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Prediction by Soft Computing, Planning, and Strategy Building of Aquatic Catch: Chilika Lagoon, Odisha, India

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Authors' contributions

This work was carried out in collaboration between both the authors. Author SPM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author ACO managed the computer analyses of the study and the results. Both authors read and approved the final manuscript.

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ABSTRACT

Introduction: The Chilika lagoon in south Odisha, India was ecologically degraded from 1985 onwards by reduction of its aquatic (fish + prawn + shrimp) catches along with reduction in salinity, hydraulic regime, water exchange, aquatic weeds invasion, and sediment influx. The aquatic catch was 8669MT in year 1985-1986 gradually reduced to 1274MT during 1995-1996 from Odisha Fisheries Dept. records which resulted in poor economic condition of ≈0,2million fishermen and they migrated to adopt other livelihood. One direct tidal inlet dredged (Sipakuda) and Naraj barrage in the apex of South Mahanadi Delta were the major hydraulic interventions made to regain hydraulic regime. After the hydraulic interventions, the eco system restored, and the aquatic catch surged but it was insufficient to livelihood sustenance for the fishermen community of the Chilika, so that they are forced for alternate occupation and migration.

Methodologies: Fish catch data collected for 30 years and soft computing models linear regression, Multi Linear Perception (ANN), SMOorg (SVM) and the Random Forest algorithms (Weka Software) are used to predict the fish catch data of the lagoon for coming decade from 2020

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to 2030. The effects of major hydraulic interventions are analyzed and the soft computing method of the fish and shrimp catch prediction of the Chilika has been attempted for the first time except some statistical approaches.

Results: The Random Forest is found to be the preferred algorithm followed by the MLP model. The amount of catch remained around 12-13TMT if the variables and the present status of the lagoon is maintained. The combined effect of the Sipakuda Tidal inlet and the effective operation of the Naraj barrage have maintained the sustainable aqua catch. The present study shall be an immense help for the lake users and policy makers to augment aquatic catch, and alternate livelihood fishers community of the Chilika lagoon.

Keywords: Prediction; planning and strategy; aqua catch; Chilika lagoon; South Mahanadi Delta.

ABBREVIATIONS

BoB : Bay of Bengal
SMD : South Mahanadi delta
MMT : Million metric tons
YBP : Years Before present
TI : Tidal inlet
OC : Outer Channel
ZSI : Zoological survey of India
CFCMS : Central Fishermen's Cooperative Marketing Society
PFCS : Primary Fishermen's Cooperative Societies)
CFIRI : Central Inland Fisheries Research Institute)
CDA : Chilika Development authority
NFHS : National Family Health Survey
ML : Machine learning
GUI : Graphical user interface
STSM : Structural Time Series Model
ARIMAX : Auto Regressive Integrated Moving Average with explanatory variables CPUE: Catch per unit effort
ANN : Artificial Neural network
MLR : Multiple linear regression
SOM : Self-organizing map
MLP : multilayer perceptron)
RF : Random forest
MLP : Multilayer perception
SVM : Support vector machine
MSE : Mean square error
NGO : Non-government Organizations

1. INTRODUCTION

The nutritious fishes, prawns, shrimps and shell fishes (Aqua fauna) has turned up as an integral part of food basket added as protein supplement of mal-nutrients and under-nutrients of common Indians. About 42.8% women and 48.9% men in India consume nonveg (fish, chicken or meat weekly), National Family Health Survey, 2015-16 (NFHS-4) [1]. The paradigm shift that India has achieved in fish sector from 0.75MMT in 1950-51 to 10.16MMT (marine 3.59MMT) in the financial year 2014-15 indicating the sector has gorgeous and promising financial growth with huge employment generation, (https://core.ac.uk/download/pdf/79425393.pdf). Fishes and shrimps are caught from lacustrine fresh-brackish-marine environment of the Chilika lagoon.

Though a promising resource, the aqua fauna sector is under jeopardy due to over exploitation fetching under employment and lower income to fisher community, dearth of alternate occupational policy in Odisha, India. The lagoon is in the coastal corridor of Bay of Bengal (BoB) and joining the south Mahanadi delta (SMD) along east coast of Odisha, India.

The fish catch has augmented after hydraulic interventions in the SMD and in the Chilika Lagoon. Simultaneously the fisher folk population is rising at faster rate so that the aquatic yield is insufficient for their livelihood. The fisher's community of the lagoon is half-fed, and has turned as migrants in search alternate livelihood. The present prediction in fish catch can enlighten the lake managers to plan for the stake holder's economy at least in coming five years.

1.1 The Chilika Lagoon

The Chilika lagoon (lat. 19°20′13"–19°54′47″ N to long 85°06′49″–85°35′33″ E) is the largest brackish water body (Ramsar site-229) in Asia and 2nd largest in the globe houses along southern east coast of Odisha, India (Fig. 1).

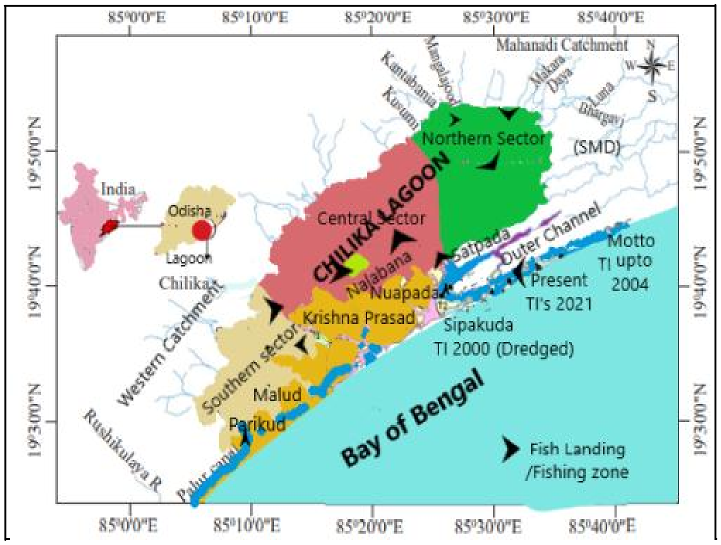

Fig. 1. Index map of the Chilika Lagoon and its local Basin

Ecologically the lagoon has four sectors northern (shallow and freshwater regime), Central (mid channel, brackish for fish hatchery), southern (brackish and deep), and outer channel (fragile spit, marine, saline fish entry, and tidal inlet activities). There is variation in salinity and aquatic species from fresh-brackish-marine hydraulic regime depending mainly upon fresh water monsoon inflow from SMD (Raman et al [2]). The lagoon is conglomeration of varying salinity of fresh, brackish and oceanic water under an estuarine character with rising activity during strong SW monsoon, spring and ebb tides. The salinity varies between 02-36ppt (Mishra [3]), and hence the biodiversity. The environment studies of the fragile ever changing salinity & aquatic catch (Fish + Prawn + crab) needs to be studied.

Aqua faunal resources in the lagoon account for 71% total earnings from the ecosystem. Some aqua species (fish, shrimps, prawns, and crabs) of about 86% are migrant between the sea and the lagoon for their advantages for feeding, breeding and hatching spots in outer channel and central sector (favorably) during post monsoon wintry period being triggered by moderately raised hydrologic regime, seasonality, salinity and temperature (Palvan et al. [4], Bruno et al. [5], Raman et al. [2]).

The depletion of tidal inlet (TI) at Motto in the OC of the Chilika, towards 1990's, the lagoon was apprehended to be transformed as a freshwater ecosystem due to depletion of the av. salinity to about 7ppt. Ameliorative measures like dredging a direct new mouth at Sipakuda (2000), functioning of a barrage at apex of major flow at Naraj, and renovation of link and pilot channels and canals, clearance on mocks from the Magarmunha has rejuvenated the ecosystem with substantial upgrading in the fish landing and catch, due to restoration of salinity gradients, escalation of auto recruitment, free trespassing of fishes, shrimps between BoB and the lagoon (Mishra et al. [6]). Present challenges are to make long term prospective plans and strategies by applying sustainability management policies for the fishing sector of the Chilika lagoon, Odisha after hydraulic interventions [7].

1.2 The Chilika in 20th Century Biodiversity

Different studies on biodiversity of the Chilika lagoon reveals that diminution of lake dimension from 393Km^2 (between 1920 to 1993), average lake depth reduction from 3m to 1.6m (1992 to 2000) are due to sedimentation, disappearance of 40% species (69 species out of 126 species), depletion in average salinity from 22ppt to 7 - 8ppt. reduction in numbers Pattanaik, [8]. The avifauna species congregation at Nalabana, proliferation of phyto planktons, inflow of polluted water through inland drainage channels, construction of gherries, prawn farming, gill nets introduction, and increase of motorized boats are the main causes of anthropogenic and natural deterioration of the lagoon. The result was reduction of fish landing, depletion in salinity, fish catch, and deteriorated eco-health of Chilika.

2. REVIEW OF LITERATURE

Researches on the aqua fauna of the Chilika was first published by Zoological survey of India (ZSI) for the period 1914-1924, & by CIFRI during 1960-65 for fish species of the Chilika, (Jhingran et al. [9,10]) followed by Z.S.1. in 1985-87 (Siddiqui et al. [11]). Since then a lot of changes in the morphology, ecology and fisheries have taken place with the passage of time for which no account is available (Pattanaik, [12], Pattanaik [13]). The Chilika has 315 species of fishes (24 orders from 87 families), crabs of 35 species (9 families), prawns of 29 species from 8 families; and lobsters of 2 species from one family during 2015, Comparing early records, 3fish families missing, 14 families of fishes and 14species of crabs, and 29species of prawns reported first time, after eco-restoration Kadekodi et al. [14], Mohapatra et al. [15] and Suresh et al. [16]. Over all belief is the there is significant link between fish catch and sel-fish catch attributed to changes in light flux/ intensity, tidal effects or from other causes (Vance et al. [17], Takemura et al. [18], Park et al. [19], Pulver [20]).

Raman et al, [21] analyzed statistically the prediction of fish catch of the Chilika by help of stochastic models like Structural Time Series Model (STSM) and ARIMAX (Auto Regressive Integrated Moving Average with explanatory variables). Iglesias et al. [22], Olden et al. [23], Quetglas et al, [24], Wen et al. [25] have applied neural computing models like Catch per unit effort (CPUE), Artificial Neural network (ANN), self-organizing map (SOM), multilayer perceptron (MLP) *etc.* for analysis and prediction for aqua catch in the Chilika which has turned up as active research for aquatic biodiversity.

2.1 The Problem Statement

The brackish water Chilika has struggled for its existence as a lagoon like the adjacent swamp Koleru Lake existing in Andhra Pradesh. The lagoon has incessantly faced physico-chemical, hydraulic and biological degradation added with human endeavors since four to five decades.

The fish catch, major sources of livelihood of the fishers of the lagoon has attenuated year after year from 8.67TMT in the FY 1985-86 to 1.27 TMT during 1995-96 (Fig. 2). The economy of 0.2million fishermen had dwindled and unrest geared up along with migration, marginalization and some socio-political issues. The last decade was the worst period for the lagoon as the devastating cyclonic storms like Phailin, Hudhud, Titili, Fani and Amphan slammed in and offshore affecting the fish population Mishra & Ojha, [7].

The killer COVID-19 made the fisher's group confined at home which triggered sharp doldrums in Indian fish market due to lock downs/shut downs, confinement, and market closure. The lagoon has transformed to fishery from port activities from 17th century, it is ubiquitous to predict the quantum of future aqua catch for its sustainable management. The soft computing technique of prediction in aquatic catch of the Chilika is yet to be attempted except some statistical approaches.

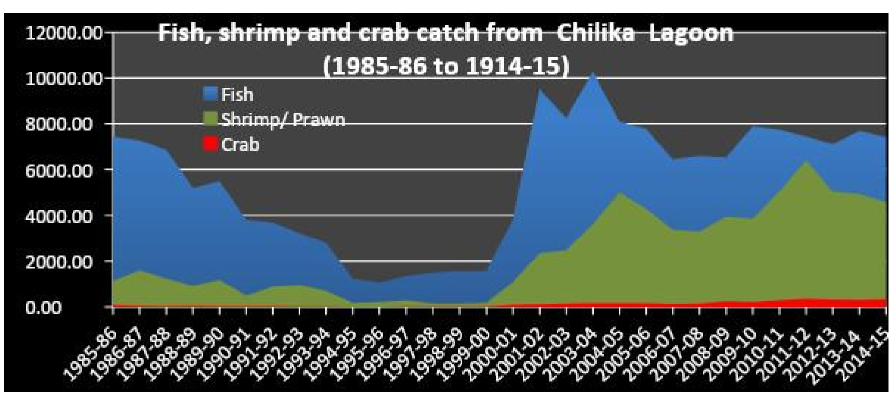

Fig. 2. The aquatic (fish+Prawn+crab)catch in the lagoon Chilika from 1985-86 to 2014-15
Source: Fisheries Department Odisha

2.2 Objective of Study

The objectives are to predict future aqua catch of the lagoon till 2025. The aim is to assess the trend of the aqua catches during the pre-intervention period, to the major anthropogenic interventions like dredging of the direct Sipakuda TI, construction of a barrage at Naraj, and the Gobakund cut to BoB from the river Bhargovi till 2016, are considered, for planning future SOP.

3. METHODOLOGY

Attempts were made by some scientists to predict future aqua catch of the lagoon apriori. The present incipient attempt is made to predict the various artificial Neural Network models for the time series data. Multilayer perception (MLP), SMO Algorithm, and support vector machine (SVM) regression (SMOreg) of (weka-dev 3.9.5 API), Random forest (RF) and linear regression has been attempted using WEKA software. The results are simulated and selection of the most suitable base line computational algorithm from the verified machine learning processes for the aqua catch of the lagoon. Discarding the processes giving erratic result, the most effective models such as the linear regression, multilayer perceptron, SMOreg, and random forest are considered. The fish catch data of the lagoon (FY 1985-86 to FY 2015-16) is collected from multiple sources and a time series has been created. The various predictive algorithms are used to predict the fish catch using the Weka data mining software.

The data mining job is undertaken by machine learning software (Weka), which is a cluster of machine learning (ML) algorithms that quickly intakes GUI (graphical user interface), and test various hyper-parameters of multiple machine learning processes. It is a tool with standard algorithm and easy operative command line software with Java applications (Mishra & Ojha [7]).

3.1 Socioeconomic, Political History of Fishing

History reveals the fishing rights in the lagoon dates back from 1790 AD, was controlled by kings of Khalikote, Parikud or Zamindaris of Mirzabeg, Suna Bibi and Choudhury family of Bhingarpur. The 'Sairat' and Khajana (Tax) was collected from the fishermen through 'Bheti' or 'Salami' till 1930. Till independence, the cooperative societies took 'Nilami' (tender) for the zamindari from the British period as 'sairats' Nayak P.K. [26].

From 1956, the Orissa state reserved the fishing rights and managed the lagoon through cooperative societies. Later with increased fisher's community, and settlements, Central Fishermen's Cooperative Marketing Society (CFCMS) hold the fishing rights and handled through Primary Fishermen's Cooperative Societies (PFCS) who neglected the livelihood and economic activity within the lagoon. That result was without any unanimous constructive planning to save the lagoon from its deteriorated eco-health.

From 1991, during economic liberalization in India, the Chilika was under the special lease policy permitting for aquaculture to private organization depriving indigenous fisher community, inclusive hike in annual lease fee by 27% on compound rate. The PFCS collapsed due to heavy compound tax incurred for payment. Later on legal imposition "the black rule" was banned and the caste based fisher community under state government (FISHFED), and CDA took over the overall management of the lagoon and the fisher's community.

3.2 Ecosystem Diversity of Chilika

The Chilika ecosystem is the ensemble of ancient maritime heritage, traditional fishing, flora, fauna, avifauna, trade and tourism. The system supports about 200k fishermen of 141 villahges and about 400K other stake holders. The annual aquatic production is evaluated from the receipt of fish, prawn and crab from the collection centers, jetties in around the Chilika (Fig. 3).

The degradation of lagoon's exemplary ecosystem was grave due to natural and anthropogenic actions from 1980 onwards which changed the lake characteristics, flow exchange, salinity depletion, aqua catches, heterogeneity and diminished winter migratory birds, Mohapatra, et al. [27], Kumar et al. [28]. It is evident from the (Fig. 3) that the aqua catches have deteriorated, posed threat to the aqua-fauna. The catch amount was increased with various interventions imposed on the hydraulics of the lagoon (Sahu, et al. [29], Mishra, [30], Suresh, et al. [31]).

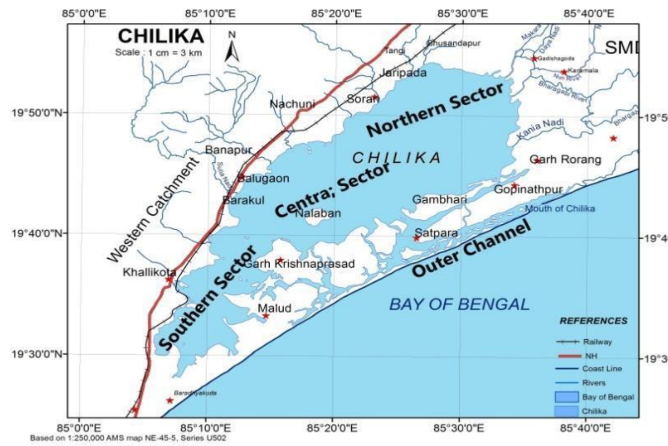

Fig. 3. Major fish collection centers in and around the Chilika lagoon

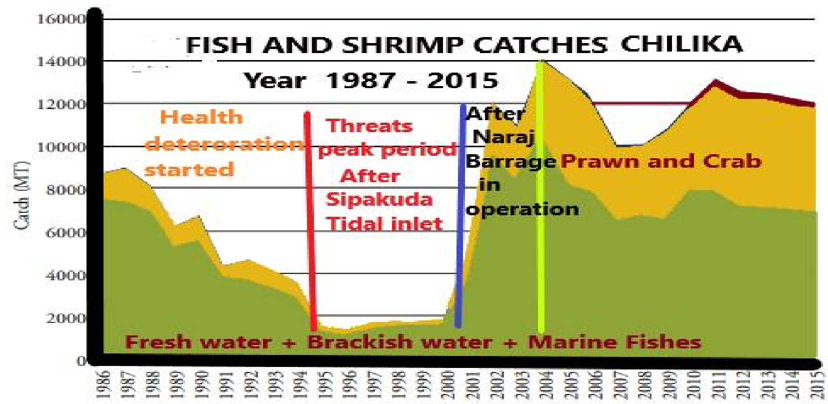

Fig. 4. The past aqua catch statistics of pre and post interventions of the Chilika lagoon

4. SOFT COMPUTING MODELS

Both stochastic and soft computing models like SPSS, ARIMA, (MLP) Multilayer perception (as ANN model), SMOreg (SVM Model), Second Generation of Particle Swarm Optimization (SGPSO), Random Forest model, the Multiple linear regression (MLR), and PSO algorithm etc. can be applied for predicting the future aqua catch, Tan, et al. [32], Zhang, G. [33], Upom, et al. [34]. The stochastic model of the fish catch of Chilika lagoon has already been done by SARIMAX model with < 10% errors and predicted rise in fish catch in the forthcoming years under the present lagoon status Raman, et al. [35].

4.1 Weka-dev 3.9.5 Software

Weka-dev 3.9.5 is ANN cognitive software that is used to handle a small time series on which many ML algorithms can be applied. The software comprises of plethora of built-in tools that executes the standard calculation of machine learning. It is an artificial intelligent machine learning paradigm that uses cutting-edge technologies but has the drawbacks of less flexibility and cannot clean the data series https://www.cs.waikato.ac.nz/ml/weka/. The different models used in the study are Prediction Performance of ML models on training data.

4.1.1 Linear regression ML model

Linear regression model in ML is to find predictive results taking the input attributes as input parameters. In this case data is linear and the label is linear. The parameters are p0, p1, p2, pn. The model with low error is

$$F(x) = p0 + p1 * x1 + p2 * x2 + + pn * xn = y* \quad (1)$$

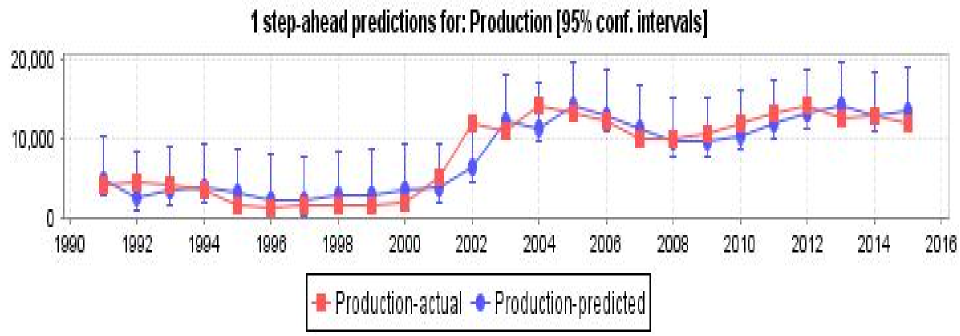

Fig. 5. One step ahead prediction for aquatic catch of Chilika using linear regression (ML) model

Weka software supports multiple linear regressions, where the error is minimized by the vertical least squares distance to a multidimensional line Wikström et al. [36], Grepcode.com, [37], Mokhort et al. [38]. From the operation of Naraj barrage it is found that there was hydraulic regime in the water body and the actual and the predicted catch have matched (Fig. 4).

4.1.2 Multilayer perception (MLP) model

The simple multilayer perception (ANN) model applied to analyse the biological neural networks which comprises of multiple nodes (sigmoid function) inter connected by weights that is resulted in weighted sum of the several inputs and controls if it is yes or no. The learning stage tries to estimate the weights amidst the layers applying a gradient descent algorithm called back propagation which calculate the MSE (mean squared error) at the conclusive MLP layer. The Neural network is a computerised computational network introduced by (McCulloch et. al. [39], Liu X. [40]) with highly interconnected nodes and neurons used to solve or predict a multi variable problem (Cook *et. al.,* [41]). The single step-ahead prediction for fish catch of the Chilika lagoon with 95% confidence interval for the 1985-1986 to 2015-2016 is in (Fig. 5).

4.1.3 Random forest (RF) model

Random Forest is a supervised machine learning algorithm technique, which is based upon huge set of decision trees developed for prediction. by Breiman L. [42], Vincenzi. et al. [43]. It is popular, versatile, dependable, simple ML algorithm that gives predictions, without hyper-parameter tuning. The algorithm can be widely used for diversity as used for dual purposes for classification and regression tasks trained with the bagging method (Benito, et al. [44], Pelletier et al. [45]). The RF is a classifier that contains a series of decision trees on various subsets of the given dataset and averaged to improve the predictive accuracy of that dataset.

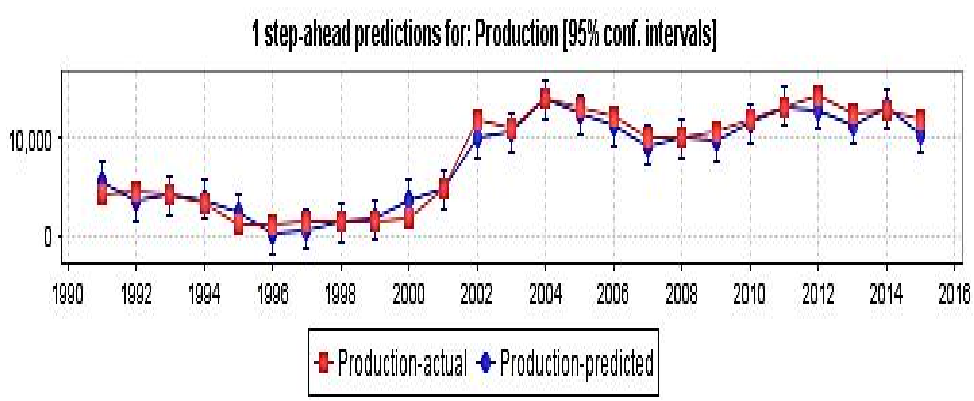

Fig. 6. One step ahead prediction for aquatic catch of Chilika (MLP (ANN) model; 95% confidence)

It takes less training time as compared to other algorithms. It predicts output with high accuracy, even for the large dataset it runs efficiently. It can also maintain accuracy when a large proportion of data is missing (Lim et al. [46], Kokala, et al. [47], Walkar [48]). The prediction is given (Fig. 6).

4.1.4 SMOreg (SVM Model)

SVM is a supervised learning model developed by Cortes & Vapnik, et al. [49]). The model has been intensively used in many data mining problems for both classification and regression purposes. In an SVM algorithm, the training set is first mapped to an n-dimensional feature space by using a nonlinear kernel mapping procedure. Then a hyperplane, a subspace that is one dimension less than its surrounding space, will be identified in this feature space according to the projected dataset. The aim is to find the optimal hyperplane that separates the data points in the classes, while simultaneously maximizing the margin (i.e., the distance between the hyperplane and the closest points of the training set) for linearly separable patterns (Leskovec, et al. [50], Corcoran, [51]) (Fig 7).

The root mean square error (RMSE) values in case of SOMorg, (SVM) model found to be so high in comparison to other three predictive models that the results are not considered for study. Prediction Performance of ML models on training data shows that MLP and Random forest perform better than other two. Further Random Forest performs slightly better than the MLP which is evident from the Root Mean Square Error.

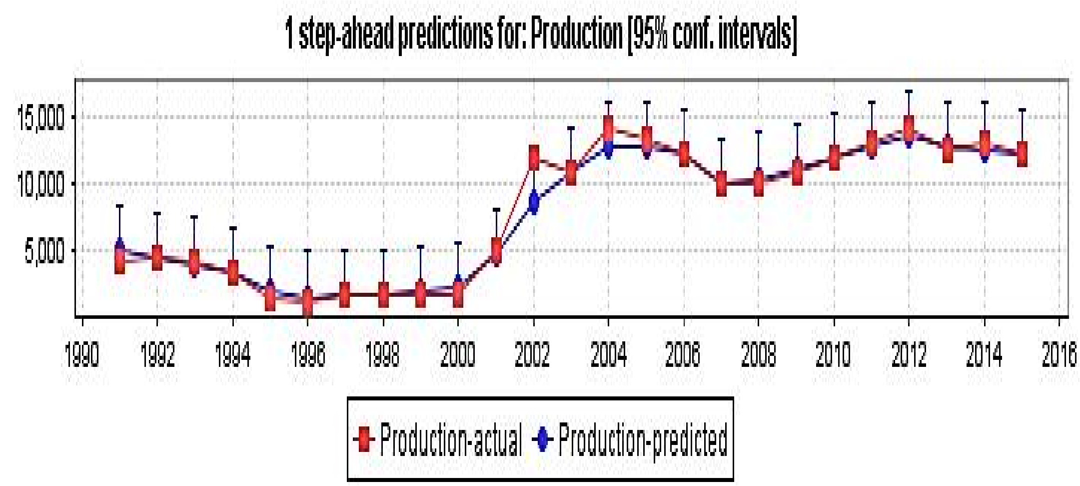

Fig. 7. One step ahead prediction for aqua catch of Chilika using random forest model

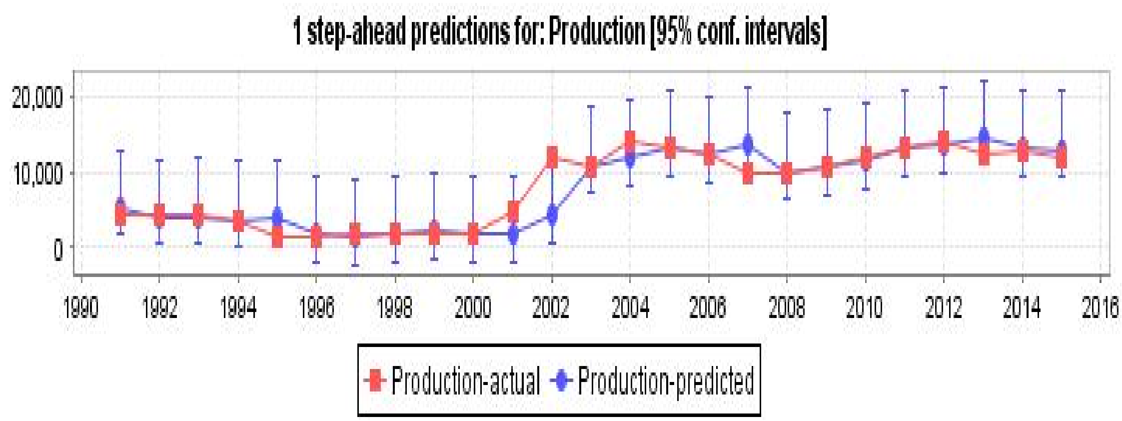

Fig. 8. One step ahead prediction for aqua catch of Chilika using SMOorg (SVM) model

Table 1. The comparison of predicted aquatic catch of the lagoon using MLP (ANN), Linear regression (ML) and random forest algorithms

Year	Predicted aquatic catch MLP model (MT)	Predicted aquatic catch Linear regression model (MT)	Predicted aquatic catch Random forest model MT)	Decision built
2016	11391.73	10212.99	12078.5437	Random Forest
2017	12276.7	9916.255	12243.9412	chosen best
2018	14207.74	16453.5	12313.2662	predictive model
2019	12339.24	19485.59	12258.3037	followed by MLP
2020	12949.84	18900.28	12190.5137	model to forecast
2021	15036.12	13849.23	12167.2453	the fish catch of
2022	13532.05	9670.191	12272.1128	the lagoon
2023	12518.53	8492.481	12272.1128	keeping all
2024	14897.42	15530.59	12208.4853	parameters as
2025	15009.06	23147.73	12208.4853	constant

Table 2. The predicted fish + prawn + Crab (aquatic) production from the Chilika (2021-2030)

Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Aquatic catch(MT)	12167	12272	12272	12208	12208	12195	12225	12238	12267	12278

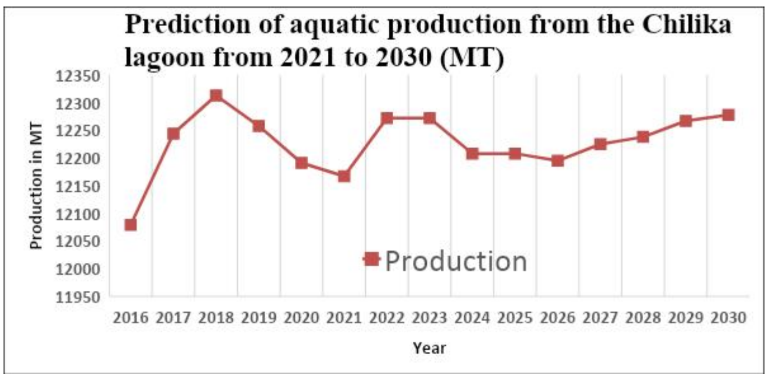

Fig. 9. Prediction of Aqua catch of the Chilika Lagoon by Random Forest algorithm (2016-2030)

MLP: 934.9175 1209.4175 1461.8675 1156.0992 1352.4619 1384.5489
1242.5633 1322.6324 1771.3151 2168.075

SMOreg: 2011.6183 2950.1225 4014.8131 4855.6262 5516.8297 6037.8095 6613.4223 7279.0931 8311.401 9178.8004

Random Forest: 776.037 837.4872 1032.2467 1117.6464 1180.6869 1250.2935 1348.8529 1394.8808 1446.3104 1478.0027

Linear Regression: 1698.1525 2303.1029 2744.4661 2876.3493 2889.1953 2849.3329 2881.1405 3019.0583 3150.163 3130.3938

4.2 The Comparative Results

Ultimately we choose Random Forecast as our ML model to forecast the fish catch quantity in the Chilika and the predictions purposes out of the four types of predictive models.

We further applied Random Forest model to predict the fish production beyond 2025 up to 2030 as shown in Fig. 8 and Table 2.

Along with the major inland flow through the river Mahanadi along with the western inflowing drains, the salinity mix, the presence of phytoplankton's control the fish catch. The predicted aquatic catch (Fish + prawn + crabs) by Random forest model from 12167MT to 12278MTwhich is almost constant (Fig. 8). The constant aquatic catch cannot sustain the livelihood of its fishermen community in and around the Chilika Lagoon. It is high time for the lagoon mangers to have a long term plan and strategies so that the fisher's community should not opt for an alternate occupation or migration.

5. DISCUSSION

The productive use of the lagoon is based on the productivity aqua catch (Fish + Shell fish) and the eco-health that provide major livelihood of about 0.2million fisher folk, the major stake holders. The annual quantity of fish catch varies directly on the inland inflow, tidal regime, salinity, mixing, water pollution, weed infestation and the catching practices. About 13.75% fishing zone has been encroached enclosures '(Gherries), reduction in flushing flow frequencies by diverting inland flow and changing the hydrologic regimes (Gobkund cut), over exploited aqua catch with inappropriate fishing gears, more motorized boats for ecotourism; restricting fish migration; and finally ambient water quality deterioration need to be attended.

Knowledge of ambient living requirements like seasonality, salinity gradient, water exchange, phytoplankton expanse and anthropogenic activities is needed along with forecasting play important role in fisheries and fish management as they institute the various steps to build strategic decision, (Stergiou, et al. [52] and Hue, et al. [53]). A major portion of the lagoon is encroached by human habitation, tourism, prawn farms (≈ more than 15%). The anthropogenic activities are polluting the lagoon, changing the transportation time scale and Peclet number hence challenging lagoon sustenance.

5.1 Impact of Major Interventions

The Hydraulic interventions dams, cuts and barrages like Hirakud, Naraj Barrage, Gabakund has with anthropologic activities within the lagoon like gherries have changed the hydrologic regime obstructing free flow. From 1985-86 to 2018-19 the Aqua catch statistics of the Chilika reveals that the average annual production is 9155.38MT constituting of 67.28% fish species, 35.15% of different prawn categories, and 1.6% are the different crabs. There were two major interventions were made in the hydraulic system i.e. the dredged mouth at Sipakuda (1st mediation during Sep.2000) and operation of Naraj Barrage for changing flow strategy (2nd interference from 2004). Indivisually the average fish, prawn and crab catches from the Chilika is given in Table 2.

The abrupt increase in prawn catch (prawn gherries) was mostly due to substitution of aquaculture in place of traditional fishery in the lagoon. The annual average fish catch has surged up after post intervention are due to higher salinity gradient and better mixing as Sipakuda inlet allowed direct entry of BoB saline water through the most shortcut route. The effect of the barrage had reduced the sediment entry and the gradually reduced the aquatic weeds, increased the primary nutrients.

Many marine seasonal species reproduce within the sea but rove to the outer channel and central sector of the Chilika for trophic motives and ocean living juveniles species migrate to use the lagoons as their nursery zones. Adventitious marine species enter lagoons are generally dwell near the outer channel, while freshwater fishes remain in the northern sector and river entries.

In the framework of management of Chilika lagoon conversion to freshwater lakes and interfaces between development of aquaculture firms and fisheries in open territories mainly in outer channel and Palur canal have raised conflicts of interest between the fisher folk and the prawn gherries owners over the past three decades. The crucial issues need to be sorted out by invoking sustainable management in the Chilika by instillation of proper interactions between aquaculture inside lagoon's coastal zone management to have enhanced public image of prawn culture.

Table 3. The effect on aqua-catch statistics are summarized between fish, prawn and crab catch

The Hydraulic intervention	Average Fish catch (MT)	Average Prawn catch (MT)	Average crab catch (MT)	Total Average aqua catch (MT)
Pre-mediation period (1985 - 2000)	3615.179	704.2638	29.66938	4349.113
Sipakuda tidal inlet (2000-2004)	9360.51	2812.657	138.7967	12311.96
Sipakuda TI + Naraj Barrage (2005-2015)	8234	5151	266	13651
Total average	6159.78	2852.041	143.5947	9155.3806

1. Degradation of fish catch during 1990's were ascribed were Sedimentation, closing of tidal inlet, encroachment of spawning and trophic grounds within the lagoon by aquaculture gherries, use of destructive fishing gears/practices, unabated and illegal aquaculture culture area encroachments etc.

2. The conversion of swamps in the NW Chilika peripheries to agricultural field (result of Gabakund cut) has helped to reduce in supplying the quantum of inland flushing flow to the lagoon Mishraetal,[54].

3. Particularly culturing of exotic fishes like Clarias gariepinus, Tilapia, Litopenaeus vennamei, etc. has escaped into the lake during flood/ storm incidents, (recorded during Phailin slam) and invading the fishing kingdom Mohanty S. K. [55], Raman et al. [56].

4. The isles in the outer channel act as conduits and conducing vent for the invasive allied species expand and are threat to the coastal ecosystems Ning Z, et al. [57]. The Phragmites Karaka in NW segment of the lagoon is the common IAS that has spread 73km^2 in 2000 to 286Km^2 in 2020 and encroachment in the old fishing zone.

5. Over exploitation of fish stocks due to ever increasing fishing gears/effort, practices and increasing number of fishing boats and gear. Rampant use of zero mesh as fishing nets are causing wanton killing of larvae, infant and juvenile fish species which are economically and ecologically important and finally the biodiversity of the lagoon.

6. The crab fishing nets like mono-filament screen barrier trap and triangular push net are to be allowed only so that the catch of juvenile fishes, prawns and crabs shall preponderate, fishery resources can be conserved in the Chilika. The zero nets need to be banned (Raman, et al. [35]).

7. Marine Fishes of the lagoon extensively depends on species those migrate to the lagoon through the sea mouth. Wide use of seine nets or Khanda (barrier nets), Alimi jaal, bag nets of varying mesh captures all fishes irrespective of size and groups including larvae, juveniles and egg bearing adults spoiling fish recruitment.

8. Parasitic infections of fishes (Fin fishes) are the one of the threats fishes in Chilika which need to be attended.

9. In the local basin of the lagoon, towns such as Cuttack, Bhubaneswar, Balugaon discharge their liquid waste through the rivers like the Kathajodi, the Kuakhai, the Daya, the Bhargovi and the Salia and other 47 rivulets/ drainage channels. These effluents along with plastics, agricultural pesticides, and spill oil from the mechanized boats added to the lagoon water pollute and deteriorate the water quality of the lagoon.

10. Historical and cartographic research reveals that the historical sea mouth has been fluctuating between Manika Patna and Arakhakuda since the early part of the seventeenth century. The dredging of a direct cut reducing OC length by about 17km has immediate fish recruitment in the year 2001 to 2004. Later there was reduction in fish catch by about 2-3 thousand MT was due to movement of the TI to north Mishra S. P, et al. [58], Parida et al. [59].

Conclusively management action plan and SOP needs to be chalked out about fishing gears, gherries bundh's around islands, prawn-culture enclosures, restricting the numbers of mechanized boats, restricting seasonally fish catch, banning movement in hatching, breeding and landing areas, building awareness for fishing practices and obstruction of migratory routes of economic species

5.2 Strategy Building

The fish resources in the Chilika are in limbo as no long term plan to save them from over exploited capture. Shrimp aqua culture started from 1980, has created commotion to the traditional practices of fishing. Overriding the fishermen, the non-fisher's communities are opting prawn farming as profitable though risks involved in the farming. This practice hinders the ecological health of the lagoon.

The lake fishers group is considered socially inferior and outcaste. Oustees from neighbor states have migrating for their livelihood. New settlements have developed in the outskirt of the Chilika lagoon. After a long stay they are in practice of making prawn aqua culture farms, and cultivating paddy (high and early yielding Rabi variety) by making earthen bundhs. The application of huge amount of fertilizer and pesticides during non-monsoon period pollutes the nearby drains and induces eutrophication in the lagoon Mohanty, et al. [55].

Table 4. The prediction of future changes in fish catch in Chilika lagoon by different authors

Type of fish in Chilika	Base years	% of Change in future	Model used	
Beloniformes	2015-16	10%	univariate SARIMA	Raman & Saho, et. al. [56]
Fishes/ shrimps	2015-16	increase	SARIMA (0,1,1)(0,1,1)4	Raman & Das, et al. [2]
Fishes/ shrimps	2015-16	increase	SARIMA (0,1,1)(0,1,1)4	Raman, et al. [22]
Aqua catch (present study)	2015-16	Predicted 12 to 13TMT	Random Forest algorithm	Mishra and Ojha 2021

The periphery and the 223Km^2 islands of the lagoon is accommodating about 12,500 fishermen families with population of ≈200000 with per capita income of ≈1200 to 1500 INR. More than 5600boats ply for tourism activities or for fishing ply within the lagoon. The free boat plying should be restricted and fixed routes are to be designed for navigation. The prediction of future changes in future is given in Table 3.

In 17th century the fishing in Chilika was caste and group based, resource partitioned, community governed at some specific places only which was administered considering healthy wetland ecology. Fishing gears like gill net (40%) followed by khonda (set net) (39.5%) which was not under practice in past 50 to 60 years back. Drag net (4%), scoop net (3.8%), sieve net (3.5%) and cast net (3%) is less in practice. Bahani, Jano, Dian or Uthapani has become obsolete https://india climate dialogue.net/2018/02/02/chilika-scripts-success-story-fishers-face-challenges/ and Parida S, et al. [59].

So a policy framework is necessary to be implements to regulate the fishing net mesh size, tourists visit areas, constant boat plying rout, the area of fishing activities to be legalized to improve the aqua catch resources in the lagoon Chilika. Banning illegal encroachments and destroying existing prawn gherries and altering catch practices, seasonal prohibition of fishing in the OC and central sector during pre and post monsoon period should be given prime importance to save the fish landing including.

Construction of cemented jetties, fish drying platforms, reduction in middleman/broker activities, sustainable alternate livelihood and incentives, easy loan from banks, welfare oriented NGO/schemes; public awareness about safe fishing practices should be encouraged among the fishermen.

6. CONCLUSION

After hydraulic interventions for adequate inland flushing flow, sustained salinity gradient and influx of aqua fauna through TI's after 2000 the aquatic catch of the lagoon has been surged up, indicating the role of salinity, aquatic weeds and sediment plays pivotal role in maintaining sustainable ecological integrity in the Chilika lagoon.

Computerized stochastic models are used for fish and shrimp catch of the lagoon but the predicting soft computing models like Linear regression, MLP (ANN), SMOorg (SVM) and Random Forest algorithms for the first time to visualize the impact of the fish catch on the fisher's community and instigating lagoon managers to impart adequate measures for forecasted upcoming period 2020 to 2025 which fluctuate between 12.00 to 12.50MMT.

An incessant monitoring of the Chilika has become ubiquitous to accomplish the rich and sustained dynamic aqua catch status to maintain the ecological integrity. The predictive model results shall alert the lagoon managers and the policy makers to efficiently frame the adequate barrage operation rule, fishing operation and management policies and strategy building for the lagoon beneficiaries. With rising fisher's population and escalating human interventions, this is the proper time for the lagoon planners to plan for other occupations along with strategies planning for the present indigenous community from drowning economy.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. International Institute for Population Sciences (IIPS) and ICF. National Family Health Survey (NFHS-4), 2015-16: India. Mumbai: IIPS; 2017.
2. Raman RK, Das BK. Forecasting shrimp and fish catch in Chilika lake over time series analysis. Open Assess Journal, 27th; 2019.
DOI: 10.5772/intechopen.85458
3. Mishra SP. Rejuvenation of lagoons along the east coast of India, management: Anthropocene approach, Int. Jr. of advanced Research; 2019;7(1):688-714.
DOI:http://dx.
doi.org/10.21474/IJAR01/8378
4. Plavan AA, Passadore C, Gimenez L. Fish assemblage in a temperate estuary on the Uruguayan coast seasonal variation and environmental influence. Braz. J. Ocean. 2010;58(4):299-314.
DOI:org/10.1590/S1679-8759
2010000400005
5. Bruno DO, Barbini SA, Astarloa JMDD, Martos P. Fish abundance and distribution patterns related to environmental factors in a choked temperate coastallagoon (Argentina). Braz. J. Oceanogr. 2013;61: 43-53.
DOI: 10.1590,S1679-87592013000100005
6. Mishra SP, Mishra S. Monitoring anthropocene epoch in the Mahanadi basin and Chilika Lagoon, India. International Journal of Advance Research. 2017;5(9):284-302.
DOI: 10.21474/IJAR01/5329
7. Mishra SP, Ojha AC. Fani, an outlier among pre-monsoon intra-seasonal cyclones over bay of Bengal. International Journal on Emerging Technologies. 2020;11(2):271-282.
ISSN No. (Online): 2249-3255.
8. Pattanaik S. Conservation of environment and protection of marginalized fishing communities of lake Chilika in Orissa, India. J. Hum. Ecol., 00(0): 000-000 (0000), JHE 1507, © Kamla-Raj 0000; 2001.
9. Jhingran VG, Natarajan AV. Final report on the fisheries of the Chilka Lake, 1957-65: CIFRJ, Bull. 1966;8.
10. Jhingran VG, Natarajan AV. A study of the fisheries and fish populations of the Chilka Lake during the period 1957-65. J Inland Fish.Soc. India. 1970;1:49-126.
11. Siddiqui SZ, Rama Rao KV. Limnology, Ibid. 1995;11-36.
12. Pattanaik S. Conservation of environment and protection of marginalized fishing communities of Lake Chilika in Orissa, India. J. Hum. Ecol., 00(0): 000-000 (0000), JHE 1507, © Kamla-Raj 0000; 2001.
13. Pattanaik AK, Pattanaik SN. Survey and characterization of phyto-diversity of Chilika Lake. Thesis Utkal University, Sodhaganga; 2003.
Avialable:http://hdl.handle.net/10603/1295
64
14. Kadekodi G, Nayampalli A. Prospects of reversing biodiversity losses in Lake Chilika in India, P acific and Asian Journal of Energy. 2003;13(1):37-60.
15. Mohapatra A, Mohanty S, Mishra SS. Fish and shellfish fauna of Chilika Lagoon: An updated checklist. In book: Marine Faunal Diversity in India: Taxonomy, Ecology & Conservation Edition: FirstChapter: 13Publisher: ElsevierEditors: K. Venkataraman, C. Sivaperuman; 2015.
DOI: 10.1016/B978-0-12-801948-1.00013-6
16. Suresh VR, Mohanty SK, Manna RK, Bhatta KS, Mukherjee MS, Karna K, et al. Fish and shellfish diversity and its sustainable management in Chilika Lake, ICAR- CIFRI, Barrackpore, Kolkata, and CDA, Bhubaneswar. 2018;376.
17. Vance DJ, Staples DJ. Catchability and sampling of three species of juvenile penaeid prawns in the Embley River, Gulf of Carpentaria, Australia. Marine Ecology-Progress Series. 1992;87:201-201.
18. Takemura A, Rahman Md S, Nakamura S, Takano K, et al. Lunar cycles and reproductive activity in reef fishes with particular attention to rabbitfishes. Fish and Fisheries 2004;5(4):317-328.
19. Park Y, Takemura A, Lee Y. Lunar-synchronized reproductive activity in the pencil-streaked rabbitfish *Siganus doliatus* in the Chuuk Lagoon, Micronesia. Ichthyol Res. 2006;53:179–181.
Available:https://doi.org/10.1007/s10228-005-0322-2

20. Pulver JR. Does the lunar cycle affect reef fish catch rates? North American Journal of Fisheries Management. 2017;37:536-549.
Available:https://doi.org/10.1080/02755947.2017.1293574
21. Raman RK, Suresh VR, Mohanty SK, Bhatta KS, Karna SK, et al. Influence of seasonality, salinity and temperature on catch trend of Penaeus indicus H. Milne-Edwards, 1837 in a coastal lagoon, India, Indian J. Fish. 2019;66(1):34-42.
DOI: 10.21077/ijf.2019.66.1.76413-05
22. Iglesias A, Arcay B, Cotos JM, Taboada JA, Dafonte C. A comparison between functional networks and artificial neural networks for the prediction of fishing catches. Neural Computing and Applications. 2004;13(1):24-31.
ISSN: 0941-0643.
23. Olden JD, Joy MK, Death RG. Rediscovering the species in community-wide predictive modeling. Ecological Applications. 2006;16,(4):1449-1460.
ISSN: 1051-0761.
24. Quetglas A, Ordines F, Guijarro B. The use of artificial neural networks (ANNs) in aquatic ecology application. In book: Artificial Neural Networks. 2011;567-586.
DOI: 10.5772/16092; InTech
25. Wen L, Liu C, Song H. Forecasting tourism demand using search query data: A hybrid modeling approach. Tourism Economics. 2019;25(3):309-329.
DOI: 10.1177/1354816618768317
26. Nayak PK. The Chilika lagoon social-ecological system: An historical analysis. Ecology and Society. 2014;19(1):1.
Available:http://dx.doi.org/10.5751/ES-05978-190101
27. Mohapatra A, Mohanty RK, Mohanty SK, Bhatt S, Das NR. Fisheries enhancement and biodiversity assessment of fish, prawn and mud crab in Chilika lagoon through hydrological intervention, Wetlands Ecol Manage, Springer. 2007;15: 229–251.
DOI: 10.1007/s11273-006-9025-3
28. Kumar A, Equeenuddin SM, Mishra DR, Acharya BC. Remote monitoring of sediment dynamics in a coastal lagoon: long-term spatio-temporal variability of suspended sediment in Chilika. Estuar Coast Shelf Sci. 2016;170:155–172.
Available:https://doi.org/10.1016/j.ecss.2016.01.018
29. Sahu BK, Pati P, Panigrahy RC. Environmental conditions of Chilika Lake during pre and post hydrological intervention: An overview. J Coast Conserv. 2014;18:285–297.
Available:https://doi.org/10.1007/s11852-014-0318-z
30. Mishra SP, Jena JG. Geo-climatic abstractions of South Mahanadi Delta and Chilika Lagoon, India: Post anthropogenic interventions. World Applied Sciences Journal, WASJ. 2015;33(2):326-335.
31. Suresh VR, Mohanty SK, Manna RK, Bhatta KS, Mukherjee M, et al. Fish and shellfish diversity and its sustainable management in Chilika lake, ICAR- Central Inland Fisheries Research Institute, Barrackpore, Kolkata and Chilika Development Authority, Bhubaneswar. 2018;376.
32. Tan CO, Beklioglu M. Modeling complex nonlinear responses of shallow lakes to fish and hydrology using artificial neural networks. Ecological Modelling. 2006; 196(1):183-194.
DOI: 10.1016/j.ecolmodel.2006.02.003
33. Zhang J, Gao Q, Zheng C. Retention index system transformation method incorporated optimal molecular descriptors through particle swarm optimization. In: Huang DS., Ma J., Jo KH., Gromiha M.M. (eds) Intelligent Computing Theories and Applications. ICIC 2012. Lecture Notes in Computer Science, Springer, Berlin, Heidelberg. 2012;7390.
Available:https://doi.org/10.1007/978-3-642-31576-3_47
34. Upom MRA, Alel MNA, Kadir A, Ab M, Yuzir A. Prediction of shear wave velocity in underground layers using Particle Swarm Optimization, IOP Conf. Ser.: Mater. Sci. Eng. 2019;527:012012.
35. Raman RK, Mohanty SK, Bhatta KS, et al. Time series forecasting model for fisheries in Chilika lagoon (a Ramsar site, 1981), Odisha, India: A case study. Wetlands Ecol Manage. 2018;26:677–687.
Available:https://doi.org/10.1007/s11273-018-9600-4
36. Wikström J, Maki A. Evaluating supervised machine learning algorithms to predict recreational fishing success. KTH Royal institute of technology, school of computer science and communication (CSC). 2015;1-41.
37. Grepcode.com. ’GC: Linearregression - Weka. Classifiers functions

linearregression (.Java) - Grepcode Class Source'. N.p. 2015. Web; 2015.
38. Mokhort H. Multiple linear regression model of meningococcal disease in Ukraine: 1992–2015. Computational and Mathematical Methods in Medicine. 2020;7. Available:https://doi.org/10.1155/2020/5105120
39. McCulloch WS, Pitts WH. 1943, 'A Logical Calculus of the Ideas Immanent in Nervous Activity', Bulletin of Mathematical Biophysics 7, 115–133. Reprinted in McCulloch. 1964;16–39.
40. Liu X. Special topics on linear mixed models, Methods and Applications of Longitudinal Data Analysis, Chapter 7. Academic Press. 2016;205-242. Available:https://doi.org/10. 1016/B978-0-12-801342-7.00007-1
41. Cook DF, Shannon RE. A sensitivity analysis of a back-propagation neural network for manufacturing process parameters. J Intell Manuf. 1991;2:155–163. Available:https:// doi.org/10.1007/BF01471362
42. Breiman L. Random forests. Machine Learning. 2001;45:5–32.
43. Vincenzi S, Zucchetta M, Franzoi P, Pellizzato M, Pranovi F, et al. Application of a random forest algorithm to predict spatial distribution of the potential yield of ruditapes Philippinarum in the Venice lagoon, Italy. Elsevier, Ecological Modelling. 2011;222(8):1471-1478. Available:https://doi.org/10.1016/j.ecolmodel.2011.02.007
44. Benito GM, Sánchez De Dios R, Sainz Ollero H. Predictive modelling of tree species distributions on the Iberian Peninsula during the Last Glacial Maximum and Mid-Holocene. Ecography. 2007;30:120–134.
45. Pelletier D, Folcher NS, Bockel T, Schohn T. A regionally scalable habitat typology for assessing benthic habitats and fish communities: Application to New Caledonia reefs and lagoons, Ecology and Evolution; Wielly. 2020;7021-7050. DOI: 10.1002/ece3.6405
46. Lim TS, Loh WY, Shih YS. A Comparison of prediction accuracy, complexity, and training time of thirty-three old and new classification algorithms. Machine Learning. 2000;40:203–228. Available:https://doi.org/10.1023/A:1007608224229
47. Kokla M, Virtanen J, Kolehmainen M, et al. Random forest-based imputation outperforms other methods for imputing LC-MS metabolomics data: a comparative study. BMC Bioinformatics. 2019;20:492. Available:https://doi.org/10.1186/s12859-019-3110-0
48. Walker S, Khan W, Katic K, Maassen W, Zeiler W. Accuracy of different machine learning algorithms and added-value of predicting aggregated-level energy performance of commercial buildings, Energy and Building. 2020;209:109705. Available:https://doi. org/10.1016 /j.enbuild.2019.109705
49. Cortes C, Vapnik V. Support-vector networks. Mach Learn. 1995;20:273–297. Available:https://doi.org/10.1007/BF00994018
50. Leskovec J, Rajaraman A, Ullman JD. Mining of massive datasets, Cambridge University Press, U.K; 2014. Available:http://proquest.safaribooksonline.com/9781316147047
51. Corcoran P. An end-to-end graph convolutional kernel support vector machine. Appl Netw Sci. 2020;5:39. Available:https://doi.org/10.1007/s41109-020-00282-2
52. Stergiou KI, Christou ED, Petrakis G. Modelling and forecasting monthly fisheries catches: Comparison of regression, univariate and multivariate time series methods. Fisheries Research. 1997;29(1):55-95. DOI: 10.1016/S0165-7836(96)00482-1
53. Hue HTT, Pradit S, Lim A, Goncalo C, Nitiratsuwan T. Shrimp and fish catch landing trends in Songkhla Lagoon, Thailand during 2003-2016. Applied ecol. and envir. Research. 2016;16(3):3061-3078. DOI:http://dx.doi.org/10.15666/aeer/1603_30613078
54. Mishra SP, Dash J. Hydro–morphology of cuts in coastal rivers debouching Chilika; South Mahanadi Delta, Odisha, India, International Journal of Advance Research. 2016;4(5):391-404.
55. Mohanty SK, Bhatta KS, Mohanty RK, Mishra S, Mohapatra A, Pattnaik AK. Eco-restoration impact on fishery biodiversity and population structure in Chilika Lake. In: Mohanty P.K. (eds) Monitoring and

Modelling Lakes and Coastal Environments. Springer, Dordrecht; 2008.
Available:https://doi.org/10.1007/978-1-4020-6646-7_1
56. Raman RK, Sahoo AK, Mohanty SK, Das BK. Forecasting of commercial fish (beloniformes : order) catch in chilika lagoon, Odisha, India. Inland Fish. Soc. India. 2017;49(1):55-63.
57. Ning Z, Chen C, Zhu Z, Xie T, Wang Q, Cui B, Bouma TJ. Tidal channel-mediated gradients facilitate *Spartina alterniflora* invasion in coastal ecosystems: implications for invasive species management. Mar Ecol Prog Ser. 2021; 659:59-73.
Available:https://doi.org/10.3354/meps13560
58. Mishra Siba Prasad, Mishra Sujit Kumar, Das Kalptaru. Geo dynamics, salinity gradient, and vegetation interdependence in Chilika Lagoon, a tropical wetland in Eastern India. Journal of Wetlands Environmental Management. 2019;7(1):1–22.
Available:http://dx.doi.org/10.20527/jwem.v7i1.18
59. Parida S, Parida P, Bhatta K, Karna SK. Paradigm shift in fishing technology of Chilika: The largest brackish water Wetland of Asia. Proceedings of the Zoological Society. 2020;72(1–2).
DOI: 10.1007/s12595-018-0267-x

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