Research Article

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Quantify distribution of topsoil erodibility factor for watersheds that feed the Al-Shewicha trough – Iraq using GIS

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Abstract: Soil functions such as water storage, soil filtration, and reducing reservoir life due to sediment load are directly affected by the process of "soil erosion." The Universal Soil Loss Equation was adopted to predict the erodibility factor for watersheds feeding the Al-Shewicha trough. The *K*-average factor's determined value was 0.156, indicating that the *K*-factor had substantial variability. The *K*-factor for erodibility values was linked to the high sand content in the topsoil of the study area because of the high sand content of the topsoil. The topsoil is coarse-textured and then permeable. ArcGIS (geographic information system) was used to obtain the distribution of soil types as well as the erodibility factor distribution.

Keywords: erodibility, factor, watershed, Al-Shewicha, trough

1 Introduction

Erosion of the topsoil layer has adverse effects. The loss of soil loss in the catchment is of great importance, being a significant threat to physical resources. Soil erosion poses threats to other soil functions such as water storage, soil filtration and transformation, and agricultural productivity [1,2]. Also, the negative impact of soil erodibility is to increase the sedimentary load of floodwater, which causes the reservoir's life to be reduced and retrogression of downstream water quality [3–5]. Based on the preceding, the need arose to focus land management on controlling the soil loss of watersheds by preventing unscientific deforestation and agricultural practices. The soil's natural susceptibility to being detached and translocated by erosion processes like splash erosion, surface runoff, or both is regarded as resistivity of the soil to rainfall and runoff erosivity. It is also known as the *K*-factor (soil erodibility factor) [6–8]. Because a wide range of physical factors influence soil erosion susceptibility, chemical and mechanical soil qualities, and hydrological processes, the idea of how to quantify the *K*-factor of such parameters is challenging [6,9–11]. Due to the importance of the topic, many researchers have studied soil erosion. Much previous research has addressed using a rainfall simulator to explain the relationship between precipitation and soil erosion [12–14]. This research aimed to determine erodible soil constant for watersheds feeding the Al-Shewicha trough (Figure 1) as a preliminary step to study sediment discharge of these watersheds.

2 Study area

The study area site is located between "509374 E and 659374 E, and between 3603825 N and 3803825 N." The area is described as plain land, mountains, and hilly regions. The Al-Shewicha trough is a flat area having a minimum elevation of +10.0 m from m.s.l. Six basins flow into the Al-Shewicha trough, as shown in Figures 2 and 3 [Shamkhi et al. [15]]. The drainage basins had varying topographic relief. In the Al-Shewicha marsh, the mean elevation of all watersheds ranges from 1,837 to 10 m. The basin's area is equal to 13,290 km^2. These watersheds are shared between Iraq and Iran's Islamic Republic, which is considered a humid area for the winter season (Figure 2).

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Figure 1: Seasonal collected water in the Al-Shewicha trough after sitting of sediment load, Wasit Province, Iraq.

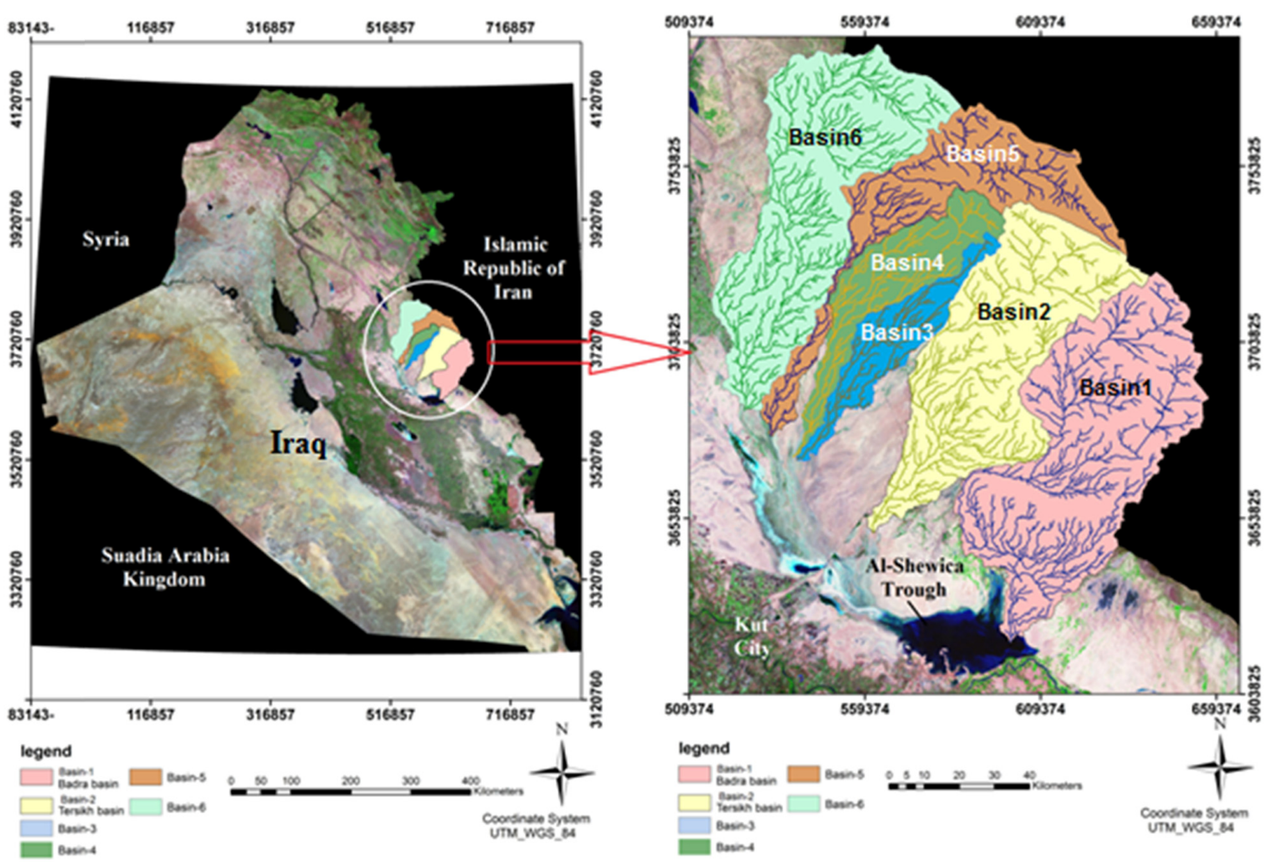

Figure 2: Location map of the study area with stream networks [15].

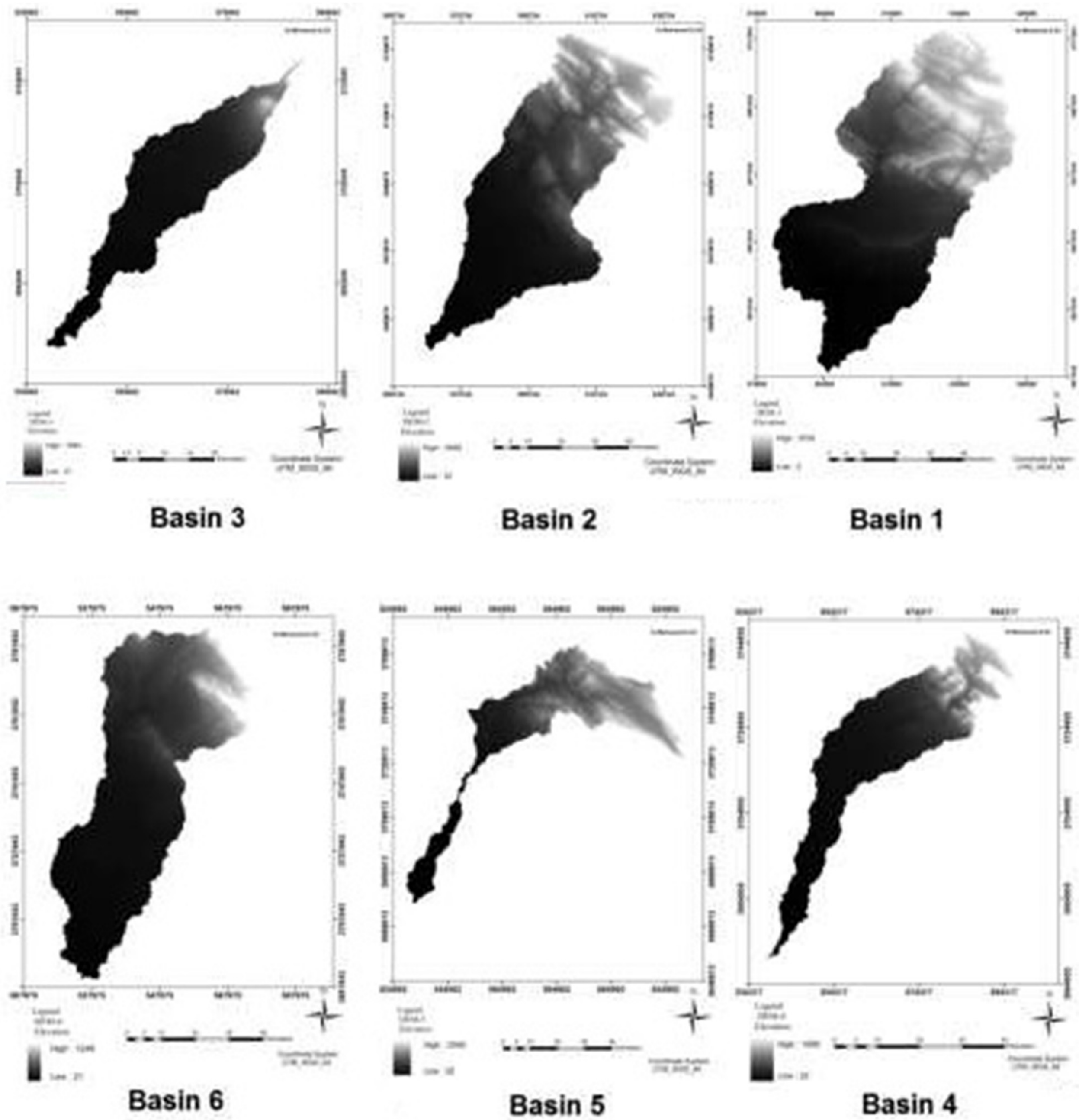

Figure 3: The six basins flow into the Al-Shewicha trough [15].

The research area's average annual rainfall was calculated to be around "325 and 233 mm, respectively; these basins "are categorized as semi-rainfall zones. The maximum annual runoff for basins 1 and 2 were 330.5 and 271.2 mm, respectively, as shown in Figures 4 and 5 [16].

3 Methods and data

3.1 Data sources

The elevation model in digital form of the research area from the Shuttle Radar Topographic Mission was used in

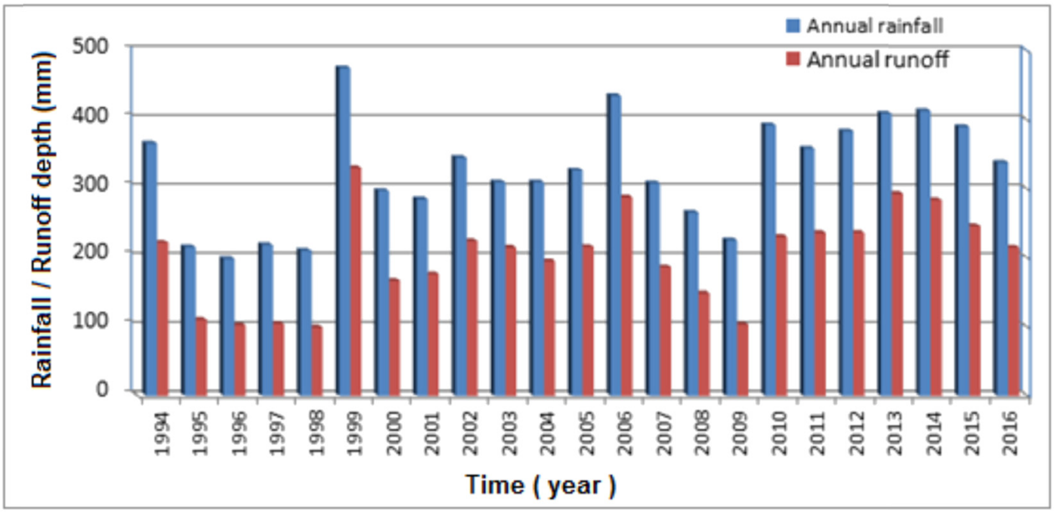

Figure 4: Annual runoff of basin 1 [16].

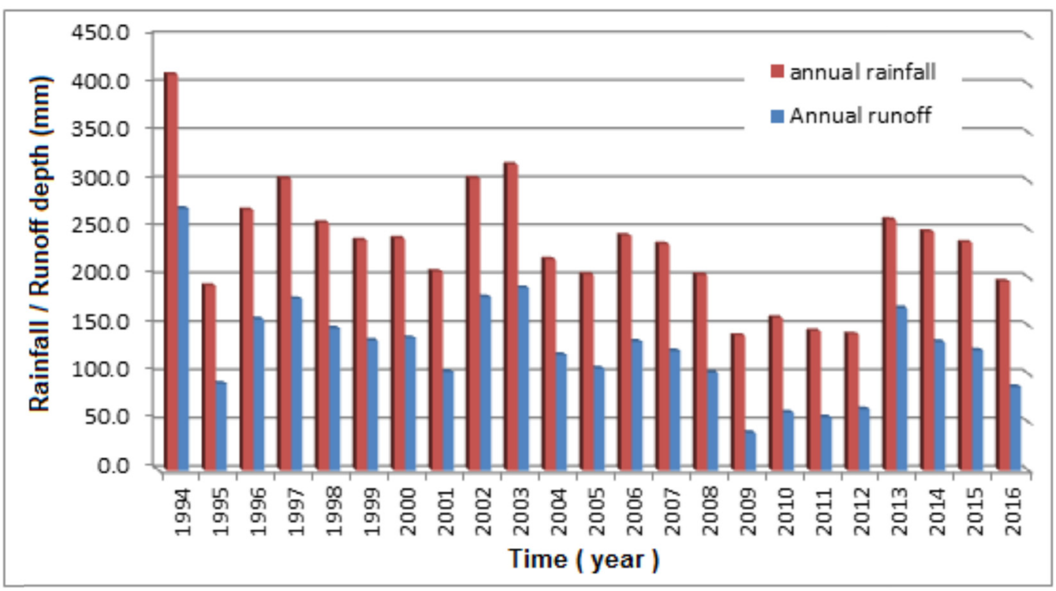

Figure 5: Annual runoff of basin 2 [16].

this work, with a horizontal spatial resolution of 30 m. It is a raster representation of the elevation of the surface topography in *XYZ* directions. The image was re-projected in a regional format (WGS 1984 UTM Zone 38). The Food and Agriculture Organization (FAO) global soil map of the world was used to classify the soils. The national land cover database 2011 was used to differentiate the land cover of watersheds.

3.2 Soil erodibility factor (*K*)

Soil erodibility expresses the resistance of soil to both detachment and transport. The "Universal Soil Loss Equation" (USLE) is an empirical equation to predict the longtime erosion of average yearly soil loss due to runoff.

$$A = R.\ K.\ LS.\ C.\ P. \tag{1}$$

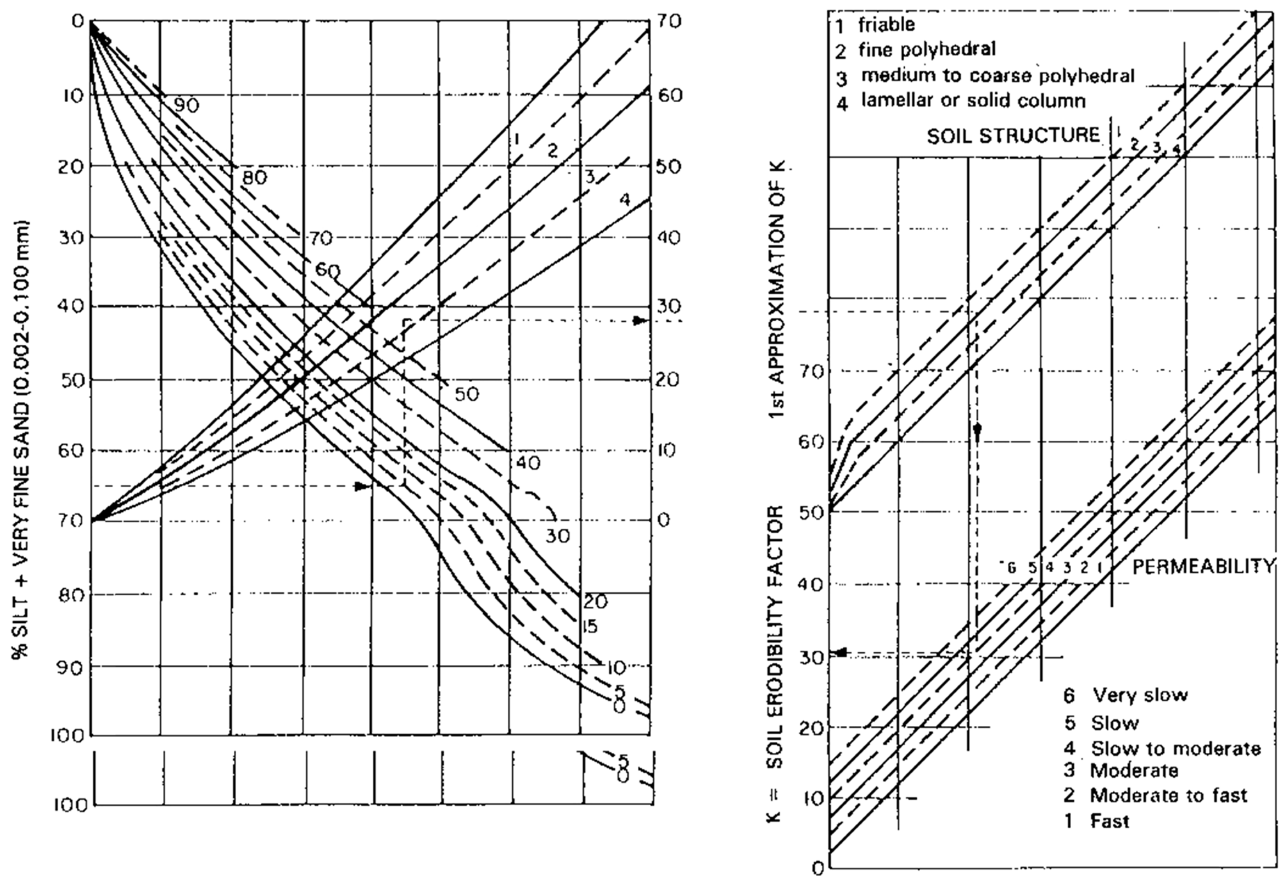

Figure 6: The monograph to extract soil erodibility factor [21].

Where A is the estimated rate of soil erosion loss per year, *R* is the rainfall-runoff erosivity factor, *K* is the soil erodibility factor, *LS* is length of the slope and the steepness factor, *C* vegetation cover and *P* support practice factor [17]. The factor of erodibility of the soil (*K*) is the criterion of soil susceptibility to runoff erosion [18]. The *K*-factor is dependent on many soil properties such as soil texture, permeability, and organic matter content, which reverberate the soil impedance to erosion [10]. It is extracted depending on the soil properties using the universal equation for soil loss USLE monograph, which was notified by Wischmeier and Smith in 1978 [17], then amended by ref. [19] and [20]. The monograph shown in Figure 6 includes the percentages of silts, very fine sand, sand, organic materials, soil structure, and permeability.

The silt percentage content in topsoil is the most influential factor in predicting soil erodibility due to high runoff. There is an inverse relation between clay percentage content in topsoil. The erodibility factor of the soil ranged from 0.05 to 0.2. The erodibility factor of the clay soil is ranged from 0.05 to 0.2. In general, the soil's erodibility factor ranges from 0.02 to 0.69 [5,6,21,22].

The *K*-factor can be predicted in the SI unit using equation (1).

$$K = f_{\text{csand}} \times f_{\text{cl}-\text{si}} \times f_{\text{orgc}} \times f_{\text{hisand}}, \tag{2}$$

Table 1: The percentage of various types of study area topsoil

Symbols	Sand % topsoil	Silt% topsoil	Clay % topsoil	OC % topsoil
I	58.7	16.13	24.2	0.97
Jc	39.35	39.54	20.46	0.65
Rc	63.5	18.44	17.3	0.76
Xk	48.7	29.06	21.6	0.64
Yk	63.5	17.54	18.7	0.26
Yy	49	10.57	40.3	0.13
Zo	43.2	24	32.4	0.4

where K is the USLE soil erodibility factor.

$$f_{\text{csand}} = \left[0.2 + 0.3 \times \exp\left(-0.256 \times m_s \times \left(1 - \frac{m_{\text{silt}}}{100}\right)\right)\right], \tag{3}$$

$$f_{\text{cl-si}} = \left(\frac{m_{\text{silt}}}{m_c \div +m_{\text{silt}}}\right)^{0.3}, \tag{4}$$

$$f_{\text{orgc}} = \left(1 - \frac{0.25 \times \text{orgC}}{\text{orgC} + \exp\left[3.75 - 2.95 \times \text{orgC}\right]}\right), \tag{5}$$

$$f_{\text{hisand}} = \left(1 - \frac{0.7 \times \left(1 - \frac{m_s}{100}\right)}{\left(1 - \frac{m_s}{100}\right) + \exp\left[-5.51 + 22.9 \times \left(1 - \frac{m_s}{100}\right)\right]}\right), \tag{6}$$

where m_s is the percentage of sand content in topsoil; m_{silt} is the percentage of silt content in topsoil; m_c is the percentage of clay content in topsoil; and orgC is the percentage of organic content in topsoil.

4 Results and analysis

Soil erodibility is the sign of the ingrained resistance of soil particles to the segregating and transporting power of rainfall. The sand, silt, clay, and organic matter percentages data for the watershed were obtained depending on United Nations-FAO (UN-FAO, 2007) data to classify the topsoil type of study area utilizing ArcGIS (geographic information system) 10.2 software, as demonstrated in Table 1 and Figures 7–10.

Erodibility K-factor for the topsoil of the study was calculated using equations (2)–(6), as presented in Table 2. Table 3 shows the percentage area of each type of topsoil. The resulting data from Table 2 in addition to data from Table 3 were utilized to produce a spatial distribution map of erodibility K-factor as demonstrated in Figure 11

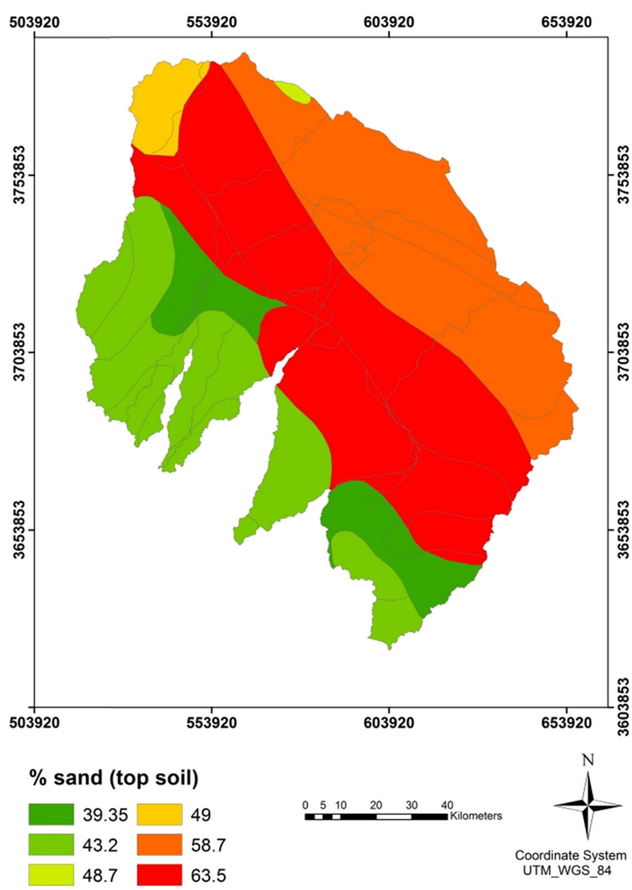

Figure 7: Sand percentage distribution of study area topsoil.

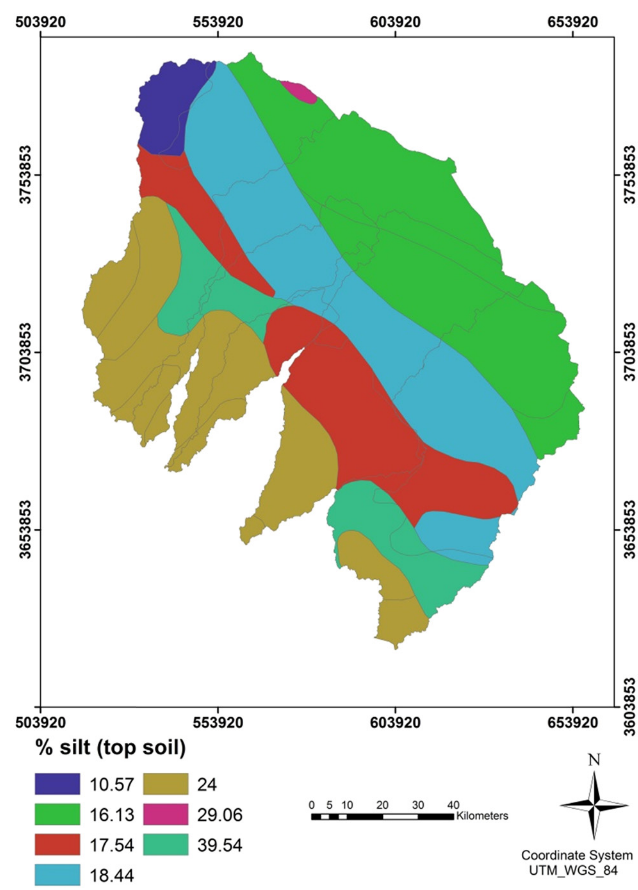

Figure 8: Silt percentage distribution of study area topsoil.

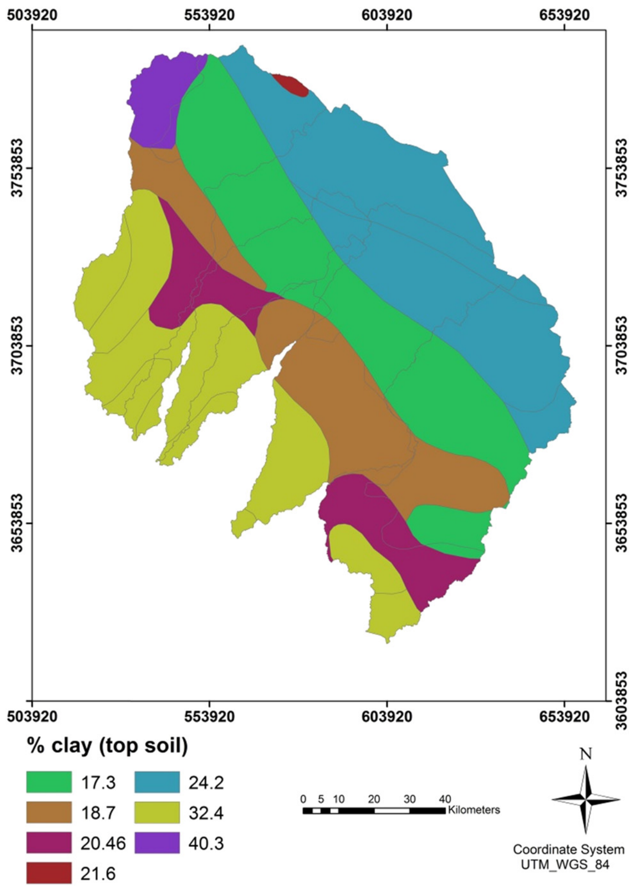

Figure 9: Clay percentage distribution of study area topsoil.

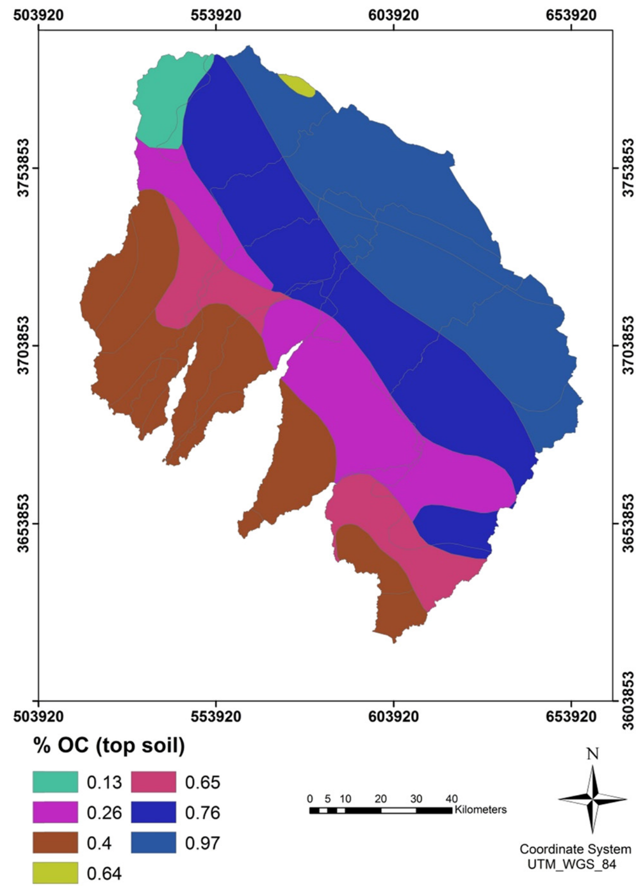

Figure 10: Organic matter content percentage distribution of study area topsoil.

Table 2: Calculation of erodibility factor for case study topsoil

Symbols	Sand % topsoil	Silt % topsoil	Clay % topsoil	Organic matter % topsoil	F_{CSand}	f_{ci-si}	f_{orge}	f_{hisand}	*K*-factor
I	58.7	16.13	24.2	0.97	0.2	0.76	0.993	0.994	0.15
Jc	39.35	39.54	20.46	0.65	0.201	0.882	0.996	1.00	0.177
Rc	63.5	18.44	17.3	0.76	0.20	0.82	0.996	0.986	0.161
Xk	48.7	29.06	21.6	0.64	0.203	0.846	0.998	1.00	0.169
Yk	63.5	17.54	18.7	0.26	0.2	0.804	1.00	0.986	0.1585
Yy	49	10.57	40.3	0.13	0.20	0.624	1.00	1.00	0.127
Zo	43.2	24	32.4	0.4	0.20	0.774	1.00	1.00	0.155

for the study area using ArcGIS. The *K*-factor varied from 0.125 to 0.177, with an average of 0.156. The erodibility *K*-factor values are reasonable, reflecting the high percentage of sand in the topsoil of the study area. So, the topsoil is coarse-textured and then permeable. The results coincided with [15].

Table 3: Percntage area of each type of topsoil

Soil unit symbol	Area (km^2)	% of area
I	3607.8	27.15
Jc	1,138	8.56
Rc	3,175	23.89
Wr	14	0.11
Xk	33.8	0.25
Yk	2118.7	15.94
Yy	372.7	2.80
Zo	2,830	21.29

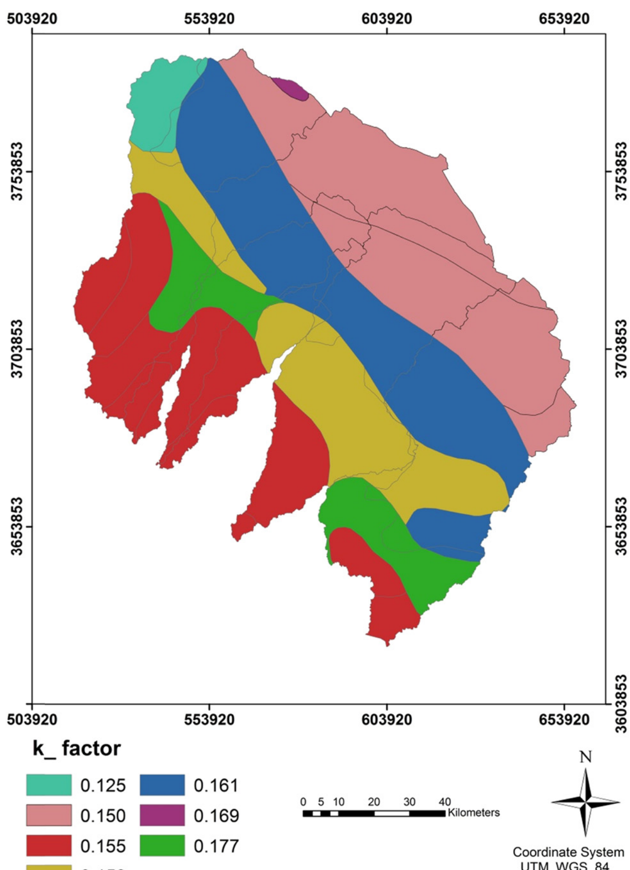

Figure 11: Erodibility *K*-factor distribution of study area.

5 Conclusion

Calculating the *K*-factor is crucial. The *K*-spatial factor's distribution for six watersheds supplying the Al-Shewicha trough was successfully estimated in this study. The *K*-factor had an average computed value of 0.156, indicating that the *K*-factor had substantial variability. The high percentage of sand in the topsoil of the study area is reflected in the erodibility *K*-factor readings.

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