Nature Environment and Pollution Technology
An International Quarterly Scientific Journal
p-ISSN: 0972-6268
e-ISSN: 2395-3454
Vol. 19 No. 1 pp.339-348 2020

Original Research Paper Open Access

Imperious Approach Towards Justifiable Strategic Lake Sediment Regulation

Shekhar Salunke* and Balbhim Chavan**
*Dept. of Environmental Science, Solapur University, Solapur, Maharashtra, India
** Dept of Environmental Science, Dr. B.A.M. University, Aurangabad, Maharashtra, India

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 03-07-2019
Accepted: 29-08-2019

Key Words:
Erosion
Sedimentation
Control strategies
Restoration actions

ABSTRACT

Lakes are extremely appreciated for the ecological, aesthetic and recreational values supporting rich biodiversity. As such, their preservation is of supreme importance. A global common problem of sedimentation that eventually seems to be responsible for eutrophication should be immediately attended to, before the degradation begins, since the restoration measures are expensive and may go beyond control. Erosion causes detachment, transportation and deposition of sediments and is the prime source of contamination where it accumulates in lakes and interrupts the ecological processes and functioning in the lake ecosystem, hence it is important to determine the risk to design management strategies for control. For the present investigation, thematic layers slope identification, NDVI, LULC, lineament density and RUSLE were employed to compute spatially distributed erosion and contaminant sources for the lake Ekrukh of Solapur district of Maharashtra State, India. The research identifies five hazardous erosion zones as; low, moderate, high, very high and severe, through the applied model and dictates formulation and implementation of innovative control strategies preventing soil and water (surface) pollution. The Soil Erosion in Maharashtra, Technical Bulletin, 2001 (Challa et al. 2001) was also referred for the studies.

INTRODUCTION

Exploration and delineation of erosion zones is important to design control strategies to prevent erosion at lakes, since the main problem faced by the lakes across the globe is siltation. Massive quantities of sediments add to the lake waters resulting in decreased water retaining capacity and increased nutrients that deteriorates the ecological health of the lakes. The eutrophic conditions of the lake indicate the presence of abundant aquatic weeds along the shoreline. As a lake or reservoir becomes rich in nutrients, it develops dense populations of planktonic algae that usually dominate. Such intense populations create unacceptable taste and odour problems, along with an increase in organic loading of the lower layers as the algae complete their life cycle and fall to the bottom. This reduces the aesthetic value of the lakes. Aside from the aesthetic deterioration of water quality, eutrophication presents many other difficulties for the aquatic life. Such water is less palatable, algae-laden water has high chlorine and coagulant demands. It often reduces filter runs, necessitating excessive backwash; it may also require certain specific forms of taste and odour control such as activated carbon, chlorine, dioxide, or permanganate. This increases the cost of lake management programmes. Certainly, a preventive measure calls an immediate attention rather than to cure later. As such the siltation through soil erosion should be controlled as an action with respect to the phrase 'prevention is better than cure'. For the reason, it is necessary to ascertain the erosion possibilities at the lakes and to define the control measures to avoid siltation. The aim can be better achieved by operating various methodological processes through Remote Sensing and Geographic Information System (GIS) techniques. As such, to define restoration strategies, a study was undertaken to understand the erosion sources and status of the lake Ekrukh. Previously our studies indicated two models to prevent or avoid siltation at the lake and were assessed to be effective in reducing the silt loads at the lake waters. However, to determine the sites of installations for the designed models to reduce silt loading, Lake Ekrukh was assessed for the significant sites of silt loading.

MATERIALS AND METHODS

Digital Data

The conduct of the investigative approach included the use of LANDSAT-7. Enhanced Thematic Mapper (ETM+) digital data was used, during fieldwork 200 Ground Control Points (GCPs) were collected with attributes using a handheld Global Positioning System (GPS) receiver with an expected error of 3-4 m. This data was used for georeferencing and ground truthing, as well as for accuracy assessment of the imageries and DEMs. Soil samples were also collected for the Revised Universal Soil Loss Equation (RUSLE).

NDVI Classification

NDVI (Normalized Difference Vegetation Index) at red wavelengths and lower reflectance at near-infrared wavelengths was used to differentiate between healthy, stressed vegetation and sparse or non-vegetated surface. High NDVI was classified as healthy and growing vegetation and low NDVI was considered to locate areas that absorb red and near-infrared radiations, like water. The analysis of the topography was done by constructing. NDVI was used for identification of bare and sparse vegetation surface, where infiltration of contaminated water is more. Using the reflectance images of band 3 (red) and band 4 (Near InfraRed – NIR) NDVI map of the study areas were generated as followed by Joshi et. al (2004).

LULC Classification

Land Use/Land Cover (LULC) classification map was generated for analysis using ERDAS Imagine 9. Ground truth and topographic sheets were used for accuracy assessment. Digital Terrain Model (DTM) was created with the help of DEM data by creating terrain surface and adding attributes and colour code to each pixel. A classified slope map was prepared with the spatial analyst module in ArcGIS environment. Soil erosion zones were identified along with the accumulation points.

DTM

DTM was carried out for the basins of study areas for the interpretation of geomorphology of the area, to delineate lineaments and to generate digital drainage from DEM, represented in the respective figures for the DTM of the basins under the study areas.

Ground Data

Regarding the ground data, during fieldwork 200 ground control points (GCPs) were collected with attributes using a handheld global positioning system (GPS) receiver with an expected error of 3-4 m. This data was used for georeferencing and ground truthing, as well as for accuracy assessment of the imageries and DEMs. Soil samples were also collected for the Revised Universal Soil Loss Equation (RUSLE). Filled and finished Shuttle Radar Topographic Mission (SRTM) data of 3arc second WRS-2 of 90 m resolution was downloaded from the GLCF website. Two tiles of height data (SRTM_ff03_p145r048.tifand SRTM_ff03_p146r047.tif) of WRS-2 have been used for the pre-processing and generation of the DEM followed by mosaic and image subset of the study area clipped from the whole scene. This work analyses LANDSAT 7 ETM+ and SRTM DEM data for the generation of erosional and contamination zones in the study areas. The flow chart has been applied for the lake studies.

RUSLE Parameters

All the RUSLE parameters determined for the study area were either in spatial format and/or in numerical format. The results of R, K, and C factors are assigned to each pixel of DEMs of the basin, as there is no variation in the results. The variables in the results of LS and P factors assigned to DEMs of the basin is presented in, for LS-factor 7 and 8 for P factor. The spatial maps were integrated using RUSLE

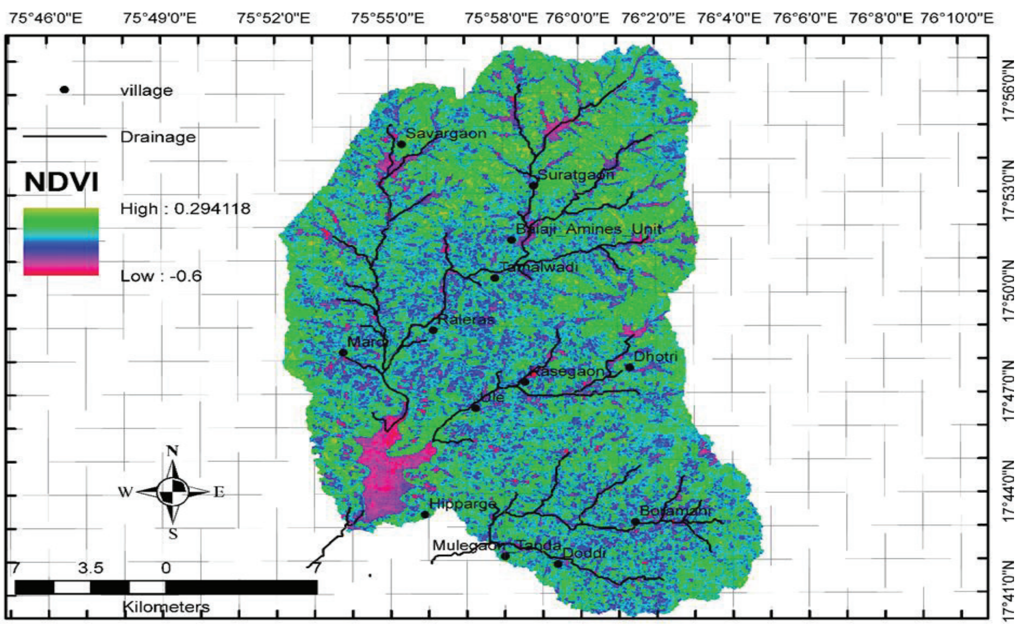

Fig. 1: NDVI classification of Ekrukh Lake basin.

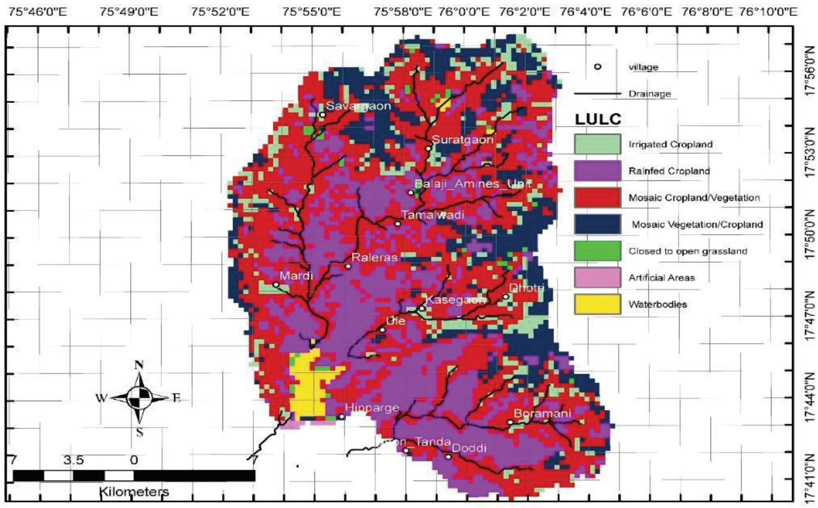

Fig. 2: LULC classification of Ekrukh.

empirical formula for the lake, basin. In the present study, LANDSAT-7 Enhanced Thematic Mapper (ETM+) digital data was used. Landsat-7 ETM+ as it is a multispectral scanner that provides a multispectral image data set in eight spectral bands. Pre-processing of images was carried out by ortho-rectification and geometrical correction. A Landsat 7 ETM+ image (path 146/ row 047 and path 145/ row 048) of Solapur and surroundings was acquired, for the study. The digital data was radiometrically corrected to remove atmospheric effects. Further the digital numbers of the pixels were converted to reflectance to understand reflectance of the objects on the earth. The soil credibility factor K of the USLE is evaluated according to soil texture classification using the values from Stewart et al. (1975) considering that the organic matter content is less than 4%.

RESULTS AND DISCUSSION

NDVI

Low NDVI values (Fig. 1) in all three lakes indicate water bodies while higher values dictate healthy vegetation. The NDVI of Ekrukh Lake Basin shows healthy vegetation (green colour), either cultivated or non-cultivated, are located along its periphery. The blue coloured area, even near to lake, indicates presence of non-healthy vegetation around Tamalwadi, Mardi, Raleras, Kasegaon and Ule may be because of contaminated sediments transported from upper reaches of the streams.

LULC

Fig. 2 represents LULC classification of Ekrukh. The area denoted as artificial area is settlement zone. The area is considered as a source of contamination and assigned a highest number in statistical and weighted overlay analysis.

DTM

DTM was carried out for the Ekrukh lake basin for the interpretation of geomorphology of the area, to delineate lineaments and to generate digital drainage from DEM. Fig. 3 represents the DTM of the basin in the study area.

Geomorphology of The Area

The study area falls in the sub-basin of Seena River, which is a tributary of Bhima River. The Bhima River itself is a tributary of Krishna River. The Krishna River has developed its basin in regional scale. Krishna River generated its plain by depositing transported load of sediments. The study area is a small part of the Krishan River basin. Geomorphologically three basins of the area are lying in the almost plain to rolling topography. Variations in the elevation are very less. This topography represents peneplain stage of erosion cycle. The streams in the area have reached their graded stage and they are flowing over the sediments deposited by their own.

Two small hillocks are located in the NE direction of Ekrukh basin at an elevation of 589 m above mean sea level (Fig. 3). The elevation difference is about 139 m spatially distributed in the 378.6309 sq. km. area of the Ekrukh basin. Geomorphologically these small isolated hillocks are inselbergs, ruminants of hills after erosion. The slopes on these hills are sources of sediments for erosion and transportation.

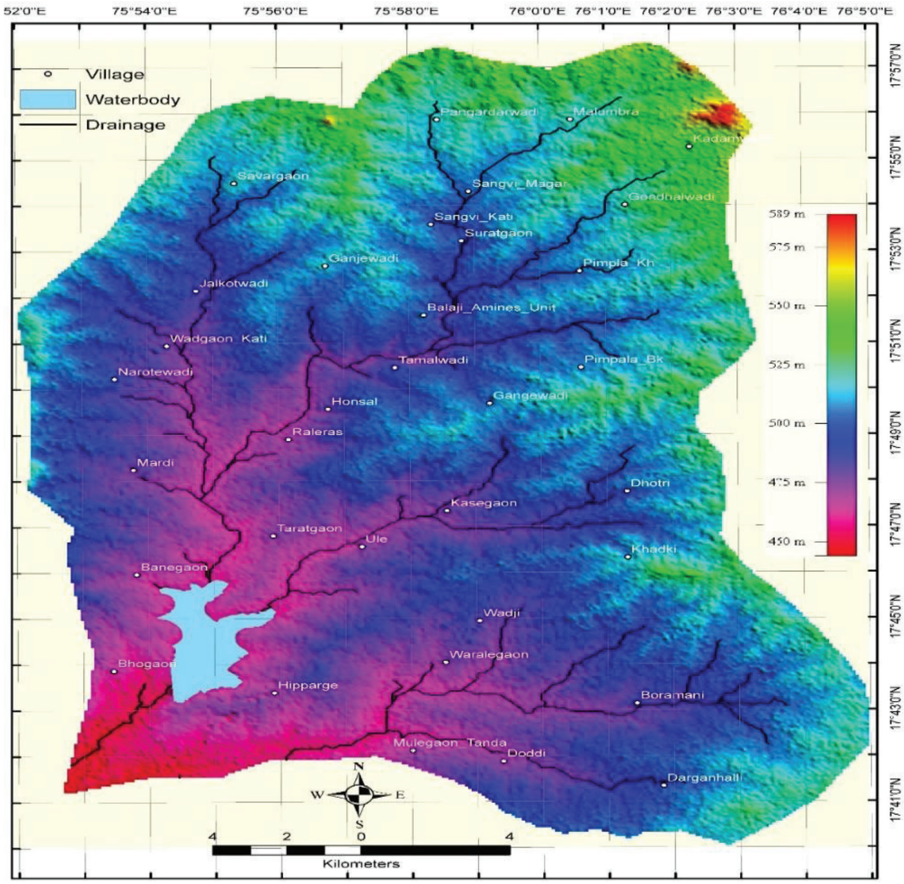

Fig. 3: Digital Terrain Map of the Ekrukh Lake basin.

Drainages and Lineaments

Digital drainage network extraction and analysis has been carried out using DEM. Digital data (SRTM DEM) and non-digital data (1:50,000 scale topographic maps) were used to extract channel networks. An extraction of the channel network from digital data was carried out in the ArcGIS 9.3 environment using D8 algorithm of ArcHydromodule. Both river 'basins' and 'watersheds' are areas of land that drain to a water body, such as a lake, stream, river or estuary. In a river basin, all the water drains to a large river. The term 'watershed' is used to describe a smaller area of land that drains to a smaller stream, lake or wetland. Figs. 4 and 5 exhibit digital drainages of Ekrukh basin. Stream order calculated using Strahler Stream Order (Strahler 1952) in hydrography deals with the hierarchy of streams from the source (or headwaters) downstream.

Ekrukh basin shows dendritic pattern of the stream, indicating plain, uniform and homogeneous surface on which these streams are flowing. The general slope of the area is towards south. The accumulation points (marked by 'x') are the sites of accumulation of water and sediments transported by headwaters. These accumulated water and sediments are further driven away when the kinetic energy of the stream increases. The increase in kinetic energy of the stream depend on the factors like increase in velocity, amount of water due to heavy rainfall, steepness of slopes, amount of vegetation, amount of load to be carried etc.

The lineaments are the surface expressions of weaknesses in the underlying rock. These are mainly fracturing, faults, dykes, jointed zones etc. The lengths of lineaments vary from 1.833303 km to 9.529145 km in Ekrukh basin, while it varies from 1.760651 km to 7.959094 km. These lineaments are deeply incised in the ground and are connected to underground fractures or joints, which are yet not reached on the surface. Therefore, water from rainfall or surface runoff infiltrate into subsurface and travel through this underground network of fractures and settled below the water table. Water table is a level, at subsurface, below which all the fractures, cracks, voids, fissures, crevices and joints are filled with

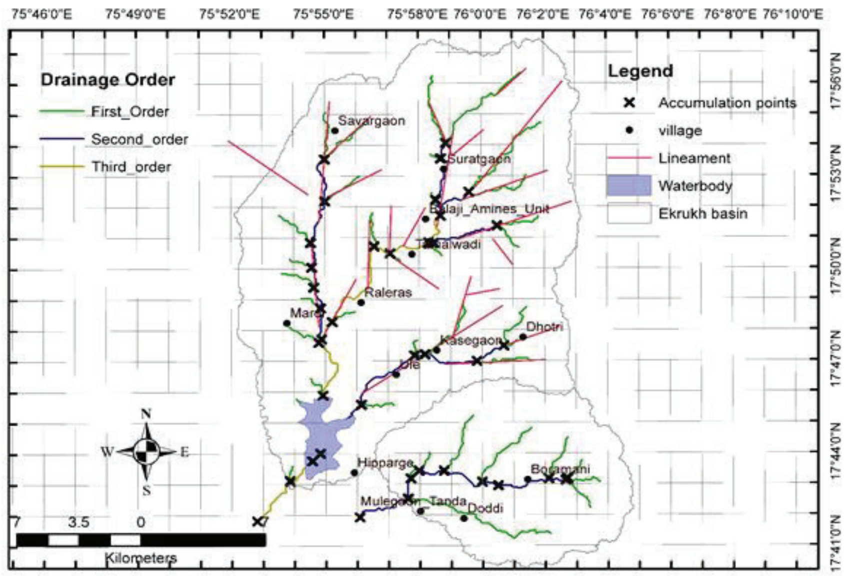

Fig. 4: Watershed boundary, drainages and lineaments of Ekrukh basin.

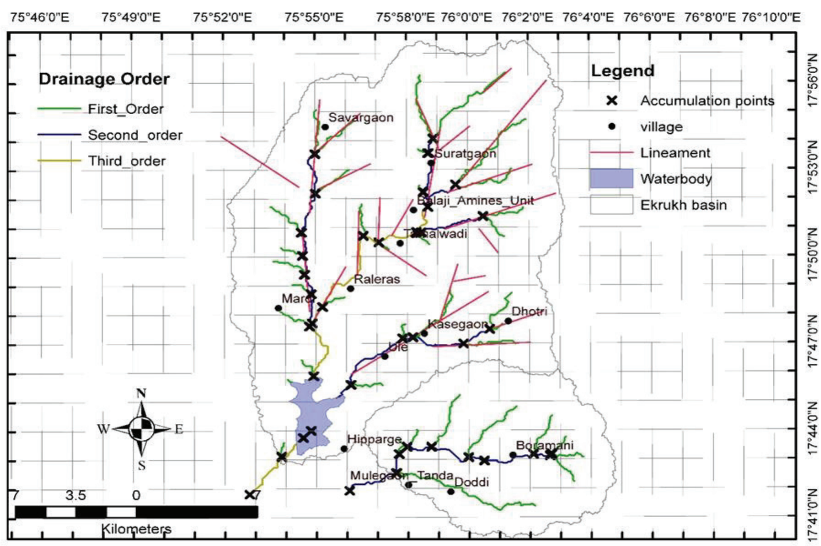

Fig. 5: Watershed boundary, drainages and lineaments of Ekrukh basin.

water. At downstream direction, when water table intersects with ground surface, the groundwater sips out in the form of spring, seepage or lake. Hence, the contamination can occur on the surface during transportation, at the accumulation points and during the infiltration through fractures and joints. This contaminated water can come up in the lakes or in the major river where these tributaries joins. Fig. 5 shows both the lineaments and accumulation points. The most possible contamination sites are intersection of lineaments and accumulation points. The density of such intersections occurs at Tamalwadi, industry of Balaji Amine units and Mardi in the Ekrukh basin. Streams flowing from Shanti Nagar and combination of stream and lineament trending NE-SW are the sources of contamination of groundwater.

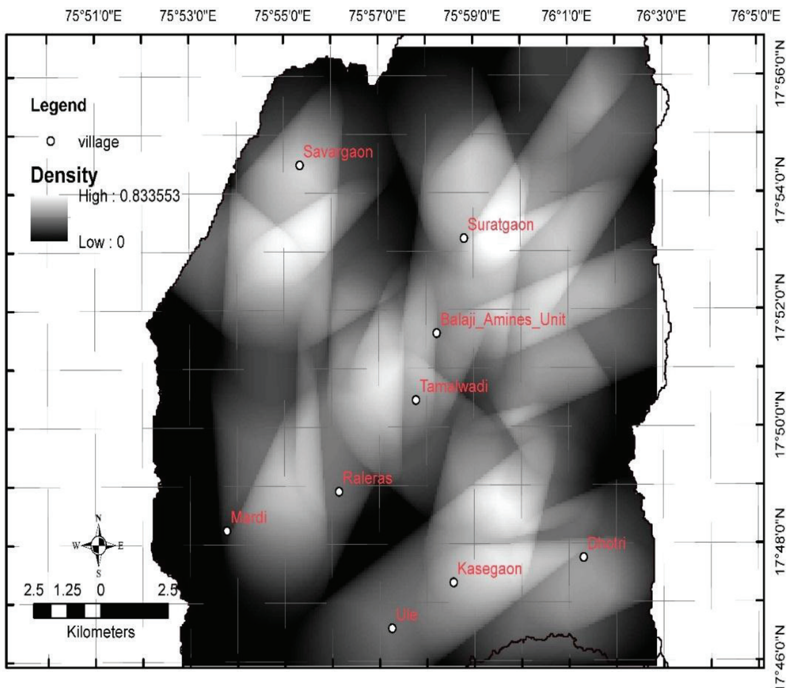

Fig. 6: The integration of data of lineaments density and buffer of accumulation points of Ekrukh basin.

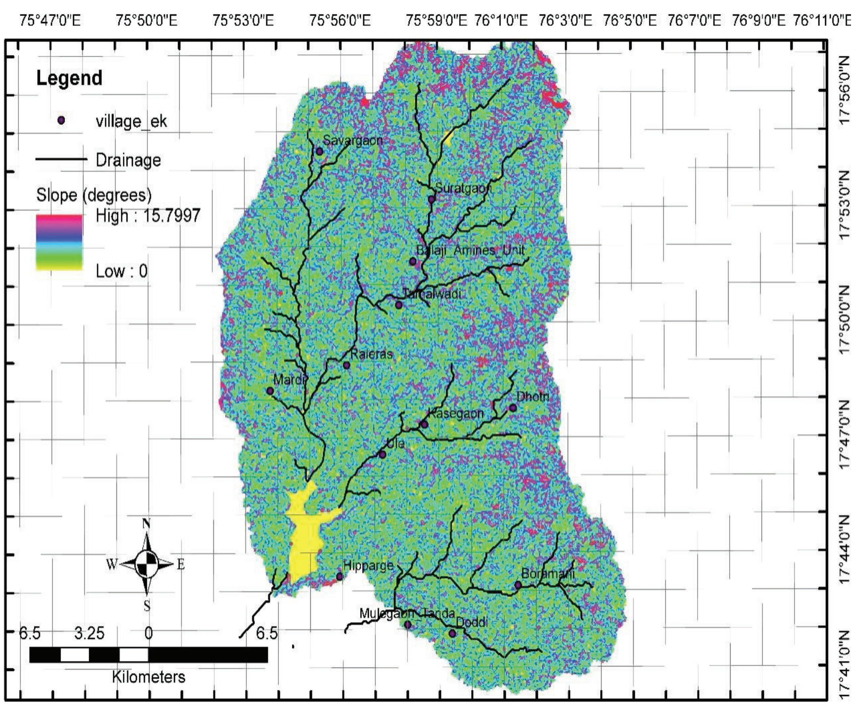

Fig. 7: Slope map of the Ekrukh Lake basin.

To understand and delineate erosion hazard zones of such intersection of accumulation points and lineaments, integrated maps lineament density (2 km periphery) and buffer zone (2 km) around accumulation points have been prepared for Ekrukh Lake basin. Fig. 6 shows the integration of data of lineaments density and buffer of accumulation points of the Ekrukh basin.

The bright coloured zones reveal high values that indicate higher possibilities of contamination hazards, while dark pixels indicate lower ordered contamination hazard zones. The accumulation points are processed for the buffer analysis in ArcGIS. The buffer was set for 100 m periphery around each accumulation points. There are more possibilities of accumulation of contaminants in these points from their area around 100 m radius. The overlapping buffers are more hazardous for contamination.

Slope

Slope is one of the controlling factors of erosion. The slope (also called grade, incline, gradient, pitch or rise) of a physical feature or landform refers to the tangent of the angle of that surface to the horizontal. It is a special case of the slope, where zero indicates horizontality. The slope angle is maximum as 90 degrees. The slope accelerates erosion as it increases the velocity of the flowing water. Table 1 gives the classes.

A slope of 9° is ideal for the soil erosion, greater than 9° causes increase in rate of erosion of soil (Challa et. al 1995 and 2001). The Ekrukh Lake basin exhibit highest slope angle of 15.7997° of moderately steep slope. Slopes of moderately steep category are situated at the northern border and eastern border of the basin at Dhotri and Kasegaon villages. Strongly sloping grounds are bordering the whole basin. These slopes are prone to weathering and erosion and can be classified as hazardous for erosion. The slope angle in this basin has very little effect on erosion, but these may take a vital part in contamination of surface flow of water.

Table 1: Slope classes.

Class	Slope range (in %)	Slope Class
1	0 - 1	Nearly level
2	1 - 3	Very gently sloping
3	3 - 5	Gently sloping
4	5 - 10	Moderately Sloping
5	10 - 15	Strongly Sloping
6	15 - 25	Moderately steep to steep Sloping
7	25 - 33	Steep Sloping
8	33 - 50	Very steep
9	>50	Extremely steep slope

Source: Soil Survey Manual (Anonymous 1971)

Soil Erosion Zones by RUSLE Analysis

The goal of this study was to test the RUSLE model in the study area for prediction of erosion risk. All the RUSLE parameters determined for the study area were either in spatial format and/or in numerical format (Table 2). The results of R, K, and C factors are assigned to each pixel of DEMs of all basins, as there is no variation in the results. The variables in the results of LS and P factors assigned to DEMs of all basins are presented in Fig. 7 for LS-factor and Fig. 8 for P factor. The spatial maps were integrated using RUSLE empirical formula Equation (1) and presented in Fig. 9 for Ekrukh basin.

Topographic influence on LS factor can be noted in LS-factor map of three basin. The slope mainly controls this factor. Light coloured pixels indicate areas of high LS factor and these pixels are spatially distributed in the basin. Clusters of high LS factor occur at eastern border of the basin as well as at the highest elevation in the basin. General slope direction of the basin is east to west; hence, LS factors are clustered near eastern side of the basin. This eastern region can be considered as high erosion zone. The high LS factor is well conglomerated around the drainage lines. The spatial distribution of P-factor presented in maps 8, where P-factors are found to be aligned well with the LS-factors of Ekrukh basin.

The annual average soil loss estimated using RUSLE for the study area are 25.8593 tonnes/ha/year for Ekrukh Lake basin. The zones of higher soil erosion are linearly accumulated around the drainage line in Ekrukh basin. It indicates that the major drainage lines are eroding more than its tributaries. The soil loss for Ekrukh basin is 25.8593 tonnes/ha/year. The K factor for soils for various organic carbon contents (%) was studied and calculated using guidelines provided by Stewart et al., (1975) (Table 3),

Referring the Table 3a., the rate of soil erosion for Ekrukh lake basin (25.8593 tonnes/ha/year) is severe.

Weighted Overlay Analysis

Table 2: Results of RUSLE parameters.

RUSLE factors	Ekrukh Lake values
R-Factor	412.809
K-Factor	0.25
LS-Factor	0.0 - 2.15
C-Factor	0.43
P-Factor	0.270 - 0.50

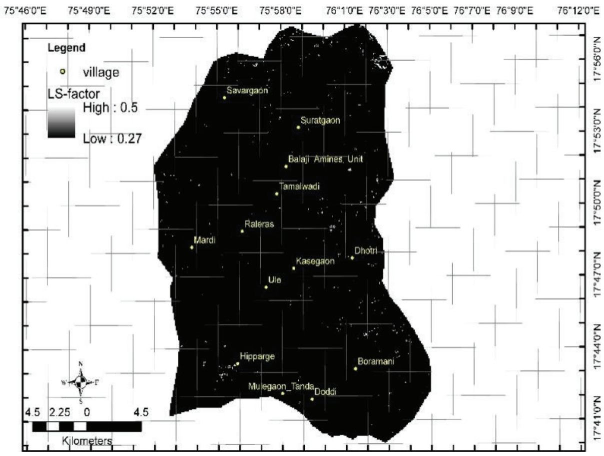

Fig. 7: LS factor map of Ekrukh basin.

Fig. 8: P factor map of Ekrukh basin.

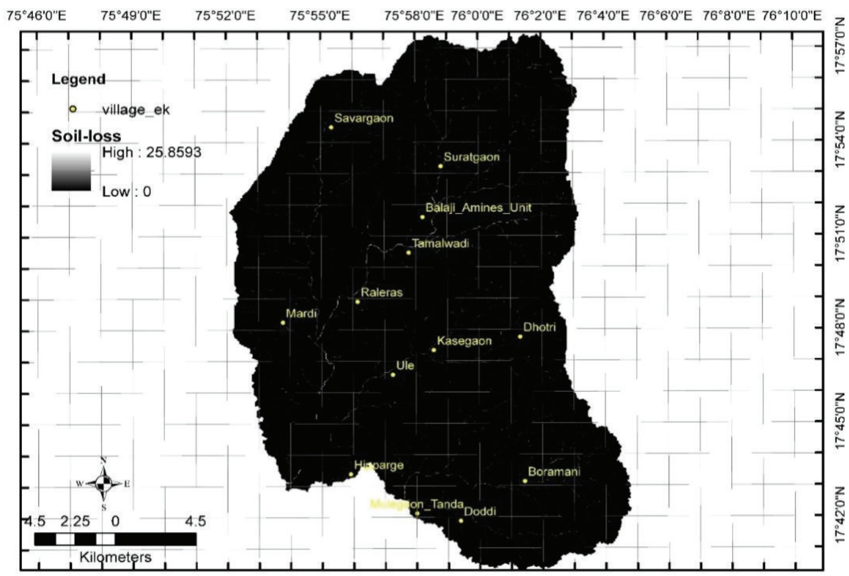

Fig. 9: Average annual soil loss map and zones of erosion of Ekrukh basin.

Weighted overlay is a type of suitability analysis that helps in analysing site conditions based on multiple criteria. Weighted overlay analysis allows to combine, weight and rank several different types of information and visualize it so one can evaluate multiple factors at once.

As with all overlay analysis, in weighted overlay analysis, to define the problem, breaking of the major model in to sub-model is essential. Hence, layers of the sub-models are created and weights are assigned to their attributes. The raster layers for each sub-models (basins) generated are: 1. Slope, 2. NDVI, 3. LULC, 4. lineament and accumulation point's density and 5. soil erosion model by RUSLE. Since the input criteria layers will be in different numbering systems with different ranges, to combine them in a single analysis, each cell for each criterion is reclassified into a common preference scale such as 1 to 5, with 5 being the most affinity for erosion. An assigned preference on the common scale implies the phenomenon's preference for the criterion. The preference values not only should be assigned relative to each other within the layer but should have the same meaning between the layers. For example, if a location for one criterion is assigned a preference of 5, it will have

Table 3. Soil Erodibility Factor K-factor (after Stewart et al. 1975)

K for Organic Matter Content (%)							
Textural Class	<0.5	2	4	Textural Class	<0.5	2	4
Sand	0.05	0.03	0.02	Loam	0.38	0.34	0.29
Fine sand	0.16	0.14	0.10	Silt loam	0.48	0.42	0.33
Very fine sand	0.42	0.36	0.28	Silt	0.60	0.52	0.42
Loamy sand	0.12	0.10	0.08	Sandy clay-loam	0.27	0.25	0.21
Loamy fine sand	0.24	0.20	0.16	Clay loam	0.28	**0.25**	0.21
Loamy very fine sand	0.44	0.38	0.30	Silty clay-loam	0.37	**0.32**	0.26
Sandy loam	0.27	0.24	0.19	Sandy clay	0.14	0.13	0.12
Fine sand yloam	0.35	0.30	0.24	Silty clay	0.25	0.23	0.19
Very fine sandy loam	0.47	0.41	0.33	Clay		0.13-0.2	

Table 3a.: Classification of Soil loss annual erosion.

Sr. No.	Class	Amount (tonnes/ha/year)
1	Very slight	<5 tonnes/ha/year
2	Slight	5 – 10 tonnes/ha/year
3	Moderate	10 – 15 tonnes/ha/year
4	Moderately severe	15 – 20 tonnes/ha/year
5	Severe	20 – 40 tonnes/ha/year
6	Very severe	40 – 80 tonnes/ha/year
7	Extremely severe	>80 tonnes/ha/year

the same influence on the phenomenon as a 5 in a second criterion. For example, in a slope model of the study area, steeper slopes are prone to erosion and hence they are assigned to 5 preference. As the slopes become levelled, they are prone to deposition, they are assigned decreasing value of preference as 1. Hence, each pixel of every model is assigned numbers from 1 to 5 according their properties of affinity to erosion. In the process of reclassification, raster models of slope, higher slopes (>10), in NDVI, lower values, in LULC, settlement and open bare spaces, in density models, higher values and in RUSLE model, higher values were assigned to preference level 5.

For the processing of weighted overlay, five raster images of reclassification generated for each basin (1) slope, 2) NDVI, 3) LULC, 4) lineament and accumulation point's density and 5) soil erosion model by RUSLE) were further processed and presented in the Fig. 10, for Ekrukh, basin. The results of hazard zonation mapping are classified as 1. low, 2. moderate, 3. high, 4. very high, and 5. severe. The results of RUSLE analysis are corroborating the results of hazard zonation mapping. Fig. 10 explains hazard zonation map of possible zones of erosion and zones of infiltration of contaminants in Ekrukh basin. The severe erosion rate occurs at Suratgaon village and very high rate of erosion occurs around Savargaon, Suratgaon, Balaji Amines Unit, Kasegaon and Dhotri.

CONCLUSIONS

The indication of non-healthy vegetation beyond the peripheral region towards associated villages is a result of contaminated sediments transported through the streams, directs to consider development of vegetation as protective shield against soil erosion to prevent sedimentation. The slopes of two small hillocks located in the NE direction of Ekrukh basin at elevation of 589 m above mean sea level are sources of sediments for erosion and transportation call for the attention to install slope protection methods. The density of such intersections occurs at Tamalwadi, industry of Balaji Amine units and Mardi in the Ekrukh basin. Streams flowing from Shanti Nagar and combination of stream and lineament trending NE-SW are the sources of contamination of groundwater. The high possibilities of contaminations identified need to be addressed to prevent sedimentation at the lake. The basin exhibits highest slope angle of 15.7997° which is a moderate steep slope. Slopes of moderately steep category are identified at the northern border and eastern periphery of the basin and strongly sloping grounds are identified to surround the whole basin and are found prone to weathering and erosion and hazardous for erosion.

At Ekrukh, the areas with high LS factor is spatially distributed across the basin. Clusters of high LS factor are identified at eastern border of the basin. General slope direction of the basin is from east to west. Hence, LS factors are clustered near eastern side of the basin indicating high erosion zone the rate of soil erosion for Ekrukh lake basin (25.8593 tonnes/ha/year) which is severe. The zones of higher soil erosion are linearly accumulated around the

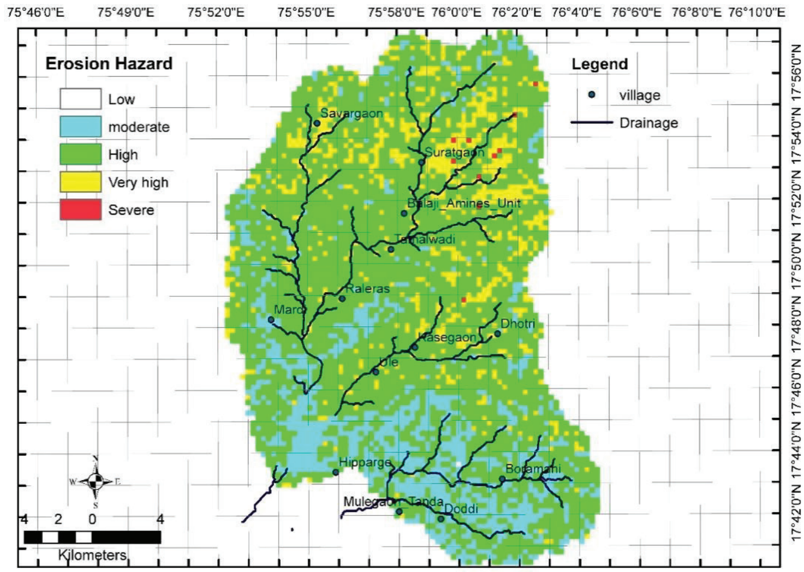

Fig. 10: Hazard zonation map of Ekrukh lake basin.

drainage line in Ekrukh basin, indicating major drainage lines eroding more than its tributaries. Ekrukh basins shows dendritic pattern of the stream, indicating plain, uniform and homogeneous surface on which these streams are flowing. The general slope of the area is towards south. The accumulation points (marked by 'x') are the sites of accumulation of water and sediments transported by headwaters and are the reasons for sedimentation. The lineament lengths vary from 1.833303 km to 9.529145 km in Ekrukh basin are the indicators of contamination on the surface during transportation, at the accumulation points and during the infiltration through fractures and joints, at downstream direction. The intersection of lineaments and accumulation points are identified as the most possible contamination sites at the lake.

The study calls immediate attention to implement integrated approaches for implementation of control measures towards prevention of soil erosion and pollution measures. In the subsequent phase, the research embarks upon designing innovative approaches to address the same.

ACKNOWLEDGEMENT

The author expresses gratitude to Dr. Vinay Dixit, Department of Geology, Dayanand College, Solapur, M.S., for his proficient and crucial directions and inputs towards the course of action and pivotal analytical assistance for the entire venture, devoid of which, it was unattainable to disembark. Sum of all the efforts has generated the organized scientific evidence supporting the investigative conclusions directing action plan for sustainable development.

REFERENCES

Anonymous 1971. Soil Survey Manual. All India Soil, Landuse Survey Organisation, IARI, New Delhi.

Challa, O., R.S. Kurothe and K.S. Gajbhiye, 2001. Soil Erosion in Maharashtra. NBSS Publ. No. 82, NBSS and LUP, Nagpur, 51 p + 1 sheet of map (1:1 M scale).

Challa, O., Vadivelu, S. and Sehgal, I. 1995. Soils of Maharashtra for optimising land use. NBSS Publ. 54b (Soils of India Series), National Bureau of Soil Survey and Land Use Planning, Nagpur, India, 112p + 6 sheets of Map (1:500,000 scale).

Joshi, P.K. Kumar, Roy, P.S., Singh Sarnam, Agrawal, Shefali and Yadav, Deepshikha 2004. Vegetation cover mapping in India using multi-temporal IRS Wide Field Sensor (WiFS) data.

Stewart, B.A. (Bobby Alton) 1932 Woolhiser, D. A., Wischmeier, W. H. and Caro, J. H. 1975. Control of Pollution from Cropland. U.S. EPA Report No. 600/2-75-026 or U.S.D.A. Rep No. ARS-H-5-1. Washington, DC.

Strahler, A.N. 1952. Hypsometric (area-altitude) analysis of erosion topology, Geol. Soc. of America Bulletin 63(11): 1117-1142.