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FLOOD PREDICTION AND MANAGEMENT

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ABSTRACT

Floods are one of the most devastating forces of nature, that destroy thousands of lives every year. Not only does the economy of a country suffer because of such a disaster, but the loss of agriculture and people is physically and mentally exhausting for a country. Especially, in a country like India where floods are frequent, and the prevention department lacks, it becomes crucial to early detect these floods, and inform the local authorities to safeguard the lives of thousands of people.

Through this paper, we aim to work on a comprehensive flood prediction system that utilizes machine learning algorithms to enhance the efficiency and accuracy of a flood prediction and management system. In this study, we have used the dataset with 142193 entries and to work with such large data we have used multiple algorithms. These machine learning algorithms have made it easy to analyze or to work with large datasets. We used multiple algorithms that have worked well with this dataset but some of them have performed better than others. Out of all algorithms, XGBoost has performed best. Along with XGBoost algorithms like CatBoost and Random Forest have also performed well as they all have accuracies of more than 90%.

Our target is accurate and early prediction of floods in an area, and then to inform the required local authorities about the forecast. So, that necessary action can be taken, and the flood-prone area can be evacuated in an organized manner.

I. INTRODUCTION

Floods are recurring and devastating natural disasters taking countless lives every year all over the world. Millions of lives are lost to this disaster, and the unpredictability with which it happens makes it worse, and very hard to tackle.

Multiple factors take part in causing a flood, which often involves an excess of water in areas that are normally dry or have less amount of water. Some common factors that are heavily responsible for flooding are:

1. Overflowing of rivers: One of the most prominent cause of a flood is the overflowing of water bodies. When a river body contains more water upstream than usual, it can flow downstream to the areas at a lower level, which is referred to as floodplains. When a huge amount of water discharges suddenly into adjacent lands it leads to flooding. The people living along the river bodies are at a high risk of flood from the overflowing of rivers, hence in a greater risk of damage. Such people need to be informed about an upcoming flood on priority and be evacuated from the scene as soon as possible.

2. Heavy Rainfall: Another big reason for a natural disaster like a flood can be heavy rainfall. Heavy rainfall can not only contribute to the overflowing of rivers, but when there is a significant amount of rainfall, it can also overpower the capabilities of a drainage system and the capabilities of a soil's absorption, which can then ultimately lead to flooding. And now with the changing climate, the intensity, frequency, and duration of rainfall is increasing. The North Indian floods of 2023 are an accurate example of heavy rainfall causing floods.

3. Deforestation: Apart from natural causes, humans contribute to floods greatly. With the reckless and unbiased cutting of trees, deforestation is a major man-made cause of flooding. As trees hold on to the soil through their roots, it prevents soil erosion and blocks the massive flow of rain, in turn preventing flooding of the area. But when a large number of trees are cut down, there are no roots to hold the soil and soak in the extra water, which then flows freely, flooding the entire deforested area.

Especially in a country like India. Where the terrains vary to a great extent, and the climate conditions change dramatically. In such a geological complexity, the prediction and prevention of natural disasters, such as floods becomes crucial. If we were to refer to the survey conducted by the National Disaster Management Authority, then according to them, an average of 1,600 lives are lost, and 75 lakh hectares of land are affected every year due to floods. Not only this, there is also the economic damage caused to crops, houses, and public utilities, amounting to Rs.1805 crores annually. With the frequency of major floods being more than once in five years, the need for effective flood detection and management systems is more critical than ever.

To tackle this exact problem, and to predict the occurrence of floods, so that appropriate measurements can be taken and countless lives can be saved, through this paper we're aiming to delve into various ML models to understand the best method to predict a flood before it happens and to develop a Flood Detection and Management system that can accurately predict a flood before it destroys countless lives, and inform the relevant authorities to take preventive measures for it, especially from an Indian perspective.

II. THEORETICAL REFERENCE

In this Literature review, we have discussed the previous research work that has been conducted on the topic of flood detection and management systems and the justification of this research. Researchers have used qualitative and quantitative data for the prediction of floods in various papers. The qualitative approach consists of identifying the vulnerable areas where flood generally occurs during monsoon on the other hand quantitative approach consists of Machine Learning algorithms that are used for the prediction of floods before they can cause destruction.

Many scholars [1-3]. have worked with different algorithms to predict the flood using different datasets. Kerala in India has faced many floods over the years due to irregular monsoons, also in the northern part where flood management is not very precise many casualties occurs [2] so we are conducting research on the rainfall pattern.

According to Adnan et al. [4], flood prediction has grabbed the attention of many scholars and as a result, Mosavi et al. [5] have combined Machine Learning technology with traditional methods so the accuracy of the prediction could be increased. This research's main purpose is to compare multiple algorithms and also use hybrid Machine Learning algorithms to find out which one is best suitable for predicting floods [2]. According to Chen et al. [6], a particular area is divided using latitudes and longitudes, and rainfall data along with the drainage of that particular area is taken into consideration because not only the rainfall but the drainage system is also responsible for the flood in a particular area.

According to Maspo et al. [7] currently used machine learning algorithms are not accurate enough. Therefore, we aim to find the best algorithm that could be used for flood prediction. Sankaranarayanan et al. [8], review the public and government plans for the rescue operations, and provide a proper system for flood victims and is very much possible if they get an early warning about the disaster but there is no accurate method for flood prediction in advance. Previously data was manually entered which made the process time-consuming so the warning was impossible with that. A new operational approach has been given by Parag et al. [9], therefore taking it as a reference we also want to conduct the study to find a new and accurate approach to predict the flood. We are generating as well as using data on a daily basis which promotes the trend of data-driven studies, as Furquim et al. [10] have reviewed the use of data to forecast the floods in order to decrease the damage caused during the floods. The neural network was considered the most accurate regarding the forecasting of floods. Adnan et al.'s [11] have suggested different plans to increase the quality of current warning systems. In order to determine the major flooding location in the Teesta River basin, Talukdar et al. [12] used multiple machine-learning modeling strategies. The Machine Learning algorithm like random forest was used by adnan et al. [4] in turn a range of Machine Learning algorithms are used to analyze the previously collected data and to get an accurate prediction with the help of our models. Gauhar et al. [13] also used the K-NN technique for forecasting a flood and for feature selection coefficients of association is used. We also work with the Bayesian forecasting methods which are used for flood prediction. Haque et al. [14] in his study finds out that 180 models were produced when he used 5 different Machine Learning algorithms during his study. Every algorithm had different accuracy depending on their mode of working and dataset compatibility.

Hossain et al. [15] points out the creation a system for predicting rainfall for a long period of time in western Australia with the help of multiple artificial-based methodologies. As per the research of Aswad et al. [16] flood prediction is very challenging and in-depth study/research is required in this field for predicting the flood also he used a TpoT-based model for predicting the time for flooding in any river. Ighile et al. [17]. This marks the flood-prone areas near Nigeria using past flood records in the time period of 1985 to 2020. His study focuses on making a perfect flood prediction model with the help of Machine Learning algorithms, as Kunvergi et al.

According to [18] research. The boosted regression tree (BTR), generalized additive model (GAM), and multivariate adaptive regression splines (MARS), were the most accurate model according to his study. Sarasa-Cabezuelo's study [19] points out the qualitative investigation for using artificial methods in order to predict rainfall. Also, he come to the conclusion that neural networks are the best approach for predicting rainfall. Liyew and Melese [20] worked with different algorithms for analyzing floods and according to their study, artificial neural network (ANN) was proved to be the best algorithm for this purpose.

III. MATERIALS AND METHODS

We aim to determine the difference in accuracy and efficiency between traditional methods and new-age technology in order to predict flood outbursts in India. We have used a very popular dataset that is about the rainfall in Kerala to predict the flood. After the data collection, we applied techniques like feature engineering, feature encoding, and data normalization to extract useful information from the dataset. Then we split data into 2 parts, 1 for training and another for testing in a 75:25 ratio, then we apply 7 different algorithms to compare the accuracy between them and find the best algorithm that can be used to in order\ to predict floods accurately and give an emergency warning in advance. The

algorithms used in our study are Logistic Regression, Decision Tree, Neural Network, Random Forest, Light GBM, CatBoost, and XGBoost. In the end the model best to predict the flood is identified based on the f1-score of the algorithms used.

Figure 1 is dedicated to showing the methodology details.

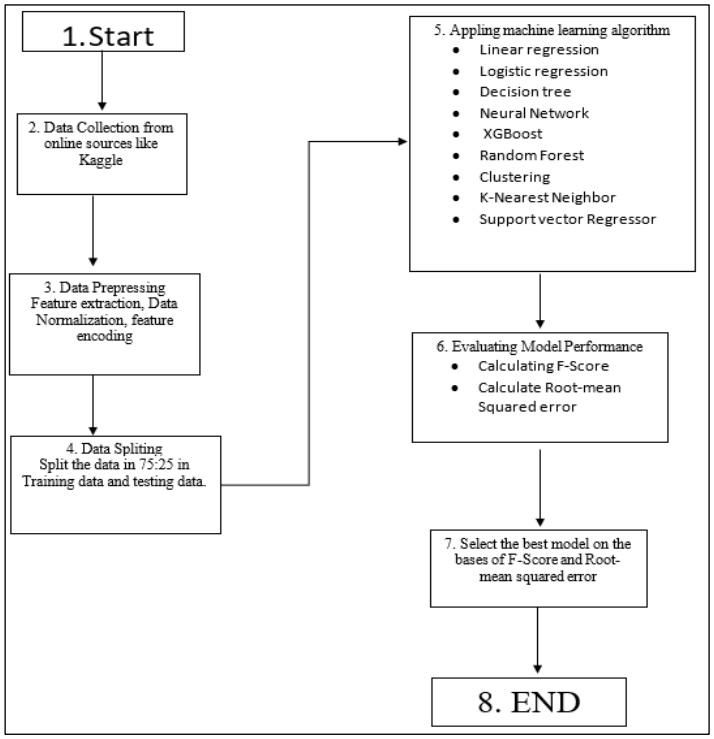


Figure 1: Pipeline to demonstrate the methodology of the Project.
Source: Authors, (2024).

Figure 2 is about the workflow of the study. We aim to use computer intelligence to get the maximum result on our training data.

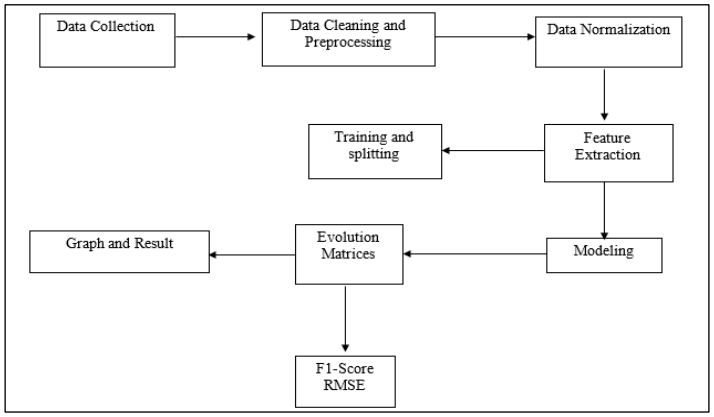
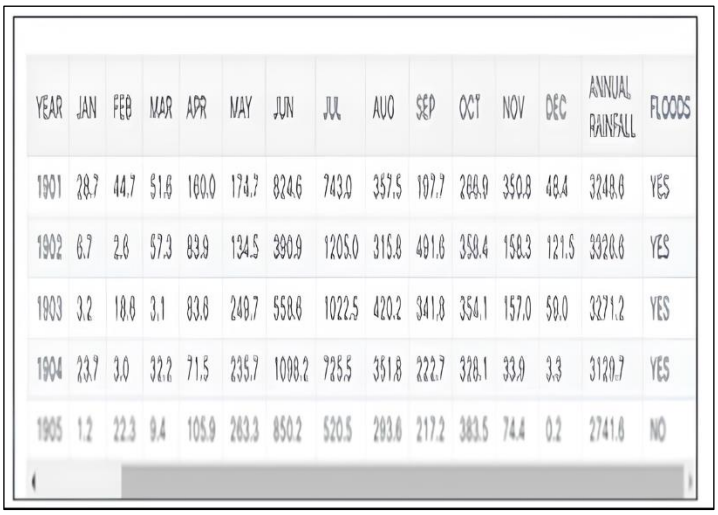


Figure 2: Block Diagram to demonstrate the workflow of the Project.
Source: Authors, (2024).

A. Dataset Description

The data we used is obtained from the Kaggle dataset which is based on the rainfall and floods caused due to rainfall. This dataset includes information about the amount of rainfall that happened in the past and did it resulted in floods or not, also it has the maximum and minimum temperature, humidity, amount of clouds, and many other factors resulting in rainfall.

Figure 3 consists of the head of our dataset used.



YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL RAINFALL	FLOODS
1901	28.7	44.7	51.6	160.0	174.7	824.6	743.0	357.5	197.7	266.9	350.8	48.4	3248.6	YES
1902	6.7	2.6	57.3	83.9	134.5	390.9	1205.0	315.8	491.6	358.4	158.3	121.5	3328.6	YES
1903	3.2	18.6	3.1	83.6	248.7	558.6	1022.5	420.2	341.8	354.1	157.0	59.0	3271.2	YES
1904	23.7	3.0	32.2	71.5	235.7	1098.2	725.5	351.8	222.7	328.1	33.9	3.3	3129.7	YES
1905	1.2	22.3	9.4	105.9	263.3	850.2	520.5	293.6	217.2	383.5	74.4	0.2	2741.6	NO

Figure 3: Dataset Used in our Project.
Source: Authors, (2024).

Figures 4 & 5 represent the monthly and yearly rainfall happened in India. As we all know months like July August and September are more prone to floods so with the help of Figure 5, we can observe clearly. Also, Figure 4 helps us to identify the areas that are prone to floods. So, in order to predict floods, we want basic information like annual rainfall and monthly rainfall.

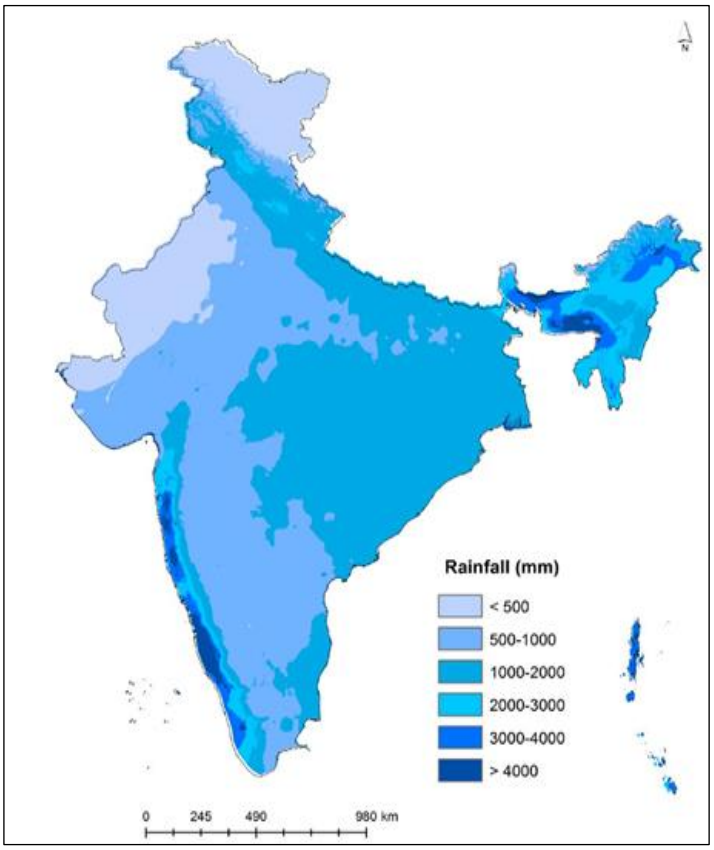


Figure 4: Yearly Rainfall in India.
Source: Authors, (2024).

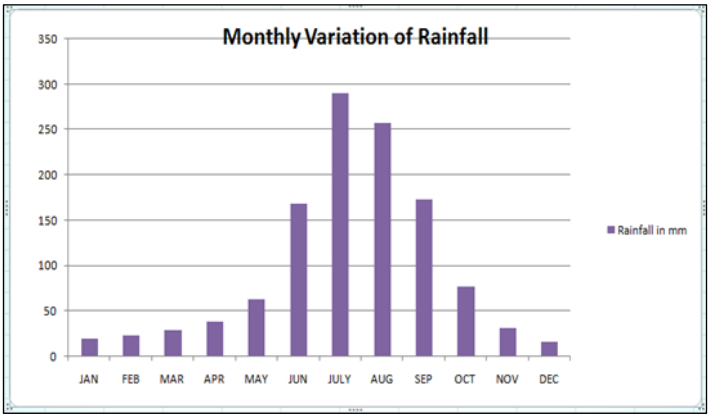


Figure 5: Monthly Rainfall in India.
Source: Authors, (2024).

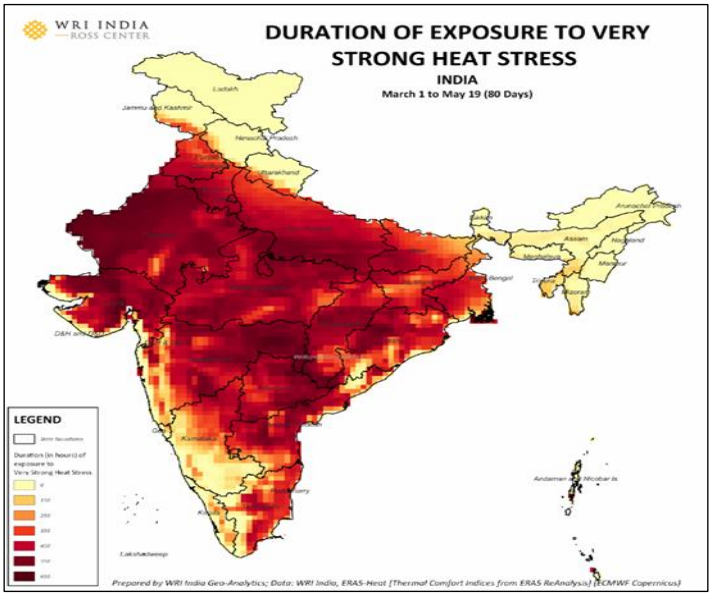


Figure 5: Yearly Temperature of India.
Source: Authors, (2024).

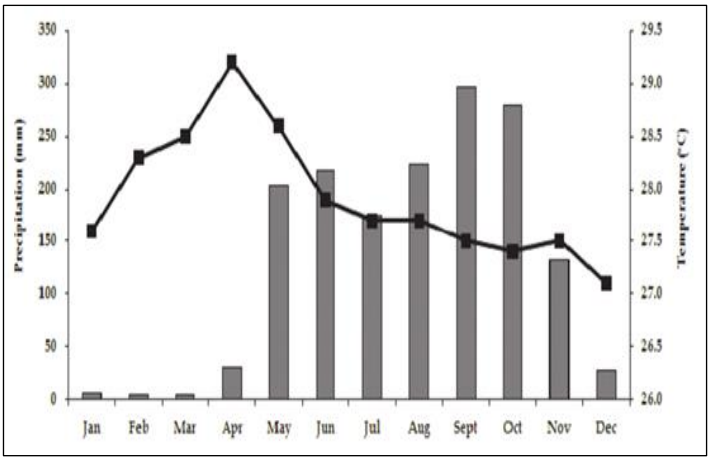


Figure 6: Monthly Temperature of India.
Source: Authors, (2024).

Figure 6 & 7 represent the maximum and minimum temperature in India. As we can observe the hottest area in India and months which have the highest temperature.

Table 1: Features used in training of the machine learning model.

S.No.	Attribute	Description	Type	Measurements
1	City Name	This consist of the name of the city.	String	Categorical
2	Year	This consist of the year of which the data is.	Integer	Numerical
3	Monthly Rainfall	This consist of amount of rainfall monthly in a particular year.	Float	Millimetre
4	Annual Rainfall	This consist of total rainfall of any particular year.	Float	Millimetre
5	Floods	This consist of the if the flood has occurred in that year or not.	String	Yes/No

Source: Authors, (2024).

This work uses multiple concepts of the machine learning and deep learning. With the help of multiple algorithms, we can find a better way to predict the floods that may occur in future in advance. With the help of concepts of data prepressing we can find the rainfall that has occurred significantly in the months of June, July, August and September. This will allow us to target the specific month where rainfall has mostly occurred this will help our model to predict more accurately. Figure 8 is the bar plot of the rainfall in India.

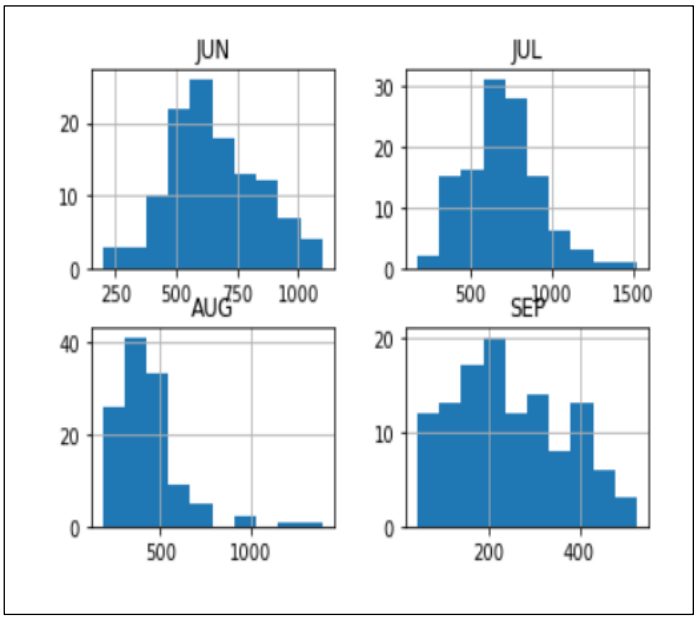


Figure 7; Histogram Depiction of the amount of rainfall occurred in particular year.
Source: Authors, (2024).

B. Data Normalization

Whenever there is any redundant data in dataset therefore to decrease that in any particular dataset, we use the techniques like data normalization so that we may get a good data. The equation used in data normalization is

$$x_{norm} = \frac{x - \min(x)}{\max(x) - \min(x)} \quad (1)$$

X is the original value in the dataset, min(x) is the minimum value in the dataset, max(x) is the maximum value in the dataset and x normalized is the value of the x within the range of [0, 1]. In the machine learning we use a function called min-max-scaler present in sklearn library which convert the all the values in the range of [0, 1].

C. Machine learning Models

There are 2 types of algorithms in machine learning, 1. Supervised learning 2. Unsupervised learning. In our study we have used most effective algorithm i.e., Supervised learning for the training of our models. In our dataset we have some independent as well as dependent data variables so in this type of dataset use of supervised algorithms works best. Our aim is to predict the accurate answer for the data that we may feed it to the model in future.so we have chosen the best algorithms that we have analysed while reading past research paper during our research time period.

We have used multiple algorithms to analyze the data and get the best algorithm to predict the flood. Some of them are mentioned below:

1. Logistic Regression:

This type of algorithm is used to predict the output in the form of (0,1) i.e., 1 if the event will happen and 0 if the event l not happens. With our data it has performed average in case of accuracy as it only can attain the accuracy of 78.96%.

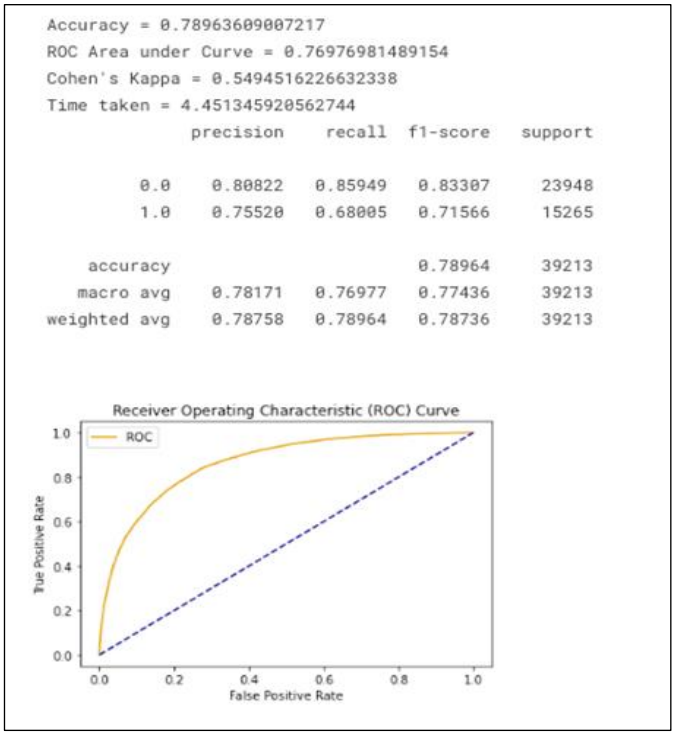


Figure 8: Experimental result of the Logistic Regression.
Source: Authors, (2024).

2. Decision Tree:

This algorithm is a powerful algorithm that is used for classification as well as regression. With 86% accuracy, this has also performed well on our data.

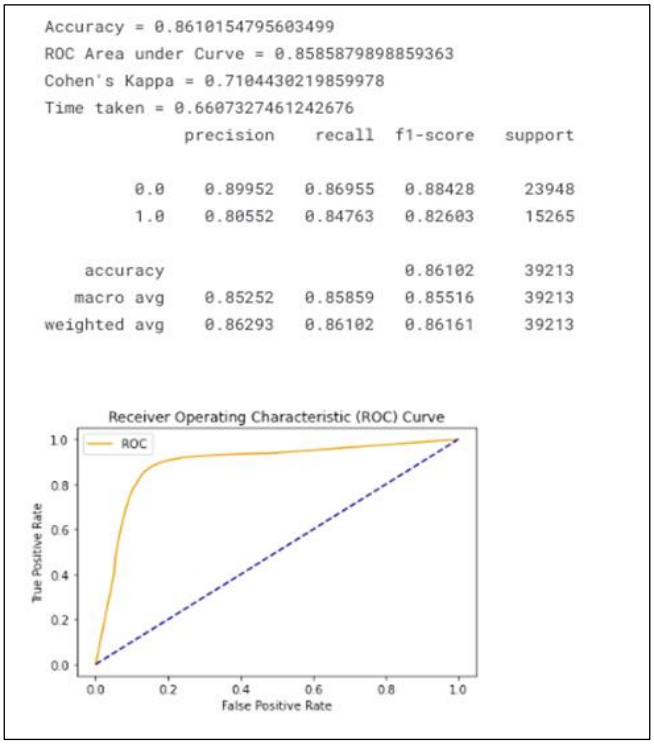


Figure 9: Experimental result of the Decision Tree.
Source: Authors, (2024).

3. Neural Network:

It is a popular algorithm that is mostly used for prediction in machine learning. It forms multiple hidden layers so that the model may process the input and may then predict any result. With 88.6% this algorithm has given good results.

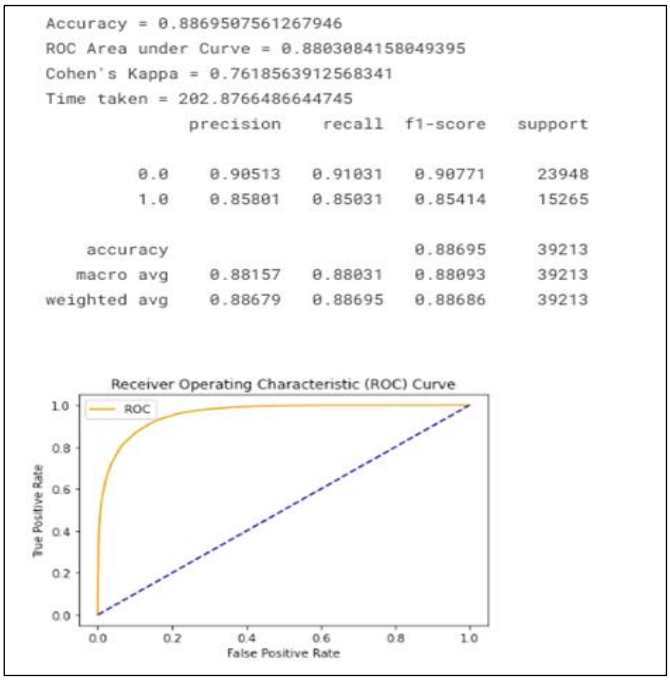


Figure 10: Experimental result of the Neural Network.
Source: Authors, (2024).

4. Random Forest:

This algorithm uses multiple concepts of decision tree to improve accuracy and prevent overfitting. This algorithm has also

had an accuracy of 92.8%, which makes it preferable to use with this type of data.

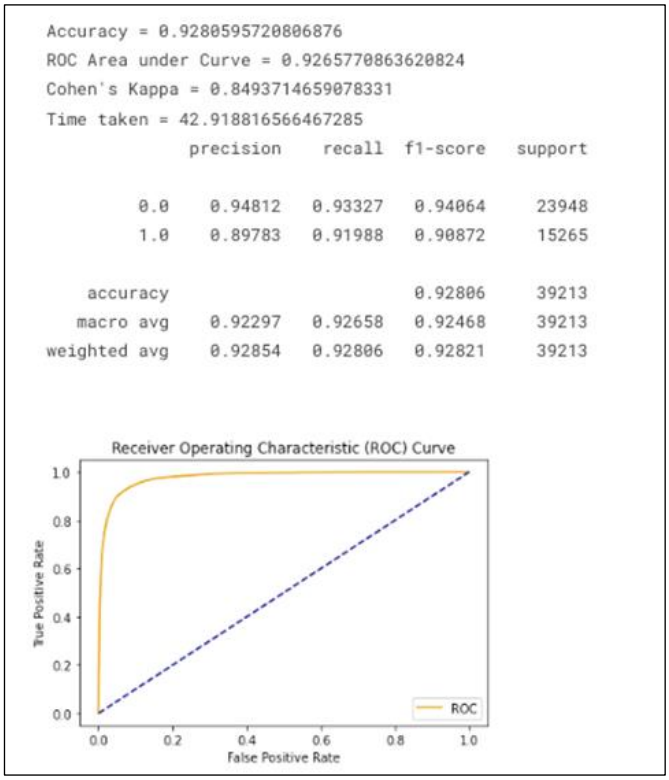


Figure 11; Experimental result of the Random Forest.
Source: Authors, (2024).

5. Light GBM (Light Gradient Boost Machine):

This is also a decision tree-based algorithm to increase the efficiency as well as the memory usage of the algorithm. It has an accuracy of 86.93%.

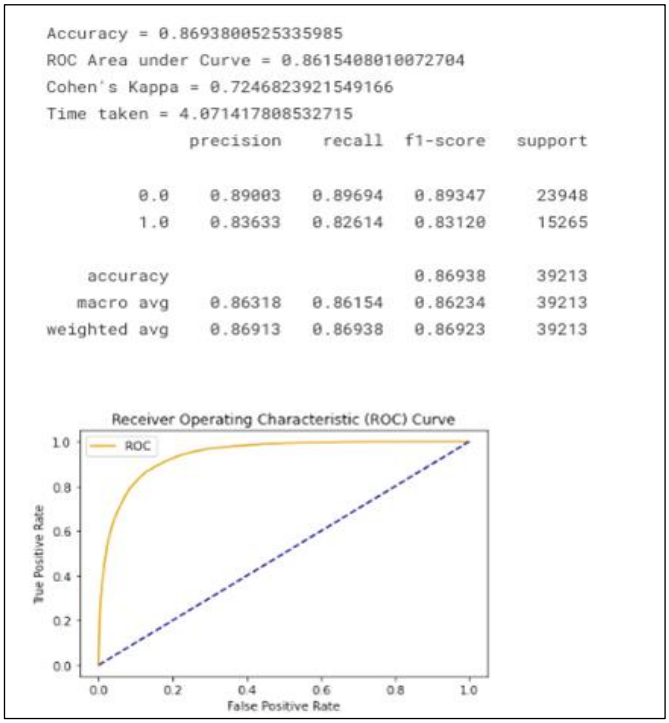


Figure 12: Experimental result of the Light GBM.
Source: Authors, (2024).

6. CatBoost:

Also called "Categorical Boost" which perform good in classification and regression tasks. With 94.1% accuracy it has performed good with our data.

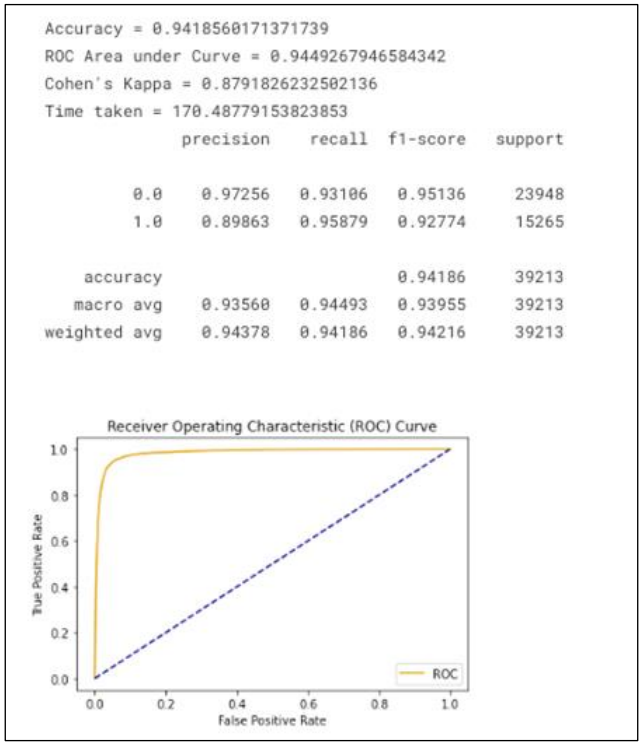


Figure 13: Experimental result of the CatBoost.
Source: Authors, (2024).

7. XGBoost:

This gradient boost algorithm is used for efficient and scalable training of our machine learning model. With 95.63% it has performed best during our research time.

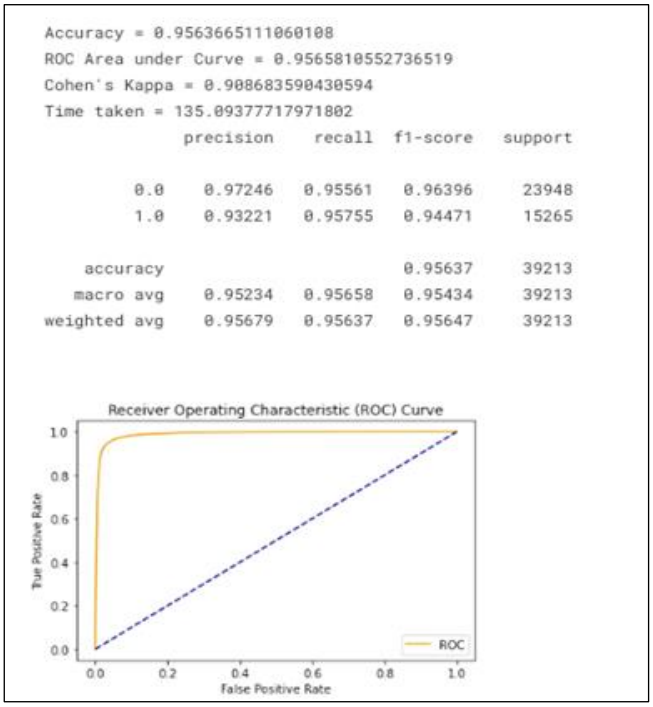


Figure 14: Experimental result of the XGBoost.
Source: Authors, (2024).

We can see that XGBoost, CatBoost and Random Forest have performed better than other algorithms as they have produced results with more accuracy.

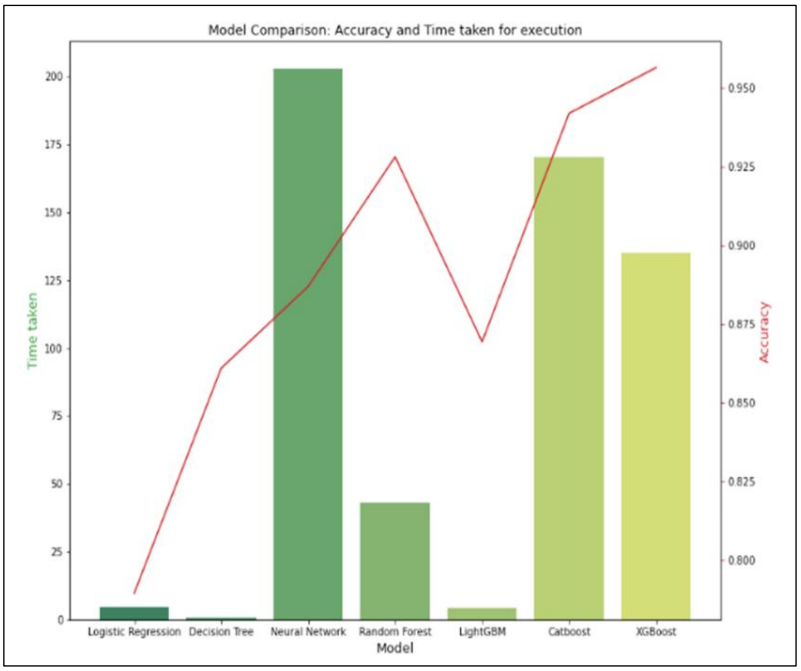


Figure 15: This figure is the comparison of Accuracy and Time taken of the algorithms used.
Source: Authors, (2024).

IV. RESULTS AND DISCUSSIONS

Figure 8-15 tells us about the accuracy of the different algorithms that are used in our study. Graphs that are placed in 8-15 along with the accuracy show the graph that mapped using False Positive and True positive values, it compares the data distribution among the predicted value and actual values.

The rainfall is recorded manually or with the help of remote sensing in India. The data that we used was from multiple sources, it was collected by the Metrological Department of India and other reliable sources.

The Aim was to find the best algorithm for flood prediction and with the help of graphs and f1-score we can determine that XGBoost and CatBoost models have performed best among our chosen algorithms and have produced good results in order to predict flood to figure out the best algorithm we have used features like accuracy score, ROC_AUC, Cohen's Kappa and total time taken for execution. Figure 16 shows the decision region for all the different models. Using this we can observe that CatBoost has a distinct regional boundary compared to all other models. However, XGBoost and Random Forest models also have a very lesser number of misclassified data points as compared to other models.

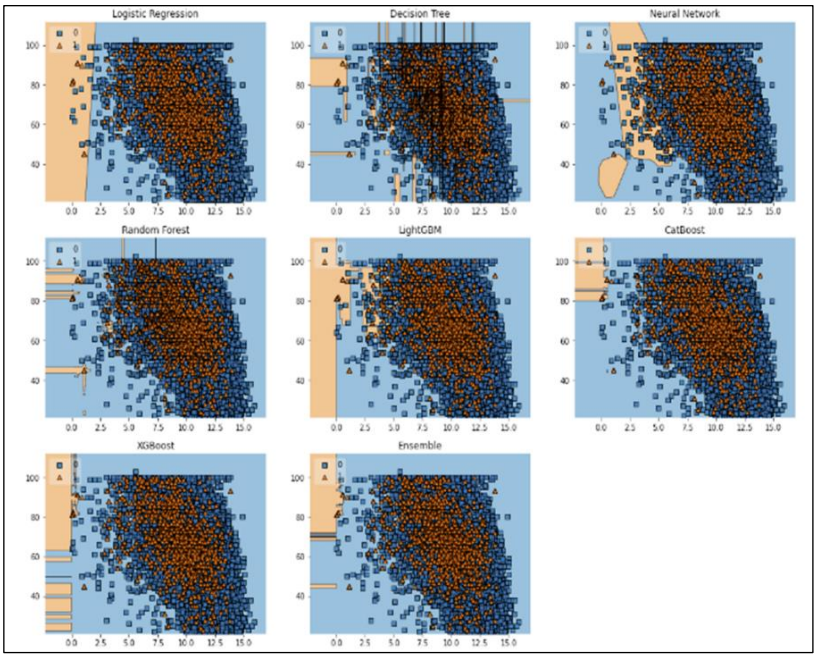


Figure 17: Rainfall Prediction with Machine Learning.
Source: Authors, (2024).

Table 2: Shows the result obtained by various statistical methods.

S.No.	*Machine Learning model*	*Accuracy*	*ROC area under curve*	*Cohen's kappa*	*Time Taken*
1	Logistic Regression	0.7896	0.7697	0.5494	4.4513
2	Decision Tree	0.8610	0.8585	0.7104	0.6607
3	Neural Network	0.8869	0.8803	0.7618	202.8766
4	Random Forest	0.9280	0.9265	0.8493	42.9188
5	Light GBM	0.8693	0.8615	0.7246	4.0714
6	CatBoost	0.9418	0.9494	0.8791	170.4877
7	XGBoost	0.9563	0.9565	0.9086	135.0937

Source: Authors, (2024).

V. CONCLUSIONS

In this study, we have used the dataset with 142193 entries and to work with such large data we have used multiple algorithms. These machine learning algorithms have made it easy to analyze the or to work with the large dataset furthermore the work that if done manually would have taken many days, but these algorithms save human efforts and time also, they are more accurate in many cases. This led us to use machine learning in our study.

In our study, we have used multiple algorithms that have worked well with this dataset but some of them have performed better than others. Out of all algorithms, XGBoost has performed best. Along with XGBoost algorithms like CatBoost and Random Forest have also performed well as they all have accuracies of more than 90%. Therefore, in the future, we may work with algorithms that use the same concepts that are used by the XGBoost algorithms

With this we can conclude that XGBoost has performed best according to our study, also algorithms using concepts of gradient boost perform well with this type of dataset and may be the best algorithm that may predict the floods in advance and with the help of that the government may take the prior actions in order to protect the people staying near the flood-prone area. With the help of our study and machine learning algorithms in the future we aim to build a proper structure that may help the citizens of India, also till now all the studies have been conducted related to Rainfall Induced floods but, in the future, we will also work on Glacier Induced floods.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Aryan Bisht, Asish Nath.
Methodology: Aryan Bisht.
Investigation: Aryan Bisht, Asish Nath and Pratibha Dimri
Discussion of results: Aryan Bisht, Asish Nath and Pratibha Dimri
Writing – Original Draft: Aryan Bisht, Asish Nath.
Writing – Review and Editing: Asish Nath.
Resources: Aryan Bisht, Asish Nath and Pratibha Dimri
Supervision: Asst. Prof. Pratibha Dimri.
Approval of the final text: Asst. Prof. Pratibha Dimri.

VII. ACKNOWLEDGMENTS

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Finally, we would also like to acknowledge and thank all the institutions and organizations that we've referred to, throughout this paper. It would have been hard to collect all this knowledge without the right references.

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