Engineering/Science/Technology Civil/WR/EE/GIS

ASSESSMENT OF SILT DEPOSITION IN THATIPUDI RESERVOIR, VIJAYANAGARAM DISTRICT- A GEOSPATIAL APPROACH

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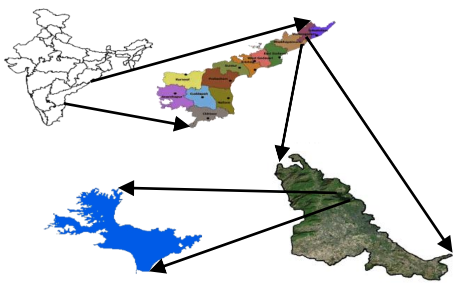
GRAPHICAL ABSTRACT



ABSTRACT

The Satellite Remote Sensing (SRS) method for assessment of reservoir sedimentation uses the fact, that the water spread area of reservoir at various elevations keeps on decreasing due to sedimentation. Remote Sensing technique gives us directly the water- spread area of the reservoir at a particular elevation on the date of pass of the satellite. This study describes the assessment of reservoir sedimentation of the Thatipudi Reservoir using Satellite Remote Sensing (SRS). The sedimentation assessment was carried out using satellite data and reservoir water level data from 2003 to 2015. Water spread area was analysed from satellite data. The Normalized Difference Water Index (NDWI) has been used to delineate open water features and to enhance the presence of water surface in satellite imagery of the Thatipudi Reservoir. Water spread area of the reservoir at a particular elevation on the date of pass of the satellite was used to develop elevation-area curve. For the present case fluctuation of water level was found to vary from 81.0768 m to 90.312 m. The linear interpolation / extrapolation technique has been employed to assess water spread area of Thatipudi Reservoir at different elevation. Further, these areas were used to compute live storage capacity of reservoir between two elevations by Prismoidal formula. From the study, it was found that due to sedimentation, the live storage capacity of Thatipudi Reservoir has reduced from 94.139 hm3 to 85.73 hm3, thus showing capacity loss of 9.108 %. To increase the live storage capacity of the reservoir it is proposed to adopt manual and mechanical digging combined with flushing for desilting of the deposited sediment .

***Keywords*— Live storage, NDWI, Reservoir Sedimentation, Satellite data and Water spread area.**

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I. INTRODUCTION

Sediments carried by rivers are an important component of the natural geochemical cycle and the movement of material from the land to the oceans. Natural River reaches are usually in state of equilibrium, where the sediment inflow on average balances the sediment outflow; Reservoirs can upset this equilibrium by slowing or halting the movement of water and allowing sediment to settle, thereby preventing the movement of sediment downstream.

Reduction in the storage capacity of a reservoir beyond a limit hampers the purpose for which it was designed (Gohil et al. 2015). Hence assessment of sediment deposition becomes very important for the management and operation of such reservoirs. Some conventional methods, such as hydrographic survey and inflow outflow approaches, are used for estimation of sedimentation in a reservoir, but these methods are cumbersome, time consuming and expensive. There is a need for developing simple methods, which require less time and are cost effective. The assessment of reservoir sedimentation of the Patratu Reservoir using Satellite Remote Sensing (SRS). The sedimentation assessment was carried out using satellite data and reservoir water level data from 2006 to 2012. Water spread area was analyzed from satellite data (Ashish et al. 2014)

With the introduction of remote sensing techniques in the recent past, it has become convenient and far less expensive to quantify sedimentation in a reservoir and to assess its distribution and deposition pattern. Remote sensing techniques, offering data acquisition over a long time period and board spectral and temporal attributes of remote sensing provide invaluable synoptic and timely information regarding the estimated water spread area after the occurrence of sedimentation and sediment distribution pattern in the reservoir. Multi-temporal satellite data are used in determining sedimentation rate in a reservoir. It is highly cost effective, easy to use and it requires lesser time in analysis as compared to conventional methods.

II. MATERIALS & METHODS

A. Study area

The methodology has been applied to Tattipudi reservoir. The catchment of Tattipudi reservoir is covering 332.72 km^2lies in Visakhapatnam and Vizianagaram districts of Andhra Pradesh state in India. The area of investigation is located in between $17^0 53^1$ – $17^0 56^1$ North latitude and $83^0 26^1$ - 8328^1Eastern longitudes. The location map of Tattipudi reservoir is shown in Figure: 1.1 and the various datasets and the software used for preparation of geospatial database for Tattipudi reservoir are shown in Table 1.

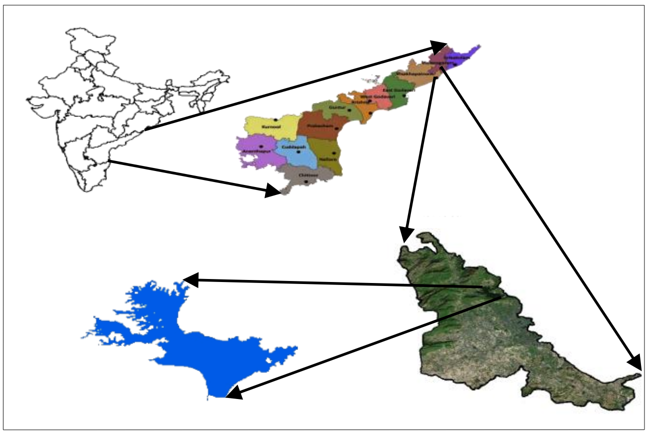


Figure 1.1: Location map of the Study area

B. Data Used

TABLE I. Data Used

S No	Datasets and Software used for geospatial database preparation		
	Data	***Purpose***	***Source***
1	SOI maps / Topo Sheets	Preparation of boundary shape files	
2	CartoDEM (Spatial Resolution: 30m	Preparation of DEM maps for study area	http://bhuvan.nrsc.gov.in
3	Landsat 5 and Landsat 8 (Spatial Resolution: 30m)	Generation of PCA images maps of study area	http://glovis.usgs.gov
S No	**Software**	**Purpose**	**Source**
1	Arc Map 10.1	Preparation of geospatial data and Generation of NDWI images	ESRI
2	ERDAS IMAGINE		https://www.google.com/earth

C. Methodology Flow chart

A methodology has been developed to estimate the capacity and sedimentation deposition in reservoir as shown in Figure.1.2. To estimate the capacity and silt disposition in reservoir is carried out by collection of topographical data i.e. toposheets, geospatial data i.e. satellite data and field data.

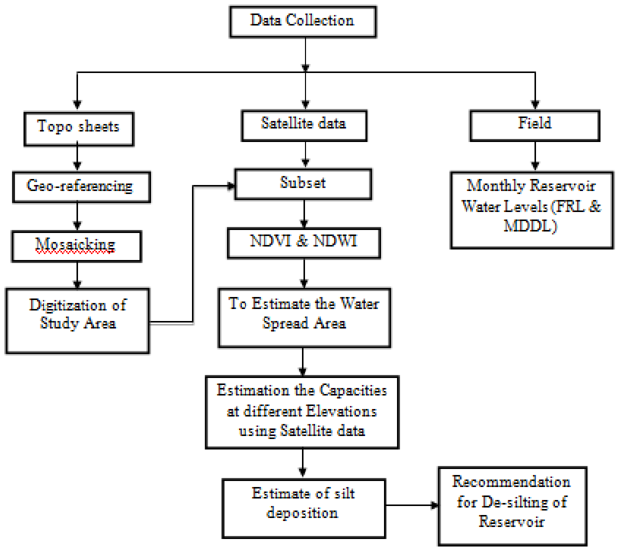


Figure 1.2: Flowchart showing the methodology

III. ANALYSIS OF SATELLITE IMAGERIES

After comparing the availability of cloud free imageries for different date of pass vis-à-vis water level variation for different dates collected from the dam site, it was observed from near FRL to MDDL. Cloud free imageries below MDDL were not available, hence the analysis of field data was restricted to live storage zone only.

The capacity estimation of Thatipudi Reservoir using Remote Sensing technique was carried out for the year 2003, 2006, 2009, 2013 and 2015 in order to know deposition of sediment since 1968 in the reservoir. The area capacity curve of 1980 (Figure 2) is thus taken as base for present study. The results of the hydrographic survey is also compared with present Remote Sensing survey.

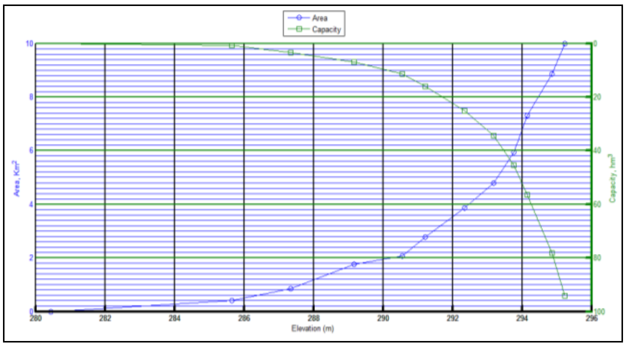


Figure 1.3: Original Elevation- Area Capacity Curve of Thatipudi Reservoir

IV. DIGITAL IMAGE PROCESSING FOR DELINEATION OF WATER AND LAND BOUNDARY

The basic output from the remote sensing analysis is the water-spread area on the date of satellite pass. For delineation of water-spread area, there are two techniques of remote sensing data interpretation, viz. visual and digital are practiced. The Normalized Difference Water Index (NDWI) is a new method that has been adopted to delineate open water features and enhance their presence in remotely-sensed digital imagery. The NDWI makes use of reflected near-infrared radiation and visible green light to enhance the presence of such features while eliminating the presence of soil and terrestrial vegetation features. NDVI index is calculated as follows:

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

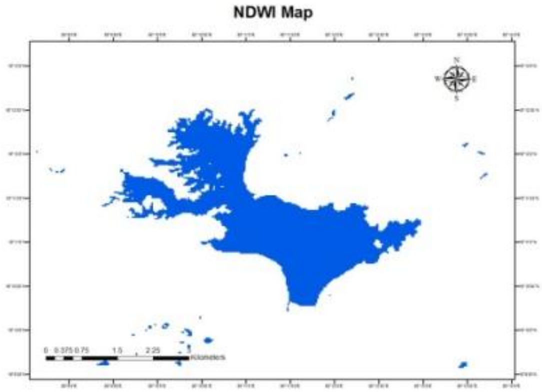
If the equation is reversed and the green band is used in place of the red, then the result would also be inverted, the vegetation suppressed and the open water features enhanced. The equation for NDWI is:

$$NDWI = \frac{Green - NIR}{Green + NIR}$$

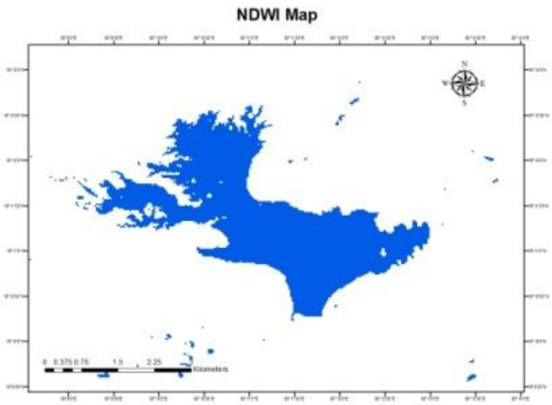
The selection of these wavelengths maximizes the reflectance properties of water as follows:
• Maximize the typical reflectance of water features by using green wavelengths;
• Minimize the low reflectance of NIR by water features; and
• Maximize the high reflectance of NIR by terrestrial vegetation and soil features.

The NDWI value ranges from -1 to 1 and zero as the threshold.If, NDWI >0, cover type is water and if, NDWI ≤ 0 cover type is non-water. According to McFeeters (1996)"If the digital number (DN) value is near-IR spectral region, the DN value of water pixels is appreciably less than the DN value of Band 2 and Band 3, then it must be classified as water, otherwise not". In the near-IR spectral region, the absorption of electromagnetic radiation by water is maximum and the DN of water pixels are significantly lower than the other land uses. Even if the water depth is very shallow, the increased absorption in Band 4 will restrict the DN value to be less than Band 3 and Band 2. If the soil is exposed and saturated at the surface, the reflectance will be as per the soil signatures, which increases with wavelength. Therefore, water pixels were clearly separated from the neighbouring pixels (Jain et al., 2002).

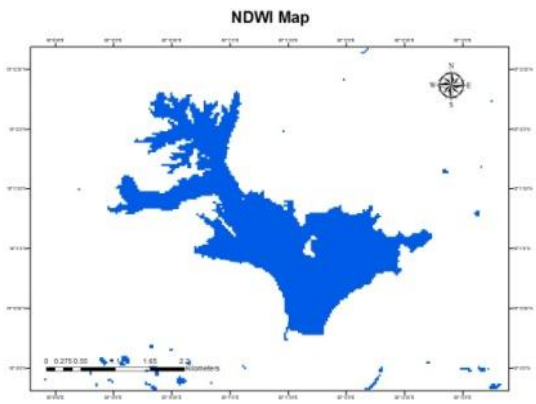
V. ESTIMATION OF CUMMULATIVE CAPACITY



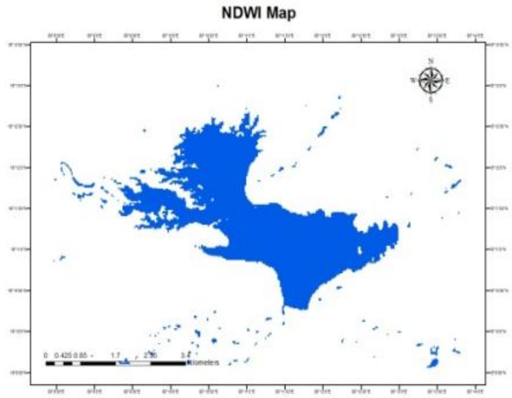
NDWI map of Thatipudi reservoir in 2003



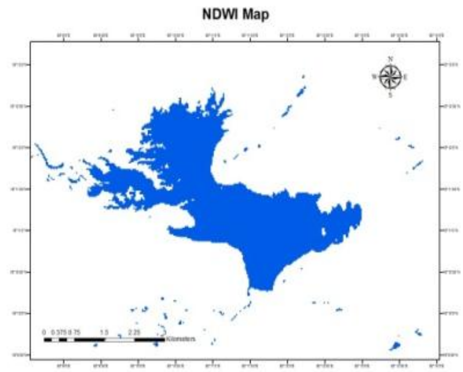
NDWI map of Thatipudi reservoir in 2006



NDWI map of Thatipudi reservoir in 2009



NDWI map of Thatipudi reservoir in 2013



NDWI map of Thatipudi reservoir in 2015

Estimated water spread areas for different dates (dates of satellite pass) obtained by digital analysis of satellite data corresponding to different elevations were plotted to generate elevation-area curve. Remote-sensing technique is limited to provide water spread area mostly in live storage zone. Variations of minimum and maximum water level were considered respectively. Linear interpolation / extrapolation technique was used to assess these areas. The overall reduction in capacity between the lowest and the highest observed water levels were obtained by adding the reduced capacities at all level. The reservoir capacity between two elevations was computed by prismoidal formula using water spread areas

$$\Delta V_{1-2} = \frac{\Delta h\left(A_1 + A_2 + \sqrt{A_1 + A_2}\right)}{3}$$

Where ΔV_{1-2} = Volume between elevation E_2 and E_1 ($E_2 > E_1$); A_1, A2 = Water spread areas at elevation E_1 and E_2 respectively; $\Delta h = E_2 - E_1$

VI. RESULTS AND DISCUSSIONS

Using the Prismoidal formula, the revised capacity between the maximum (90.52m) and minimum (81.24m) observed levels were obtained. The loss in live storage capacity since base period (year 1980) to recent remote sensing survey in the year 2015 was 85.73hm^3. Based on satellite remote sensing (SRS) survey the annual sedimentation rate is 0.4 hm3/year and seems to be quite high against the designed sedimentation rate of 9.43 ha-m/year. The gross, dead and live storage capacity of Thattipudi Reservoir for the base year (1980) was found to be 89.8922 hm3, 4.2469 hm3 respectively. The original live storage capacity of the Thattipudi Reservoir (94.139 hm3) reduced to 85.73 hm3 i.e. by 9.018 % till date. In the study, satellite remote sensing (SRS) survey could be done for the available imageries of live storage zone only. Satellite Remote Sensing survey for live storage zone to provide more accurate sedimentation deposition volume and rate with integrated system

VII. CONCLUSION

From the satellite remote sensing survey of Thatipuddi Reservoir, it was found that the live storage capacity of reservoir was reduced by 94.139 to 85.73 showing 9.108 % of loss in its original capacity. On the basis of analysis of satellite remote sensing survey, sedimentation rate in the Thatipuddi Reservoir seems to be on higher side. Moreover in order to get true picture of sediment deposition in reservoir the integrated hydrographic survey carrying out below MDDL and multispectral analysis from MDDL to FRL would be more appropriate. Manual and mechanical digging combined with flushing is recommended for desilting of the Tattipudi Reservoir

VIII. ACKNOWLDGEMENT

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TABLE II Thatipudi Reservoir capacity loss estimation of year 2003 compared with base year 1980

Elevation (m)	Elevation Difference (m)	WS area (10^6 m2)		Capacity (hm3)		Cumulative capacity (hm3)		Sediment deposition (hm3)
		1980	2003	1980	2003	1980	2003	
81.467	0	0.1	0.2	0	0	0	0	0
82.719	1.252	0.53	0.44	9.4	8.26	9.4	8.26	1.14
83.340	0.621	1.21	0.92	10.1	8.29	19.5	16.89	2.61
84.590	1.250	2.04	1.85	12.33	10.54	31.83	27.42	4.41
86.639	2.050	3.54	3.51	7.52	6.89	39.35	34.32	5.03
87.314	0.675	4.23	3.89	11.52	10.52	50.87	44.84	6.03
88.604	1.290	5.79	5.02	12.74	11.32	63.61	56.16	7.45
89.286	0.682	6.45	6.23	16.4	14.5	80.01	70.66	9.35
89.692	0.406	8.36	8.42	6.49	5.56	86.5	76.22	10.28
90.126	0.435	9.34	8.52	2.34	2.04	88.84	78.26	10.58

TABLE III Thatipudi Reservoir capacity loss estimation of year 2006 compared with base year 1980

Elevation (m)	Elevation Difference (m)	WS area (10^6 m2)		Capacity (hm3)		Cumulative capacity (hm3)		Sediment deposition (hm3)
		1980	2006	1980	2006	1980	2006	
81.467	0	0.1	0.2	0	0	0	0	0
82.719	1.252	0.53	0.44	9.4	8.46	9.4	8.46	0.94
83.340	0.621	1.21	0.92	10.1	8.88	19.5	17.34	2.16
84.590	1.250	2.04	1.85	12.33	10.82	31.83	28.16	3.67
86.639	2.050	3.54	3.51	7.52	7.58	39.35	35.74	3.61
87.314	0.675	4.23	4.28	11.52	11.34	50.87	47.08	3.79
88.604	1.290	5.79	5.89	12.74	12.74	63.61	59.82	3.79
89.286	0.682	6.45	6.55	16.4	15.52	80.01	75.34	4.67
89.692	0.406	8.36	8.52	6.49	5.82	86.5	81.86	4.64
90.126	0.435	9.34	8.99	2.34	2.42	88.84	83.58	5.26

TABLE III Thatipudi Reservoir capacity loss estimation of year 2009 compared with base year 1980

Elevation (m)	Elevation Difference (m)	WS area (10^6 m2)		Capacity (hm3)		Cumulative capacity (hm3)		Sediment deposition (hm3)
		1980	2009	1980	2009	1980	2009	
81.467	0	0.1	0.12	0	0	0	0	0
82.719	1.252	0.53	0.34	9.4	8.16	9.4	8.16	1.24
83.340	0.621	1.21	0.82	10.1	8.2	19.5	16.36	3.14
84.590	1.250	2.04	1.25	12.33	10.24	31.83	26.6	5.23

86.639	2.050	3.54	3.22	7.52	6.33	39.35	32.93	6.42
87.314	0.675	4.23	3.52	11.52	9.82	50.87	42.75	8.12
88.604	1.290	5.79	4.88	12.74	10.82	63.61	53.57	10.04
89.286	0.682	6.45	6.1	16.4	13.5	80.01	67.07	12.94
89.692	0.406	8.36	8.24	6.49	4.82	86.5	71.89	14.61
90.126	0.435	9.34	8.26	2.34	2.14	88.84	74.03	14.81

TABLE IV Thatipudi Reservoir capacity loss estimation of year 2013 compared with base year 1980

Elevation (m)	Elevation Difference (m)	WS area (10^6 m2)		Capacity (hm3)		Cumulative capacity (hm3)		Sediment deposition (hm3)
		1980	2013	1980	2013	1980	2013	
81.467	0	0.1	0.2	0	0	0	0	0
82.719	1.252	0.53	0.52	9.4	9.2	9.4	9.2	0.2
83.340	0.621	1.21	1.96	10.1	9.82	19.5	19.02	0.48
84.590	1.250	2.04	2.01	12.33	11.25	31.83	30.27	1.56
86.639	2.050	3.54	3.52	7.52	7.32	39.35	37.59	1.76
87.314	0.675	4.23	4.2	11.52	10.98	50.87	48.57	2.3
88.604	1.290	5.79	5.52	12.74	11.56	63.61	60.13	3.48
89.286	0.682	6.45	6.48	16.4	15.32	80.01	75.45	4.56
89.692	0.406	8.36	8.42	6.49	6.2	86.5	81.65	4.85
90.126	0.435	9.34	9.32	2.34	2.22	88.84	83.57	5.27

TABLE V Thatipudi Reservoir capacity loss estimation of year 2015 compared with base year 1980

Elevation (m)	Elevation Difference (m)	WS area (10^6 m2)		Capacity (hm3)		Cumulative capacity (hm3)		Sediment deposition (hm3)
		1980	2015	1980	2015	1980	2015	
81.467	0	0.1	0.22	0	0	0	0	0
82.719	1.252	0.53	0.51	9.4	8.99	9.4	8.99	0.41
83.340	0.621	1.21	1.98	10.1	9.82	19.5	18.81	0.69
84.590	1.250	2.04	2.03	12.33	11.88	31.83	30.69	1.14
86.639	2.050	3.54	3.55	7.52	7.42	39.35	38.11	1.24
87.314	0.675	4.23	4.32	11.52	11.22	50.87	49.33	1.54

88.604	1.290	5.79	5.72	12.74	11.84	63.61	61.17	2.44
89.286	0.682	6.45	6.42	16.4	15.98	80.01	77.15	2.86
89.692	0.406	8.36	8.38	6.49	6.02	86.5	83.17	3.33
90.126	0.435	9.34	9.34	2.34	2.56	88.84	85.73	3.11