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REMOTE SENSING STUDY ON GEOMORPHOLOGICAL DEGRADATION OF BAIGUL RESERVOIR OF *TARAI* REGION OF UTTARAKHAND

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ABSTRACT

An attempt was made to estimation the geomorphological degradation due to sedimentation of the Baigul reservoir, situated in Sitargang tehsil of district Udham Singh Nagar of Uttarakhand. IRS LISS III (2007) and Landsat-8 (2014-15) remote sensing data and original capacity curve were optimized in the study of the capacity loss to various water levels. The morphology of the reservoir has been changed significantly due to sedimentation during the period 1968 to 2007 and 1968 to 2014-15. Observed that the original Storage capacity of the reservoir was estimated to 86.68 Mm^3 while 55.21 Mm^3 and 46.06 Mm^3 of derived reservoir capacity was estimated from the remote sensing data. The reservoir has lost of 31.34 Mm^3 (36.21%) and 40.50 Mm^3 (46.79%) from the live storage capacity due to sedimentation between 203.35 m and 208.79 m elevation of the reservoir during 1968 to 2006-07 and 1968 to 2014-15, respectively. It's concluded that the maximum siltation deposited on an upper region on first interval (1968-2007) and silt deposited on dead storage level during second interval (2007-15) of the reservoir.

KEY WORDS
Geomorphological changes
Degradation
Remote sensing
Reservoir.

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INTRODUCTION

Sedimentation is a natural incident in the reservoirs. The world's reservoirs are currently filled up with sediments at the rate of approximately 1% per year (WCD 2000). These reservoirs were created mostly for irrigation, power generation, flood control and water resource development purposes. Now a day, reservoirs are also used for enhancing the inland fisheries and increasing the food security in many countries (Sahni *et al.,* 2011; Sugunan 2011). Loss of storage capacity of the reservoirs due to siltation is one of the most serious consequences of soil erosion (Sugunan, 1995).

The reservoir was selected for the study since no investigation has been made on the sedimentation impact on geomorphological changes in the reservoir. Satellite remote sensing technology and geographical information system (GIS) has played a handy role in carrying out the reservoir capacity frequently and economically as well as studies of groundwater modelling and soil erosion (Mukharjee *et al.,* 2007; Meiaraj and Sundararajan, 2007). Multi-dated satellite remote sensing data provides information on elevation contour areas directly in the form of water spread areas. Any reduction in reservoir water-spread area at a specified elevation observed by the satellites is indicative of sediment deposition (Shanker, 2004; Ingole *et al.,* 2015b). Smith *et al.* (1980) observed siltation in the Aswan High Dam Reservoir by comparing reflectance values in the green and red portions of the spectrum. Spatial, spectral and temporal attributes of remote sensing data provide stupendous and timely synoptic information regarding the changes in the water-spread area of the reservoir after deposition of sedimentation and the sediment distribution patterns in the reservoir (Goel *et al.,* 1996).

The present study is an attempt to gather base line data on sedimentation and fisheries of Baigul reservoir in order to chalk out the appropriate management strategies for augmenting fish production in the region. A spatial database is the part of this study, which is basically a geo-reference database on different fisheries related environment for assessment of sediment and geomorphological degradation of the reservoir between years 1968 to 2006-07 and 1968 to 2014-15.

MATERIALS AND METHODS

Our present study deals with the geomorphological degradation of Baigul reservoir in Tarai region of Uttarakhand, India Fig. 1 during 1968- 2007 and 1968-2015 using a remote sensing approach. The methodology applied for delineation of water spread area, estimating reservoir capacity and loss due to sedimentation follows (Goel *et al.,* 2002; Nagaanupama *et al.,* 2005; National Remote Sensing Agency (NRSA) 2003; Rathore *et al.,* 2006; SPARC (Spatial Planning and Analysis Centre Pvt. Ltd.) 2002).

Satellite Data

IRS 1C-LISS III multi-dated Remote Sensing data for the year 2007 to the study area were procured from National Remote Sensing Centre, Hyderabad. LISS III satellite has three sensors that provide multi-spectral data in four bands; two in visible (0.52-0.59 microns and 0.62-0.68 microns), one in infrared (NIR, 0.77-0.86 microns) and one in the short wave infrared (SWIR, 1.55-1.70 microns) region of the electromagnetic spectrum with a swath of 141 x 141 km.

Multi-dated satellite images of LANDSAT 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) for the year 2014-2015 of the study area were freely downloaded from the USGS Glovis website (http://glovis.usgs.gov) in the "GeoTIFF plus Metadata" format, all images are available in terrain corrected format. LANDSAT-8 is having a repeativity or temporal resolution of 16 days; therefore, a five number of images of the same path and row are available for study purpose.

Data Analysis

The digital data of LISS-III from CD ROM was transferred to the system (computer) and then geo-referenced with demarcating Ground Control Points (GCPs) using a Global Positioning System (GPS). The digital data were then processed in the laboratory using ERDAS IMAGINE 8.7 software. The obtained Root Mean Square (RMSE) error while geo-rectifying the image was less than 0.5 pixel through nearest neighborhood resembling technique. Initially, a False Color Composite (FCC) of the satellite data was visualized. These registered images for ten different dates (in years 2007 and 2014-15) pertaining to study area were used to estimate water spread area through supervised classification. The pixels representing water spread area of the reservoir were clearly distinguishable in the FCC. Remote sensing data represent the elevation level in between 205.075 m and 208.25 m in the year 2007 and 2014-15. Interpolation and extrapolation techniques were also used to derive the required water spread area at different elevations.

Estimation of reservoir capacity

For estimation of reservoir capacity and loss due to sedimentation, the area elevation curve was plotted for the water spread areas for the different water level of the reservoir. The computation of the reservoir capacity at various elevations has been made by using the following formula.

$$V = h/3\{A_1+A_2+ \text{“} (A_1*A_2)\} \quad \ldots\ldots\ldots\ldots \text{(1)}$$

Where

V = the capacity of reservoir between two successive elevations h_1 and h_2

h = the elevation difference (h_1-h_2) and

A_1 and A_2 are the areas of reservoir water spread at elevations h_1 and h_2 respectively.

Derived volume of water at a different elevation from the remote sensing data was compared with original volume at the same elevation. The difference between original volume and derived volume is the capacity loss of reservoir obtained due to sedimentation according to various workers. Several workers was used this formula for The computation of the reservoir capacity at various elevations (Mukharjee *et al.,* 2007; Kumar *et al.,* 2013; Ingole *et al.,* 2015_a; Jain, *et al.,* 2002). We were used same method for analyzing geomorphological degradation of Baigul reservoir.

RESULTS

Geomorphologic changes in reservoir

The water spread area of the reservoir in the different dates during 2006-07 and 2014-15 of satellite passes was delineated, which is depicted in Table 1. The original area of the particular elevation during the satellite pass in a reference to the year of establishment of the reservoir was calculated from the original capacity curve by using interpolation technique. The maps of the classified images are depicted in the Fig. 2-11 that shows the water spread area of the reservoir. The elevation 208.25 m corresponding to November 8, 2007 satellite overpass is closer to Full Reservoir Level 208.79 m, whereas elevation 205.07 m corresponding to May 24, 2007 is lowest amongst all the satellite overpass elevation. The water spread area for the original data and derived one is shown in Table 2, which is also depicted in Fig. 12. The complete set of data was used in assessing the sedimentation rate.

Estimation of water spread area

The water spread area of the reservoir was obtained from the

Table 1: Delineation of water spread area during 2007 to 2014

Date of Satellite Pass	Reservoir Elevation (m)	Water Spread Area (ha)assessed from RS data (2007)	Water Spread Area (ha)assessed from RS data (2014)
Interpolation	203.35 (DRL)	-	-
24.5.2007	205.075	751.00	720.14
26.06.2014	205.54	879.99	736.27
28.05.2015	205.55	881.64	787.03
06.04.2007	205.9	967.00	791.04
17.2.2007	206.275	1045.00	823.27
20.10.2007	206.625	1072.00	825.35
30.09.2014	206.69	1069.51	837.55
17.11.2014	206.75	1079.40	882.10
10.04.2015	207.22	1156.85	906.34
08.11.2007	208.25	1298.00	993.00
Extrapolation	208.79 (FRL)	1415.59	1039.41

Table 2: Assessment of Sedimentation Rate of the Reservoir (1968- 2007 & 2014)

Date of Satellite pass	Reservoir Elevation (m)	Original Capacity (Mm^3)	Water Spread Area (ha) assessed from RS data (2007)	Water Spread Area (ha)) assessed from RS data (2014	Volume of water (Mm^3) assessed fromRS capacity curve (Trapezoidal Formula)-07	Volume of water (Mm^3) assessed from RS data (Trapezoidal Formula)-14	Difference between Original volume & Derived volume (1968-07) (Mm^3)	Difference between Original volume & Derived volume (1968-14) (Mm^3)
	203.35 (DRL)	8.379	474.08	467.899	0	0	0	0
	204	17.96	**581.2	**566.76	6.618	6.388	11.341	11.571
	205	32.7	**746	**713.7	0.561	0.537	32.138	32.162
24.5.2007	205.075	33.8055	751	*720.1455	3.788	3.386	30.017	30.419
26.06.2014	205.54	40.6596	*879.992	736.27	0.088	0.0761	40.571	40.583
28.05.2015	205.55	40.807	*881.64	787.03	3.233	2.761	37.573	38.045
06.04.2007	205.9	45.966	967	*791.046	0.961	0.795	45.004	45.17
	206	47.44	*955.8	*799.64	2.75	2.231	44.689	45.208
17.2.2007	206.275	51.4935	1045	*823.2735	3.704	2.885	47.788	48.608
20.10.2007	206.625	56.6525	1072	*825.3525	0.695	0.54	55.956	56.112
30.09.2014	206.69	57.6106	*1069.512	837.55	0.644	0.515	56.965	57.094
17.11.2014	206.75	58.495	*1079.4	882.1	2.749	2.209	55.745	56.285
	207	62.18	*1120.6	*885.58	2.505	1.971	59.674	60.208
10.04.2015	207.22	65.4228	*1156.856	906.34	9.52	7.322	55.902	58.1
	208	76.92	*1285.4	*971.52	3.229	2.455	73.69	74.464
8.11.2007	208.25	80.605	1298	*993.005	7.324	5.487	73.28	75.117
	208.79 (FRL)	86.5646	**1415.592	**1039.4126	55.217	46.06	31.347	40.503
Total		86.56			55.21	46.06	31.34	40.5

* Interpolation ** Extrapolation

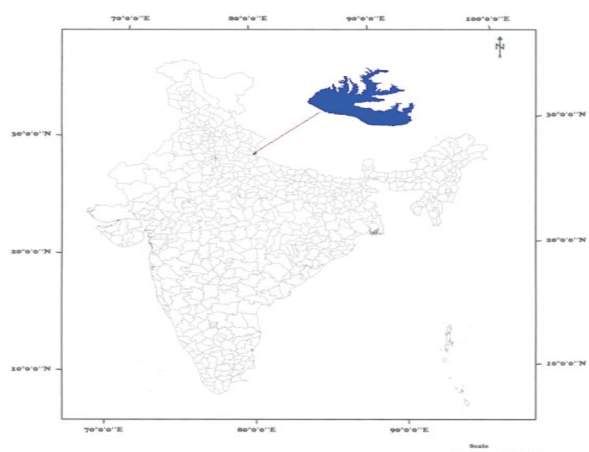

Figure 1: Location map of Baigul reservoir

classified satellite images of different dates. The water spread areas of the Full Reservoir Level (FRL) and Dead Storage Level (DRL) were interpolated and extrapolated from the available data. Original water spread at Full Reservoir level was 2995 ha which has been reduced to 1415.59 ha in 2007 and 1039.41 ha in the year 2014 assessed though Satellite Remote Sensing data at the same elevation. Other corresponding areas to various elevations are given in Table 2 and Fig. 13.

Estimation of reservoir capacity

Water spread areas estimation from satellite data were then used to calculate the reservoir capacity between two successive elevations by using Trapezoidal formula. Cumulative volumes were calculated by adding the successive volumes between elevations, satellite derived water spread area; capacity between elevations and cumulative capacity in different elevation which were given in Table 2. The derived Live Storage capacity of Baigul reservoir using satellite remote sensing data during 2006-2007 and 2014-15 was estimated to be 55.21 Mm^3 and 46.06 $Mm^{3,}$ respectively. While, original Live Storage capacity was estimated as 86.68 Mm^3 using original capacity curve. The difference between the two volumes is the capacity loss due to sedimentation during 1968 to 2006-07 and 1968 to 2014-15. Original and derived capacity curve at different elevation is plotted in the graph which is shown in the Fig. 12.

Estimation of capacity loss

Capacity loss = Original capacity – Derived capacity

From the Table 2, it is observed that the original Storage capacity of the reservoir was estimated to 86.68 Mm^3 while 55.21 Mm^3 and 46.06 Mm^3. of derived reservoir capacity was estimated from the remote sensing data. This reveals the loss of 31.34 Mm^3 (36.21%) and 40.50 Mm^3 (46.79%) from the live storage capacity due to sedimentation between 203.35 m and 208.79 m elevation of the reservoir during 1968 to 2006-07 and 1968 to 2014-15, respectively. Thus the average rate of loss of capacity is computed to be 0.80 Mm^3 (0.92%) per year during 1968 to 2006-07 and 0.84 Mm^3 (0.97%) per year during 1968 to 2014-15. Table 2, shows computations of satellite derived reservoir capacity and its loss due to sedimentation at various elevations. It also shows corresponding field data on reservoir capacities and sediment quantities pertaining to the original ground survey (1968).

In a previous hydrographical survey conducted by U.P. Irrigation Research Institute, Roorkee it was revealed that the sedimentation in the live storage was found 24.52% during the period June 1968 to June 1992. In the present study, the total capacity loss was calculated to 46.79% with an average silt deposition of 0.97%. Several worker have studied on the different reservoirs such as (Jain *et al.,* 2002) for Bhakra reservoir during 1965- 1997(0.29 %); (Nagaanupama 2005) for Ujjani reservoir during 1977-2003 (1.8%); (Mukharjee *et al.,* 2007) Hirakud reservoir during 1957-1989 (0.75%); (Kumar

Classified Images of satellite LISS-III (2007) and Landsat-8 (2014-15)

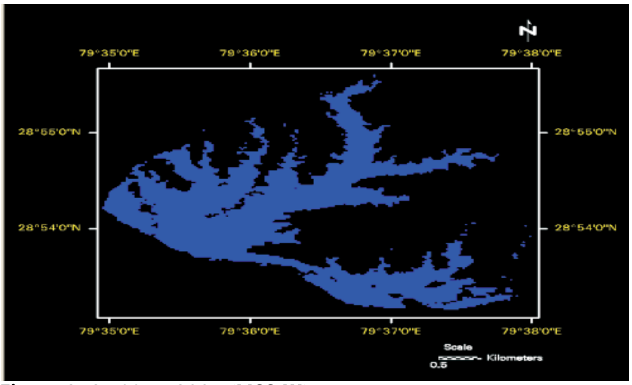

Figure 2: 24 May, 2007 (LISS-III)

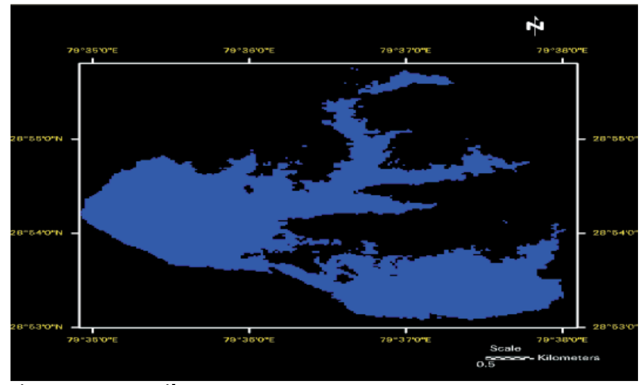

Figure 3: 06 April, 2007 (LISS-III)

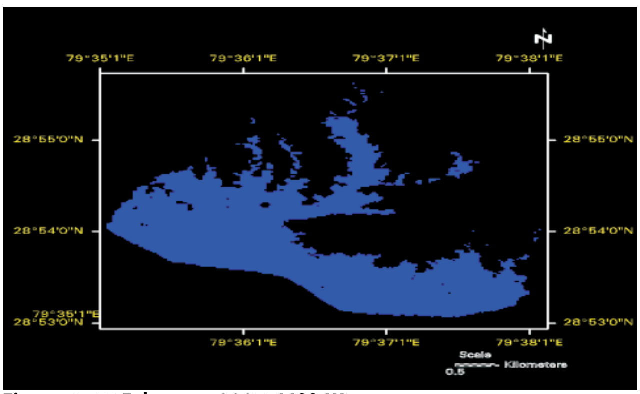

Figure 4: 17 February, 2007 (LISS-III)

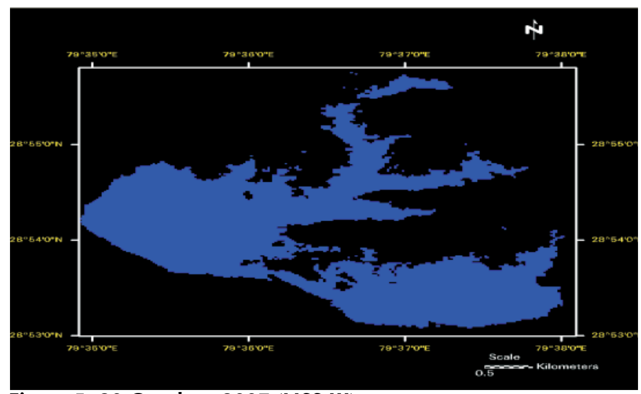

Figure 5: 20 October, 2007 (LISS-III)

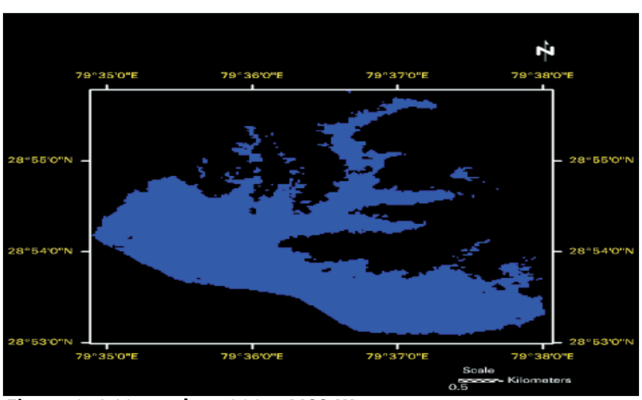

Figure 6: 8 November, 2007 (LISS-III)

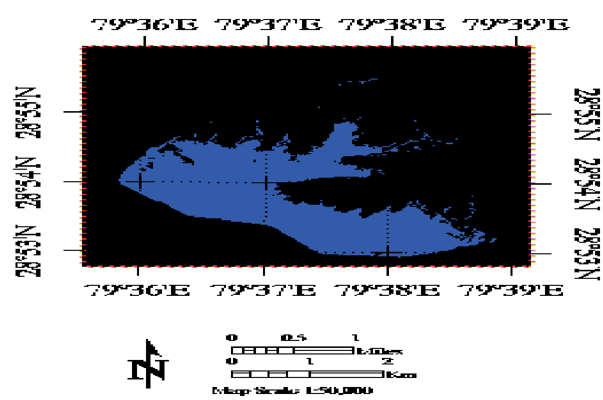

Figure 7: 26 June, 2014 (Landsat-8)

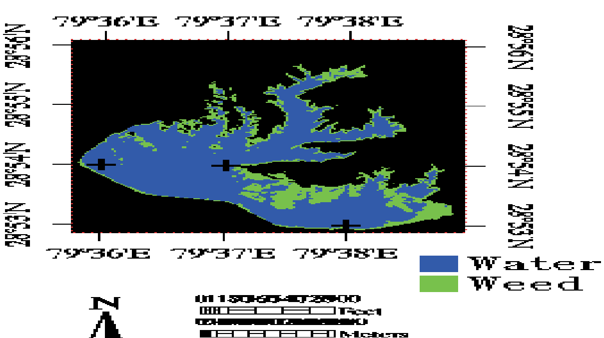

Figure 8: 28 May, 2015 (Landsat-8)

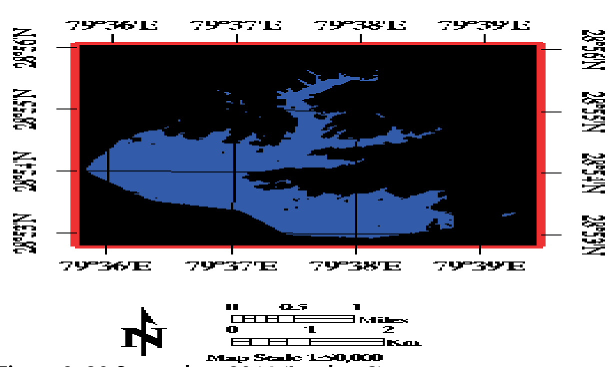

Figure 9: 30 September, 2014 (Landsat-8)

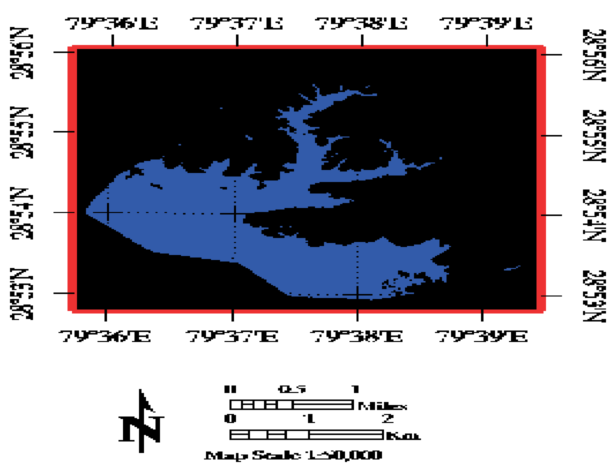

Figure 10 : 17 November, 2014 (Landsat-8)

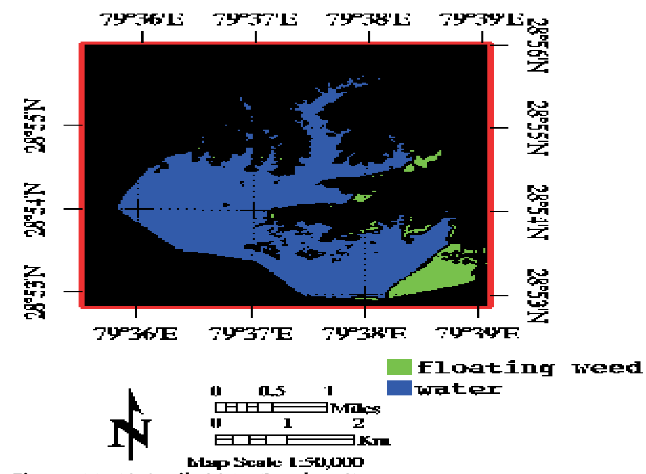

Figure 11: 10 April, 2015 (Landsat-8)

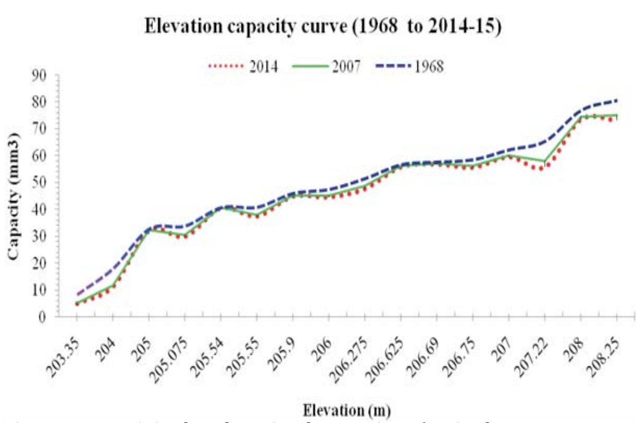

Figure 12: Original and Derived Capacity of Baigul (1968 to 2006-07 to 2014-15)

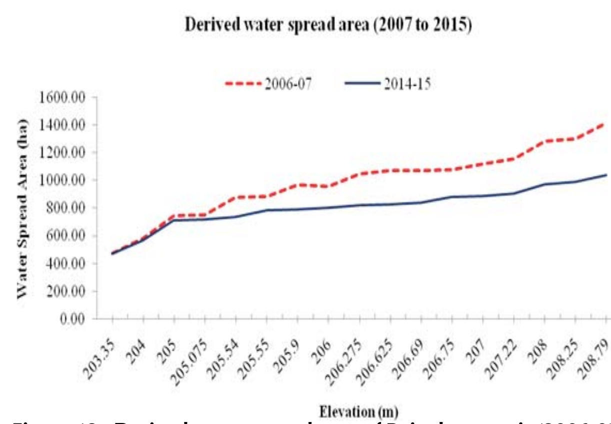

Figure 13: Derived water spread area of Baigul reservoir (2006-07 to 2014-15)

et al., 2013) for Sarda sagar reservoir during 1962-2006-07 (0.26 %). Further, (Ingole *et al.,* 2015_b) for Nanak Sagar reservoir average deposition was computed as 1.25 Mm3 (0.59%) per year. National Remote Sensing Agency (2003) observed sedimentation rate per year for different reservoirs in India as Kuttiyadi (0.12%) during 1989-1995; Bargi (0.07%) during 1990-2000; Sriram Sagar (1.0%) during 1970-2002; Tawa (0.7%) during 1975-1996; Bhakara (0.14%) 1958-1996; Pong (0.22%) during 1974-1996; Ujjani (1.18%) during 1976-1992; Nathsagar (0.48%) during 1976-1992; Tunbhagra (0.59%) during 1953-1995. The sedimentation rate of Baigul reservoir was 0.84 Mm^3 per annum which was computed as 0.97% per year of the total capacity. It can be concluded that the results of the present study on Baigul reservoir fall within the range at national level studies.

DISCUSSION

From the results, water spread area of Baigul reservoir during different satellite passes for the year 2006-07 and 2014-15 was delineated and depicted in Table 2. The designed total capacity of the reservoir was 86.68 Mm^3 at elevation 208.79 m (FRL) and 8.32 Mm^3 at elevation 203.35 m (DSL) (Anon 1980). The results show reduction of 1955.19 ha which about 66.17 % of the total area. It is also observed that the difference in water spread area at different elevation is not in linear proportion to the water level from DSL increases the difference also increases (Table 2 and Fig. 13) that have changed the morphology of the reservoir significantly. The difference between original and derived water spread area was 467.89 ha at the elevation 203.35 m which has been increased to 566.76 ha at the elevation level to 204 m finally, an area of 1955.35 ha has been reduced to the original data at the elevation of 208.79 m (FRL). The results on the derived water spread area revealed that the sedimentation rate is more on the higher elevation rather than low elevation areas.

The volume of water in-between two successive elevations was estimated Trapezoidal formula using corresponding water spread areas derived from the satellite. The process was continued till the elevation of full reservoir level. The study revealed that the area of the reservoir has reduced very sharply as the elevation increases but this trend is not found in the water volume that can be concluded that the sediment deposition was more on the higher elevations rather than low elevation by that way causing the destruction of the natural ground of prized fishes *i.e.* carps. It was observed during the visit to the site that silted zone of the river mouth area is being used for the agriculture purposes.

The sedimentation in the reservoir is due to soil erosion in the catchment area and eroded soil is transported by different means to the live storage of the reservoir. Loss of storage capacity of the reservoirs due to siltation is one of the most serious consequences of soil erosion (Sugunan, 1995). Uncontrolled deforestation, forest fires, grazing, improper method of tillage and unwise agricultural and land use practices accelerate soil erosion resulting in a large increase of sediment inflow into streams. The deposition of sediment in channels or reservoirs creates a variety of problems, such as the raising of stream beds, increasing flood heights, choking of navigation channels and of course depletion of storage capacity of reservoirs. Suspended particles tend to settle down in the lentic waters of the reservoir causing many problems (Santhosh *et al.,* 2011; Sharma *et al.,* 2011). It is estimated that in India 5,334 million t of soil is eroded every year from the cultivable land and forests. The Indian rivers carry about 2050 million t of silt of which nearly 480 million t is deposited in the reservoirs and 1572 million t is washed away into the seas (Sugunan, 1995).

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