A Review on reservoir capacity loss due to sedimentation studies using remote sensing technique

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Abstract: *Reservoir sedimentation clustered the process of erosion, entrainment, transportation and deposition. The sediment particles from the catchment area enter and get deposited in the storage area of the reservoir due to soil erosion. The computation of reservoir sedimentation is essential to determine the capacity loss of the reservoir. For the sedimentation survey, traditional hydrographic surveying, stream measurements are prolonged, burdensome, manpower requirement, weather dependable and hence economical. These inconveniences were overwhelmed by new technological development which can be used as a tool to carry out capacity survey rapidly, periodically and economically. The purpose of the present study is to estimate the reservoir sedimentation and capacity loss by using remote sensing technique. The satellite imageries should be delineated by remote sensing technique to deliver directly the water spread area of the reservoir. Any reduction in the water spread area at specified elevations over the time period is the indicative of sediment deposition at that level. This can be used to compute the capacity loss through sedimentation. This paper interrupts the detail research and evaluation of various studies written by well-known researchers in the remote sensing field.*

Key Words: *Sedimentation, remote sensing, water spread area.*

1. INTRODUCTION:

Water is the major source of our earth. It is the elixir of life a precious gift of nature to mankind and millions of other species living on the earth. The surface water and ground water have been used for the purpose of agriculture, domestic and industrial purposes. According to the current scenario there is an increasing demand of water use due to higher rates of urbanization, development of industrial and agriculture sector and the economical waste water treatment. This situation leads to severe water crisis water resources management aims at optimizing the available natural water flows and satisfying the needs for various demands in different sectors. Additionally climate change also increasing the complexity of managing water resources. This problem can be overwhelmed by the storage of water in water storage structures like reservoirs, dams barrages and manmade streams by constructing the dam across the river, the velocity of flowing water get reduced due to obstruction thereby helping the sediment particles to settle down in the reservoir formed .this phenomenon is called reservoir sedimentation (bounder 1985).

Sediments are in the form of sand, silt, gravel and even larger boulders. Sedimentation is the process initialized by the soil erosion , which is caused by moving wind and water sediment deposition creates a variety of problems, the most important among them being raising of stream beds and consequent increasing of flood height, meandering and flow along banks, chocking up of navigation and irrigation canals and lastly the depletion of the storage capacity of the reservoirs sediments has deposited not only in the dead storage space it is also encroached in to the live storage place. The problem associated with sedimentation occurs in both upstream (storage loss, delta deposition, abrasion and ecology) and downstream at the reservoir. The most effective and economical control measure to reduce the rate of sedimentation in the reservoir is to conducting the sedimentation surveys periodically. Sediment deposition pattern in various zones of a reservoir is essential. Because it has used for proper allocation and management of water in the reservoir for urban water supply and flood mitigation. The proper planning of reservoir sedimentation studies can be used for the reservoir operation schedule to analyze the optimum utilization of water. Thus the sediment deposition pattern in the reservoir can be identified by the systematic capacity surveys. Some of the methods presently in use for prediction of sediment deposition in the reservoir like hydrographic surveying, stream measurements are prolonged, man power requirement and uneconomical.

But now days by using new and improved computational algorithms are finding applications in reservoir sedimentation using remote sensing technique. This advanced technique gives the spatial, spectral and temporal information of the water spread area of the reservoir using satellite imageries. The sediment deposition can be identified by decreasing the water spread area of the reservoir at specific elevations over a time period. By comparing the decrease in water spread area with time, the sediment distribution pattern in a reservoir can be determined indirectly. This information can be used to determine the rate and volume of the reservoir sediments and also gives the storage capacity loss of the reservoir.

2. LITERATURE REVIEW:

Following papers were reviewed for the present study. They discussed about the situations where the methods were used, and how they analysed a particular problem of reservoir sedimentation in the remote sensing environment.

2.1 V.S.Jeyakanthan, S.Sanjeevi (2011)

This paper describes the assessment of reservoir sedimentation in singoor reservoir, Telangana. In the present study per pixel and sub pixel processing by multi-date satellite images has been used to estimate the reservoir capacity. The storage capacity has been observed using remote sensing techniques of the year 2005 multi-date satellite images (IRS 1C,1D,P6) were used to analyse the reservoir capacity with spatial resolution of 24m x 24m the water spread area has been extract from the satellite images using per pixel and sub pixel classification approaches. The water spread area extracted using four different spectral bands 0.52–0.59, 0.62–0.68, 0.77–0.86 and 1.55–1.70 µm in IRS1D, P6. The per pixel method requires the NIR band for six satellite images used to extract the water spread area. Then by using the trapezoidal formula the capacity of the reservoir at the water level 523.49 m was 727.75 Mm^3. The sub pixel method uses the linear unmixing technique that allows for the identification of the "material of interest" and the determination of its "material part fraction" or cover percentage within a pixel ranges from 0 to 1. Then the trapezoidal formula used to estimate the capacity of the reservoir at the water level of 523.49 m was 716.11Mm^3.

2.2 Kamju Narasayya, UC Roman, S.Sreekanth And Sunneta Jatwa (2012)

This paper describes the assessment of sedimentation carried out for the srisailam reservoir, Andrapradesh using satellite Imageries. The author collected the three types of data (topographical, satellite and field). These data were geo-referenced by using the software named as EASI/PACE. The water spread area of reservoir at various elevations on the data of pass of satellite keeps on decreasing due to sedimentation. The water spread area was analyzed using digital images processing by using water index and NDWI method in there holding technique.This help us to estimate the sedimentation over a period of time (2001 to 2004). The area capacity curve of the year 1976, when actual impoundment was started. It's used as a base for sedimentation assessment for the year 2004. By using prismoidial formula the capacity of the reservoir has been observed, the actual capacity of the srisaila m reservoir for the year 1976 were 8724.88 Mm^3 reduced to 6764.04Mm^3 in 2004 respectively. The result shows that the deposition pattern of srisailam reservoir followed type-1 in 2004 compared with the standard types of pattern as per area reduction method suggested by Borland and Miller. The sediment index have been considering the total sediment deposition since 1976 to 2004 was found to be 543.84 $T/km^2/yr$ which is close to the value of 600 to 700 $T/km^2/yr$ which is lower than the rates suggested by Grade and Kothyari Storage capacity was reduced by 23.714% in 28 years. The data indicates that a definite relationship exists between the reservoir shape and the percentage of sediment accumulated in various depths since its impoundment.

2.3 Milli Bhavasar, Prof.K.B.Gohil, Dr.N.J.Shrimali (2013)

This paper describes the estimation of loss of reservoir capacity of Sukhi reservoir Gujarat. In this present study, they used the multi date satellite imageries to extract the water spread area. The area capacity curve of year 2005 is used as a base for the assessment for the year 2010, The digital satellite data was processed and analyzed using digital image processing software, ERDAS/IMAGINE. Here they used LANDSAT images to extract the water spread area. The original capacity was calculated by using prismoidal formula at the intermediate elevations. The revised volume was compared with the original volume in each zone and the difference between the two volumes gave the capacity loss due to sedimentation. It is observed that there is capacity loss of 16.221Mm^3 during 2005 to 2010 for 5 years. The capacity loss of reservoir is 3.244 Mm^3/year. Thus the remote sensing is an effective method for the calculation of reservoir capacity loss.

2.4 Issa E.Issa L, Nadhir Al-Ansari, Govand Sherwany, Sven Knutsson (2013)

This paper describes a Sedimentation Processes and Useful Life of Mosul Dam Reservoir, Iraq. In their paper two topographic maps of Mosul reservoir dated 1983 and 2011 in "Triangular Irregular Network" were used for the calculation of sedimentation rate and determining the reduction in storage capacity for live and dead storage as well as whole Mosul reservoir during its operational period. The TIN maps were used to compute the storage capacity and water spread area for live storage and dead storage using ArcGIS software. The reduction in storage capacity of the reservoir for the two surveys at different time represent total volume of sediment accumulated and reduction in water spread area for reservoir. Furthermore two surveys were used to determine the future shift in the stage storage capacity curve of reservoir. Also the observed result and algebraic equation that were proposed by Gill were used to determine the useful life of Mosul reservoir is about 125 years.

2.5 Elangovan Arunbabu, Seetharaman Ravichandran, Paulraj Sreeja (2014)

This paper examines the sedimentation rate, capacity and internal phosphorus loading of krishnagiri reservoir, Tamilnadu. In this present study an acoustic Doppler profiler and remote sensing data in an ArcGIS environment. It is

used to produces the bathymetry map and water spread area at specific elevations were extracted for calculating the capacity rate of sedimentation and phosphorous loading. The bathymetry survey was done using Q-linear to measure the reservoir depth. Then volume between any two adjacent elevations was determined by prismoidal formula, it also give stage-storage curve phosphorous release rate and internal phosphorous load was calculated by using Warnberg equations and then values were interpolated in ArcGIS tool. The result shows that actual capacity of the krishnagiri reservoir is 68.20 MCM was reduced to 35.57 MCM over a period of 55 years (1957 to 2012). It has been observed that the loss of storage capacity was 32.63 MCM, with sedimentation rate of 0.59 MCM per year until 2012. Here the phosphorous release rate from sediments to pore water varied from 10.22 to 70 mg/m^2. According to that internal phosphorous loading was estimated at 43.36 tonnes respectively. The results suggested that soil conservation programs were very useful to increase the life time and improve its water quality. And also prevent the soil erosion which would eventually reduce the eutrophication process in the reservoir.

2.6 R.Ninija Merina, M.C. Sashikkumar, N.Rizvana, R.Adlin (2016)

This paper describes the evaluation of sedimentation carried out for vaigai reservoir, Tamilnadu. The present study illustrates the prediction of reservoir sedimentation uses directly by the water spread area of the reservoir at a particular elevation on the date of pass of satellite at 3rd August 2009, 17th March 2009, 10th January 2012, 1st April 2012 and 5th March 2005. The work has been carried out using digital image processing software ARCGIS. The water spread area for different satellite over pass dates and the corresponding elevation are plotted using liner interpolation method in digital images processing. Any shift in the curve will indicate the loss in capacity of the reservoir due to sedimentation. The reservoir capacity can be assessed using the cone formula between two successive elevations. The vaigai reservoir has been surveyed periodically. The original capacity of vaigai reservoir for the year 1958 was 194.785Mm^3. It could be compared with fourth sedimentation survey in the year 2000 and also with remote sensing data in the year 2012. Thus the result shows the observed capacity in 2000 and 2012 was reduced to 166.533Mm^3 (i.e.) 14.50% and 162.620Mm^3 (i.e.) 16.512% respectively. It also suggested the sediment deposition rate between 1958 and 2012 is 32.164 Mm3 average annual sitting load per sq.km of drainage area is $2.641x10^{-4}$ Mm^3/sq.km/year.

2.7 Liphapang Khaba, James Andrew Griffiths (2017)

This paper aims at identifying reservoir storage capacity loss due to sediment deposition between 1985 and 2015 at muela reservoir, Northern Lesotho. In the present study they conducted eight surveys between 1985 and 2015 were analysed to quantity the bathymetry survey. Here the volume of sedimentation was estimated by DEM interpolation method and TIN method. Four type of DEM interpolation method is used they are inverse distance weighting, kriging, natural neighbour and spline. But in TIN method they used the direct linear interpolation technique. In DEM method kriging shows to be more computationally demounting than the other two methods. But when it comes to spline method it is unsuitable for this work. Because it goes beyond the ranged of surveyed data According to TIN surface it is easy to implement and accurate. The results shows that sediment calculation between TIN and DEM shows closer value using ASTER GEM data at full supply level are 5.59 Mcm and 5.94 Mcm. Thus the average reservoir capacity loss of muela reservoir between 1985 and 2015 are 15400 m^3/year based on kriging. There is a steady linear decrease in the reservoir volume at the rate of sedimentation in 30years is 17500 m^3/year could be identified. According to the inter annual variability in reservoir storage capacity the reduction rates in kriging DEM and TIN varies between 11400 m^3/year and 18200 m^3/year. Finally, the study suggested that information related to water transfer and releases from the reservoir should be optimized when assessing sedimentation rates and also to identifying the larger water and associated with sediment flushing.

2.8 Elangovan Arunbabu, Seetharaman Ravichandran (2017)

This paper describes the estimation of sediment displacement in Krishnagiri reservoir, Tamilnadu. Reservoir sedimentation was assessed by using tools of GIS, GPS, ADCP and field measurement. In the present study is to conduct a bathymetry study by using an acoustic Doppler current profiler. This could be integrated with remote sensing data and GPS. The ADCP used to measure the depth at various locations in the reservoir for the preparation of bathymetry map. It was conducted between the period 2012 at February and March. The water spread area was surveyed by using echo sounding technique in ADCP. The volume between two adjacent elevations was determined by prismoidal formula is 4.138 MCM. Then the depositional pattern was determined by using cut/fill tool in Arc GIS. This is used to identify the regions of surface material removal, surface material addition, and areas where the surface has not changed. The sediment volume using cut/fill method in the year 2012 is 3.955 MCM. The comparison between prismoidal and cut/fill method in the krishnagiri reservoir under remote sensing platform is 0.183 MCM respectively. The integration of field measurement and GIS is successfully demonstrated. This is one of the new methods to estimate the sediment displacement pattern in remote sensing environment.

2.9 C.Hethin Genitha, S.Shanmugapriya, M.Indhumathi and S.Sanjeevi (2017)

This study describes the super resolution mapping of multi spectral and hyper spectral images acquired by remote sensing at Peechi reservoir ,Kerala In this present study a per-pixel algorithm (maximum likelihood) , sub pixel algorithm (FUZZY C means) and super resolution mapping algorithm (Hopfield neural network) has been used as a methodology These three methods have been used to extract the water spread area of the reservoir and then the capacity of the reservoir is calculated by using trapezoidal formula. In this paper the experiments are carried out using multi date (before monsoon and after monsoon) hypersonic images of resolution 30m the area estimation of the peechi reservoir using per pixel sub-pixel and super resolution mapping are 7.66, 6.34 and 5.69 sq.km. Then water spread area was validated by using ground truth verification in above mentioned three approaches.

Here they used two steps verification.

1. To evaluate the accuracy of the classification
2. To check the validity of the reservoir water spread area estimated from the classified images.

The actual reservoir water spread area is 5.95 sq.km. The deviation between the original and the present water spread area at per pixel sub pixel and super resolution mapping area 1.71, 0.39 and 0.26 respectively. The error in area estimation by the per-pixel approach is 28.7%, where it is 6.55% for sub pixel approach and 4.36% for the super resolution mapping. Hence the result suggested that super resolution mapping proves to be a better approach for reservoir water spread area estimation in the remote sensing environment.

2.10 Kaiguo Taozou, Dejnan Jiang, Cheng Tang and Hua Zheng (2017)

This paper describes the dynamic transport of freshwater and sediment during water sediment regulation in yellow river, china. It has been illustrated with MODIS and GOCI satellite data. Here they conducted three hydrographic surveys in the year 2014. Thus the MODIS reflectance data were processed by selecting, geo referencing and filtered the images. Here GOCI data were considered to be exclusive and specific in identifying spatiotemporal dynamics of river plume on hourly basis salinity and turbidity were quantitatively assessed and correlated with external forces. Inter day and intraday plume variation interpreted with regard to river discharge, coriolis force and Ekman transport according to river discharge at the end of year 2014 water sediment regulation was decreased to 900m3/s the correlation between plume area and discharge (R^2=0.96) is controlled by upstream release of freshwater. When it comes to Coriolis force and Ekman transport did not show the significant correlation between plume area and shape. Dominance of field current on intraday dispersal pattern of fresh water and sediment plume were $4.8x10^9m^3$ and $7.0x10^7$ mg in the year 2004 was compared with discharge of $3.5x10^9m^3$ and sediment load of $4.5x10^7$mg in the year 2009. The result suggested that the satellite remote sensing data were capable of capturing the short term (intraday) as well as long term (inter- annual) variation of yellow river and also provide a low cost and efficient tool for the planning and design of water sediment regulation. Finally it shows that anticyclone turning of buoyant plume around the yellow river delta and downstream transport towards the west coast of Laizhou bay overall remote sensing based on MODIS and GOCS data provide a detailed quantification of yellow river plume dynamics. This tool is used for monitoring plume dynamics and it potential impacts on the ecological health.

The above papers have been reviewed for the present study and details of the papers depicted in Table I

Table I. Details of the reservoir sedimentation using remote sensing

S.No	Reservoir name	Satellite data images	Software Used	Techniques	Rate of Sedimentation Mm^3, Mm^2/year
1.	Srisailam reservoir	IRS, 1C, 1D, P6, LISS III	EASI/PACE	NDWI & WI	70.03
2.	Sukhi reservoir	LANDSAT	ERDAS/IMAGINE	NDWI	3.24
3.	Mousl reservoir	SRTM	ArcGIS	ECOSOUNDING, GPS	0.045
4.	Krishnagiri reservoir	SRTM	MapInfo, ArcGIS	ADCP, GPS	0.593
5.	Vaigai reservoir	IRSP6, LISS III	ArcGIS	LINEAR INTERPOLATION	0.595
6.	Signoor reservoir	IRS, 1C, 1D, P6	ERDAS	PER-PIXEL, SUBPIXEL	2.31
7.	Mulea reservoir	SRTM	ArcGIS	INTERPOLATION (KRIGING)	17.5
8.	Peechi reservoir	HYPERION	ERDAS	SUPER RESOLUTION MAPPING (HNN)	0.26
9.	Yellow river	MODIS,GOCS	SEADAS, GDPS, ACAT	SALINITY RETRIEVAL, TURBIDITY RETRIEVAL	35.4

3. CONCLUSION:

This summarized report of the reviewed papers was used to study the different parameters of reservoir sedimentation by using Remote Sensing technique. This method is very easy, timesaving and economical than the traditional methods like hydrographic surveying. Because those traditional methods are difficult, prolonged and uneconomical especially discontinuous in ground data. The satellite images of IRS 1A, 1B, 1C, 1D and P6 for LISS II and LISS III sensors and LANDSAT, MODIS, GOCI images are used for interpreting the regulating factors of sedimentation for various reservoirs in different regions. The water spread area can be delineated from the satellite images by using different software tools like ERDAS/IMAGINE, ArcGIS, MapInfo, Idrisi, Easi/Pace, etc. Even though there is an inadequacy of ground data availability, this advanced technique can be used for analysis of short intervals and also hence a continuous record can be obtained from the satellite images. Thus the Remote Sensing technique is merely applicable and most useful in the study of reservoir sedimentation to delineate the water spread area for estimating the capacity loss of the reservoir.

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