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Remote sensing study on geomorphological degradation of Sarda Sagar reservoir

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Abstract

An attempt was made to estimate the geomorphological degradation due to sedimentation of Sarda Sagar reservoir, located in Pilibhit and Udhamsingh Nagar, district of Uttar Pradash and Uttarakhand respectively. The study was conducted using multidated IRS LIISS III remote sensing data for the year 2006-2007. Using satellite images of different seasons during 2006-2007, a total of 45.23 million m^3 volume of sedimentation was computed in-between the 183.704 m and 190.504 m elevation. The reservoir has lost 11.72 % of the total capacity of water storage and an average rate of sedimentation was calculated as 0.26 % per year. Due to this sedimentation the new feeder channel of Sarda Sagar is choked with silt and the water flow from this channel has almost stopped. The morphology of the reservoir has been changed due to sedimentation during the period 1962 to 2007. This has altered breeding ground of fishes since important indigenous fish species which need flowing water condition to perform the breeding. This study would be helpful for the planners to manage the reservoir and to assess the biological productivity.

Key words

Degradation, Morphology, Remote sensing, Reservoir, Sedimentation

Introduction

The reservoirs provide significant contributions to global fisheries. In some parts of the world's reservoir commercial fisheries are essential for subsistence and often represent an irreplaceable source of high-quality and low-cost animal protein crucial to the balance of human diets. Fish harvested from reservoirs are generally marketed regionally and contribute to the livelihood of impoverished people and local economies. In this context geomorphology and yield assessment of reservoirs is important to work out for best management practices (GMP). Predictive fish yield models for lakes and reservoirs of the Philippines, Sri Lanka and Thiland were developed by Moreau and DeSilva (1991). Petrere (1996) described the fishery in large tropical reservoirs of South America. Fernando *et al.* (1998) also reviewed the reservoir fishery in relation to the hydrology. Miranda (1999) developed a conceptual model based on typology of fisheries in large reservoirs of United States.

After impounded with water, the reservoir begins to receive sediments irrespective of type of basin. Sediment deposited encroach not only the dead storage portion but also the live storage of the reservoir. Various processes like soil erosion in the catchments, changes in land use, tillage practices, deforestation and lack of soil conservation measures in the catchments speed up the rate of sedimentation in the reservoir and subsequently causes reduction in the capacity of reservoir (FAO, 2001).

Reservoirs effectively trap suspended solids and sedimentation increases turbidity to limit primary production and decreases depth and thereby storage capacities, all of which affect various physical and chemical processes that eventually influence the biotic community. Fish production in some reservoirs may be limited by the availability of suitable spawning sites or poor quality of available sites (Summerfelt, 1993). Siltation from the catchment areas besides changing the ecology due to construction of dams, has also destructed the feeding and breeding grounds of many fishes (Sehgal, 1994). Loss of storage capacity of the reservoirs due to siltation is one of the most serious consequences of soil erosion that affects the habitat of endemic species of fish (Sugunan, 1995). Siltation also affects the biota by blanketing the benthic and periphytic community. It also hampers the recruitment by destroying the breeding grounds and retards the overall productivity of the ecosystem (Sugunan, 1995). The silt transported by the rivers and their tributaries is deposited in the reservoirs reducing the capacity of the reservoirs and affecting their useful life. Several workers such as Rao *et al.* (1985), Mohanty *et al.* (1986), SPARC (2002), Jain *et al.* (2002), NRSA (2003) and Nagaanupama (2005) used satellite images to estimate the area as well as capacity loss due to sedimentation.

The mighty river, Sarda feeds the Sarda Sagar reservoir, which known to be a turbulent type of river. Geographically, the river is natural border between India and Nepal. The reservoir was created in 1962 with a catchments area of 121.0 km^2 by constructing 22.2 km. long earthen dam. The reservoir is fed by old and new feeder channels having discharges of 113.27 and 28.32 million m^3 respectively. The heavy load brought by the river is deposited in the reservoir as well as in the feeder canals. Thus assessment of sediment deposition becomes very important for the management and operation of Sarda Sagar reservoir.

The suspended solids and sediments derived from erosion and deposition damage fish habitat and produce adverse impacts like those described for non-point sources of sediments. Barren shores and mudflats are poor food producers, unsuitable habitat for nest builders, and poor nursery habitat for fish (Meals and Miranda, 1991). As a result, environmentalists and water resource planners are very much concerned with this impact on the fragile ecosystem. The present paper gives details of the sedimentation of the Sarda Sagar reservoir during 1962 to 2006-07.

Materials and Methods

The methodology applied for delineation of water spread area estimating reservoir capacity and loss due to sedimentation by Rao *et al.* (1985); Mohanty *et al.* (1986); SPARC (2002); Jain *et al.* (2002), NRSA (2003) and Nagaanupama (2005) was adopted for the present study.

Procurement of suitable data : IRS, 1C-LISS III multidated remote sensing data that represent to all seasons of the study area were procured from NRSC, Hyderabad. LISS III satellite has three sensors that provides multi-spectral data in four bands; two in visible (0.52-0.59 and 0.62-0.68 microns), one in infrared (NIR, 0.77-0.86 microns) and one in short wave infrared (SWIR, 1.55-1.70 microns) region of electromagnetic spectrum with a swath of 141 x 141 km.

Data analysis : The digital data from CD ROM was imported to the system and were geo-referenced with demarcating Ground Control Points (GCPs) using Global Positioning System (GPS). Digital data were processed in laboratory using software; ERDAS IMAGINE 8.7 version. The Root Mean Square (RMS) error while geo-rectifying the image was less than 0.5 pixel and nearest neighborhood resembling technique. These registered images for five different dates pertaining to study area were used to estimate water spread area through supervised classification. Remote sensing data represent the elevation level of 185.244 m to 189.00 m. Extrapolation techniques were also used to compute water spread area at an elevation of Dead Reservoir Level (DRL, 183.704 m) and Full Reservoir Level (FRL, 190.504 m).

Estimation of reservoir capacity and loss due to sedimentation : Area elevation curve plotted for the water spread areas for different water level in the reservoir. The computation of the reservoir capacity at various elevations has been made with the help of using the following formula.

$$V = h/3\{A_1+A_2+\sqrt{(A_1*A_2)}\}$$

Where 'V' is the reservoir capacity between two successive elevations h_1 and h_2 'h' is the elevation difference (h_1-h_2), 'A_1 and A_2' are areas of reservoir water spread at elevations h_1 and h_2. Derived volumes of water at different elevation from the remote sensing data were compared with original volume at the same elevation. The difference between original volume and derived volume is the capacity loss of reservoir due to sedimentation.

Results and Discussion

The water spread area of the reservoir in the different dates during 2006-2007 of satellite passes was delineated and depicted in the Table 1. The original area for the particular elevation of the date of satellite pass in reference to the year of establishment of reservoir was calculated from the original capacity curve. The difference of water spread area in between original and derived data is given in the Table 1. The temporal maps of the classified images of boundary of the reservoir are depicted in the Fig. 1.

The morphology of the reservoir has changed significantly due to sedimentation from its origination to the period of study (Table 1). A total of 45.23 million m^3 of sedimentation was deposited in-between the 183.704 m and 190.504 m elevation of reservoir level, which is 11.72 % of the total capacity of the reservoir. In a previous hydrographic survey conducted by U.P. Irrigation Research Institute, Roorkee revealed that the sedimentation in the

Table 1 : Assessment of sedimentation rate of the Sarda Sagar reservoir

Reservoir elevation (m)	Date of satellite pass	Water spread area (km^2) assessed from original capacity curve	Water spread area (km^2) assessed from RS data	Difference of area (km^2)	Volume of water (mm^3) assessed from the capacity curve	Water volume (mm^3) assessed from RS Data	Original commulative water volume (mm^3)	Commulative water volume (mm^3) assessed from RS
183.704	Extrapolated	30.68552	21.74	8.96			76.25	76.25
185.244	May, 2007	37.68783	29.28	8.4	52.56	39.14	128.81	115.39
187.82	Feb., 2007	49.27167	43.93	5.34	111.672	93.65	240.482	209.04
188.445	April, 2007	52.05824	45.2	6.85	31.662	27.84	272.144	236.88
188.506	Oct., 2006	52.32972	45.9	6.42	3.18	2.78	275.324	239.66
189	Nov., 2007	54.52498	48.3	6.22	26.393	23.25	301.717	262.91
190.504	Extrapolated	57.65	55.4	2.25	84.348	77.92	386.065	340.83

live storage was found 9.5 % during the course of period during 1962-1991 (Anon, 1992).

NRSA (2003) observed sedimentation rate per year for different reservoirs in India as Kuttiyadi (0.12 %) during 1989-1995; Bargi (0.07 %) during 1990-2000; Sriram Sagar (1.0 %) during 1970-2002; Tawa (0.7 %) during 1975-1996; Bhakara (0.14 %) 1958-1996); Pong (0.22 %) during 1974-1996; Ujjani (1.18 %) during 1976-1992; Nathsagar (0.48 %) during 1976-1992 and Tungbhagra (0.59 %) during 1953-1995.

The sedimentation rate of Sarda Sagar is 0.26 % per annum which comes in the range at national level studies. Due to this sedimentation the new feeder channel of Sarda Sagar is choked with silt and the water flow from this channel is almost stopped resulting in the portion that is highly infested with macro aquatic vegetation. Due to this, the breeding ground of endemic species fishes has been altered. The flow modifications affects water quality, water depth and velocity, substrate composition, food production and transport, stimuli for migration and spawning, survival of eggs, spatial requirements and eventually fish species composition (FAO, 2001).

The indigenous groups of fishes are the most suitable endemic fishes those need flowing water condition to perform the breeding. But due to habitat destruction other catfishes are dominating in the Sarda sagar Reservoir. Sehgal (1994) mentioned that habitat alterations in Himalayan waters had affected distribution and abundance of native fishes. Mitigation techniques for flow alterations include construction of re-regulating weirs (FAO, 2001), low level releases to maintain negotiated minimum flows, and manipulation of cross-sectional stream geometry. Maine *et al.* (1996) suggested that the environmental assessment should be based on participatory methods that support scientific and consultative approaches, accommodate the uncertainties and complexities of environmental issues, and include non-expert participants.

Thus, the present study revealed that there is a need of effective management strategies for de-silting the head portion of reservoir that would help in maintaining required flow for breeding of endemic fishes which may in turn in restoring the important habitat of fishes and the ecosystem of the Sarda Sagar Reservoir.

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