Sedimentation assessment of Bhatghar reservoir through satellite remote sensing

Suhas Kamble[1], D.M. Wankhede[2]
Research Scholar,Rashtrasant Tukdoji Maharaj Nagpur University, Nagpur
Associate Professor,Department of Geography, Govt. Vidarbha Institute of Sciences and Humanities, Amravati.

Abstract:

Sediments in the reservoir are related to the reservoir's capacity because it affects live and dead storage. The present study covers the use of satellite remote sensing data in the sedimentary study of bhatghar reservoir in Bhortaluka of Pune district in Maharashtra. Satellite data furnishopportunity to study the reservoir characteristics at different scale and at different stages. The energetic aspect of the reservoir is mainly the spread of water, and the distribution and concentration of suspended matter need to be regularly mapping and monitoring. Multi-date satellite remote sensing data provide information on elevation contours in terms of water spread area. According to the existing records, (Pune Irrigation Division) the Bhatghar Dam was built in 1927 Therefore, the area capacity curve in 1927 was used as the base year for this study. Gross storage The Bhatghar Reservoir was 672.65 Mm^3 in 1927. The dead and live storage for the equal ware 2.16 Mm^3 at 578.48 m for MDDL and 670.49 Mm^3 at 623.28 m for FRL respectively.After analyzing the satellite data in year 2015-16, the study found that there was loss of gross storage of 98.07 Mm^3 in 89 years.Therefore, from the current study, application technology plays an important role in reservoir sediment assessment.

Keywords:1. Sediment Assessment , 2.GIS,3. RS, 4.NDVI, 5.Bhatghar Reservoir.

1. Introduction:

Though water being a replenishable natural resource, in recent times, the rate of exploitation and usage has been expotentially increased over availability and recharge rate. Our country depends on monsoon rainfall to a significant extend which is well known for its irregular in nature. still, 50% of the totality serviceable surface water has been harnessed by approach of build largescale dams mediium storage tanks and minar barrages and weirs. Due to adverse circulation of clean water equally in period and space, storage reservoirs are helpful tools for reduceing the difference in time variation of the needs and resources. Storage reservoirs play a very important role in helping long-term profit in various ways. The reservoirs furnish the purpose of water deliver, irrigation, industrial, hydropower generation, flood control, recreation and various other uses. Silting in reservoir is decreasing the capacity of reservoir and hence sedimentation of reservoir is of great concern to all the water resources development projects. Storage loss is one of the various categorys of sedimentation problems that can influence reservoirs. As reservoirs age and sediments continue to collect, sediment connected problem will raiseing in harshness and further sites will be affected. *(*Central Water Commission)

Sediment may enter and block the inlet, and significantly accelerate the wear of the hydraulic machinery, thereby reducing its efficiency and rising maintenance costs. Silt not only occurs in the dead, but also invades the live storage capacity, which has a long-term and short-term impact on the operation of the project and the economy. The major factors affecting sedimentation in reservoir are Longitudinal and lateral valley shape, Length and shape of reservoir, Flow patterns in reservoir, Capacity to inflow volume ratio (trap efficiency), Grain size distribution of sediment, Water and sediment discharges, Mode of reservoir operation, and Nature of incoming floods Appropriate assessment of the deposition rate is critical to assess the life of the reservoir and the optimal reservoir operating schedule. Since 1927, when the real-time storage of reservoirs was reduced due to silting, various departments/organizations systematically evaluated the reservoir capacity. Various technologies such as ship echo sounder are replaced by hydrologic data acquisition system (HYDAC) and HITECH method using differential global positioning system (DGFS). It has been found that traditional technologies are time-consuming or expensive and have considerable human resources. Due to its synoptic and repetitive coverage, it has been found that remote sensing techniques used to calculate the current reservoir capacity are very useful in this case. Surveys based on remote sensing data are faster, more economical, and more reliable. The present study, appropriate measures will selected to control siltation, and the reservoirs will effectively managed and operated so as to bring maximum benefits to society.

2. Study Area:

The Bhatghar reservoirlocated among the beautiful Western Ghats and falls under the Bhortaluka of Pune district in Maharashtra.Bhoris located midway between Satara and Pune and falls on NH 4 Dam can easily be accessed from Pune. It is about 50 Km by road where first impounding started in the year 1927. It is a multipurpose major project constructed on river yelwandi in sub-basin Kannad and basin Nira. Bhatghar Reservoir is located at 18^0 10'30" Latitude and $73^0$52'12.50" Longitude at village Bhatghar. Following map shows the location and extent of the study area. Total catchment area of the reservoir is 274.33sq km. Catchment has yearly average rainfall as 800 -1000mm.

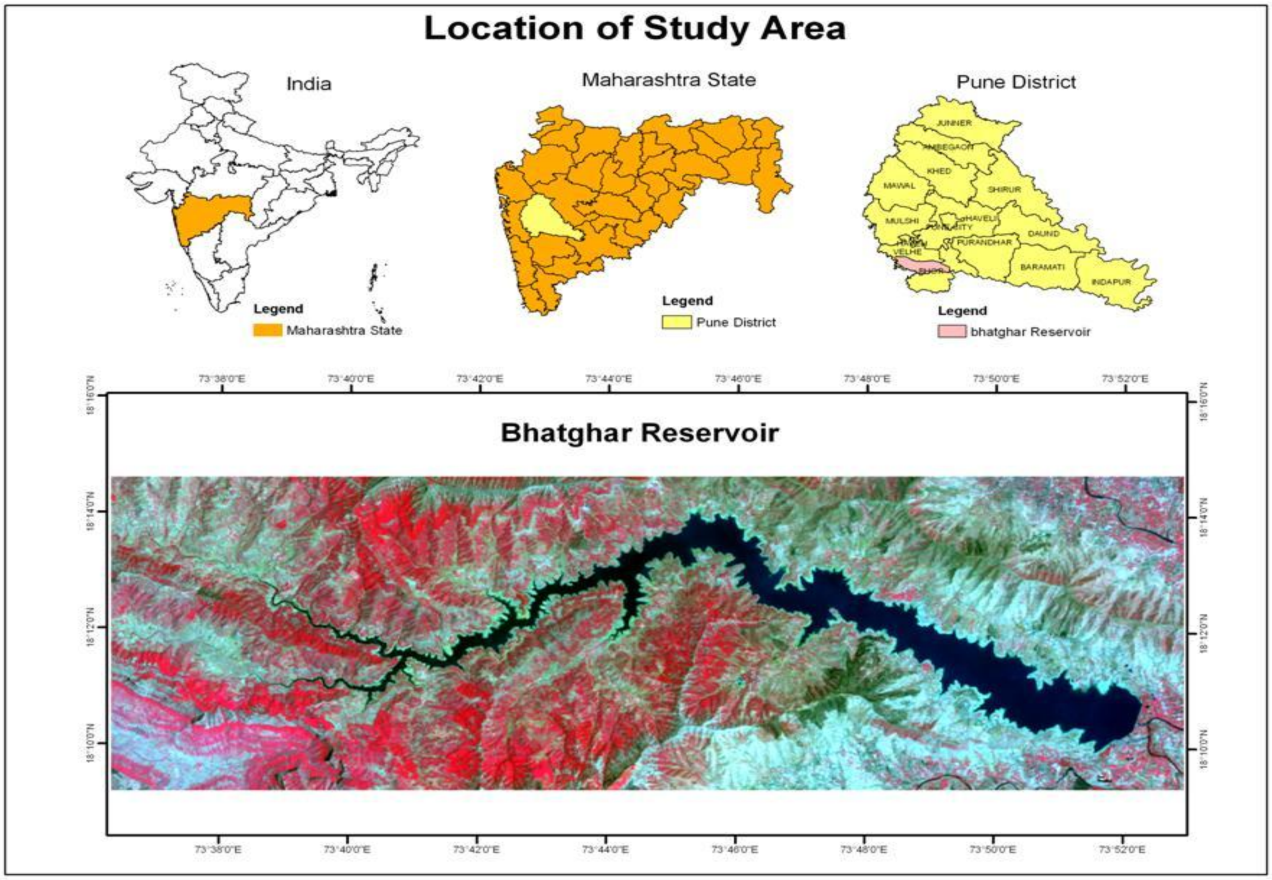

Fig.No.1 Location map of study area

3. Data Used

3.1 Satellite data

Land sat 8 satellite data data for six (06) dates has been used in the analysis. Table No. 1 depicts the Path and Row index along with date of pass of satellite.

Table No.1. Date of pass for satellite data

Satellite	Path	Row	Date of pass	Elevation (m)
LANDSA T 8	147	47	26th May, 2015	595.38

LANDSAT 8	147	47	08th Apr, 2015	611.97
LANDSAT 8	147	47	07th Mar, 2015	615.48
LANDSAT 8	147	47	18th Jan, 2015	618.19
LANDSAT 8	147	47	20th Nov, 2016	622.28
LANDSAT 8	147	47	19th Oct, 2016	623.28

3.2 Field Data

The field data has been obtained from project authorities, Elevation – Area - Capacity data (Original) and Salient features of Bhatghar reservoir, reservoir levels on specified dates

4. Methodology

Digital image analysis using Image Processing System on computer mainly, Normalize Difference Vegetation Index (NDVI) (NDVI = NIR-R/NIR+R), and classified NDVI values were found water spread, turbidity levels and surgical aquatic vegetation. For the Bhatghar reservoir study, multi-date LANDSAT 8 data (06 images) were used for analysis. Image processing with ERDAS imagine software was used for the analysis.

The methodology adopted in this analysis is shown in the flow chart. Fig.No.2

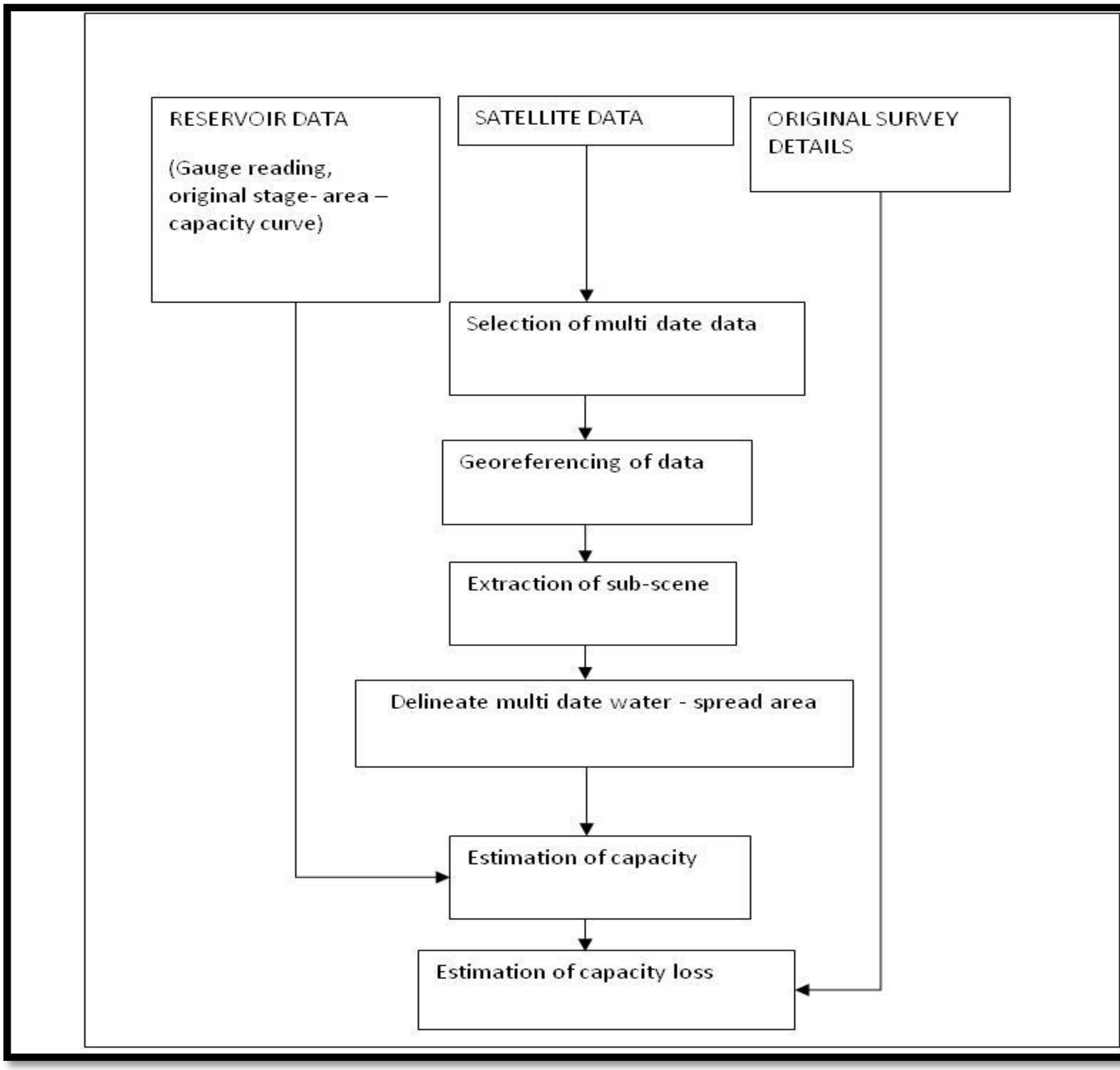

Fig.No.2 Flow chart of sedimentation Assessment

4.1 Data Base Georeferencing

The Georeferenced satellite data related to the reservoir area obtained from USGS Earth Explorar was loaded on the system. The cross checking georeferenc satellite data with the hepl of GPS points which is collected from the field survey and Ground Control Points. (GCP) after that data were used for further analysis.

4.2 Water Spread Area Estimation

Reducing the Water Spread Area (WSA) at different water levels describes the decrease in reservoir capacity at different water levels. Various digital image processing (DIP) techniques are used to estimate the water-spread area. Various techniques for water spread area estimation are as follows

- Generation of False Color Composite (FCC) and analysis of histogram
- Thresholding and modeling

Generation of FCC and analysis of histogram

The FCC is generated from the three spectral bands of the satellite data, typically the NIR, red and green bands, where the characteristics of the water are displayed in black and blue shades according to depth and turbidity. Histograms are plotted for each band, which is a plot of the gray value and the frequency of occurrence. NIR band information is more useful for identifying WSA. Spectral separability between features is more in the NIR band. The water pixels are identified and the range of gray values is recorded. In the normal case where there is no cloud shadow effect, water usually occupies a lower histogram range.

Thresholding and modeling

The areas where freshwater / terrestrial boundaries occur, density slices have been successfully used to delineate water spread areas. Density slice is a technique that divides the entire gray value of a pixel appearing in an image into a series of analyst-specified intervals. All grayscale values that fall within a range are grouped into a single grayscale value and displayed in the output. This process divides the image into water and land pixels. From the study of the histogram peaks, the minimum and maximum values of the water pixels were determined and then the images were density sliced. Thresholding can be performed on single and or combination of bands. The frequency band ratio is a technique that enhances specific feature or class from satellite data. Different ratio indices can be used to enhance water, vegetation, soil, etc. The normalized Difference vegetation index (NDVI) is an indicator that can enhance vegetation and water. NDVI has been used to estimate the water propagation area of the Bhatghar reservoir. NDVI has been generated using 16-bit unsigned channels and uses the following formula:

$$\mathbf{NDVI = (NIR - R) / (NIR + R)}$$

Where, 'NIR' is digital number in near infrared band and 'R' is digital number in red band. The rationed image is then density sliced. Water pixels generally occupy lower range of histogram in ratioed image. Table No. 2shows Range of NDVI (digital number) for water body delineated and noted for different imageries of Bhatghar Reservoir as per date of pass.

Table No. 2Range of NDVI for satellite data

Date of pass	**Range of NDVI (Threshold values)**	
	Minimum	**Maximum**
26th May, 2015	-0.0972189	-0.010748
08th Apr, 2015	-0.077596	0.0110382

07th Mar, 2015	-0.132224	-0.000105843
18th Jan, 2015	-0.0601479	0.0200218
20th Nov, 2016	-0.122639	0.0140484
19th Oct, 2016	-0.0412298	0.0607912

Use the above range of values to extract the water sprea area for all scenes. Fig. No. 4 shows the FCCs for different dates, and Fig. No. 3 shows the water level difference for the superimposed reservoirs at different dates. The water sprea area is calculated by multiplying the number of pixels by the area of each pixel (28.5 m x 28.5 m). Table 3 shows the water- sprea area corresponding to different dates estimated from satellite images

Table No. 3Water Spread Areas estimated from Satellite Images

Date of pass	**Elevation (m)**	**Area (sq.km)**
26th May, 2015	595.38	05.27
08th Apr, 2015	611.97	22.57
07th Mar, 2015	615.48	26.85
18th Jan, 2015	618.19	29.48
20th Nov, 2016	622.28	32.00
19th Oct, 2016	623.28	32.23

The water elevation 623.28m for 19th Oct, 2016 is the Full Reservoir Level (FRL) of and water elevation 595.38m for 26th May, 2015 is well above the Minimum Draw Down Level (MDDL) of 578.48 m.

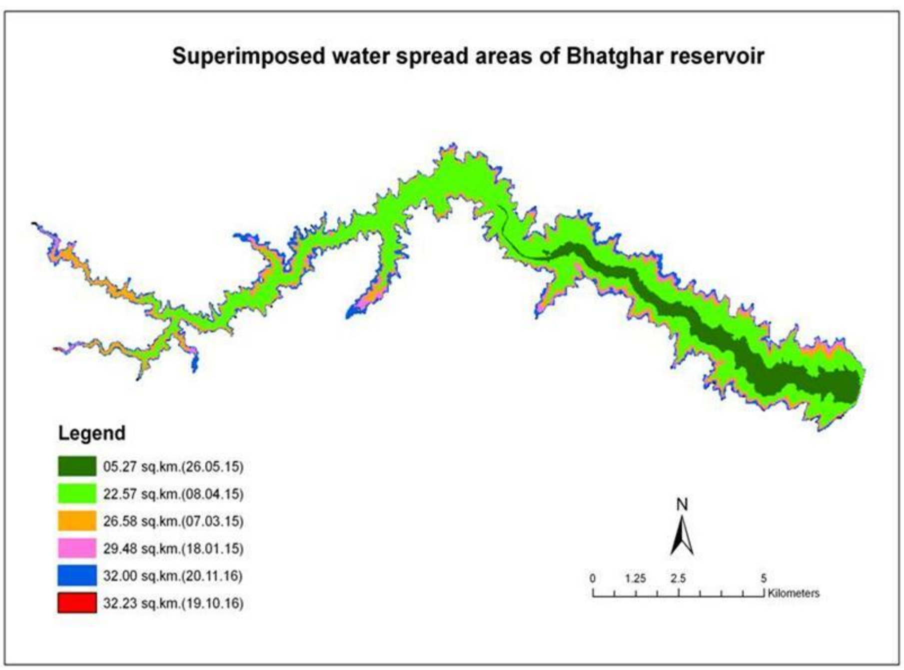

Fig.No. 3. Bhatghar Reservoir water spread area on different datas

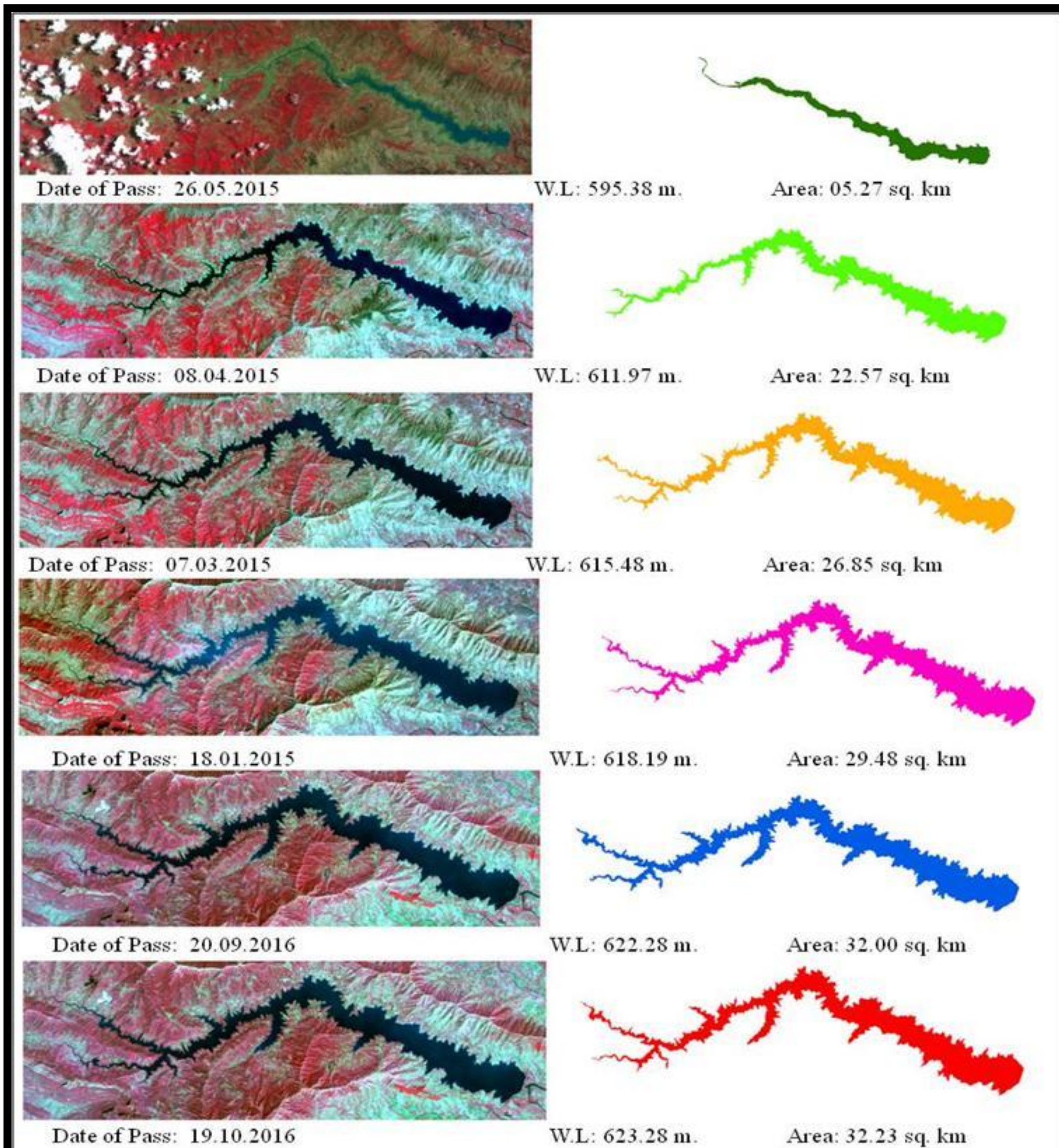

Fig.No. 3. False color composites (FCCs) showing water spreads at different dates

4.3. Estimation of Reservoir Capacity

Area elevation curve has been plotted using these above six (06) water-spread areas for different water level in the reservoir and a best-fit polynomial equation of second order as given below has been derived.

Y = 0.0095*X^2 +12.75 * X - 4109

R2 = 0.9973

Where X is Elevation in meters

Y is Water Spread Area in Million m2

The elevation - area curve using this equation has been plotted and shown in Fig. No.4.

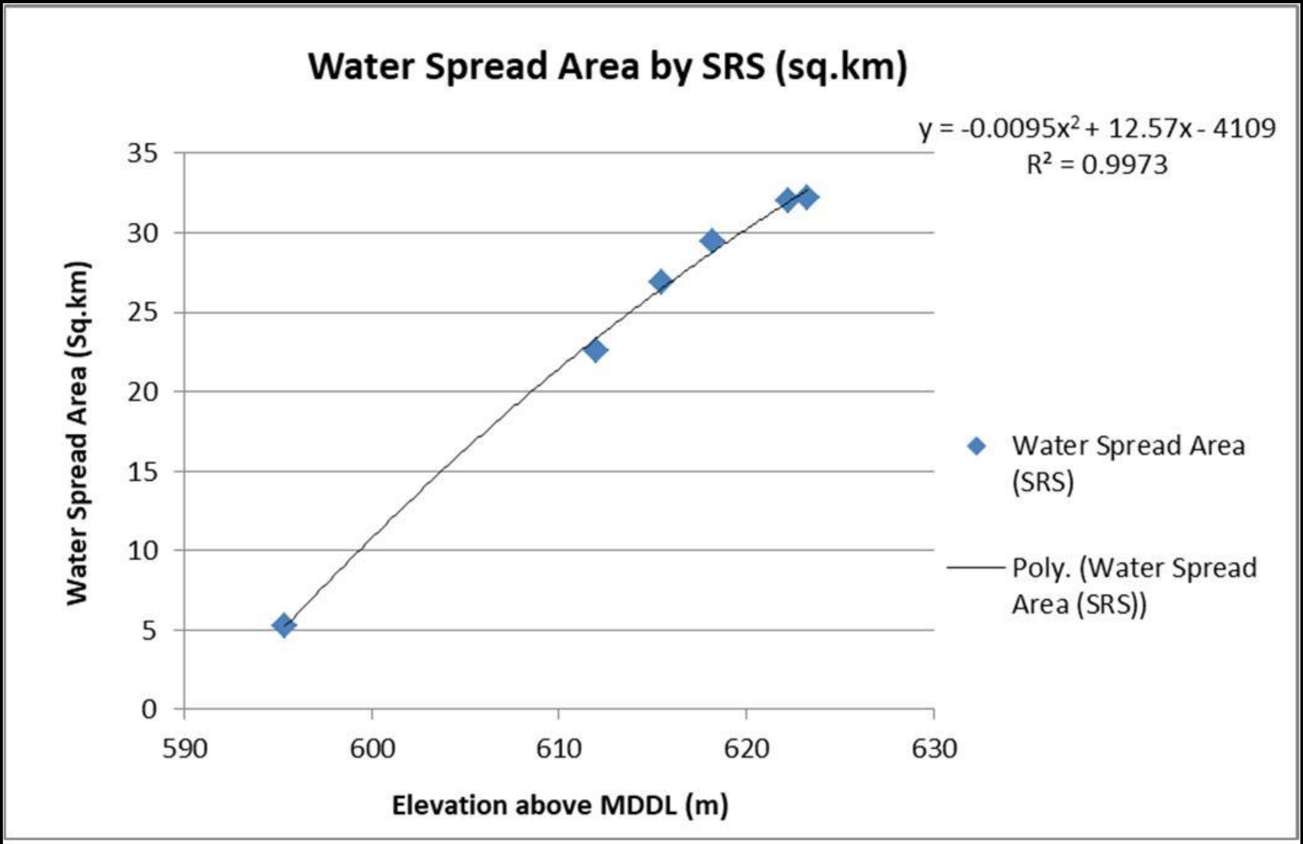

Fig. No. 4: Water spread Area of Bhatghar Reservoir

Water spread areas derived from satellite data for various dates are also marked on the curve.calculation of the reservoir capacity at various elevations was made using following formula

V = h/3{A1+A2 + sqrt. (A1*A2)}

Where,'V' is the reservoir capacity between two successive elevations h1 and h2,'h' is the elevation difference (h1-h2),'A1 & A2' are areas of reservoir water spread at elevations h1 & h2.Table 5.5 gives the values of Live storage capacity and submergence areas have been worked out using this best-fit polynomial equation at different elevationsFig. No.5..The elevation – area –capacity curves are plotted and shown in Fig. No.6.

Table No. 4: Aerial extent of reservoir using SRS Survey 2015-16

Reservoir water level in Metre		Water spread area (sq.km)	Live Capacity (Mcm) by SRS technique	Cumulative Live capacity (Mcm) by SRS technique
MDDL	578.84	0.28	0.00	0.00
	595.38	5.27	37.30	37.30

	611.97	22.58	214.33	251.63
	615.48	26.85	86.64	338.27
	618.19	29.49	76.31	414.58
	622.28	32.01	125.72	540.30
FRL	623.28	32.24	32.12	572.42

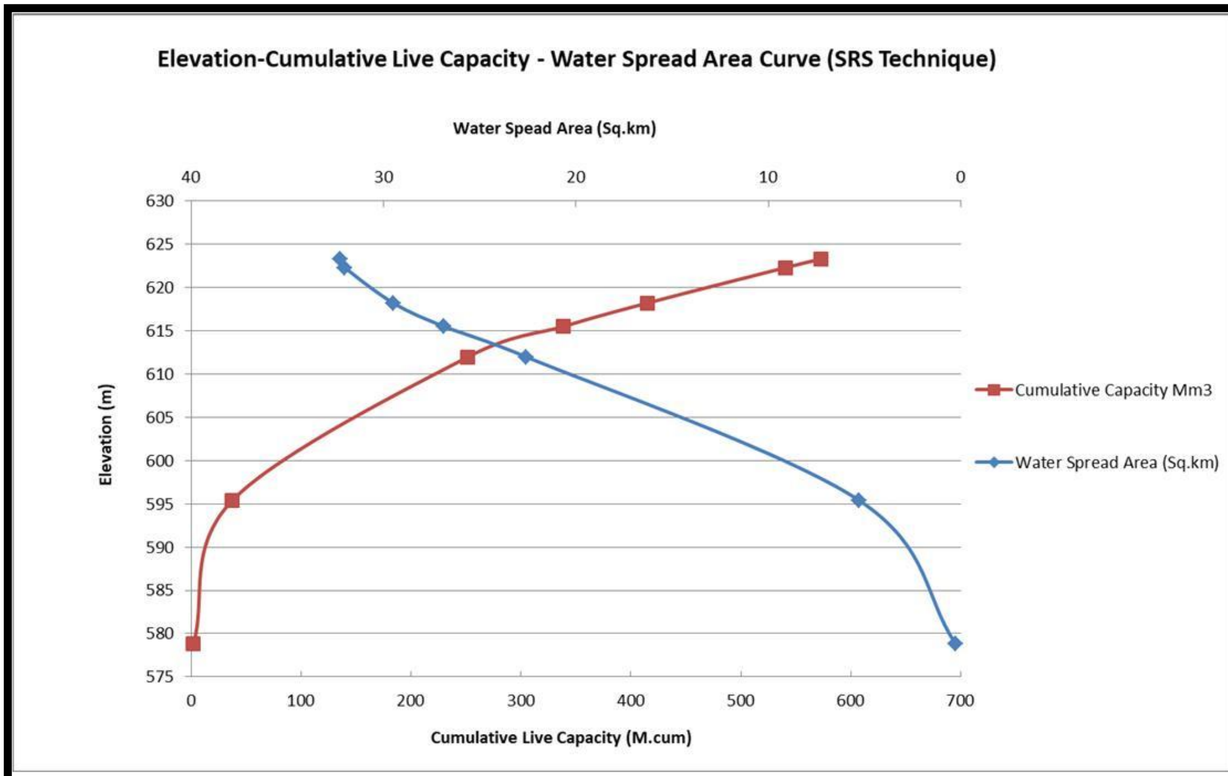

Fig. No.6 Elevation – Area- Capacity Curve

5. Result

The loss in live storage capacity of the reservoir due to sedimentation since original survey has been shown in Table No. 5.

Table No. 5: Live storage capacity loss due to sedimentation

Details	**Original (1927)**	**Previous SRS (2002)**	**SRS (2016)**
Live Capacity in Million m^3	670.49	584.07	572.42
Loss in live capacity in Million m^3	-	86.42	98.07

% Live capacity loss (since 1927)	-	12.88	14.62
Annual % live capacity loss	-	0.174	0.164

6. Conclusion

Sedimentation assessment of bhatghar reservoir through satellite remote sensing observed that the 572.42 Million m^3 in 2016 against the original live storage capacity of 672.65 Million m^3 in 1927.There is a live capacity loss of 98.07 M cum in 89 years which is 14.62 % of original live capacity. Annual live capacity loss is 0.164%.

7. References

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