ANALYSIS OF CATCHMENT AND RESERVOIR FOR STAGE – AREA – CAPACITY ESTIMATION USING REMOTE SENSING AND GIS

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ABSTRACT

The natural hydrologic procedure like erosion in the catchment area produces a good amount of silt which gets deposited in the reservoir, there by reducing its capacity. There is a need to know the capacity of reservoir from time to time and to control the sediment yield from watershed so as to avoid premature loss of storage dedicated to particular purpose. The present paper produces the results of analysis done for Mahi Bajaj Sagar reservoir and its catchment area using Remote Sensing and GIS approach..

1.0 INTRODUCTION

The natural hydrologic processes like erosion in the catchment area, movment of sediment and its deposition in various parts of reservoir require careful consideration in planning of major reservoir projects. The silt which gets deposited at different levels, reduce the storage capacity of reservoir. Due thought is necessary towards the capacity surveys of the reservoir at the planning stage and afterwards. Periodical capacity surveys of reservoir help in assessing the rate of sedimentation and reduction in storage capacity. Every reservoir will ultimately silt up but the useful life of the reservoir can be increased if proper remedial measures are adopted. This is not only necessary for efficient management of reservoir, but also helps in taking a decision about treatment of catchment area, if the rate of sedimentation is excessive. The analysis of catchment area will help in taking various measures to reduce the entry of silt in the reservoir.

Satellite Remote Sensing by virtue of its synoptic coverage and repeativity is found to be very useful in capacity surveys of the reservoirs. Its multi date data directly provides the elevation contours in the form of water spread area. Any change in relation between elevation and areal extent of reservoir is indicative of sedimentation in the reservoir. The loss of storage capacity of the reservoir can thus be determined by evaluating the change in the areal spread of reservoir at different elevations. The new values can be used for modification of stage area capacity curve. Satellite Remote Sensing provides vital inputs for prioritization of watersheds. The vegetation status is a good indicator of health of watershed. The Remote Sensing inputs are also useful for taking in stream measures.

The present paper describes the Remote Sensing method for finding the capacity of reservoir and prioritization of watersheds of Mahi Bajaj Sagar reservoir and catchment.

2.0 OBJECTIVES

Objectives of the present study were:

- Updating the stage – area – capacity curve.
- Estimation of storage loss due to sedimentation.
- Prioritisation of watersheds of Bajaj Sagar sub-catchment
- Prioritisation of micro watersheds of critical watershed

3.0 STUDY AREA

Mahi Bajaj Sagar reservoir located near village Borekhera, about 16 km North-Est of Banswara town has its spread between 23°20' to 23°45' East longitude (Figure 1). The dam was built across river Mahi which has its source in Amarkantak area of Dhar district in Madhya Pradesh. After flowing 120 km in Madhya Pradesh towards North-West, it enters Rajasthan and turns North wards. In Rajasthan Mahi receives water from four of its major tributaries viz. Erau, Som, Chap, and Anas. Total length of Mahi river is 152.9 km and total catchment area is 6233 sq km. Erau tributary which is one of the major tributary rises from the nearby hills of tehsil Pratapgarh and after flowing for about 80 km, joins river Mahi. Figure 2 shows the index plan for catchment area.

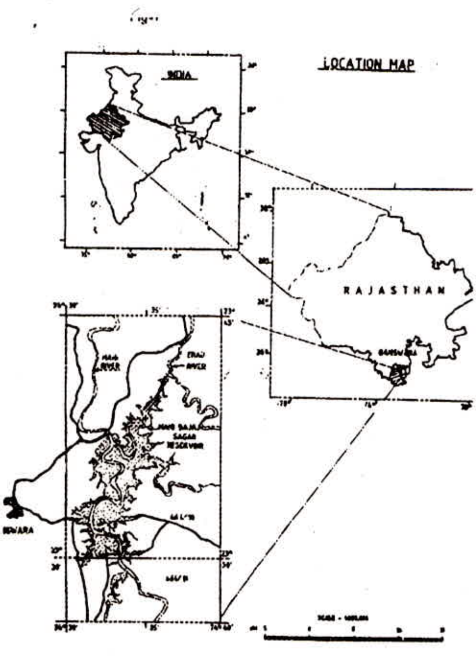

Figure 1 : Location map for reservoir

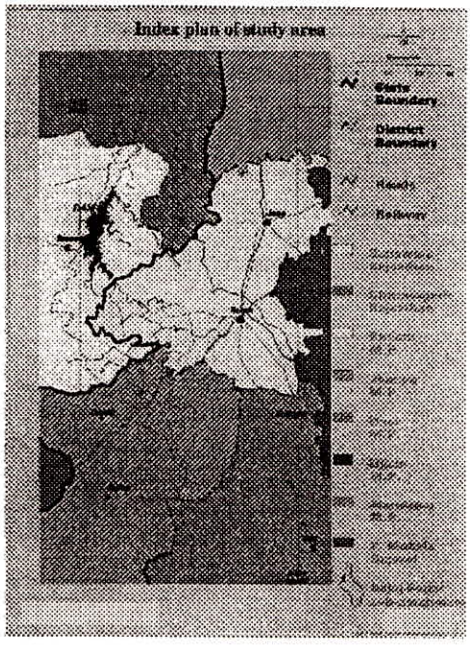

Figure 2: Index plan for catchment area

4.0 DATA USED

IRS 1B LISS II data with 36 m resolution was used for the analysis. Table 1 shows the details of data pertaining to capacity estimation study and table 2 shows the data for watershed prioritization.

Table 1: Data for Capacity estimation

Quadrant	Date of pass
30 / 51 A2	21 October 94
	28 April 94
	30 January 94
	17 December 93
	06 March 93

Table 2: Data for watershed prioritisation

Quadrant	Date of pass
30 / 51 A2	October 94 and March 93
30 / 51 B1	
30 / 51 B2	
30 / 52 A1	
29 / 52 A1	

The other data which were used include:

- SOI toposheets at 1:50,000 scale.
- Reservoir level, area and capacity on date of pass of satellites data.
- Original stage – area – capacity curve
- Watershed atlas at 1:1 M scale

5.0 METHODOLOGY

Methodology was divided in two major steps

1. Estimation of reservoir capacity
2. Prioritisation of watersheds in sub catchment

5.1 Estimation of reservoir capacity

For estimation of reservoir capacity satellite data were georeferenced with each other. Water spread area estimation was done using near infrared and red bands of satellite data. NIR band was density sliced to obtain water spread. NDVI output was also used for the analysis. FCC, NIR band and NDVI output, all were used to correctly demarcate water pixels on the image. Tail portion of the reservoir were it merges with river were removed. FCC of different dates are shown in plate 1. Water spread area was calculated by multiplying number of pixels with area of each pixel. Table 3 shows the area for different dates and corresponding elevation values obtained from Bajaj Sagar dam authorities.

Table 3: Areal extent of reservoir from Remote Sensing data.

Date of pass	Areal extent $M^2 \times 10^6$	Elevation in meter
21 October 94	111.73	279.25
28 April 94	49.01	264.35
30 January 94	80.52	272.75
17 December 93	99.43	276.75
06 March 93	59.32	267.8

The elevation 279.25 m for October 1994 is near to full reservoir level (FRL), whereas elevation 264.35 m for April 94 is near minimum draw down level(MDDL). To calculate the reservoir estimation capacity area values were calculated at regular intervals. After evaluating the results from trapezoidal, modified trapezoidal and prismoidal formulae, trapezoidal formula was used for analysis. Figure 3 shows the elevation values in meter and the cumulative capacity in Mm^3 and Figure 4 shows modified area elevation capacity curve.

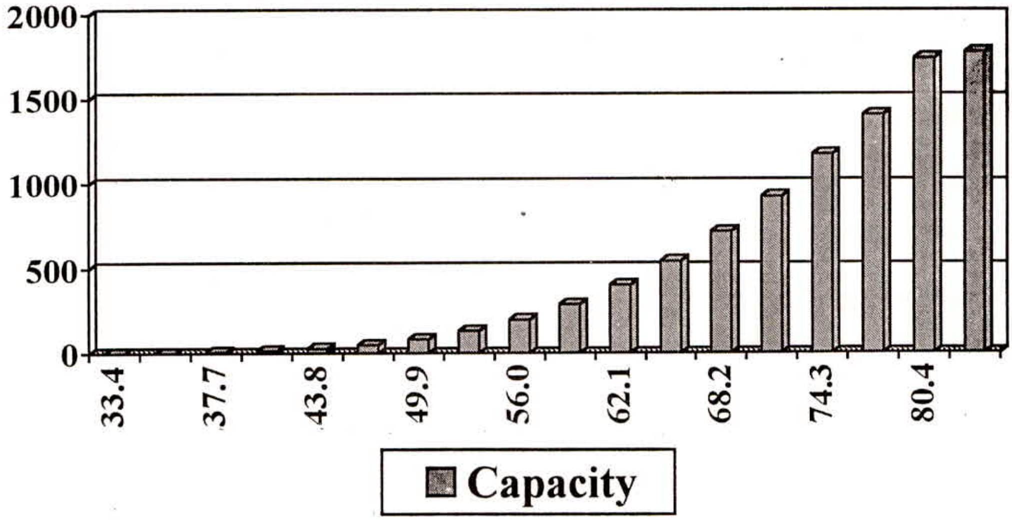

Figure 3: Cumulative capacity in Mm^3

New zero elevation of the reservoir has been fixed at 233.78 m against the original of 228 m. Present dead storage is 288.38 cum indicating that the reservoir is filled by 58.62 cuM (2.07 TMC) with sedimentation deposition in dead storage.

Present live capacity works out to be 1491.71 Mm^3 or 52.69 TMC against designed capacity of 1712 Mm^3 or 60.45 TMC. It means that there is 12.85 % reduction in live storage over a period of 11 years. (1983 – 1994).

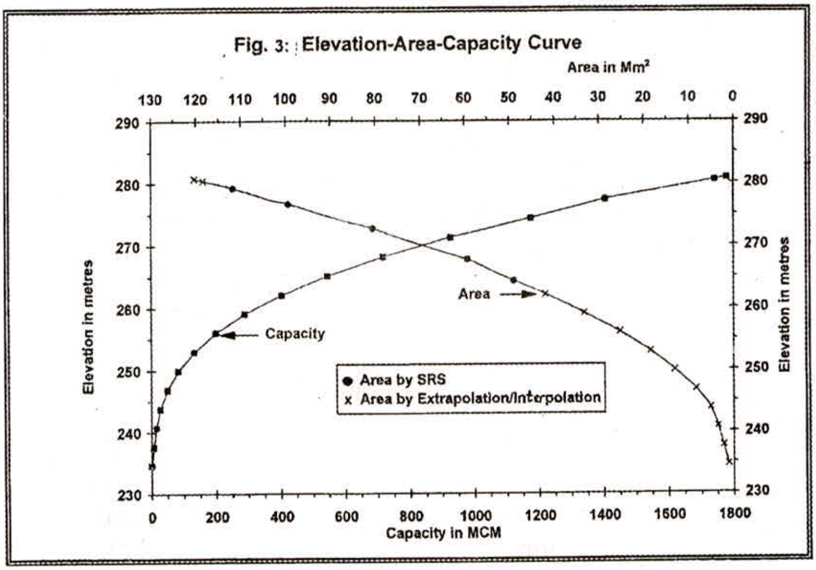

Figure 4 : Elevation area capacity curve

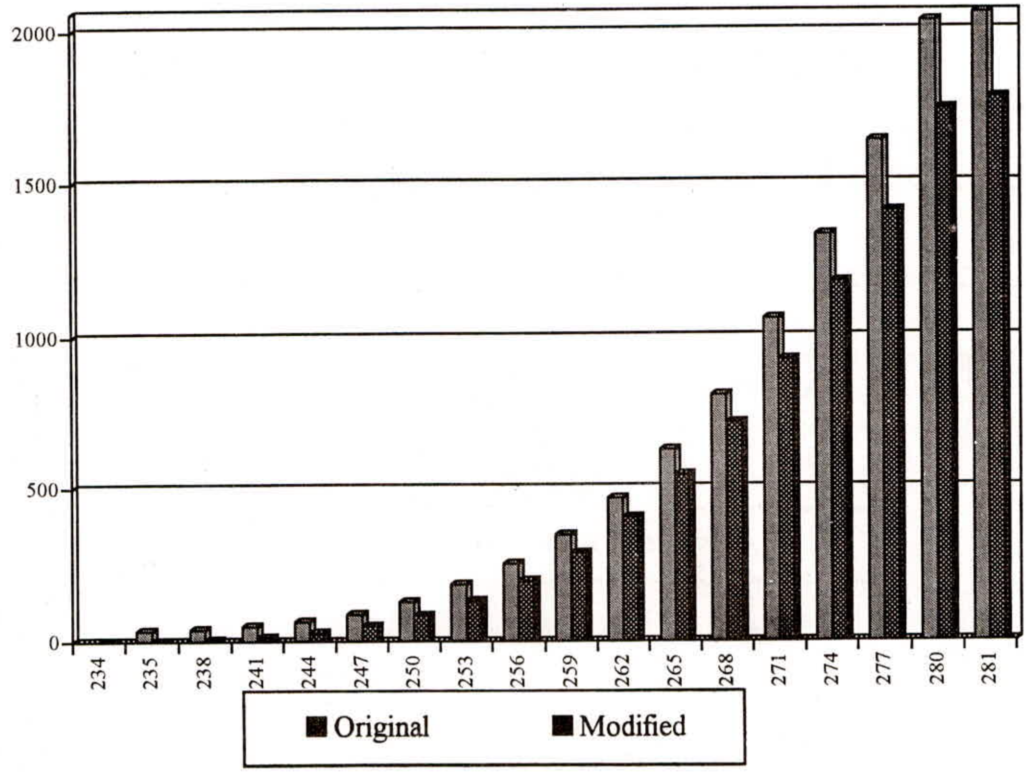

Figure 5 : Shows the comparison between original capacity and calculated capacity

5.2 Prioritisation of watersheds

For prioritization of watersheds various theme layers viz. watershed, drainage, contour, vegetation and texture etc. which affect the watersheds erosion response pattern were prepared using satellite data and SOI toposheet. Figure 6 shows the methodology for the watershed prioritization using erosion response model.

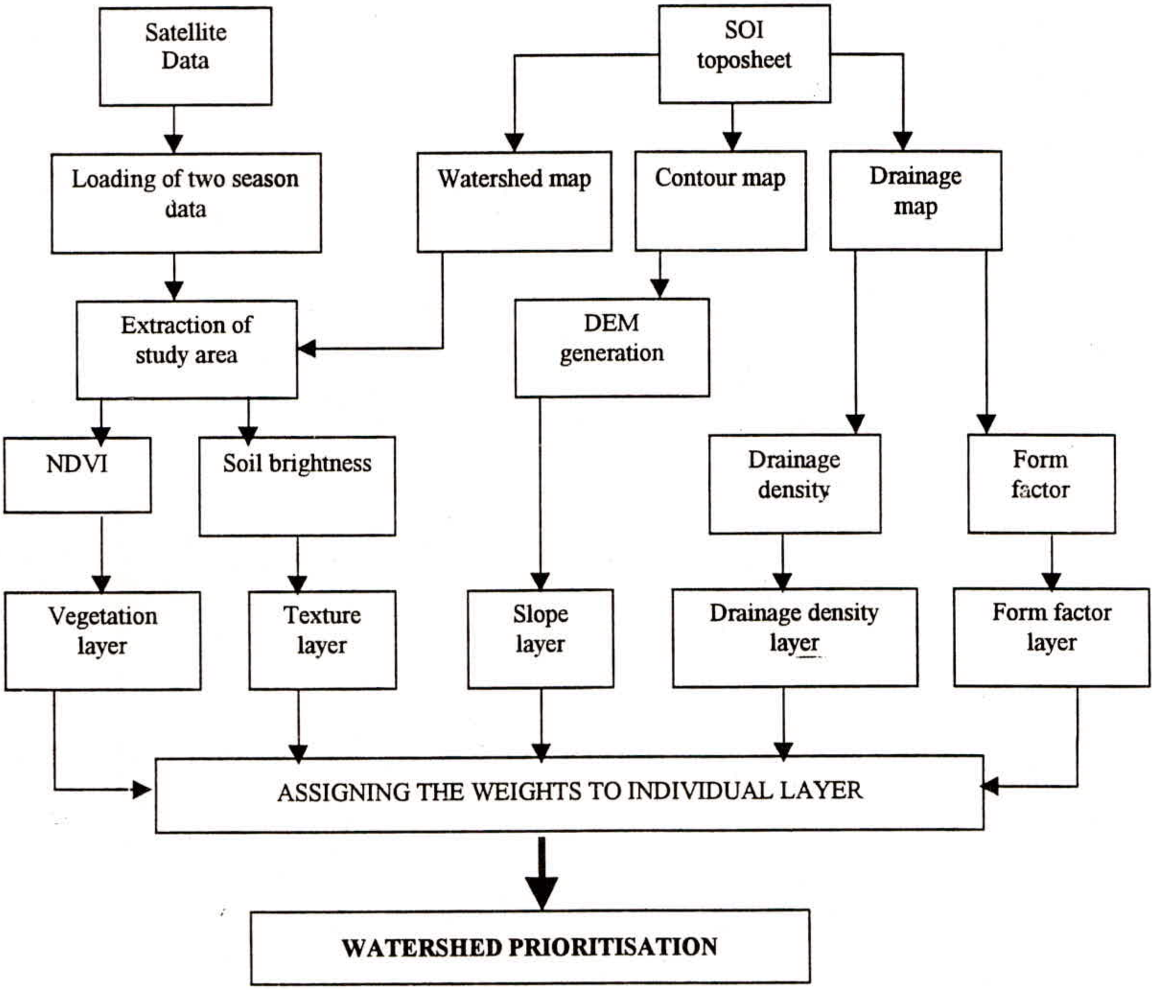

Figure 6 : Flow chart for methodology

Figure 7 gives the map for seven watersheds of the area. After making all layers, relative weights have been assigned to all seven watersheds for various parameters keeping in view the range of value for each parameter. Narrow ranges were used for higher priority and a larger range is used for lower order priority. Table 4 shows the ranges and their weights.

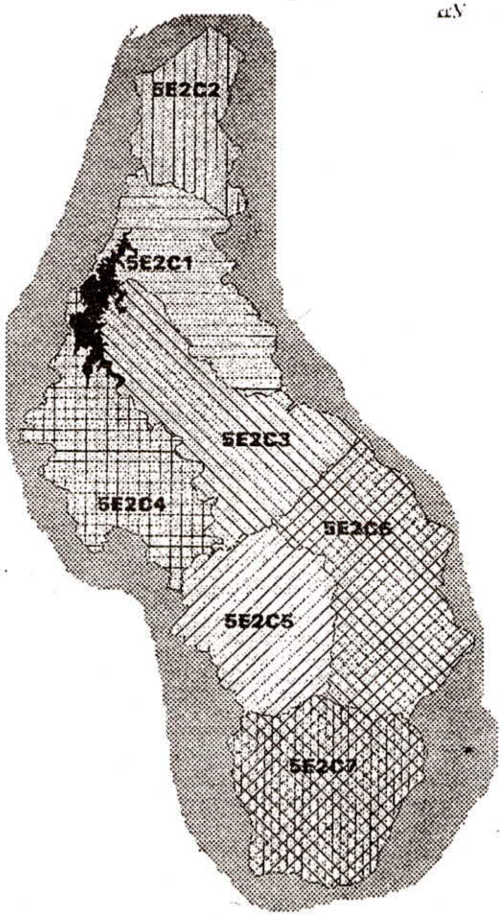

Figure 7 : Watershed map

Table 4: Ranges and their weights

% of range above minimum value	Weight
100 – 90 %	5
90 – 75 %	4
75 – 55 %	3
55 – 30%	2
Less than 30%	1

Using the above ranges weights were assigned to all the layers for both the season. Are weightage average was calculated for slope, vegetation and texture layer. The final priority for each watershed was calculated using both season data and is given in Table 5. Figure 8 shows the prioritized watershed for area.

Table 5 : Priority of each watershed

Watershed	Name	Sumwt for March 93	Sumwt for October 94	Average weight	Priority
5E2C1	**Erau**	**15**	**16**	**15.5**	**Highly critical**
5E2C2	Bhunan	14	14	14	Critical
5E2C3	Pundia	13	15	14.0	Critical
5E2C4	Telni	11	11	11	Not Critical
5E2C5	Pampawa	9	12	10.5	Not Critical
5E2C6	Bageri	13	14	13.5	Critical
5E2C7	Mahi	12	12	12.0	Low Critical

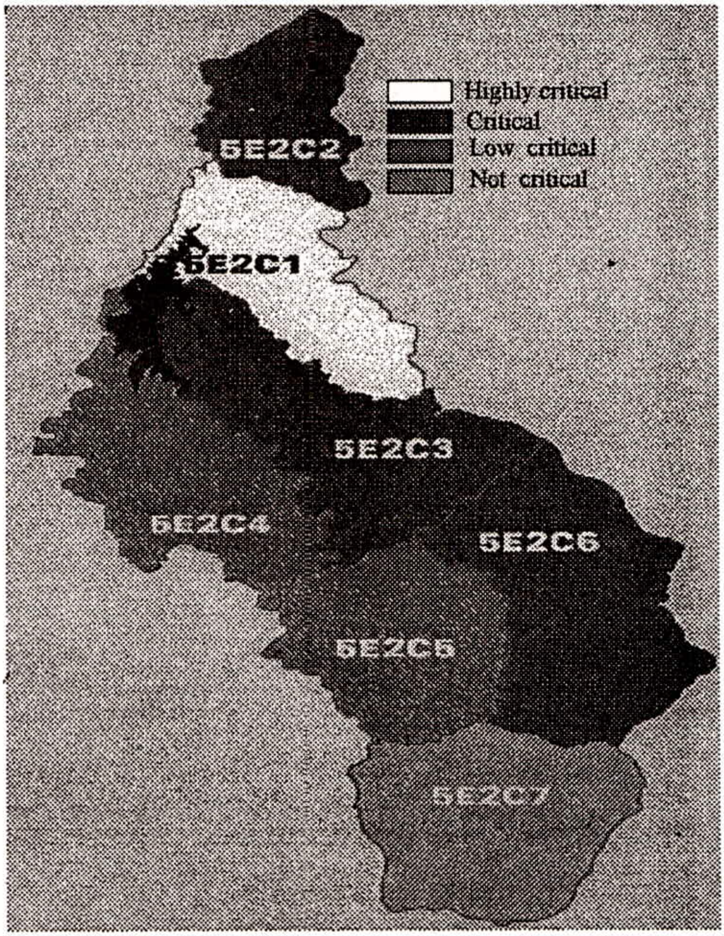

Figure 8 : Prioritised watershed

6.0 RESULTS AND DISCUSSION

The following results emerge from the study :

- The present dead, live storage estimated capacities are 288.38 Mcum (10.18 TMC), 1491.7 Mcum (52.68 TMC) and 1780.09 Mcum (62.86 TMC).
- Capacity loss of 16.86 % is observed in dead storage and 12.85 % in live storage, in a period of 11 years.
- The gross capacity loss of 278.6 Mcum i.e. 9.84 TMC (13.53 %) is observed over a period of 11 years. The annual capacity loss works out to be 1.23 %.
- Capacity estimation by RSR technique enables a quick and dependable estimation of capacity loss due to sedimentation in a major reservoir.
- Prioritisation of watersheds using two season data differ marginally in both the seasons.
- Seasons do not have major influence on response for Baja Sagar sub – catchment.
- Out of the three direct draining watersheds one is highly critical and other is critical.
- Direct draining watersheds are likely to contribute more silt load to reservoir.
- Erau watershed is most critical as slope factor is very high, status of vegetation is poor and drainage density is also very high.
- The erosion response model provides a quick approach to prioritise the watersheds in absence of detailed soil map which usually is very difficult to prepare.

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