. Soil erodibility mapping highlights Chandgad, Ajra, Gaganbawada, and Shahuwadi tehsils as high-priority areas for soil conservation efforts. In contrast, tehsils like Hatkanangale, Shirol, and Karveer, which feature relatively flat landscapes and lower K values, demonstrated lower erosion susceptibility.

4. Given that the K factor may fluctuate over time due to factors such as land use changes, deforestation, agricultural practices, and rainfall intensity, it is advisable to conduct regular monitoring and update soil erodibility maps to facilitate effective planning and conservation.

References

CSWCRTI. 2015. Annual Report. Central Soil and Water Conservation Research and Training Institute, Dehradun.

Das, S., Bora, P. K., and Katre, P. 2019. Determining and mapping of soil erodibility index for Nongpoh Watershed. Indian Journal of Hill Farming, 32(1).

Essien, O. E. 2013. Evaluation of potential erodibility of basin wetland using soil particles distribution. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS). 4(4): 10-16. p-ISSN: 2319-2372.

FAO. 2015. Status of the World's Soil Resources. Food and Agriculture Organization of the United Nations.

IIT Bombay. 2020. Western Ghats region at risk from rapid soil erosion. https://acr.iitbombay.org

Imani, R., Ghasemieh, H., and Mirzavand, M. 2014. Determining and mapping soil erodibility factor (case study: Yamchi Watershed in Northwest of Iran). Open Journal of Soil Science, 2014.

Jadhav, D. S., Gavit, B. K., Nandgude, S. B., Barai, V. N., Durgude, A. G., and Shinde, S. S. 2024. Mapping of soil erodibility factor (K) using geospatial technique for soils in Nashik district, Maharashtra, India. International Journal of Advanced Biochemistry Research, 8(11), 102-109.

Manrique LA. A methodology to assess land erodibility from information contained in Soil Taxonomy-based soil surveys. Agronomy Abstracts. 1988;22. American Society of Agronomy Annual Meeting, Atlanta, GA.

MRSAC. 2019. Land Degradation Mapping of Maharashtra. Maharashtra Remote Sensing Application Centre.

Murphy, B. W. Soil organic matter and soil function - Review of the literature and underlying data. Department of the Environment, Canberra, Australia; 2014. p. 1-129.

Nandgude, S., Kambale, A., Shinde, S., Mahale, D., and Shinde, V. 2014. Soil erodibility estimation for soil conservation in dapoli region of Maharashtra. Trends in Biosciences, 7(6), 486-490.

Narayan, D. and Babu, R. 1983. Estimation of soil erosion in India. Journal of the Indian Society of Soil Science, 31(2), 266-271.

National Bureau of Soil Survey and Land Use Planning (NBSS and LUP), Nagpur. Field handbook. Printed at Cartography Division, NBSS and LUP, New Delhi: Agrobias India; 1988. p. 29-34.

NBSS&LUP. 2021. Soil Resource Mapping Reports. National Bureau of Soil Survey and Land Use Planning, Nagpur.

Nelson, D. W., Sommers, L. E. Total carbon, organic carbon and organic matter. In: Page AL, editor. Methods of soil analysis: Part 2 chemical and microbiological properties. Madison (WI): American Society of Agronomy; 1982. p. 539-579.

Olaniya, M., Bora, P. K., Das, S., and Chanu, P. H. 2020. Soil erodibility indices under different land uses in Ri-Bhoi district of Meghalaya (India). Scientific reports, 10(1), 14986.

Patil, S. N. and Ingle, R. W. 2018. Evaluation of soil erosion risk using RUSLE and GIS: A case from Maharashtra. Journal of Soil and Water Conservation, 17(1), 15–22.

Peter, A. I., Mustapha, H. I., Musa, J. J., and Dike, J. 2008. Determination of Erodibility Indices of Soils in Owerri West Local Government Area of Imo State, Nigeria. AU J.T., 12(2), 130–133.

Renard, K. G., G. R. Foster, G. A. Weesies, D. K. McCool and D. C. Yoder. 1997. Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). (Agriculture Handbook No. 703). United States

Department of Agriculture.

Stanchi, S., Falsone, G., and Bonifacio, E. 201. Soil aggregation, erodibility, and erosion rates in mountain soils (NW Alps, Italy). Solid Earth, 6(2), 403-414.

Tesfaye, G., and Ameyu, T. 2021. Soil Erodibility Analysis and Mapping in Gilgel Gibe-I Catchment, Omo-Gibe River Basin, Ethiopia. Applied and Environmental Soil Science, 2021(1), 8985783.

UNCCD. 2020. The Global Land Outlook. United Nations Convention to Combat Desertification.

Wischmeier, W. H., Johanson, C. B. and Cross, B. V. 1971. An erodibility nomograph for farmland and construction. Journal of Soil and Water Conservation. 26: 189-192.