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Assessment of Spatial Variability in Soil Erodibility Factor (K) for Dhule District

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Abstract
Soil erosion is a critical environmental challenge that threatens agricultural productivity and land sustainability, particularly in semi-arid regions of India. The soil erodibility factor (K) is a key parameter of the Universal Soil Loss Equation (USLE) that quantifies the inherent susceptibility of soil to detachment and transport by rainfall and runoff. This study was conducted to examine the spatial variation of the soil erodibility factor (K) across Dhule district, Maharashtra, using soil physico-chemical data and geospatial techniques. A total of 1,110 soil samples were obtained from the District Soil Testing Laboratory, supplemented by field validation samples, to determine soil texture, organic matter, structure, and permeability. The K values were computed following the Wischmeier and Smith (1978) method and spatially interpolated using the Inverse Distance Weighted (IDW) technique in ArcGIS. The results showed that the K factor values in Dhule district ranged from 0.02 to 0.69 t·ha·h/ha·MJ·mm, with an overall mean of 0.33, indicating moderate to moderately high erodibility. Across all four tehsils (Dhule, Sakri, Shindkheda, Shirpur), the majority of soils (65-70% of the area) fell into the moderately high erodibility class (0.30-0.40). Moderate erodibility (0.20-0.30) covered about 20-25% of the area, while high to very high erodibility (>0.40) occurred in localized pockets (6-8%). Areas of low erodibility (<0.20) were negligible. The spatial distribution maps clearly highlight erosion-prone zones that require priority conservation measures. This study provides the first district-scale assessment of soil erodibility in Dhule, offering a scientific basis for erosion risk modeling, land use planning, and watershed management. The generated K factor maps can support policymakers and land managers in designing targeted soil conservation practices to safeguard agricultural productivity and environmental sustainability.

Keywords: Soil erosion, Soil erodibility factor (K), Dhule district, Universal Soil Loss Equation (USLE), Spatial variation, GIS mapping, Land degradation

Introduction

Soil erosion is one of the most serious forms of land degradation, threatening agricultural productivity, water quality, and ecosystem stability worldwide. It is estimated that nearly 24 billion tonnes of fertile soil are lost annually due to erosion, resulting in reduced crop yields, declining soil fertility, and sedimentation of water bodies (Pimentel & Kounang, 1998; FAO, 2015) [10]. In India, water-induced soil erosion is the most dominant form of degradation, affecting about 93 million hectares of land, or nearly one-third of the country's total geographical area (ICAR, 2010). Maharashtra is among the severely affected states, where soil erosion is exacerbated by erratic rainfall, undulating topography, and intensive agricultural practices (Singh *et al*., 2018) [15].

A key parameter in assessing soil erosion risk is the soil erodibility factor (K), which represents the susceptibility of soil particles to detachment and transport by rainfall and surface runoff. The K factor is an integral component of the Universal Soil Loss Equation (USLE) and its revised form (RUSLE) developed by Wischmeier and Smith (1978) [19], widely applied across the globe for predicting soil erosion. It is influenced by inherent soil properties such as texture, structure, organic matter, and permeability (Renard *et al*., 1997) [13]. Soils with higher proportions of silt and very fine sand, along with low organic matter, are generally more erodible, while clay-rich and well-aggregated soils tend to exhibit greater resistance (Morgan, 2005; Shukla *et al*., 2014) [7, 14].

Several studies have demonstrated significant spatial variation in K values across different agro-climatic zones.

For instance, Zhang *et al*. (2019) [20] reported that loamy soils in China exhibited higher K values due to elevated silt content, whereas sandy soils displayed relatively lower values. In India, Mandal & Sharda (2011) [5] emphasized the role of soil texture and organic carbon in controlling erodibility, with black soils of central India being moderately to highly susceptible. More recently, Raj *et al*. (2023) [12] and Kaundal *et al*. (2025) [4] highlighted the utility of integrating soil laboratory data with geospatial techniques to generate district-level erodibility maps, thereby improving erosion risk assessment and conservation planning.

The Dhule district of Maharashtra, located in the semi-arid region of northern Maharashtra, represents a critical agricultural landscape where soil erosion poses serious threats to sustainable land use. The district is characterized by diverse soil textural classes ranging from sandy loam to clay, with significant variation in rainfall distribution, topography, and land use practices. Despite its vulnerability, limited research has been carried out to quantify and map the spatial variation of the soil erodibility factor (K) at the district scale. Understanding these variations is essential for prioritizing conservation measures, optimizing land management strategies, and mitigating erosion risks.

Therefore, the present study aims to study the variation of the soil erodibility factor (K) across Dhule district using soil physico-chemical data, permeability analysis, and geospatial techniques.

Study Area

The study was conducted in Dhule district, located in the northern part of Maharashtra, India, between 20°38′ to 21°61′ N latitude and 73°50′ to 75°11′ E longitude. The district covers an area of 7,184 km² and consists of four tehsils: Dhule, Sakri, Shirpur, and Shindkheda. Agriculture is the primary occupation, with about 4,752 km² under cultivation. The Tapi River forms the major drainage system. The district experiences a semi-arid climate with an average annual rainfall of 608 mm and summer temperatures reaching up to 44 °C.

Soil Data Collection

Soil data were obtained from the District Soil Testing Laboratory, Dhule, which included 1,110 samples collected from agricultural lands across the four tehsils. The dataset contained information on soil particle-size distribution (sand, silt, clay) and organic carbon. Geographic coordinates of each sampling location were derived using the *Maha Bhumi* application of the Government of Maharashtra.

Additionally, 20 field samples were collected using a screw auger at a depth of 0-15 cm for validation of soil textural classes and permeability characteristics.

Soil Properties for K Factor Estimation

The following parameters were considered for computing soil erodibility factor (K) values, as per the method of Wischmeier and Smith (1978) [19]:

1. Soil Texture: Determined from particle size distribution and classified using the USDA textural triangle.
2. Soil Structure: Assigned based on textural class following NBSS & LUP (1988).
3. Soil Organic Matter (OM): Calculated by multiplying organic carbon values with a factor of 1.724 (Hesse, 1971) [2].
4. Soil Permeability: Determined using the constant head permeameter method (Punmia, 2005) [11] on 40 representative samples covering major soil textural classes. Permeability codes were assigned following USDA (1983) and Smith & Browning (1946) [16].

Computation of Soil Erodibility Factor (K)

The soil erodibility factor (K) was computed using the algebraic equation proposed by Wischmeier & Smith (1978) [19], which incorporates soil textural properties, organic matter, structure, and permeability:

Formula

The computed K values were categorized into six classes ranging from very low (0.00-0.10) to very high (>0.50) as per Manrique (1988) [6].

Results and Discussion

This study assessed the spatial variation of the soil erodibility factor (K) across Dhule district using laboratory data, field validation, and geospatial techniques. The analysis covered all four tehsils—Dhule, Sakri, Shindkheda, and Shirpur—spanning a total geographical area of 7,184 km². The computed K values were categorized into five classes: low (0-0.20), moderate (0.20-0.30), moderately high (0.30-0.40), high (0.40-0.50), and very high (>0.50), following Manrique (1988) [6].

Table 1: Distribution of Soil Erodibility Classes Across Tehsils of Dhule District

Tehsil	Low (%)	Moderate (%)	Moderately High (%)	High-Very High (%)
Dhule	0.25	21.30	71.05	7.39
Sakri	0.25	21.30	71.05	7.39
Shindkheda	0.56	41.72	50.88	6.82
Shirpur	0.65	35.26	62.13	1.94

Dhule Tehsil

The K factor values in Dhule tehsil ranged from 0.04 to 0.63 t·ha·h/ha·MJ·mm, with an average of 0.33. A large proportion of the area (71.05%) was classified as moderately high erodibility (0.30-0.40), while 21.30% fell under the moderate class (0.20-0.30). Only 0.25% of the area showed low erodibility, whereas 7.39% exhibited high to very high erodibility (>0.40). The spatial map (Fig. 4.1) highlights the concentration of high K values in localized pockets, particularly where soils contain higher proportions of silt and fine sand with relatively low organic matter.

Sakri Tehsil

In Sakri tehsil, K values varied between 0.06 and 0.69, with an average of 0.33. Similar to Dhule tehsil, the majority of the area (71.05%) was in the moderately high class (0.30-0.40). About 21.30% was moderate, and 7.39% fell under high to very high erodibility classes. Only 0.25% of the area showed low susceptibility. The distribution (Fig. 4.2) indicates that erosion risk is widespread across Sakri, reflecting the dominance of sandy clay loam soils with low organic matter retention capacity.

Shindkheda Tehsil

The K values in Shindkheda tehsil ranged from 0.07 to 0.56, averaging 0.33. More than half of the tehsil (50.88%) was categorized as moderately high, while 41.72% was moderate. Only 0.56% of the area fell under the low class, whereas 6.82% was in high and very high categories. The soil erodibility map (Fig. 4.3) shows relatively higher spatial variability compared to Dhule and Sakri tehsils, with localized hotspots of high erodibility.

Shirpur Tehsil

In Shirpur tehsil, K values ranged from 0.07 to 0.56, with a mean of 0.32. A majority of the area (62.13%) was under moderately high erodibility, followed by 35.26% under moderate. Low and very high erodibility zones were minimal, accounting for less than 1% of the total area each. The spatial distribution (Fig. 4.4) indicates that erosion susceptibility is generally uniform, though some northern parts of the tehsil display relatively higher K values.

District-Wide Variation

At the district level, the computed K factor values ranged from 0.02 to 0.69, with an overall average of 0.33 t·ha·h/ha·MJ·mm, indicating a moderate to moderately high susceptibility to soil erosion across Dhule. The predominant class was moderately high (0.30-0.40), covering nearly 65-70% of the district's area, followed by the moderate class (0.20-0.30). High to very high erodibility (>0.40) accounted for about 6-8%, highlighting specific erosion-prone zones that require priority attention. Only a negligible fraction of the district exhibited low erodibility (<0.20).

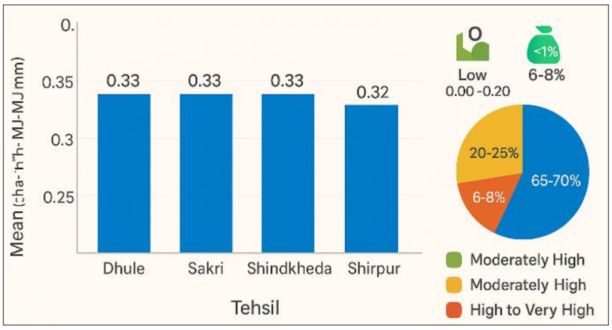

Fig 1: Variation in Soil Erodibility Factor (K) Across Different Tehsils of Dhule District

Discussion

The findings reveal a consistent pattern across all four tehsils, with the majority of land falling into the moderately high erodibility class (0.30-0.40). This indicates that soils in Dhule district are inherently susceptible to erosion, mainly due to their textural composition dominated by sandy clay loam and clay loam soils. Localized patches of high to very high K values correspond to areas with higher silt and very fine sand content, which are known to increase soil detachment risk (Morgan, 2005; Renard *et al*., 1997) [7, 13].

These results align with earlier studies in semi-arid regions of India that reported similar erodibility ranges (Mandal & Sharda, 2011; Raj *et al*., 2023) [5, 12]. The spatial maps clearly identify erosion hotspots, underscoring the need for targeted conservation measures such as contour bunding, cover cropping, and vegetative barriers in vulnerable areas.

Summary

The present study was undertaken to assess the spatial variation of soil erodibility factor (K) across Dhule district of Maharashtra. A total of 1,110 soil samples were analyzed using laboratory data and field validation, and the K factor was computed following the Wischmeier and Smith (1978) [19] equation. Geospatial mapping through IDW interpolation was applied to evaluate tehsil-wise and district-wide distribution of erodibility classes.

The results revealed that the K factor in Dhule district ranged from 0.02 to 0.69 t·ha·h/ha·MJ·mm, with an overall mean of 0.33, indicating a moderate to moderately high susceptibility to erosion. The majority of soils across all four tehsils fell into the moderately high erodibility class (0.30-0.40), covering nearly 65-70% of the total area. Moderate erodibility (0.20-0.30) accounted for 20-25% of the district, while high to very high erodibility (>0.40) occurred only in localized patches (6-8%), mainly in parts of Dhule, Sakri, and Shindkheda tehsils. Areas with low erodibility (<0.20) were negligible (<1%).

The spatial maps and tehsil-level analysis highlight that, although the district is predominantly under moderately high erodibility, specific erosion hotspots exist, particularly where soils contain higher proportions of silt and very fine sand. These zones are most vulnerable to detachment and require priority attention in soil conservation planning.

Conclusion

In conclusion, this study provides the first comprehensive district-level soil erodibility assessment for Dhule. The generated K factor maps can serve as a valuable input for erosion risk modeling (RUSLE/USLE), land use planning, and watershed management. Targeted measures such as vegetative cover, contour bunding, and check dams should be prioritized in the high and very high erodibility zones to mitigate soil loss and ensure sustainable agricultural productivity.

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