ASSESSMENT OF RESERVOIR SEDIMENTATION IN CHHATTISGARH STATE USING REMOTE SENSING AND GIS

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ABSTRACT

In a modern scenario, reservoir sedimentation is vital problem as every reservoir are bound to suffer a loss in their storage capacity potential because of silt load, for short or long period of time. For water resources planning and land & water management system, computation of soil erosion, sediment conveyance and its deposition in reservoir, irrigation canal, hydropower systems should be taken as top priority. The capacity and useful life of reservoir should be known for harvesting the maximum quantity of water in the whole year for treatment plant, irrigation, hydroelectricity, flow balance, flood control etc. Conventional techniques used for the evaluation of the reservoir capacity and the sedimentation in a reservoir, like inflow-outflow technique and hydrographic survey, Integrated bathymetric survey etc are cumbersome, clumsy, time consuming and uneconomical, and even they involve huge manpower. An alternative of traditional methods, GIS & Remote sensing technique is used in present work to compute the loss of storage capacity and sedimentation in Murrumsilli reservoir situated in dhamtari district, Chhattisgarh state, India. Several scenes of Linear Image Self Scanning (LISS III) digital data of Indian Remote Sensing (IRS) satelliteIRS-1D/P6 have been imported and normalized difference water index (NDWI), image rationing and slicing techniques have been implemented to detect the water and non-water pixels from the images using Integrated Land and Water Information System 3.0 (ILWIS 3.0), a GIS software. The revised water spread area at various elevations has been computed which will provides the revised capacity of the reservoir. Final results obtained by study shows that in Murrumsilli reservoir total deposition of sedimentation is found to be 29,956 MCM and percentage loss of capacity is equals to 18.37 % from 1923 to 2015. It also shows that rate of sediment deposit are about 0.32 MCM/year.

Key words: Reservoir Siltation, Revised Capacity, GIS, Murrumsilli Reservoir, NDWI, Water Spread Area.
1. INTRODUCTION

Dam based reservoirs are known as the temple of modern India [1, 2], which is continuously suffering by deposition of sedimentation. Various types of problems due to sediment deposition in channels or reservoirs are, increased stream beds, greater flood heights, throttling of navigation channels and reduction of storage capacity of reservoirs [1, 2, 3]. Reservoirs, sea & rivers become a natural means for storage of transported sediment or eroded soil [4, 5, 6]. There are various agents like climate change, deforestation, vegetation, topography, grazing, inappropriate techniques of tillage, an imprudent agriculture and anthropogenic land use practices, which accelerate the high flow eroded sediment into the streams or river [7, 8]. The main objectives of reservoir are flood control, supply of water for industrial and domestic purposes, irrigation, hydropower, fisheries and maintenance of minimum flow in river etc, which is continuously lacking behind, reducing economic life and effective storage capacity, due to fast deposition of sediment [9, 10]. In India the total live storage capacity of completed medium and large dam is about 253 BCM i.e. 37 % of the evaluated usable water surface resource, almost 50% dams are 50 years older [1]. An estimated 1% reduction in the total capacity of world’s reservoir due to sedimentation is observed every year [8, 11, 12]. Due to sedimentation deposition reconstruction of dam has also observed like Sanmenxia dam on yellow river in china [13]. So the regular sediment monitoring or assessment is very essential for estimating the rate of sedimentation, pattern, economic life & capacity loss of reservoir. Globally used traditional techniques of reservoir sedimentation are, inflow-outflow method, calculate the sediments in inflow and outflow from reservoir, assessment of reservoir capacity surveys (Range and Contour surveys), one of most accurate method but time consuming and very expensive, certain mathematical models that have been developed for this purpose include HEC-6, GSTARS, FLUVIAL, TABS, etc are very specific [14, 15, 7, 16, 17, 18, 19, 20]. The rapid growth of nation requires fast and accurate technology like remote sensing (RS) and GIS to explore and digging of water resources development [21, 22, 23]. Various studies [1, 23, 24, 25, 26, 21, 27, 28, 29, 30, 31] revealed that RS and GIS techniques provides the rapid, accurate, economical and unbiased information about the use, current status, physiographic, distribution of soil, drainage profile etc of watershed body. The general output of remote sensing data is spatial, spectral and temporal revised water spread image of reservoir. Water pixels from the remote sensing data can be obtained by digit image processing technique (visual and digital) and identification of water pixels is done with the help of normalized difference water index (NDWI), image ratioing (IR) and slicing [13,25]. These geo-referenced Multidate satellite images give revised water spread area at different elevations and along with the altitude between them, revised volumes between these elevations can be computed by prismoidal formula [26, 25, 23, 32, 33, 34].

[29] Used nine different dates’ images of Bargi Reservoir, Madhya Pradesh State, India, from the IRS-1C satellite, LISS-III sensor, analyzed with the help of ERDAS/ IMAGINE software to find capacity of reservoir. [27] Estimated the capacity of Hirakud reservoir by using simple ratioed (NIR/RED) image of 5 optimal dates corresponding to various water elevations. [21] assessed the reservoir sedimentation of Ravishankar sagar by using data of IRS 1D, LISS III of ten different dates and digital image processing had been carried out in ILWIS 3.0 GIS software. [26] Assess sedimentation of Shetrunji, Rajaval and Kharo reservoirs of South Gujarat with remote sensing technique by using LISS III digital data of IRS satellite-1D/P6 and
normalized difference water index (NDWI), rationing of image and slicing are applied to differentiate the water and non-water pixels from the images on ILWIS 3.0, a GIS software.

[32] Computed the Capacity survey of the Nagarjuna Sagar reservoir by using sub-pixel or linear mixture model (LMM) technique with IRS-1C and 1D satellite image data (24m) of eight different dates. [23] Determine storage sedimentation in Reservoirs at Nagpur region by using Satellite Remote Sensing (SRS) approach and found that the sedimentation rate of Nagpur region is 5.22ha-m/100km²/year is much lower than the rate presented in ISO EROSION Map study by Gurmel Singh, Ram Babu, and Pratap Narain (1978). [22] computed sedimentation in Major Reservoirs of Hard Rock Terrain of India by using digital image processing of remotely sensed data and found revised Elevation-Area-Capacity against original capacity of reservoir.

[35] studied capacity loss in Kanhaiya nala watershed situated in Satna district of Madhya Pradesh by using Landsat (ETM) satellite images and execute on ERDAS 9.1 software to get land cover information. The information such as soil map, elevation map, rainfall map and land cover map were executed on Arc GIS 9.3. [14] predicted area storage curve of Mosul dam reservoir on the River Tigris in northern Iraq using Empirical and semi-empirical techniques.

2. STUDY AREA

Murrumsilli dam was constructed in beginning of twentieth century (1914-1923) on Sillari River which is a tributary of Mahanadi, in dhantari district of Chhattisgarh. It is situated near to the Ravishankar sagar dam. It have a coordinates of latitude and longitude 20°32’17” N AND 81°39’82” E and it is about 95 Km from Raipur. Murrumsilli is earth-fill/embankment dam, which is also known as madam silli and mordem silli, the dam had started from 1923 on sillari river. It is the first dam in the Asia which has siphon spillways. The reservoir of dam has total capacity of 165,340,000 m³, surface area 25 Km² and active storage capacity 161,913,000 m³. The dam has height of 34.15 m(112 ft) and length of 2591 m (8501ft), dam has a volume of 1,619,000 m³ and spillway capacity 1,132 m³/s, The Dead storage level (DSL) and Full supply level (FSL) of Murrumsilli reservoir are 360.20 m and 376.31 m respectively. The base map of the study area has been given in fig 1.
3. DATA USED

Considering the different reservoir levels between dead storage level (D.S.L) and Full storage level (F.S.L) on various dates in between 2013 to 2015 for covering full range of live storage of reservoir. Ten LISS III scene of IRS 1D/P6 (Path53, Row 96) have been selected for analysis. The satellite data used in the analysis has shown in the Table 1. The original elevation-area-capacity curve/table and the reservoir level of year 2014 to 2015 have also been used in the analysis.

<table>
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<tr>
<th>S.NO</th>
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<th>Satellite used</th>
<th>Sensor</th>
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<td>LISS-III</td>
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<td>20-04-15</td>
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<td>IRS-P6</td>
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<td>4</td>
<td>25-04-14</td>
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<td>5</td>
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<td>10</td>
<td>28-09-14</td>
<td>376.23</td>
<td>IRS-ID</td>
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4. MATERIAL AND METHODS
The method of remote sensing does not directly compute the silt in the reservoir. It helps to determine the present storage capacity, which is compared with the original or designed capacity and the reduction in capacity over a period of time is attributed to silt deposition. The fundamental principle of revised capacity assessment by remote sensing and GIS is that reservoir water spread area get reduced with deposition of sedimentation comparing with original area before impoundment. The IRS 1D/P6, LISS III data (scenes) of ten different dates have been collected and digital image analysis have been processed out in ILWIS 3.0 GIS software. The ten images have been geo-referenced by using Survey of India topo-sheets so that they can be superimposed and associate with the latitude and longitude and the geographical area also can be found out directly in sq. m. After geo-referencing, ten images have been slice to small sizes to display the water spread area of the reservoir and its surroundings. The visible region of the spectrum (0.4-0.7 μm) shows the transmittance of water significant and the absorption and reflectance are low. The absorption of water swift in the near-IR band, where both the reflectance and transmittance will low. The normalized difference water index (NDWI) has been used to identify the water pixels in the images. The NDWI can be representing as:

\[ \text{NDWI} = \frac{\text{Green} - \text{NIR}}{\text{Green} + \text{NIR}} \quad \text{OR} \]
\[ = \frac{\text{BAND2} - \text{BAND4}}{\text{BAND2} + \text{BAND4}} \]

The slicing of the NDWI images has been executed to extract the water pixels from the rest. The revised areas brought in from this operation are used to compute the revised volume between two consecutive elevations by using cone formula. In the cone formula, the volume of water \(V\) between two successive spread \(A_1\) and \(A_2\) and height difference \(h\) can be represent as:

\[ V = \frac{h}{3} (A_1 + A_2 + \sqrt{A_1 \cdot A_2}) \]

The revised cumulative capacity of reservoir has been obtained by adding revised volumes between consecutive intervals. For comparing the original cumulative capacities on different elevation on date of pass have been obtained from the original elevation-area-capacity curve.

5. RESULTS AND DISCUSSION
The satellites data (scenes) of ten different dates have been analyzed to found the revised water spread areas of Murrumsilli reservoir. The digital analysis of remote sensing data has been done on ILWIS 3.0, GIS software like import, geo-referencing. After that slicing operation of NDWI images have been carried out to extract the water pixel from the rest. The NDWI and masked out water Spread area Image of Murrumsilli on 28-NOV-13 has been shown below in Fig 2.

![Figure 2 The NDWI and masked out water Spread area Image of Murrumsilli on 28-NOV-13](image-url)
The availability of satellite data at D.S.L. i.e. 360.20 m and at F.S.L., i.e. 376.31 m has not achieved. For computation of revised spread area at these levels, a graph has been made between reservoir elevations and revised spread areas. After plotting of best fit line, revised water spread at 360.20 m and 376.31 m have been computed as 54.45294 hectare and 2239.487 hectare respectively. Using revised water spread areas, the revised cumulative capacity and percentage loss in grass storage at different levels have been computed. The assessment of percentage loss in storages of Murrumsilli reservoir has been presented in Table 2. The graphical representation of the elevation v/s original and revised cumulative capacities of Murrumsilli reservoir has been in shown Fig. 3.

Table 2 Revised elevation-area-capacity table for Murrumsilli Reservoir

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<td>3.650</td>
<td>3.000</td>
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<td>14.138</td>
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<tr>
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<td>0.000</td>
<td>1.221</td>
<td>0.127</td>
<td>0.327</td>
<td>4.119</td>
<td>3.650</td>
<td>3.000</td>
<td>7.362</td>
<td>14.138</td>
<td>370.70</td>
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<td>% Loss in Cumulative Capacity</td>
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<td>74.85</td>
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<td>9.23</td>
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5. CONCLUSION

The remote sensing techniques are very effective in the estimation of reservoir sedimentation and its capacity loss as compared to the conventional method which involve surveying, planning, investigating etc. It is essential to assess the sedimentation in reservoir using such techniques which gives effective result in a shorter period of time. From the analysis of the outcome it may be concluded that 29.956 MCM gross storage of Murrumsilli reservoir has been lost in last 92 years (1923 to 2015). If the sedimentation rate in the reservoir is assumed as constant over the period of 92 years, the rate of silting may come out as 0.3256 M. cum/year. So it is necessary to put great concern and take corrective measures in the catchment area to reduce input of silt in the reservoir.

REFERENCES


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