SEDIMENTATION STUDY ON RANAPRATAP SAGAR RESERVOIR USING REMOTE SENSING DATA- A CASE STUDY

Engineering

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ABSTRACT
The reservoirs of the world suffer with sedimentation problem and their capacities reduce due to sedimentation hence they do not serve the required purpose. Periodic monitoring and studies are carried out to solve the problem of sedimentation through sustainable operation and management. In this study a remote sensing technique has been used for the evaluation of sediment deposition and capacity of Ranapratap Sagar Reservoir, Rajsthan, India. The principle of reduction in water surface areas as sedimentation goes on increasing is used to estimate the present capacity of the reservoir. Three cloud free satellite imageries of the year 2011-12, covering water spread area of Ranapratap Sagar Reservoir provided by Resourcessat-1: LISS III were used to evaluate the water surface areas with the help of Arc/GIS10.1 software. Results show that the live storage capacity has increased by 14.23 Mm^3 in 40 years. This increase may be due to scouring in live storage zone.

KEYWORDS
Ranapratap Sagar, remote sensing, sedimentation, Arc/GIS 10.1, LISS III.

INTRODUCTION: Water is an essential element for all kinds of life on the earth but everywhere scarcity has emerged due to hydrological changes and increased use by human (Stewart, 2014). It is nexus of food security, energy production, nutrition security, economic growth, poverty reduction and human health. The water in the world is found in different forms and locations such as on the surface, in the air, in the oceans and under the ground. Only 2.5% of the water found on the earth is as fresh water and remaining 97.5% water is useless for human or agriculture purposes. (Cullen, 2009, A Summary by Green Facts, 2016, and WWDR, 2016). Only 0.3% of 2.5 % fresh water is in liquid form and remaining in the frozen state (Green facts, 2016; Water Distribution on Earth, 2016). The availability of this fresh water varies region to region in the world and human activities and natural forces such as urbanization, climate change, deforestation, pollution, high living standard, ill management and wastage are reducing available water resource (Green facts, 2016).

Water crisis and its management has become a prime issue for all nations of the world. The frugal use of water and efficient management of water resources is the only solution to face the water crisis in present and future. Every person on the earth is responsible to help in efforts for improving the living standards of millions by through well planning, designing and operation of water resources (WWDR, 2016).

The water is stored for sustainable management of water resources by constructing a dam across the river. This body of stored water is known as reservoir. Thus reservoirs are very important structures to store rain water directly as precipitation and run-off. These reservoirs help in the progress of society and meet the increasing demand of water (State of the Art Report, 2010).

The soil erosion is natural phenomena caused due to natural physical forces of wind and water or forces from farming like tillage. Soil erosion is very detrimental for water resources in semi arid areas (Noori et al., 2016). A vast land area of about 53% of India is suffering from problem of erosion (Narayana and Babu, 1983). Recently due to increased human impacts on land the rate of global erosion has increased by about 2.3 billion metric tons per year (Syvitski, et al., 2005). According to Shangle (1991), the average annual rate of soil erosion in India is about 6000 Mt due to sheet erosion only. The sediments produced by erosion are transported naturally by all the rivers.

The construction of dam and formation of reservoir provides valuable water storage on one hand but causes change in river flow regime on both upstream and downstream of reservoir on the other hand (Mathew et al., 2017). The flow velocity of river on upstream of reservoir reduces before it entering the reservoir due to large cross sectional area of reservoir (Carvalho et al., 2000). Thus the sediment transporting capacity of river is reduced and deposition of sediment takes place (Michalec, 2014).

An analysis of sedimentation data of 43 Indian reservoirs of major, medium and minor categories showed that the sediment silting rate ranges between 0.34-27.85 ha m/100sq km/year, 0.15-10.65 ha m/100 sq km/ year and 1.0-2.63 ha m/100 sq km/year in these reservoirs respectively (Garg and Jothiprakash, 2008, Shangle, 1991).

The reservoirs are usually planned initially assuming sedimentation rate on the basis of inadequate data. Later on it is found that assumed rate is very low than the actual rate of sedimentation in most of the reservoirs (CWC, 2001).

Estimation of sediment deposition in reservoirs is carried out through widely used following techniques.

1. Indirect measurement of sediment through water inflow and outflow analysis
2. Hydrographic Survey method
3. Satellite Remote Sensing (SRS) Method
4. Empirical Methods e.g. Area Reduction and Area Increment methods
5. Mathematical Models

The conventional method of Hydrographic survey is considered very accurate but it is time consuming, costly and tedious hence cannot be conducted regularly at short interval for monitoring sedimentation in reservoirs (Roman et al., 2012). Remote sensing techniques which are less time consuming, cost effective, easy and provide data of long period for a broad spectral range, repetitive coverage of a given area every three to four days. Remote Sensing data provide timely synoptic view of changes in water spread area of the reservoir after deposition of sediment and distribution pattern which cannot be obtained even with high-tech survey system hence Remote Sensing techniques presently preferred over conventional methods (Jain et al., 2002). The water spread area goes on decreasing at an elevation with deposition of sediment in the reservoir. The sediment deposited and distribution pattern is determined indirectly by comparing the decrease in the water spread area with time. Thus rate of reservoir sedimentation can be quantified (NIH, 1998-99).

Smith et al. (1980) applied remote sensing technique in estimation of siltation in the Aswan High Dam Reservoir. Reflectance values in the green and red portions of spectrum were compared to determine the surface area of entire reservoir by counting all pixels classified as water. After identifying the heavily silted areas, silt amount was determined through ground surveys to predict the sediment distribution in the reservoir. Rao et al. (1985), Wang et al. (2013), Vibulsresth et al. (1988), Jain et al. (2002), Jeyakanthan & Sanjeevi (2013) & many other researchers have successfully used various techniques of remote sensing.

MATERIALS AND METHODS
Characteristics of Research Objects
The Rana Pratap Sagar Dam in Rajsthan located 56 km downstream of the Gandhi Sagar Dam in Madhya Pradesh, is the second dam in sequence of three dams and one barrage of Chambal Valley project.

This dam was completed in constructed across Chambal River in the 1970. This Rana Pratap Sagar masonry dam is 54 m high and located at Rawat Bhata in Chittorgarh District of Rajsthan. It is constructed 48 km upstream of the Kota Barrage. Location of the Rana Pratap Sagar Reservoir is shown in Fig. 1.

To estimate the actual silt deposits, its distribution pattern and to know the life of the reservoir, a hydrographical survey was carried out in 2011 for Ranapratap Sagar Reservoir. Thus, the satellite data in the form of imageries for year 2011-12 of LISS III were downloaded from Indian Space Research Organization (ISRO) Geoportal Bhuvan. Only three geo-referenced cloud free satellite imageries available on dated 12 May 2012, 19 January 2012 and 15 October 2011 shown in Fig. 2, were available for live zone of reservoir ranging between maximum drawdown (MDDL) level and full reservoir level (FRL).
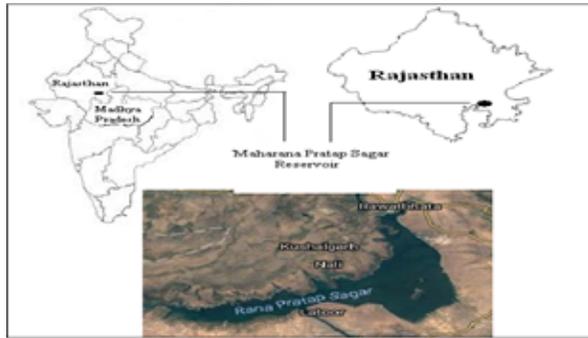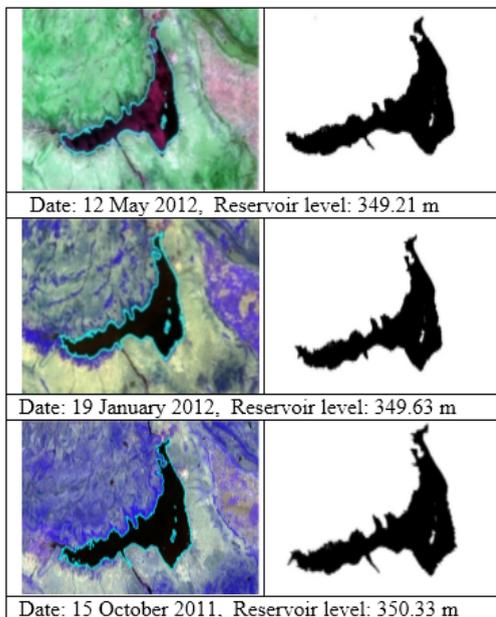

Fig. 1. Location and Satellite image of Rana Pratap Sagar

The data of, sediment deposited in live and dead storages and capacity loss of Ranapratap Sagar Reservoir, up to 2011 were obtained through draft report (November 2011) of capacity survey conducted in 2011 by Tojo- Vikas International (Pvt.) Limited Consulting Engineers, submitted to Central Water Commission (CWC), Govt. of India. The initial areas and capacities at different elevations were also found out from this report. The water levels of Ranapratap Sagar Reservoirs, on satellite pass dates were obtained from dam site office of the reservoirs.

Fig. 2. Satellite imageries of Ranapratap Sagar Reservoir (2011-12)

Date: 12 May 2012, Reservoir level: 349.21 m

Date: 19 January 2012, Reservoir level: 349.63 m

Date: 15 October 2011, Reservoir level: 350.33 m

RESEARCH METHODOLOGY
The basic principle that the water spread area at different elevations goes on decreasing due to sedimentation is used in Satellite Remote Sensing technique for quantitative assessment of sediment in reservoir. The water spread areas at different elevation between Full Reservoir Level (FRL) and Minimum Draw Down Level (MDDL) are computed through cloud free satellite imageries obtained in particular period. In this study, three cloud free and georeferenced imageries at different

pass date for year 2011 as the hydrographic survey of Gandhi Sagar Reservoir was carried out in this year.

The water in extended river main channel and other tributary tail channels seems to be the part of reservoir in imageries. These extended tails were terminated at point where the water surface level was higher to reservoir water surface level using contour map of site and longitudinal section of the main river channel. Location of Gandhi Sagar Dam was very clear on imageries; hence dam downstream water spread area was excluded during marking area of interest on imageries.

Above satellite data were processed and analyzed using Arc/GIS 10.1 software. This software directly measure the water spread area on date satellite passes in required unit.

The reservoir capacity between two consecutive reservoir elevations is usually computed by the Prismoidal formula, the Simpson formula and the Trapezoidal formula (Patra. K. C., 2001). From these formulae, the Trapezoidal formula has been used by most of the researcher to compute the capacity of reservoir (Goel & Jain 1998) as follow.

$$V = \frac{H}{3}(A1 + A2 + \sqrt{(A1 * A2)}) \qquad (1)$$

Where V is the volume between two consecutive water levels, A1 and A2 are the water spread areas at the reservoir water levels 1 and 2 respectively and H is the difference between these two water levels. Water levels corresponding to the date of pass satellite were collected from dam site and initial elevation-area table was used to find original areas at these levels by linear interpolation. Knowing the values of original areas and computed areas through satellite data at different elevations the corresponding original and revised capacity of reservoir were computed using Eq. (1). The difference in original and revised capacity at particular level is the loss in capacity of reservoir. The total loss in capacity due to sedimentation in live storage was determined by adding the loss in capacity at all levels between the lowest and highest observed water levels.

RESULTS AND DISCUSSION
The results of analysis are presented in Table 1. These results show that revised cumulative capacity in 2011 is more to the original cumulative capacity. This indicates that no sediment has deposited in live storage zone. The all sediments deposited in the dead storage only. Instead of reduction in live storage capacity, it increased by 14.23 Mm^3. This increase may be due to scouring in live storage zone as suggested in the hydrographic survey report of 2011. Thus it can be concluded that Remote Sensing method is applicable in Gandhi Sagar reservoir as well as Ranapratap Sagar successfully.

Table 1. Capacity assessment of Ranapratap Sagar Reservoir using Remote Sensing method for year (2011-12)

Date of satellite pass	Elevation (m)	Original area (Km2)	Revised area by Remote sensing (Km2)	Original volume (Mm3)	Revised volume by remote sensing (Mm3)	Original cumulative capacity (Mm3)	Revised cumulative capacity by remote sensing (Mm3)
12 May 2012	349.21	173.24	187.89	---	--	2240.09	2240.09
19 January 2012	349.63	176.20	189.11	73.38	79.17	2313.47	2319.26
15 October 2011	350.33	181.14	192.33	125.06	133.50	2438.53	2452.76

The results of this study were compared with the results of hydrographic survey conducted for the assessment of the sediment deposited and loss of capacity in 2011. The results of hydrographic survey show that no loss of live storage has occurred since impoundment. The total loss of 238.59 Mm3 in capacity occurred in the dead storage only. Hydrographic survey report also reported that instead of reduction in live storage, it increased and this increase in live storage capacity may be due to scouring in the live storage zone.

CONCLUSIONS
Following are the conclusions drawn from this study.
•   The remote sensing method measures the increase in live storage

capacity of Ranapratap Sagar reservoir by 14.23 Mm3 in 40 years since impoundment.
- The hydrographic survey report of 2011 also reported the increase in live storage capacity of Ranapratap Sagar reservoir.
- This increase in live storage may be due to scouring in this zone.
- Remote sensing method may be well applied in future sedimentation study on Ranapratap Sagar reservoir and study on other reservoirs.
- Remote sensing method is quick, easy and reliable.

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