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Assessment of Reservoir Sedimentation Using Remote Sensing Technique with GIS Model- A Review

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ABSTRACT

Assessment of the sediments in the reservoir is much essential as it affects the life of the reservoir & also the quality .To assess the sedimentation in the reservoir mainly we have conventional & Remote sensing technique .The conventional techniques of quantification of sediment deposition in a reservoir such as hydrographic surveys and the inflow-outflow methods, are cumbersome, costly and time consuming while on the other hand an alternative of conventional technique that is the digital image processing technique of remotely sensed data is easy, less costly and subjective of minimum human errors can be used for routine assessment of sedimentation in reservoirs. Remote sensing technique uses the fact, that the water spread area of reservoir at various elevations keeps on decreasing due to sedimentation .Remote sensing satellite provides information regarding the water spread area of the reservoir at a particular elevation on the date of pass of the satellite which helps to estimate sedimentation in a Reservoir over a period of time. In the present paper ,an attempt has been made to give a review on remote sensing technique adopted by researcher earlier for the assessments of reservoir sedimentation .This paper also delineates the use of different GIS MODEL with remote sensing data to assess the sedimentation & revised capacity of reservoir.

***Keywords*----** Sedimentation, Water spread, Remote sensing technique, Normalized difference water index (NDWI), Slicing, Evaluation of capacity of reservoir & GIS model.

I. INTRODUCTION

Reservoir is one of the credible hydraulic structures mainly made for storage of water so that this store water may be used for human life in various aspects. But when the Soil is eroded due to rainfall and wind, resulting in sediment movement into watercourses by flood and storm waters. A great amount of sediment is carried annually by the Indian rivers to reservoirs, lakes, estuaries, bays, and the oceans. Reservoir sedimentation and the consequent loss of storage affects water availability and operation schedules. An analysis of sedimentation surveys in respect of 43 reservoirs in India indicates that the sedimentation rate varies between 30 and 2785 m^3 km^2/year (Shangle, 1991). Many of the reservoirs in India are losing capacity at a rate of 0.5-1.5% annually. Hence Knowledge about the deposition of sediment & the rate of sedimentation in a reservoir is very essential to assess the balance life of reservoir. In view of this the conventional technique such as hydrographic survey and inflow-outflow approaches, for the estimation of sedimentation in a reservoir carried out periodically are cumbersome, time consuming, expensive and involve more man power. An alternate to conventional methods, remote sensing technique provides cost and time effective estimation of the sedimentation in a reservoir (Jain 2002). Multi-date satellite remote sensing data provide information on elevation contours, in the form of water-spread area, at different water levels of a reservoir. Water-spread area thus interpreted from the satellite data is used as an input in a simple volume estimation formula to calculate the capacity of a reservoir. Using the Remote Sensing techniques, it has become very efficient and convenient to quantify the sedimentation in a reservoir and to assess its distribution and deposition pattern. Remote Sensing technology, offering data acquisition over a long period of time and broad spectral range, can provide synoptic, repetitive and timely information regarding the sedimentation characteristics in a reservoir. Reservoir water spread area for a particular elevation can be obtained very accurately from the satellite data. Reduction if any, in the water spread area for a particular elevation indicates deposition of sediment at that level.

II. RESERVOIR SEDIMENTATION ASSESSMENT USING SATELLITE DATA

In India, the water level in a reservoir is likely to be near the full reservoir level (FRL) by the end of the monsoon season (September/October) before it gradually depletes to lower levels towards the end of the drawdown cycle (May/June). Due to deposition of sediments in the reservoir, the water-spread area at an elevation keeps on decreasing. Using the remote sensing approach, the water-spread area can be determined at different reservoir levels and a revised elevation-capacity curve can be prepared. By comparing the original and revised elevation-capacity curves, the amount of capacity lost to sedimentation can be assessed. With the availability of high-resolution satellite data, capacity surveys of reservoirs by remote sensing technique are gaining recognition and acceptance. A number of studies using this approach have been carried out (Manvalan et al, 1991; Goel & Jain, 1996, 1998; Gupta, 1999; Jain et al, 2002). Clearly, an analysis of the data of a year that has maximum variation in the reservoir water level will be most useful. The satellite imagery can be analysed by either visual or digital techniques to determine the water-spread area. Knowing the water-spread area from a particular image, the periphery of the water-spread area is obtained using image processing techniques. Elevation values are assigned to such water-spread boundaries and contours corresponding to different water spreads are overlain to represent the revised conditions in the zones of study. The reservoir capacity between two consecutive levels is computed using the prismoidal formula and a revised elevation capacity table is generated. Comparison of revised and original elevation-capacity tables gives the capacity loss due to sedimentation in various zones of the reservoir.

Past work done by the scientists, research scholars' etc. in this technique are summarized below:

Jain et al, (1996) used this technique to determine the capacity & sedimentation of **singoor reservoir**, India. In this study both the per-pixel and sub-pixel approaches have been performed to extract the water spread area of the reservoir using medium resolution multi-spectral image data and the results were validated using high resolution panchromatic image data. After determining the reservoir capacity they concluded that high spatial-resolution image data enables accurate mapping of terrain features. The use of high spatial resolution satellite image data, however, is constrained by factors such as cost and the smaller area covered by the sensor. Hence, in hydrological applications estimating the water spread area may be difficult because a reservoir may not be imaged in a single pass of the satellite and atmospheric conditions would be different from path to path (Hung and Wu 2005).

Agarwal ,et al (2001) assessed the sedimentation in Hirakud Reservoir using digital remote sensing technique. The digital image processing was done by Erdas imagine GIS software. In their study they concluded that the live storage capacity estimated using remotely sensed data for Hirakud reservoir was 4842 m^3 in year 2001. During 44 years, live storage capacity was reduced by nearly 17 % (at the rate of 0.376 % year") of live storage. Silt index for Dive storage area was 2.623 ha m (I00 km2/year) . This rate though low was more than the design rate. Yearly live storage capacity loss was significant.

Goel et al, (2002) assessed the reservoir sedimentation of **Bargi Reservoir** M.P ,INDIA using digital image processing data & satellite image data. In this study, digital processing was carried out using the **ERDAS/IMAGINE image processing software**. The steps of analysis were to Import, visualized and geo-referencing the satellite data, identification of water pixels, removal of discontinuous pixels , removal of extended tail and channels , derivation of revised contours and at last calculation of revised capacity. After estimating the sedimentation they concluded that the procedure to remove the discontinuous pixels and the derivation of contours has been considerably automated & the remote sensing technique is a time- and cost-effective and convenient approach to estimate the elevation-area- capacity curves for a reservoir.

Jain et al (2002) Assessed sedimentation in **Bhakra Reservoir** in the western Himalayan region using remotely sensed data. The application of remote sensing techniques for estimating the sedimentation rate in the Bhakra Reservoir (located on Satluj River in the foothills of western Himalayas) showed that the average sedimentation rate for 32 years (1965-1997) is 25.23 Mm^3 per year, whereas ground observations through hydrographic survey provided sedimentation rate of 20.84 Mm^3 for the same period. In study it was concluded that the higher sedimentation rate obtained using remote sensing data can be explained on the basis of accuracy in the determination of water spread area and the mixing of water pixels with the land around the periphery of the reservoir. However, the use of better (spatial and temporal) resolution satellite data maybe a remedy for these problems to some extent. It was also concluded that remote sensing techniques give the information on the capacities only in the water level fluctuation zone, which generally lies in the live zone of the reservoir.

Jain & Goel (2002) Assessed Reservoir sedimentation for **Ukai dam** using satellite data .In study it was found that the average loss of sedimentation is 15.46 M.CUM per year. It was also concluded that remote sensing technique gives the value of sedimentation between MDDL & FRL of the reservoir sedimentation in the portion below the lowest observed water level & above the highest observed level cannot be determined. It was suggested that if sedimentation is required between this portion then hydrographic survey can be carried out and the result can be combined.

Mandwar, et al (2003) estimated the Capacity Evaluation and Sedimentation of **Totla Doh Reservoir,In** Nagpur District By Remote sensing Technique. MERI. Nashik , had conducted sedimentation study of Totla Doh reservoir in 2002-03, 2006-07 and recently in 2010-11. In 2002-03, the study covered storage zone of reservoir between R.L. 463.00 m. to R.L. 488.18 m. covering 90% of designed live storage zone and smaller portion of dead storage. In 2006-07 study covered 100% live storage zone of reservoir between FRL 490.00 m. and MDDL 464.00 m. and some portion of dead storage. In the third study the reservoir zone between RL 458.30 m. and RL 490.00 m. has been covered. The conclusion of their study was that the Remote Sensing based capacity estimation, works between FRL and the minimum water level in the reservoir only. Thus changes can be estimated only in this zone of reservoir. For the capacity estimation below minimum water level in reservoir, other method like hydrographic survey is to be conducted. Availability of cloud free dates throught reservoir operation period is the problem.

Durbude et al (2005) assessed the revised capacity and the sedimentation loss in

Linganmakki Reservoir using remote sensing & GIS Technique. In study it was found that the Revised capacity in the zones of Reservoir levels (533.05-548.78 m) for the year 1989-90 and 2001-2002 was 2837.84 m & 2207.95 m for 532.30 and 545.91 m respectively. Based on these the sedimentation loss came out to be 8.96 ha-m/100 km^2/ year.

Narasayya et al, (2005) Assesed the Reservoir Sedimentation Using Remote Sensing Satellite Imageries the study area was **Srisailam Reservoir** subsequently renamed as Neelam Sanjeeva Reddy Sagar (NSRS) located in Nandikotkur taluka of Kurnool District of Andhra Pradesh State ,INDIA. The steps involved in their technique was to carried out the field data, satellite data & analysis of Satellite Imageries , Digital Image Processing for Delineation of Water and Land Boundary and at last computation of rvised capacity. The gross, dead and live storage capacities of Srisailam Reservoir for the year 1976 were 8724.88 Mm^3, 1557.68 Mm^3 and 7167.2 Mm^3 respectively. As per recent Remote Sensing survey of 2004, it was observed that the original live storage capacity of 7167.20 Mm3 was reduced to 5467.54 Mm^3 i.e. by 23.714% in 28 years. Thus, the average annual rate of loss of live storage capacity worked out to 0.846%. In addition to these the rate of percent annual loss of live capacity appears to be in line with annual loss of 0.5 to 1.0% in many of the Indian Reservoirs therefore it is necessary to take corrective measures in the catchment area to reduce entry of silt in the reservoir.

Thomas, et al (2010) estimates the reservoir sedimentation of **Ravishankar sagar reservoir** situated on river Mahanadi in Dhamtari district of Chhattisgarh state. The IRS 1D, LISS III data of ten different dates have been obtained and digital image analysis have been carried out **in ILWIS 3.0 GIS software**. All the images have been geo-referenced with the help of Survey of India toposheets so that they can be overlaid and linked with the latitude and longitude and the geographical area also can be determined directly in sq. m. After geo-referencing, all the images have been cut down to small sizes to cover the water spread area of the reservoir and its surroundings. For digital analysis of remote sensing data, ILWIS 3.0, GIS software has been used. All the images have been imported, georeferenced in ILWIS software. From the analysis of the results it may be concluded that 45.93 M. cum of gross storage and 31.00 M. cum. of live storage of Ravishankar Sagar reservoir has been lost in last 24 years (1979 to 2003).

Singh et al (2010) used the remote sensing technique to assess the Reservoir capacity loss & sedimentation of **Ujjaini reservoir** (also called Yashawant Sagar reservoir) on river Bhima, in Solapur district of Maharashtra state of India.. Total catchment area of the project was 14856 km2. It was found that there was loss of gross storage of 498.375 Mm^3 from 1977 upto 2004 (i.e. 27 years). In study it was found that the gross, dead and live storage capacities of Ujjani reservoir for the year 1977 were 3491.21 Mm^3,1802.81 Mm^3 and 1688.40 Mm^3 respectively. As per the studies with SRS data for the period 2002 -2004, these storages are estimated as 2992.835Mm^3, 1540.99 Mm^3 and 1451.845 Mm^3 respectively. It was also estimated that the overall loss in capacity of Ujjani reservoir since its impoundment in 1977 to recent remote sensing survey in 2004 comes out to 498.375 Mm^3, which is 14.275% of the gross storage (3491.21 Mm^3). It was concluded that the original live storage capacity of 1688.40 Mm^3 reduced to 1451.845 Mm^3 i.e. by 14.011%in 27 years .Thus, the average annual rate of loss of live storage capacity is 0.519%.

V.S.Jeyakanthan and S.Sanjeev (2011) Evaluated the sedimentation and the storage capacity lost in **Somasila reservoir**, located on the Pennar river that flows through the Nellore district of Andhra Pradesh, INDIA using remote sensing & GIS technique .in this study it was that the reservoir lost its storage capacity as 23.96 M.cum during the period 1987 to 2002 between the water level 83.17 M and 94.39 M respectively . From these it was concluded that ,if the sedimentation rate is assumed to be uniform for the 15 years then the sedimentation rate is 1.597 M per year.

Jaiswal et al (2011) used remote sensing technique to assess the sedimentation & trend analysis of sedimentation in reservoir of **southern Gujrat**. In analysis Shetrunji, Rajaval and Kharo reservoirs of South Gujarat (India) have been taken for sedimentation assessement . To assess the sedimentation Seven Linear Image Self Scanning (LISS III) digital data of Indian Remote Sensing (IRS) satelliteIRS-1D/P6 have been used and normalized difference water index (NDWI), image rationing and slicing methods have been applied to classify the water and non-water pixels from the images using Integrated Land and Water Information System 3.0 (ILWIS 3.0), a GIS software. From the analysis, it has been observed that 120.66 M. cum of gross storage and 97.17 M. cum of live storage of Shetrunji reservoir have been lost in last 42 years (1965 to 2007). The Rajaval reservoir has been first impounded in the year 1982 and 5.043 M. cum of gross storage has been lost in 25 years. Similarly, in case of Kharo reservoir, 4.332 M. cum of gross storage has been lost in 22 years (1985 to 2007). In their analysis it was concluded that by Assuming constant rate of sedimentation over a period of since impoundment, the average rate of silting in Shetrunji ,Rajaval and Kharo reservoirs may come out as 0.067 M. cum/100 km2/year, 0.071 M. cum/100 km2/year and 0.082 M. cum/100 km^2/year respectively.

Jeyakanthan and V.S, Sanjeevi. S (2012) estimated the Capacity survey of **Nagarjuna** Sagar reservoir, India. To compute the water-spread area accurately, the sub-pixel or linear mixture model (LMM) approach has been adopted in this study. IRS-1C and 1D satellite image data (24m) of eight optimal dates ranging from minimum draw down level (MDDL) to full reservoir level (FRL) were used to estimate the water-spread area of the reservoir. The extracted water-spread areas using sub-pixel approach was in turn used to quantify the capacity of the Nagarjuna Sagar reservoir for the water year 2002. The estimated capacity of the reservoir using sub-pixel approach was 8014.49 Mm3.

Shukla et al in 2012 tried to assess the sedimentation in **pong reservoir** (Rana Pratap reservoir) created on the Beas river in the low foothills of Himalaya on the northern edge of Indo Gangetic plain, located in the Kangra district, Himachal Pradesh . This study was based on spectral mixture analysis, to estimate the concentration of suspended sediment in Reservoir from IRS(P6) LISS – III images. Eight dates of IRS (P6) LISS – III data (from 10 oct. 2008 to 4 July 2009) between 426.720 m and 388.696 m water level were used to assess temporal and spatial patterns of lake area and dimensions of suspended sediment concentration in pong Reservoir . The Normalize Different Water Indices (NDWI) approach was used for delineating water spread area of reservoir. In study it was found that the sediment yield was 18.20 Mm3 in the live storage area. The study also illustrated the advantages of remote sensing and demonstrates the value of IRS (P6) LISS – III data for use in mapping geographic variations in water area and major flood event.

Roman et al in 2012 carried out a case study on **Panshet Reservoir** of Pune city near village Panshet, Taluka Velhe, District Pune of Maharashtra (State), India, popularly known as Tanaji Sagar which is a part of Mutha canal system was taken to carry the sediment assessment. In this study Remot sensing technique was used to assess the sediments in the reservoir. In assessment multi date remote sensing data (IRS-1C/1D/P6, L1SS III) has been utilised to calculate water spread area. The revised capacity of the reservoir between maximum and minimum water levels were computed using the prismoidal formula. It was observed that the gross, dead and live storage capacities of Panshet reservoir for the year1977 were 303.93 Mm3, 9.00 Mm^3 and 294.93 Mm^3 respectively. As per remote sensing survey from, these storage capacities were estimated as 278.85 Mm3, 8.56 Mm3 and270.29 Mm3 respectively. The overall loss in capacity of Panshet reservoir since 1977 to remote sensing survey in 2002 came out to 25.08 Mm3 which was 8.25% of the gross storage. Therefore, the percentage average annual rate of siltation since 1977 to 1991 was 0.216%, from 1977 to 1998 was 0.252% and for the year 2002 was 0.330% respectively. The loss in dead and live storage capacity since 1977 to recent remote sensing survey in 2002 Came out to 0.44 Mm^3 and 24.64 Mm^3 which was 4.89 % and 8.35% respectively. It could be seen that for the live storage capacity of 294.93 Mm3, the capacity of the dam has reduced by8.35% in 25 years. Thus, the average annual rate of loss of capacity was 0.334%.

Panday et al (2013) estimated the reservoir sedimentation loss in **Patratu reservoir** lake, Jharkhand, INDIA using Satellite Remote sensing (SRS) technique. The sedimentation assessments was carried out using satellite data & reservoir water level data from 2006-2012.from these study it was found that ,due to sedimentation, the live storage capacity of Patratu reservoir has reduced from 101.95 hm^3 to 89.96 hm^3,thus showing capacity loss 11.76% in 44 years.

Mandwar et al (2014) evaluated the performance of Reservoirs in Nagpur region using Satellite Remote Sensing (SRS) technique .In the study it was found that the average rate of sedimentation of Nagpur region **5.22 ha-m/100km^2/year** is quite less than the rate given in ISO EROSION Map by Gurmel Singh, Ram Babu, and Pratap Narain (1978). The rate of sedimentation has been observed in the Nagpur region is alarming and demands catchment area treatment of reservoirs. It was also conclude that the rate of sedimentation on the basis of single Satellite Remote Sensing Survey may not be taken for future planning of the reservoir storage as permanent solution .The detail analysis of catchment area considering, soil texture, slope of land, land use, topography, lithology, and hydrology are required to assess the rate of sedimentation. To predict soil loss the Revised Universal Soil Loss Equation (RUSLE) module can be used. At least two to three SRS survey each of the reservoirs at the interval of five years span may be required for accurate assessment of rate of sedimentation. In addition to this Hydrographic survey can be conducted to assess the accurate rate of sedimentation of the reservoirs.

III. CONCLUSION

The conventional methods, such as hydrographic surveys, are laborious, costly and time-consuming. For these reasons, the hydrographic surveys of reservoirs are normally conducted at a frequency of 5-15 years, though the recommended frequency is every five years. Remote sensing techniques can be used as a cost- and time effective tool to estimate capacity loss. The major limitation of the remote sensing-based approach is that the revised capacity below the lowest observed and above the highest observed reservoir water levels cannot be determined. It is only possible to calculate the sedimentation rate within the zone of fluctuation of reservoir water level. From the point of view of operation of the reservoir, this limitation is not very significant. Since the reservoir level rarely falls below the minimum drawdown level in normal years, the interest mainly lies in knowing the revised capacity and the sediment deposition pattern within the live storage zone. However, if the sedimentation in the entire reservoir is to be found, in addition to remote sensing data analysis, the hydrographic survey within the water-spread area corresponding to the lowest observed elevation may be carried out. This will decrease the amount of effort required carry out the hydrographic survey. Further, it may be seen that the estimation of sedimentation by remote sensing is highly sensitive to the accuracy of: (a) the determined water-spread area, (b) water level information, and (c) the original elevation-area-capacity table. However, if the water level information is exact and the water-spread area is interpreted accurately, it is possible to find the revised elevation-area-capacity curves quite precisely. Accuracy in the identification of water pixels, particularly at the tail end of a reservoir, affects the accuracy of sedimentation assessment using remote sensing. Further, the satellites of higher spatial resolution are now becoming available and the data of these must be utilized to increase the accuracy of the water-spread area determination. Remote sensing images can be chosen at closer time intervals so that the revised water-spread area may be obtained at smaller elevation intervals, thereby increasing the accuracy of sedimentation assessment.

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