**Mapping of Soil Erodibility Factor (K) For central MPKV Campus Watershed**

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**Abstract**

Soil is a complex mixture of minerals, organic materials, water, and living organisms covering the Earth's surface, exhibits varying degrees of susceptibility to erosion. The parameter used to quantify this susceptibility, known as the soil erodibility factor (K), is subject to fluctuations within a watershed due to distinct soil characteristics such as texture, structure, permeability, and organic matter content. It is the most important soil factor that cause the soil erosion. Soil erodibility influences the rate at which soil particles are detached and transported by erosive agents such as water and wind. This research endeavour was carried out within the central MPKV campus watershed, with the primary objective of determining the soil erodibility factor (K). For determination of soil texture and organic carbon, soil sampling was done and 51 soil samples were collected from points from the study area. The calculated soil erodibility factor (K) values were assigned to respective soil sample locations in soil map. This soil map was converted in grid format and then K factor map was generated using Inverse Distance Weighted (IDW) technique of interpolation in ArcGIS environment. The study revealed that the predominant soil type in the area was clay loam and sandy clay loam, comprising over 50% of the total area. The computed values for the soil erodibility factor ranged from 0.0396 to 0.0571 t-ha-h/ha-MJ-mm.

**1. Introduction**

Soil is a complex mixture of minerals, organic matter, water, air, and various living organisms that form the top layer of the earth's surface (Anonymous, 2015) Soil degradation and erosion pose significant threats to agricultural productivity and food security. The state of Maharashtra loses about 773.5 million tonnes of soil every year due to erosion (Shejale et al., 2022). The soil erodibility factor (K) is linked to how rain, runoff and infiltration all work together to cause soil loss. Soil erodibility is the most important soil factor that cause the soil erosion. Soil erodibility influences the rate at which soil particles are detached and transported by erosive agents such as water and wind. It is a key component in soil erosion modelling systems like the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE), both widely used in soil conservation planning (Wischmeier & Smith, 1978). Soil erodibility also aids in identifying vulnerable areas and prioritizing erosion control measures (Sinshaw et al., 2021). Understanding its significance is vital for sustainable land use and environmental management.

In practice, K is the average long-term response of the soil and soil profile to the eroding power of rainstorms. It is the average annual value of the total response of the soil as well as soil profile to many erosion and water processes. The rate of soil erosion per rainy erosion index unit is used to figure out the K factor on a unit plot. The unit plot is 22.1m long and has a consistent slope of 9%. It is always kept in a clean-tilled waste state by tilling upslope and downslope (Wischmeier and Smith, 1978) Soil erodibility is a complicated property that is influenced by a wide range of interconnected parameters, but only some of these parameters can be linked to soil types (Veihe, 2002). So, the best way to get K-factors is to take readings directly on natural runoff plots. Long-term studies take a lot of time and money, though, so many people have tried to find a link between observed K-factor values and soil properties (Cohen et al., 2005). The most used and cited relationship is the soil erodibility nomograph (Wischmeier et al., 1971). Thus, understanding the significance of soil erodibility and the various assessment methods available is vital for sustainable land use and environmental conservation.

**2. Materials and Methods**

**2.1. Study Area**

The study area is the central MPKV campus watershed located in Rahuri taluka in Ahmednagar district of Maharashtra state, India. The location map of study area is shown in Figure 1. The study area is located between latitudes from 19° 21.77' N to 19° 18.73' N and longitudes from 74° 37.79' E to 74° 36.49’ E. Ahmednagar district is the largest district of Maharashtra state in western India.



**Figure 1. Location map of study area**

# 2.2 Soil Erodibility Factor (K)

This factor relates the various soil properties by virtue of which a particular soil becomes susceptible to get erode, either by water or wind. The soil erodibility factor (K) is expressed as tones of soil loss per hectare per unit rainfall erosivity index from a field of 9 % slope and 22 meters as field length. Wischmeier et al., (1971) simplified the procedure for determination of soil erodibility factor by developing an equation based on soil parameters. A useful algebraic approximation of the nomograph that includes soil parameters such as texture, structure, organic matter and permeability is proposed by Wischmeier and Smith, (1978) and Renard et al., (1997) for estimation of soil erodibility factor K which is as follows,

K = $\frac{\{[2.1× 10-4 × M1.14 (12 -a) + 3.25 × (b-2) + 2.5× (c-3)] ×0.1317\}}{100}$ …(3.1)

Where,

K = Soil erodibility factor (t-ha-h/ha-MJ-mm),

M = (% silt + % very fine sand) × (100-% clay),

a = Organic matter content = Organic Carbon × 1.724,

b = Structural code of soil,

c = Permeability code of soil (determined from soil textural class).

The erodibility factor (K) is rated on scale from 0 to 1, with 0 indicating soils with least susceptibility while 1 indicating soils which are highly susceptible to soil erosion by water. In present study, the K factor was computed for watershed with the help of data obtained from soil analysis such as soil texture, soil structure, soil permeability and soil organic matter content. For determination of soil texture and organic carbon, soil sampling was done and 51 soil samples were collected from points shown in Figure 2 from the study area.



**Figure 2. Sampling points location map**

**2.2.1. Soil Texture Determination**

Soil texture is relative proportion of sand, silt and clay which are making the soil. It is an inherent property of soil. The methodology adopted for determination of soil texture is discussed in this section. Texture analysis of soil samples was carried out by International Pipette method (Robinson, 1927; Kilmer and Alexander, 1949). The procedure is as follows:

* 20 gram of air-dried soil sample passed from 2 mm sieve in 500 ml capacity beaker.
* 100 ml of water was added in that beaker and it was stirred for 5 minutes.
* After adding 10 ml of 30% H2O2, it was boiled for 20 minutes by continuously swirling the suspension to reduce foaming.
* On adding 40 ml of Calgon solution again, it was boiled for 5 minutes and after cooling.
* The suspension was transferred through 70 mesh (0.2 mm) sieve to separate coarse sand by 1 litre capacity bottle.
* Coarse sand was transferred from sieve into pre-weighted aluminium or steel dish, extra water was then poured out from dish
* The dish with coarse sand was kept in oven for more than 105°C and weighted it (CS).
* 300 to 400 ml of water was added into the suspension left in the bottle and it was shaked for one hour on rotary shaker.
* Next day (morning) again, the bottle was shaked for 30 minutes and that suspension was transferred into measuring cylinder of 1 lit. capacity and volume were made 1 lit. by adding water, then temperature was recorded.
* Plung the solution with the help of plunger for 1 minute and kept for sedimentation for the time corresponding to the temperature of solution as per Table 2.1.
* After proper time international pipette was slowly immersed vertically into cylinder exactly up to the depth of 10 cm with the help of mechanical stand and 20 ml of fluid was pipette out into pre-weighted container dish and it was kept in an oven for drying. After drying, weights were taken again. Which gave the weight of silt + clay + Calgon solution (W1).
* After the first pipetting is over, the cylinder was kept undisturbed. The temp was measured and the sediment inside was set for the required time corresponding to the temperature. For clay separation as the time of sedimentation is over 20 ml of fluid was pipette out for clay separate in preweighted container and it was kept in oven for oven drying (W2).
* Decant the supernant fluid after every 4 minutes 48 second till the supernant liquid is very clear. Transferred the fine sand in preweighted container dish, kept it in oven for drying and weighted it (FS).

**Calculation**

Oven dry weight of calgaon solution of 40 ml (f) = 0.048 g/ 40 ml

% coarse sand = $\frac{CS}{20 g}×100$ … (3.2)

Per cent clay = $\frac{W2-(f)}{20 ml}×\frac{1000 \left(Vol. Made\right)}{1}×\frac{100 (\%)}{20 g}$ … (3.3)

Per cent silt = $\frac{W1-W2}{20 mL}×\frac{1000 }{1}×\frac{100 (\%)}{20 g}100$ … (3.4)

 Per cent fine sand $=\frac{FS}{20 g}×100$ … (3.5)

**Table 1. Sedimentation times for soil particles settling through a depth of 10 cm in water (Particle density 2.6 Mg m-3)**

|  |  |
| --- | --- |
| **Temperature (°C)** | **Settling time with indicated particle diameter** |
| **20 microns (Silt + Clay)** | **2 microns (Clay)** |
| **Hour: Minute** | **Hour: Minute** |
| 20 | 4: 48 | 8:00 |
| 21 | 4: 41 | 7:49 |
| 22 | 4: 35 | 7:38 |
| 23 | 4: 28 | 7:27 |
| 24 | 4: 22 | 7:17 |
| 25 | 4: 16 | 7:07 |
| 26 | 4: 10 | 6:57 |
| 27 | 4: 04 | 6:48 |
| 28 | 4: 00 | 6:39 |
| 29 | 3: 55 | 6: 31 |
| 30 | 3: 49 | 6:22 |
| 31 | 3: 44 | 6:14 |

**2.2.2. Soil Organic Carbon**

The collected soil samples were then analysed to determine organic carbon in soil mechanics laboratory of SWCE department, Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri. Organic carbon was determined by wet oxidation method of Walkley and Black Carbon Method (Nelson and Sommers, 1996) as follows;

* 1 gram of each soil samples were weighed and put in conical flasks (Take 2-3 blank reading i.e., reading without soil samples).
* Add 10 ml potassium dichromate and 20 ml concentrated sulphuric acid was added to each of them and kept undisturbed for 30 minutes.
* 200 ml distilled water was then added to each of them.
* Before titration added 3-4 drops of ferroin indicator.
* Titrated the content against 1 N Ferrous sulphate solution till colour changes from brown-green-blue to finally red.
* The burette reading was recorded and calculate the organic carbon by given formula.

**Calculations**

Organic matter content was calculated from organic carbon of soil by

Organic carbon= $\frac{(Blank-sample) ×Normality× (0.003×100)}{Weight of soil sample}$ …(3.6)

Correction Factor was taken as 1.3

Subsequently organic matter was calculated from organic carbon by following formula:

Organic matter = $organic carbon × 1.724$ …(3.7)

**2.2.3. Soil Structural and Permeability Codes**

Soil structure and soil permeability depends upon texture of the soil. Soil structure is defined by the way individual particles of sand, silt and clay are assembled. Single particles when assembled appear as larger particles are called as aggregates. Aggregation of soil particles can occur in different patterns, resulting in different soil structures. The soil structure codes determined based on soil textural classification (Schut and Denholm, 1993) and is shown in Figure. 3.

The soil permeability depends upon soil texture, the permeability of a soil is a measure of the ability of soil to allow water to pass through it. The permeability codes were judged from permeability classes (Anonymous, 1983) obtained using SPAW model (Saxton and Rawals, 2006) (Figure 4), the soil permeability codes are given in Table 2.



**Figure 3. Soil structural code**



**Figure 4. User interface of SPAW model**

**Table 2. Soil permeability code from soil texture class (National Soil Handbook USDA, 1983)**

|  |  |
| --- | --- |
| **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 |

**2.2.4 Soil Erodibility Factor (K) Map**

Soil erodibility reflects the soil's inherent properties that affect the capacity of the soil to resist or be displaced by erosive forces. There are a number of elements that affect how easily soil erodes, which depends on several factors such as soil texture, organic matter content, structure and permeability. The calculated soil erodibility factor (K) values were assigned to respective soil sample locations in soil map. This soil map was converted in grid format and then K factor map was generated using Inverse Distance Weighted (IDW) technique of interpolation in ArcGIS environment (Figure 3.1).

**3. Results and Discussion**

From soil textural analysis, it was found that central MPKV campus watershed has two major soil types: sandy clay loam, clay loam. The soil permeability codes for collected soil samples were taken from soil texture class as per the National Soil Handbook USDA, 1983 (Table 2.2). Soil permeability indirectly affect soil erodibility, as soils with high permeability may allow water to infiltrate more easily, reducing the amount of runoff and erosion. Soils that have high permeability rates tend to be less erodible than soils with low permeability. The soil structural codes determined based on soil textural classification (Ontario Centre for Soil Resource evaluation, 1993) (Figure 5). These selected permeability and structural codes were used for soil erodibility estimation.

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**Figure 5. Soil erodibility factor (K) map of watershed**

Among the different soil found within the watershed, sandy clay loam soil type has the highest erodibility value and clay loam has the lowest erodibility value. Accordingly, K factor map of watershed was prepared using ArcGIS 10.3.1 environment using Inverse Distance Weighted (IDW) technique of interpolation (Figure 5). The generated maps of the soil erodibility factor (K) factor, shows the spatial variability within the watershed. The soil type, permeability code, structural code and soil erodibility were given in Table 3.

**Table 3. Textural analysis of soil for K factor estimation**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sample No** | **% Coarse Sand** | **% Clay** | **% Silt** | **% fine Sand** | **OC** | **Textural Class** | **Permeability Code (c)** | **Structural Code (b)** | **K-Factor** |
| 1 | 38.12 | 32.50 | 28.70 | 27.49 | 0.68 | Clay Loam | 4 | 4 | 0.0479 |
| 2 | 39.44 | 29.33 | 30.57 | 28.08 | 0.66 | Clay loam | 4 | 4 | 0.0518 |
| 3 | 34.89 | 36.46 | 27.91 | 24.84 | 0.74 | Clay loam | 4 | 4 | 0.0428 |
| 4 | 32.53 | 33.00 | 33.50 | 23.49 | 0.98 | Clay loam | 4 | 4 | 0.0464 |
| 5 | 36.98 | 35.05 | 27.72 | 26.33 | 0.26 | Clay Loam | 4 | 4 | 0.0470 |
| 6 | 47.82 | 30.55 | 21.18 | 34.05 | 0.45 | Sandy Clay Loam | 4 | 4 | 0.0497 |
| 7 | 40.30 | 35.40 | 23.40 | 28.69 | 0.90 | Clay loam | 4 | 4 | 0.0422 |
| 8 | 37.75 | 29.59 | 32.30 | 26.88 | 0.36 | Clay loam | 4 | 4 | 0.0540 |
| 9 | 51.21 | 28.78 | 19.45 | 36.46 | 0.57 | Sandy Clay Loam | 4 | 4 | 0.0506 |
| 10 | 45.01 | 32.61 | 21.67 | 32.05 | 0.72 | Sandy Clay Loam | 4 | 4 | 0.0458 |
| 11 | 23.60 | 34.75 | 41.20 | 16.60 | 0.45 | Clay Loam | 4 | 4 | 0.0489 |
| 12 | 34.56 | 35.68 | 29.25 | 24.61 | 0.51 | Clay Loam | 4 | 4 | 0.0452 |
| 13 | 38.56 | 28.45 | 32.24 | 27.45 | 0.75 | Clay Loam | 4 | 4 | 0.0526 |
| 14 | 27.57 | 32.20 | 39.38 | 19.63 | 0.86 | Clay Loam | 4 | 4 | 0.0490 |
| 15 | 53.83 | 24.56 | 21.09 | 38.32 | 0.53 | Sandy Clay Loam | 4 | 4 | 0.0565 |
| 16 | 47.53 | 27.13 | 24.59 | 33.84 | 0.75 | Sandy Clay Loam | 4 | 4 | 0.0525 |
| 17 | 25.40 | 38.86 | 35.10 | 18.09 | 0.65 | Clay Loam | 4 | 4 | 0.0422 |
| 18 | 41.99 | 25.57 | 31.65 | 29.90 | 0.78 | Loam | 3 | 2 | 0.0439 |
| 19 | 38.97 | 30.06 | 30.58 | 27.75 | 0.39 | Clay loam | 4 | 4 | 0.0528 |
| 20 | 18.51 | 40.75 | 40.25 | 13.15 | 0.50 | Silty Clay | 5 | 4 | 0.0453 |
| 21 | 21.30 | 37.94 | 40.33 | 15.16 | 0.44 | Clay Loam | 4 | 4 | 0.0454 |
| 22 | 46.12 | 28.51 | 24.45 | 32.83 | 0.93 | Sandy Clay Loam | 4 | 4 | 0.0496 |
| 23 | 37.87 | 35.21 | 26.38 | 26.96 | 0.54 | Clay Loam | 4 | 4 | 0.0450 |
| 24 | 27.77 | 37.07 | 34.29 | 19.77 | 0.87 | Clay Loam | 4 | 4 | 0.0427 |
| 25 | 38.97 | 36.78 | 23.43 | 27.75 | 0.83 | Clay Loam | 4 | 4 | 0.0396 |
| 26 | 35.40 | 37.59 | 26.51 | 25.20 | 0.51 | Clay Loam | 4 | 4 | 0.0426 |
| 27 | 38.89 | 33.88 | 26.31 | 27.69 | 0.93 | Clay Loam | 4 | 4 | 0.0441 |
| 28 | 28.85 | 36.21 | 34.52 | 20.54 | 0.42 | Clay Loam | 4 | 4 | 0.0462 |
| 29 | 29.56 | 22.15 | 47.53 | 21.05 | 0.77 | Loam | 3 | 2 | 0.0524 |
| 30 | 30.76 | 39.53 | 29.02 | 21.90 | 0.69 | Clay | 6 | 4 | 0.0468 |
| 31 | 41.41 | 32.94 | 25.32 | 29.49 | 0.33 | Clay Loam | 4 | 4 | 0.0485 |
| 32 | 24.28 | 36.73 | 38.44 | 17.28 | 0.56 | Clay Loam | 4 | 4 | 0.0456 |
| 33 | 38.70 | 31.57 | 29.31 | 27.55 | 0.42 | Clay Loam | 4 | 4 | 0.0505 |
| 34 | 21.31 | 33.80 | 44.20 | 15.23 | 0.69 | Clay Loam | 4 | 4 | 0.0493 |
| 35 | 20.74 | 38.95 | 39.64 | 14.77 | 0.66 | Clay Loam | 4 | 4 | 0.0429 |
| 36 | 18.49 | 43.25 | 37.75 | 13.23 | 0.51 | Clay | 6 | 4 | 0.0456 |
| 37 | 55.14 | 24.75 | 19.75 | 39.22 | 0.36 | Sandy Clay Loam | 4 | 4 | 0.0571 |
| 38 | 55.53 | 23.55 | 20.05 | 39.53 | 0.87 | Sandy Clay Loam | 4 | 4 | 0.0549 |
| 39 | 46.72 | 28.62 | 24.13 | 33.27 | 0.53 | Sandy Clay Loam | 4 | 4 | 0.0521 |
| 40 | 51.53 | 24.52 | 23.21 | 36.69 | 0.74 | Sandy Clay Loam | 4 | 4 | 0.0555 |
| 41 | 41.55 | 28.94 | 28.87 | 29.58 | 0.65 | Clay Loam | 4 | 4 | 0.0520 |
| 42 | 35.37 | 32.79 | 31.47 | 25.18 | 0.38 | Clay Loam | 4 | 4 | 0.0498 |
| 43 | 39.51 | 33.93 | 26.09 | 28.13 | 0.47 | Clay Loam | 4 | 4 | 0.0467 |
| 44 | 37.60 | 35.55 | 26.16 | 26.77 | 0.69 | Clay Loam | 4 | 4 | 0.0437 |
| 45 | 26.13 | 31.75 | 41.25 | 19.00 | 0.87 | Clay Loam | 4 | 4 | 0.0501 |
| 46 | 46.42 | 27.39 | 25.51 | 33.05 | 0.68 | Sandy Clay Loam | 4 | 4 | 0.0529 |
| 47 | 52.37 | 35.00 | 11.75 | 37.68 | 0.89 | Sandy Clay | 5 | 4 | 0.0440 |
| 48 | 38.91 | 33.33 | 27.45 | 27.70 | 0.32 | Clay Loam | 4 | 4 | 0.0486 |
| 49 | 36.66 | 32.88 | 29.72 | 26.10 | 0.75 | Clay Loam | 4 | 4 | 0.0470 |
| 50 | 27.41 | 39.45 | 32.44 | 19.52 | 0.69 | Clay | 6 | 4 | 0.0475 |
| 51 | 19.70 | 42.50 | 37.25 | 14.27 | 0.55 | Clay | 6 | 4 | 0.0462 |

The soil erodibility factor (K) of the study area shows that value of K ranges from 0.0396 to 0.0571 t-ha-h/ha-MJ-mm. The greater value of K indicates higher erodibility, and a lower value indicates low erodibility. The soil erodibility factor (K) map of watershed is shown in Figure 3.1. This analysis reveals that the in variation of soil erosion, the variability in K factor plays major role.

**4. Conclusions**

The Central MPKV Campus Watershed is located in Rahuri taluka in Ahmednagar district of Maharashtra state, India. The total geographical area of the watershed is 13.83 km2 (1383 ha). The area is in semi-arid sub-tropical zone, with an average annual rainfall of 592 mm. The soil erodibility factor was calculated by analysing the collected soil samples from the watershed. The soil textural analysis was done by using the international pipette method. It was found that the major soil type of area is clay loam and sandy clay loam. Organic carbon content was calculated using Walkley black carbon method. It was found that the soil erodibility factor values vary from 0.0396 to 0.0571 t-ha-h/ha-MJ-mm. This method of estimating soil erodibility factor K can also be used for other watersheds. The spatial map of the soil erodibility factor shows the location wise variation in the K factor values. The spatial maps helpful for the planning and management of soil conservation measures.

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