SEDIMENTATION STUDY OF TAWA RESERVOIR THROUGH REMOTE SENSING

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ABSTRACT

In India reservoir projects are the prime centres of food and power production. Hence, it is necessary to often check the amount of sedimentation and the rate of sedimentation in the reservoir. In this study, estimation of sedimentation in Tawa reservoir has been done using Remote Sensing technique. The advantages and disadvantages of using remote sensing technique in the sedimentation study has been discussed. The procedure and the various technique in doing the remote sensing sedimentation survey is also discussed. The Tawa reservoir capacity evaluation using Indian Remote Sensing Satellite during 1995-96 indicates that the reservoir has lost 9.16% of its capacity since its last hydrographic survey in 1990 with the average sedimentation rate of 0.9% per annum.

1.0 INTRODUCTION

The assessment of the sedimentation in a reservoir is very important to take appropriate measures to control sedimentation as these reservoirs irrigate thousands hectares of land and generate electricity. The sedimentation in the reservoir occurs due to deposition soil/silt particles carried by the river from its catchment. Soil particles get eroded from its parent body due to rain, weathering or due to wind. The detached soil particle are then washed away from its location by the rain water into the stream, river and finally into reservoir or sea. The sedimentation of these soil particles in the reservoir reduces the water holding capacity of the reservoir thus reducing its utility and life. When the reservoir capacity is planned, the sediment load from its catchment is also taken into account and the life period for the reservoir is determined. But due to changes in agricultural practices, deforestation, urban development, industrialization etc., in the catchment area, the sediment load that arrives at the reservoir are far high compared to the predicted sediment yield. The annual siltation rate has been generally 1.5 to 3 times more than the designed rate and reservoirs are losing capacity at the rate of 0.3 to 0.9% annually (Lagwankar, V.G., 1995). It is also estimated that by the year 2020 over 20% of the Indian reservoirs will have lost 50% of their storage capacity due to sedimentation (Gregory, L. Moris, 1995).

It is, thus, necessary to monitor the sedimentation rate of the reservoir continuously. Most of the reservoirs have been surveyed, but the mode of survey is mostly by hydrographic technique or inflow outflow method which is time consuming, laborious and cumbersome. With the introduction of remote sensing technique in the recent past, it has become very heap and convenient to quantify the amount of sedimentation in the reservoir and to assess its deposition pattern. It is also less time consuming and less laborious.

In the sedimentology survey, the use of remote sensing technique to estimate suspended sediments has been reported by several studies (Solomonson 1973, Bartolucci et al. 1977, Holyer 1978, Khorram 1981 and Bhargava 1991). Hanumantha Rao et. al. 1985 and Mohanty et. al. 1986 adopted visual interpretation method for water spread estimation and found that the area capacity curves derived, fairly agreed, with the figures worked out by hydrographic survey. Manavalan et. al. 1990 adopted digital technique for simple density slicing of near infrared data (Jeyaseelan et al, 1995 and 1997) adopted digital classification technique using multi band information to delineate water pixel for estimation of water spread.

1.1 Drawback due to Remote Sensing

Sedimentation survey of reservoir through remote sensing may over or under estimate the water spread due to haze in atmosphere, moisture in soil surrounding the reservoir, burnt land around the reservoir, mixed land and water boundary pixels and cloud shadow. Usually the survey through remote sensing is carried out either during the water accumulation period or during the water depletion period i.e. from full reservoir level to minimum draw down level. This may not happen always. Secondly, sufficient cloud free scenes may not be available at all the level-pattern and especially below the maximum draw down levels, as the reservoir water rarely goes below this level.

2.0 BRIEF DESCRIPTION OF TAWA RESERVOIR

The Tawa project is one of the major irrigation project in Narmada valley as well as in Madhya Pradesh. The dam is constructed 823m down stream of the confluence of Tawa and Denwa rivers, both tributaries of Narmada river at village Ranipur of Itarsi Tehsil, Hoshangabad district of Madhya Pradesh. It is located 22°33'40" N latitude and $77^0 58'30"$ E longitude. It has a catchment area of 5982.9 Km^2. The dam comprises of a composite masonry and earthen dam with centrally located spillway across the Tawa river. It has a gross storage capacity of 2310 MM^3 and live storage of 2050 MM^3 with a command area of 2.47 lakh ha on both banks of the river. The project has two canal system viz. Left bank canal (LBC) designed to irrigate 186.16 thousand hectares and Right bank canal (RBC) designed to irrigate 60.70 thousand hectares. The dam construction was completed in the year 1978.

3.0 METHODOLOGY

3.1 Data Used

Satellite data

Tawa Reservoir is covered in single scene of IRS 1B, LISS 1 sensor which has the pixel resolution of 72.5m x 72.5m. Based on the reservoir draw down from full reservoir level to minimum draw down level overpass dates of satellite data have been acquired. The multi-date satellite image of Tawa reservoir in standard FCC (4,3,2), starting from maximum water level period during November 1995 to the minimum water level period May 1996 have been selected for this study. Since no cloud free data is available during May 1996, the nearest possible data for the same period in 1993 is considered.

Field data

The details of the Tawa reservoir was obtained from the published report on sedimentation studies of Tawa reservoir (1994). The reservoir water level data during satellite overpass in 1995-96 is also obtained from the office of Superintending Engineer, Tawa Circle, Water Resources Department, Hoshangabad district, Madhya Pradesh.

3.2 Basemap Generation

The base map of the Tawa reservoir was generated by scanning the 1:250,000 scale SOI toposheet No.55F and 55J with 72.5 x 72.5m pixel resolution covering 22°N to 23° N latitude and 77° E to 79° E longitude.

3.3 Geometric Correction

The first LISS 0.1 scene covering the Tawa reservoir and its command area is geometrically corrected with digital base map by selecting ground control points distributed uniformly all over the scene and with a suitable model for rectification with a Root Mean Square (RMS) error less than 0.4 pixel. The remaining overpasses were corrected using the rectified satellite imagery.

3.4 Water-spread Area Estimation

Water reflects most of the visible wavelength. The energy at near-infrared wavelength (i.e. greater than 0.7 μm) is almost totally absorbed by water. This helps in delineating the water-spread area with the surrounding land. Sometimes certain features like black soil, cloud shadow, moist soil, burnt land etc. have the same characteristic spectral signatures as that of water. Aerosol or hazy cloud, present in the atmosphere, can also increase water radiance and thus make land/water discrimination difficult. In order to oversome the above problem, the characteristic of water which reflect red radiance and absorb infrared radiance is taken advantage off.

For calculating water spread area from the satellite images, methodology given in the flow chart as shown in Fig.1 is followed. A sub-area is selected from the full scene which covers the reservoir water-spread area at full reservoir level. Unsupervised classification is done within this sub-area. The accuracy of classification is checked by overlaying with standard FCC image and by zooming and roaming around the periphery of the reservoir. The shallow water pixels, which are classified as a separate class, are merged with the main water body class by using programs like thresholding and bitmap logical operation. Under situation where both soil and water signature merge, ratioing is done between NIR and red channel to delineate the water pixels from the adjacent land which has the same signature as water. A reservoir mask was created for each overpass date which are considered for water spread area estimation. Care is taken to isolate water patches within the reservoir masked area which was not connected to the main water body.

After all the above operations is completed, a final bitmap of the water-spread area is created for each of the overpass date under study. The area under the water-spread area bitmap is calculated.

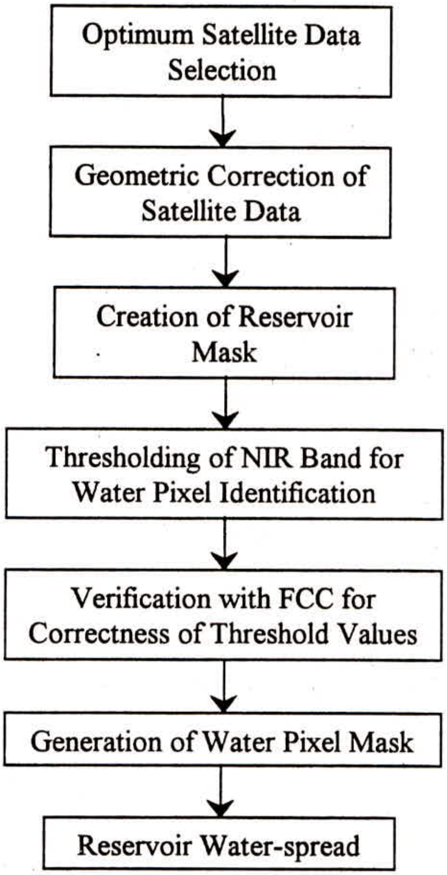

Fig. 1 : Methodology to Estimate Reservoir Water-spread Area using Multidate Satellite Data

3.5 Reservoir Capacity Estimation

In the first sedimentation assessment study conducted for the Tawa Reservoir in 1990, the capacity estimation was worked out by adopting the Prismoidal formula.

Capacity $V = H/3(a+b+\sqrt{(a \times b)})$

Where V : Volume between two successive elevation h1 and h2, i.e. the water level measured at reservoir on the corresponding satellite overpass date

H : is the difference between the elevation (h1 – h2)

a and b : are the area at h1 and h2 respectively

In this study also, the same formula is used to find out the reservoir capacity.

3.6 Capacity Loss due to Sedimentation

The volume of sedimentation deposit between two reservoir levels is computed based on the difference between the designed volume at the time of impoundment and the satellite derived information or based on the difference between previous capacity survey and the satellite derived information. The reduction in storage volume of the reservoir is integrated between the maximum and minimum draw down level to get the total sedimentation between the period from the current year to the year of previous study.

4.0 RESULTS AND DISCUSSION

The water-spread area bitmap for the seven dates, under study, which is generated based on the methodology given in flow chart. Table 1 gives comparison between satellite based (1996) water-spread area and first survey (1990) for different elevation under consideration. The water-spread

Table 1 : Comparison of Water-spread Area Estimates Obtained from SRS (1996) and first Hydrographic Survey (1990)

S. No	Date of overpass	Elevation m	Water Spread Area Km^2	
			SRS estimate as of 1996	Hydrographic Survey Estimate as of 1990
1	08 May '93	340.820	46.040	62.729
2	29 Mar '96	344.119	70.430	84.178
3	07 Mar '96	346.313	81.680	97.130
4	14 Feb '96	348.477	106.680	119.387
5	23 Jan '96	350.489	118.980	132.742
6	10 Dec '95	353.171	152.010	170.780
7	18 Nov '95	354.604	170.380	190.210

For the same elevation during the first survey was interpreted from the capacity area curve of the first survey (1990). The average water-spread area reduction at different elevation considered is about 15.85 km^2 between 1990 and 1996. An overlay of multi-date water-spread areas for Tawa reservoir is created by super imposing bitmaps one over the other for different elevation indicating the pattern of shrinkage in reservoir water-spread area (Fig.2).

The capacity between two successive elevation is estimated using prismoidal formula for the Tawa reservoir and presented in Table 2. Though the capacity is directly estimated between the levels of satellite overpass dates, to estimate the live capacity of reservoir, extrapolation of the area elevation curve with slope as that of previous survey is carried out. A plot between satellite derived water spread area and capacity is illustrated in Fig.3.

The elevation of 354.604 m on 18 November 1995 is close to the full reservoir level of 355.48 m. Similarly the elevation of 340.820m is the nearest available level close to the dead storage level of

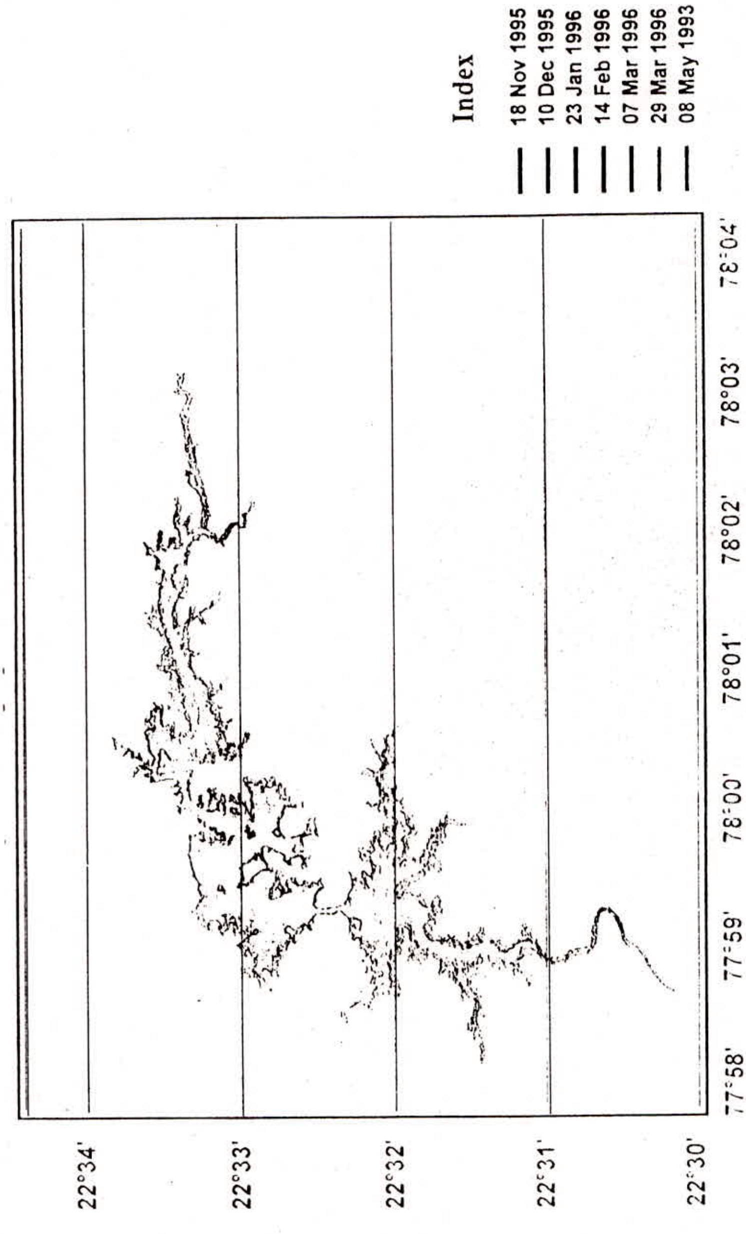

Fig. 2 : An overlay of multi date water spread area indicating shrinkage pattern in the reservoir

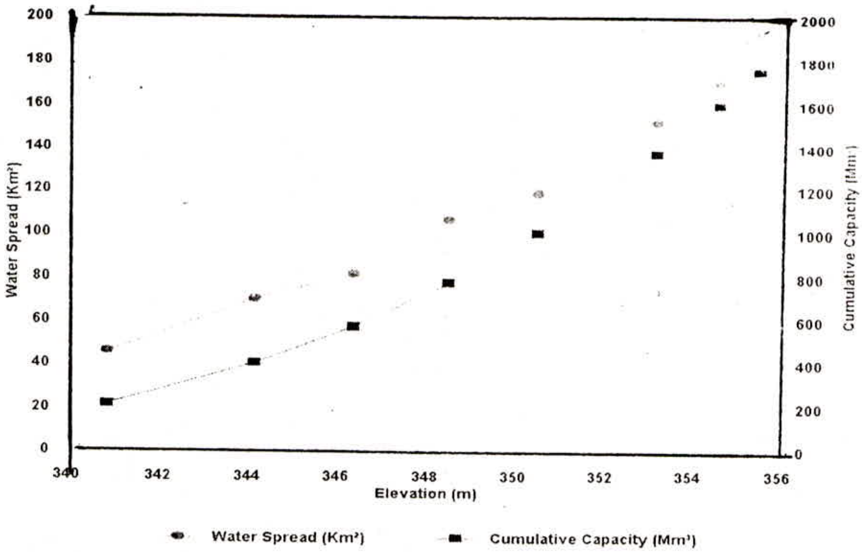

Fig. 3 : Satellite derived water spread area and capacity of Tawa Reservoir

332.243m. Though the satellite based area is valid for levels under study, slight extrapolation of the area curve towards Minimum Draw Down Level (MDDL) and (FRL) is done extending the area curve with the same slope as that of previous study.

Table 2 : Satellite Estimate of Water Spread Area and Capacity

Date	Elevation m	SRS Estimate as of 1996		
		Water Spread Sq.Km	Capacity	Cumulative Mm^3
08 May 1993	340.820	46.040		
			190.697	190.697
29 Mar 1996	344.119	70.430		
			166.712	357.410
07 Mar 1996	346.313	81.680		
			203.204	560.614
14 Feb 1996	348.477	106.680		
			226.901	787.516
23 Jan 1996	350.489	118.980		
			362.494	1150.010
10 Dec 1995	353.171	152.010		
			230.867	1380.877
18 Nov 1995	354.604	170.380		

Table 3 : Capacity Estimation of Tawa Reservoir

Date	Elevation m	SRS Estimate as of 1996 Capacity MCum	Hydrographic Survey Estimate as of 1990 Capacity MCum	SRS Estimate as of 1996 Cumulative MCum	Hydrographic Survey Estimate as of 1990 Cumulative Mcum
MDDL	334.243				
08 May 1993	340.820	219.00	221.415	219.000	221.415
29 Mar 1996	344.119	190.70	213.079	409.697	434.494
07 Mar 1996	346.313	166.71	190.113	576.410	624.607
14 Feb 1996	348.477	203.20	233.722	779.614	858.329
23 Jan 1996	350.489	226.90	259.421	1006.516	117.75
10 Dec 1995	353.171	362.494	415.029	1373.196	1532.779
18 Nov 1995	354.604	230.867	254.226	1599.066	1787.005
FRL	355.480	158.969	148.292	1758.035	1935.297

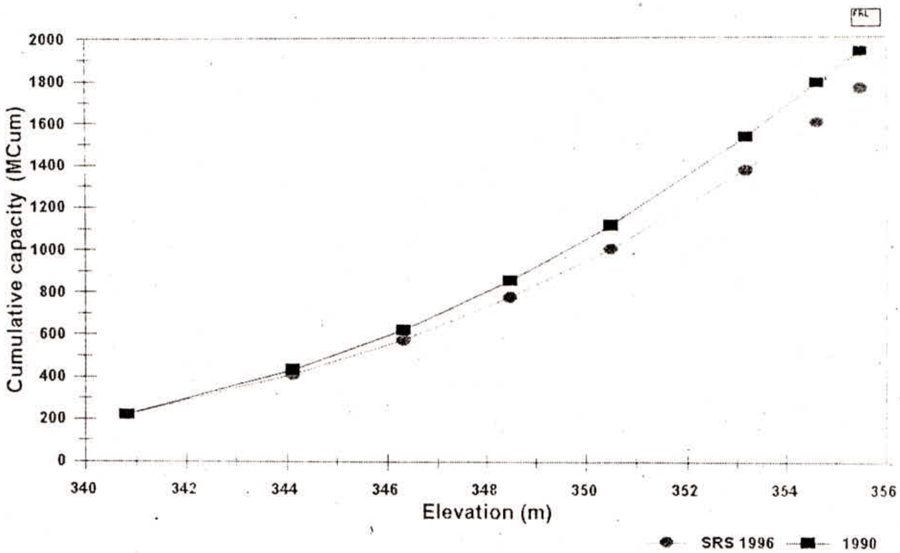

Fig. 4 : Cumulative capacity of Tawa Reservoir

The capacity estimated from satellite data during 1995-96 is compared with estimated capacity for previous period of 1990 and the original capacity. The results indicate that the average capacity reduction between 1990 and 1995 is 177.26 million cubic meter (MCum) i.e. 9.16% less than the 1990 value and 437.26 MCum i.e. 18.93% less than the 1975 value. The reservoir as a whole is losing its capacity at an average rate of 0.9% per annum. The annual rate of sedimentation is 35 MCum between 1990 and 1996. The capacity loss due to sedimentation at different elevation ranges during 1995-96 in comparison with 1990 is given in Table 3. A plot between cumulative capacity and elevation for SRS (1996) and first survey (1990) is shown in Fig. 4.

5.0 CONCLUSIONS

1. The total capacity loss since the 1990 hydrographic survey is estimated to be 177.262 MCum i.e.9.16% less than the 1990 storage capacity of the reservoir.

2. The average sedimentation rate is 0.9% per annum for the period between 1990-91 to 1995-96.

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