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Estimation of soil erodibility (K) using GIS: A case study of Sukhna Lake watershed in lower Shiwalik, India

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Abstract
Soil is considered as one of the world's limited, non-renewable resource. Under cropland conditions, it takes between 200 to 1000 years for 2.5cm of top soil to form. Soil is one of the most important natural resources of each country. One of the main and effective parameters in soil erosion is the natural characteristics of the soil which is erodibility. Erodibility is the part and parcel of soil erosion. The objective of this study was to estimate the soil erodibility (K) factor of thirty four soil sample of Sukhna Lake catchment using Geographic Information. The study was carried out through particle size distribution with pipette method and GIS approach using SOI topographical sheets No. H43K13, H43K14 of 2009 scale of 1:50,000 and by using ArcGIS 9.3 software. Soil erodibility (K) factor varies from <0.35 to > 0.65. The area under severe erosion zone were 2023.35 ha, only 54.07 ha and 214.54 ha falls under very low and low erosion zones. Maximum area of erodibility falls under high erosion zone in which 2023.35 ha were estimated. Similarly 1139.81 ha fall under moderate erosion. The analysis shows that catchment is very prone to the soil erosion with an appropriate soil conservation measures, soil erosion may reduce and also provide positive result to the Sukhna Lake. Remote sensing and GIS data is very useful for estimating the soil erosion more easily and accurately within short time duration.

Keywords: Soil erodibility (K), GIS, Sukhna Lake

Introduction

Soil is considered as one of the world's limited, non-renewable resource under cropland conditions, it takes between 200 to 1000 years for 2.5cm of topsoil to form (Piementel *et al.*, 1995) [9]. Soil is one of the most important natural resources of each country. One of the main and effective parameters in soil erosion is the natural characteristics of the soil which is erodibility. Erodibility is the part and parcel of soil erosion (Fotouhi *et al.*, 2012) [4]. Soil erosion is a complex dynamic process by which productive surface soils are detached, transported and accumulated in distant place resulting in exposure of subsurface soil and siltation in reservoirs or in natural streams. Soil Erosion by water is being increasingly recognized as a problem, all over the world. About 85% of land degradation in the world is associated with soil erosion, it not only potential threat to agricultural productivity which causing a 17% reduction in crop productivity (Oldeman *et al.*, 1991) [7] but also because of the importance of its offsite effect through pollution and sedimentation.

Soil erodibility is one of the factors affecting erosion, which can be considered as a physical measure to assess the degree of soils vulnerability to erosion (Chikhaoui *et al.*, 2005) [2]. In the universal soil loss equation (USLE) and its revised version (Renard *et al.*, 1991) [10], the factor K expresses soil susceptibility to the processes of sheet and rill erosion. The inherent properties of soil play a major role in the ability of water to detach and transport its particles. The K collects the majority of soil properties and for that reason, it has been one of the most common methods applied to evaluate erosion risks (Pérez-Rodríguez *et al.*, 2007) [8]. The evaluation of K may be difficult because it requires data collected over the long-term (Moebius-Clune *et al.*, 2011) [5]. However, this work is essential for making effective management decisions for agricultural lands. The important of this study is to estimate the soil erodibility factor for the Sukhna catchment. The catchment symbolize one of the most fragile ecosystems and have been identified as one of the eight most degraded rain-fed agro systems of the country. Natural vegetation consists of trees, shrubs, climber and grasses (Yadav *et al.* 2006) [12]. Limited studies as well as data are available for this catchment. The primary purpose of the present study is to evaluate the factor of soil erodibility using GIS in the Sukhna catchment which is very important factor to evaluate potential soil erosion risk for further studies. As Erodibility factor (K) is a key factor in some of the erosion and sediment models such as MUSLE, RUSLE and USLE is a function of grain size distribution, organic matter, structure, and infiltration.

Material and Method

In the present study estimation of soil erodibility (K) was done using GIS techniques. The delineation of Sukhna Lake watershed was done from SOI topographical sheets no. H43K13, H43K14 of 2009 scale of 1:50,000 and by using ArcGIS 9.3 software. To determine K factor thirty four soil sample were collected from different part of Sukhna lake catchment and dried for two- three days after that determination of particle size distribution were done. Particle size distribution is a fundamental property of soil. It is properties on which other soil properties viz., structure water retention hydraulic conductivity, porosity consistence etc. According to size of the particles there are three major size groups namely sand silt and clay. These groups are called soil separates and can be further subdivided into smaller size classes. The International Society of Soil Science (ISSS) has grouped the soil particles into Size classes.

Table 1: International society of soil science (ISSS) soil particles into size classes.

S. No.	Soil fraction	Diameter of the particles (mm)
1	Coarse sand	0.2 to 2.0
2.	Fine sand	0.02 to 0.2
3.	Silt	0.002 to 0.02
4.	Clay	<0.002

Based on this proportion of sand silt and clay particles a soil is given a textural name viz loamy sand, sandy loam and clay loam, etc. The analysis procedure which the relative proportion of each above four fractions in a soil sample were determined to know the particle size distribution.

For this studies pipette method was used for particle size analyses and determined different K factor at different places of catchment and also generated K factor map. To determine the K factor Triangular classification of USDA and ISSS were used to determine texture of soil from relative proportion of sand, silt and clay content. The value of texture was used in Wishmeir *et al*. (1971) [11] nonograph to find the value K factor. For this catchment different K values were determined which was mention below and similarly on the bases of K factor map were generated through GIS which were also given below.

General description of Study Area

The study area covered three states – The union territory of Chandigarh, in some parts of Punjab and Haryana. The catchment area of 42.843 sq. Km is drained by two seasonal rivulets i.e. Kansal and Nepli which originate in Haryana and are fed by number of rivulets to Sukhna Lake located in Chandigarh. It lies in between latitude 30^0 45’0” N to 30^0 49’0”N and longitude 76^0 49’0” E to 76^{0}53’0”E.

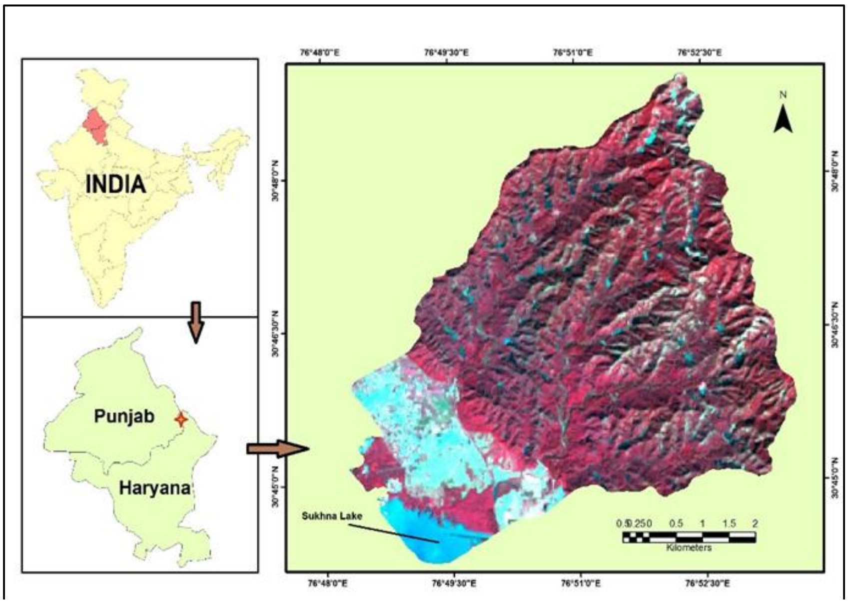

Fig 1: Location of study area

The study area has a humid subtropical climate. There are four distinct season viz., Summer or hot season (mid-March to Mid-June), Rainy season (late-June to mid-September), Post monsoon autumn/transition season (mid-September to mid-November) and Winter (mid November to mid-March). May and June are the hottest months of the year with the mean daily maximum & minimum temperatures being about 37^{0}C & 25^{0}C respectively. Maximum temperatures can rise up to 44^{0}C. The variation in annual rainfall on year to year basis is noticeable i.e. 700 mm to 1200 mm, winds are generally light and blow from northwest to southeast direction with exception of easterly to southeasterly winds that blow on some days during the summer season. The catchment areas are highly variable within short distance. Murthy and Shankaranarayana (1977) [6] mapped the soils and Grewal and Juneja (1984) [3] characterizes the soil of this catchment as erosive in behavior.

Result and Discussion

On the bases of soil texture a soil erodibility (K) were estimated and also estimated percent of organic carbon, organic matter present according to soil texture in the catchment. The catchment was mainly sandy characterized by weak structure and granular type (Table 1). The weak structure (granular) as evidenced by the relatively low organic matter (0.20% for sand and 0.52% for loam soil, in more detail Table 3) makes the soil susceptible to erosion in eroded areas. The chances of more soil erosion were on junctions such as Kansal + Kantwal+ Barotawal junction, Kansal Barotawala (outerside), Kansal top were maximum soil susceptibility chance because of sand, sandy loam sand soil texture. This was supported by Ball (1990) [1] who reported an increase of erosion with decreasing organic matter.

On the other hand, soil samples in the non-eroded area have more clay (0.51%) and are less susceptible to erosion. Nathewala Tutawala top zone (away from choe), Gaheri Middle zone Nepali top zone(Mundanwala dam) were soil susceptibility chance are less because of binding nature of clay, loam as well as higher organic matter then junction area shown in Table 2. In first categories i.e. <0.35 were very less in area wise shown in blue color which were less susceptible or we can say that very low erosion region and > 0.65 were severe erosion region which were highly susceptible to erode near junction shown as red colors. Low erosion were falls under very small part of catchment in light blue colors. Moderate (0.45-0. 55) and high erosion (0.55-0.65) were major in this catchment area which were represented in light green and yellow color shown in Fig.2.

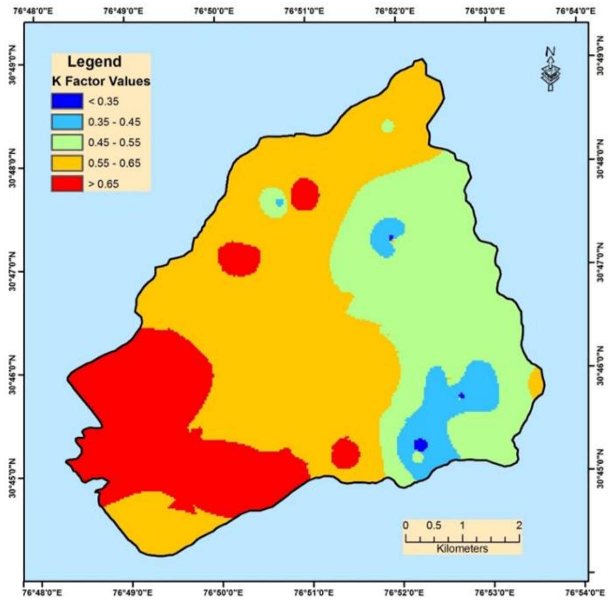

Fig 2: K factor map

Table 2: Soil texture and Soil erodibility factor (K)

	Elevation	Texture	K factor
Gaheri lower zone (near choe)	373”	LS	0.65
Gaheri (near road	374”	LS	0.68
Gaheri middle zone (near road)	394”	SL	0.52
Gaheri middle zone	394”	L	0.25
Gaheri Top Zone (Bara Pathran wala)	412”	SL	0.55
Gaheri End point(Near road)	441”	SL	0.46
Gaheri Top Zone (outside)	444”	SLS	0.49
Nepali lower zone (choe)	368”	SL	0.6
Nepali lower zone (near road)	368”	SLS	0.69
Nepali middle zone (Laatwala choe)	385”	SLS	0.61
Nepali middle zone (outer side)	386”	SLS	0.59
Nepali middle zone (near road)	388”	SLS	0.64
Nepali Rest House (main choe)	411”	SL	0.45
Nepali top zone (Mundan wala dam near road)	420”	SL	0.58
Nepali Top Zone (Mundan wala dam)	418”	SCL	0.35
Nepali Top	446”	L	0.19
Nathewala Tutawala Top Zone dam	432”	SLS	0.67
Nathewala Tutawala top zone (away from choe)	434”	CL	0.25
Nathewala Tuta wala Top Zone (Outer side road)	438”	SL	0.4
Nathewala Middle Zone (outer side near well)	392”	SL	0.56
Nathewala middle zone (Jhuggian wal main choe)	393”	LS	0.57
Nathewala Tarkhan wala choe bottom zone	377”	LS	0.59
Nathewala Tarkhan wala choe bottom zone (out side)	377”	LS	0.55
Nathewala Nepali Junction	366”	SLS	0.56
Nepali Gaheri Junction (Main gate)	351”	S	0.7
Kansal 3 dam Top zone (main choe)	451”	SCL	0.49
Kansal 3 dam top zone (outside)	442”	LS	0.6
Kansal 4 dam top zone(main choe)	442”	LS	0.61
Kansal Barotawala(outside)	405”	SLS	0.72
Kansal logae middle zone (main choe near guest house)	408”	SLS	0.69
Kansal logae middle Zone (outside near old Kua)	413”	SL	0.42
Barota wala bottom (out side)	401”	LS	0.61
Kansal Top	397”	SLS	0.71
Kansal Middle bit	380”	SLS	0.59
Kansal + Kantwal+ Barota wala Junction	366”	S	0.72
Kansal Nepali Junction	343”	SCL	0.69
Kansal Nepali Junction (outside)	346”	SLS	0.59

Table 3: Percent of organic Carbon, Organic matter and K factor

S. No	Texture	Organic Carbon (%)	Organic Matter (%)	K factor
1.	Loamy sand	0.345	0.59478	0.65
2.	Loamy Sand	0.225	0.3879	0.68
3.	Sandy Loam	2.415	4.16346	0.52
4.	Loam	0.3	0.5172	0.25
5.	Sandy Loam	0.54	0.93096	0.55
6.	Sandy Loam	0.33	0.56892	0.46
7.	Sandy Loam sand	0.225	0.3879	0.49
8.	Sandy loam	0.75	1.293	0.6
9.	Sandy loam sand	0.42	0.72408	0.69
10.	Sandy loam sand	0.45	0.7758	0.61
11.	Sandy loam sand	0.345	0.59478	0.59
12.	Sandy loam sand	0.45	0.7758	0.64
13.	Sandy loam	0.45	0.7758	0.45
14.	Sandy loam	0.225	0.3879	0.58
15.	Sandy clay loam	0.225	0.43962	0.35
16.	Loam	0.45	0.7758	0.19
17.	Sand loamy sand	0.18	0.31032	0.67
18.	Clay loam	0.69	1.18956	0.25
19.	Sandy loam	0.675	1.1637	0.4
20.	Sandy loam	0.615	1.06026	0.56
21.	Loamy sand	1.005	1.73262	0.57
22.	Loamy sand	0.3	0.5172	0.59
23.	Loamy sand	0.57	0.98268	0.55
24.	Sandy loamy sand	0.54	0.93096	0.56
25.	sand	0.42	0.72408	0.7
26.	Sandy clay loam	0.27	0.46548	0.49
27.	loamy sand	0.42	0.72408	0.6
28.	Loamy sand	0.195	0.33618	0.61
29.	Sandy loamy sand	0.18	0.31032	0.72
30.	Sandy loamy sand	0.15	0.2586	0.69
31.	Sandy loam	0.78	1.34472	0.42
32.	Loamy sand	0.3	0.5172	0.61
33.	Sandy loamy sand	0.345	0.59478	0.71
34.	Sandy loamy sand	0.18	0.31032	0.59
35.	Sand	0.12	0.20688	0.72
36.	Sandy clay loam	0.525	0.9051	0.69
37.	Sandy loamy sand	0.24	0.41376	0.59

Table 4: On the bases of soil texture a map of K factor were generated in which percent of area under each categories were also divided into 5 part shown below in Table 4.

S. No.	Erodibility (K) factor	Area in (ha)	% of area	Weighted Area	Categories
1	<0.35	54.07	1.26	0.189	Very low erosion
2.	0.35-0.45	214.54	5.00	0.86	Low erosion
3.	0.45-0.55	1139.81	26.74	5.69	Moderate erosion
4.	0.55-0.65	2023.35	47.47	12.14	High erosion
5.	> 0.65	878.70	20.61	5.71	Severe erosion

Conclusion

The objective of this study was to estimate the soil erodibility (K) factor of thirty four soil sample of Sukhna Lake catchment using Geographic Information. Soil erodibility (k) factor varies from <0.35 to >0.65. The area under severe erosion zone were 2023.35 ha. Only 54.07 ha and 214.54 ha falls under very low erosion zone and low erosion zone. Maximum area of erodibility falls under high erosion zone in which 2023.35 ha were estimated. Similarly 1139.81 ha fall under moderate erosion shown in Table 5.The analysis shows that catchment is very prone to the soil erosion. Byusing an appropriate soil and water conservation techniques may reduce soil erosion and also provide positive result to the Sukhna Lake. The estimation of soil erodibility factorusing Geographic Information System tools retrieved to analysis the potential erodibility influenced by inherent soil properties, climate, land use /land cover and management practices easily and accurately in short time duration.

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