Ensemble Tree Classifier based Analysis of Water Quality for Layer Poultry Farm: A Study on Cauvery River

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***Abstract*—Indian poultry industry has evolved from a simple backyard occupation to a large commercial agri-based enterprise. Chicken dominates poultry production in India, accounting for almost 95% of total egg production. Several factors affect the egg production such as feeding material, drinking water, environmental factors etc. Analyzing the water quality is one of the important tasks. Cauvery River is considered as the study area because of its importance in several states of South India which have significant contribution in poultry farming. The aim of the proposed study is to develop an automated approach of water quality analysis and present a novel machine learning approach which considers an improved feature ranking method and ensemble tree classifier with majority voting. The experimental result shows that proposed approach performs better with an accuracy of 95.12%.**

Keywords*—*Water quality; poultry; machine learning; Cauvery river; feature ranking; ensemble tree classifier; accuracy

I. Introduction

Agriculture and farming has become the most important source of income and it plays an important role in Indian economy. The livestock with poultry farming is one of the major parts of Indian agricultural population and considered as backbone of the Indian Farmers. According to a study presented by *Statista*, the demand of chicken meat and eggs has increased drastically worldwide [1].

Animal husbandry plays a major role in Indian economy under which taming birds such as chicken ducks, turkeys for production of various goods such as egg, meat, feathers, is called poultry farming. It has evolved from a backyard hobby to a full-fledged technological-commercial industry [2]. Chicken farming is prevalent in places like as Andhra Pradesh, Tamil Nadu, West Bengal, Maharashtra, Orissa, Bihar, Kerala, and Karnataka, among others [3].

The recent 20th Livestock Census has reported that total numbers of 851.8 million poultry birds are present in India and 30% (250 million) of this population is covered by backyard, small or marginal farmers [4].

Below given Table I present the data of 20th Livestock census which shows the livestock population and egg production in South India [4].

There is a significant variation in poultry industry in different regions of India. The South Indian states like – Karnataka, Tamil Nadu, Kerala and Andhra Pradesh produce for about 45 percent of the country's egg production, with a per capita consumption of 57 eggs and 0.5 kg of broiler meat [5].

Based on the above facts and data, we can say that the poultry is considered as the expediting segment of the agricultural sector. Moreover, current technological advancements, up gradations have paved the way for multi-fold growth in the poultry and its allied sectors. This growth has led to high yielding layers, broilers, with the help of appropriate nutrition, and management, the egg and meat production also have grown during last decades.

On the other hand, poultry industry suffers from various challenges which degrade the production of eggs. Some of the challenges are feeding material, raw materials, disease outbreak, water quality, and temperature etc. Water plays an important role in this context of poultry rearing and management. For chickens, water is one of the most vital nutrients for the following reasons:

- To maintain maximum egg production and egg shell quality, and to achieve good body weight and growth, good quality of water is needed.
- To properly manage bodily functions water is essential.

Some of the water related factors which affect the performance of poultry are as follows:

- Water source: The water source is an important parameter to be considered because the acidity or alkalinity of water depends on the depth of well from where water is extracted. Water found at 30-meter depth is generally acidic in nature whereas water level of more than 100 meters is more alkaline nature [6].

TABLE I. Livestock Population EGG Production in India [4]

State	Livestock population (million)	Year (2019-2020)
Karnataka	59m	66511 lakh
Tamil Nadu	120m	200216 lakh
Kerala	29m	21845 lakh

Consumption of acidic water is prone to parasitic infestation whereas consumption of alkaline water leads to deficiency of required minerals such as calcium, phosphorus, magnesium and potassium.

- Watering system: The water consumption through the trough based system is greater when compared with the nipple system. Layers which are using the nipple drinker system have reflected in feed conversion, less mortality when compared with channel based watering systems. Table II shows the comparison of nipple and trough watering system. Moreover, the nipple based drinker system are enclosed and more sanitary can be ensured by disinfecting and cleaning the system which prevents the disease problems [7].

TABLE II. COMPARATIVE PERFORMANCE OF BROILER REARED ON NIPPLE OR TROUGH WATERING SYSTEM [7]

	Trough	**Nipple**
Water consumption	166	245
Food conversion	1.91	1.92
Bodyweight (kg)	1.95	1.96
Mortality in first 14 days (%)	1.20	1.30
Condemnations (%)	1.17	1.40

- Water temperature: For four weeks, researchers tested the effects of cold water (8°C) and regular water (29.5°C) on the production characteristics of chickens. The effects of heat stress were eased by using cold water, and the birds were able to acquire more weight and had improved feed efficiency as a result. When given cold water, birds were more sensitive to vitamin C supplementation (500mg/liter of water), resulting in enhanced survival and carcass quality, with a focus on breast meat output [8].

When exposed to different environmental temperatures the consumption of water and feed intake varies as shown in the following Table III.

TABLE III. CONSUMPTION OF WATER AND FEED INTAKE AT DIFFERENT TEMPERATURES [9]

Characteristics	**Temperature**		
	18°C	29°C	35°C
Age (days)	245	200	180
Feed (lbs/hen/day) (g)	0.23	0.19	0.14
Water(gal/100hens/day)	5.5	5.8	7.9
Water to Feed Ratio	2.03	2.60	4.67

For the adequate performance of laying hens and other poultry, good quality of water is essential. The foreign substances present in water may affect its' drinkability and well-being of the hens. Drinking water composition will differ in various regions across the country. Water may get polluted from the practices that occur naturally or from run-off sources. Water quality standards include many factors that affect the quality of water used in the poultry. These factors include items like pH, bacterial load, color, hardness, total solids, and dissolved oxygen, biochemical oxygen on demand, conductivity, water temperature and mineral content [9].

Water quality plays important role in the poultry farming. The source of water should be good in poultry farms otherwise it may lead to water borne diseases which affect the egg quality and egg production. To characterize water quality several parameters are used. Below given Table IV illustrates the standard water parameters for poultry farming.

The manual inspection of water sample is not feasible solution due to continuous variations in several quality parameters. Our paper aims to analyze and predict quality of water based on water quality index computation and machine learning algorithms. However, the performance of machine learning techniques depends on the nature of attribute, dimensionality of attribute and classifier model. Thus, the main objectives of the proposed work are as follows:

- To use the weighted arithmetic model for dataset generation.
- To present the feature ranking and selection model.
- To present the tree based ensemble classifier to improve the prediction accuracy.

Rest of the paper is organized as follows: Section II presents the brief literature review about the recent existing techniques of water quality prediction, Section III provides the proposed solution for WQI prediction by using machine learning, Section IV presents results and the comparative analysis of proposed approach and finally, Section V describes the concluding remarks of the proposed approach.

II. LITERATURE SURVEY

This section presents the brief literature review about existing schemes of water quality prediction based on chemical parameters. The previous section has described the advantages, growth of poultry farming in India. However, the review study briefs about various challenges faced in poultry farming such as manoeuvrability in broiler prices, availability of trained workers, shortage of raw material and many more. However, water quality has a significant impact on the egg and meat production.

Pujar et al. [10] presented a study for Krishna river water quality analysis by using an IoT system. The IoT system was utilized to gather data for several water quality indicators such as pH, turbidity, DO, BOD, NO3, temperature, and conductivity from selected stations, resulting in a data collection that was used to monitor water quality. Using one-way ANOVA, the acquired data was effectively used to analyze the quality of water of Krishna River. One-way ANOVA is used to analyze a specific parameter and predicts the quality of water based on the value obtained.

The study of two parameters as a separate entity as well as a combination of two parameters was done using two-way ANOVA [10].

Nayak et al. [11] developed a fuzzy logic based model by using triangular and trapezoidal membership function. This model used centroid, bisector and mean of maxima (MOM) methods for defuzzification.

TABLE IV. WATER QUALITY STANDARDS FOR PROPOSED STUDY

Parameter	Average level	Maximum Acceptable Level	Remarks
pH	6.8-7.5	8	pH of less than 6.0 is not desirable. Levels below 6.3 may degrade performance
Total Coliforms(TC)	0CFU/ml	0CFU/ml	Presences of Coliforms affect growth of poults.
Dissolved Oxygen(DO)	4.0-6.0mg/L	6mg/l	Affects growth and performance of chickens.
Biochemical Oxygen Demand(BOD)	1.0-5.0mg/L	5.0mg/L	Affects growth and performance of chickens.
Temperature(Temp)	25°C	-	Affects feed conversion ratio and growth
Conductivity(CND)	300μS	-	Performance of chickens get reduced

Khullar et al. [12] focused on anticipating the water quality of the Yamuna River in India by using a deep learning based Bi-LSTM model. Generally, the existing schemes do not focus on missing value an imputation which degrades the reliability of the system. To overcome these issues, author demonstrated novel scheme that includes missing value imputation in the first phase, feature maps generated from the given input data in the second phase, Bi-LSTM architecture in the third phase to improve the learning process, and finally, an optimised loss function to reduce the training error in the fourth phase.

Kim et al. [13] developed a water forecasting method to improve the water quality analysis. The first phase is developed by using ensemble of empirical mode decomposition with Bidirectional LSTM model. Once the predictions are obtained, a novel error correction module is incorporated which uses variation mode decomposition and BLSTM neural network. Thus, this combination helps to achieve the less accuracy during forecasting.

Prasad et al. [14] reported that handling the complexity of existing schemes is cumbersome process. Thus, authors developed artificial intelligence based machine learning approach.

Choi et al. [15] adopted three standalone and a hybrid deep learning scheme for water quality analysis based on time series analysis. These methods include univariate dataset with single dependent variable, multivariate dataset with single and multiple dependent variables and identifying the other parameters which has impact on the performance.

Dimri et al. [16] presented water quality analysis for Ganga River by using multivariate statistical techniques such as Pearson correlation, principal component analysis and cluster analysis.

Several works have considered underground water for water quality analysis and presented machine learning based techniques such as Panneerselvam et al. [17] identified that the rock-water interaction and ion exchange are also considered as important factors which affect the water quality. To identify their impact authors developed a Hierarchical Cluster Analysis (HCA) and K-mean cluster analysis based approach.

Vijay et al. [18] presented artificial neural network based approach for water quality prediction. The preliminary steps include pre-processing, and feature extraction. The ANN classifier uses three different activation functions such as Tanh, rectifier, and Maxout to process these features.

Wang et al. [19] used an AI-based LSTM (long short-term memory network) to identify water pollutant features as well as identifying the industrial pollution source. In line to this, a correlation based map is used to extract the relation among attributes. The correlation map is used to trace the fluctuations and identify the location and causing agents.

In our previous work [20], experimental study was conducted to test the water quality of different sources used in poultry farms using sensors and laboratory methods.

III. PROPOSED MODEL

According to literature survey, several water quality parameters are analysed to characterise the water quality. In this work also, we consider various parameters as in Table to predict the water quality whether it is drinkable or not and to provide the recommendation for poultry farm. In order to perform this task, we have collected the samples of Cauvery River.

A. Study Area: Cauvery River

In proposed study, we considered the Cauvery River which is a great river of India flowing in Southern region is considered as Dakshin Ganga. The origin point of this river is Talakaveri which is in the Coorg district of Karnataka. The catchment area of this river includes Karnataka, Tamil Nadu, Pondicherry, and Kerala before merging in Bay of Bengal. These southern states have agriculture as its main occupation. These states have significant livestock population where poultry farming is also considered as an important segment and share 50% of total production value. In this regard, it is important to consider the quality of Cauvery River water flowing in these regions as it is primary source of water. The water quality can have impact on the egg yield and meat production thus analyzing water quality is most important task.

The Fig.1 shows the Cauvery River basin and its tributaries flowing from Karnataka to Tamil Nadu.

We have obtained the data from various locations [21] and these samples are processed through the water quality analyser where indicator parameters are extracted.

B. Architecture Diagram for the Proposed Model

The proposed model architecture is shown in Fig. 2 and each component is explained:

1) Feature ranking method: In this work, we adopt the Relief algorithm based feature selection method to identify the relevance of features. This approach computes the proxy statistics known as feature weights $W[A]$ for each feature to identify its relevance which is ranging from -1 to +1 i.e. worst to best. Generally, the feature relevance is assigned based on the difference of probabilities. The pseudo code of complete process of this method is presented Algorithm 1. This approach estimates the nearest instance of the target where one is with same class is known as nearest hit H and the opposite class is nearest miss M. In algorithm 1 Step 9 updates the weights of feature.

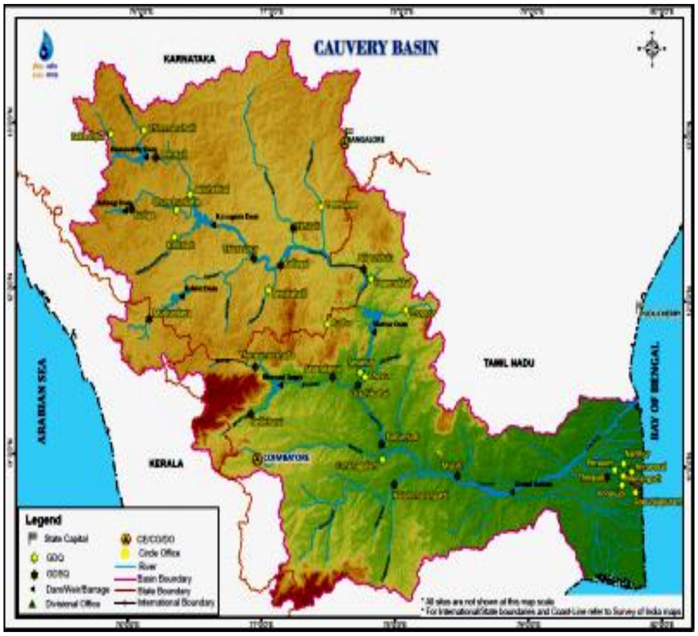

Fig. 1. Cauvery River Basin.

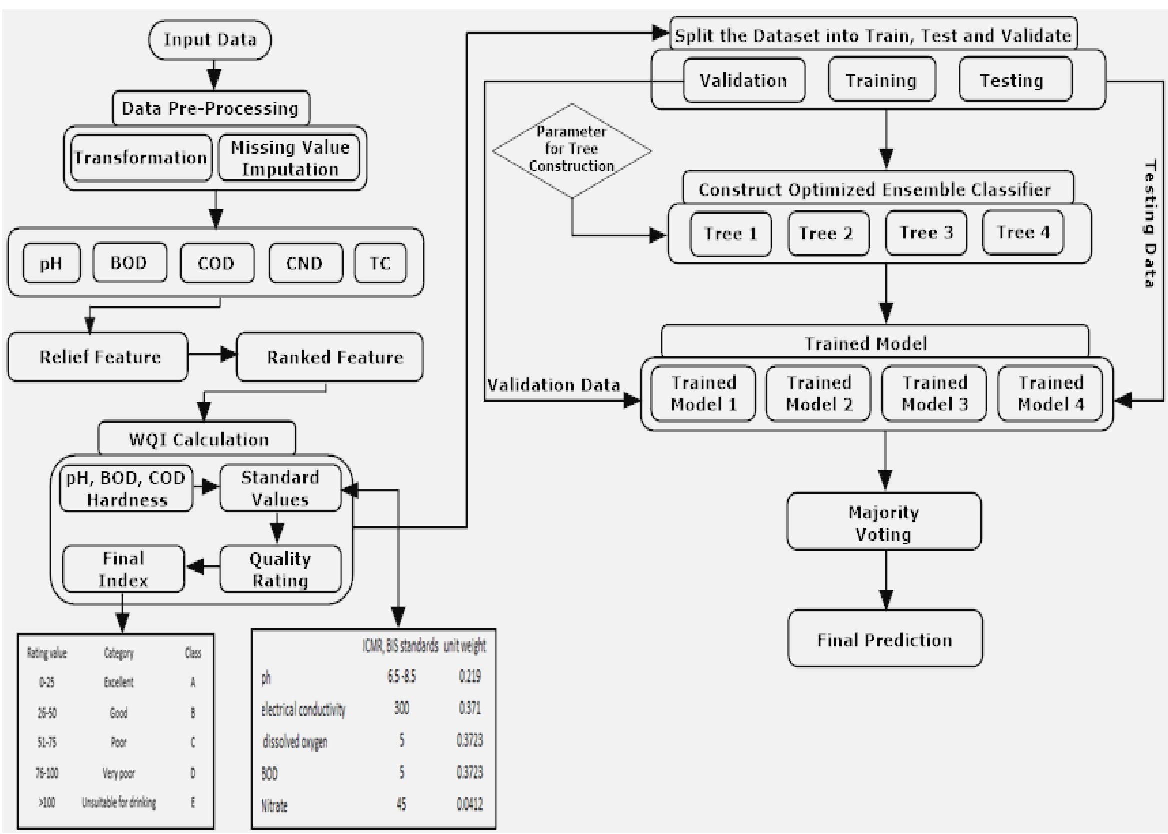

Fig. 2. Architecture of the Proposed Model.

Algorithm 1:Relief Algorithm

Step 1: Input: each training instance with feature values and corresponding class values.

Step 2: n ←number of training instances

Step 3: a ← number of attributes

Step 4: Output: m ← pick random training from n and update the weights W

Step 5: for $i \coloneqq 1$ to m do

Step 6 : initialize the selection of random 'target' from R_i

Step 7: identify the nearest hit and miss as H and M

Step 8: For $A \coloneqq 1$ to a do

Step9: $W[A] = W[A] - diff\ (A, R_i H)/m + diff\ (A, R_i M)/m$

Step 10: End for

Step 11: End for

Step 12: Return updated weights to identify the quality of attributes

To perform weight updates, calculate the difference in value for feature A between two instances I_1 and I_2, where $I_1 = R_i$ and I_2 is either H or$M$, the diff function in Algorithm 2 is computed as:

$$diff(A, I_1, I_2) = \begin{cases} 0, if\ value\ (A, I_1) = value\ (A, I_2) \\ 1\ if\ otherwise \end{cases} \quad (1)$$

In order to further, improve the weight update process, we define a Bayes rule based on the conditional probability of prediction differences and probability of different class. The Bayes rule can be expressed as:

$$W[F] = \frac{P_{diffC|diffF} P_{diffF}}{P_{diffC}} - \frac{(1 - P_{diffC|diffF}) P_{diffF}}{1 - P_{diffC}} \quad (2)$$

In order to calculate the difference between feature spaces, we used a weighted Euclidean distance measure which is calculated as:

$$diff(S_i, S_j) = \sqrt{\sum_k w(c_k)\left(L_{i,k} - L_{j,k}\right)^2} \quad (3)$$

Where S_i and $S_j$represents the target description for random instance R_i and target instance I_j, respectively. $L_{i,j}$ and $L_{j,k}$ denotes their corresponding binary representation. The updated algorithm of k feature ranking and selection is given in Algorithm 2. Initialize random instance $R_i$and find the k nearest instances I_j. Using these instances, approximate the relevance $W[F]$ from Equation 2 for each feature by calculating $N_{diff\ C}$, $N_{diff\ F}[F]$ and $N_{diffC\ \&\ diffF}[F]$ described in lines 6, 8 and 9 of Algorithm 2. The values of these estimations are based on the calculation of distance in the feature space, $diff(F, R_i, I_j)$ as specified in lines 8 and 9 of Algorithm 2.

Algorithm 2: Pseudo code for Feature ranking and selection

Input: training instances and corresponding class values

Output: weight vector W to estimate relevance of features.

Step 1: initialize $N_{diff\ C}$, $N_{diff\ F}$, $W[F]$ to 0

Step 2: for $i = 1\ to\ m$ do

Step 3: initialize with randomly selected instances R_i

Step 4: select k instances from I_j as nearest instances to R_i

Step 5: for j=1 to m do

Step 6: $N_{diffC} = N_{diffC} + diff(S_i, S_j).d(i,j)$

Step 7: for $F = 1\ to\ f$ do

Step 8: $d_{diffF}[F] = N_{diffF}[F] + diff\ (S_i, S_j).d(i,j)$

Step9: $N_{diffC\ \&\ diffF}[F] = N_{diffC\ \&\ diffF}[F] + diff(S_i, S_j).diff(F, R_i, I_j).d(i,j)$

Step 10: end for

Step 11: end for

Step 12: end for

Step 13: for $F = 1$ to f do

Step14: $W[F] = N_{diffC}|diffF\ [F]/N_{diffC} - \left(N_{diffF}[F] - N_{diffC|diffF}[F]\right)/(m - N_{diffC})$

Step 15: end for

2) Water quality index calculation: In this section, we consider the water quality parameters such as conductivity, hardness, nitrates, BOD, pH, and dissolved oxygen and presented a method to obtain the water quality index which can be used to classify the potability of water. In this work, we have used weighted arithmetic method to compute WQI which is expressed as:

$$WQI = \frac{\sum Q_n W_n}{\sum W_n}$$

□□□

Where, Q_n is the quality rating and W_n is the weight for each quality parameter. The quality rating can be calculated based on the observed value and ideal values. It can be computed as follows:

$$Q_n = 100\left[\frac{V_n - V_0}{S_n - V_0}\right] \quad (5)$$

Where $V_n$is the observed value, V_0 is the ideal value (V_0 value is 7 for pH and 14.6 for DO and 0 for others). Similarly, W_n is the unit weight vector which is computed as:

$$W_n = \frac{1}{S_n} \quad (6)$$

Where S_n is the recommended value such as WHO temperature standard value is 28, then $W_n = \frac{1}{28} = 0.036$, DO recommended value is 6 then $W_n = \frac{1}{6} = 0.166$.

By substituting the values of (5) and (6) in (4), we obtain the WQI parameter and based on this value the water grading can be presented. Below given Table V shows the quality index parameters.

TABLE V. WQI WATER QUALITY GRADING

WQI Value	Comment	Grading	Labels
0-25	Excellent	A	1
26-50	Good	B	2
51-75	Poor	C	3
76-100	Very Poor	D	4
Above 100	Unsuitable	E	5

A sample dataset used for training the network is obtained as presented in Table VI which considers pH, DO(Dissolved oxygen), TC(total colifroms), BOD(biochemical oxygen demand), CND(conductivity) and temperature to measure the WQI value.

TABLE VI. WATER QUALITY PARAMETERS

pH	DO	TC	BOD	CND	Temp	WQI
7.4	10.2	6800	1	445	24.5	1
8.2	8.4	110000	2	514	25	2
8.3	9.1	1300	1	449	26	1
7.8	13.1	1100	6	374	27.5	2
8.3	7.7	7800	4	730	27.5	2
8.3	7.7	7800	4	730	28	2
7.3	6.1	9200	2	236	27	1
7.3	6.1	9200	2	236	26	1
7.8	6.4	17000	1	300	27	2
7.7	7.4	3300	1	401	26.5	1
8.5	9.5	1700	2	460	27	1
7.7	11.5	3300	4	710	27.5	1

3) Classifier model: In this work, we present an ensemble classifier where multiple instances of random forest model are constructed which produces the preliminary classification results. Later, these predicted outcomes are processed through the majority voting where final prediction is computed. Fig. 3 depicts the ensemble of tree classifier.

The Random Forest is a promising technique which is a collective learning method used for classification, regression, and other machine learning tasks. It imitates with cluster formation of decision trees and generates a class as mean of individual tree. This approach follows specific these steps which are mentioned below:

- First stage: Random Forest Tree construction.

In order to construct the tree, this approach performs four operations as:

- Selection of k random features from the m set of features.
- Determining d as the best point for split
- These nodes are further distributed as daughter nodes
- This process is repeated until l numbers of nodes are obtained via tree construction.
- Second stage: Classification

In next stage, the constructed trees are considered as inputs and classification is performed by following the steps mentioned below:

- Rules are assigned for each tree and a decision tree is formulated based on test features.
- Votes are calculated according to the target value
- The target which obtains the highest votes is considered as final result.

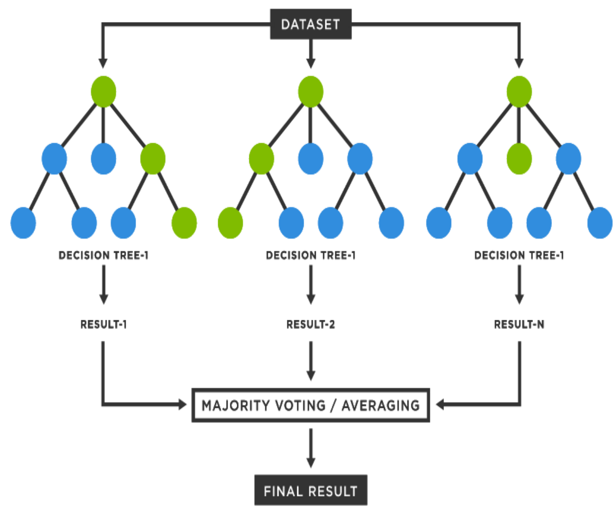

Fig. 3. Random Forest Tree Ensemble Classifier.

IV. RESULTS AND DISCUSSION

This section presents the complete outcome of proposed approach. The proposed approach uses WQI dataset generation as the first step and later classifiers are trained to obtain the predication performance. In this work, we have considered pH, electrical conductivity, dissolved oxygen, BOD, and nitrate. For these parameters, ICMR has given some standard values for identifying the water quality. These standard values are presented in Table VII.

Based on these standards, we compute the water quality parameters. Samples of generated and their calculation example for WQI data is presented in below given Table VIII.

TABLE VII. STANDARDS OF ICMR FOR WATER QUALITY ANALYSIS

	ICMR, BIS standards	unit weight
pH	6.5 -8.5	0.219
electrical conductivity	300	0.371
dissolved oxygen	5	0.3723
BOD	5	0.3723
Nitrate	45	0.0412

TABLE VIII. WQI DATASET GENERATION

Parameter Name	**Standard value**	**Observed value**	**Unit Weight**	**Quality rating**	W_iQ_i
pH	6.5-8.5	7.7	0.2190	46.67	10.22
Conductivity	250 $\mu S/cm$	96.3$\mu S/cm$	0.3710	38.52	14.29
Dissolved oxygen	500mg/L	3.2mg/L	0.3723	118.75	44.21
BOD	5mg/L	1.1mg/L	0.3723	22	8.19
Nitrate	1.70mg/L	1.7mg/L	0.0412	3.40	0.14
Temperature	28	27.04	0.036	96.57	3.476
			1.4118		80.52

Based on these values, we compute the WQI parameter as:

$$WQI = \frac{80.52}{1.4118} = 57.033$$

Similarly, complete dataset is generated and trained.

1) Performance measurement: The classification performance is measured using performance metrics such as accuracy, specificity, sensitivity, precision, recall and F-score. These values can be computed with the help of confusion matrix which is given in Fig. 4.

Accuracy is defined as a rate of correct classification and it is denoted by Accuracy. It is calculated by taking the ratio of correct prediction and total number of prediction [22]. It can be expressed as:

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (7)$$

Sensitivity is another parameter used to do the sensitivity analysis of the model. It is used to measure true positive rate. This can be expressed as:

$$Sensitivity = \frac{TP}{TP+FN} \quad (8)$$

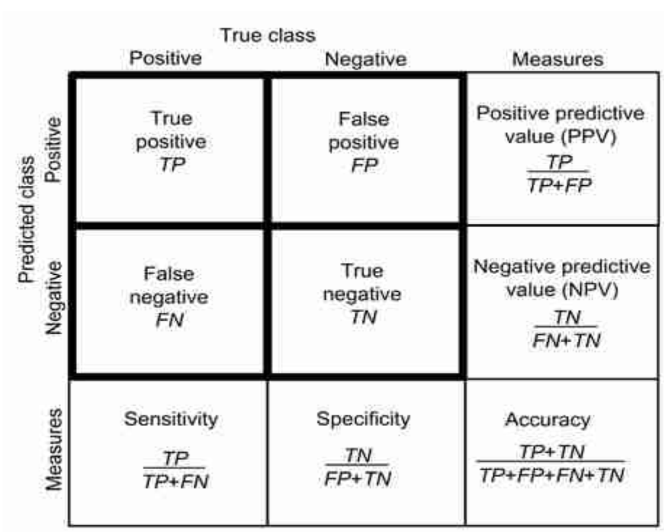

Fig. 4. Confusion Matrix.

Then, the proposed approach precision can be computed by taking the ratio of True Positive and (True and False) False positives.

$$P = \frac{TP}{TP+FP} \quad (9)$$

Similarly, recall is computed based on TP, and FN, as given below:

$$Recall = \frac{TP}{TP+FN} \quad (10)$$

Finally, F-measure is calculated using the mean of precision and sensitivity performance. It is expressed as:

$$F = \frac{2*P*Sensitivity}{P+Sensitivity} \quad (11)$$

2) Comparative analysis: This section presents the comparative analysis by considering different classifiers such as K-Nearest Neighbour (KNN), Naïve Bayes, Decision Tree and proposed ensemble approach. First of all, we present an experiment, where feature selection algorithm is not combined with the classification module. The classification performance in terms of percentage is presented in below given Table IX.

TABLE IX. COMPARATIVE PERFORMANCE WITHOUT FEATURE SELECTION

	KNN	Naïve Bayes	Decision Tree	Ensemble Tree Classifier
Accuracy	92.11	93.51	94.5	95.12
Sensitivity	87.5	91.2	93.56	94.8
Specificity	91.2	93.5	95.2	96.1
Precision	92.2	93.8	95.6	96.5
F-score	93.5	94.25	95.05	97.5

Below given Fig. 5 shows the graphical representation of different classifiers where feature selection approach is not incorporated.

Further, we extend this experiment and incorporated feature selection approach with different classifiers. The obtained performance in terms of percentage is presented in below given Table X.

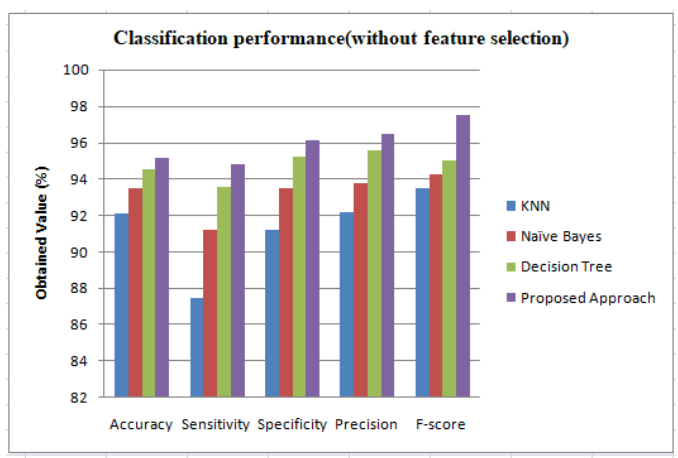

Fig. 5. Classifier Performance without Feature Selection.

TABLE X. COMPARATIVE PERFORMANCE WITH FEATURE SELECTION

	KNN	Naïve Bayes	Decision Tree	Ensemble Tree Classifier
Accuracy	93.52	94.63	95.86	96.55
Sensitivity	88.12	93.1	94.52	94.8
Specificity	92.5	94.5	96.12	97.22
Precision	93.42	94.68	97.1	97.3
F-score	94.6	95.2	96.3	98.21

Similarly, the overall performance with feature selection strategy is depicted in Fig. 6.

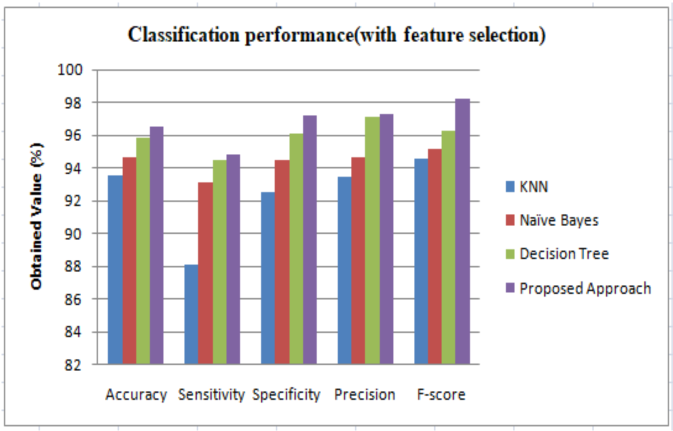

Fig. 6. Classifier Performance with Feature Selection.

These analysis results shows that the proposed feature selection and classification approach improve the classification accuracy when compared with the conventional methods.

This model can be used by the poultry farmers to analyze the quality of water used in the farms in order to reduce the effect of water borne diseases which lead to decrease in egg quality and egg production in layer poultry farms.

V. CONCLUSION

In our work, the suitability of Cauvery River water for layer poultry farm is carried out. Several methods are present for predicting the water quality analysis but accuracy and reliability become a challenging task.

The proposed machine learning model introduces a feature ranking model along with the ensemble tree based classifier for water quality analysis and prediction. The comparative analysis shows the significant improvement in prediction performance when compared with the conventional machine learning algorithms. This automated approach can be used by the poultry farmers to analyze and predict the potability of water used in the farms.

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