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Management of Soil Losses in South Mahanadi Delta, India

SIBA PRASAD MISHRA AND KALPATARU DAS

Civil Engineering Department, Centurion University and Technology, Jatni, Bhubaneswar-752050, Odisha, India

***Email:** 2sibamishra@gmail.com, daskalpataru8@gmail.com*

Abstract: *Arc GIS and RUSLE software's are used for classification and estimation of the annual average soil loss of four watersheds in the South Mahanadi delta along east coast of India. The uplands between the distributaries constitute the West of Daya, Daya- Bhargovi, Bhargovi- Kushabhadra and the coastal watersheds. The major water shed is the upland bounded by the rivers Daya and Bhargovi which decant to the Chilika lagoon which has unique ecosystem and hotspot biodiversity. The lagoon receives 70-80% of its inland flow from the Mahanadi system. About 6-8% of total sediment of the total Mahanadi system debouches into the lagoon threating the lagoon to be a depleted wetland in future. The sediment due to reel and the gully erosion of the local catchments plays important role in soil management. To study the average annual loss of soil of the watersheds, the rainfall erodent factor (R), soil erosion factor (K), basin length (L), gradient (S), crop type coefficient (Cc), tilling practice coefficient (Cp) and support practice factor (P) have been derived using rainfall data, satellite imageries and agriculture statistics of the area. The West of Daya watershed shows higher soil erosion rate than others. The average erosion rate of the south Mahanadi delta is estimated as 8.347 MT/ha/yr. and the coastal sandy area as 0.393 MT/ha/yr. Management strategies for reducing erosion rate are check dams, stone terraces, contour ploughing and cultivating salinity tolerant crops by proper catchment treatment plan for the area.*

Keywords: *Mahanadi Delta, Chilika, Soil, RUSLE, crop factor, East Coast*.

1. Introduction

Erosion is the natural process of detachment, entrainment, carriage and deposition of soil particles from a surface by eroding agents like rain, constructions, mining activities etc. Soil loss, a nonrenewable source drops crop yields, augment cost of crop production, damage top soil structure, reduce soil water retentively, enhance runoff and soil transmissivity. The loss in deltaic coastal top soil strata are sheet, rill, gully, wind and water erosions. Erosion in alluvial and sandy soils along coast is susceptible to agriculture practices, sand mining, deltaic subsidence, anthropogenic activities and water logging.

About 5334 MMT (@ 16.4 MT/ha/yr. of soil is eroded annually in India. About 29% of it is transported by rivers into the sea and 10% is retained behind the dams, weirs and barrages resulting in reduction of their storage capacity (Dhruva N. et al., 1983)[1]). The Hirakud dam on Mahanadi has reduced 66.67% of sediment flow to its delta within last 30 years [Gupta et al 2012[2], Mishra et al., (2015) [3]].

The apex of the Mahanadi delta (Naraj, a village) has geographical position 20^0 28' 30'' N Lat. and $85^0$46'50''E Long. The coastal fringes are at Ramachandi Temple $19^0$27'50''N Lat. and $85^0$07'E Long. to south and $19^0$51' N Lat. and $86^0$03' E Long. near the mouth the river Kushabhadra.

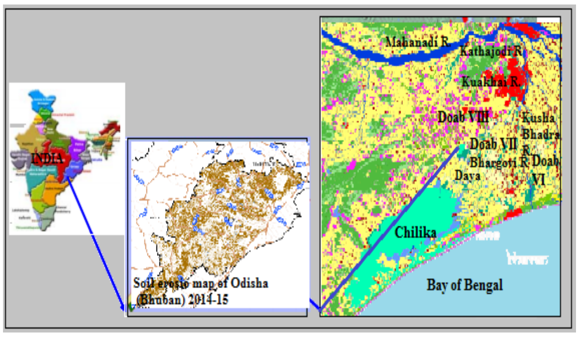

Fig.1: *Index map of Study area SMD and Chilika Lake (Source: Google, http://bhuvan-noeda. nrsc.gov. in/projects/moef/)*

The agro climatic zone of the SMD extends inland from 24-72km from coast. The problems of poor yield are the unattended drainage channels, flat topography, flow congestion, water logging and degraded mouthing problems in the lagoon and pervasive aquatic vegetation like water hyacinth and ipomeas in water bodies of the areas Fig. 1.

The study area is a part of Indian peninsular subtropics, having tropical climate and sub-humid temperate region. 1450-1500 mm rainfall occur annually and 75-80% during by South West monsoon in June -Oct. The summer temperature is 40^0-45^0C and minimum winter temperature ranges 10^0-15^0C. The monthly PET rate of the SMD is 45mm (minimum in January) and maximum of 320mm in the month of May (Mishra et al., 2015) [4].

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The lower canopy of the delta has sandy beaches, lagoon, recent alluvial plains, back swamps, waterlogged areas, mud flats and isolated hillocks of laterite soils. The uplands of the delta consist of denudation hills, lateritic uplands, pediments and inselbergs in the west. Major soil category consists of Lateritic, clayey, coastal saline sands and deltaic alluvium Fig. 1. The soil loss in the deltaic areas of Odisha is estimated to be 10-20 MT/ha/yr. (Singh et al 1992) [5].

The South Mahanadi delta (SMD) in east coast of India covers an area of 2446 km^2 (Fig. 2). Chilika Lake receives flow from the branches of the river Kuakhai via the rivers Daya and the Bhargovi of their own catchment (1777 km^2) from the Mahanadi deltaic system. The SMD consists of four watersheds (called doab) i.e. West of Daya (Doab VIII) of area 653.50 Km^2, Daya-Bhargovi (Doab VII) of area 890 Km^2, Kushabhadra-Bhargovi (Doab VI) of area 627.53 Km^2 and coastal land of area 237.5 Km^2. The drainage channels of Doab VII and VIII are draining to the Chilika and that of runoff from Kushabhadra (Doab VI) are draining to Bay of Bengal. The coast consists of micro water sheds and sand dunes.

The present study attempts to find the rate of soil loss in the deltaic stretches of flood plains of peninsular river systems in east coast of India. It is in literature, the delta and coast have fewer slopes and the soil is sandy. The quantity of erosion from those soils is less than that of high gradient hill slopes. The commonly used USLE and RUSLE methods have been used to estimate the rate of soil loss from the individual watersheds of south Mahanadi delta, soil received by the lagoon and compared with upper Basin areas of the Mahanadi.

2. Review of Literature

The first attempt to find a mathematical relation for the soil loss in an area was attempted by Zingg, et al., (1941) [6] as $A = C\,S^{1.4}L^{0.6}$, Where A = average soil loss/area, S = the % of land slope and L= the slope length. Further (Smith H. J.., 1999) [7] added the conservation practice factor (P) and modified the equation as $A = C\,S^{1.4}\,L^{0.6}\,P$.

About 57% of total lands in India is eroded losing soil of about 5334 MMT (@ 16.4 MT/ha annually. The loss can be estimated of 5.4 to 8.4 MT of nutrients which could have produced 30.5MT food grains/year as per National Bureau of Soil Survey and Land Use Planning and Research Centre (NBSS & LP) (Reddy et al., 2005) [8]. The Mahanadi basin has soil loss @ of 7.1×10^6 MT/yr. as sediment flow to Bay of Bengal (Subramanian, 1978) [9].

Different methods are used for estimating of soil loss of an area. They are Universal Soil Loss Equation (USLE) by Wischmeier et al., 1975 [10], the empirical Soil Loss Estimation Model (SLEMSA) in South Africa by Elwell et al., (1978)[11], Modified Universal Soil Loss Equation (MUSLE) by Williams and Berndt, 1972[12], Chemical Runoff and Erosion from Agricultural Management Systems was studied by Creams- Knisel (1980)[13] and Agricultural Non-point Source pollution model (AGNPS) was developed by Young et al. (1987)[14]). Revised Universal Soil Loss Equation (RUSLE-1), was given by U S Deptt. of Agriculture – (USDA-ARS), Indiana. The computer based model, RUSLE-2 was developed which is one of the common method for estimation of soil loss (Renard et al., 1993, 1997) [15],[16]. WEPP, the USDA-Water Erosion Prediction Project model said to be better than RUSLE-1 model. Parveen et al., 2012 [17] claimed USLE is a popular empirically based model to estimate soil loss in an area.

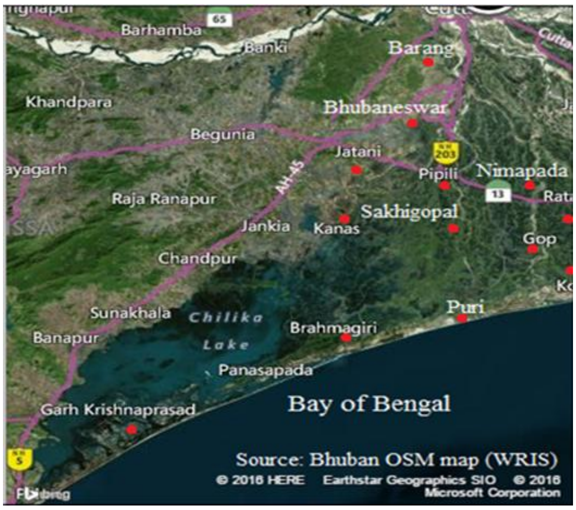

Fig 2: *The map of the SMD, the Chilika lagoon and rain gauge stations (Source: Google)*

Study of soil erodibility, and erosion indices in Odisha was initiated by Water Tech. Centre for Eastern Region, BBSR and classified soil erosion in water sheds as slight (>5), moderate (5-10), high ((10-20), very high (40-80) and very severs for >80 by (Singh et al, 2002[18]. Mishra S. et al., 2012[19]), on studying the soil loss in Upper Mahanadi Basin reported that the average annual soil loss of the area is 0-5 tons/acre/year and the maximum erosion obtained was in 30% areas and soil stiffness factor was <40 during the years 2006-10. Vemu et al., (2012) [20] studied the soil erosion of an adjacent catchment of the River Indrāvati in Odisha and found that about 54% catchment area of the river have av. soil loss@ 5 MT/ha/yr.

During study of the watershed in Daltonganj area (adjoining to the present study area), Tirkey et al. (2013) [21] reported that annual average soil loss was up to 69 MT/ ha/ yr but agricultural farms having slope <5˚ was 10 MT /ha/yr. Lenka et al. 2014 [22], reported that the Basic infiltration rate (cm/hr.), Bulk density (mg/m^3), Soil erodibility factor (K-factor in RUSLE method), Soil organic content in % of coastal and deltaic plains of west Bengal were 0.08–11.4, 1.36–1.43, 0.16–0.35 , 0.30–1.50 respectively. Sharda et al., 2013 [23] reported Odisha state has 48832 Km^2 from 155707 Km^2 of total geographical area is prone to low erosion risk. Bhuban, NRSC, India, has prepared a map of scale 1:50,000 using 3-seasons from Satellite data of Soil Loss for the years 2005-06. The water erosion map gives the rate of soil loss > 10 tons/ha/year in Odisha.

3. Methodology

Present study envisages annual average soil loss in a deltaic terrain is Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation (RUSLE- 1 and RUSLE-2).

3.1.1. USLE Method

The popular and the oldest empirical method for estimating of soil loss is the Universal soil loss model given by Wischmeier and Smith et al. (1975) [10] mostly used for sheet or rill erosion. The original equation for long term average annual soil loss (A) in MT/ha/yr. is

$$A = R \times K \times L \times S \times C \times P \quad (1)$$

Where R= rainfall-runoff erosivity factor (in MJ/ha/mm/yr.), K= soil erodibility factor (in ton/MJ/mm), L= slope length, S= Steepness factor, C=cover management factor ($C = \sum(f_j * c_i)$ where: fj = the annual temporal distribution of erosivity and j = an index for the time step crop stage and P is the support practice factor. The av. amount of soil losses are estimated using average annual values for each factor for computation Foster et al. (1987) [24].

3.1.2 RUSLE-1 Method

The Revised Universal Soil Loss Equation (RUSLE) is an update to USLE estimation of the average annual loss of soil (A) which is given by

$$A = R\ K\ L\ S\ C\ P \quad (2)$$

Where the variables R, K, LS, C are defined above but the soil practice factor ‘P’ is estimated considering contouring (ridging), barriers (vegetative strips, silt fences), flow interceptors (diversions), sediment basins, and subsurface drainage. RUSLE-1 is a combination of empirical and process-based routines to calculate soil loss. The amount of soil loss by the USLE and RUSLE-1 methods accounts for sheet or rill erosion in single slope but do not consider gulley or wind or tillage erosion and yield of the catchment due to anthropologic constructions Wall et al. (2002) [25].

3.1.3 RUSLE-2 Method

RUSLE-2 is a soft computing formula for multi water sheds used to compute average annual soil erosion of an area is given as

$$A = \sum R_k K_k C_k L_k P_k \quad (3)$$

Where: R_k, K_k, C_k, L_k, P_k have their usual meaning and k is an index for the day of the year. The soft computation in RUSLE-2 is different from the methods used in USLE and RUSLE-1 (Foster et al., 2003)[24]. In RUSLE-2 method of estimating of average annual soil loss of the south Mahanadi delta, six thematic layers like elevation, slope angle, land use and land cover, soil texture, precipitation etc. are used.

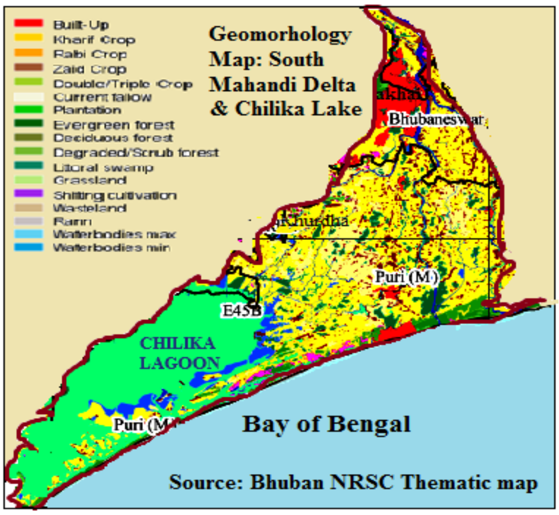

Fig 3: Geomorphology map of the SMD (Source Bhuvan http://bhuvan.nrsc.gov.in/gis/ thematic)

4.1 Rainfall erodibility factor (R)

In the USLE method the exact quantity and intensity of rainfall is difficult to evaluate (Renard et al., 1994) [16] and are to be estimated by R-equivalent cases ± 0.05 and 0.6 near the sea (< 40 km), 0.3 to 0.2 in tropical mountain areas and 0.1 in Mediterranean mountain areas. Wischmeier and Smith (1975) [26] recommended a procedure for getting the R- values (Fig. 3).

Present data set consists of 13 rain fall stations in different blocks and district headquarters of Puri, Khurdha and Cuttack districts of Odisha. Rainfall is considered from the rainfall records of district and block headquarters of Puri, (for Doab VII and Doab VI) and Barang block of Cuttack district and Jatni block of Khurdha district of Odisha (Table 3).

The R-factor of the south Mahanadi delta has been calculated as per (Turkey et all 2012) [24] and (Behera et al., 2016) [27]. The factor is derived by using equation as R= 79 + 0.363*Mean annual r/f for the three water sheds. The equation was given by Gurung Singh, 1981[28] and was further used by Bera et al., (2014) [29], Vinay et al., (2015) [30] and Jadav et al., (2015) [31] and the corresponding R-factors are given in Table-2.

4.2 Soil Erodibility Factor (K):

The soil-erodibility factor (K) is represented by the susceptibility of the soil for erosion, conveyance of the detached soil and runoff resulted from rainfall. It is measured under a standard form. Chance of detachment of soil particles depend upon the structure, infiltration, optimum moisture content, water retentions, presence of cations, texture and composition (Organic content) of it. The % of organic matter in soil drops erodibility, declines susceptibility of soil detachment, but enhances infiltration rates, hence the runoff by reducing erosion Behera et al., (2016) [27]. .

NBSS & LUP reported the percentage of carbon in the area as <2%. The SMD area has been designated by them as sub arid and sub humid region as per bioclimatic map. A small patch along the coast line has % of organic content < 5% as per Chandran et al., (2015) [32]. K is determined by the Water Technology Centre for Eastern Region, BBSR by (Singh et al., 2002) [18]. At present the K-factor is adopted from the soil classification table (Stewart et al., 2006 [33], Schwab et al., 1981[34] (Table 3)). The K-values of different workers in different regions of Odisha are in Table 4.

The coastal areas consist of mainly waterlogged areas, sand dunes and fine sand. But the soil of the area is fine sandy loam or silt clayey loam and covered with organic matters > 2%, are more susceptible less soil erosion at a enhance infiltration. K-factor calculated for different watersheds of India are in Table 3.

Table 1: *Data source for finding of annual average soil loss by USLE/RUSLE model*

Rainfall data	Rainfall erosivity factor	Area type	Characteristics	Source
MAR	R = MAR * 0.5	Coastal area, West Africa	where a=0.5 ± 0.05 & 0.6 near sea (< 40 km),	Morgan (1984) [35]
MAR	R = 22.8+0.64 MAR	All India		Tirkey et al., 2013 [21]
MSP	R = 81.5 + 0.375 *MSP when r/f is 340< r/f<3400mm	All India	Jharkhand (inland), Ong Basin, Odisha	Tirkey et al., 2013[21], Behera S K. 2016 [27]
Delhi wea ther stn.	R value for India=as 100	Dwarakeswar R. Basin	WB (Coastal)	Bera et al., 2014 [29]
MAR	R=79+0.363*MAR	Cauvery ayacut. Mandya, and Himalayas	Inland, Karnataka	Vinay et al., 2015 [30], Jadav et al., 2015 [31]
P_i =monthy r/f and P= annual r/f in mm	$\boldsymbol{R} = \sum_{1}^{n} 1.735\ 10\{1.5(log_{10}\left(\frac{P_i^{\ 2}}{P}\right) - 0.08188$	Kallar (Bhavani River)	Tamilnadu	Wischmeier & Smith 1975) [10]/ (Rehaman et al., 2015) [39]

R= Rainfall (r/f) erosive Factor in (MT/ ha cm /h/ 100), MAR = Mean Annual rainfall in mm, MSR = Mean Seasonal rainfall in mm, P=Annual Rainfall in mm

But in the present case the soil is studied by ground observations. The details of the soils of Doab VI, VII, VII and the coastal area for the doabs are given below. These sandy clayey and loamy soils are less carbonaceous and calcareous. The soils come under the category of clayey loam and % of carbon content (<2%), the k factor is taken as 0.33.

Table 2: *Average rainfall and R-factor (R=79+0.363*MAR) of thirteen rainfall stations at block headquarters in SMD (1998-2014) Vinay et al 2015[30], Jadav et al., 2015[31]*

Year	DOAB VIII (Water Shed -1)			DOBA VII (Water Shed -2)						DOAB VI (Water Shed -3)			
	Barang	BBSR	Jatani	Delang	B-giri	Kanas	K Prasad	Pipili	Puri	A-Rang	Gop	K-pur	N-pada
2000	881	1572	1136	1064	977	483	1003	750	1590	891	1058	403	1167
2001	1735	1861	1929	1439	1812	1737	1761	1883	2521	1912	1542	2197	2309
2002	1788	1884	2005	1462	1977	1766	1835	1939	2629	1933	1585	2218	2280
2003	2135	2785	1718	1367	1189	1657	1302	1443	1997	1792	1506	1172	1266
2004	1523	1169	1330	872	1062	1117	664	1130	1318	1114	1163	1221	1180
2005	1511	1264	1302	730	1712	1078	506	1220	1438	1284	897	1221	1378
2006	1735	1777	1843	1449	1964	1770	1830	1932	2636	1922	1578	2230	2327
2007	1381	1662	1551	646	1412	1229	1336	1388	1437	1659	966	1818	1601
2008	1534	1498	1929	398	1504	1497	1157	1534	1884	1786	1002	1832	1589
2009	1207	1183	1084	546	1596	1329	1962	1445	1437	2112	1039	1869	1873
2010	1317	1434	1469	544	1668	1322	1971	1378	1458	2092	1027	1753	1783
2011	1252	1437	1469	890	1616	1287	1881	1432	1408	2069	1176	1791	1779
2012	1457	1377	1694	1800	759	1163	1243	1346	1239	1235	790	1533	1726
2013	1642	1598	1846	1942	945	1726	1769	1695	1756	1209	716	1138	1490
2014	1749	1638	1424	1839	1238	1458	1737	1542	1705	1709	1319	1718	1762
2015	1035	969	1151	1287	852	812	1009	1382	1279	1438	798	1322	1616
2016	1493	1569	1555	1142	1393	1339	1435	1465	1733	1635	1135	1590	1695
Av.		1539				1418					1514		
R-fac		637.60				593.73					628.50		

***Table 3:** Soil erodibility factor K (Source: Schwab et al., 1981[34], Pravin Kumar et al., 2012 [17] and Rahman et al., 2015) [37]*

Sl No	Textural Class	Organic Content <0.5	Organic content < 2%	Organic content < 4%
1	Fine sand	0.16	0.14	0.1
2	clay	0.24	0.13- 0.21	<0.13
3	Very fine sand	0.42	0.36	0.28
4	Loamy sand	0.12	0.10	0.08
5	loamy+ fine sand	0.44	0.38	0.30
6	Sandy loam	0.27	0.24	0.19
7	Fine sandy loam	0.47	0.41	0.33
8	Silt loam	0.48	0.42	0.33
9	sandy clay loam	0.27	0.25	0.21
10	Clay loam	0.28	0.25	0.21
11	Silt clay loam	0.37	0.32	0.26
12	silty clay	0.25	0.23	0.19
13	Very fine sandy loam	0.41	0.33	<0.3

4.2.1Soils of Doab VI: Most of the areas of Nimapada and Gop block possess coastal deltaic alluvium. These flat and regular soils are good for irrigation network and agriculture. Top soils of the upper zone of the delta consist of flood deposits of older alluvium (Bhangar) and middle reaches are of young alluvium (Khadar).

4.2.2 Soils of Doab VII: Major portion of the coastal soil is saline to alkaline. The top surface is being impregnated (soak or saturate) by the dissolved sediments carried by the rivers in the delta. In the water logged areas with poor drainage system (Bramhagiri, Puri, Kanas and Sakhigopal areas) have heavy deposits of salts of higher concentration which are injurious. In summer evaporation causes these the salts to leach from underneath and get deposited on top soil.

4.2.3. Soils of Doab VIII: The area covers lateritic soil of deciduous hills of Eastern Ghats. The major portion of soils is loamy but gradually it is from clayey sand. The uplands are rich in red soils moorum as top soil and laterite stretches below. They are gravelly, and porous. The land is clay loam and need intensive leaching. Since soil has less organic content (<0.5%) the K factor for the sandy clay soil can be taken as 0.44.A portion of soils is loamy but gradually it is of clayey sand. The uplands are rich in red soils moorum as top soil and laterite stretches below. They are gravelly, and porous. The land is clay loam and need intensive leaching. Since soil has less organic content (<0.5%) the K factor for the sandy clay soil can be taken as 0.44 Table 4.

4.2.4 Coastal Soils: Below the left embankment of the river Bhargovi and between the coasts are sandy lands and water logged areas of 237.5 km^2. As the area is of fine sands with small amount of loam, the K factor is taken as 0.16

4.3. The LS factor:

The LS factor of an area depends upon the gradient, length, aspect ratio and shape of the basin. The slope length and steepness factor can be measured from the field survey data or by using GIS methods of analysis. The steeper the slope and longer the basin, the higher is the risk for erosion. The LS factor of the study area can be calculated by using the relation whenf soil loss is in per acre/ But the present method has estimated crop management factor considering the crop type factor (C_c) and tilth practice factor (C_p). The covers of land due to cropping or mulching have effect on the soil loss due to cultivation or bald soil. Vegetation decides the C-value which prevents soil erosion due to vegetative cover. But on average the C-value is taken as 0.5, [Balasubramani et al., 2015[38]. Bera et al., (2014) [29]], the value of Crop factor (Cc) = Crop type factor (Cc) x Tilth method factor (Cp) (Table 6) year. LS=0.065+0.0456(S)+0.006541(S)2] (S L/const) NN when length of slope = Constant = 22.1 in SI unit and NN = 0.2 when slope is <1. The elevation at head of the Mahanadi delta is 30.78 m and the average distance from coast is about 70 km. The LS factor of the area was found to be 0.1787 Table -5.

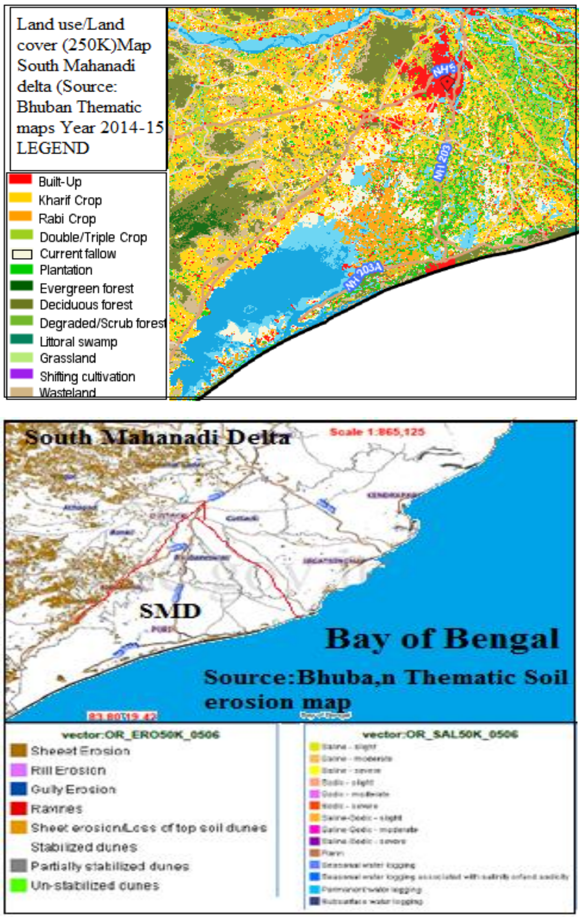

***Fig.6:** LU/LC and soil erosion map of the south Mahanadi delta (Source: Bhuvan thematic map)*

4.3.1 The Cover management factor (C):

The land use and land cover has been studied by various authors from Chilika Dev. Authorities, Odisha. A doab wise study of watersheds of various districts of the south Mahanadi delta taking help of Bhuvan LU/LC maps is given in Fig. -6. The ground cover of the area depends upon the shelter of the canopy, the biome, the root system, the species of vegetation and the biodiversity. Cropping in the area is paddy (grain corn). The crop type factor (C) is taken as 0.4 Table -6.

Table 4: *Soil erodibility factor K in various Basins, India*

Sl. No.	Soil type	Place	K value	Reference
1	Very fine loamy /coarse loamy	Daltonganj, Jharkhand	0.24 0.42	Tirkey et al., 2013[21]
2	Silt Clay Loam soil Av. organic matter	Dwarikeswar R., W.B.l	0.32	Bera et al., 2014[29]
3	Different soil from K-factor map	Cauvery ayacut. Mandya,	Karnataka	Vinay et al., 2015,[30]
4	Generated in ArcGIS using attributes	Hiran basin, NarmadaR., MP	0.071 to 0.0175	Jadav N et al., 2015[31]
5	USDA1978 (from the soil erodibility monograph)	Kallar (Bhawani River)	0.14=sandy clay, 0.15= loamy,0.20= clay loam), 0.27= sandy clay loam, 0.28=clay and 0.37= sandy loam	Rehaman et al., 2015[37]

Table 5: *District wise Land use and land cover map of south Mahanadi delta (including EGB hills)*

LU/LC category	Districts Type	PURI	Jatni, Khurdha	Barang, Cuttack)	SMD area
Agriculture	crop	898.00	166.34	161.88	1226.21
	Fallow	148.44	5.15	2.83	156.41
	Plantation	47.47	4.51	0.33	52.31
Scrub		23.84	22.63	11.41	57.88
Sandy area		10.16	0.00	0.36	10.52
Builtup	Mining	0.00	0.70	0.00	0.70
	Rural	164.17	10.93	27.43	202.52
	Urban	23.46	116.16	8.69	148.31
Forest	Decedious	65.79	80.24	43.53	189.56
	plantation	36.13	6.51	2.36	45.00
	Scrub forest	7.28	43.86	9.50	60.64
	Swamp	0.02	0.00	0.00	0.02
Wet Land	Inland	120.51	16.84	3.72	141.08
	River/canal	52.88	1.58	34.33	88.80
	Water bodies	63.84	1.62	0.96	66.42

Table 6: *Different crop type factor (C_c) and tilth practice factor (C_p) (OMFRA fact sheet (2015)*

Sl No	Ploughing practice	P-Factor	Type of soil erosion	Potential Soil Loss (MT/acre/yr.)
1	Up & Down Slope	1.0	Very Low	<3
2	Cross Slope	0.75	Low	3 to 5
3	Contour farming	0.50	Moderate	5 to10
4	Strip cropping cross slope	0.37	High	10 to 15
5	Strip cropping, contour	0.25	Severe	>15

4.4. Support practice factor (P): The support practice factor (P) is the ratio of soil loss in a normal condition to the soil loss due to ploughing in a hilly terrain. P values can be abridged by contouring, vegetative strips, periphery soil bundhs, diversions, sediment basins and channel of an eroding area can also reduce P-Value. The tillage method is spring loaded tillers mounted over tractors. The tiling factor is taken as 0.9 in the present study. Hence cover management factor (C) is 0.36 Table 7. The value of P-factor is 1 for the upland and 0.28 for lower land with gentle slope and cultivation is done by contour strip method Table-6. The topography of the area is flat and the ploughing practice is traditional and along cross slope. So the support practice factor considered for the area is 0.75 (Table 7).

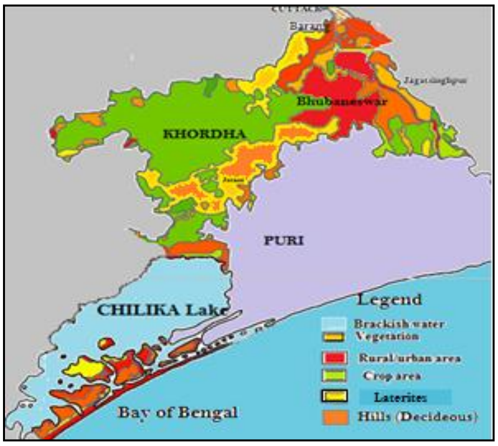

Fig 7(a): *Land use and Land cover of study area 2012-13 (Source: District Profile (GoO)*

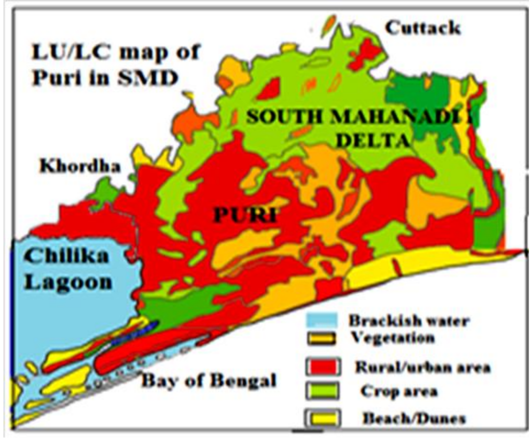

Fig 7 (b): *Land use and Land cover of study area 2012-13 (Source: District Profile, (GoO)*

Table 7: *The values of the support practice factor (P) and soil loss class (OMFRA fact sheet (2015)[39]*

Sl No	Crop type factor (Major crop)		Tilth practice factor (major method)	
1	Type of crop	Crop type factor	Tilting method	Tilting factor
2	Grain Corn	0.40	Fall Plough Ridge	1.0
3	Silage Corn	0.50	Spring Plough	0.90
4	Cereals	0.35	Mulch Tillage	0.60
5	Horticultural Crops	0.5	Tillage	0.35
6	Fruit Trees	0.1	Zone Tillage	0.25
7	Hay and Pasture	0.02	No-Till	0.25

4.5 Soil loss calculation the erosion factors for the Doab VI, Doab VII, Doab VIII and along the coast are given in table below (Table 8):

Considering Potential Soil Loss of the area in MT/hectare/year the coastal areas have value 0.393 MT/Ha/year and the average soil loss of the interior water sheds is 8.347 MT/ Ha/yr. The coastal areas are classified as very low erosion class and the interior of south Mahanadi delta can be classified as of low erosion class. The rates of annual soil loss estimated by various methods and authors in India are given in (Table 8).

Table 8: *The soil loss from different Doabs and the SMD calculated by USLE method*

The upland between rivers	Area in sqkm	Acre	R-factor	K factor	LS factor	C-factor	P-factor	RUSLE Soil loss MT/yr	Total soil loss MT/ha/yr
K-bhadra-Bhargovi (Dab VI)	627.5	155066	638	0.330	0.382	0.1	0.75	$2.09*10^6$	5.464
Bhargovi-Daya (Doab VII)	890.0	219923	608	0.330	0.382	0.1	0.75	$2.83*10^6$	5.212
West of Daya (Doab VIII)	649.5	160495	629	0.440	0.382	0.2	0.75	$5.69*10^6$	14.364
Coast below Bhargovi river	237.5	58686	608	0.16	0.018	0.1	1.0	$0.057*10^6$	0.393
Soil Loss In the SMD (Except coast)	2446	535484	625	0.367	0.382	0.1	0.75	$3.54*10^6$	8.347

4.6 The anthropogenic factor:

The anthropogenic interventions and infrastructural constructions add to the soil erosion. The factor includes economic social and political aspects. They include loss of top soil by excavation, compaction, poor drainage, damming, overgrazing, afforestation, constructions and soil acidity levels. The features include deforestation and afforestation, mining, urbanization, biomass, industrialization and infrastructural constructions (roads, dams, barrages, watersheds and check dams etc.). The social factors include record of right (ROR), demography, economy and social stability. The corresponding political aspects are legislation, land polices and political stability of an area which is not accounted for in USLE/RUSLE estimate of soil loss.

Two sediment traps were constructed by the author in the rivers Daya and Bhargovi and the sediment data were collected. It was observed that the average sediment concentration of both the rivers i.e. in Doab

VII was increased by 3.75times in the year 2000-01. Massive infrastructural construction (expansion of NH-5) taken up in the year 2001, may be the cause of the abnormal increase.

5. Management strategies for soil losses

For higher crop yield we need a good fertile soil that should have perfect soil structure, maintaining nutrient levels, non- erodible by wind /water and tillage practices, mineral rich, good water holding capacity & perfect drainage which should encourage seedling and crop growth and inspire growth of earth worm. To stabilize the watershed, the aim should be to enhance ground water recharge by increasing infiltration rate, by efficient management of the runoff, conserving the land of the watershed, restricting sediment entry to the drainage system at origin, types of landfills. The Doab VIII is the extended capital city of Odisha and infrastructural development by construction is in full swing. The R-factor and K factor of the soil cannot be altered.

Table 9: *Annual average soil erosion loss in different river basins studied by various authors*

Basin in India	Method used	Average annual erosion rate	Studied by
Jharkhand, India	RUSLE/GIS	26 and 30 tons/ ha/ yr.	Turkey et al 2013[21]
Dwarikeswar R. basin, West Bengal	USLE/GIS	8.303 MT/ha/year	Bera et al 2014[29]
Cauvery R. Ayacut Mandya dist., Karnataka	RUSLE/GIS	150 MT/ha/year	Vinay et al 2015[30]
Hiran basin, Narmada R, MP	RUSLE/GIS	2.19 to 3.25 MT/ha/year	Yadav N. et al 2015[31]
Jamni River Basin, Bundelkhand	USLE/GIS	3.22 MT/ha/year	Singh et al 2006[40]
Bakreshwar River (Mayurakhi R. system	RUSLE/GIS	6.99 MT/ha/year	Ghosh et al., 2015[41]
Upper South Koel Basin, Upper Mahanadi, Jharkhand	RUSLE/ARC GIS	12.2 MT/ha/year	Parveen et al., 2012[17]
Upton Rajim, UMB, Chhattisgarh	RUSLE/ARC GIS	34.59 MT/ha/year	Mishra S. et al., 2013[19]
Up to Jonk, Upper Mahanadi Basin, Odisha	RUSLE/ARC GIS	25.84 MT/ha/year	Behera S K et al. 2015[27]
Up to Bay of Bengal, Mahanadi Delta, Odisha	USLE/ GIS	8.347 MT/ha/year	Mishra S. P. 2016 (present study)
Upper Subarnarekha R. Basin, Jharkhand	USLE/GIS	2001 – 40 MT/ha/year 2011 – 49.8 MT/ha/year	Chatterjee S., et al., 2014[42]

If changes are to be done, it involves very high cost. Only C and P factor for an agricultural field can be changed. The modus operandi used for reducing soil loss are terracing, cross slope tillage methods and altering cropping pattern.

The key management strategies of the watersheds are strengthening of Infrastructure, augment Training/Research Centre/ Laboratories which is being taken care of by the state government. However, mini (1-100 Ha), micro (100 -1000 Ha), milli (1000 -10000 Ha),, sub (10000 - 50000 Ha), and micro (100 -1000 Ha), macro (>50000 Ha) watersheds are to be located in the SMD area.

The LS characteristics of the above watersheds such as size, shape, length and slope, type of soil and relief are to be studied. The macro watershed protective measures are difficult due to social, administrative and political issues as it involves land acquisition, reserved forests, urban areas and mining lands. Micro and milli-watershed development should be taken up to reduce erosion at low cost by constructing structures like check dams, terracing, rainwater harvesting, contour bunds, rock dams, gully controlling structures, silt detention tanks, earthen embankments and diversion structures with proper catchment treatment plan.

The number of check dams is found to be effective to control soil loss. The federal government of Odisha has taken up 3128 check dams. Numbers of check dams in Cuttack, Puri and Khurdha districts completed were 163, 123 and 24 respectively by 2013. It is observed that the benefits of check dams are commendable.

6. Conclusions

The south Mahanadi delta (SMD) consists of four water sheds (Doabs) of area 2446 km^2. From study of LU and LC of the SMD area it is observed that crop area is about 50% and rest are mainly settlement, fallow land, deciduous forests and water bodies. The average soil loss of three watersheds of SMD is 8.347 MT/ha/yr. The rate of soil loss is much high (@ 14.36 MT/ha/yr.) in the Eastern Ghats Hill areas towards south in the SMD. The potential soil loss of the mountainous, transportation and deltaic reaches of the Mahanadi river basin are 34.59, 25.84 and 8.35 MT/hectare/year respectively. The rate of soil loss the coastal area is 0.393 MT/Ha/year. The deltaic areas are classified under very low erosion class and interior of south Mahanadi delta can be classified as low erosion class. The soils in the upper reach and middle reach of the Mahanadi basin is as high to severe erosion class. Management strategies to reduce the rate of soil loss are construction of terraces in the upper deltaic zone and check dams in the anastomosed channels of the distributaries. The soil erosion can be controlled by implementing mangrove plantation and execution of efficient water shed management plan as needed.

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