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Estimating life of Reservoir and Simulation of Sediment Deposition of Sri Ram Sagar Dam of Nizamabad District in Telangana State

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ABSTRACT:

Every Reservoir is prone to certain problems that affect its functionality and lifespan including stresses, seismic actions, floods etc., But, Life of reservoir is momentously depended on the sediment occurring in the reservoir. Assessing the quantity of sediment and implementing remedial measures will greatly help to sustain storage capacity of reservoir. This study deals with finding varies sediment deposited annually in Sri ram Sagar Project, using Arc GIS 10.4 by plugin called Arc SWAT (Soil and Water Analysis Tool). The obtained results are compared to validated from Godavari sediment year book (15-16) from Central Water Commission and SWAT analysis was found to give appropriate sediment Deposit Edition. Further, the useful life of reservoir is numerically calculated and compared with useful life obtained from Gill equation and was found satisfactory. Finally,the analysis of variance for a change in sediment deposited and inflow and runoff to analyze fully and appropriately is done using Anova and the results are inferred.

Key Words:Anova Analysis, Gill Equation, Life of Reservoir, Reservoir Sedimentation Analysis, SWAT Analysis.

1. INTRODUCTION:

In simple words, a reservoir is an artificial lake formed by building a dam across a valley by excavating the land to enable the river flow. A Reservoir is fed by precipitation rainwater runoff (or) from a constant flow of river.The water stored in the reservoircould be amusingly used for domestic, industrial and agricultural purposes. This water could also help in hydropower generation and controlling barrier during unexpected floods and droughts.

Coming to Sedimentation, it is one of the inevitable and really difficult problems every reservoir faces. Reservoir Sedimentation is a ploddingprocess where the reservoir gets filled with sediments and other matter carried by the river during its flow process in the catchment. This process takes place as the construction of the dam or the barrier reduces the velocity of the flowing stream and subsequently the turbulence gets reduced, which causes the flowing sediments to settle down.

The primary causes for Sedimentation could be: [6]

(a) Capacity to Inflow Ratio (C/I)
(b) Amount of Sediment flowing water
(c) Size and Texture of the Sediment
(d) Trap efficiency (T_e) of the reservoir
(e) The Reservoir Operation Method

The other causes for sedimentation could also be:
(a) Nature of soil in catchment area
(b) Topography of the catchment area
(c) Cultivation in catchment area
(d) Vegetation cover in catchment area
(e))Intensity of rainfall in catchment area

Coming to Effects of Sedimentation, the devastating effects of this phenomenon are:

ISSN:0971-2143
Vol-31-Issue-26-May -2020

- It reduces in the storage capacity of Reservoir
- Decreases the ability to produce hydroelectric power
- Retrogressive deposition
- Increase in cost for maintenance
- Reduced availability for Irrigation
- Shortening of life of a reservoir

Therefore, Sedimentation should be considered as a serious problem and need to be analyzed from time to time to have an expected working condition, serviceability and durability of a Reservoir. This study considers Sri ram Sagar Dam and estimates the Sedimentation in it along with its Life expectancy using SWAT Analysis and Gill's Equation. Finally, the results are verified using Anova Analysis.

2. LITERATURE REVIEW:

Gosain et al. (2005) assessed SWAT's ability to simulate return flow after the introduction of canal irrigation in a basin in Andra Pradesh, India . SWAT provided the assistance water managers needed in planning and managing their water resources under various scenarios. [8]

Reetesh Katiyar, P. K. Garg, S. K. Jain (2006) in their study divided the catchment for Ramganga into nine sub watershed to determine the sub-watershed most prone to soil erosion. Topographical maps are digitized for preparing contour map and drainage network. By drainage network, delineation of catchment and sub catchment is done and then by generating slope and water pixels from satellite images, sub-catchment contributing to max soil erosion is determined. Also through temporal IRS-1B LISS-III images between 2000 and 2001 are used on ILWIS image processing and GIS software for assessment of reservoir sedimentation. Conclusion derived from the study says that the Remote Sensing gives good accuracy for determining sediment rate. [9]

Vaibhav Garg (2009) and others have developed artificial neural network models for estimation of sediment load. The observations of hydrometry vary over time and discharge and differ very significantly for different discharges. Therefore, this method was developed. It was stated that Hydrographic observations are costly for small reservoirs and hence it was suggested that for small reservoirs this method can be used in the absence of hydrographic surveys. [10]

Roman, Uday C. Suneeta, Jatwa, et. al. (2010) in their paper described the assessment of sedimentation using SRS technique, for Ujjani reservoir on river Bhima, in Solapur district of Maharashtra state of India. The water spread area of reservoir at different water levels between FRL and MDDL IN different month of year were computed from satellite imageries. New elevation-capacity curve would be established and compared with availability of imageries from IRC 1C, 1D and P6 satellites using LISS-III sensors. And hence by comparing both original and revised curve, capacity loss was estimated. [20]

3. OBJECTIVES:

- Calculating the sediment yield for the Sri ram Sagar reservoir situated in Pochampad Mandal, Nizambad District, Telagana using SWAT analysis.
- Comparing the sediment yield obtained from SWAT analysis to sediment data from sediment year book Godavari basin.
- Estimation of useful life of reservoir is computed and compared with Gill's equation method.
- Analysis of variance between annual sediment, inflow, runoff results are analyzed and modelled.

ISSN:0971-2143
Vol-31-Issue-26-May -2020

4. STUDY AREA:

This study works on the Sedimentation caused from the inflow by Godavari River for Sri ram Sagar dam. This dam is also called as Pochampad Project. It is situated in Nizamabad district and at a distance of 3km from National Highway 44. This dam lies at 18°58′03″N and 78°20′35″E on the Earth.

This dam severs water for agriculture in Waragal, Adilabad, Karimnagar, Nalgonda and Khammam Districts. This dam is situated at an altitude of from 333m MSL. This dam has got a catchment area of 451 km^2. The majority of this area is situated in Maharastra. It holds a water of 90TMC(ft) with an active capacity of 2,322,000,000 m^3. This dam has 42 flood gates. Finally, it provides 36MW of Electricity every year. This dam is stated as "Lineline for a large part of Telangana" by The Hindu.

The **Fig:1** below presents the pictorial view of Sri ram Sagar project, **Fig:2** presents its Catchment area, **Fig:3:** Slope map of the Catchment area from Bhuvan

Fig:1: Sri ram Sagar Project

Fig:2: Catchment area of Sri ram Sagar Project

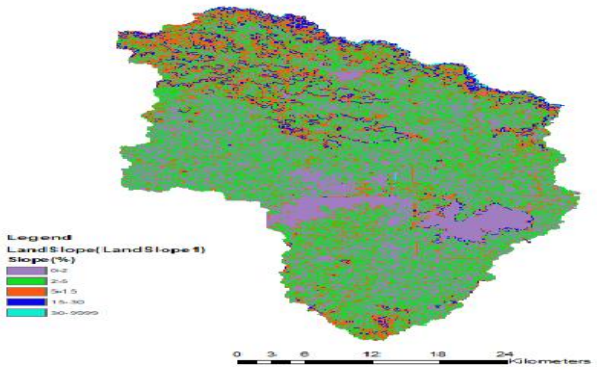
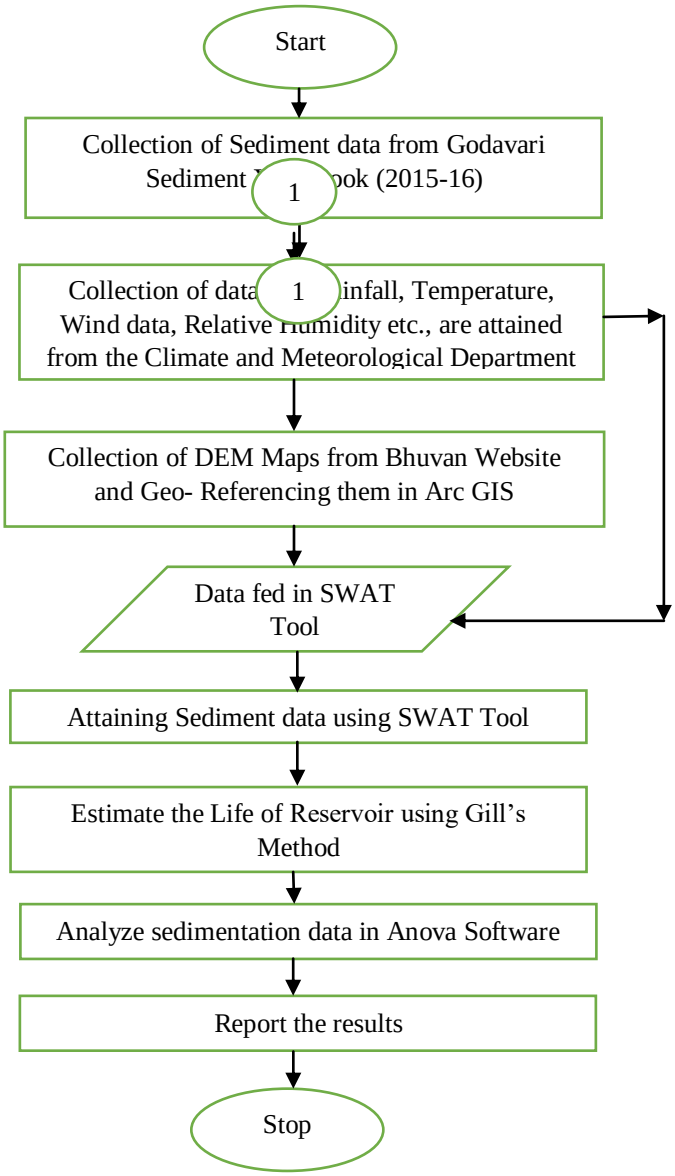


Fig:3: Slope map of the Catchment area from Bhuvan

ISSN:0971-2143
Vol-31-Issue-26-May -2020

5. METHODOLOGY:



Flow Chart: 1 : Methodology of this study

Elucidation of Methodology:

By observing the Flow Chart:1 stated above, the process of this study goes as explained below:

- To begin with, initially the Sedimentation yield data from Godavari Sediment Year Book (2015-16) of this dam from the Irrigation Department was collected.

- Then the Digital Elevation Model Maps (DEM Maps) are obtained from Bhuvan website. Those maps are merged and Geo-Referenced using Arc GIS 10.4.1 Software. Other physical data like Rainfall, Temperature, Wind data , Relative Humidity etc., are attained from the Climate and Meteorological Department.

ISSN:0971-2143
Vol-31-Issue-26-May -2020

- Using Arc SWAT Watershed Delineation and hydrologic response units analysis of DEM maps are obtained by giving the inputs like Rainfall, Temperature, Wind data, Land Use, Relative humidity, Soil Properties etc. After completion of HRU analysis, edit the input data after editing the input data.

- Now this data is proceeded further for SWAT Analysis. SWAT stands for "Soil and Water Assessment Tool". By that, it is possible to attain the sedimentation yield from SWAT Tool. Then a comparative analysis is done among the Sedimentation from Godavari Records and SWAT Analysis.

- Then comes estimating the Life Capacity of the Reservoir, Life of the reservoir is calculated using trap efficiencies values. For calculating trap efficiencies sediment inflow values and reservoir annual inflow and out flow values are collected. Using Browns method trap efficiencies are calculated. Using trap efficiencies and reservoir initial reservoir capacity and annual flood inflow values life of reservoir is calculated.

- Finally, using Anova Tool, it is likely to analyze and model the data. First the collected values like sediment inflow and runoff and water inflows for every year. The collected values are tabulated in the excel sheet. After that using one way Anova in the xlstat software analyze the tabulated values.

RESULTS AND DISCUSSIONS:

Step:1: Sedimentation Analysis

As stated in the methodology, we have initially attained the sedimentation data from Godavari Year for the year (2015-16). Then we have also attained the Sedimentation results from SWAT Analysis. The sediment yield in tonnes per hectare of every year is presented in Table:1. Also, the results and a comparison statement for the sediment yield from the year 1983 to 2014 is presented in metric tonnes in the **Table:1.**

Table :1 : Comparison of Sedimentation Yield from Godavari Sediment Year Book and our SWAT Analysis.

Year	Sediment Yield (t\ha)	Sediment yield from sediment year book 2015-16 (m.t)	Sediment yield from SWAT (m.t)
1983	2.65	19927478	23827735
1984	0.13	210041	1168907.7
1985	0.75	360156	6743698.5
1986	2.65	4477097	23827735
1987	0.36	272203	3236975.3
1988	6	3002070	539495.88
1989	1.75	NA	15735297
1990	3.58	12646554	32189921
1991	0.29	1802150	2607563.4
1992	1.43	701896	12857985
1993	0.79	158075	7103362.4
1994	1.76	388671	15825212
1995	2.21	4144891	20321011
1996	0.54	411357	4561462.9

ISSN:0971-2143
Vol-31-Issue-26-May -2020

1997	0.56	50894	5035294.9
1998	0.41	1041635	3686555.2
1999	0.96	278469	8631934.1
2000	0.67	1865799	6024370.7
2001	0.96	196851	8631934.1
2002	2.4	1274830	21579835
2003	1.03	549114	9261345.8
2004	0.08	66693	719327.84
2005	1.88	2556806	16904204
2006	1.75	2565304	15735297
2007	1.23	42984	11059606
2008	0.87	277184	7822690.3
2009	0.47	22373	4226051.1
2010	0.66	1589272	5934454.7
2011	2.58	302000	23198323
2012	1.79	215439	16094960
2013	1.21	974895	10879834
2014	0.55	90676	4945378.9

Step:2: Estimation of Life of Reservoir using Gill's Method:

Annual sediment inflow = 8.3 x 10^4metric tonnes (From Table:1)

Volume of sediment inflow = 8.3 x 10^4/6 = 0.13

Using Brown's Equation for trap efficiency (T_e)= ((Vi-Vo)/Vi)*100

Table:2: Calculation of Life of Reservoir using Gill's Method

Capacity		**Capacity inflow ratio (C/I Ratio)**	**Trap efficiency**	**Avg. Trap efficiency for the interval**	**Annual sediment trapped (St)**	**Year to fill =6/St**
in (%)	**volume x 10^6 m^3**					
100	2377.37	1.94	0.974	0.951	0.12	50
80	1901.8	0.754	0.928	0.915	0.11	54
60	1426.42	0.542	0.902	0.874	0.11	54
40	950.42	0.302	0.846	0.74	0.9	66
20	475.47	0.134	0.64	-	-	-
Useful Life of Reservoir						224 Years

ISSN:0971-2143
Vol-31-Issue-26-May -2020

Therefore, by Gill's Analysis we have found the Theoretical Life of Reservoir as 224 Years.

Step:3: Sedimentation Analysis using Anova

In the next step, the Run-off, sediment, Inflow results are fed into Anova Software, various comparisons are made and the results are presented below:

1) Run-off V/s Sediment V/s Inflow:

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
RUNOFF	34	281793	8288.029	108943323.6
INFLOW	34	8528.328	250.8332	73890.05482
SEDIMENT	34	64225493	1888985	1.65515E+13

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.0517E+13	2	4.03E+13	7.296870479	0.001106	3.08824
Within Groups	5.462E+14	99	5.52E+12			
Total	6.2672E+14	101				

Fig:4 : Run-off V/s Sediment V/s Inflow summary in Anova

2) Sediment V/s Inflow:

Summary statistics (Quantitative data):

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
SEDIMENT	34	0	34	0.000	19927478.000	1888985.088	4068351.886

Regression of variable SEDIMENT:

Goodness of fit statistics (SEDIMENT):

Observati	34.000
Sum of we	34.000
DF	2.000
R^2	0.998
Adjusted I	0.962
MSE	627082830612.510
RMSE	791885.617
MAPE	
DW	
Cp	32.000
AIC	891.258
SBC	940.102
PC	0.076

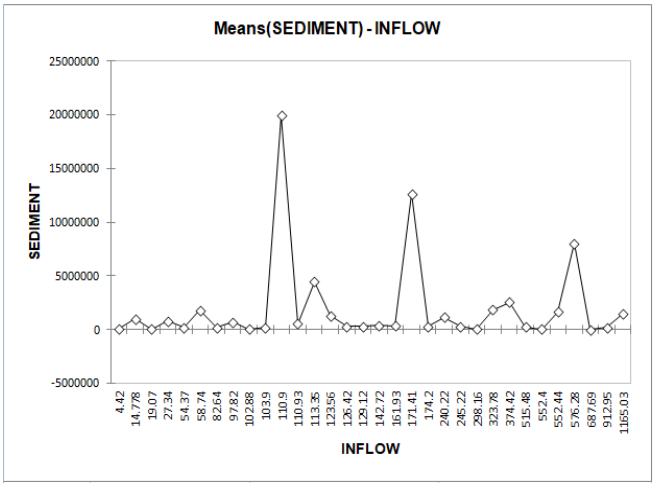
Analysis of variance (SEDIMENT):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	31	54494490762843O.000	17578867988013.900	28.033	**0.035**
Error	2	1254165661225.020	627082830612.510		
Corrected	33	546199073289655.000			

Computed against model Y=Mean(Y)

Fig:5 : Sediment V/s Inflow summary in Anova

ISSN:0971-2143
Vol-31-Issue-26-May -2020



Graph:1 : Anova Analysis **for** Sediment V/s Inflow

3) **Sediment V/s Run-off:**

Regression of variable SEDIMENT:

Goodness of fit statistics (SEDIMENT):

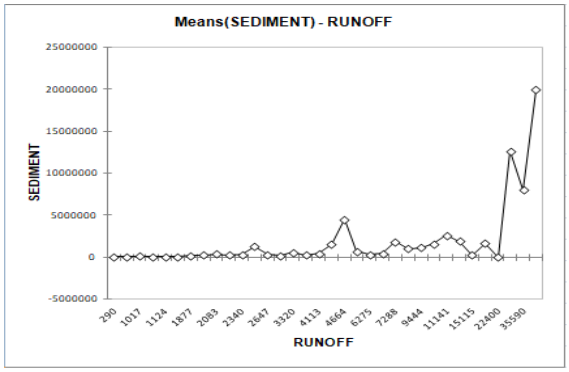
Observati	34.000
Sum of we	34.000
DF	0.000
R^2	1.000
Adjusted R^2	
MSE	
RMSE	
MAPE	
DW	
Cp	
AIC	
SBC	
PC	

Analysis of variance (SEDIMENT):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	33	546199073289655.000	16551487069383.500		
Error	0	0.000			
Corrected	33	546199073289655.000			

Computed against model Y=Mean(Y)

Fig:6 : Sediment V/s Run-off summary in Anova



ISSN:0971-2143
Vol-31-Issue-26-May -2020

Graph: 2 : Anova Analysis **for** Sediment V/s Inflow Analysis

CONCLUSIONS:

- This study has achieved all its objectives, initiallythe features of the Sri ram Sagar damareexplored and are presented in the study area.
- The required data is fed into SWAT Tool and have attained the sediment yield of every year.
- The Sedimentation results from SWAT tool are compared with that of Godavari Sedimentation Records and the results are almost same.
- With further analysis, it is found that the useful life span of this dam as 224 years by Gill's Equation.
- Also, the Reservoir is analyzed in Anova Software, and a comparison is made for every parameter in it and is presented in Results topic.

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