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Estimation of Soil Loss in Three Agro-climatic Zones of Belagavi District, Karnataka Using USLE and GIS

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Estimating soil loss using Universal Soil Loss Equation (ULSE) and geographical information system (GIS) was attempted in three agro-climatic zones of Belagavi district in north Karnataka. The study area included one micro-watershed in each agro-climatic zone *viz*., Yadawad in northern dry zone (zone 3), Hukkeri in northern transitional zone (zone 8) and Khanapur in hilly zone (zone 9). Slope gradient map was prepared from SRTM-DEM and the R, K and LS factors in USLE were determined from the established equations. Information on conservation was obtained from field survey. Using a grid-based approach, soil loss map was prepared in GIS environment. The predicted soil loss varied among the agro-climatic zones. The soil loss was very low to low (< 10 t ha^{-1}) in the entire Yadawad micro-watershed area, whereas, it was moderately high to high (15-40 t ha^{-1}) in 32% of Hukkeri and 19% of Khanapur micro-watersheds due to slope and land use characteristics. Despite heavy rainfall in Khanapur watershed, the soil loss risk was more for Hukkeri watershed suggesting that factors other than rainfall played an important role in rendering the soil loss.

Key words: Agro-climatic zones, erosion risk assessment, GIS, soil loss, USLE

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. Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing serious loss of top soil. Eroded sediment is the top soil rich in nutrients and organic matter. Soil loss calculations provide important information because losing soil means losing expensive nutrients. Problems associated with soil erosion, movement and deposition of sediment in rivers, lakes and estuaries persist through the geologic ages in almost all parts of the earth. But the situation is aggravated in recent times with increasing human interventions with the environment. Subsistence farming practices, increasing population and high density of livestock contributing to unsustainable land use; erratic rainfall and accelerated water erosion of soil have led to degradation of land in Karnataka. It is reported that 49% of total geographical area (TGA) of Karnataka (93,978 km^2) is degraded due to water erosion (NAAS 2010). Erosion is a problem associated with non-arable land and 54.5% of non-arable lands are severely eroded. Soil erosion due to water is a serious problem in semi-arid and sub-humid areas of India. Universal soil loss equation (USLE) was derived empirically from approximately 10,000 plot-years of data (Wischmeier and Smith 1978) and may be used to calculate erosion at any point in a watershed that experiences net erosion. The equation has become a useful tool for planners to keep soil erosion within permissible limits of soil loss tolerance by managing slope length, terrace spacing and cropping practices (Singh *et al*. 1981). Water induced soil erosion is a very dynamic spatial phenomenon. The information on the spatial extent of erosion risk area and its severity are pre-requisites for soil conservation planning and watershed management programmes. While conventional methods yield point-based information, geographical information system (GIS) integrates the spatial analytical functionality for spatially distributed data on soil loss to identify the priority areas in terms of soil erosion intensity so as to evolve appropriate conservation management strategies.

Belagavi district in Karnataka has three distinct agro-climatic zones varying from semi-arid to sub-

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Table 1. Particulars of watersheds studied

Sl. No.	Micro-watershed and code	Area (ha)	Agro-climatic zone	Mean annual rainfall (mm)	Geology	Slope classes
1.	Yadawad 4D7D3I1a	572.9	Northern dry zone (zone 3)	507.6	Basalt	Level (0-1%) to Nearly level (1-3%)
2.	Hukkeri 4D7D7D2a	498.3	Northern transition zone (zone 8)	658.4	Basalt	Nearly level to gently sloping (5-8%)
3.	Khanapur 4D7C9L1c	586.2	Hilly zone (zone 9)	1859.1	Peninsular gneiss	Nearly level to gently sloping (5-8%)

humid. The properties of soils across this climatic gradient, including the erosion properties, have been studied by Prabhavati *et al*. (2017). Because there were few studies (Amara *et al*. 2013) on assessment of soil erosion using USLE, it was of interest to make an erosion risk assessment of the soils across the climatic gradient using USLE. This paper discusses the results of such an attempt.

Materials and Methods

The Belagavi district is located east of the Western Ghats and is situated in the north-western part of Karnataka state. Three micro-watersheds were selected representing the three agro-climatic zones of the district, the salient features of which are presented in table 1. These micro-watersheds were selected from the watershed atlas of Karnataka prepared by the Karnataka State Remote Sensing Application Centre (KSRSAC 2004) on 1:10000 scale. The codes furnished by them is presented in table 1.

The location of micro-watersheds is shown in fig. 1. The climate of the Yadawad and Hukkeri micro-watersheds is semi-arid and that of Khanapur micro-watershed is sub-humid.

The rainfall erosivity (R) factor was derived using the relationship between rainfall erosivity index and annual/seasonal rainfall, developed by Ram Babu *et al*. (2004) with the data available from 123 meteorological observatories in India.

$$Y = 81.5 + 0.380X \ (r = 0.90) \qquad \ldots(1)$$

$$Y = 71.9 + 0.361X \ (r = 0.91) \qquad \ldots(2)$$

where, Y is the average annual erosion index (t ha^{-1} cm^{-1}) in equation (1) and average seasonal erosion index in equation (2), X is the average annual rainfall (mm) in equation (1) and average seasonal rainfall (mm) in equation (2). The average annual rainfall data of nearest meteorological stations for the Yadawad, Hukkeri and Khanapur micro-watersheds were collected from Arabhavi, Sankeshwar and Khanapur, respectively were used in the calculation of R-factor.

Soil erodibility (K) factor was estimated by an empirical equation developed by Wischmeier *et al*. (1971) and an attribute table was prepared for different soil types using the relation:

$$100K = 2.1 \times 10^{-4} \ (12\ OM)\ M^{1.14} + 3.25\ (S2) + 2.5\ (P3) \qquad \ldots(3)$$

where, OM = organic matter (%), M = (% silt + % very fine sand) (100 - %clay), S = soil structural code, P = profile permeability class.

L, the slope-length factor, is the ratio of soil loss from the field slope length to that from a 22.04 m of slope length under identical conditions. The slope steepness factor (S), is the ratio of soil loss from the field slope gradient to that from a 9% slope underotherwise identical conditions. Digital elevation model (DEM) was developed based on Shuttle Radar Topography Mission (SRTM) data of 90 m resolution, which was available at http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp. The slope gradient map and LS factor was generated using this DEM. The LS-factor was derived as described by Gitas *et al*. (2009) using the calculation of the S (slope steepness) and L (slope length) factors:

$$L = 1.4\ (A_S/22.13)^{0.4} \qquad \ldots(4)$$

$$\text{and } S = (\sin \beta / 0.0896)^{1.3} \qquad \ldots(5)$$

where, A_S: catchment area (m2) and β: slope angle in degrees.

The IRS P-6 LISS-IV data with a resolution of 5.8 m was used to delineate different land use/land cover (LUCC) categories for the studied micro-watersheds. The cover and management factor, C, is the ratio of soil loss from land use under specified conditions to that from continuously fallow and tilled land. The support practice factor (P), is the ratio of soil loss with a support practice like contouring, strip cropping, or terracing to that with straight-row farming up and down the slope. Information on conservation practices (P) followed in various land use/land cover classes was collected through field survey. Crops under agricultural land use were wheat,

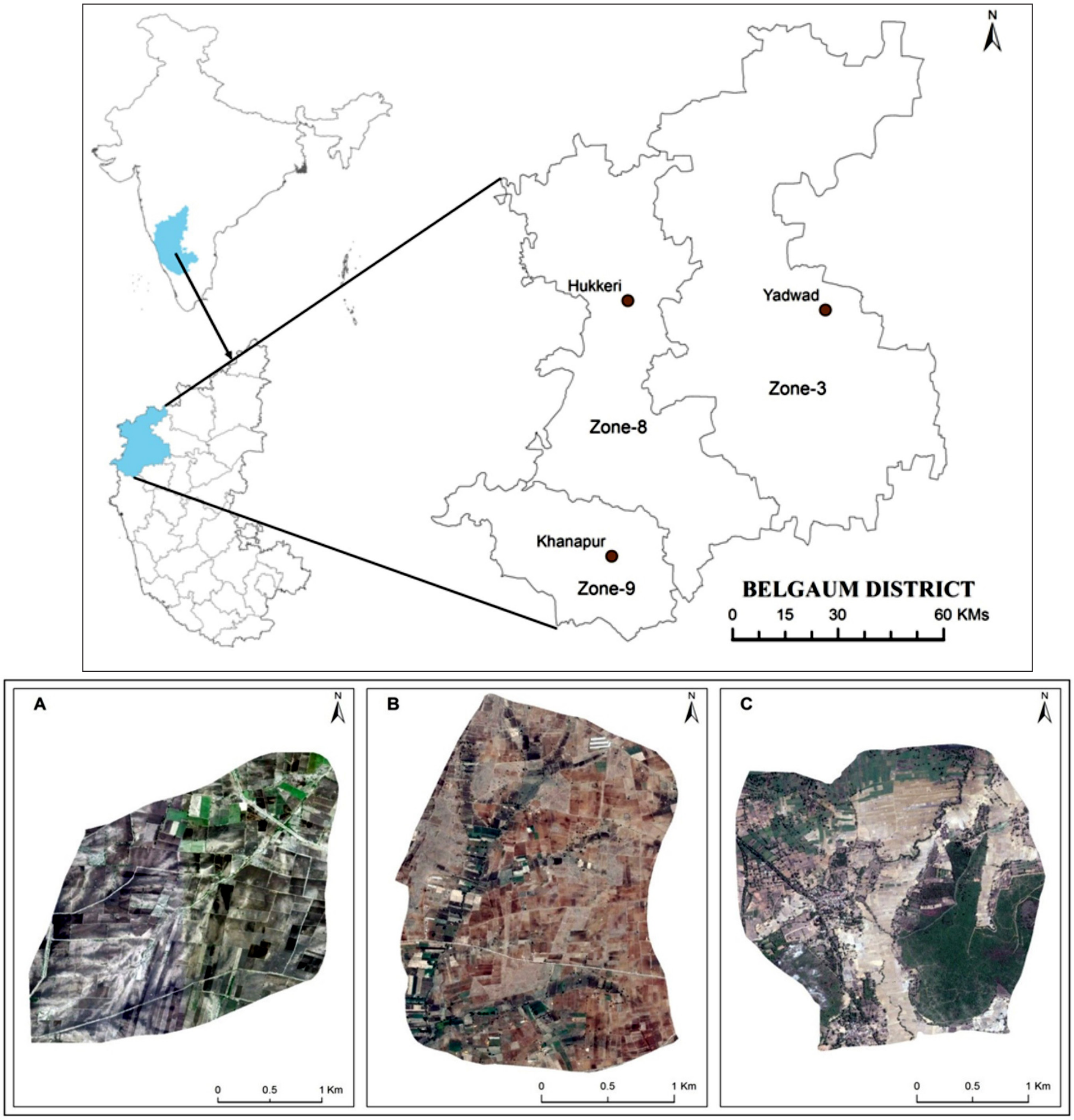

Fig. 1. Location of micro-watersheds and their satellite images [Yadawad (A), Hukkeri (B) and Khanapur (C)]

sorghum and safflower in Yadawad micro-watershed; maize, jowar, soybean, redgram in Hukkeri micro-watershed; drill sown rice, sugarcane and banana plantation in Khanapur micro-watershed. Based on this information, C and P values for each land use/ cover class were assigned based on the literature (Singh *et al*. 1981; Narain *et al*. 1994; Yadav and Sachdev 2008; Suresh Kumar and Kushwaha 2013).

The USLE map was prepared in the spatial domain using GIS, *i.e.*, all USLE factors were derived as raster (grid) geographic layers after processing the original data and then they were multiplied together for calculating the final risk map. The methodology used was the implementation of the USLE in a raster GIS environment (or grid-based approach) using the formula:

$$A = RKLSCP \quad \ldots(6)$$

where, A = average annual soil loss in t ha^{-1} yr^{-1}; R = rainfall erosivity index for a given location; K = soil erodibility factor; L = slope length factor; S = slope steepness factor; C = cover and management factor; P = conservation or support practice factor.

Predicted soil loss was classified into soil erosion risk classes *viz*., very low (0–5 t ha^{-1} yr^{-1}), low

Table 2. R-factor and average and seasonal rainfall in the micro-watersheds

Sl. No.	Micro-watershed	R-factor		Average rainfall (mm)	
		Annual (R_a)	Seasonal (R_{sw})	Annual	Seasonal
1	Yadawad	241.8	164.2	422.0	255.7
2	Hukkeri	413.4	314.5	873.4	672.1
3	Khanapur	820.3	683.1	1944.3	1693.2

(5–10 t ha^{-1} yr^{-1}), moderate (10–15 t ha^{-1} yr^{-1}), moderately high (15– 20 t ha^{-1} yr^{-1}), high (20–40 t ha^{-1} yr^{-1}) and very high (>40 t ha^{-1} yr^{-1}) as per Singh *et al.* (1992).

Results and Discussion

R-factor

The annual R-factor presented in the table 2 revealed that the annual erosivity index (Ra) for Khanapur micro-watershed (820.34) was higher compared to that of Hukkeri (413.38) and Yadawad (241.85) micro-watersheds due to higher average annual rainfall received in Khanapur. These values are used to predict average annual soil loss from the respective micro-watersheds. The seasonal R-factor (Rsw) values also followed a similar trend as that for annual for the thee micro-watersheds and contributed 67.9, 76.1 and 85.7 per cent to the annual R factor values, respectively in Yadawad, Hukkeri and Khanapur micro-watersheds which is identical to seasonal rainfall received as percent of total. The distribution of erosion index values clearly indicated that most of the erosive rain occurs during south west monsoon period in all the three micro-watersheds. The results were in conformity with Ram Babu *et al.* (2004).

K-factor

The K-factor used for the estimation of average annual soil loss in the selected micro-watersheds are presented in table 3. The Yadawad micro-watershed had shown K-factor value ranging between 0.148 and 0.224 for clay soil type. Whereas, K-factors observed were 0.136, 0.147 and 0.220 for sandy loam, sandy clay loam and clay loam soil types, respectively in Hukkeri micro-watershed. The K-factor values observed were 0.168 and 0.199 for sandy clay and clay soil types in Khanapur micro-watershed. Organic matter in the soil influences the aggregation of soil particles into stable soil structure. Soils with less than 3.5 per cent organic matter are considered to be erodible (Evan 1980). Higher K-factor (0.224) was observed in Yadawad micro-watershed indicating higher susceptibility of these soils to erosion. The reason might be the low organic carbon status observed in surface samples of the entire micro-watershed.

LS factor

The slope steepness classes observed in Yadawad micro-watershed were 0-1 and 1-3 per cent. The slope classes observed in Hukkeri micro-watershed were 0-1, 1-3, 3-5 and 5-8 per cent with major portion of the TGA was very gently sloping

Table 3. K-factor for different soils of the selected micro watersheds

Sl. No.	Soil texture	Clay (%)	Silt (%)	Very fine sand (%)	Organic matter (%)	Structure code#	Permeability code@	K-factor
Yadawad								
1	Clay	56.2	15.7	9.1	0.71	4	6	0.224
2	Clay	62.0	15.9	5.7	0.80	4	6	0.203
3	Clay	51.9	14.0	5.6	0.74	2	6	0.148
Hukkeri								
4	Sandy loam	13.6	13.4	14.0	0.54	2	1	0.136
5	Sandy clay loam	20.5	14.0	8.8	0.67	3	2	0.147
6	Clay loam	28.3	21.0	9.2	0.98	3	4	0.220
Khanapur								
7	Sandy clay	35.6	11.1	9.7	0.72	4	3	0.168
8	Clay	45.5	13.2	7.3	0.94	4	5	0.199

2 fine granular; 3 coarse granular; 4 blocky

@ 1 rapid 2 mod. to rapid; 3 moderate; 4 slow to moderate ; 5 slow; 6 very slow

Table 4. C and P factors for different land use classes in the micro-watersheds

Sl. No.	Micro-watershed	Land use / Cover type	C factor	P factor
1	Yadawad	Agriculture	0.5	0.5
2	Hukkeri	Agriculture	0.4	0.4
		Open scrub	1.0	0.6
3	Khanapur	Agriculture	0.4	0.3
		Sheet rock (stony waste land)	1.0	1.0
		Degraded forest	0.4	1.0

land (1-3% slope) followed by level land (0-1% slope) (Fig. 3). In Khanapur micro-watershed strongly rolling (8-15% slope) and gently rolling (5-8% slope) land was observed in area with sheet rock. Strongly undulating (3-5% slope) topography was observed in land surrounding the sheet rock. The rest of the land was under 0-1 and 1-3 per cent slope classes (Fig. 4).

C and P factor

The land use land cover (LULC) classes obtained from remote sensing imagery were used for assigning C and P factor values. The entire area of Yadawad micro-watershed (572.93 ha) is under agricultural land use. The Hukkeri micro-watershed was under agricultural land use and open scrub land in 40.1 and 59.9 per cent of the total geographical area (498.38 ha), respectively. Forest land use occupied an area of 151.20 ha accounting for 25.8 per cent of the total geographical area (586.24 ha) of Khanapur micro-watershed. It appeared as bright red to dark red tone in the imagery because of the foliage and very dense canopy associated with moisture. Agricultural land use was observed in 69.3 per cent area with sheet rock in 4.9 per cent of TGA.

The C value assigned to agricultural land use in Yadawad watershed was 0.5 (Table 4). The C value of 0.4 and 0.6 was assigned to agricultural land and open scrub land in Hukkeri micro-watershed. Whereas, C values assigned to agricultural land and open forest in Khanapur micro-watershed were 0.3 and 0.4, respectively. The C factor value of 0.4 was assigned to forest land use in Khanapur micro-watershed due to reason that it is open forest and sheet erosion is observed from remote sensing imagery. The C value assigned was in accordance with Yadav and Sachdev (2008) who assigned C value between 0.30 and 0.50 for the degraded forest. As such no mechanical or biological measures are adopted in forest area; a conservation practice (P) factor value of 1.0 was assigned to forest land and lands with scrub/rock outcrop. Based on field management practices such as field bunds in Yadawad micro-watershed, terrace farming in Khanapur micro-watershed and across slope farming in Hukkeri micro-watershed, P factor values were assigned.

Prediction of soil loss and erosion risk assessment

The predicted soil loss in the selected micro-watershed areas using USLE was presented in table 5. Major portion (85.2%) of Yadawad micro-watershed recorded average annual soil loss < 5 t ha^{-1} yr^{-1} as it constitutes nearly level lands with slope <1%. Nalatwadmath *et al*. (2006) also observed very slight (0–5 t ha^{-1} yr^{-1}) and slight (5–10 t ha^{-1} yr^{-1}) soil erosion in the flat areas in the Deccan plateau of Karnataka. The entire micro-watershed is categorised into very low and low erosion risk rating class which might be because of low Ra factor observed owing to low amount of average annual rainfall and seasonal rainfall received in that area and slope being <1% in major area (Fig. 2).

The spatial distribution of high soil erosion risk class observed in Hukkeri micro-watershed is associated with areas of gently undulating topography (3-5% slope) and lowlands with very gently undulating topography (1-3% slope). The reason might be the steepness of slope and intensive agriculture in lowland. The results of the study are in

Table 5. Estimated rate of soil erosion in the selected micro-watersheds

Sl. No.	Average annual soil loss (t ha^{-1} yr^{-1})	Soil erosion risk classes	Yadawad		Hukkeri		Khanapur	
			Area (ha)	% of TGA	Area (ha)	% of TGA	Area (ha)	% of TGA
1	<5	Very low	487. 9	85.2	173.8	34.9	207.5	35.4
2	5 -10	Low	85.0	14.8	87.6	17.6	241.7	41.2
3	10-15	Moderate			79.5	15.8	23.2	4.0
4	15-20	Moderately high			107.9	21.7	14.7	2.5
5	20-40	High			50.6	10.1	94.5	16.1
6	>40	Very high					4.6	0.8
	Total		572.9	100	498.4	100	586.2	100.0

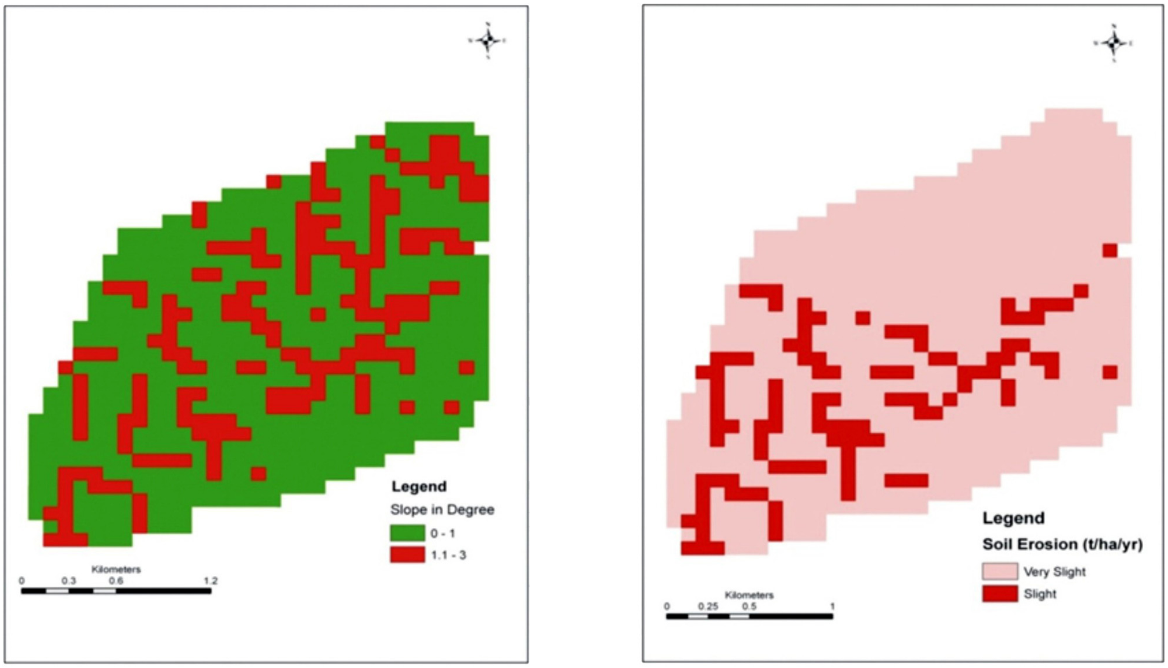

Fig. 2. Slope class map and soil erosion risk map of Yadawad microwatershed

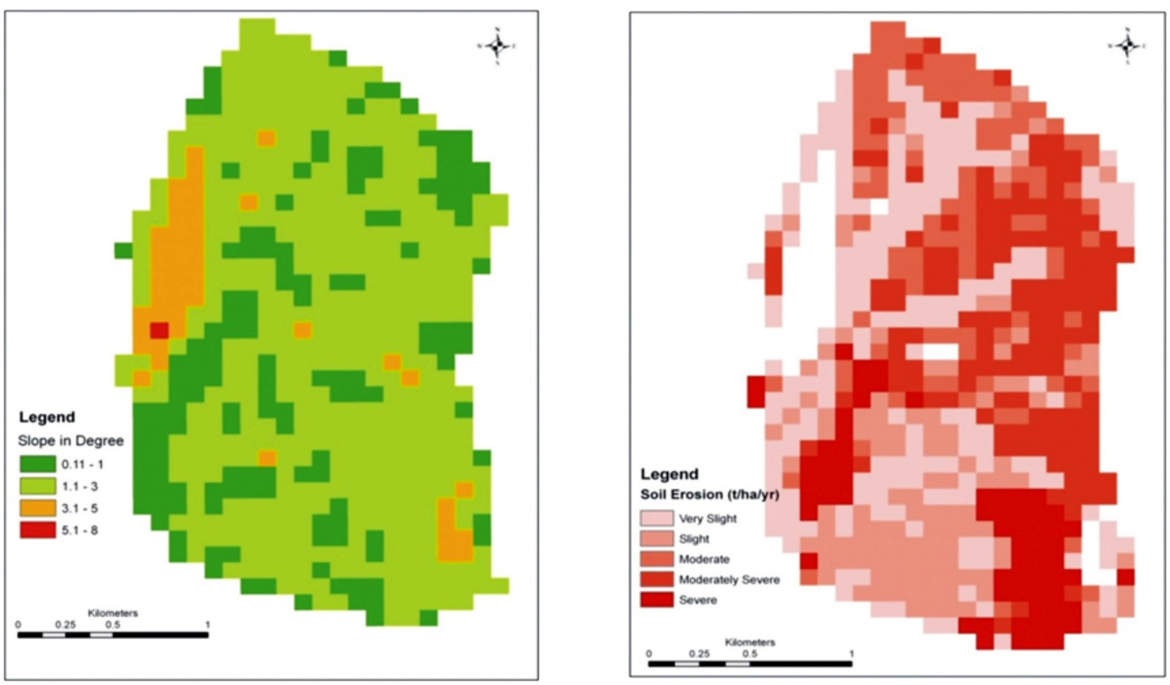

Fig. 3. Slope class map and soil erosion risk map of Hukkeri microwatershed

agreement with those reported for steep slope (Lo 1995; McConkey *et al*. 1997; Sikka *et al*. 2003) and for intense cultivation (Singh *et al*. 1992; Lufafa *et al*. 2003). The nearly level land with < 1 per cent slope had shown very low soil erosion risk (34.9% of TGA). Whereas, gently undulating land (1-3% slope) was observed to render low soil erosion risk (17.6% of TGA) under agriculture land and moderate (15.8% of TGA) to moderately high soil erosion risk (21.7% of TGA) in open scrub land due to poor soil cover (Fig. 3).

The results of the mapping of potential soil erosion scenario in Khanapur micro-watershed revealed that about 16.1% of the TGA (94.5 ha) was

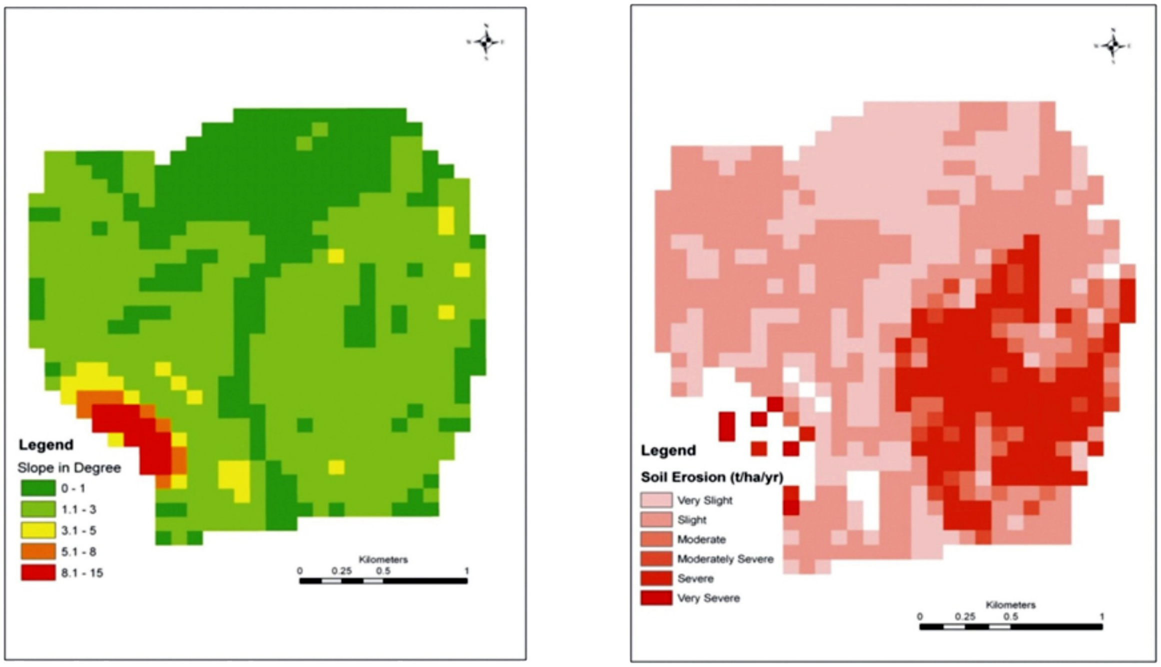

Fig. 4. Slope class map and soil erosion risk map of Khanapur microwatershed

affected by high erosion risk class (Fig. 4). The high erosion was because of intense rainfall, gently undulating topography and land use/ land cover. Of all the factors, the high Ra of 820.34 in Khanapur micro-watershed appears to be an important factor contributing to the amount of soil eroded. Very low soil erosion risk class observed in Khanapur micro-watershed was with slope class of 0-1%. Whereas, gently undulating land (1-3% slope) was observed to cause 5-10 t ha^{-1} yr^{-1} of annual soil loss (low soil erosion risk) under agricultural land and moderate, moderately high and high soil erosion risk under forest land use. The reason might be the terrace farming being practiced in the agricultural land in that area as well as human intervention in the forest area without adopting any conservation measures. Only 0.79% of the TGA was subjected to very high erosion risk and it was concentrated in sheet rock area. This may be attributed to high rainfall intensity and steeper slopes in that area.

Conclusions

High intensity rains during pre-monsoon season when there is no crop cover, low organic carbon in these soils and and lack of adoption of soil conservation measures by farmers are the common causes of soil erosion across the zones. The overlapping influence of different components of USLE determine the soil loss. The soil loss was more in transition zone (zone 8) than in hilly zone (zone 9) due to slope and land use characteristics despite higher rainfall in zone 9. The effect of rainfall can be best evaluated by selecting sites of watersheds that share similar conditions of all other variables in the USLE. Therefore, within and across a agro-climatic zone, the intensity of soil erosion depends on the factors used in USLE and can not be generalized with respect to agro-climatic zone alone.

References

Amara, D., Patil, P.L., Dasog, G.S. and Manjunath, M.V. (2013) Rainfall erosivity (R-factor) estimation for Singhanalli-Bogur micro-watershed in Northern Transition zone of Karnataka. *Research Journal of Agricultural Sciences* **4**, 644-647.

Evan, R. (1980) Mechanics of water erosion and their spatial and temporal controls: An empirical viewpoint. In *Soil Erosion,* (M.J. Kirkby and R.P.C. Morgan, Eds.) Chichester: Wiley, pp. 109-128.

Gitas, I.Z., Douros, K., Minakoul, C., George N.S. and Christos, G.K. (2009) Multi-temporal soil erosion risk assessment in Chalkidiki using a modified USLE raster model. *EARSeL eProceedings* **8**, 40-52.

KSRSAC (2004) Watershed Atlas of Karnataka. Karnataka State Remote Sensing Application Centre. http://www.karnataka.gov.in/ksrsac/documents/Watershed%20Atlas.pdf

Lo, K.F.A. (1995) Erosion assessment of large watershed in Taiwan. *Journal of Soil and Water Conservation* **50**, 180-183.

Lufafa, A., Tenywan, M.M., Isbiyeb, M., Majaliwaa, M.J.G. and Woomerc, P.L. (2003) Prediction of soil erosion in a Lake Victoria basin catchment using GIS-based universal soil loss mode. *Agricultural Systems* **76**, 883-894.

McConkey, B.G., Nicholaichuk, W., Stepphun and Reimer, C.D. (1997) Sediment yield and seasonal soil erodibility for semi-arid crop land in western Canada. *Canadian Journal of Soil Science* **77**, 33-40.

Nalatwadmath, S.K., Rama Mohan Rao, M.S., Adhikari, R.N., Shiva Prasad, C.R., Krishnan, P., Patil, S.L., ManaMohan, S. and Bhaskar Rao, P. (2006) Soil erosion map of Karnataka. *Indian Journal of Soil Conservation* **34,** 207-213.

Narain, P., Khybri, M.L., Tomar, H.P.S. and Sindhwal, N.S. (1994) Estimation of run-off, soil loss and USLE parameters for Doon valley. *Indian Journal of Soil Conservation* **22**, 129–132.

NAAS (2010) *Status and Spatial Distribution of Degraded and Wastelands of India.* National Academy of Agricultural Sciences, NASC Complex, New Delhi.

Prabhavati, K., Dasog, G.S., Sahrawat, K.L., Patil, P.L. and Wani, S.P. (2017) Characterization and classification of soils from three agro-climatic zones of Belagavi district, Karnataka. *Journal of the Indian Society of Soil Science* **65**, 1-9.

Ram Babu, Dhyani, B.L. and Kumar, N. (2004) Assessment of erodibility status and refined iso-erodent map of India. *Indian Journal of Soil Conservation* **32**, 171-177.

Sikka, A.K., Selvi, V., Singh, D.V., Madhu, M., Mohanraj, R., Krishnan, P., Srinivas, S., Ramesh, M. and Nair, K.M. (2003) Soil erosion map of Kerala state, India. *Indian Journal of Soil Conservation* **31**, 127-130.

Singh, G., Ram Babu and Chandra, S. (1981) Soil loss prediction research in India. *Technical Bulletin* T-12/D-9. Central Soil and Water Conservation Research and Training Institute, Dehradun, India, 70p.

Singh, G., Ram Babu, Narain, P., Bhusan, L.S. and Abrol, I.P. (1992) Soil erosion rates in India. *Journal of Soil and Water Conservation* **47**, 97-99.

Suresh Kumar and Kushwaha, S.P.S. (2013) Modeling soil erosion risk based on RUSLE-3D using GIS in a Shivalik sub-watershed. *Journal of Earth System Sciences* **122**, 389–398.

Wischmeier, W.H., Johnson, C.B., Washington, D.C. and Cross, B.V. (1971) A soil erodibility Nomograph for farmland and construction sites. *Journal of Soil and Water Conservation* **26**, 189-196.

Wischmeier, W.H and Smith, D.D. (1978) *Predicting rainfall erosion losses – A guide to conservation planning*. Agriculture Handbook No. 537, USDA.

Yadav, R.P. and Sachdev, C.B. (2008) Assessment of soil erosion in Haryana state. *Journal of the Indian Society of Soil Science* **56**, 99-105.

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