Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2019; 8(5): 1413-1419
Received: 15-07-2019
Accepted: 19-08-2019

SS Shinde
Assistant Professor, Agricultural Engineering Section, College of Agriculture, Pune, Maharashtra, India

SB Nandgude
Professor and Head, Department of Soil and Water Conservation Engineering, MPKV, Rahuri, Maharashtra, India

MS Mane
Head Interfaculty, Department of Irrigation Water Management, PGI, MPKV, Rahuri, Maharashtra, India

SS Salunkhe
Research Associate, Agricultural Development Trust, Baramati, Pune, Maharashtra, India

Corresponding Author:
SS Shinde
Assistant Professor, Agricultural Engineering Section, College of Agriculture, Pune, Maharashtra, India

Determining and Mapping of Soil erodibility factor of Urmodi Basin of Krishna River using geographical information system

SS Shinde, Dr. Sachin Nandgude, Dr. Mahanand Mane, Dr. Sanjani Salunkhe

Abstract
Soil erosion is major contributing to land degradation and impairing environmental quality. The texture of soil was largely clay (50.16%), clay loam (24.53%), sandy clay loam (17.66%), sandy clay (5.83%), and loam (1.79%). Structural classes for the soils of Urmodi basin were fine granular and very fine granular. Estimated organic matter content of soil was ranging between 0.66 to 2.96% with the mean 1.33%. The permeability of soils in Urmodi basin was ranging from 0.5 to 20 mm/hr. So the majority of soil comes under slow to moderate, slow and very slow permeability class having the permeability code 4, 5 and 6. Percent sand, percent silt and percent clay of the district varies between 27.86 to 61.83, 11.25 to 31.67 and 14 to 56%, respectively with average 43.94, 19.23 and 36.83%, respectively. Soil erodibility factor for different villages of Urmodi basin was found in the range of 0.11 to 0.24. Soil erodibility analysis is useful for prediction of soil erosion from Urmodi of krishna river. The studies are required for effective development, utilization and management of the land and water resources in an integrated and comprehensive manner.

Keywords: Organic matter, permeability, soil erodibility, soil structure, texture, GIS

Introduction
The total geographical area of India is 329 million hectares, from which about 174 million hectare (53 percent) is affected by serious problems such as water erosion, wind erosion, water logging and salinity. According to an estimate about 5334 m tonne (16.4 tons/ha) soil is lost annually due to agriculture and associated activities (Narayana and Babu, 1981) [4]. Apart from detached soil, which is about 2052 m tonne (6.25 tons/ha) per year and about 480 m tonne silt, is transported by rivers and deposited in reservoirs. Soil erosion is a process of detachment and transportation of soil materials from its original place by the action of various erosive forces. Soil erodibility is different from soil erosion in a sense that the total erosion may be influenced by other factors like rainfall-climate, crops, management of the land etc. Some soils erode more readily than others even when all other factors are same. Vulnerability of the soils to get eroded is referred as erodibility of soils. It is the function of both the physical characteristics of soils and the land management practices. However, effects of physical properties can be evaluated more precisely compared to the effects of the management practices.

Organic constituents of the soil are important because of their influence on aggregate stability. By virtue of its binding action, OM helps stabilize loose soils against erosion. Soils with less than 3.5% organic content can be considered erodible. Most soils contain less than 15% organic content and many of the sands and sandy loam have less than 2%. Whereas soil detachment by raindrop impact decreased exponentially with increasing organic content over a zero to 12% range. However, these relationships cannot be extrapolated. Some soils with very high OM particularly peats, are highly erodible by water and wind whereas others with very low OM can become very hard and therefore stronger under dry conditions.

SPAW model estimates the hydraulic conductivity as a function of sand, silt, clay and organic matter. Permeability of study area was judged from the hydraulic conductivity calculated using SPAW model. Soil erodibility factor was calculated using Wischmeier and Smith (1978) [9] formula. Our objective was to estimate soil erodibility factor of Urmodi basin which is useful for prediction of soil loss.

Materials and Methods
Study Area
The study area lies between 17°30' N to 17°45' N latitude and 73°45' E to 74°00' E longitude. The total valley area covered by Urmodi basin is 43,719 ha. Mean annual rainfall in the basin is of the order of 1250-1800 mm and about 80% of rain precipitates during the summer monsoon (June to September). Urmodi basin is having an undulating topography with slope ranging between 4 to 33%. The major crops taken in study area are paddy, wheat, sugarcane, soyabean and jowar. Location map of the study area is shown in fig.1

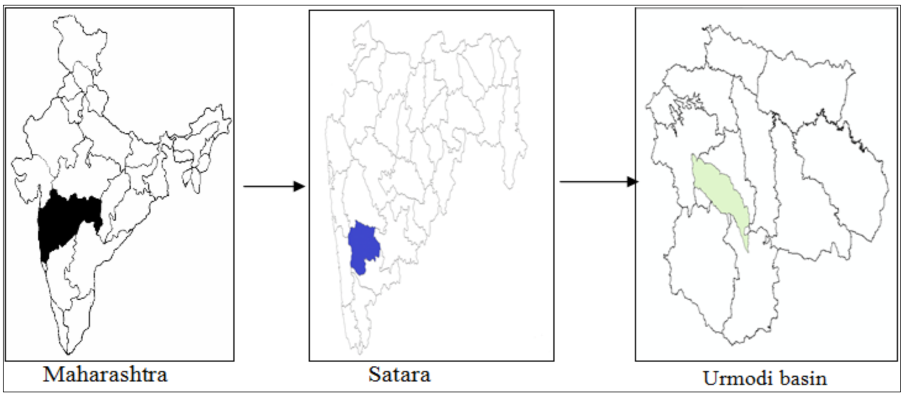

Fig 1: Location map of study area

Data collection
The different soil parameters such as sand, silt, clay and organic carbon were collected from District Soil Testing Laboratory, Hamdabad (Satara), Maharashtra for each village of Urmodi basin. Organic matter was calculated from organic carbon content of soil. The soil data regarding texture, structure, permeability and organic matter content were used to derive soil erodibility factor (K).

SOI toposheets 47 K/14, 47 K/02, 47 K/03 of 1:50,000 scale of study area were obtained from GIS unit Cell, Commissionorate of Agriculture, Pune. Village map of Urmodi basin was prepared by using Geographical Information System.

Soil Erodibility Factor (K)
Concept of soil erodibility
Soil erodibility is defined as the susceptibility of the soil particles to both detachment and transport by raindrop impact and runoff (Renard, *et al*., 1997) [7]. These processes are influenced by soil properties, such as particle size distribution, structural stability, organic matter, soil chemistry and water transmission characteristics (Lal, 1994) [3]. Soil erodibility factor is defined as the average rate of soil loss per unit of rainfall erosivity index from a unit plot (Zhang, *et al*., 2004) [11]. A unit plot is defined as a ploughed continuous fallow land having a uniform 9% slope and 22.1 m length.

Soil erodibility factor (K) is a measure of the total effect of a particular combination of soil properties. Some of these properties influence the soil capacity to infiltrate and therefore, help to determine the amount of rate of runoff. Some other properties influence its capacity to resist detachment by the erosive forces of falling raindrops and flowing water and thereby determine soil content in the runoff. The inter-relation of these variables is highly complex.

Computation of soil erodibility
Soil erodibility is function of the complex interaction between sand, silt and clay fractions in the soil and other factors such as organic matter, soil structure and profile permeability class. Soil erodibility equation is statistically accurate and technically valid but has proven too complex as an operational tool for a technician to solve. Direct determination of the K factor requires long- term measurements of soil loss, which is costly and time-consuming. Values of the soil erodibility factor K of the soil samples calculated using the following formula of Wischmeier and Smith (1978) [6].

$$100\ K = 2.1\times 10^{-4} \times M^{1.14}\,(12 - a) + 3.25 \times (b-2) + 2.5\times (c-3) \quad (1)$$

Where

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

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

a = Per cent organic matter content,
b = Structure code used in soil classification,
c = Soil permeability code.

In present study, the K factor was computed for each village of Urmodi basin with the help of data obtained from soil analysis such as soil texture, structure, permeability and organic matter content. Organic matter content was calculated from organic carbon of soil (Equation 2). Permeability code (Table 2) was judged from permeability classes based on hydraulic conductivity (Table 1) and also from saturated hydraulic conductivity obtained using SPAW model.

Erodibility and permeability
Permeability is a measure of the rate at which water percolates through a soil and is a function of texture, structure and soil bulk density. Water rapidly enters highly permeable soils, reducing runoff and therefore reduces soil erosion. The permeability of the subsoil is also an important consideration.

Soil water characteristics
To understand the hydrologic behavior of soils, it is essential to estimate soil water characteristics for water potential, unsaturated hydraulic conductivity and saturated hydraulic conductivity using soil variables such as texture, organic matter (OM) and structure. Field or laboratory measurements are difficult, costly and often impractical for many hydrologic analyses. Models of soil texture, soil water potential, and hydraulic conductivity can provide estimates sufficiently accurate for many analyses and decisions (Saxton and Rawls,

2006) [8]. In one of such models "Soil-Plant-Air-Water" (SPAW) (Saxton and Rawls, 2006) [8] hydraulic conductivity (inch/hr) and saturated hydraulic conductivity (inch/hr) were obtained from values of sand (%), clay (%) and organic matter (%) as shown in Fig 2. Permeability code was derived based on hydraulic conductivity (Smith and Browning, 1946) [9] and textural class and saturated hydraulic conductivity of soil (Rawls, *et al*.,1982) [6] as shown in Table 1 and 2.

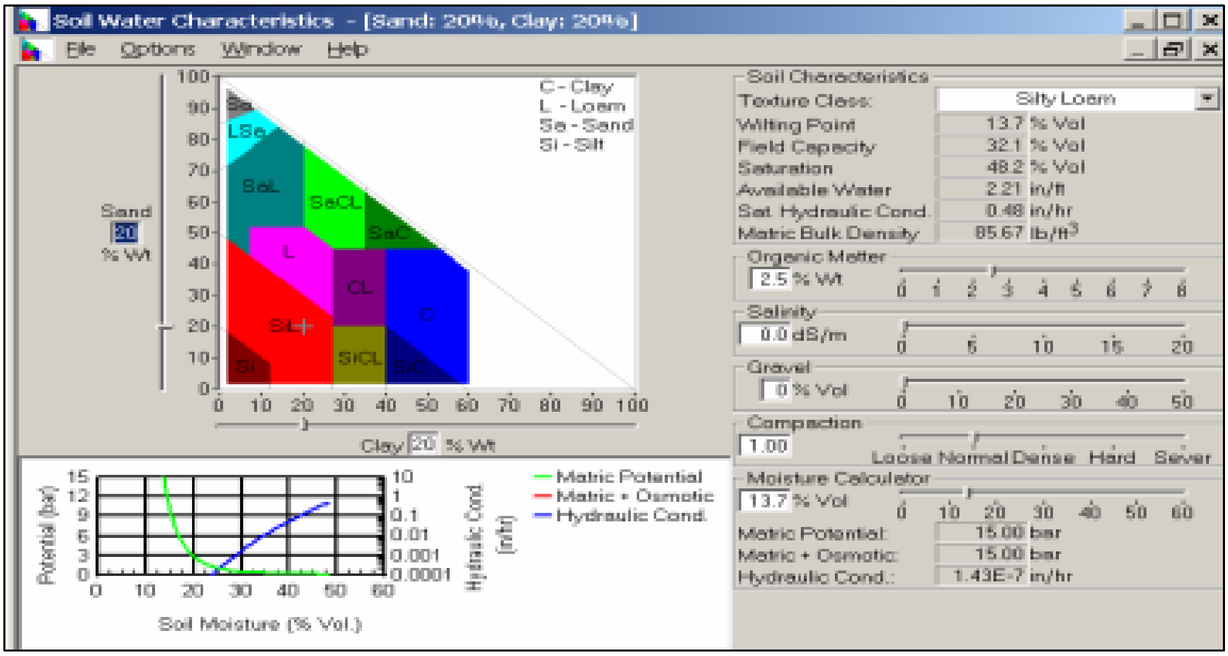

Fig 2: Soil water characteristics determined by SPAW

Erodibility and soil structure

The soil structure is defined as the manner in which soil particles are assembled in aggregate form. Structure may be designated as blocky, prismatic, platy, granular and structure less. Very fine granular structure is stable and it does not break down under cultivation and a high infiltration capacity. Blocky and platy structures are more erodible. Good soil structure and high aggregate stability are important for improving soil fertility, enhancing porosity and decreasing erodibility (Bronick and Lal, 2005) [1]. Structure of soil was determined by textural class of soil.

Soil textural data was obtained from District Soil Testing laboratory as well as textural class was determined by using SPAW model as explained earlier. Structural code (Table 5) was obtained from different particle size proposed by USDA and NBSS & LUP (Table 3 and Table 4). Particle size distribution of sand, silt, clay was taken into account for deciding textural class.

Table 1: Permeability classes based on hydraulic conductivity of soil

Permeability classes	Hydraulic conductivity(cm/hr)
Extremely slow	< 0.0025
Very slow	0.0025-0.025
Slow	0.025-0.25
Moderate	0.25-2.5
Rapid	2.5-25.0
Very rapid	> 25

Table 2: Permeability code for different types of soil

Code	Description	Rate (mm/h)
1	Rapid	>130
2	Moderate to rapid	60-130
3	Moderate	20-60
4	Slow to moderate	5-20
5	Slow	1-5
6	Very slow	<1

Table 3: Textural class proposed by USDA

Soil separate	Diameter range (mm)
Coarse sand	2.00 – 0.20
Fine sand	0.20 – 0.02
Silt	0.02 – 0.002
Clay	Below 0.002

Table 4: Structural class

Class	Range (mm)
Very fine	Less than 1 mm thick
Fine	1-2 mm thick
Medium	2-5 mm thick
Coarse	5-10 mm thick
Very coarse	More than 10 mm thick

(Source: NBSS and LUP, 1988)

Table 5: Sstructure code for soil

Code	Structure	Size (mm)
1	Very fine granular	<1
2	Fine granular	1-2
3	Medium or coarse granular	2-10
4	Blocky, platy or massive	>10

Erodibility and organic matter

Soil organic matter (SOM) is an aggregating agent that binds mineral particles together to develop structure in the soil. Soils that are higher in SOM are more resistant to erosion. Soil organic matter (SOM) affects or influences soil loss by improving soil structure, root penetration, water holding capacity and infiltration. In present study organic carbon data was available. So, organic matter of soil was estimated using following equation (Hesse, 1971) [2]:

$$\text{Organic Matter} = \text{Organic Carbon} \times 1.724 \qquad \dots (2)$$

Creation of soil erodibility (K) map

Soil analysis data for various parameters of the watershed was available for all villages at District Soil testing Laboratory, Satara. Soil erodibility factor (K) for each village was determined based on different soil parameters using the above procedure. Soil erodibility factor (K) factor value was assigned in attribute table in Arc GIS 10.7.1 to each village of Urmodi basin to get soil erodibility (K) map.

Results and Discussions

Soil parameters

The parameters like texture, structure, organic matter content and permeability were very significant in determining soil erodibility. These soil parameters were determined using SPAW model and various relationships of soil characteristics. The texture of soil was largely clay (50.16%), clay loam (24.53%), sandy clay loam (17.66%), sandy clay (5.83%), and loam (1.79%). Structural classes for the soils of Urmodi basin were fine granular and very fine granular. Estimated organic matter content of soil was ranging between 0.66 to 2.96% with the mean 1.33%. Hydraulic conductivity values of Urmodi basin were ranging from 0.0025 to 0.25 cm/hr. saturated hydraulic conductivity values ranging from 0.1016 to 0.508 cm/hr. The permeability of soils in Urmodi basin was ranging from 0.5 to 20 mm/hr. So the majority of soil comes under slow to moderate, slow and very slow permeability class having the permeability code 4, 5 and 6. Soil sample collected mostly from agricultural land. Percent sand, percent silt and percent clay of the district varies between 27.86 to 61.83, 11.25 to 31.67 and 14 to 56%, respectively with average 43.94, 19.23 and 36.83%, respectively.

Table 6: Soil Erodibility factor of different villages of Urmodi basin

Village	Sand (%)	Silt (%)	Clay (%)	O.M%	b	C	M	K Factor (t-ha-ha/ha-MJ-mm)
Alwadi	38.4	26.6	35	1.34	1	4	2477.8	0.16
Ambale	35.84	17.08	47.08	1.48	1	6	1473.293	0.13
Ambavade Kh	37.82	18.2	43.98	0.99	1	6	1655.391	0.15
Ambavde Bk	35.39	15.78	48.83	0.94	1	6	1350.888	0.13
Anavale	56.09	18.91	25	1.72	2	4	2680.5	0.20
Are	39.05	16.04	44.91	0.92	1	6	1529.298	0.14
Asangaon	46.91	20.24	32.85	1.33	1	4	2304.588	0.15
ashte	42.89	22.4	34.71	0.77	1	4	2302.778	0.15
Atali	42.04	27.14	30.82	1.86	1	4	2750.597	0.17
Bharatgaon	51.72	20.01	28.27	0.84	1	4	2548.567	0.17
Bhatmarali	36.32	17.04	46.64	0.84	1	6	1490.878	0.14
Bhondawade	61.28	15.94	22.78	1.02	2	4	2650.963	0.21
Dare t parali	46.56	19.69	33.75	1.22	1	4	2229.975	0.14
Dhavali	50.37	24.38	25.25	2.48	2	4	2795.65	0.19
Dhidhavale	55.75	25	19.25	2.04	2	3	3369.698	0.22
Dolegaon	34.66	18.41	46.93	1.25	1	6	1528.947	0.14
Gajawadi	54.17	16.11	29.72	1.44	1	4	2274.964	0.14
Ghatwan	44.37	21.88	33.75	2.07	1	4	2332	0.14
Kaloshi	41.78	15.09	43.13	1.01	1	6	1571.318	0.14
Karandi	59.66	15.42	24.92	0.72	1	4	2501.666	0.17
Kari	42.89	17.03	40.08	1	1	4	1791.608	0.11
Kasani	48.96	22.71	28.33	1.91	2	4	2680.458	0.20
Katawadi bk	48.04	17.06	34.9	1.2	1	4	2049.348	0.13
Katawadi kh	59.25	20	20.75	1.8	2	3	2994.065	0.20
Kelavali	41.75	23.91	34.34	1.28	1	4	2392.65	0.15
Khodad	28.37	21.5	50.13	1.14	1	6	1497.097	0.14
Kumathe	47.72	16.25	36.03	1.16	1	5	1955.563	0.15
Kurul Baji	53.33	12.92	33.75	1.58	1	4	1915.95	0.11
Kurul tijai	46.5	18	35.5	1.78	1	5	2060.775	0.15
Kurun	42.81	15.63	41.56	1.02	1	6	1664.371	0.15
Kus bk	46.98	20.84	32.18	1.76	1	4	2369.631	0.14
Kus Kh	51.17	21.25	27.58	1.83	1	4	2651.296	0.16
Kusavade	40.28	20.71	39.01	1.02	1	4	2000.472	0.13
Lavanghar	55.54	13.13	31.33	0.97	1	4	2046.366	0.13
Lumane Khot	46.75	20	33.25	0.66	1	4	2271.503	0.15
Mandave	36.92	21.51	41.57	1.42	1	6	1904.234	0.16
Naghthane	27.86	20.69	51.45	0.94	1	6	1419.602	0.13
Navali	44.02	18.06	37.92	1.72	1	4	1941.242	0.11
Nigudmal	41.93	11.25	46.82	1.21	1	6	1267.279	0.12
Ninam	38.3	15.03	46.67	1.06	1	6	1414.312	0.13
Nitral	42.14	17.5	40.36	1.07	1	6	1798.146	0.16
Padali	32.84	17.15	50.01	0.98	1	6	1350.23	0.13
Palsavde	34.58	31.67	33.75	2.96	1	4	2785.813	0.15
Pangare	47.02	22	30.98	2.39	1	4	2492.312	0.14
Parali	43.46	18.56	37.98	0.81	1	4	1959.832	0.13
Parmale	42.32	20	37.68	1.64	1	4	2037.864	0.12
Pateghar	39.37	25.5	35.13	1.55	1	4	2420.948	0.15
Petri	49.17	21.04	29.79	1.71	2	4	2513.518	0.19

Pilani	41.38	18.1	40.52	1.15	1	6	1815.33	0.16
Pogarwadi	29	15	56	0.89	1	6	1042.8	0.11
Punawadi	40	16.39	43.61	1.13	1	6	1600.912	0.15
Raighar	49.85	15.31	34.84	1.98	1	4	1972.393	0.11
Rajapuri	36.49	27.19	36.32	1.96	1	4	2428.755	0.15
Revali	39.75	14.25	46	1.62	1	6	1413.72	0.13
Rewande	47.96	20.87	31.17	1.59	1	4	2426.946	0.15
Rohot	40.15	21.8	38.05	1.2	1	4	2097.008	0.13
Sandavali	42.5	24.53	32.97	1.49	1	4	2498.878	0.16
Savali	61.75	24.25	14	0.99	2	2	3679.08	0.24
Sayali	61.83	16.75	21.42	0.81	2	4	2773.874	0.22
Shahapur	34.19	15.9	49.91	0.66	1	6	1310.354	0.13
Shelkewadi	54.43	13.25	32.32	0.98	1	4	2001.974	0.13
Shendre	49.34	13.35	37.31	1.15	1	5	1765.35	0.13
Sonawadi	37.39	17.27	45.34	1.13	1	6	1557.263	0.14
Songaon	39.39	17.38	43.23	1.03	1	6	1657.684	0.15
Takawali	39.72	17.64	42.64	0.87	1	6	1695.562	0.15
Upali	39.55	22.61	37.84	0.75	1	4	2143.277	0.14
Valase	32.21	22.03	45.76	0.88	1	6	1719.408	0.16
Vechale	35.29	18.47	46.24	0.84	1	6	1562.266	0.15
Venekhot	49.77	21.59	28.64	1.71	2	4	2606.781	0.19
Wavdare	42.5	20	37.5	2.45	1	4	2046.875	0.11

Based on these values and codes, erodibility factor was calculated for each village of Urmodi basin.

Soil Erodibility (K) Factor

Based on these values and codes erodibility factors were calculated for 70 villages. Erodibility factor for Kasani, Katawadi Kh, Anavale, Bhondawade, Dhidhavale, Sayali and savali villages was found in the range of 0.20 to 0.24. The soils in these villages were more susceptible to erosion because the sand% (Greater than 30%) of these villages was high than the clay%. Erodibility factor for remaining villages was found in the of 0.11 to 0.19. The soil in these villages was less susceptible to erosion. The soil erodibility decreases linearly with increasing organic content over the range of zero to 10%. Organic matter of these villages was ranges between 0.66 to 2.96.

Calibration and validation of SPAW model

SPAW model was then validated for other 15 locations in the same watershed by keeping calibrated parameter density factor (DF) as a constant. Bulk density values of 15 locations estimated by manual method and SPAW model were close to each other. They are ranging from 1.16 to 1.34 for manual method and 1.17 to 1.36 for SPAW model with coefficient of determination 0.80. High coefficient of determination (R^2) shows the acceptable performance of model. So, SPAW model was used for estimation of hydraulic conductivity and saturated hydraulic conductivity of villages of Urmodi basin.

Soil erodibility factor (K) map of Urmodi basin

Soil erodibility factors of study area soils were estimated using information on sand (%), silt (%), clay (%), organic matter content (%), structural code and permeability code of each village. Accordingly, K factor map of Urmodi basin was prepared (Fig.3). Soils were more susceptible to erosion on the remote side of the Urmodi basin. So, this erodibility factor in the north western part of Urmodi basin was ranging between 0.20 to 0.24 t-ha-hr/ha-MJ-mm. These values have major influence on soil loss from the micro watersheds of that region.

4. Conclusions

Erodibility of soil is a major consideration in developing sound management practices for agricultural, forest and other land uses. The parameters like texture, structure, organic matter content and permeability were very significant in determining soil erodibility. The organic constituents of the soil are important because of their influence on aggregate stability. The hydraulic conductivity was determined using SPAW model and erodibility of soil was determined by various relationships of soil characteristics. Field or laboratory measurements are difficult, costly and often impractical for many hydrologic analyses. Models of soil texture, soil water potential, and hydraulic conductivity can provide estimates sufficiently accurate for many analyses and decisions. SPAW model is useful for the determination permeability code based on hydraulic conductivity of soil. Soil erodibility factor for different villages of Urmodi basin was found in the range of 0.11 to 0.24. It was concluded that villages having more amount of% sand the erodibility factor was high. This was having major influence in soil loss from the villages of Urmodi basin of Krishna river. Estimation soil loss is necessary to identify potential erosion areas and to carry out the conservation measures. Observations shows that organic matter content is higher for non-eroded areas than eroded and it is in agreement that when organic matter is high, the soil will be less susceptible to erosion because of the binding effect of organic matter and therefore less vulnerability to particle detachment.

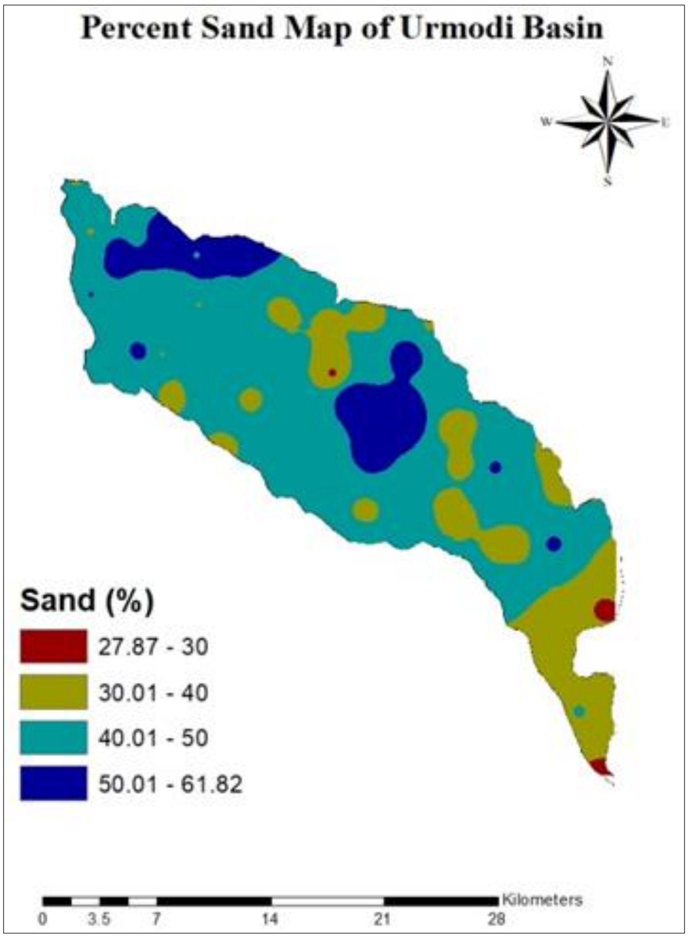

Fig 3: Percent Sand Map of Urmodi Basin

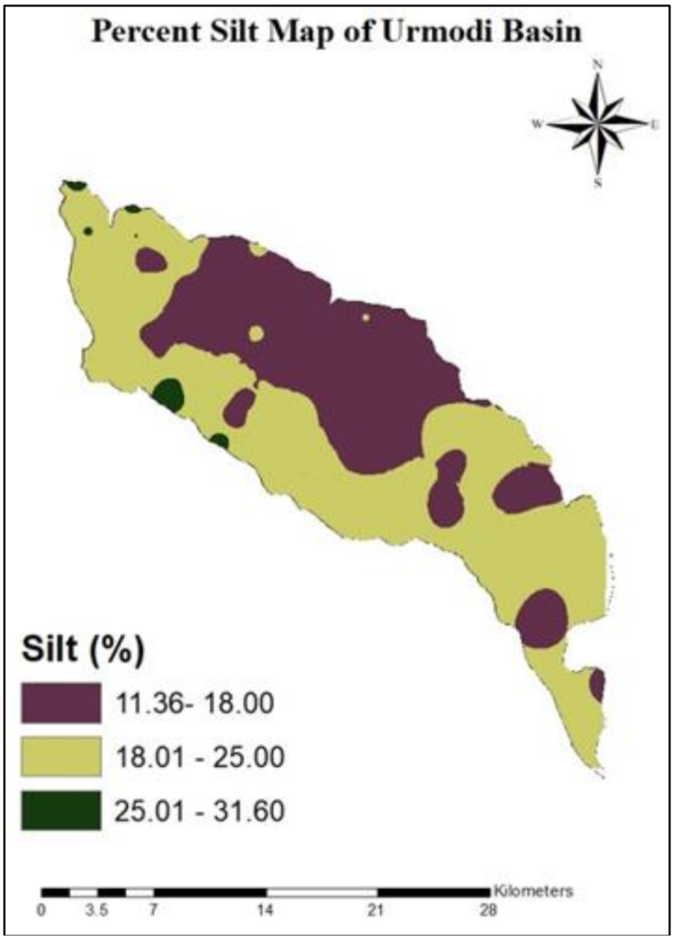

Fig 4: Percent Silt Map of Urmodi Basin

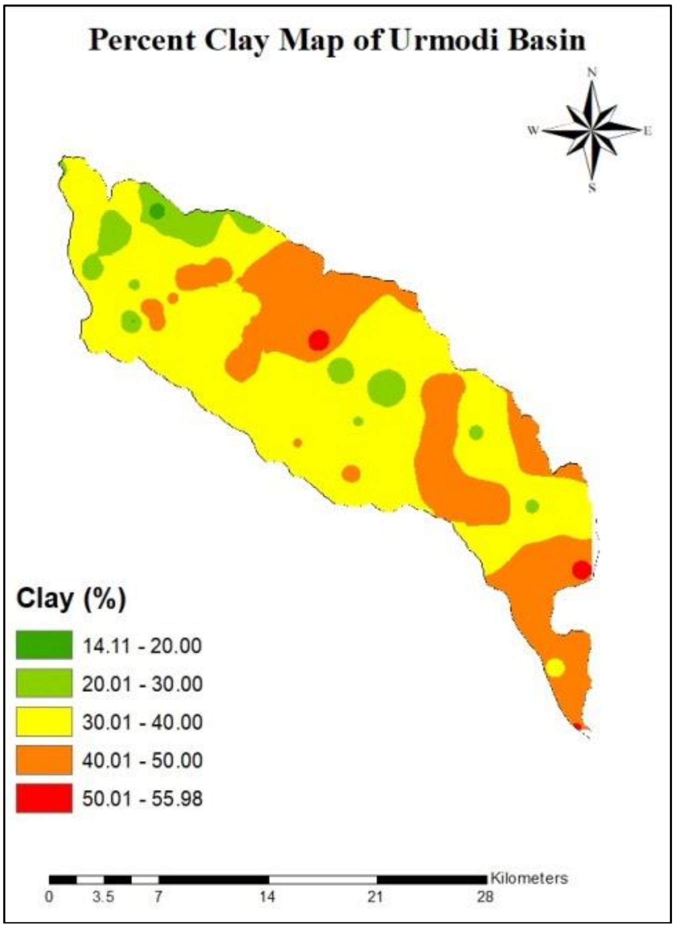

Fig 5: Percent Clay Map of Urmodi Basin

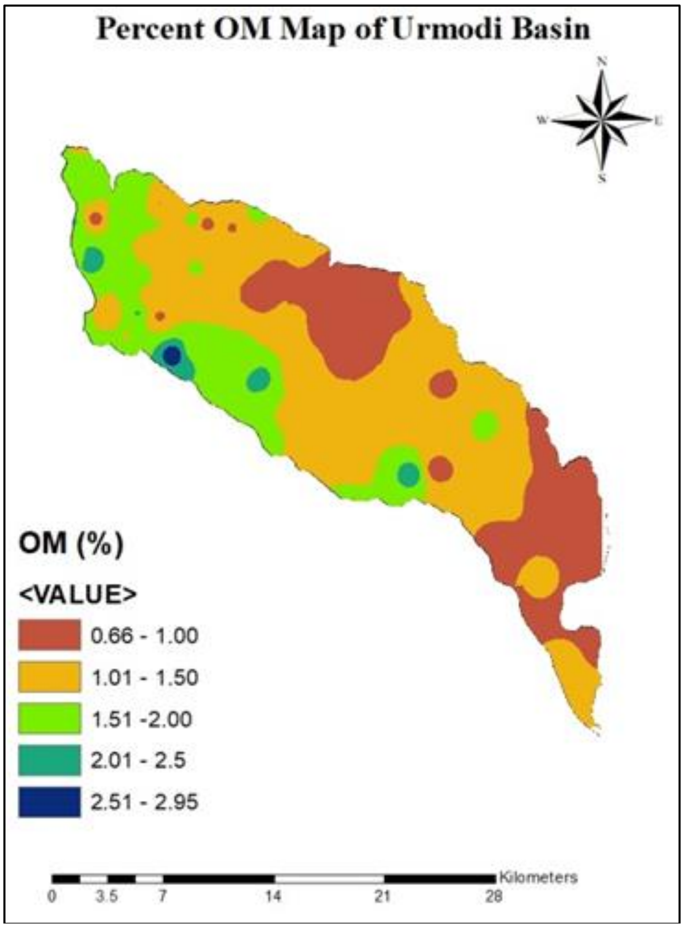

Fig 6: Percent OM Map of Urmodi Basin

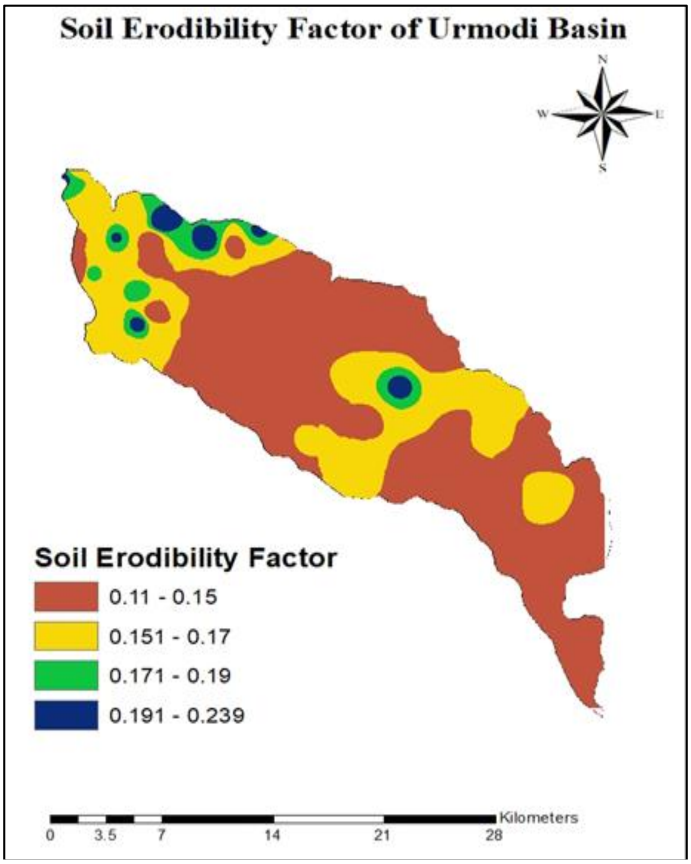

Fig 7: Soil Erodibility Factor (K) Map of Urmodi Basin

5. References

1. Bronick C, Lal R. Soil structure and management: a review. Geoderma. 2005;124:3-22.
2. Hesse PR. A text book of Soil Chemical Analysis. John Murray publ. ltd. London WLX- 4 BD, 1971.
3. Lal R. Soil erosion research methods. Soil and Water Conservation Society (Aunkeny), 3rd ed. St. Lucie Press, Delray Beach. 1994.
4. Narayana VVD, Ram Babu. Estimation of soil erosion in India. Journal of Irrigation and Drainage Engineering, 1981;109(4):419-434.
5. NBSS LUP. Field handbook, printed at cartography Div. NBSS & LUP, New Delhi. Agrobias India, 1988, 29-34.
6. Rawls WJ, Brakensiek DL, Saxton KE. Estimation of soil water properties. Transactions of the American Society of Agricultural Engineers, 1982, 1316-1328.
7. Renard KG, Foster GR, Weesies GA, McCool DK, Yoder DC. Prediction of soil erosion by water: a guide to conservation planning with the revised universal soil loss equation (RUSLE), Agricultural Handbook 703, USDA, Washington, DC. 1997.
8. Saxton KE, Rawls WJ. Soil water characteristic estimates by texture and organic matter for hydrologic solutions. Journal of Soil Science Society of America. 2006;70:1569-1578.
9. Smith RM, Browning DR. Some suggested laboratory standards of subsoil permeability. Soil Science Society of American Proceedings. 1946;11:21-26.
10. Wischmeier WH, Smith DD. Predicting rainfall erosion losses-A guide to conservation planning. Agricultural Handbook No. 537, U.S. Department of Agriculture, Washington DC. 1978.
11. Zhang K, Li S, Peng W, Yu B. Erodibility of agricultural soils and loess plateau of China. Soil Tillage Research Journal. 2004;76:157-165.