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Soil erosion estimation using usle factors of mustur micro-watershed in Yadagir district, Karnataka

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Abstract

A study was undertaken to evaluate eight soil series belonging to Mustur micro watershed (Yadgir district) in North Eastern Dry Zone of Karnataka for soil erosion estimation using USLE model. Eight soil series were tentatively identified and mapped into twelve mapping units using GIS technique. These mapping units were grouped into soil erosion ratings as low, medium and high with the help of rainfall pattern and rainfall erosivity factor (R factor), Erodibility factor (K factor), Slope length and steepness factor (LS factor), Crop cover and conservation practice factor (C and P factor). Soil loss in different mapping units ranged from 3.41 to 25.24 presented in table 3. BMAkC(A)1, KLUmB(A)1, KLUmC(A)1, KLUmB2, PGLmB2, MSTcB2, KLRmB2, SHTc̲B2, SHTc̲C2, HSLb̲B2, HSLb̲C2 and KKRc̲C2 recorded the soil loss of 6.77, 3.41, 6.56, 15.02, 11.95, 12.40, 13.99, 12.81, 21.06, 15.07, 23.52 and 25.24 t ha^{-1}yr^{-1} respectively. Lower rate of soil loss was recorded in BMAkC(A)1, KLUmB(A)1 and KLUmC(A)1 mapping units. Moderate soil loss was recorded in KLUmB2, PGLmB2, MSTcB2, KLRmB2, SHTc̲B2 and HSLb̲B2 mapping units and SHTc̲C2, HSLb̲C2 and KKRc̲C2 mapping units were recorded high.

Keywords: Soil erosion, rainfall erosivity factor, Erodibility factor

1. Introduction

Land and soil are the vital natural resources for the survival of life on the earth. The natural resources assessment is the prerequisite for the assessment of productivity of land and the sustainability of the ecosystem. Land is a limited resource having competing demands. Man has been persistently recycling on the land for his sustenance: for food, clothing, shelter, fuel, fodder and energy requirements. The biggest challenge to the mankind today is to produce the basic necessities of life from the ever shrinking land resources. The land resources are under severe strain due to the pressure of the growing population and competing demands of the various land uses. In reality most of the arable lands are degraded, water resources are depleting and the degrading land resources at an alarming rate has not only rendered the enhanced stability of production questionable but also causing numerous environmental problems.

Soil is a vital natural resource on whose proper use depends on the life supporting system of a country and the socio-economic development of its people. Soils provide food, fodder and fuel for meeting the basic needs of human and animal. With the growth in human and animal population, demand for more food production is on the increase. However, the capacity of the soil to produce is limited and limits to production are set by intrinsic characteristics, agro-ecological setting, use and management. This demands systematic appraisal of our soil resources with respect to their extent, distribution, characteristic, behaviour and use potential, which is very important for developing an effective land use system for augmenting agricultural production on sustainable basis.

Soil erosion is the detachment, transportation and deposition of material from one place to another through the action of wind or water. Soil erosion, for whatever cause, destroys man-made structures, fills reservoirs, lakes and rivers with washed soil sediment and dramatically damages the land. Eroded sediment is the richest part of the soil, the nutritive top soil containing most of the organic matter. Soil loss calculations provide important information because losing soil means losing expensive nutrients.

Soil degradation is influenced by land use, soil management and soil susceptibility to degradation processes. The need to maintain sustainable use of these lands requires that these ought to be monitored for the onset of land degradation so that the problem may be addressed during early stages. In order to develop technologies to combat with the problem, it is imperative to know the extent and degree of land degradation. Effect of land use systems on soil properties provides an opportunity to evaluate sustainability of land use system and thus the basic process of soil degradation in relation to land use. Further, quantification of soil erosion under various sub watersheds will help to prioritize soil conservation planning, which is expected to support effective natural resource conservation and sustainable development.

The Yadgir district with a geographical area of 5234 sq. km, located in the Northern part of the state with three taluks namely Shahapur, Shorapur and Yadgir. It lies between 16° 20' to 17° 45' North Latitude and 76° 04' to 77° 42' East Longitude. It comprises of both red and black soils differing in their morphological, physical and chemical characteristics. The district recorded about 310.5 thousand hectares of net sown area during 2008-09 and forest occupied 34 thousand hectares. The total land not available for cultivation is about 28 thousand hectares like non agricultural, barren etc. and other un-cultivable land is about 0.8 thousand hectares (Anonymous, 2009) [1].

Keeping these considerations in view, a detailed soil resource inventory at 1:8,000 scale will be carried out for Mustur micro watershed in Yadgir district to estimate soil erosion using USLE factors.

2. Material and Methods

Mustur micro watershed is located in Yadgir taluk of Yadgir district, Karnataka and having total area of 666.86 hectares lies between 77°10' 16.68" N latitude and 16° 40' 23.37" E longitudes (Fig. 1). Study area is characterized by granites and gneiss complex, belong to Archaean period. The study area includes eight soil serieses with twelve mapping units (Fig. 2). The elevation of the area ranges from 350 to 370 m above MSL. The slope in the Mustur micro watershed area is varied from very gently sloping to gently sloping (1-5 %). The slopes are having NW-E aspects. Based on the general slope, the area can be broadly classified into upland, low land and river/stream banks. Semi-arid climate prevails on Mustur micro-watershed and it belongs to north eastern dry zone of Karnataka state. Mean maximum and minimum temperatures are 33.24 °C and 21.50 °C, respectively. The average annual rainfall is 872.02 mm.

Detailed survey of the land resources in the village was carried out by using cadastral map as a base. The cadastral map shows field boundaries with their survey numbers, location of tanks, streams and other permanent features of the area.

Apart from the cadastral map, remote sensing data products from IRS and Google at the scale of 1:8000 were used in conjunction with the cadastral map to identify the landforms and other surface features. The Imageries helped in the identification and delineation of boundaries between, uplands and lowlands, water bodies, forest and vegetated areas, roads, habitations and other cultural features of the area. Apart from the cadastral maps and imageries, topo sheets of the area (1:25,000 scale) were used for initial traversing, identification of geology, landform, drainage features, and present land use and for the selection of transects to study soil profiles at village level.

3. Results and Discussion

3.1 Rain fall pattern and Rain fall erosivity factor

The highest total rainfall of 1073.3mm and least total rainfall of 727.6mm were received during the year 2010 and 2006 respectively (Table 2). The rainfall erosivity was ranged from 503.4 MJ $ha^{-1}mm^{-1}h^{-1}$ to 982.8 MJ $ha^{-1}mm^{-1}h^{-1}$, with the highest annual rainfall erosivity was recorded in the year 2008 and was lowest in the year 2006, which was resulted from rainfall effect during these years compared within (2005 to 2014) 10 years of annual rainfall with mean rainfall erosivity were 625.08 MJ $ha^{-1}mm^{-1}h^{-1}$. There was close correlation between the rainfall characteristics and soil loss, and an increase in rainfall amount is generally accompanied by an increase in soil loss (Dabral *et al*., 2008) [2].

Over the year's highest rainfall was received during the monsoon season (June to September) and followed by post monsoon season (October and November). It might be due to heavy rainfall during these months contributed by the south west monsoon forms 65 per cent of the annual rainfall. The highest and lowest monthly rainfall of 360 mm and 0.3 mm was received during 2010 (July) and 2010 (February) respectively.

Rainfall erosivity is concerned monsoon and post monsoon seasons were the most important contributor of water for the plant growth and also soil was more prone to erosion. The distribution of erosion index values clearly indicated that most of the erosive rain occurs during south west monsoon period in the micro-watershed. The effect of rainfall erosivity that monsoon and post monsoon season poses erosivity risk in the area. These results were in conformity with Ram Babu *et al.* (2004) [5] and Denis *et al*. (2014).

3.2 Erodibility factor (K factor)

The soil erodibility depends primarily on the physical characteristics of the soils *viz*., nature and amount of soil aggregates, organic matter content and particle size distribution. These physical characteristics of soils are much affected by the land use *ie.,* Cultivated soils were more prone to erosion than forest and grasslands. In this study soil erodibility was estimated based on the characteristics of the soils using the following formula developed by Wischmer and Smith (1978) [11]. Soils having higher K factor values are highly susceptible and low value are more prone to erosion.

The soil erodibility of the micro-watershed ranged from 0.23 to 0.29 (Reshma and Uday 2012) [7]. K factors have been reported by Satisha, (2008) that soils originated from granite gneiss having erodibility factor ranges from 0.28 to 0.46 and classified as very low (<0.1), low (0.1-0.2), moderate (0.2-0.3), moderately high (0.3-0.4), high (0.4-0.5) and very high erodibility (>0.5).

Based on these groupings the mapping units like BMAkC(A)1, KLUmC(A)1, KLUmB(A)1, KLUmB2, PGLmB2, MSTcB2, MSTcB2, KLRmB2, SHTcB2, SHTcC2, HSLbB2, HSLbC2 and KKRcC2 were categorized as soils having K factor in the range between 0.2< K >0.3 (Table 4) and grouped as medium category. It was observed that soils with higher content of intermediate particle-size showed more erodibility risk than the soils with higher clay and higher sand content.

3.3 Slope length and steepness factors (LS factor)

The topographic factor includes the length (L) and degree (gradient) of slope (S) affect the soil erosion by water in a landscape. For field applications the L and S factors are combined as single topographic factor. However, with the incorporation of Digital Elevation Models (DEM) into a GIS, the slope gradient (*S*) and slope length (*L*) was determined and both the factors *L* and *S* are combined to give the topographic factor LS. The precision with which it can be estimated depends on the resolution of the digital elevation model (DEM). The combined topographic (*LS*) factor was computed rather than the individual slope length and slope angle, because the upstream contributing area is generally preferred instead of individual slope lengths.

Slope gradient of class was observed in the micro-watershed ranged between 0-1 and 1-3 per cent, with major portion of the TGA was nearly level land (0-1% slope) to gently undulating land (1-3% slope). The LS combined factor was calculated from the table prepared by Renard *et al.* (1994) [6]. LS factor of mapping units ranged from 0.10 to 0.86 with a mean of 0.43. All the mapping units were below the range (0.43), except KLUmB2, SHTcC2, HSLbC2 and KKRcC2. It might be due to higher slope degree/ length and were classified as high LS factor (Table 4). The data indicates that slopes have the highest LS values because of steep slopes and lower alluvial plain had lowest LS value because of field bundings. Results were in accordance with Potdar *et al.* 2003 [3] estimated the LS value for very gently sloping (1-3%) and nearly level (0-1%) slope.

4.4 Crop cover and conservation practice factor (C and P factor)

The C factors are related to the land use, vegetation cover percentage and defined as the ratio of soil loss from specific crops to the equivalent loss from tilled, bare plots. The value of *C* depends on vegetation type, growth stage and cover percentage. Therefore, it is very important to have good knowledge concerning land use pattern in the basin to generate reliable C factor values.

The crop cover factor of the study area ranged from 0.20 to 0.38 (Table 4). Lower the C factor value better the soil cover and lower will be the soil loss. Potdar *et al.* (2003) [3] estimated the C factor values, if the area was dominated by single crop assigned C factor values of 0.35, 0.38 for double cropped fields and 0.2 for wastelands were considered for assessment of soil loss. Based on the estimated C factor values (Potdar *et al*., 2003) [3] and farmers cropping system in the study area, resulted in C factor values of 0.35 and 0.38 to respective mapping units was assigned. Results were in accordance with Purnima and Ravi, 2009 and Reshma and Uday, 2012 [7].

The conservation practice of the mapping unit ranged between 0.5 and 0.6 (Table 4). The mapping units with lower slope SHTcC2, HSLbC2 and KKRcC2 were recorded lower conservation factor value of 0.50 and conservation factor value of 0.60 in CHK3-sc-d2/Ae1, CHK3-c-d2/Ae1, CHK3-sc-d2/Ae1g1, CHK3-sc-d3/Ae1, CHK3-sl-d5/Ae1, CHK3-c-d5/Ae2 and CHK3-ls-L4/Ae1 recorded mapping units. The results were in accordance with Shinde *et al.* 2010 [9].

4.5 Prediction of soil loss and erosion risk assessment (A)

After estimating the different USLE factors (R, K, LS, C and P), the total soil loss (A) was estimated by multiplying all the factors. Annual erosion classes were made as per guidelines suggested by Singh *et al.,* 1992 for Indian conditions and were categorized into different erosion classes. Based on estimated soil loss mapping units of the watershed were falls under slight, moderate and high category.

Slight erosion was recorded in the mapping units of BMAkC (A)1, KLUmB (A)1 and KLUmC(A)1. It might be due to slight soil losses in the study area were due to the topographic position of the land coupled with varying crop, rainfall erosivity and soil erodibility.

Mapping units like KLUmB2, PGLmB2, MSTcB2, KLRmB2, SHTcB2 and HSLbB2 recorded moderate soil losses were as a result of cultivation in areas without proper soil conservation measures, denuded uplands with little or no vegetation and cultivated fallow on moderate slope. The severe soil losses in SHTcC2, HSLbC2 and KKRcC2 mapping units were attributed to steepness of slopes coupled with cultivation during monsoon seasons under rainfed agriculture. In addition denuded uplands without vegetation, cultivated fallow on steeper slopes, farmers cultivating crops on moderate to steeper slopes without proper soil conservation measures and poorly managed forest cover were observed in these areas. In agriculture and scrub lands, the lack of complete ground cover was the main reason for the high soil loss.

5. Conclusion

The study reveals that there is a close relationship between physiography and soils. The formation of the diverse group of soils can be attributed to the variation in topography, causing erosion, leaching, sedimentation and other pedogenic process modified by water table. Slight erosion was recorded in the mapping units of BMAkC (A) 1, KLUmB (A)1 and KLUmC (A)1. It might be due to slight soil losses in the study area were due to the topographic position of the land coupled with varying crop, rainfall erosivity and soil erodibility. Mapping units like KLUmB2, PGLmB2, MSTcB2, KLRmB2, SHTcB2 and HSLbB2 recorded moderate soil losses were as a result of cultivation in areas without proper soil conservation measures, denuded uplands with little or no vegetation and cultivated fallow on moderate slope. The severe soil losses in SHTcC2, HSLbC2 and KKRcC2 mapping units were attributed to steepness of slopes coupled with cultivation during monsoon seasons under rainfed agriculture. In addition denuded uplands without vegetation, cultivated fallow on steeper slopes, farmers cultivating crops on moderate to steeper slopes without proper soil conservation measures and poorly managed forest cover were observed in these areas. In agriculture and scrub lands, the lack of complete ground cover was the main reason for the high soil loss.

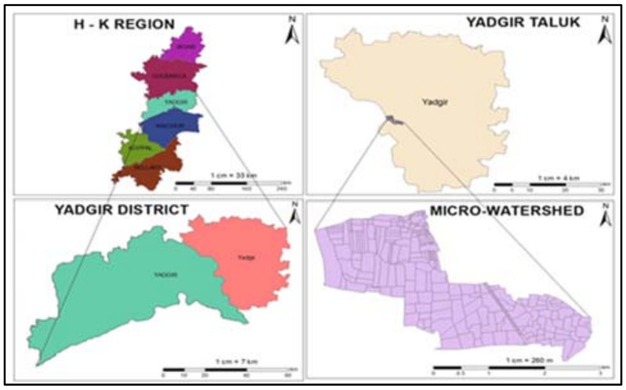

Fig 1: Location of the study area

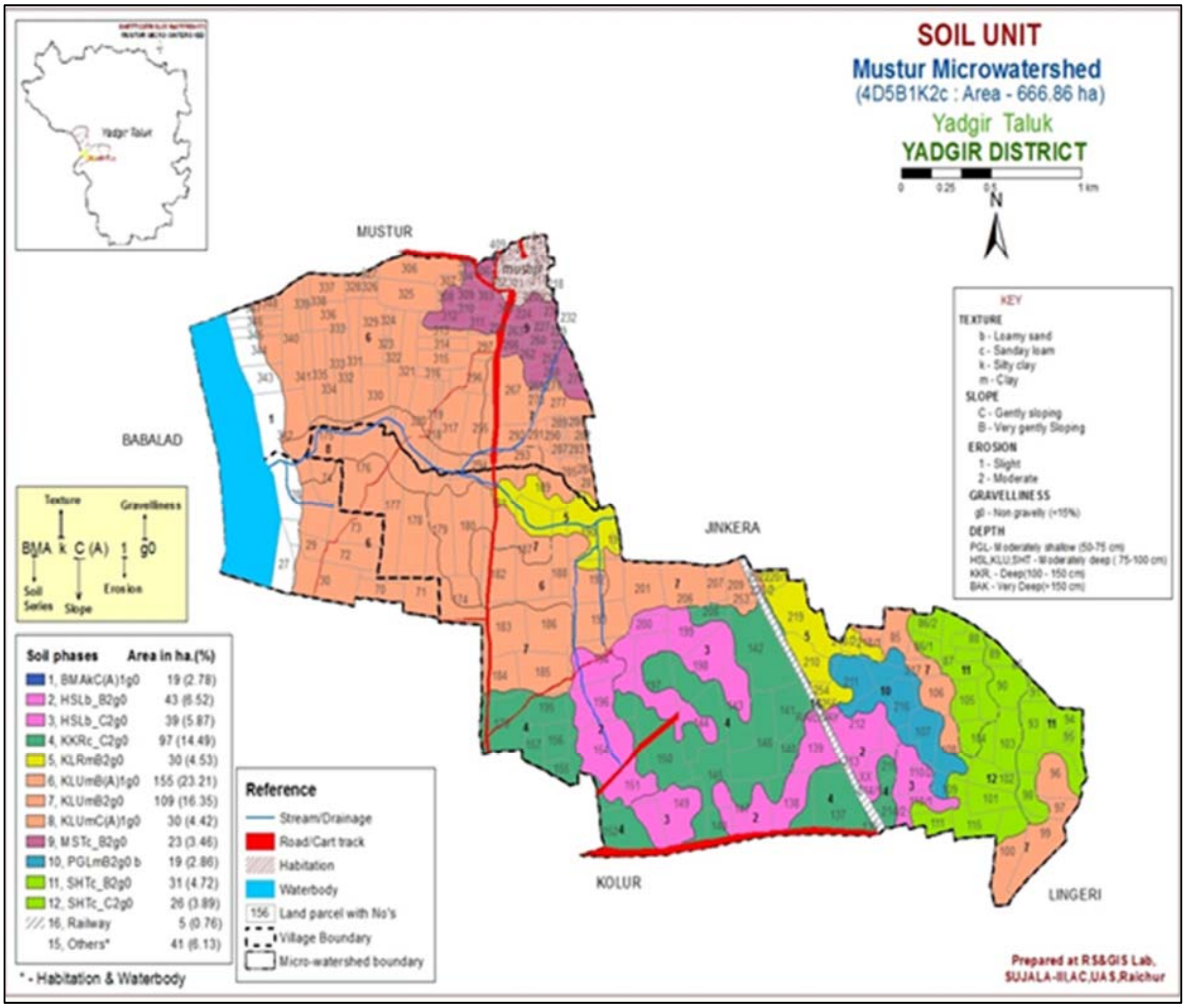

Fig 2: Soil phase map of Mustur microwatershed

Table 1: Area distribution of Soil mapping units of Rastampur-3 microwatershed

Name of the series	Mapping units	Area (ha)	Area covered (%)
Bheema series	BMAkC(A)1	19	2.78
Hosahalli series	HSLbB2 & HSLbC2	82	12.39
Killanakeri series	KKRcC2	97	14.49
Kolur series	KLUmC(A)1, KLUmB(A)1 & KLUmB2	294	43.98
Koiloor series	KLRmB2	30	4.53
Mustur series	MSTcB2	23	3.46
Pagalapur series	PGLmB2	19	2.86
Shettigeri series	SHTcB2 & SHTcC2	59	8.61

Table 2: Mean monthly 15 years rainfall distribution of Mustur micro-watershed (2000-2014)

Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Mean monthly
January	0.0	3.6	13.6	0.0	0.0	18.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	2.5
February	0.0	0.0	3.0	0.0	0.0	13.0	0.0	0.0	0.0	0.0	0.3	9.0	0.0	0.0	0.0	1.7
March	0.0	0.0	0.0	61.3	0.0	0.0	32.4	0.0	174.0	3.9	0.0	0.5	0.0	0.0	19.5	19.4
April	6.4	55.6	12.0	0.0	24.5	52.8	1.5	28.2	0.0	10.4	1.2	40.0	75.5	11.0	16.0	22.3
May	46.0	2.0	55.0	0.0	94.2	10.7	107.0	26.9	0.0	28.7	49.9	76.0	11.5	16.5	61.0	39.0
June	222.1	76.4	20.4	51.2	44.1	65.2	94.6	281.6	91.0	99.6	114.9	84.0	106.5	98.0	50.5	100.0
July	129.3	106.2	117.2	130.6	125.7	190.1	99.6	100.4	86.3	30.7	360.4	261.5	242.5	181.5	241.5	160.2
August	230.9	234.7	88.0	193.6	35.7	261.9	72.8	93.2	131.4	233.7	209.2	191.0	101.5	204.0	285.5	171.1
September	84.6	278.5	95.4	147.6	137.6	218.2	203.6	162.6	185.8	216.1	194.9	66.0	101.5	374.0	109.5	171.7
October	103.8	176.8	120.3	20.9	61.3	182.0	91.7	32.8	63.6	254.1	103.1	59.0	116.0	120.5	77.0	105.5
November	0.0	5.6	1.0	0.0	0.0	0.0	24.2	10.4	64.4	29.7	33.6	2.0	11.0	6.0	29.0	14.5
December	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	4.2	3.6	0.0	0.0	0.0	1.0	1.0
Total Rf	823.1	939.4	525.9	605.2	523.1	1011.9	727.4	736.1	803.3	911.1	1073.4	789.0	766.0	1011.5	890.5	809.1
R factor	569.4	649.6	364.9	419.7	362.9	696.6	503.3	508.0	555.7	603.5	744.1	544.7	529.7	696.3	616.7	557.5

Table 3: Mean Monthly Climatic data of Mustur MWS.

Sl. No	Months	Temp-Max	Temp-Min	RH-8.30AM	RH-5.30PM	Average Rain fall(mm)
1	January	27.93	16.23	63.23	41.33	2.03
2	February	33.47	18.91	56.80	36.72	2.23
3	March	36.99	20.98	46.84	29.65	23.03
4	April;	39.79	25.28	47.34	29.89	23.66
5	May	40.33	26.57	53.40	34.12	38.82
6	June	35.33	24.86	68.32	50.73	108.59
7	July	31.21	23.04	81.23	67.13	179.45
8	August	31.11	23.31	80.04	67.44	178.42
9	September	31.21	23.04	81.23	67.13	183.22
10	October	31.29	21.57	76.00	63.07	109.98
11	November	30.36	18.53	70.63	56.37	21.03
12	December	29.91	15.68	66.27	45.67	1.56
Mean of 10 years		33.24	21.50	65.94	49.10	872.02

Table 4: Soil erosion potential of Mustur micro watershed

Mapping Units	R(mm)	K	LS	C	P	A (Tons/Ha/Yr)
BMAkC(A)1	557.50	0.25	0.19	0.38	0.6	6.04
KLUmC(A)1	557.50	0.23	0.20	0.38	0.6	5.85
KLUmB(A)1	557.50	0.26	0.10	0.35	0.6	3.04
KLUmB2	557.50	0.26	0.44	0.35	0.6	13.39
PGLmB2	557.50	0.26	0.35	0.35	0.6	10.65
MSTcB2	557.50	0.27	0.35	0.35	0.6	11.06
KLRmB2	557.50	0.26	0.41	0.35	0.6	12.48
SHTcB2	557.50	0.29	0.31	0.38	0.6	11.43
SHTcC2	557.50	0.25	0.77	0.35	0.5	18.78
HSLbB2	557.50	0.28	0.41	0.35	0.6	13.44
HSLbC2	557.50	0.25	0.86	0.35	0.5	11.99
KKRcC2	557.50	0.25	0.85	0.38	0.5	22.51

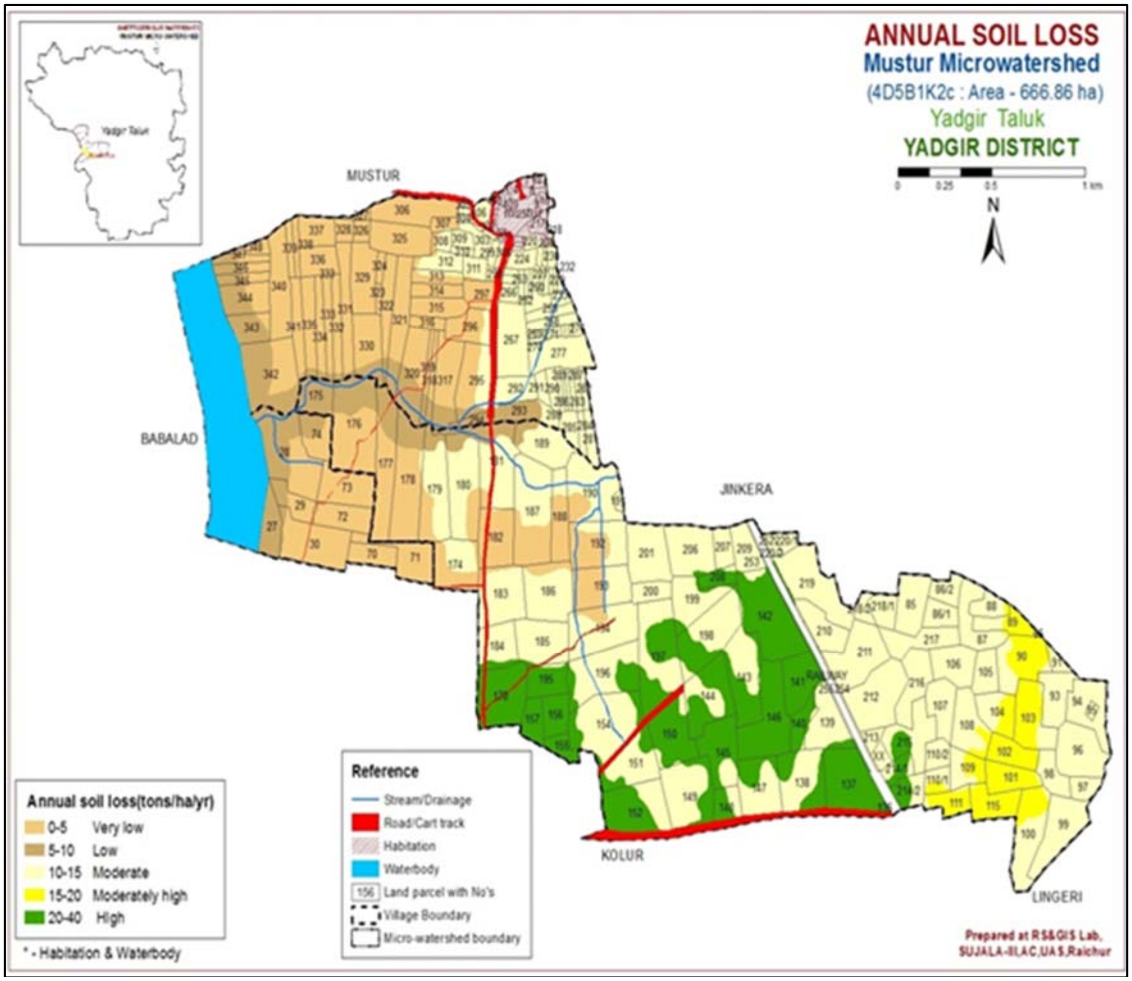

Fig 3: Annual soil loss of Mustur MWS

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