

Fire Weather Index Prediction

Machine Learning Model To Predict Fire Whetehr Index



Infosys Springboard virtual Internship Program

Submitted By

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Project Statement:

Wildfires pose a significant threat to ecosystems, human life, and property. The Fire Weather Index (FWI) is a crucial tool used by meteorological and environmental agencies worldwide to estimate wildfire potential. This project aims to build a machine learning model that predicts FWI based on real-time environmental data, enabling proactive wildfire risk management. The model is trained using Ridge Regression, deployed via a Flask web application, and supports early warning systems for wildfire hazards.

Outcomes:

- A predictive ML model trained using Ridge Regression to forecast FWI.
- A pre-processing pipeline using StandardScaler for normalization.
- A Flask-based web app where users can input environmental values and get FWI prediction.
- A system that can help forest departments, emergency planners, and climate researchers make data driven decisions.

Modules to be implemented

- Data Collection
- Data Exploration (EDA) and Data Preprocessing
- Feature Engineering and Scaling
- Model Training using Ridge Regression
- Evaluation and Optimization
- Deployment via Flask App
- Presentation and Documentation

Milestone 1 – Data Collection & Preprocessing

1. Import Required Libraries

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from sklearn.preprocessing import LabelEncoder
import math
```

2. Load the Dataset

```
data=pd.read_csv("C:/Users/autad/Downloads/FWI
Dataset.csv")
print(data.head())
```

Output -

day	month	year	Temperature	RH	Ws	Rain	FFMC	DMC	DC	ISI	BUI	
0	1	6	2012	29	57	18	0.0	65.7	3.4	7.6	1.3	3.4
1	2	6	2012	29	61	13	1.3	64.4	4.1	7.6	1.0	3.9
2	3	6	2012	26	82	22	13.1	47.1	2.5	7.1	0.3	2.7
3	4	6	2012	25	89	13	2.5	28.6	1.3	6.9	0.0	1.7
4	5	6	2012	27	77	16	0.0	64.8	3.0	14.2	1.2	3.9

	FWI	Classes	Region
0	0.5	not fire	Bejaia
1	0.4	not fire	Bejaia
2	0.1	not fire	Bejaia
3	0	not fire	Bejaia
4	0.5	not fire	Bejaia

3. Initial Inspection of the Dataset

```
data.info()
data.describe()
data.isnull().sum()
```

Explanation :

The dataset was inspected to understand feature types, data ranges, and overall distribution. This step helps identify missing values, incorrect data types, and potential preprocessing requirements before model training.

4. Fix Data Type Issues

```
# Handling Missing Values

data['DC'] = data['DC'].astype(str).str.replace(' ', '',
regex=False)
data['FWI'] = data['FWI'].astype(str).str.replace(' ', '',
regex=False)

data['DC'] = pd.to_numeric(data['DC'], errors='coerce')
data['FWI'] = pd.to_numeric(data['FWI'], errors='coerce')
data.info()
```

Output -

Data columns (total 15 columns):

#	Column	Non-Null Count	Dtype
0	day	244	non-null int64
1	month	244	non-null int64
2	year	244	non-null int64
3	Temperature	244	non-null int64
4	RH	244	non-null int64
5	Ws	244	non-null int64
6	Rain	244	non-null float64
7	FFMC	244	non-null float64
8	DMC	244	non-null float64
9	DC	244	non-null float64
10	ISI	244	non-null float64
11	BUI	244	non-null float64
12	FWI	244	non-null float64
13	Classes	243	non-null object
14	Region	244	non-null object

dtypes: float64(7), int64(6), object(2)

memory usage: 28.7+ KB

5. Identify rows with missing values

```
null_rows = data[data.isnull().any(axis=1)]
print("Rows with missing values:\n", null_rows)
```

Output -

```
Rows with missing values:  
day month year Temperature RH Ws Rain FFMC DMC DC ISI  
165 14 7 2012 37 37 18 0.2 88.9 12.9 14.69 12.5
```

```
BUI FWI Classes Region  
165 10.4 0.4 NaN Sidi-Bel Akbes
```

6. Fill missing values using mode

```
for col in data.columns:  
    data.loc[:, col] =  
        data[col].fillna(data[col].mode()[0])  
  
    # Drop remaining missing values  
    data.dropna(inplace=True)  
  
data.isnull().sum()
```

Output -

```
day      0  
month    0  
year     0  
Temperature 0  
RH       0  
Ws       0  
Rain     0  
FFMC    0  
DMC     0  
DC      0  
ISI     0  
BUI     0  
FWI     0  
Classes  0  
Region   0  
dtype: int64
```

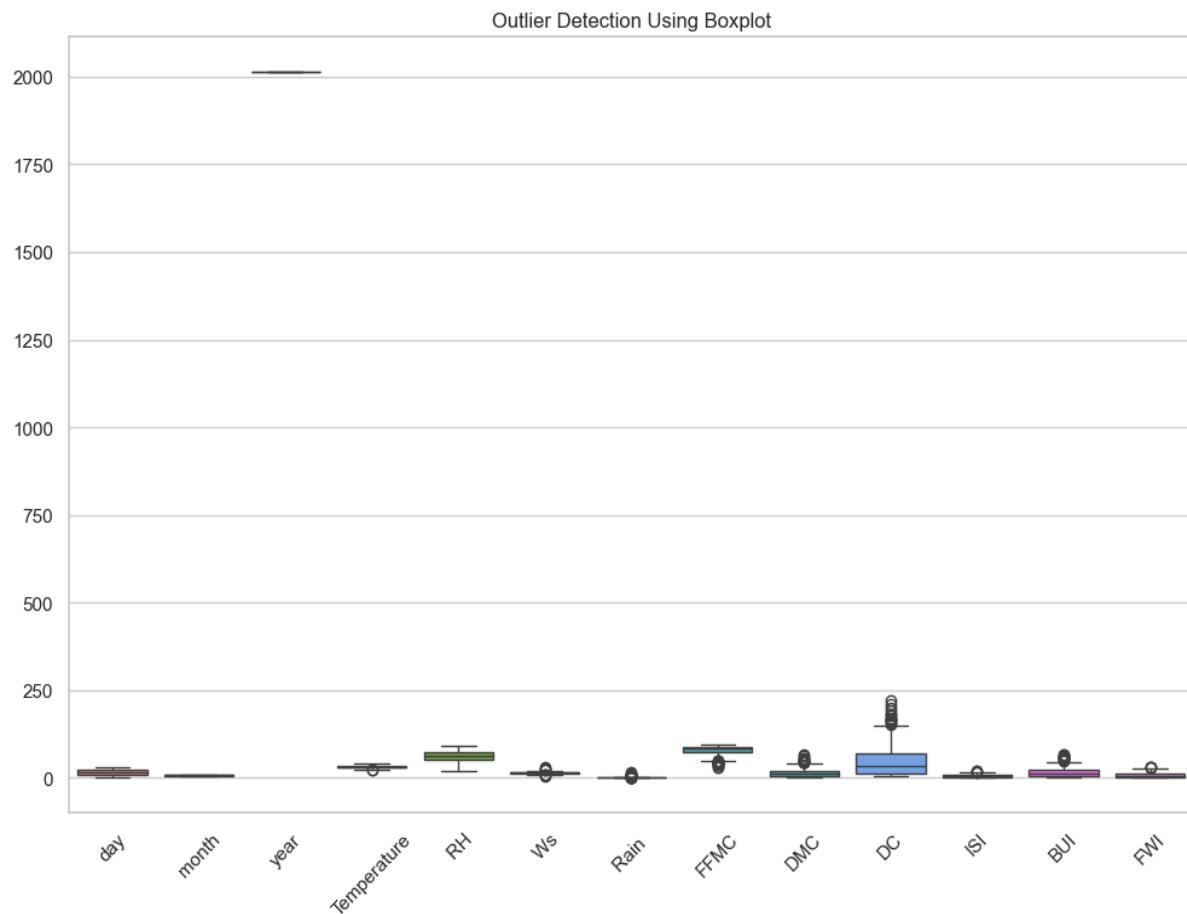
Explanation :

Missing and inconsistent values were identified and handled appropriately to ensure data quality. Numerical inconsistencies were corrected and missing categorical values were filled using the mode to maintain dataset integrity.

7. Outlier Detection Using Boxplots

```
plt.figure(figsize=(12, 8))
sns.boxplot(data=data)
plt.xticks(rotation=45)
plt.title("Outlier Detection Using Boxplot")
plt.show()
```

Output



Explanation :

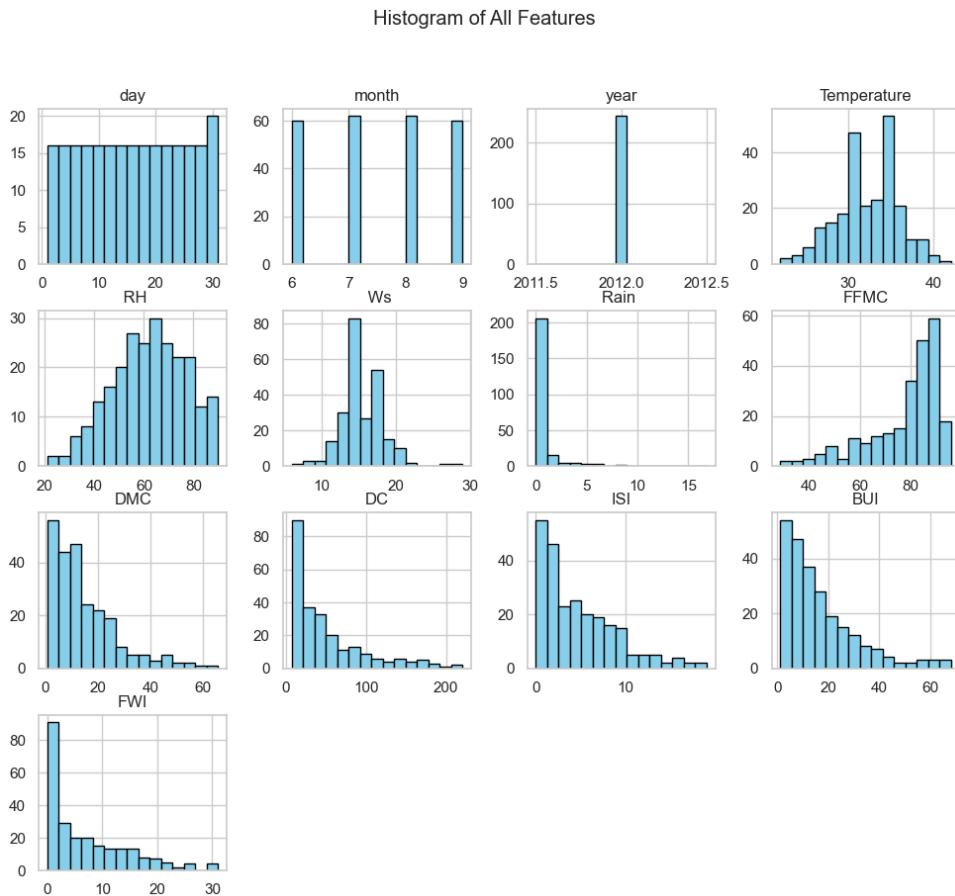
Boxplots were used to detect the presence of outliers in numerical features. This analysis helps understand data spread and ensures that extreme values do not negatively impact model performance.

8. Histograms for All Features

```
data.hist(figsize=(12, 10), bins=15, color='skyblue',
edgecolor='black')
```

```
plt.suptitle("Histogram of All Features")
plt.show()
```

Output -



Explanation :

Histograms were plotted to analyze the distribution of each numerical feature. This visualization provides insights into data skewness, variability, and overall feature behavior.

9. density plots for numerical features

```
# Select numerical columns
num_cols = sorted([col for col in data.columns if
data[col].dtype != "object"])

valid_cols = []

# Filter out columns with zero variance
for col in num_cols:
```

```

if data[col].nunique() > 1:
    valid_cols.append(col)

cols = 3
rows = math.ceil(len(valid_cols) / cols)

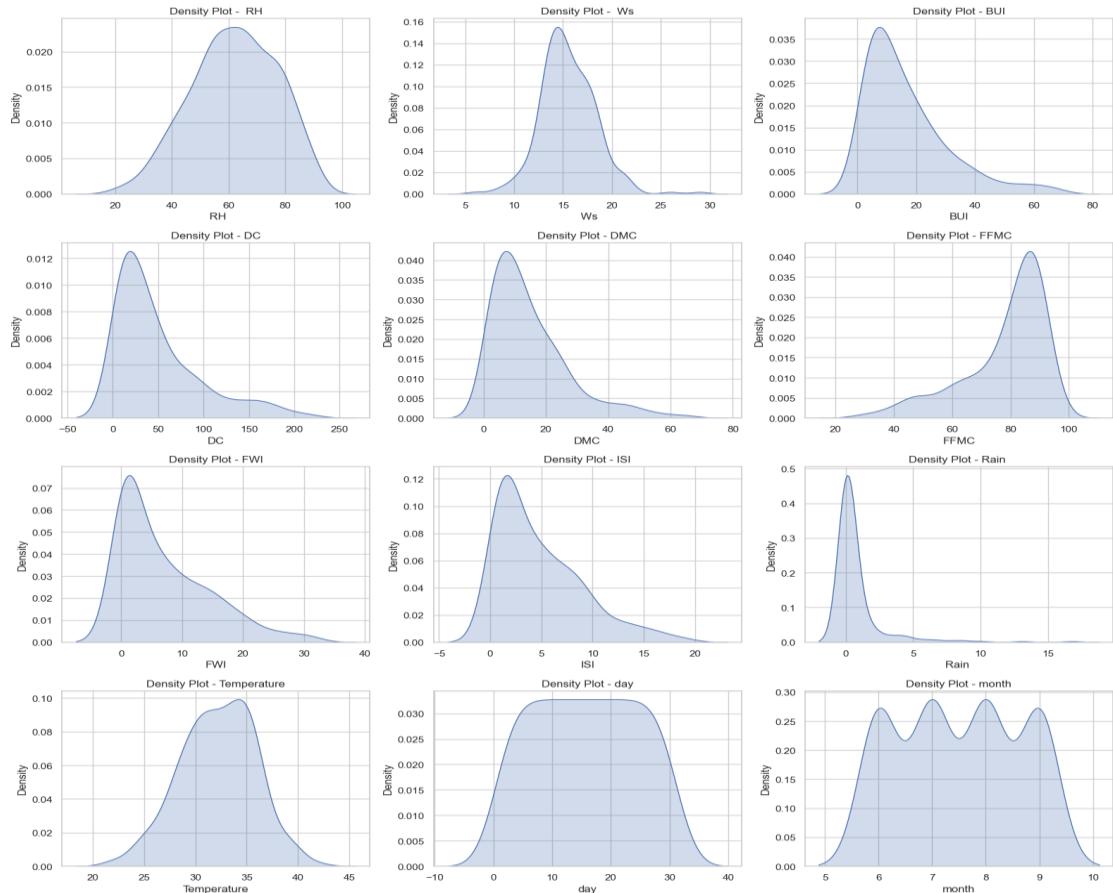
plt.figure(figsize=(16, 4 * rows))

for i, col in enumerate(valid_cols, start=1):
    plt.subplot(rows, cols, i)
    sns.kdeplot(data[col], fill=True)
    plt.title(f"Density Plot - {col}")
    plt.xlabel(col)
    plt.ylabel("Density")

plt.tight_layout()
plt.show()

```

Output –



Explanation :

Density plots were used to visualize the probability distribution of numerical features. This helps in understanding data concentration and smooth distribution patterns.

10.Scatter Plots of Numerical Features vs FWI

```
um_cols      = [col      for      col      in
data.select_dtypes(include=['float64',    'int64']).columns
if col != "FWI"]

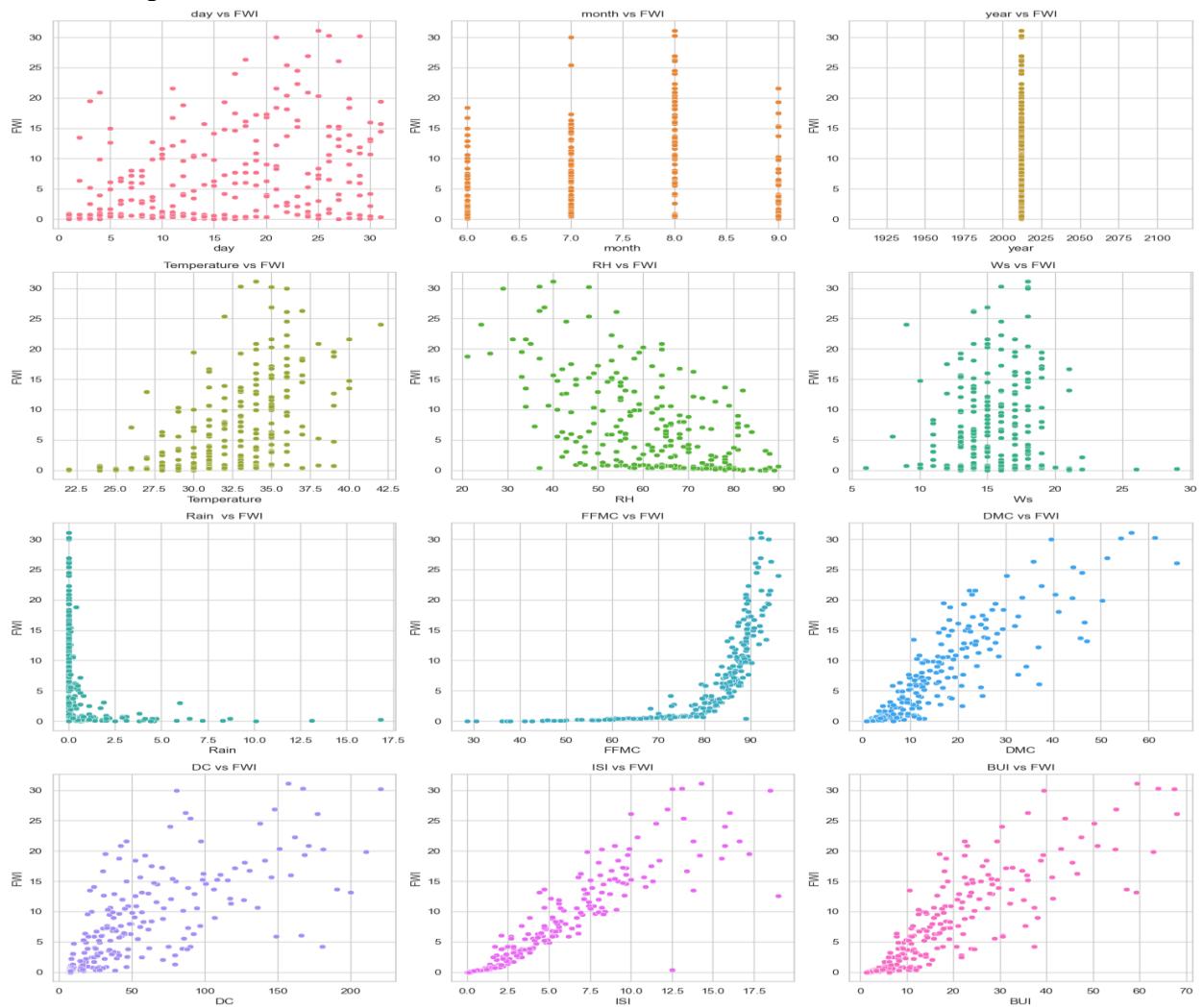
palette  = sns.color_palette("husl",  len(num_cols))    #
colorful palette
cols = 3
rows = math.ceil(len(num_cols) / cols)

plt.figure(figsize=(15, 5 * rows))

for i, col in enumerate(num_cols, start=1):
    plt.subplot(rows, cols, i)
    sns.scatterplot(x=data[col],           y=data["FWI"],
color=palette[i-1])
    plt.xlabel(col)
    plt.ylabel("FWI")
    plt.title(f"{col} vs FWI")

plt.tight_layout()
plt.show()
```

Output



Explanation :

Scatter plots were generated to analyze the relationship between each feature and the Fire Weather Index (FWI). This helped identify positively and negatively correlated features influencing fire risk.

11. Correlation Heatmap

```
plt.figure(figsize=(7, 8))
corr
data.select_dtypes(include=['float64','int64']).corr()

mask = np.triu(np.ones_like(corr, dtype=bool))
```

```

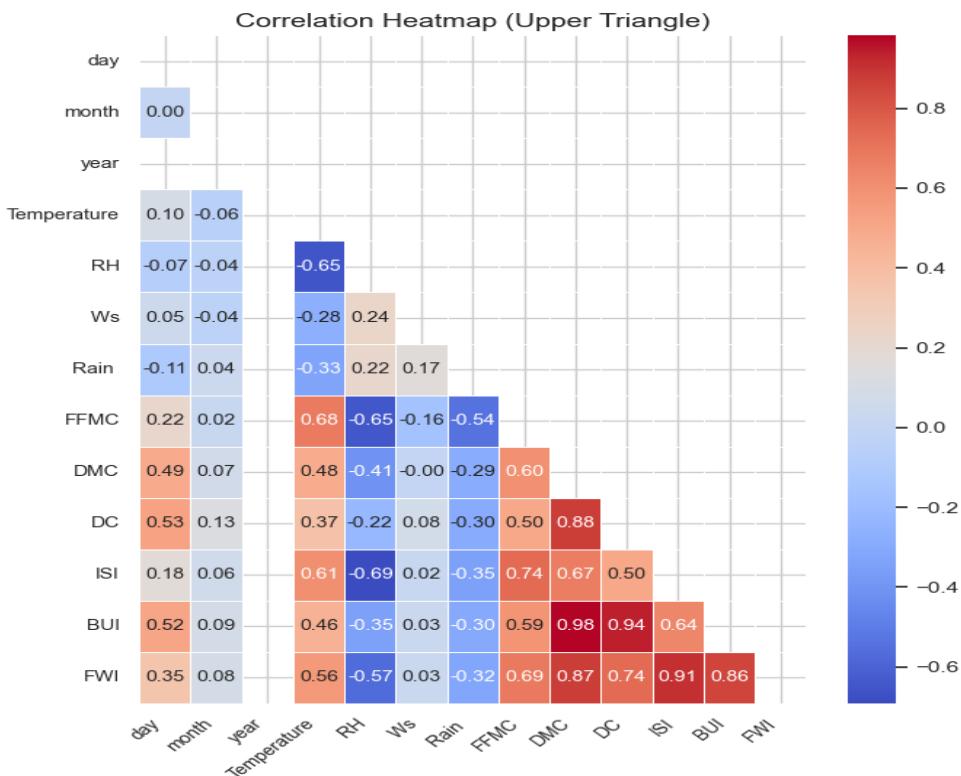
ax = sns.heatmap(
    corr,
    annot=True,
    cmap="coolwarm",
    fmt=".2f",
    mask=mask,
    linewidths=0.5,
    annot_kws={"size": 10}
)

plt.xticks(rotation=45, ha="right", fontsize=10)
plt.yticks(fontsize=10)

plt.title("Correlation Heatmap (Upper Triangle)",
          fontsize=14)
plt.tight_layout()
plt.show()

```

Output -



Explanation :

A correlation heatmap was used to quantify the relationship between numerical variables. Strong correlations with FWI guided the selection of important features for model training.

12.Encoding Categorical Variables

```
if "Region" in data.columns:  
    le = LabelEncoder()  
    data["Region"] = le.fit_transform(data["Region"])
```

13.Save the Dataset

```
data.to_csv("cleaned_FWI_dataset.csv", index=False)  
print("Cleaned dataset saved successfully!")
```

Output -

Cleaned dataset saved successfully!

Milestone 2 - Week 3-4

Module 3: Feature Engineering and Scaling

14. Imports

```
import pandas as pd
from sklearn.model_selection import train_test_split
import pickle
from sklearn.preprocessing import StandardScaler
from sklearn.linear_model import LinearRegression, Ridge,
Lasso
from sklearn.ensemble import RandomForestRegressor
from     sklearn.metrics      import      mean_absolute_error,
mean_squared_error, r2_score
data1=pd.read_csv('Cleaned_Data.csv')
data1.columns = data1.columns.str.strip()
data1.info()
data1.head()
```

15. Feature Selection

```
selected_features = {
    'Temperature',
    'RH',
    'Ws',
    'Rain',
    'FFMC',
    'DMC',
    'DC',
    'ISI',
    'BUI'
}
selected_features
```

Output –

```
{'BUI', 'DC', 'DMC', 'FFMC', 'ISI', 'RH', 'Rain', 'Temperature', 'Ws'}
```

Explanation :

A correlation heatmap was used to quantify the relationship between numerical variables. Strong correlations with FWI guided the selection of important features for model training.

16. Split Datasets into Features and Target

```
X = data1[list(selected_features)]
y = data1['FWI']
X = X.apply(pd.to_numeric, errors='coerce')
# handle missing values
X = X.fillna(X.mean())
print(X.isnull().sum())
print("Input Features Shape:", X.shape)
print("Target Shape:", y.shape)
```

Output -

Input Features Shape: (243, 9)
Target Shape: (243,)

Explanation :

The dataset was split into training and testing sets to evaluate model performance on unseen data and prevent overfitting.

17. Find correlation

```
X_train, X_test, y_train, y_test = train_test_split(
    X, y,
    test_size=0.2,
    random_state=42
)
```

Output -

Correlation of selected features :

FWI	1.000000
ISI	0.922895
DMC	0.875864

```
BUI      0.857973
DC       0.739521
FFMC     0.691132
Temperature 0.566670
Ws        0.032368
Rain      -0.324422
RH        -0.580957
Name: FWI, dtype: float64
```

18. Split the dataset into train and test

```
X_train, X_test, y_train, y_test = train_test_split(
    X, y,
    test_size=0.2,
    random_state=42
)
print("Training Data:", X_train.shape)
print("Testing Data:", X_test.shape)
```

Output -

```
Training Data: (194, 9)
Testing Data: (49, 9)
```

19. Feature Scaling using StandardScaler

```
scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)
X_train_scaled      =      pd.DataFrame(X_train_scaled,
columns=X.columns)
X_test_scaled      =      pd.DataFrame(X_test_scaled,
columns=X.columns)
```

Explanation :

Feature scaling was performed using StandardScaler to normalize the data. This ensures that all features contribute equally to model training, especially for distance-based and regularized models.

20. Save the Scaler for Deployment

```
with open("scaler.pkl", "wb") as file:  
    pickle.dump(scaler, file)  
# Verify Scaling  
print("Scaled Training Data Sample:\n",  
x_train_scaled[:5])  
print("Scaled Testing Data Sample:\n", x_test_scaled[:5])
```

Output -

```
Scaled Training Data Sample:  
[[-0.08970416 -0.00689226 -0.75106006 -0.37323064 0.75250838 0.05482497  
-0.02118058 0.47497183 0.03023485]]  
Scaled Testing Data Sample:  
[[ 1.03159787 -0.27569035 0.12070608 -0.37323064 0.61213517 -0.08272731  
0.25217046 0.19245173 0.06361987]]
```

Module 3: Model Training using Ridge Regression

21.Train the Ridge Regression Model

```
ridge_model = Ridge(alpha=1.0)  
ridge_model.fit(X_train_scaled, y_train)
```

22.Hyperparameter Tuning

```
alphas = [0.01, 0.1, 1, 10, 100]  
results = {}  
  
for a in alphas:  
    model = Ridge(alpha=a)  
    model.fit(X_train_scaled, y_train)  
    y_pred = model.predict(X_test_scaled)  
    results[a] = r2_score(y_test, y_pred)  
results
```

Output -

```
{0.01: 0.9862989285583842,  
0.1: 0.9863565713829123,
```

```
1: 0.9860021470799126,  
10: 0.9754134485119687,  
100: 0.8890275614195375}
```

23. Model Evaluation

```
y_train_pred = ridge_model.predict(X_train_scaled)  
y_test_pred = ridge_model.predict(X_test_scaled)  
print("Training R2 Score:", r2_score(y_train, y_train_pred))  
print("Testing R2 Score:", r2_score(y_test, y_test_pred))  
print("Testing MSE:", mean_squared_error(y_test, y_test_pred))
```

Output –

```
Training R2 Score: 0.9558863792898478  
Testing R2 Score: 0.9860021470799126  
Testing MSE: 0.5455797557324075
```

Milestone 03

24. Train Different Models

```
models = {
    "Linear Regression": LinearRegression(),
    "Ridge Regression": Ridge(alpha=1.0),
    "Lasso Regression": Lasso(alpha=0.01),
    "Random Forest": RandomForestRegressor(
        n_estimators=100, random_state=42
    )
}

results = []

for name, model in models.items():
    model.fit(X_train_scaled, y_train)
    y_pred = model.predict(X_test_scaled)

    results.append({
        "Model": name,
        "MAE": mean_absolute_error(y_test, y_pred),
        "RMSE": np.sqrt(mean_squared_error(y_test,
y_pred)),
        "R2 Score": r2_score(y_test, y_pred)
    })
results_df = pd.DataFrame(results)
results_df
```

Output –

	Model	MAE	RMSE	R2 Score
0	Linear Regression	0.424018	0.596185	0.988273
1	Ridge Regression	0.476902	0.751348	0.981374
2	Lasso Regression	0.433096	0.622218	0.987226
3	Random Forest	0.543429	0.832229	0.977148

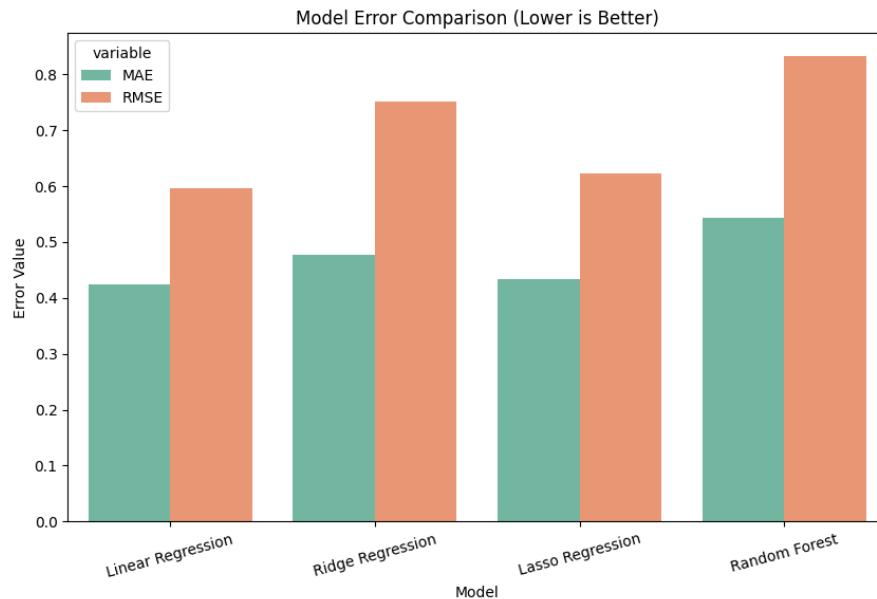
Explanation :

Multiple regression models were evaluated using MAE, RMSE, and R² score. While Random Forest showed slightly better predictive performance, Ridge Regression demonstrated stable and consistent results

25. Error Metrics Table

```
plt.figure(figsize=(10, 6))
sns.barplot(
    data=results_df.melt(id_vars="Model",
                          value_vars=["MAE", "RMSE"]),
    x="Model",
    y="value",
    hue="variable",
    palette="Set2"
)
plt.title("Model Error Comparison (Lower is Better)")
plt.ylabel("Error Value")
plt.xticks(rotation=15)
plt.show()
```

Output –



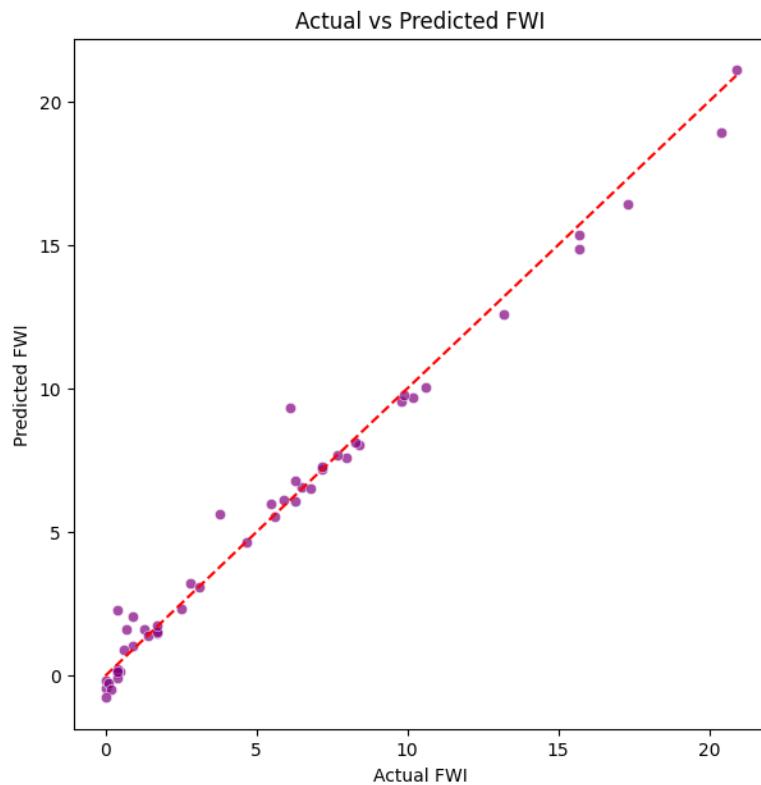
Explanation :

The error comparison plot visually highlights differences in MAE and RMSE across models. Lower error values indicate better predictive accuracy.

26. Actual vs Predicted Plot

```
best_model = Ridge(alpha=1.0)
best_model.fit(X_train_scaled, y_train)
y_pred_best = best_model.predict(X_test_scaled)
plt.figure(figsize=(7, 7))
sns.scatterplot(
    x=y_test,
    y=y_pred_best,
    color="purple",
    alpha=0.7
)
plt.plot(
    [y_test.min(), y_test.max()],
    [y_test.min(), y_test.max()],
    'r--'
)
plt.xlabel("Actual FWI")
plt.ylabel("Predicted FWI")
plt.title("Actual vs Predicted FWI")
plt.show()
```

Output -



Explanation :

The actual versus predicted plot illustrates how closely the model predictions align with true FWI values. Predictions closer to the diagonal line indicate higher model accuracy.

27. Save The Model

```
with open("ridge.pkl", "wb") as file:  
    pickle.dump(ridge_model, file)
```

Explanation :

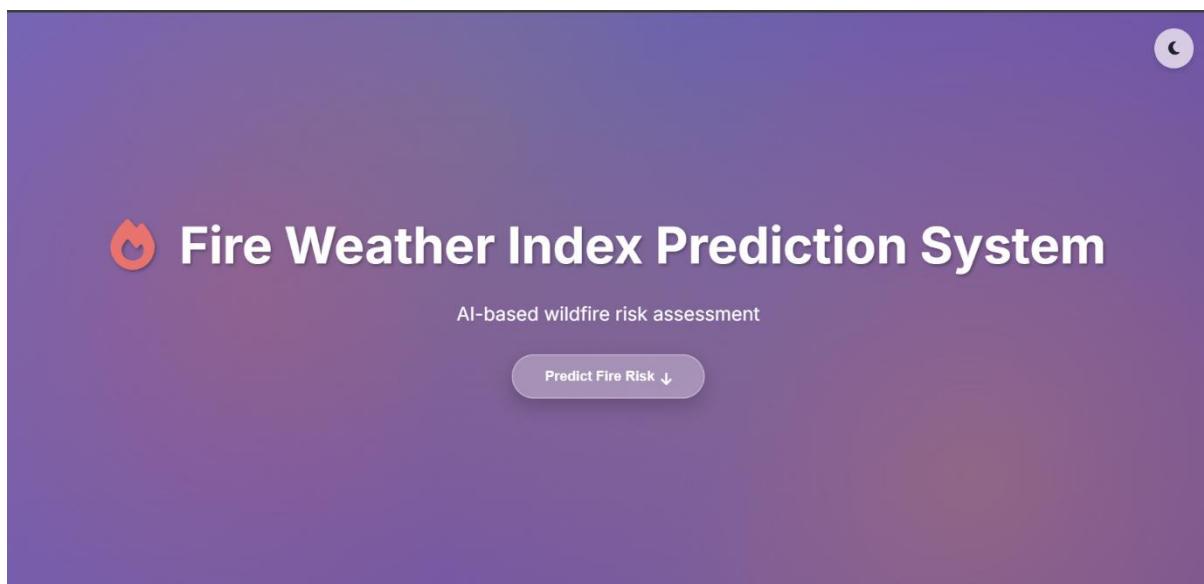
The trained Ridge Regression model was saved using Pickle to enable reuse during deployment without retraining.

Module 6: Deployment Via Flask

In this module, the Fire Weather Index prediction system was deployed using the Flask web framework. A Flask application was developed with `app.py` serving as the main backend file to manage routing and prediction logic. The user interface was created using `index.html`, which allows users to enter the required weather and fire parameters. Upon form submission, the input data is sent to the Flask server, where the trained **Ridge Regression model (ridge.pkl)** and the associated **scaler (scaler.pkl)** are loaded during runtime. The input values are preprocessed using the saved scaler to ensure consistency with the model training process. The processed data is then passed to the Ridge Regression model to predict the Fire Weather Index value. The prediction result is displayed on `home.html`, providing users with a simple and interactive web-based interface. This module enables effective deployment of the machine learning model and demonstrates its real-world usability through a Flask-based application.

Results :

1. Main Interface Of App :



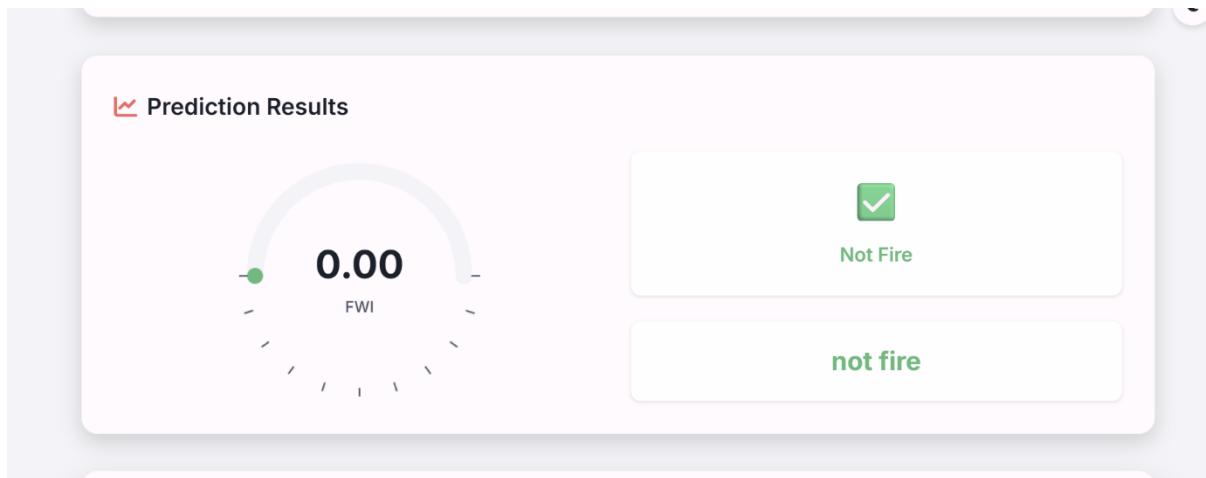
2. Input Parameters For Prediction

Input Parameters

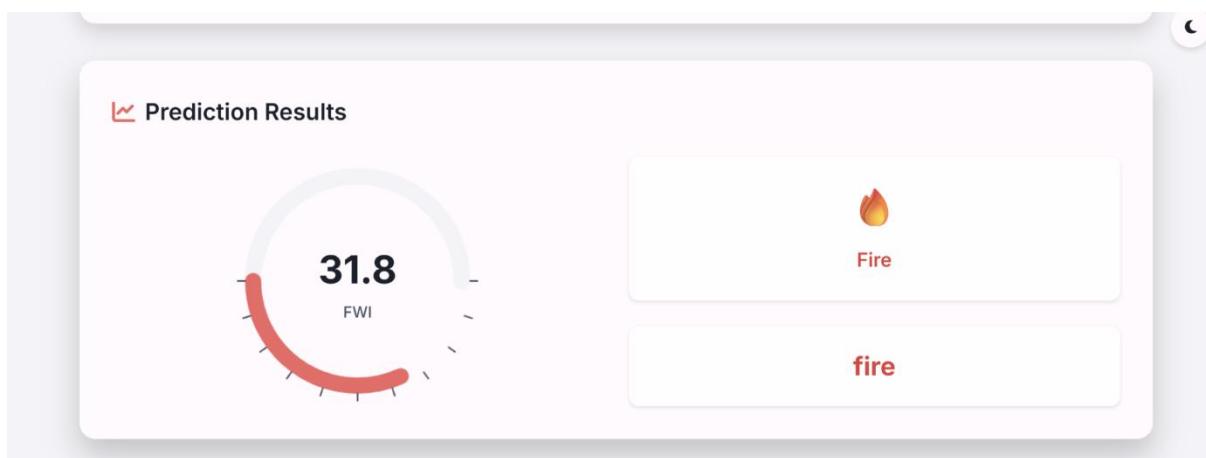
Temperature (°C)	29	RH - Relative Humidity (%)	69	Ws - Wind Speed (km/h)	18	Rain (mm)	0.0
0°C	50°C	0%	100%	0 km/h	100 km/h	0 mm	50 mm
FFMC	65.7	DMC	354.5	DC	7.6	ISI	1.3
0	101.2	0	800+	0	800+	0	56+
BUI	3.4						
0	800+						

Reset Inputs **Predict Fire Index**

3. Low Risk Prediction Result



4. Fire Risk Prediction Result



5. Some Seafty Tips

The image shows a mobile application screen. At the top, there is a circular progress bar with a green dot at the 0.00 mark, labeled "FWI". To the right of the bar, the text "Not Fire" is displayed above a button labeled "not fire". Below the bar, there is a section titled "Fire Safety Tips" with a shield icon. This section contains four items, each with an icon and a title: "Campfire Safety" (campfire icon), "Clear Debris" (leaf icon), "Home Preparation" (house icon), and "Stay Informed" (bell icon). Each item also has a brief description below its title.

- Campfire Safety**
Always fully extinguish campfires and never leave them unattended.
- Clear Debris**
Remove dry leaves and debris from around your property to reduce fire risk.
- Home Preparation**
Create defensible space around your home and have an evacuation plan ready.
- Stay Informed**
Monitor fire weather conditions and alerts in your area regularly.