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Appraising the Impact of Naraj Barrage on Sedimentation of Chilika Lagoon; the Soft Computing Model for Prediction

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Authors' contributions

Author SPM designed the study, performed taking observation and statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author ACO managed the Random forest analyses of the study.

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ABSTRACT

Estimation of suspended sediment transport in a catchment area is very important to manage water resources, construction of dam and barrage, as well as to protect the surrounding environment. The daily monsoon sediment and flow were observed physically and quantity of total sediment input by the two major rivers of the south Mahanadi deltaic rivers to Lagoon Chilika were calculated during pre Naraj barrage (FY 2000 to 2003) and post Naraj Barrage period (FY's 2004, 2012, 2013) establishing an observatory in the rivers the Daya and the Bhargovi.[b] The non-linear complex relationship between quantity of suspended sediment transport and volume of river-discharge inflicts challenge to the estimation process. In this paper, two southern-most distributaries, the Daya and the Bhargovi of the Mahanadi River System which flow into Chilika lagoon are studied. Random Forest, an ensemble machine learning algorithm is used to estimate the transport of sediment by these two distributaries using predictive modeling. Predicted figures based on the gathered data from these distributaries during pre-barrage period 2000-2003 have

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been compared with the observed data gathered in post-barrage years 2004, 2012 and 2013. Comparative data suggests that the construction of Naraj barrage has significantly reduced the concentration of sediment influx into Chilika lagoon while controlling the discharge through effective barrage management.

Keywords: Impact of Naraj barrage; Chilika Lagoon; rule curve; Random forest; sediment influx; South Mahanadi System.

1. INTRODUCTION

The deltas in tropics are accommodating approximately 61% of global population and coastal lagoons are the eco-hubs for the flora and fauna [1]. Syvitski et al. [2], has reported that 33 major deltas in the globe are plummeting at very fast rate due to anthropogenic activities. The lagoon Chilika, a gulf in pre-Holocene, shaped its spit from southern flank 2500-3000 years BP due to sedimentation and became later an estuarine lagoon of the river Daya lying in the southern corner of Mahanadi delta. Gradually sedimentation has deteriorated the lagoon's health from 1500 km2 to present 1165 km2 or even less and threatened its ecology and biodiversity Nageswar Rao et al. [3]. The lagoon was subjected to rapid sedimentation since 1990s. It was downsized with incessant decrease in salinity due to shifting of mouth to remote north and depleted inlet Mishra S. P. et al. [4]. Consequently, conversion of the brackish water lagoon to a sweet water one similar to the Kolleru Lake in Andhra Pradesh was apprehended. The concentration of sediment at delta head Naraj was 0.506 gm/lit in 1980 and 0.558 gm/lit in 1981. The historic flood of 1982 increased the sediment concentration to 1.006 gm/lit and more in the years 1983 and 1984 Mishra et al. [5].

The average erosion rate of the south Mahanadi delta was estimated at 8.347 MT/ha/yr and that of the coastal sandy area as 0.393 MT/ha/yr Mishra et al. [6]. The average catch of fishes significantly reduced from average 8000 MT to 1500 MT and put the ecology to threat. The Chilika lagoon got silted up and salinity was changed. It was proliferated with phyto-planktoms, ipomeas, sea grasses and water hyacinths. Additionally, other fresh water weeds and species structure was changed CDA Report [7]. Sedimentation which is the major constraint of the lagoon's ill health was seriously viewed at state administrative level.

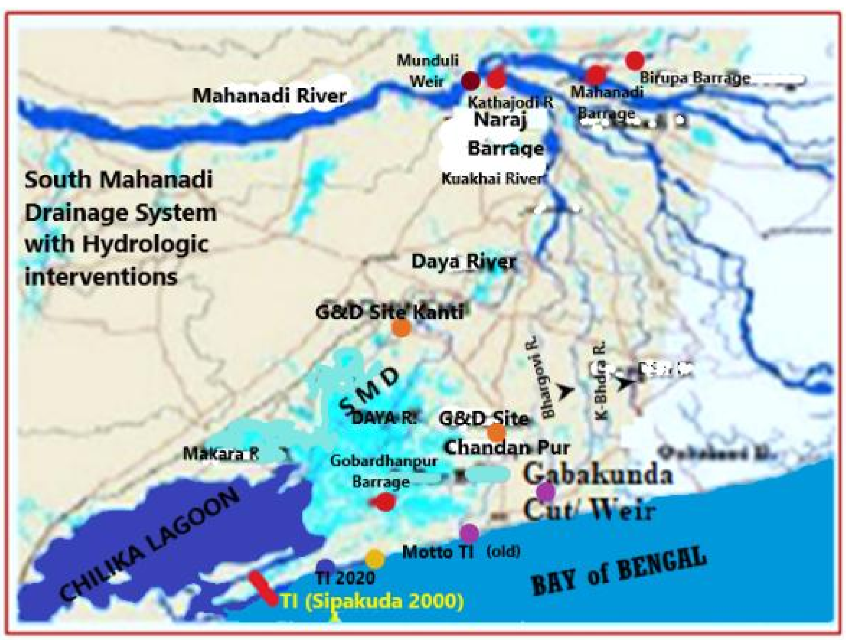

Fig. 1. The Hydrologic Interventions to improve silting of Chilika Lagoon

Ameliorative measures like opening of a direct new mouth near Sipakuda village, construction of a barrage at apex of the Delta at Naraj village and a cut to direct flood water to Bay of Bengal at Gabakund village with a low level weir at mid reach of river Bhargovi were taken (Fig. 1). After the structural and hydraulic interventions, the overall eco-health of the lagoon was improved with increase in fish catches and salinity, decrease in retention period of flood, and decline in aquatic plants ICZM Report [8]. However, effect of Naraj barrage on the sedimentation of the lagoon could not be established properly although there is an observational study by Mishra et al., 2016.

The present study envisages the effect of the barrage at Naraj along with all hydraulic interventions are accounted to predict the sedimentation and downsizing of the lagoon by use of machine learning techniques as availability of field data is scanty.

1.2 Related Work

The Mahanadi, a major east flowing river along east coast of Indian peninsula carries huge amount of discharge (av. 47BCum) and total suspended sediment (TSS) @ 11MMT/year (1993-2012) through its flood discharge to Bay of Bengal Mishra S. P. [5]. About ≈ 90% of the total annual suspended sediment load is discharged Bay of Bengal with the flood flow depositing about 10% within the Chilika lagoon, delta or depleting the river bed Chakrapani et al. [9]. Through littoral drift sediment carried from bay to the lagoon is @ 1MMT/year Chandramohan et al. [10]. Anthropogenic accomplishments (dams, barrages and change in agricultural methods, etc) supplemented by the natural events (floods, droughts, tsunamis etc.) have reduced the sediment fluxes to the mega deltas and sediment flow in major deltaic rivers in the globe and so also in India, Bharali B. [11],Gamage et al. [12], Syvitski et al. [2,13], Gupta et al. [14] and Dandekar [15]. Panda et al. [16], Shaji KA [17] have reported the east flowing large rivers in India, like the Ganges, the Mahanadi, the Godavari, the Krishna and the Cauvery have reduced their discharge and sediment. Sanil Ku. V. et al. [18] reported that shoreline along east coast oscillate and seasonally. Tandon and Sinha et al. [19] reported the high sediment flux in the peninsular rivers is due to the result of tropical weathering of rocks but not like Himalayan rivers in India. Lal et al. [19], identified four stages of formation of the rivers along the east coast which are of Cretaceous origin but global cooling and warming caused large modifications during Quaternary period. Dune dynamics and reactivation along east coast have also added to the change the river dynamics from late Holocene to recent (Mahalik et. al. [20], Kumaran et al. [21], Kakani et al. [22, Prabakaran et al. [23] and Sundaresh et al. [24]., Mishra [25]. The erratic annual climatic changes, comprising of flow reduction due to reduced precipitation in the upper and middle Mahanadi basin, and debouching of major portion of discharge (≈30%) unutilized to Bay of Bengal (BoB), Samuel A, et al, [26].The northern sector of the Chilika is fed by northern tributaries of SMD rivers contribute huge inland water and sediment and highly turbid due to sediment and resuspension due to shallowness, Chandar S. et al., [27].

1.3. Study Area

Chilika Lagoon, the largest brackish water body of Asia lies adjacent to the Bay of Bengal and South Mahanadi delta in Odisha, India. The lagoon is of prime importance from ecological sustenance point of view. In and around the area, there are 137 fisherman villages comprising of 0.2 million population, 1031 farming villages having 0.7 million population. The lagoon lies in the Central Asian Flyway of migratory birds with 211 bird species including 97 migratory species & more than 1 million birds in number. Further, the largest Irrawaddy dolphin population and around 217 fish species which include fresh, marine and brackish water live in this fragile ecosystem. According to Chilika Development Authority (CDA) report [7], direct economic benefits from the wetland are fishery, tourism, aquatic vegetation, inland navigation, agriculture, and mangroves which have been estimated to USD 62.1 million per annum. Additionally, the indirect benefits are derived from harvesting of aquatic plants, aqua culture, salt pans, and tourism *etc.*

The Chilika lagoon is divided into four prominent ecological sectors i.e. northern, central, southern and the outer channel. The northern sector receives sediment transport estimated to 1.6 MMT annually from the Mahanadi system via the Kuakhai subsystem wherein the Daya and the Bhargovi rivers are part of (Sarkar et al.,). Around 95% of the sediment is discharged to the Bay of Bengal through tidal inlets in the outer channel during monsoon period Chakrapani et al. [9]. During non-monsoon period, around 1 MMT of the sediment transported (literal drift) through spring tides Chandra mohan et al. [10]. The balance sediment during influx and efflux transportation process, gets deposited which is downsizing the lagoon at a very faster rate. The ecological impact is lessening the salinity (i.e. from brackish to sweet water), reduction in average lake depth, and decrease in the water spread area (≈1.5Km2/annum) of the lagoon (Pattnaik S, [28]). The imbalance in the ecosystem created from marine to brackish then to terrestrial which was prominently observed during 1990's. The water resources managers apprehended that the lagoon would become a sweet water lake like the adjacent Koleru lake of Andhra Pradesh. Consequently, the Naraj barrage has been constructed as a major structure among others to minimize the sediment influx into the lagoon and save the deteriorating ecosystem.

The hydrologic interventions at the head of the Mahanadi delta, four barrages have been constructed. The Munduli weir; (1863-69; later 1970's) is located at just upstream of the parent river before bifurcation. The Mahanadi barrage (1980's) over the main branch and the Birupa barrage (1990's) over river Birupa (Link River to Bramhani basin) and Naraj barrage (2004) over the Kathajodi river (Fig. 2). During survey and Investigation stage; the Water Resources department had opted for four options for the operation of the Naraj barrage. The main principle based on which the first flood flow is to flow through the Mahanadi main branch to save Chilika from sedimentation. Above 18500cumec discharge the operation of the Naraj barrage starts up to 31500 cumec flood in the parent river as per the decisions of the WR Dept. Odisha (Mishra S. P. et al 2012)[29].

The methodology applied in the present study by directly taking field observation during pre and post intervention period at the same site over the distributaries feeding flow and sediment to the lagoon without any diversion. The gauge sites are at Chandanpur over the river Bhargovi and at Kanti over the river Daya. The purpose of the present study was to check whether the construction and implementation of policy of operation that can reduce concentration sediment inflow to the lagoon so that the downsizing of the Lagoon Chilika can be ameliorated. [e].

2. MATERIALS AND METHODS

This section of the paper provides information on the data collection, selection of machine learning algorithm and the tool environment used to process the data for estimating the impact of the barrage on sedimentation of Chilika lagoon. Considering the sporadic very high floods in the Mahanadi system the fluvial interventions made in the anastomoses system are Hirakud dam (1957), Mundali weir (1970's), Mahanadi barrage(1990's), Burupa barrage (1990's) and Gobardhanpur Barrage (1990's) and the Gabakund barrage during 2004. To manage flood the drainage systems improved are Gobakund cut, Achyutapur cut and Kanchi system over the river Bhargovi (Fig. 2). The major interventions are Naraj barrage, Direct cut at Supakuda, renovation of Gabakund cut with a low level weir. Since the major sediment influx to the lagoon is from the rivers Daya and Bhargovi of the Mahanadi system is through northern sector. It has been decided to take observations of the two rivers for both discharge and sediment during monsoon periods only.

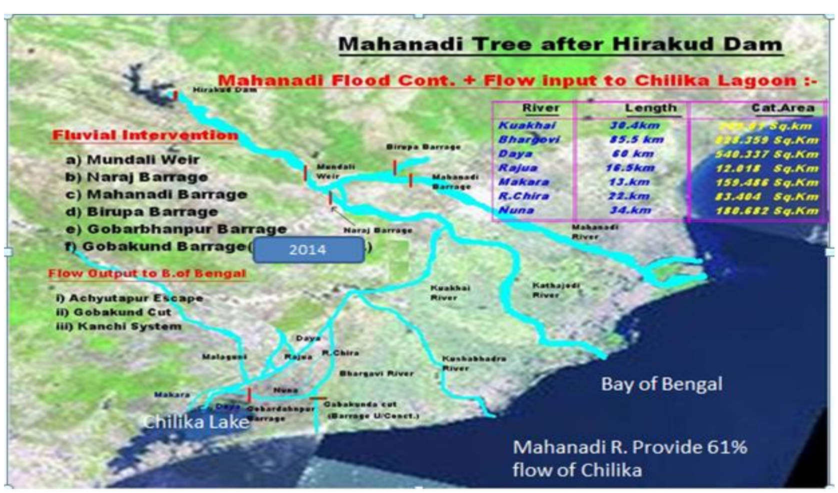

Fig. 2. The fluvial interventions on hydrologic system of the south Mahanadi delta

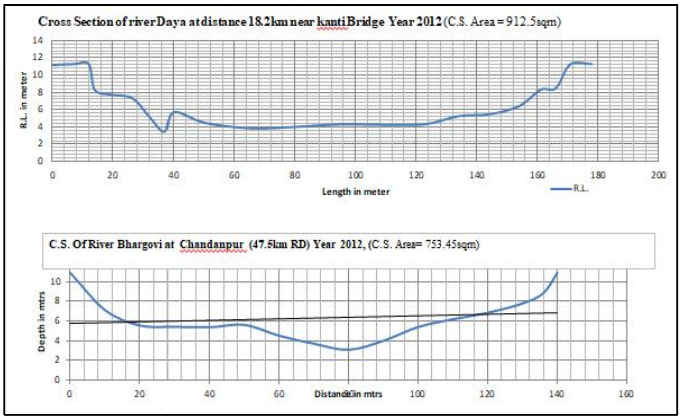

Fig. 3. The Cross Sections of the Daya and the Bhargovi river at gauge sites Kanti & Chandanpur

Station:Chandanpur Bridge site					R/f Data	:	Skgpl+ Pipili				
River:Bhargavi(R.D.47.50)											
Zero Value:3.47 m(RL 1.47)					Pre,Wind, Temp	:	BBSR				
Danger Value:6.72 m											
HFL:7.18m on 11.9.11			1st jul 00								
Month-July					Current meter No: 863						
Year: 2000											
Time of Observation:6:00 A.M.											
conversion factor: .89											
Date	**Gauge (m)**	**Area (sqm)**	**Velocity m/sec**	**Discharge cumec**	**T.S.S/ltr (gm)**	**R/F mm**	**Av. Temp 0^c**	**Pressure in hpa**	**Av. wind km/h**	**Discharge Tcum/ day**	**TSS/Day**
1st July 00	3.9	16	0.2550	4.08	0.0463	0	29.1	1001.7	8.7	352.512	16.321
2nd July 00	3.85	14	0.2314	3.24	0.0513	0	29.9	1001.9	6.5	279.936	14.361
3rd July 00	3.81	12.5	0.2304	2.88	0.0525	0	29.5	1001.5	2.6	248.832	13.064
4th July 00	3.77	12.5	0.2304	2.88	0.045	0	30.2	1001.3	3.9	248.832	11.197
5th July 00	3.76	12.5	0.2304	2.88	0.05	0	30.1	1000.9	4.6	248.832	12.442
6th July 00	3.75	12.5	0.2304	2.88	0.0813	0	30.6	1000.3	5.2	248.832	20.230
7th July 00	3.72	12	0.2292	2.75	0.0763	0	29.8	999.6	3.5	237.6	18.129
8th July 00	3.98	7.5	0.2467	1.85	0.0713	0	29.7	998.4	3.5	159.84	11.397
9th July 00	3.96	14	0.2043	2.86	0.12	0	29.7	997	4.4	247.104	29.652
10th July 00	3.95	14	0.2043	2.86	0.1588	0	28.4	995.7	8.9	247.104	39.240
11th July 00	3.92	15	0.1820	2.73	0.2363	60.7	26.4	994	8.9	235.872	55.737
12th July 00	3.8	12	0.2808	3.37	0.1963	45	26.8	994.5	6.3	291.168	57.156
13th July 00	3.86	12.5	0.3344	4.18	0.2025	1	28.7	998.1	16.1	361.152	73.133

Fig. 4. A sample excel sheet prepared to analyze and predict flow and sediment of river Chandanpur

2.1 Dataset Used

Catchment area of study was planimetered from Topo-Sheets. Gauge and Discharge (G&D) observations of the two rivers, the Daya (at Kanti) and the Bhargovi (at Chandanpur) for the period 2000 to 2004 were taken by the first author when he was in the Department of Water Resources, Govt. of Odisha. The G&D observations of the Daya and the Bhargovi were also taken at the same point for years 2012 and 2013 by establishing observatories. The Cross Sections of the distributaries were taken at fields and cross sectional areas were found out at different stages of flow (Fig. 3).Field levels were taken at the bifurcation point of the river Kuakhai at Trisulia near Cuttack city. It was found that the bed level of the Kuakhai remains 2m higher than the bed level of the Kathajodi, indicating that Kuakhai receives flood flow when the parent river has minimum 2500cumec of discharge.

Since the flow in the rivers is lean and sediment transport is meager, discharge and sediment observations were taken during monsoon period (from July to October) only. A snapshot of the time series data of daily discharge and sediment transport is provided in Fig. 4.

2.2 Predictive Model

Considering the nature of the data, Random Forest (RF), an ensemble algorithm has been used to develop a predictive model to assess the impact of the barrage. RF model solves both regression and classification problems. It is more robust and easier to train than other models particularly. RF is a collection of regression (and classification) trees that are constructed using bootstrap samples of the training dataset randomly. Once the individual trees are fitted using bootstrap samples, the final model is obtained by aggregating (i.e. averaging the output in case of regression) over the ensemble. This procedure used by RF is called bagging that reduces instability of individual regression trees, minimizes variance, avoids overfitting and improves accuracy of the model). RF is successfully used to predict accurately in many fields (Kane et al.,[30]; Dudek, [31]; Tyralis and Papacharalampous, [32] and Moore et al.,[33]) and. (Breiman L, [34]).

2.3 Modeling Environment

In the paper, Weka, a popular machine learning tool has been used to build predictive model (Amrehn et al, [35]). The time series modeling environment of Weka provides a simple GUI interface for data processing. Particularly, it allows the user to specify the skip list wherein one can mention time periods that should not be considered as time stamps for modeling and forecasting. Since the data considered in the study is only for monsoon period (July to October) of a year, this feature of Weka makes the data processing easier. It also provides multiple time steps to predict as against the normal one step prediction in time series data (Fig. 5).

2.4 Experiment Design

The daily data has been aggregated to monthly discharge and sediment transport in order to reduce the volume of data used for analysis. The data is then converted to ARRF file, a suitable format supported by Weka software. The predictive algorithm, Random Forest is configured with its default parameter values. A skip list is developed not to consider the months other than July to October in different years of data. A recursive multi-step forecasting has been used considering the pre-barrage monthly data of years 2000, 2001, 2002, and 2003 to predict monthly discharge and sediment transport for year 2004, 2012 and 2013. The procedure not only reduces mean absolute error (MAE) of the model but also helps improve prognosis. A series of runs has been performed using data of both the rivers, the Daya and the Bhargovi. The predicted data is then compared with the observed data collected for the years 2004, 2012, and 2013 as mentioned in section 4.1 to evaluate the impact of the barrage on sedimentation.

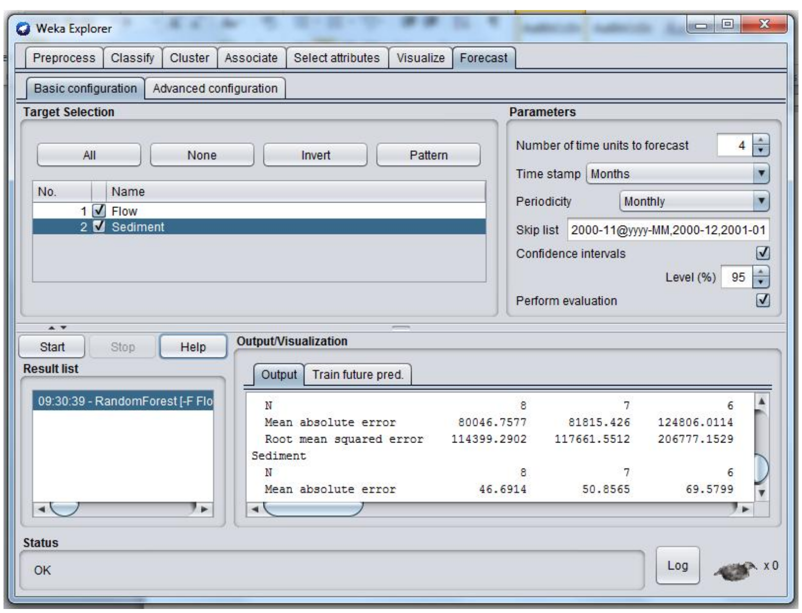

Fig. 5. Basic configuration of Weka Explorer (The model)

3. RESULTS AND DISCUSSION

The discharge and sediment data for the Mahanadi branches debouching the Chilika lagoon has been observed for the monsoon period FY2000 to FY2003 (4years) after the first hydraulic intervention the dredging of the direct cut as Sipakuda Tidal inlet. Though salinity and the fish catch have surged up but the remote mouth in the north (near Motto village) was operating in a depleted stage. After the 2nd intervention the operation of the Naraj barrage (2004) it was physically observed that the motto mouth was closed in the same year and the phyto-plankton proliferation reduced keeping the health and fish catch from the lagoon was unaltered. This indicated that the operation of the barrage with some modalities has improved the status of the lagoon. However the sedimentation status was under dark. The river Daya is active, young and straight reaches of length of 60Km running as boundary of the delta. The river is less anastomosed channels and carries about 50% of the total flow of the river Kuakhai and totally debouching in the northern swamps of the Chilika Lagoon.

The parameters for sedimentation like discharge and Total Suspended Solids transport were observe for the year 2004 and after 8years 2012 and 2013. The physical and geomorphological changes within the lagoon were witnessed from outside. The lagoon had allowed to pass through the floods in the years 2003, 2004, 2006, 2008 and 2011 where in the lagoon has achieved its flushing flood 2830cumec in the Kuakhai system. Moreover the year 2008 has got a historic (ever highest measured 44875cumec) and the ESCS tropical cyclone Phailin in the year 2013 which had changed the hydrodynamic of the river system the Daya and the Bhargovi. The changes in the in the tidal inlets were seen increased from one in 2004 to four numbers in 2013.

Table 1. Post Barrage data of the river Daya

Month	Observed		Predicted		Difference (Predicted-Observed)	
	Discharge	Sediment	Discharge	Sediment	Discharge	Sediment
2004-07	33783	1.81112	290015.96	102.8987	256232.9596	101.08758
2004-08	761150	251.225	341000.45	163.509	-420149.551	-87.716
2004-09	29477	2.68815	428662.1	198.8683	399185.1047	196.18015
2012-07	33197	12.08679	306229.81	113.8496	273032.81	101.76281
2012-08	303998	75.86479	350802.03	143.1904	46804.03	67.32561
2012-09	127211	34.78051	409722.14	158.7389	282511.14	123.95839
2012-10	35217	2.820144	399034.31	154.9433	363817.31	152.123156
2013-07	132347	11.62766	413217.39	164.5757	280870.39	152.94804
2013-08	771901	126.9783	357308.18	146.9865	-414592.82	20.0082
2013-09	367300	46.15119	373144.83	160.3618	5844.83	114.21061
2013-10	438511	65.48151	382498.53	155.4579	-56012.47	89.97639

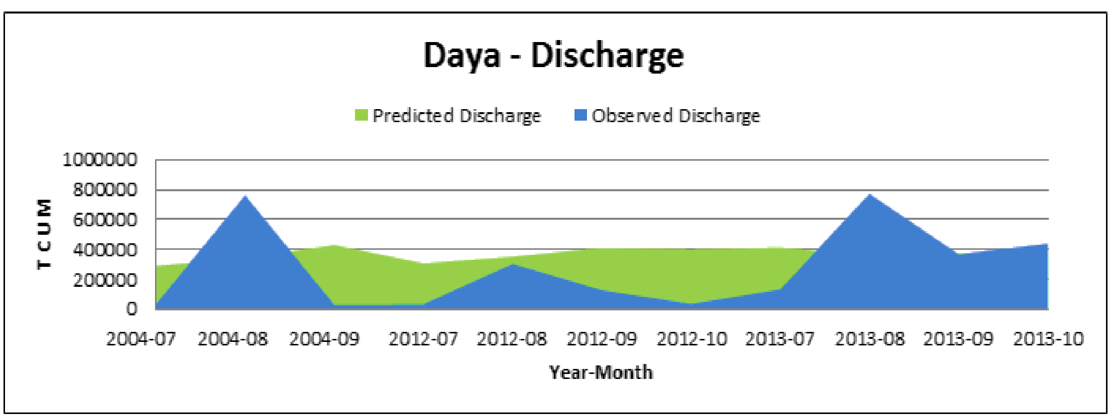

Fig 6. The predictive model vs observed discharge results of the River Daya: Pre and post Naraj barrage period

The flow and sediment study of the major inflowing rivers the Daya and the Bhargovi were studied tentatively with scanty observation during preparation of Mahanadi Delta Development plan stage II during 1986 where only a share of 4% each (the rivers Daya, the Bhargovi and the Kushabhadra) was provided to the distributaries of the (SMD) south Mahanadi deltaic system, and pre-barrage data was taken by the author when working in Water resources Dept, Odisha [D].

The observation data of discharge and sediment flux through the lagoon were considered and the soft computing model WEKA was used to predict by using multiple time steps to predict as against the normal one step prediction in time series data. The model results for the discharge and the sediment inflow via the river Daya are shown in Fig. 6 and Fig. 7.

The experimental results had shown for the individual result for the years 2004, 2012 and 2013 had shown that the discharge were regulated and the sediment concentration has been reduced from gm/lit to gm/lit by %. The predictive model as shown in the graph indicates that both discharge and sediment has been reduced from no Naraj barrage period to post barrage period.

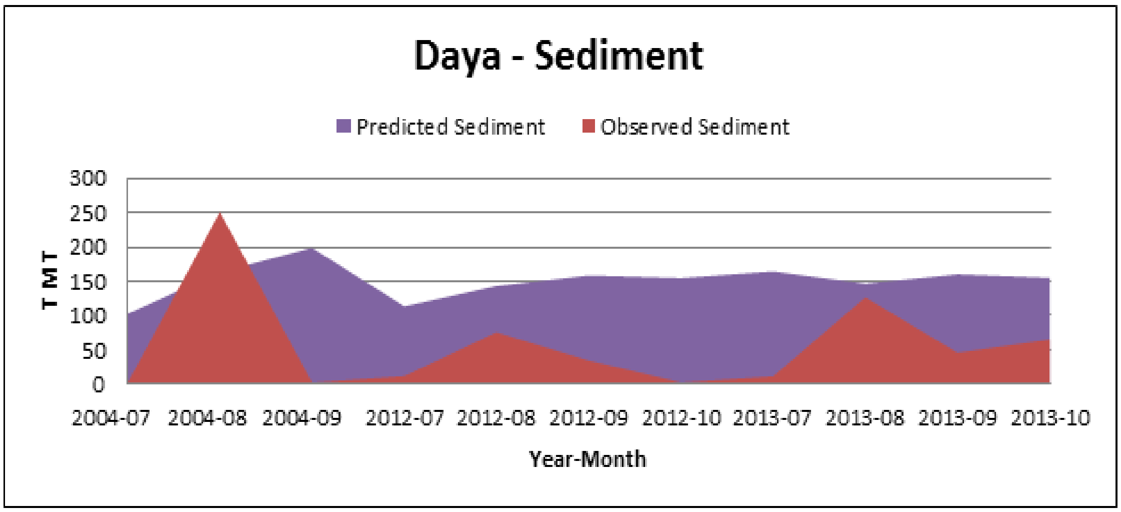

Fig. 7. The predictive model vs observed sediment results of the River Daya : pre and post Naraj barrage period

Table-2. Post Barrage data of the River Bhargovi during observation period (Year/month)

Year/ Month	Observed		Predicted		Difference (Predicted-Observed)	
	Discharge	**Sediment**	**Discharge**	**Sediment**	**Discharge**	**Sediment**
2004-07	299	5.54135	15609.87	5.2862	15310.8668	-0.25515
2004-08	93652	34.62056	18678.89	4.7404	-74973.1138	-29.88016
2004-09	738	6.7176	24370.21	7.2561	23632.2053	0.5385
2012-07	4202	0.1726	20667.28	7.9092	16465.28	7.7366
2012-08	64430	6.11035	17458.13	6.1354	-46971.87	0.02505
2012-09	14537	7.3087	20426.81	7.5734	5889.81	0.2647
2012-10	335	0.098168	19184.7	6.6791	18849.7	6.580932
2013-07	10497	2.19347	22675.08	7.1516	12178.08	4.95813
2013-08	80720	8.814	19061.63	6.061	-61658.37	-2.753
2013-09	71460	7.0677	20766.63	6.9471	-50693.37	-0.1206
2013-10	84004	10.967	19132.59	6.165	-64871.41	-4.802

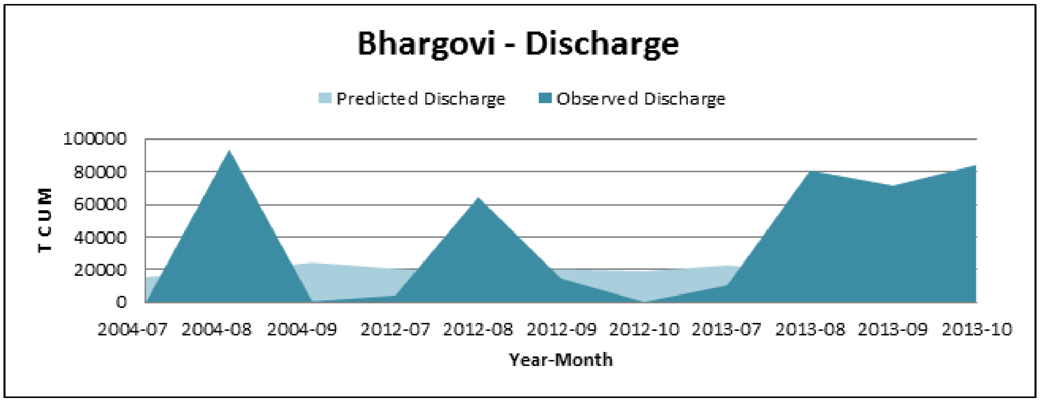

Fig. 8. The predicted discharge vrs the observed discharge of the river Bhargovi at Chandanpur

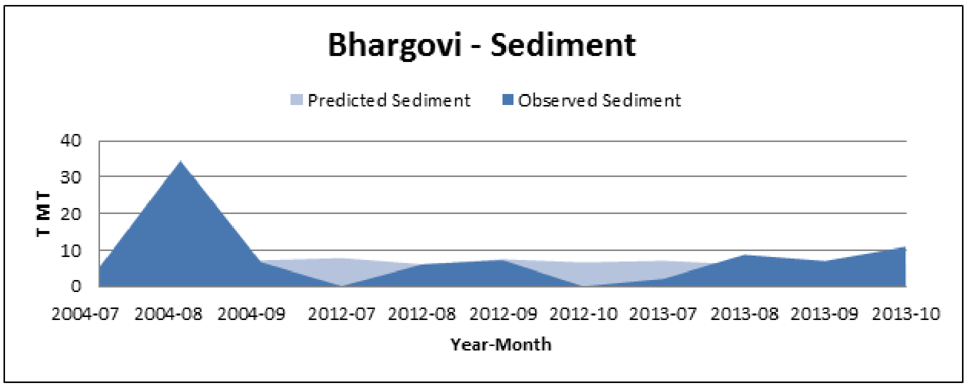

Fig. 9. The predicted sediment vrs the observed sediment of the river Bhargovi at Chandanpur

The Bhargovi river is of length 87.5Km is the northern branch of the Kuakhai river running zigzag in its course till the village Gabakund which is at reduced distance 37 Km. The Table 2 give the observations taken during post barrage period. Data has been interpolated to fill up the missing data [F]. Then it takes a 90^0 bend and runs almost parallel to the coast Fig. 8 and Fig. 9.

Due to the construction of the barrage and its effective management, annually on the average, 62% less sediment transported and 25% less water discharged into the Chillika lagoon by the Daya River. Contrary, the Bhargovi discharge more water and transported more sediment that the predicted. However, the overall sediment transport by both the rivers has been reduced to 58.44%.

[e]The observed data specifies the amount of sediment reduction for pre Sipakuda tidal inlet (2000-2003) and post Naraj and Sipakuda TI the sediment concentration of the rivers Bhargovi were 0.631gm/lit to 0.599gm/lit (reduction by 5.12% where as in the river Daya the reduction was 0.272gm/lt to 0.236gm lit (@14.71%).

Observation data for flow and sediment was observed/gathered in the distributaries the Daya and the Bhargovi of the South Mahanadi delta debouching the Chilika lagoon. The data went through methodical analysis using Randon Forest, a machine learning approach. The predictive results based on the time series data, the study inferred that the construction of the Naraj barrage construction of the barrage at Naraj; at the apex of the delta across the Kathajodi River is a success. The effective management of the barrage has increased the numbers of flushing flows to the lagoon to wash out the underneath sediments and maintain the depth of the shallow lagoon to deplete. As a result the depth, water spread area, ecosystem, stability of the tidal inlets, uniform shifting of the inlet and the interest of the stake holders shall stand for the 2nd largest brakish water lagoon of the world.

4. CONCLUSION

[C] The study used data of post-barrage years 2004, 2012 and 2013 which reveal that the flushing flow (2830 at the Kuakhai river) to the lagoon can be provided by efficient operation of the Naraj barrage at the apex of the system. Since it is a self-financed project, data was not collected for years 2005-2011. The concentration of sediment in the rivers the Daya and the Bhargovi have reduced after effective operation of the barrage from 2004. Further, the erratic discharge and sediment flow of the Bhargovi due to the direct cut at Gabakund (mid of the river Bhargovi) needs further study considering interventions like the dredging of Gabakund cut, and widening of Kanchi river mouth with a number of bridges constructed which constrict the width and reduce the flow like the pre-barrage period.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bianchi TS, Allison MA. Large-river delta-front estuaries as natural 'recorders' of global environmental change, Proc. of the National Academy of Sci. 2009;106(20):8085–92.
2. Syvitski PMJ, Kettner AJ, Overeem I, Hutton EWH, Hannon MT, Brakenridge GR, et al., Sinking deltas due to human activities", Nature Geosciences; 2009. Available:www.nature.com/naturegeoscience
3. Nageswara Rao K, Sadakata N. Holocene Evolution of Deltas on the East Coast of India "Delta of the World " Proceedings, 8th Symposium on Coastal and Ocean Management held July 19-23,New Orleans, Louisiana, USA. 1993;1-15.
4. Mishra SP, Mishra SKu, Das K. Geo Dynamics, Salinity Gradient, and Vegetation Inter-dependence in Chilika Lagoon, a Tropical Wetland in Eastern India, Journal of Wetlands Environmental Management, Indonesia. 2019;7(1):1-22. DOI:10.20527/jwem.v7i1.186
5. Mishra S. P., 2017, Management of the sediment transported by the south Mahanadi deltaic rivers to the Chilika lagoon. Int., Jour. Adv. Research, Vol, 5(6),pp- 1005-1020
6. Mishra SP. Stochastic Modelling of Flow and Sediment of the Rivers at Delta head, East Coast of India, American Journal of Operation Research, Scientific Research. 2017;7(6):331-347. DOI:10.4236/ajor.2017.76025.
7. Chilika Development Authority DPR. Integrated Coastal Zone Management: Strengthening of Wetland Research &Training Centre and Bio-diversity Conservation on Chilika Lagoon", zmpodisha.org/./Chilika; 2012.
8. Ministry of Environment and Forests. Visit to Chilika Lake, Orissa, a wetland included under the National Wetland Conservation and Management Programme of the Ministry of Environment and Forests. Report on the Visit of A Three-Member Team For Conducting A Half-Yearly Review. 2008;1-22, Available:http://planningcommission.gov.in/reports/E_F/ChilikaLake.pdf
9. Chakrapani GJ, Subramanian V. Preliminary studies on the geochemistry of the Mahanadi river basin, India, Chemical Geology. 1990;81:241–253.
10. Chandramohan P, Kumar VS, Nayak BU. Coastal processes along the shorefront of Chilka lake. Indian J. Mar. Sci. 1993;22:268–272.
11. Bharali B, Rath S, Sharma R. A brief review of Mahanadi delta and the deltaic sediments in Mahanadi basin, Mem. Geol. Soc. India. 1991;22:31-49.
12. Gamage N, Smakhtin V. Do river deltas in east India retreat? A case study of the Krishna delta. Geomorphology. 2009;103:533–540.
13. Syvitski JPM, Kettner A. Sediment flux and the Anthropocene Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences. 1938;369:957-97.
14. Gupta H, Kao Shuh JI, Dai M. The role of mega dams in reducing sediment fluxes: A case study of large Asian rivers, Journal of Hydrology. 2012;464:447-458.
15. Dandekar P. Shrinking and Sinking Deltas: Major role of Dams in delta subsidence and effective sea level rise, South Asia Network on Dams Rivers and People. 2014;1-14.
16. Panda DK, Kumar A, Mohanty S. Recent trends in sediment load of the tropical

(Peninsular) river basins of India. Global Planet. Change. 2011;75(3–4):108–118.
17. Shaji KA. Why-the-kaveri-delta-is-shrinking-and-farm-productivity-with-it, The wire in; 2019. Available:https://thewire.in/environment/why-the-kaveri-delta-is-shrinking-and-farm-productivity-with-it
18. Sanil Ku V, Pathak KC, Pednekar P, Raju NSN, Gowthaman R. Coastal processes along the Indian coastline, Current Science. 2006;91(4).
19. Lal NK, Siawal A, Kaul AK. Evolution of East Coast of India – a plate tectonic reconstruction", Journal Geological Society of India, Volume. 2009;73:249-260.
20. Misra Pavani, Sampat Tandon, Sinha Rajiv. Holocene climate records from lake sediments in India: Assessment of coherence across climate zones, Earth-Science Reviews. 2019;190:370- 397, DOI:10. 1016 /j. earscirev.2018.12.017
21. Mahalick NK. A Study of the morphological features and bore hole cuttings in understanding the evolution and geological processes in Mahanadi Delta in East Coast of India, Jour. of Geo. Society of India. 2006;67(5).
22. Kumaran KPN, Limay R, Padmalal. India's fragile coast with special reference to late quarterynary dynamics, Proc Indian National Science Academy. 2012;78(3):343-352.
23. Prabhakaran K, Anbarasu K. Evolution of Vaigai Delta, Tamilnadu, India (East Coast) During Quaternary, International Journal of Geomatics and Geosciences. 2010;1(2).
24. Sundaresh, Mani Murali R, Seelam Jaya Ku, Gaur AS. Shoreline changes along Tamil Nadu coast: A study based on archaeological and coastal dynamics perspective, Indian Journal of Geo-Marine Sciences. 2014;43(7):1167-1176.
25. Mishra SP. Delineation of fluvial-Aeolian dunes along the SMD and Chilika coasts of Odisha, India, Int. Journal of Advance Research. 2017;5(12):412-425. DOI:10.21474/IJAR01/5975
26. Samuel A, Joy KJ, Bhagat S. Integrated water management of the Mahanadi Basin: Water resources, water allocation and inter-sectoral use.Forum for Policy Dialogue on Water Conflicts in India, Pune. 2017;1-79.
27. Chander S, Gujrati A, Hakeem KA, Garg V, Issac AM, Dhote PR, Kumar V, Sahay A. Water quality assessment of River Ganga and Chilika lagoon using AVIRIS-NG hyperspectral data, Current Science. 2019;116(7):1172-1181.
28. Pattanaik Ajit. "Rejuvilation of Chilika Lagoon, restoration of coastal wetland with community participation", EPTRI-Envis News letter. (Fragile ecosystem of Eastern Ghat). 2005;2(2).
29. Mishra SP, Jena JG. "Effects of variable inflow from Northern major rivers In to the Chilika Lagoon, Odisha, India", Int Journal of Lakes and Rivers. 2012;5(2):123-132.
30. Dudek G. Short-Term Load Forecasting using Random Forests. In: Filev D. et al. (eds) Intelligent Systems'2014. Advances in Intelligent Systems and Computing. Springer, Cham. 2015;323
31. Kane Michael J, Price Natalie, Scotch Matthew and Rabinowitz Peter. Comparison of ARIMA and Random Forest time series models for Prediction of Avianinfluenza H5N1 Outbreaks, BMC Bioinformatics. 2014;15:276.
32. Tyralis H, Papacharalampous G. Variable Selection in Time Series Forecasting Using Random Forests. Algorithms. 2017;10:114. DOI:10.3390/a10040114
33. Weka. Weka 3: Machine Learning Software in Java; 2019.Available:https://www.cs.waikato. ac.nz/ml/weka/
34. Breiman L. Random forests,Mach. Learning. 2001;45(1):5–32.
35. Amrehn M, Mualla F, et al. The Random Forest Classifier in WEKA: Discussion and New Developments for Imbalanced Data;Balanced Random Forest Classifier in WEKA. 2018;1-6.

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