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A Predictive Model for Identifying Forest Fire-Prone Zones

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Abstract: *Forest fire frequency and intensity are rising due to climate change, which is having catastrophic repercussions on ecosystems and humans. This article assesses a substantial amount of scientific material to demonstrate how temperature, vegetation dynamics, and precipitation patterns all affect the risk of wildfire. These fires have terrible effects in addition to higher carbon emissions, destroyed biodiversity, and financial costs. To counteract these effects, immediate action is needed in the form of regulations to reduce greenhouse gas emissions, planning for sustainable land use, early warning systems, and improved fire management practices. We need to address the connection between climate change and fire in order to safeguard our forests and ensure the well-being of the affected populations. We discovered a range of Mean Squared Error (MSE) values when analyzing several regression models in the field of predictive modeling for the outcomes of forest fires. Specifically, the MSEs obtained from Lasso Regression were 8124.705 and Ridge Regression were 8116.007. With a notably lower MSE of 8063.459, the Random Forest Regression model unexpectedly performed better than its rivals. This suggests that when it comes to prediction accuracy, the Random Forest model outperforms the other models, indicating that it could be a more valuable tool for modeling and predicting the study's target variable. Remarkably, the Support Vector Machine (SVM) Regression model yielded an MSE of 8154.193, demonstrating the superiority of the Random Forest model even further.These results highlight the need of using cutting-edge modelling methods, such Random Forest Regression, to tackle the urgent problem of forest fires made worse by climate change.*

Keywords: **Lasso Regression, KNN, Forest Fire , Machine Learning, Climate Change**

1. Introduction

Climate change poses a severe threat to the planet's ecosystems, with wooded areas being especially vulnerable to its effects. This study aims to identify certain forest regions that are susceptible to forest fires using a machine learning system.Modern machine learning techniques like lasso and ridge regression and knn modelling are used to study the relationship between meteorological variables including temperature, rainfall, and wind patterns. This study identifies the main climatic causes and their consequences on fire behavior, providing significant new insights into how the dynamics of forest fires are changing in the context of global warming. The impact of increasing fire frequency and severity on forest ecosystems—including the loss of biodiversity, carbon emissions, and forest regeneration—is also examined in this study. These findings are critical for planners, land managers, and conservationists trying to develop workable strategies for mitigating and adapting to the changing fire regime in forested areas.Ultimately, this study adds to our understanding of the complex interactions between forest fires and climate change and lays the groundwork for preventative actions that will protect and maintain these vital ecosystems in the face of rapidly shifting weather patterns.The study's findings have far-reaching implications for climate change adaptation and mitigation strategies. Understanding how forest fire behavior is impacted by climate change is essential for enhancing early warning systems, preparing firefighters, and land-use planning. In order to strengthen resistance to future fire outbreaks, the study also emphasizes the importance of restoring ecosystems that are suited to fire and using sustainable forest management techniques.Ultimately, this study adds to our understanding of the complex interactions between forest fires and climate change and lays the groundwork for preventative actions that will protect and maintain these vital ecosystems in the face of rapidly shifting weather patterns. As we deal with more frequent and devastating forest fires, the study's recommendations are even more crucial for preserving the ecological, economic, and social services that forests offer.

Fig 1.Satellite Image of Forest Fire
(ImageCredit:https://www.hindustantimes.com/india-news/nasa-satellites-show-fires-still-raging-over-similipal-rest-of-odisha-101614927032452.html)

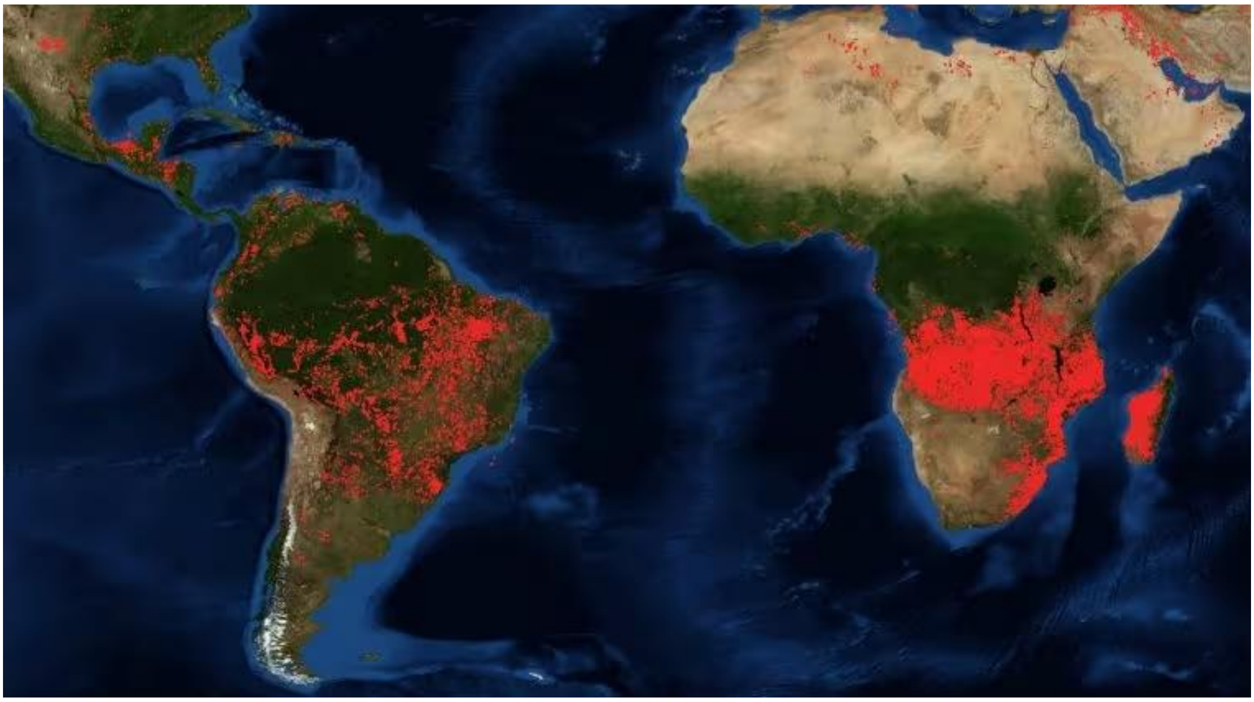

Fig2. Satellite Images showing Forest Fire in Africa
(Imagecredit:https://indianexpress.com/article/technology/science/nasa-satellite-images-show-central-africa-forest-fires-more-intense-than-that-of-amazon-5941162/)

2. Literature Review

The research conducted by Indu.V et al. [1]The main risk that users of online social networks have to deal with is the spread of rumors. Rumor transmission is greatly decreased by analyzing the pattern of rumor dispersion in social networks, which is made possible by modeling rumor propagation. Many factors affect the widespread dissemination of rumors in social networks, but pinpointing the crucial elements is crucial to accurately and swiftly modeling the spread of rumors. In this study, we present a novel method that is inspired by nature and concentrates on identifying the most suitable characteristics to mimic the propagation of rumors in virtual social networks. The proposed approach draws a comparison between the propagation of rumors within social networks and the development of wildfires within forests. The main factors involved in modeling the propagation of rumors are determined by examining the main causes of forest fires. We have developed a revolutionary algorithm based on the Forest Fire model and inspired by nature. It assesses the level of rumor propagation over a network by identifying the nodes affected by the rumor and uses the detected salient attributes to determine the likelihood that a node would propagate a rumor. The proposed method also identifies the critical nodes in the rumor transmission process by examining the nodes that shared the rumor and analyzing their circulation patterns. The results of the experiment show how well our recommended approach and selected traits work. We used two datasets extracted from Twitter to evaluate the effectiveness of the suggested strategy. Furthermore, we offer a rumor propagation graph that facilitates the analysis of the pattern of rumor dissemination and highlights the key participants in the process. We also provide a feature-level comparison with several rumor modeling methodologies to show how effectively the proposed technique matches the forest fire spread with the problem of rumor spreading.

The research done by Vipin Venugopal and colleagues [2] To identify forest fires, a novel approach to image processing is proposed. To classify fire pixels, a rule-based color model is utilized. The recommended approach makes use of the YCbCr and RGB color spaces. The advantage of using YCbCr color space over RGB is that it can separate brightness and chrominance more effectively. The effectiveness of the proposed method is assessed using two sets of pictures, one of which has areas that resemble fire and the other of which has fire. The performance of the algorithm is computed with traditional methods. The recommended method has a higher detection rate and a lower false alarm proportion.Due to its low computing costs, the method may be used for real-time forest fire detection. Keywords: image processing, segmentation of images, rule-based color model, detection of forest fires.The research done by C.Emmy Permal and colleagues [3].The YCbCr color model is recommended by this study for image processing-based forest fire detection. The recommended method makes use of a rule-based color model due to its effectiveness and ease of usage. The YCbCr color space effectively separates luminance from chrominance in contrast to other color schemes like RGB and rgb(normalized RGB). The proposed method separates high temperature fire center pixels from fire flame pixels by utilizing statistical properties of the fire image in the YCbCr color space, such as mean and standard deviation. Using four rules, this method separates the actual fire zone into four categories.Two rules are used to split the fire region into two segments, and two more rules are used to divide the high temperature fire center into two segments. In comparison to other methods in the literature, the results show a higher rate of true fire detection and a lower percentage of false detection. The proposed method could be used to detect forest fires in real time with a moving camera. The Yongqi Pang et al. experiment was released. *[4] Forest fires can have a devastating effect on both the ecosystem and human lives. Anticipating when forest fires may occur is crucial to preventing them. Studies on the capacity to predict forest fires in China over extended periods of time are still few. This is due to the unpredictability of forest fires. Numerous factors affect the probability of forest fires. When utilising standard analysis, it is unclear what percentage each component specifically contributed to the occurrence of forest fires. In order to combine data from many sources (such as fire hotspots, climatic conditions, topography, vegetation, and socioeconomic data collected from 2003 to 2016), we used artificial intelligence systems, which excel at doing so. Four techniques were finally selected for formal data processing after a series of tests. Using an artificial neural network, a random forest, a support-vector machine, and a radial basis function network, the thirteen primary causes of forest fires in China were identified. The models were evaluated using the five performance measures of area under the curve, f1 value, accuracy, precision, and recall. We were able to calculate the probability of forest fires happening in every Chinese province by using the ideal model. A map showing the high-to-low risk zones for forest fires was also made. The four forest fire prediction models had predicted accuracy ranges of 75.8% to 89.2%, while the area under the curve (AUC) values ranged from 0.840 to 0.960. The research done by C. Yuvan and colleagues.(5) This study suggests utilizing unmanned aerial vehicles (UAVs) to track and detect forest fires. First, a summary of a UAV-based system for monitoring and identifying forest fires is provided. Next, a set of algorithms is developed for the purpose of identifying and monitoring forest fires. Blob counting, color space conversion, median filtering, Otsu threshold segmentation, and Otsu space conversion are a few of these. The core idea of the proposed method is to extract fire-pixels by utilizing the color properties of fire through the usage of the Lab color model's channel "a". Numerous experimental validations have demonstrated the effectiveness of the proposed method in extracting the fire pixels and monitoring the fire zone.The research done by Jiao Zhentian and colleagues.(6) Unmanned aerial vehicles (UAVs) are being used more and more in the monitoring and detection of forest fires because of their excellent mobility and ability to cover a range of terrain at various heights and places at a very low cost. Even though traditional fire detection algorithms mostly use the RGB color scheme, they still need to be made faster and more accurate. This paper proposes a strategy for identifying forest fires by combining YOLOv3 with UAV-based aerial pictures. To begin with, a UAV platform is developed with the goal of identifying forest fires. Next, YOLOv3 is used to build a small-scale convolution neural network (CNN) based on the available computational capacity of the onboard hardware. Test results show that this method has a detection frame rate of more than 3.2 fps and a recognition rate of almost 83%. There are numerous advantages to using UAVs in this real-time forest fire detection system.The research done by Qilin Xue and colleagues.(7)Big, fierce forest fires can cause a lot of damage and be challenging to put out. Depending on the surrounding conditions, different fire behaviors might occur in different locations. Based on the location and degree of damage caused by forest fires, this study examines the classification and identification of surface fires and canopy fires. Deep learning-based forest fire identification uses convolutional neural networks to automatically extract multidimensional variables with high detection accuracy from pictures of forest fires. In order to effectively identify various forest fire types in complex backgrounds, this work offers an improved forest fire classification and detection model (FCDM) based on YOLOv5. Substituting SIoU Loss for the YOLOv5 bounding box loss function and adding directionality to the loss function's cost to accelerate convergence significantly improves the detection algorithm's training and inference. The network is enhanced using the Convolutional Block Attention Module (CBAM) to improve the accuracy of categorization recognition. It blends spatial attention with channel attention.The Path Aggregation Network (PANet) layer of the YOLOv5 algorithm is improved into a weighted Bi-directional Feature Pyramid Network (BiFPN) in order to improve the identification of different types of forest fires by fusing and filtering features with different dimensions. The experimental results show that our improved model outperforms the YOLOv5 algorithm in both detection performances when it comes to categorizing and recognizing forest fires. The mAP@0.5 improvements for fire detection, surface fire detection, and canopy fire detection were 3.9%, 4.0%, and 3.8%, in that order. Among them, 83.1% of surface fires had a mAP@0.5 and 90.6% of canopy fires were detected. This demonstrates how well our new model has performed, and it may have some useful applications in the identification and classification of forest fires.The study conducted by Chi Yuan and colleagues [8] Presently, computer vision systems based on unmanned aerial vehicles (UAVs) are widely used, and they show great promise as a means of monitoring and identifying forest fires. This research presents an image processing method for UAV application that includes the automated detection of forest fires in infrared (IR) photos. The methodology provided uses image processing techniques based on brightness, motion cues, and segmentation based on histograms to detect fire pixels. The hot items are initially retrieved using histogram-based segmentation as areas that could possibly catch fire. The motion vectors of the potential locations are then ascertained using the optical flow technique. The motion vectors are also analyzed in more detail in order to distinguish flames from other fire imitators. Using morphological methods and the blob counting approach, each infrared photo may be used to identify a fire. Experimental results show that the presented technique can effectively extract and track fire pixels in infrared video sequences.The research done by Robin and colleagues.In [9]While surveying less well-known wood species in eastern Gabon, a unique Dialium morphospecies was discovered. To differentiate it from the two other 2–5 leaflet Dialium species, 25 leaf features were measured on 45 trees (16 Dialium pachyphyllum, 14 Dialium lopense, and 15 Dialium sp. nov.). Nine wood chemical properties and infrared spectra were also examined on four harvestable Dialium pachyphyllum and four Dialium sp. nov. trees. Seven distinctive leaf traits were found in this investigation, which made it possible to create a field identification key. Five significant differences in sapwood and four in heartwood were found in the composition of the wood.The PLS-DA technique using FT-IR wood spectra allowed for the accurate identification of the novel morphospecies. These results provide strong support for the designation of a new species for this genus.The research conducted by Hu et al.10] One of the largest ecological hazards is a forest fire, which can be detected early thanks to smoke. Smoke is only visible in a very tiny area in photos shot early in the smoke's occurrence or when the smoke is far from the camera. Due to modest pixel-based features, smoke dispersion is uneven and the backdrop environment is dynamic and complicated, making smoke identification challenging. In this work, we present a multioriented detection method based on Mixed-NMS (MVMNet) and a value conversion-attention mechanism module. First, a multioriented detection method is proposed.Unlike conventional detection methods that do not include an angle parameter in the data loading process, the classification prediction approach calculates the target's rotation angle and has reference relevance for determining the direction of the fire source. Next, an approach called Softpool-spatial pyramid pooling (Soft-SPP) is proposed to address the problem of uneven picture input size while retaining more feature information. Then, we construct a value conversion-attention mechanism module (VAM) that can specifically extract the color and texture of the smoke by utilizing a combined weighting technique in both the horizontal and vertical directions. Utilizing the DIoU-NMS and Skew-NMS hybrid nonmaximum suppression approaches, the issues of smoke false detection and missed detection are resolved. Experiments are conducted using the in-house multioriented forest fire detection system.Unlike conventional detection methods that do not include an angle parameter in the data loading process, the classification prediction approach calculates the target's rotation angle and has reference relevance for determining the direction of the fire source. Then, in order to address the problem of uneven picture input size while retaining more feature information, Softpool-spatial pyramid pooling (Soft-SPP) is proposed. Finally, we construct a value conversion-attention mechanism module (VAM) that can specifically extract the color and texture of the smoke by employing a combined weighting technique in both the horizontal and vertical directions. The DIoU-NMS and Skew-NMS hybrid nonmaximum suppression techniques are applied to address the issues of smoke false detection and missed detection. The research conducted by Rihan and colleagues [11]In the hilly area of the Western Himalayas, forest fires play a significant role in the devastation of forests and decline of biodiversity. Therefore, addressing the issue of forest fires is essential to reducing the effects of these events. Thus, the objective of this research is to assess and map the regions in Uttarakhand, a hilly state, that are susceptible to forest fires utilizing geospatial methods, deep learning-based sensitivity and uncertainty assessments, and machine learning algorithms (MLA). Thirteen forest fire ignition factors were used to map the vulnerability to forest fires.We also used five different machine learning algorithms (MLAs): an ensemble machine learning model, logistic regression, random forests, support vector machines (SVM), and artificial neural networks (ANN). The proposed models were validated through the application of receiver operating characteristic (ROC). The results show that the "very high" and "high" zones for forest fires span more than 55% of Uttarakhand's entire geographical area. Upon validation, all the models produced very meaningful results. The most accurate method was ensemble machine learning (AUC = 0.977), followed by RF (0.973) and ANN (0.972). Furthermore, it is advised to use a Deep Neural Networks (DNN) based sensitivity technique to do a sensitivity and uncertainty analysis of the ignition parameters. We select the most effective prediction model (Ensemble Machine Learning) in order to evaluate the sensitivity and uncertainty analyses. Evapotranspiration is the factor that most affects forest fires, according to the sensitivity analysis. Other factors that are related to forest fires are wind speed, yearly rainfall, distance from tourist destinations, agricultural areas, and heavily populated areas. On the other hand, the susceptibility of this research area to forest fires was less affected by aspect, temperature, and closeness to holy places. This work is unique in that it provides new insights into the construction of an ensemble machine learning model and the incorporation of sensitivity and uncertainty based on DNNs for accurate and dependable forest fire susceptibility prediction.It will be helpful to comprehend how a single parameter sample influences forest fire susceptibility using a special strategy, as demonstrated by the contribution of parameters, in order to design preventative measures. For mapping forest fire vulnerability, other parts of the world with similar human and natural variables might use a similar approach. The investigation conducted by Lin Xufeng et al.[12] Modeling and occurrence prediction play a major role in forest fire prevention. Forest fires are considered a high-risk natural disaster on a worldwide scale. As a result, many countries have conducted the required study and acknowledged that forecasting mountain fires is an essential part of managing and preventing wildfires. In this work, a model for predicting forest fires based on LSTNet is proposed to improve the accuracy of forest fire forecasts. Data on the factors influencing forest fires are collected using remote sensing satellites and GIS, and their association is examined using multicollinearity tests and Pearson correlation analysis. In order to account for the spatial aggregation of forest fires, the LSTNet forest fire prediction model was developed based on eight major criteria. The data set was constructed utilizing proportionate stratified sampling and oversampling procedures. After the predicted data were incorporated into the model, the predicted risk map of forest fires in Chongli, China, was produced. This study shows that the proposed LSTNet model has a high accuracy (ACC 0.941) when comparing traditional machine learning techniques utilizing metrics such as RMSE. This study shows how the model can effectively use spatial background knowledge and the periodicity of forest fire components. The model is a novel way for geographic prediction of forest fire susceptibility. The research done by Lin and colleagues [12]Modeling and occurrence prediction play a major role in forest fire prevention. Forest fires are considered a high-risk natural disaster on a worldwide scale. As a result, many countries have conducted the required study and acknowledged that forecasting mountain fires is an essential part of managing and preventing wildfires. In this work, a model for predicting forest fires based on LSTNet is proposed to improve the accuracy of forest fire forecasts. 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The model is a novel way for geographic prediction of forest fire susceptibility.The research done by Sivrikaya and associates [13] This study suggested a comprehensive method for creating a map of the danger of forest fires. Applications included the use of a statistical index (SI), the analytical hierarchy process (AHP), and geographic information system-based multiple criteria decision analysis (GIS-MCDA). The study was carried out in the Mersin Regional Directorate of Forestry (RDF) in the eastern Mediterranean region of Turkey. Four main criteria—forest structure, topography, environment, and climate—as well as sixteen subcriteria were used to create the fire risk map. Each criterion's relative importance was ascertained using the AHP. The AHP model states that the two factors that have the biggest influence on how quickly forest fires spread are environmental conditions and forest structure. In order to assess the results, 990 historical forest fire ignition locations were gathered using the Mersin RDF. More than 85% of the ignition locations were found in areas with a high or extremely high risk of forest fires, according to the forest fire risk map. The findings suggest that there is a high probability of forest fires happening within the studied area. The accuracy of the fire risk map was verified using the area under the curve and the relative operating characteristic curve. The validation of the AHP model produced a very high accuracy of 0.775, demonstrating a great degree of precision in mapping the risk of forest fires. The research done by Zhong and colleagues [14] In video-based fire detection systems, wavelet was frequently utilized to identify whether a pixel is in a fire zone and fast Fourier transform was used to characterize the fire area's contour. We evaluate these two methods using forest fire photographs and develop a novel methodology that combines FFT and wavelet. Our method first determines the contour of the fire, displays it via FFT, and then looks at the FFT descriptors from each frame of a video clip using temporal wavelet.While eliminating the contour threshold value setting in the FFT approach, our method detects fire frames more accurately than the wavelet method. The research done by Hosseini and colleagues [15]Government officials employ burn susceptibility mapping to forecast wildfire risks and provide the appropriate emergency management measures. We examined ensemble techniques and Gene Expression Programming (GEP) for creating wildfire susceptibility maps using Victoria, Australia as a case study. Bushfire risk is highest in Victoria's eastern region, where forests are the predominant land cover, according to maps illustrating wildfire vulnerability. The western part of Victoria, which is primarily agricultural with some shrubland and grassland, has the lowest chance of experiencing a fire. Two ensemble approaches—an ensemble of GEP and Frequency Ratio (GEPFR) and an ensemble of Logistic Regression and Frequency Ratio (LRFR)—were contrasted with a stand-alone GEP technique and a stand-alone Frequency Ratio (FR) approach.AUC, or Area Under Curve, was employed to evaluate the recommended strategies. GEPFR, LRFR, GEP, and FR have respective AUCs of 0.860, 0.852, 0.850, and 0.840. In summary, ensemble methods outperform stand-alone methods, and GEPFR outperforms the other three approaches. Better natural hazard management solutions are therefore beneficial to both managers and policy makers. The wildfire probability was reported by GEPFR, LRFR, and GEP with an accuracy ranging from 90.79% to 92.27%.

3. Proposed Methodology

The methodology employed in the forest fire regression analysis comprised a systematic series of steps intended to fully understand and predict forest fire zones. The initial step involved loading the data, and the forest fire dataset (forestfires.csv) was imported using pandas. The month and day of the fires, the weather, and the extent of the afflicted regions were among the many parameters included in this dataset, which formed the basis for more research. Data collecting was an essential part. The two key elements were target variable transformation and categorical encoding. Using the scikit-learn tool LabelEncoder, the categorical columns "month" and "day" were encoded as numbers to aid the models in handling these features. The target variable "area," which indicated the magnitude of the forest fire, underwent a logarithmic transformation as a result of np.log1p. This change improved the data stability by addressing potential issues brought on by skewed data distributions. Training set (70%) and testing set (30%) were created from the dataset using train_test_split and a predefined random seed for repeatability. To ensure consistent feature scaling across all attributes and prevent any one feature from significantly influencing the models, standardization was employed.Feature selection was another crucial element of the method. Using the SelectKBest technique in conjunction with the f_regression scoring function, the top five most relevant features were identified based on their correlation with the target variable. By focusing on the most valuable aspects at this point, the modeling process was shortened.Feature selection was another crucial element of the method. Using the SelectKBest technique in conjunction with the f_regression scoring function, the top five most relevant features were identified based on their correlation with the target variable. By focusing on the most valuable aspects at this point, the modeling process was shortened.To ensure that the forecasts could be understood, np.expm1 was used to return the scale from the log-transformed scale to the original scale. Model performance was evaluated using Mean Squared Error (MSE), which compares the accuracy of predictions to actual values from the test set.An analysis of correlation is one step in the procedure. The model produced a correlation matrix, which was used to analyze relationships between the variables in the dataset. A heatmap visualisation was created using *seaborn* to visually represent these correlations. As a result, it was simpler to spot possible connections and patterns in the dataset, which significantly improved the quality of the research as a whole. To sum up, this well-structured approach provided a comprehensive plan for handling data, testing regression models, assessing their performance, and learning more about the machine learning techniques used to anticipate forest fires.

4. Results

Three separate regression models were employed in our analysis to forecast the target variable. By examining the Lasso Regression model's Mean Squared Error (MSE), which was approximately 8124.71, we can evaluate the model's efficacy. The Ridge Regression model, like the prior one, demonstrated an MSE of about 8116.01, demonstrating its ability to predict the target variable. Additionally, the Random Forest Regression model showed an MSE of about 8063.46, indicating that it was effective in generating predictions based on the data that was provided. These MSE values offer crucial information about the performance of each regression model used in our investigation.

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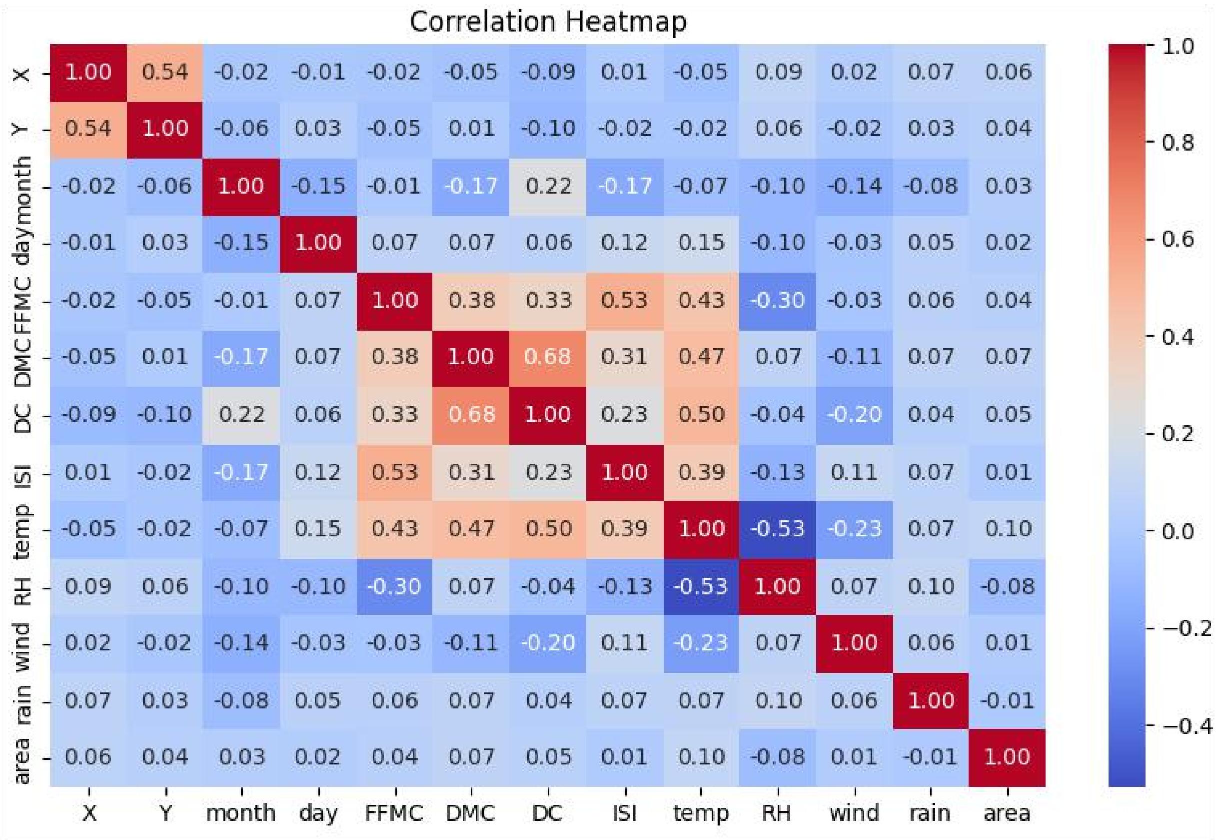

Fig 8. Confusion matrix showing the model's performance

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