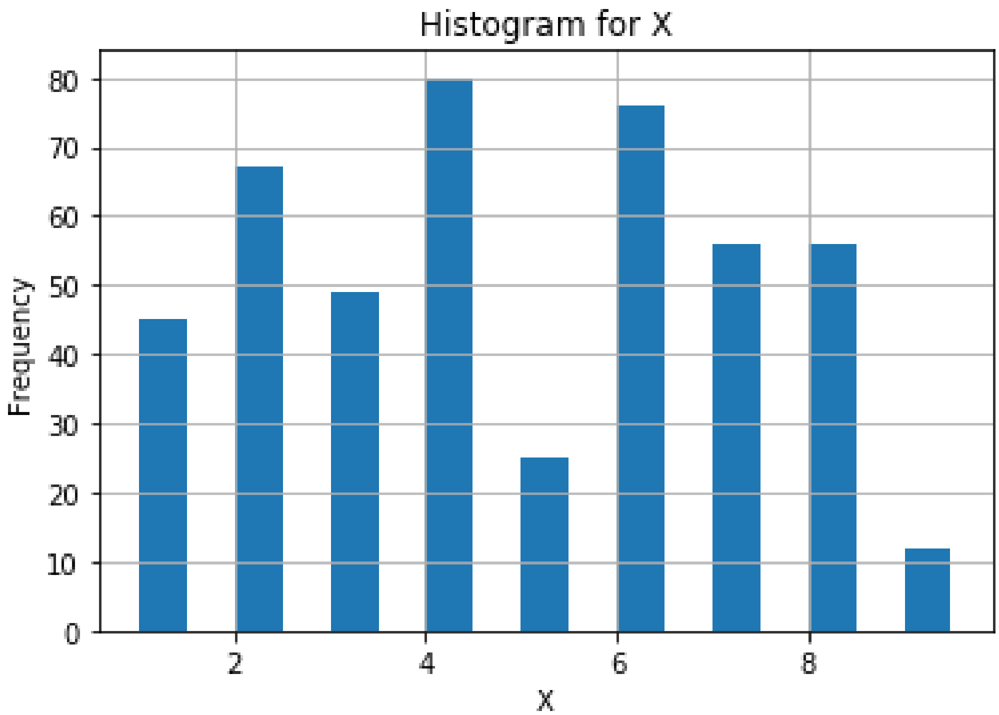
MLHW1

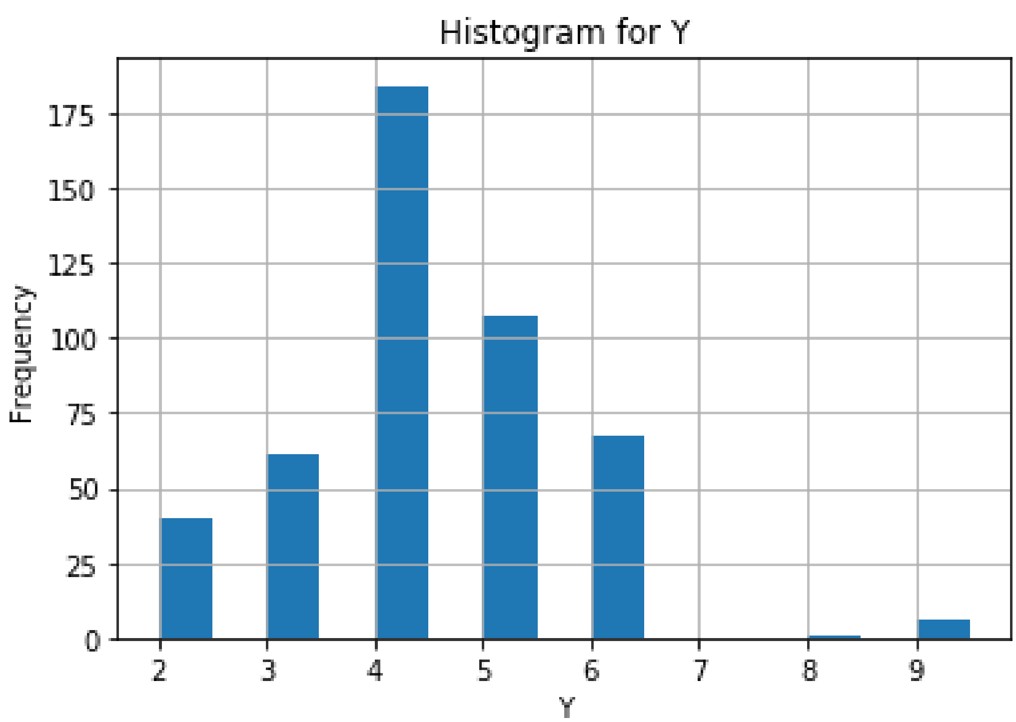
February 23, 2019

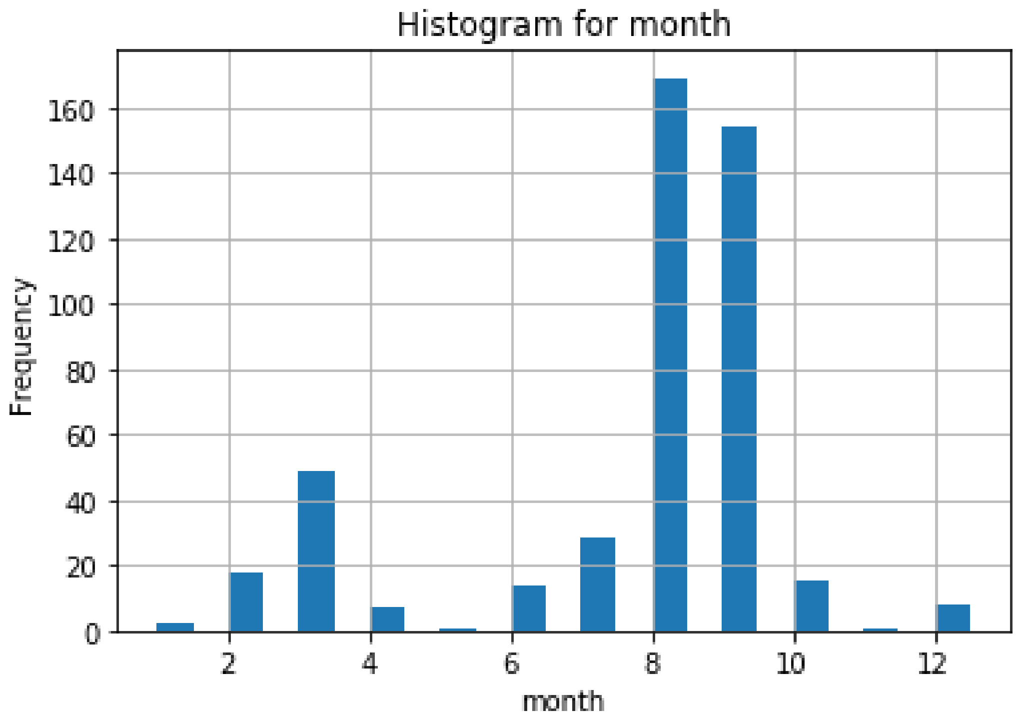
```
In [165]: import pandas as pd
          import matplotlib.pyplot as plt
          import math
          import numpy as np
          import random

          train_df  = pd.read_csv("train.csv")
          test_df = pd.read_csv("test.csv")

          print("Training data dimension: ", train_df.shape)
          print("Test data dimension: ", test_df.shape)
```

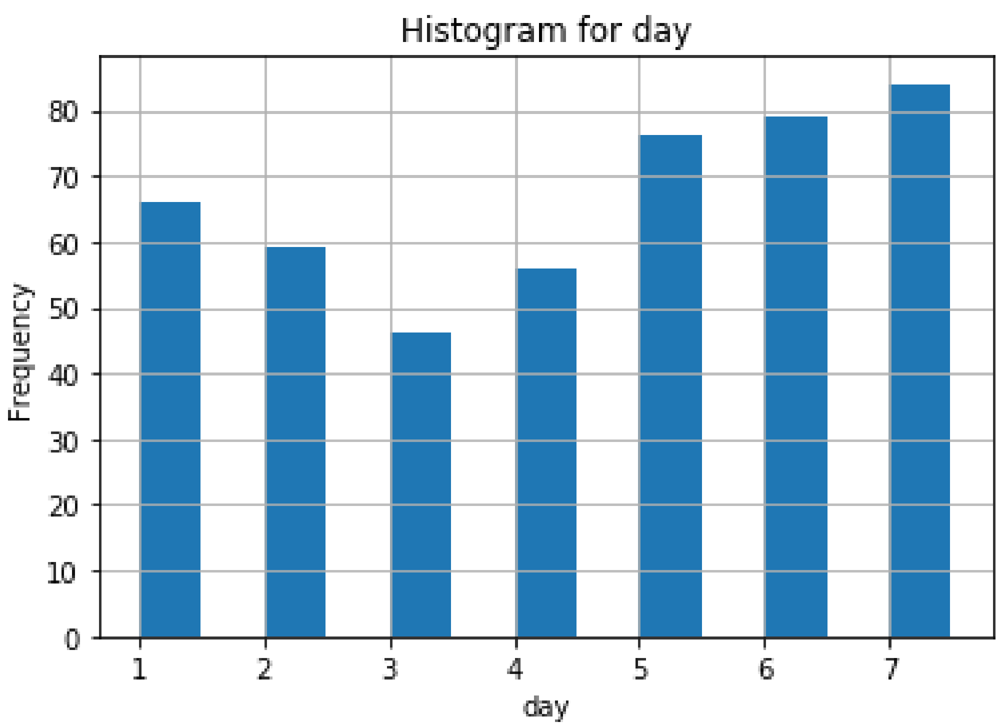
```
Training data dimension:  (466, 13)
Test data dimension:  (51, 13)
```

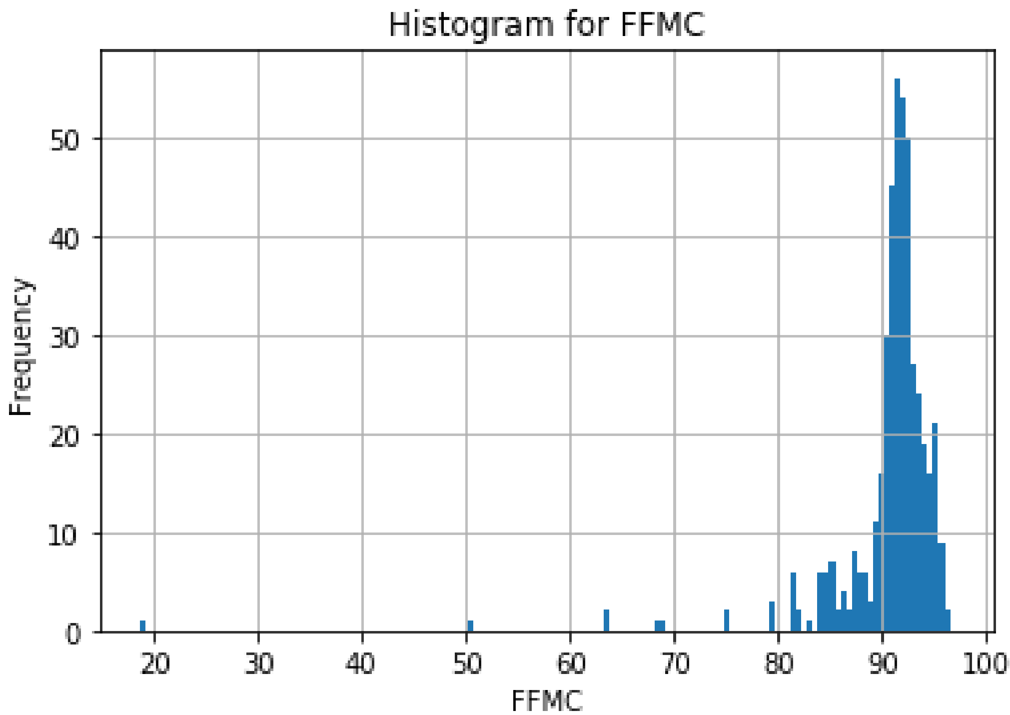
```
In [166]: #3 (a) Data exploration
          #Plotting the histograms of all features

          features_list = list(train_df.columns.values)

          for i in range(12):
              plt.hist(train_df.iloc[:,i],bins=np.arange(min(train_df.iloc[:,i]),
                                              max(train_df.iloc[:,i]) + 1, 0.5))
              plt.xlabel(features_list[i])
              plt.ylabel('Frequency')
              plt.title('Histogram for {}'. format(features_list[i]))
              plt.grid(True)
              plt.show()
```

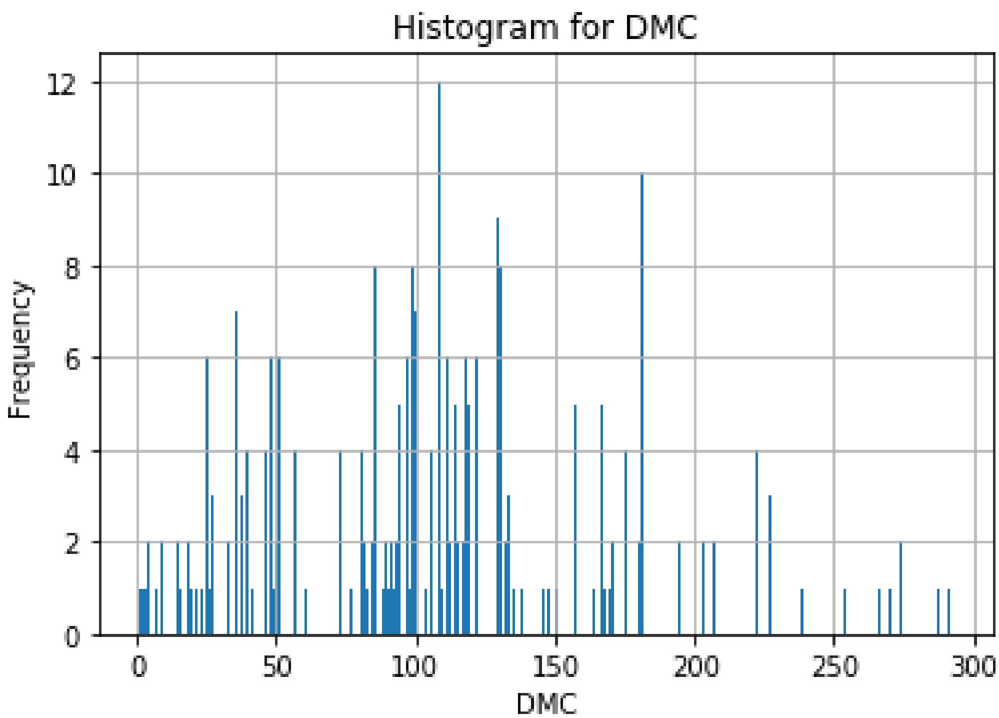

Histogram for X
Frequency
0
10
20
30
40
50
60
70
80
2
4
6
8
X

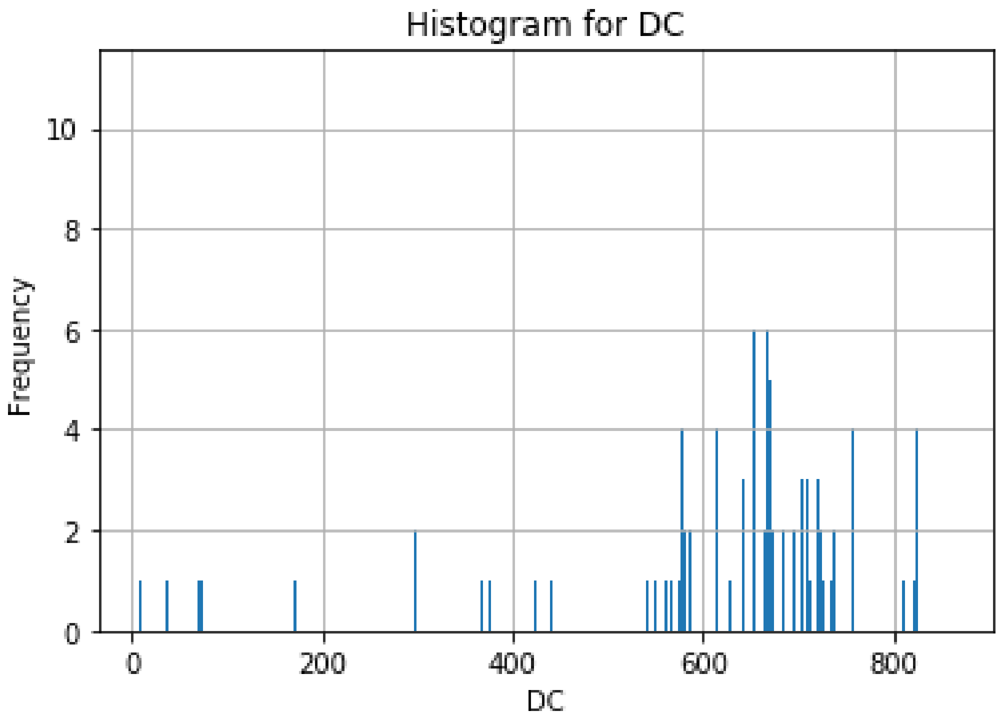

Histogram for Y
Frequency
0
25
50
75
100
125
150
175
2
3
4
5
6
7
8
9
Y

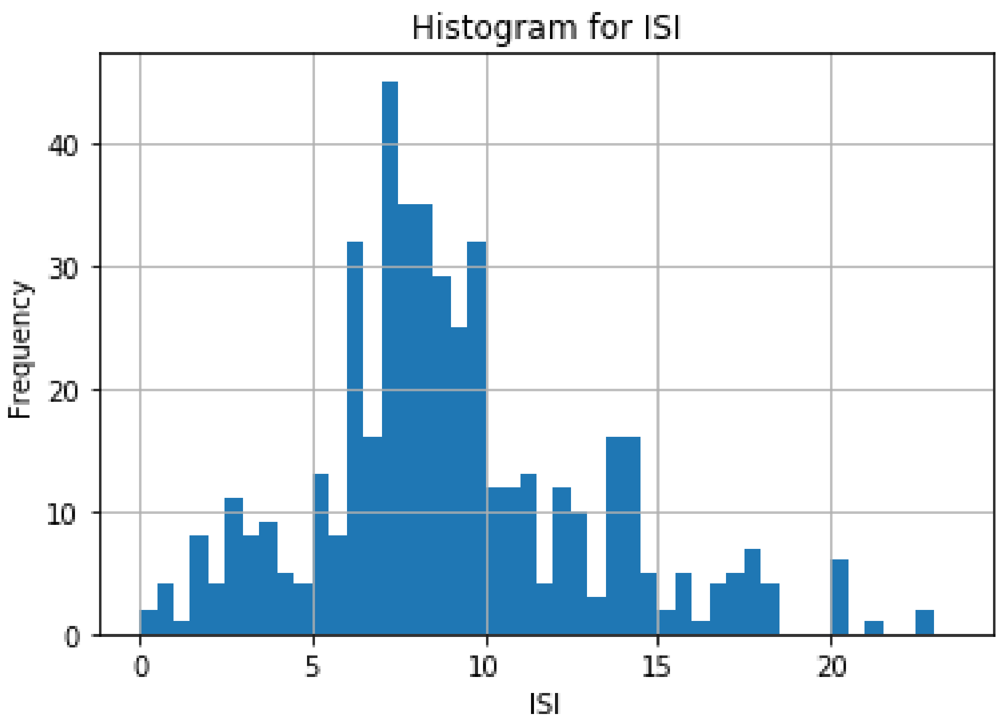

Histogram for month
Frequency
0
20
40
60
80
100
120
140
160
2
4
6
8
10
12
month

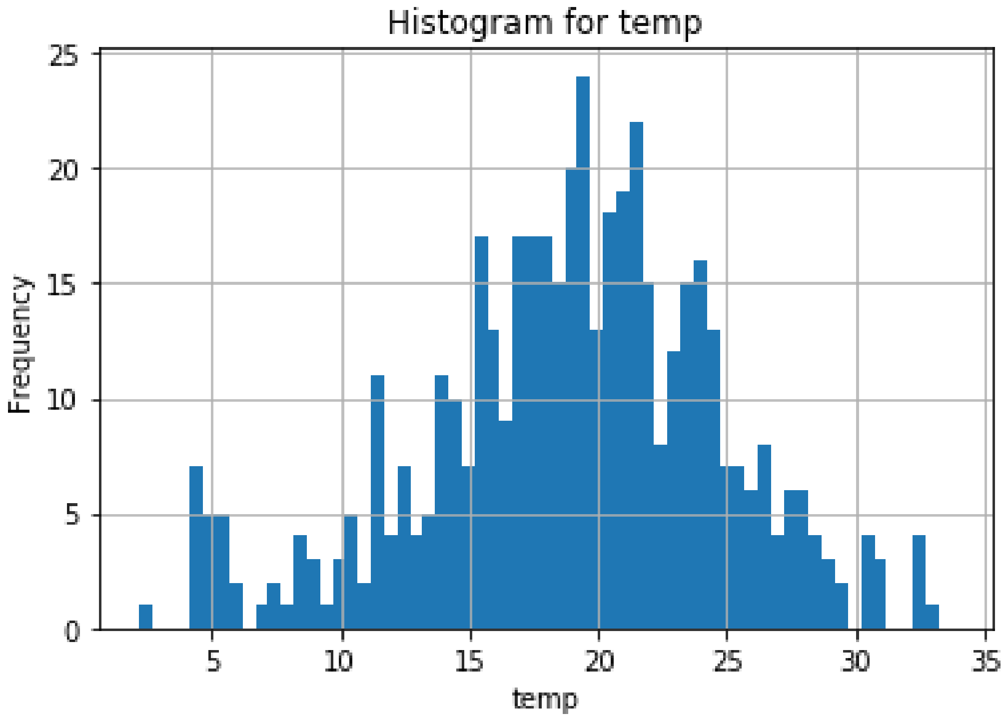

Histogram for day
Frequency
0
10
20
30
40
50
60
70
80
1
2
3
4
5
6
7
day

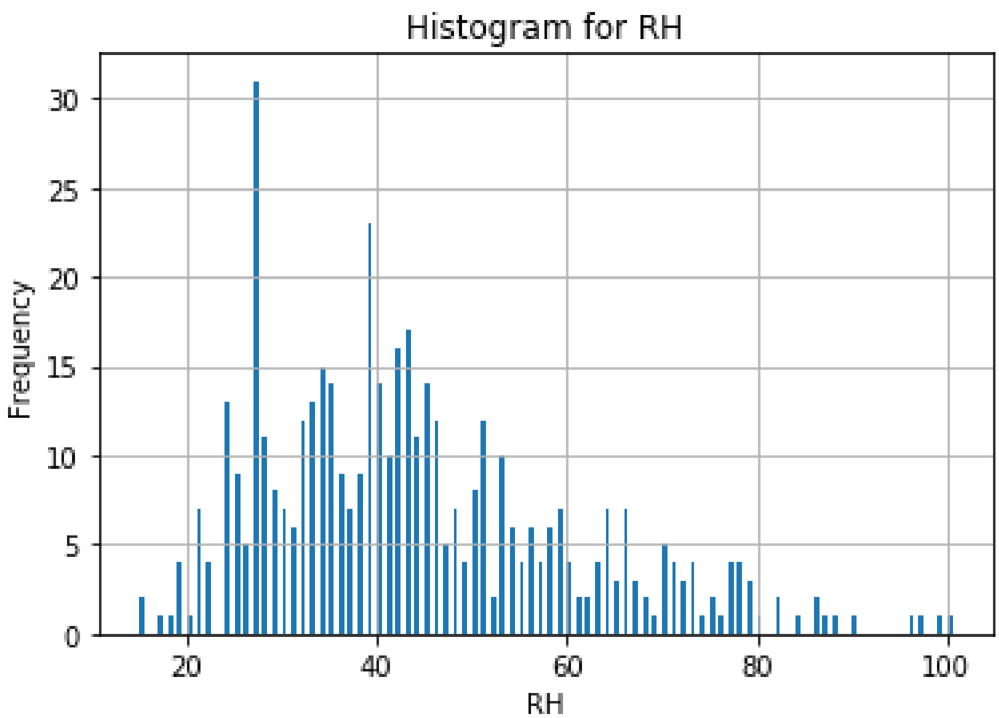

Histogram for FFMC
Frequency
FFMC
0
10
20
30
40
50
20
30
40
50
60
70
80
90
100

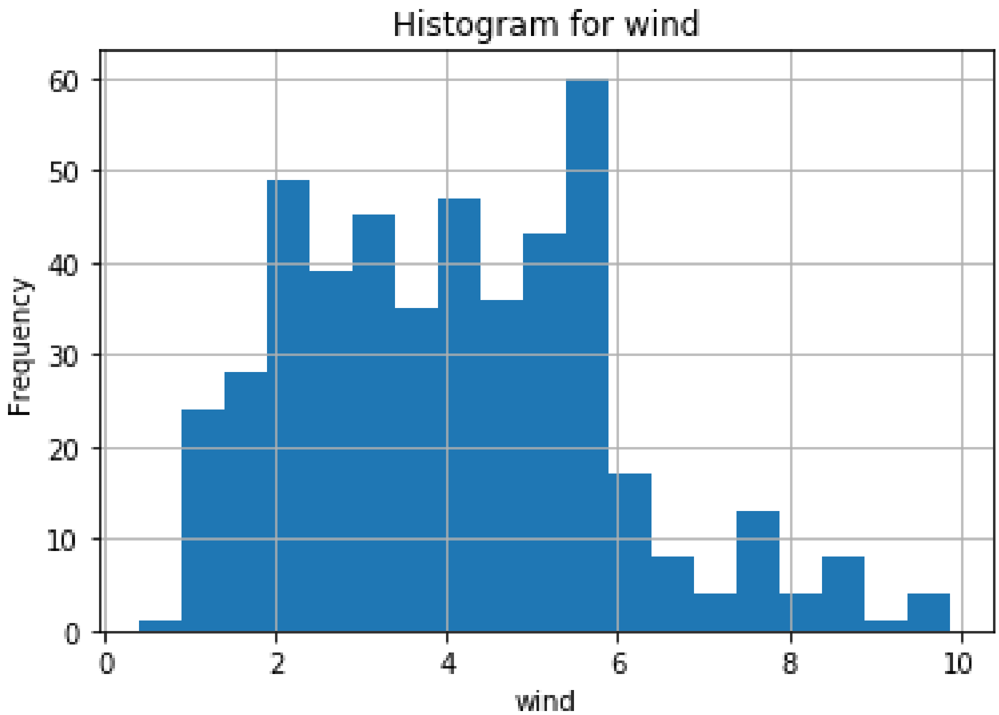

Histogram for DMC
Frequency
DMC
0
2
4
6
8
10
12
0
50
100
150
200
250
300

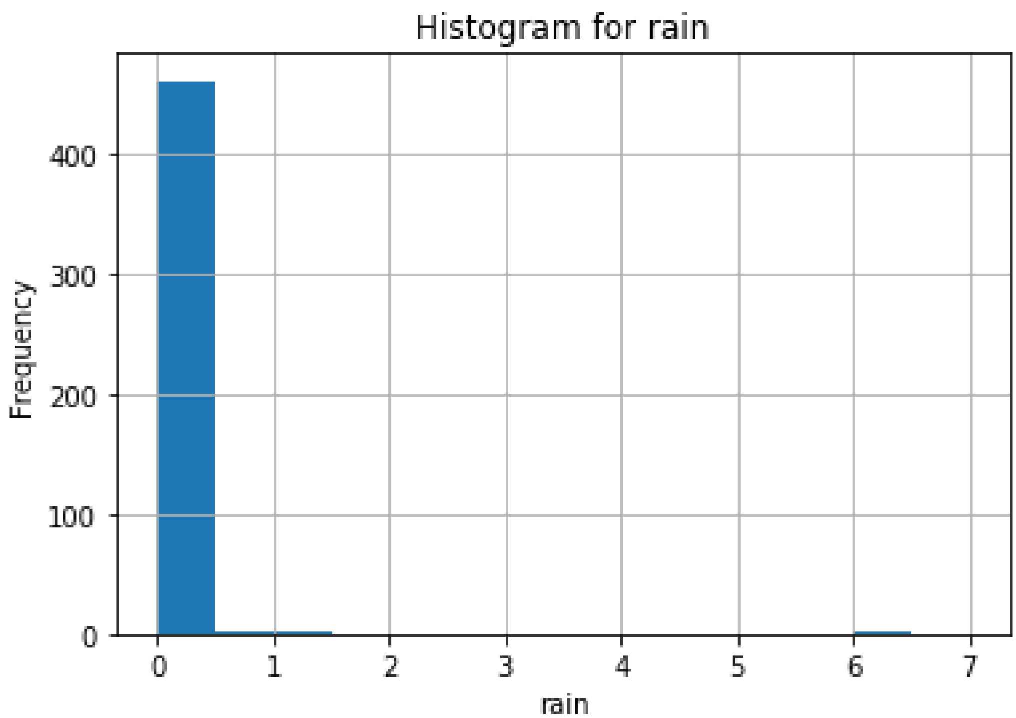

Histogram for DC
Frequency
DC
0
2
4
6
8
10
0
200
400
600
800


Histogram for ISI
Frequency
ISI
0
10
20
30
40
0
5
10
15
20

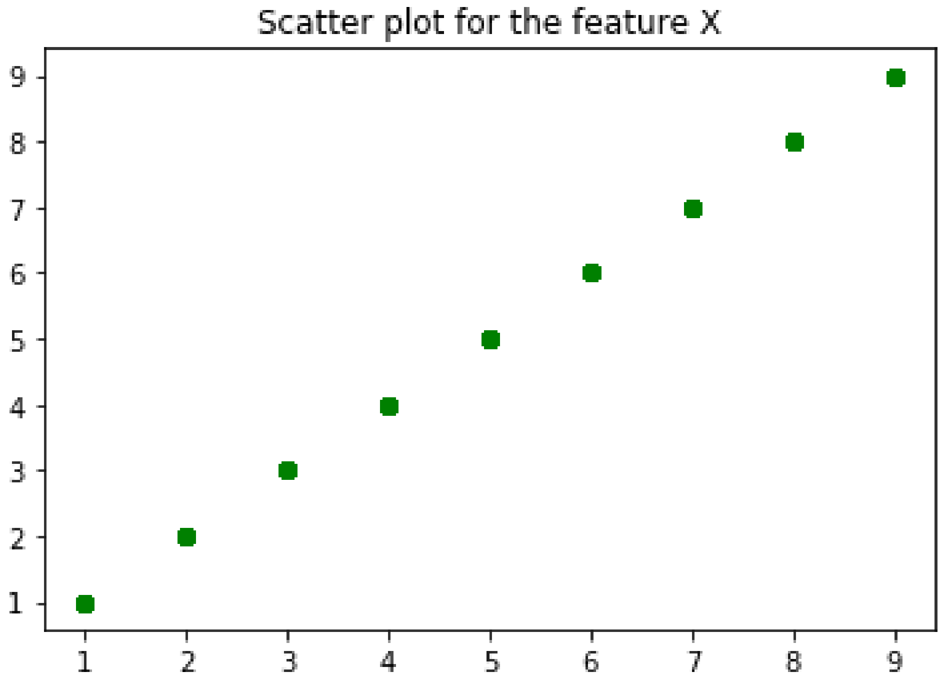

Histogram for temp
Frequency
temp
0
5
10
15
20
25
30
35

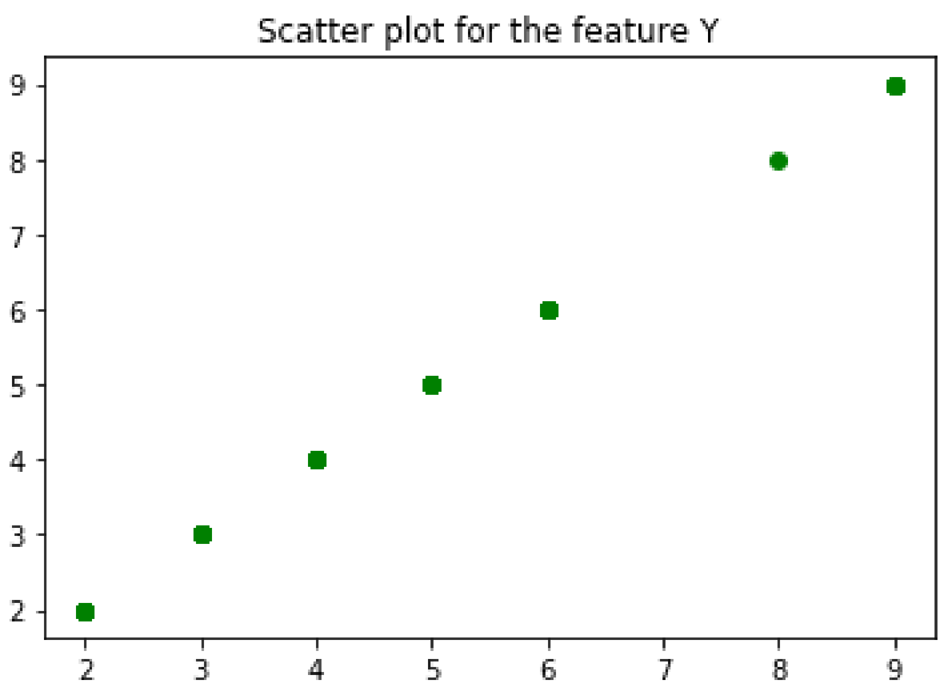

Histogram for RH
Frequency
RH
0
5
10
15
20
25
30
40
60
80
100

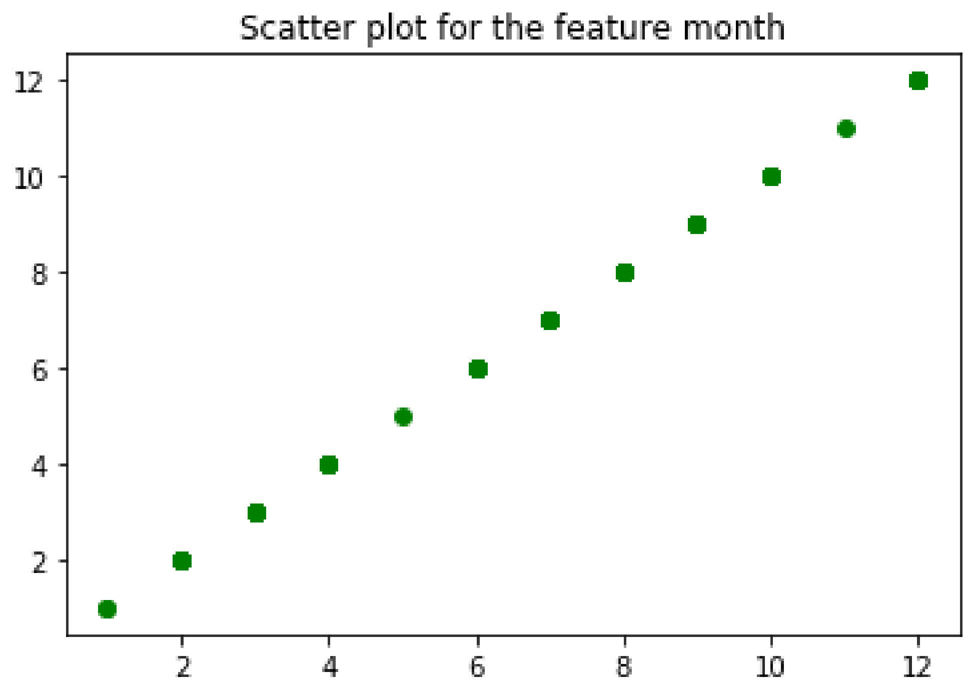

Histogram for wind
Frequency
0
10
20
30
40
50
60
0
2
4
6
8
10
wind

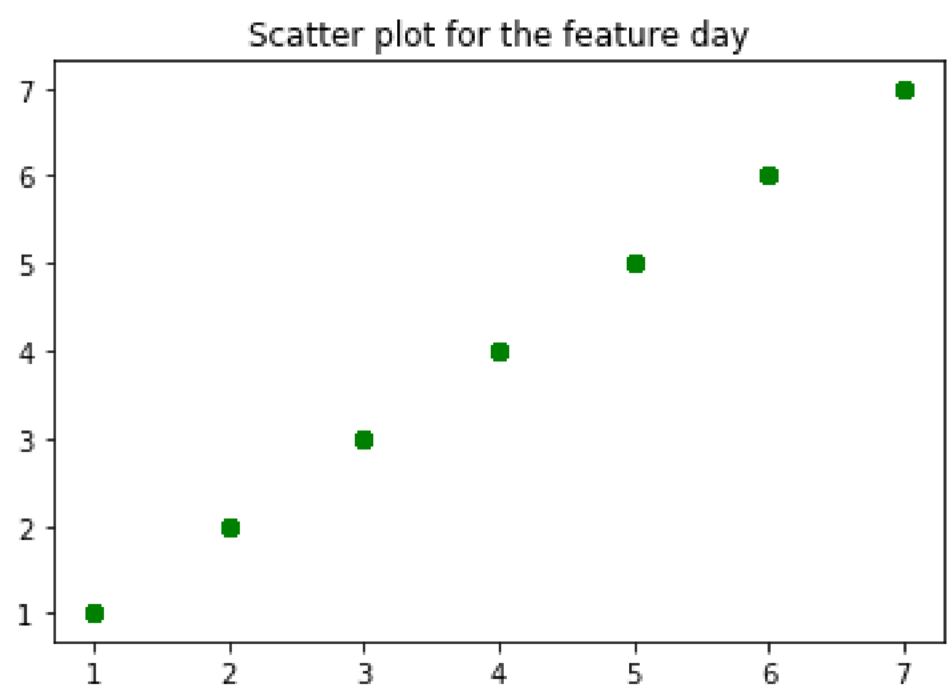

Histogram for rain
Frequency
0
100
200
300
400
0
1
2
3
4
5
6
7
rain

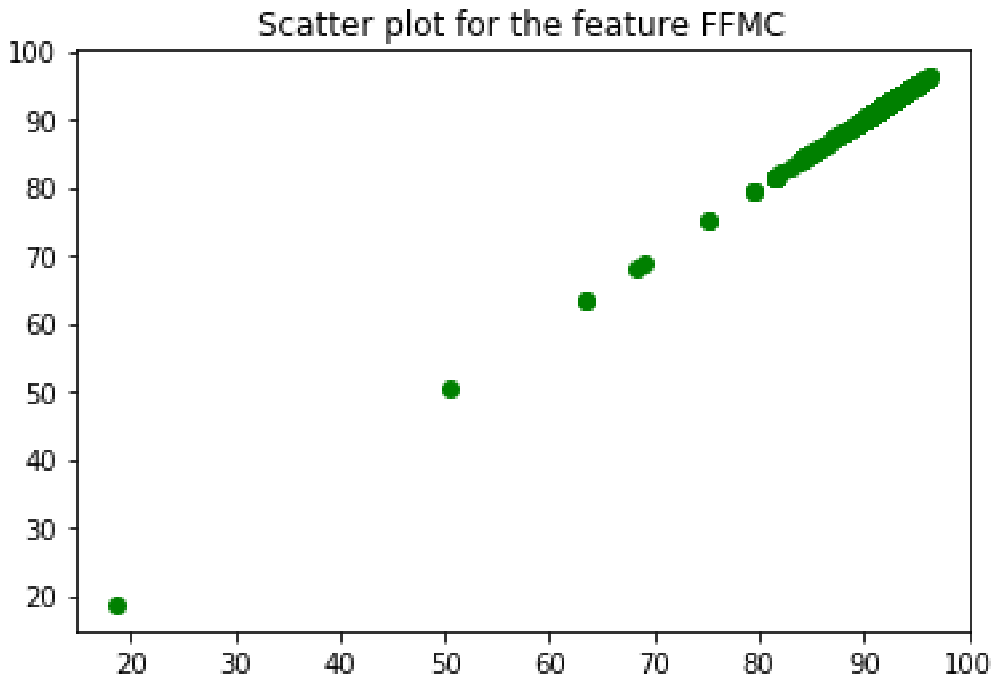
In [167]:
```
#Plotting scatter plots for the features
for i in range(12):
    plt.scatter(train_df.iloc[:,i],train_df.iloc[:,i],c='g')
    plt.title('Scatter plot for the feature {}'. format(features_list[i]))
    plt.show()
```

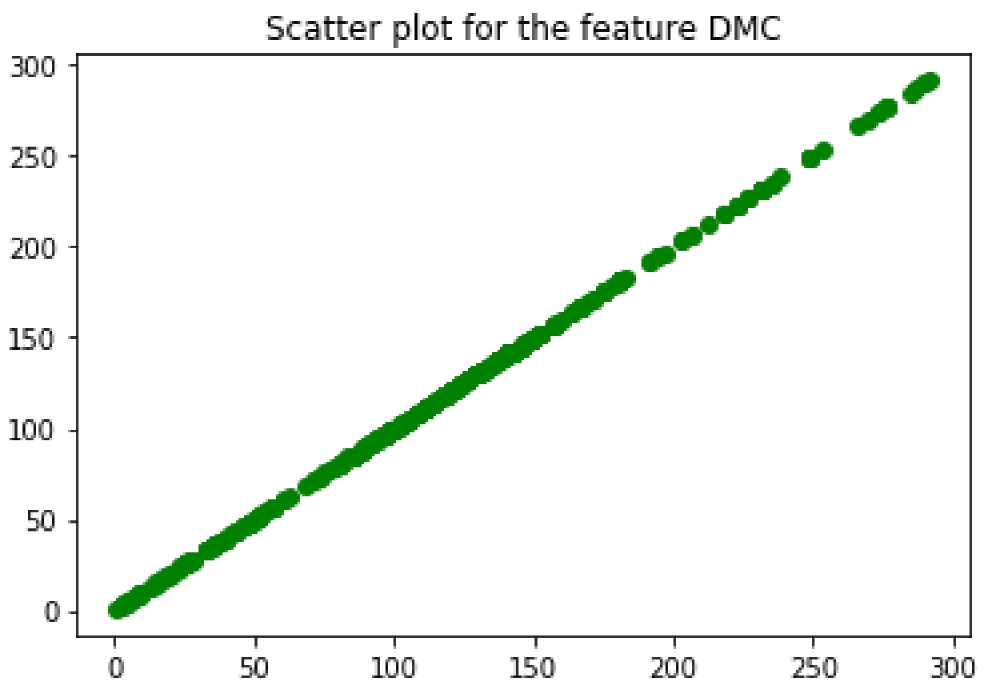


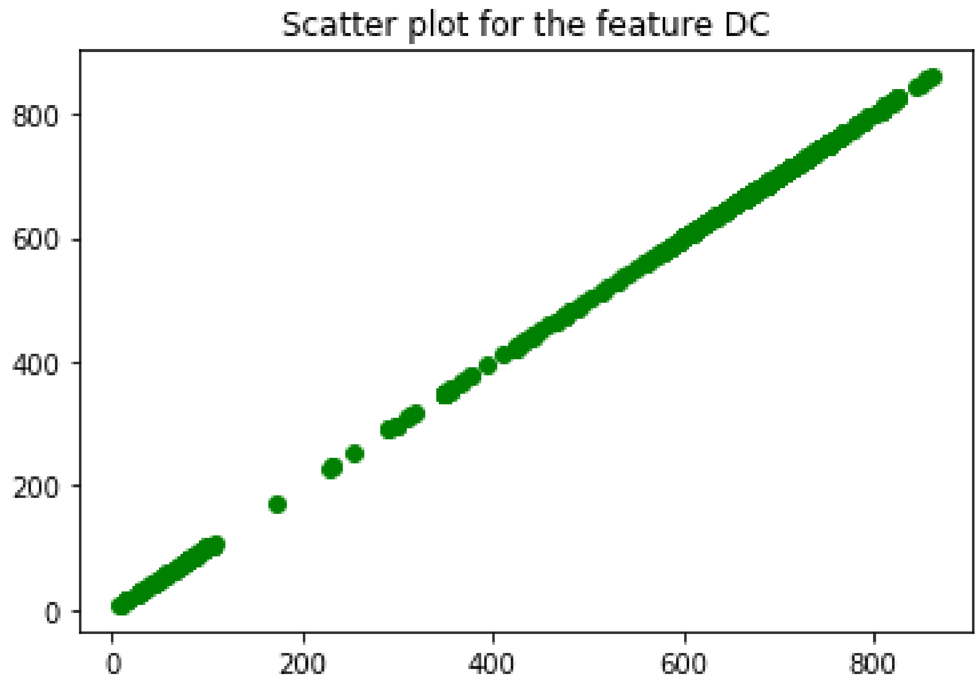


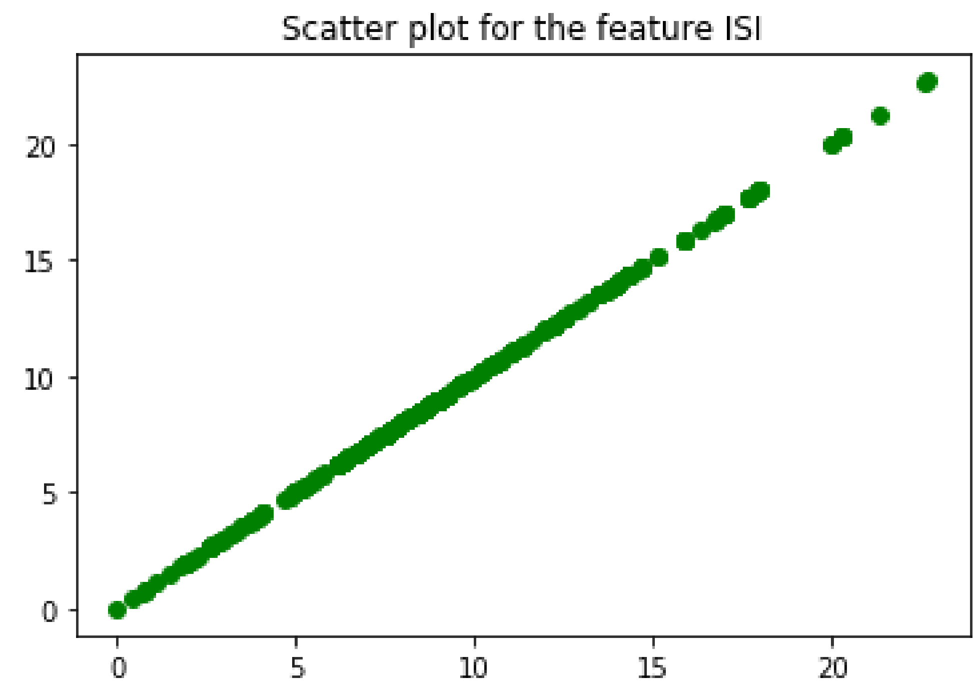

Scatter plot for the feature month
12
10
8
6
4
2
2
4
6
8
10
12

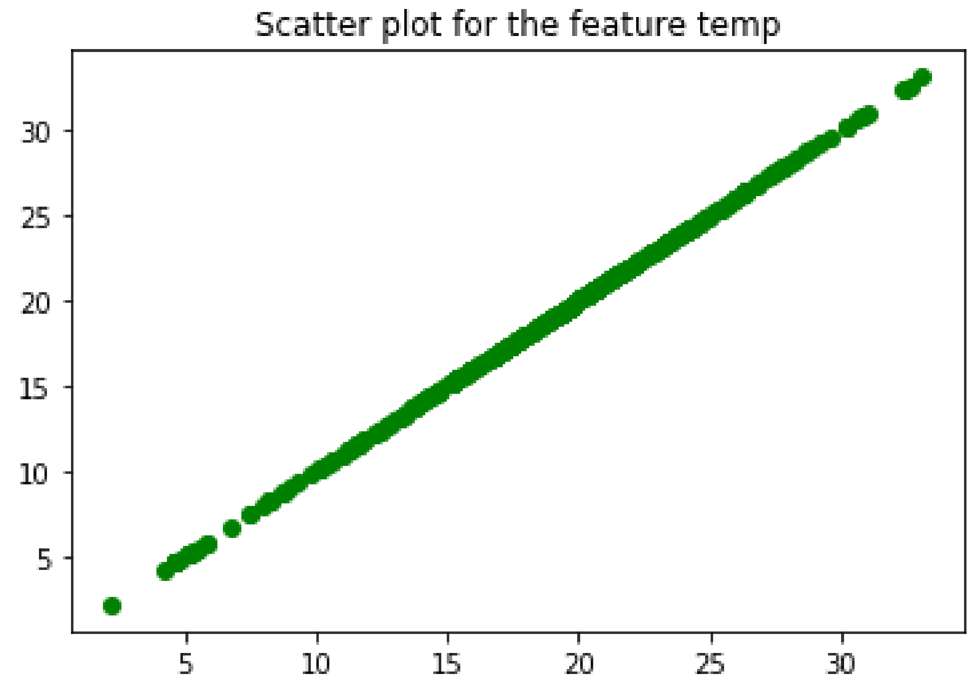

Scatter plot for the feature day
7
6
5
4
3
2
1
1
2
3
4
5
6
7

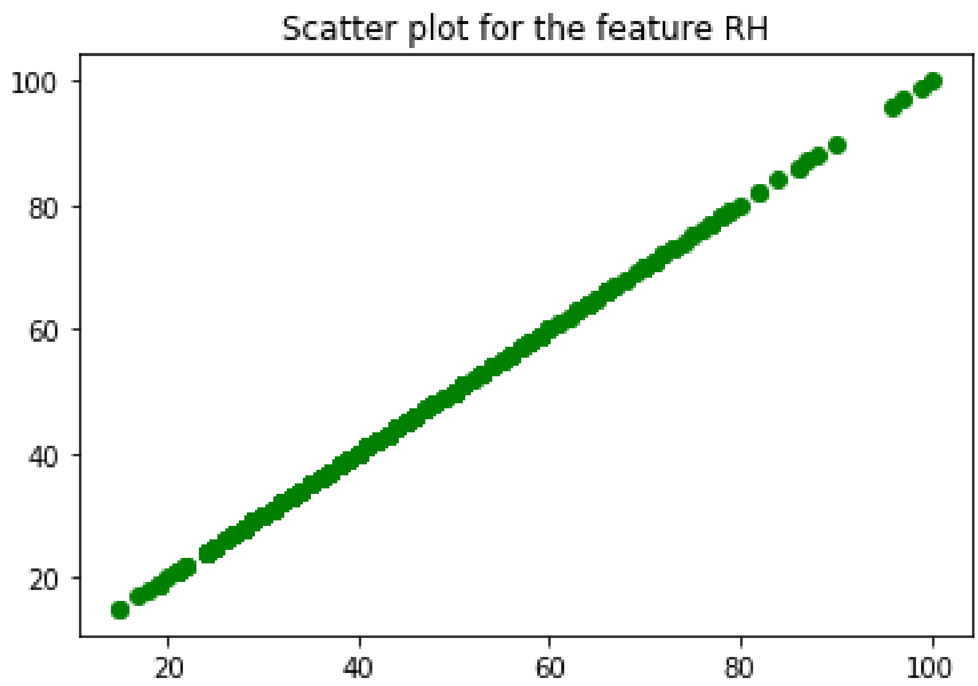

Scatter plot for the feature FFMC
100
90
80
70
60
50
40
30
20
20
30
40
50
60
70
80
90
100

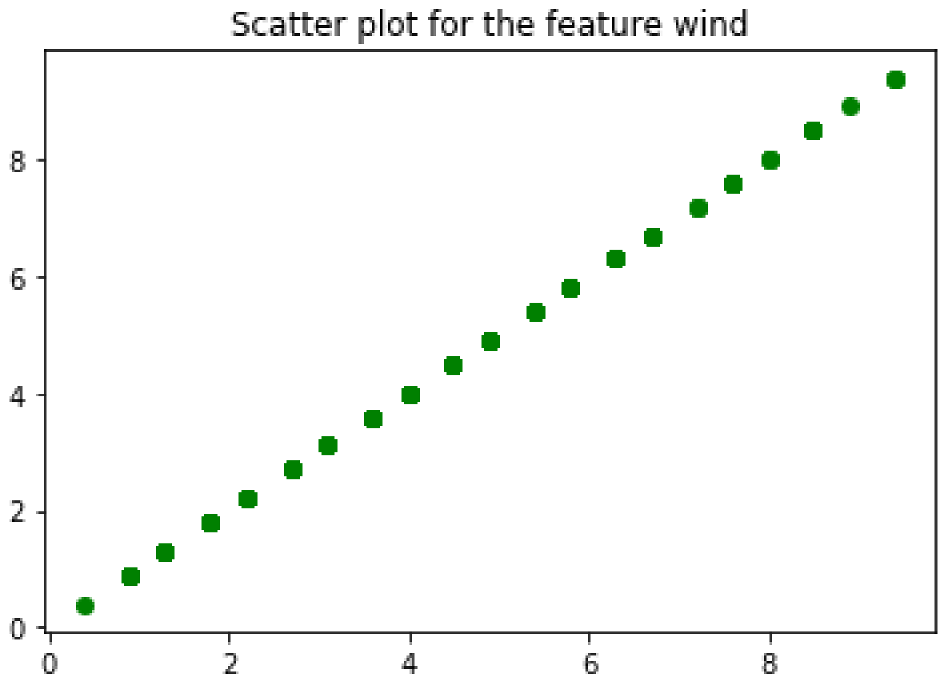

Scatter plot for the feature DMC
300
250
200
150
100
50
0
0
50
100
150
200
250
300

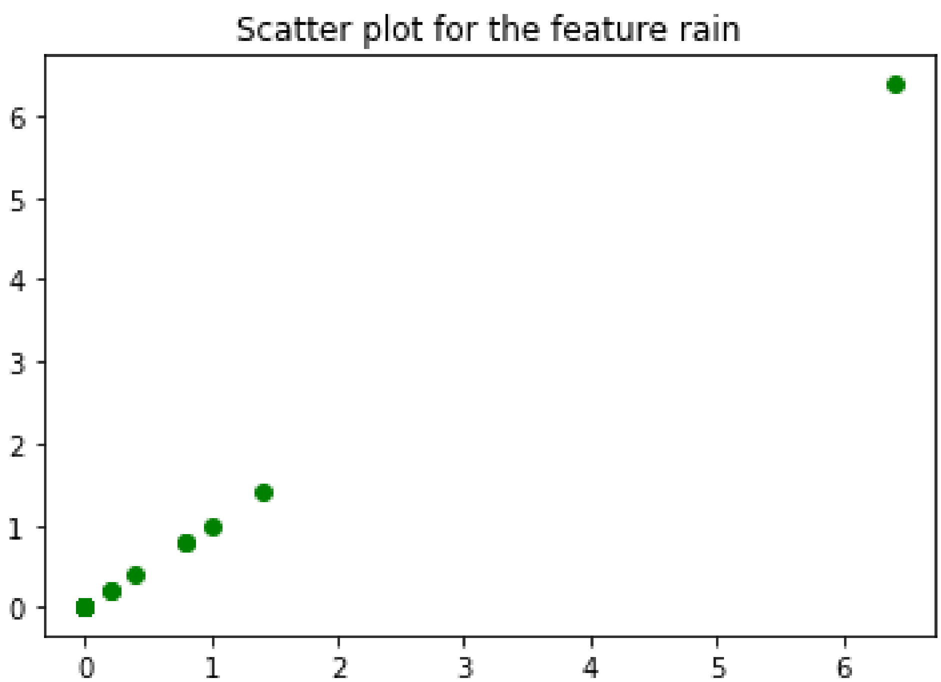

Scatter plot for the feature DC
800
600
400
200
0
0
200
400
600
800


Scatter plot for the feature ISI
20
15
10
5
0
0
5
10
15
20


Scatter plot for the feature temp
30
25
20
15
10
5
5
10
15
20
25
30


Scatter plot for the feature RH
100
80
60
40
20
20
40
60
80
100






```
In [ ]: Categorical Features: 'X', 'Y', 'month', 'day'
        Continuous Features: 'FFMC', 'DMC', 'DC', 'ISI', 'temp', 'RH', 'wind', 'rain'
```

In [168]:
```
import math

#Feature normalization
#min-max normalization
n_train_df=(train_df-train_df.min())/(train_df.max()-train_df.min())
n_test_df = (test_df-train_df.min())/(train_df.max()-train_df.min())
```

In [169]:
```
#Question 3 b.i) KNN classifier using the euclidean distance
#(customized distance metrics option also available)
#KNN classifier
#Returns a list of labels for all the test samples
def KNN(k,n_train_df,n_test_df,distance_metric):
    testList = []
    for test_row_index, test_row in n_test_df.iterrows():
        distList = []
        for train_row_index, train_row in n_train_df.iterrows():
            distance = computeDistance(train_row,test_row,distance_metric)
            distList.append((distance,train_row[-1]))
        distList.sort()
        fire_class , no_fire_class = 0,0
        for i in range(k):
            if(distList[i][1] > 0):
                fire_class += 1
            else:
                no_fire_class += 1
        if(fire_class > no_fire_class):
            testList.append(1)
        else:
            testList.append(0)
    return testList
```

In [170]:
```
#Function to compute the distance between two given samples,
#given the specific distance metric
def computeDistance(train_row,test_row,metricType):
    if metricType == "euclidean":
        distance = 0
        for i in range(len(train_row)-1):
            distance = distance+(train_row[i]-test_row[i])*(train_row[i]-test_row[i])
        return math.sqrt(distance)
    elif metricType == "manhattan":
        distance = 0
        for i in range(len(train_row)-1):
            distance = distance + abs(train_row[i] - test_row[i])
        return distance
    elif metricType == "hamming":
        distance = 0
        #calculating euclidean distance for the non
        #categorical features
```

```
            for i in range(4,len(train_row)-1):
                distance = distance+(train_row[i]-test_row[i])*(train_row[i]-test_row[i])
            distance = math.sqrt(distance)
            for i in range(4):
                #first four features are categorical features
                if(train_row[i] != test_row[i]):
                    distance = distance+1
            return distance
        elif metricType == "similarity":
            distance = 0
            #calculating euclidean distance for
            #the non categorical features
            for i in range(4,len(train_row)-1):
                distance = distance + (train_row[i]-test_row[i])*(train_row[i]-test_row[i]
            distance = math.sqrt(distance)
            for i in range(4):
                #Computing similarity(opposite of hamming distance)
                #for categorical features
                if(train_row[i] == test_row[i]):
                    distance = distance + 1
            return distance
```

In [171]:
```
def computeTestLabels(test_df):
    givenLabelsList = []
    for row_index, row in test_df.iterrows():
        if(row[-1] == 0):
            givenLabelsList.append(0)
        else:
            givenLabelsList.append(1)
    return givenLabelsList
```

In [172]:
```
#Computes the accuracy given a list of actual Labels and predicted labels as
#(#samples correctly classified / (#total samples))
def computeAccuracy(computedTestList, originalTestList):
    total_samples = len(originalTestList)
    correct_samples = 0
    for i in range(total_samples):
        if computedTestList[i] == originalTestList[i]:
            correct_samples += 1
    return correct_samples/total_samples
```

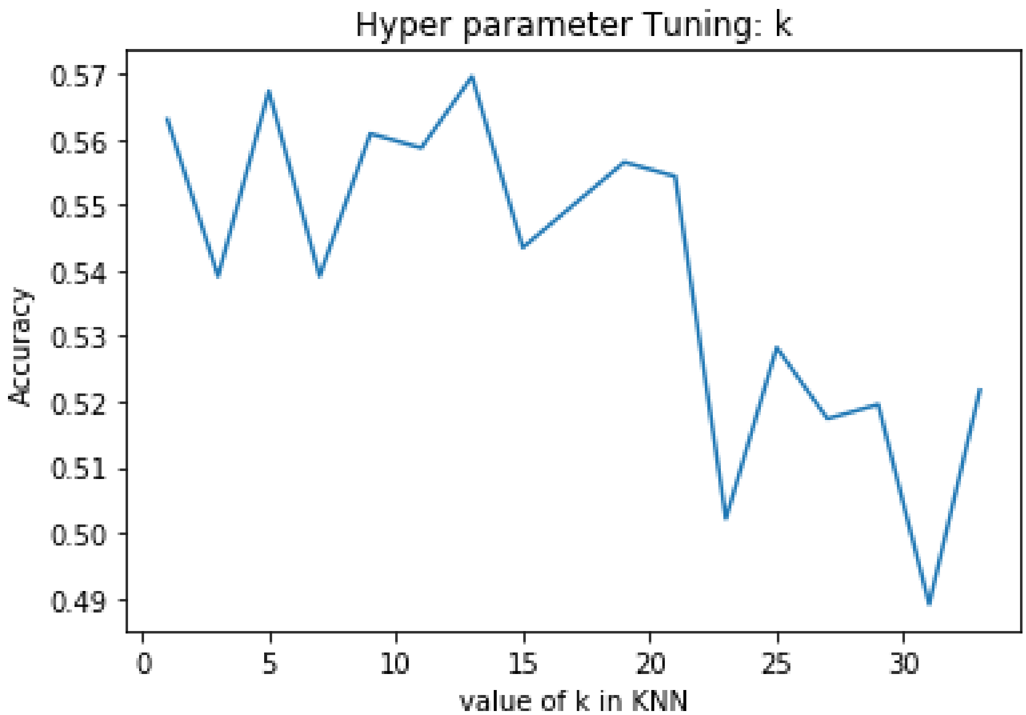
In [173]:
```
def plotAccuracy(accuracyList):
    y = [temp[1] for temp in accuracyList]
    x = [temp[0] for temp in accuracyList]
    plt.plot(y,x)
    plt.title('Hyper parameter Tuning: k')
    plt.xlabel('value of k in KNN')
```

```
        plt.ylabel('Accuracy')
        plt.show()
        return
```

In [121]:
```
#Cross Validation (10 Fold) on the Training set
def crossValidation(n_train_df):
    nFolds = 10
    dataPerFold = len(n_train_df)/nFolds
    max_k = 0
    max_accuracy = -1
    accuracyList = []
    for k in range(1,35,2):
        n_train_df = n_train_df.sample(frac=1).reset_index(drop=True)
        accuracy = 0
        for i in range(nFolds):
            start_index = int(i*dataPerFold)
            test_df = n_train_df.iloc[start_index:(int)(start_index+dataPerFold)]
            train_df = [n_train_df.iloc[0:start_index] ,
                        n_train_df.iloc[int((i+1)*dataPerFold) : ]]
            computedLabelsList = KNN(k,pd.concat(train_df),test_df,"euclidean")
            givenLabelsList = computeTestLabels(test_df)
            accuracy += computeAccuracy(computedLabelsList,givenLabelsList)
        accuracyList.append((accuracy/nFolds,k))
        if(accuracy > max_accuracy):
            max_accuracy = accuracy
            max_k = k
    return max_k, accuracyList

max_k, accuracyList = crossValidation(n_train_df)

print("Maximum value of k obtained after cross validation is: ",max_k)
print("Maximum accuracy obtained on cross validation is: ", max(accuracyList))
```

```
Maximum value of k obtained after cross validation is:  13
Maximum accuracy obtained on cross validation is:  (0.5695652173913044, 13)
```

In [174]:
```
#Plotting the accuracy against different values of k while cross validation
plotAccuracy(accuracyList)
```

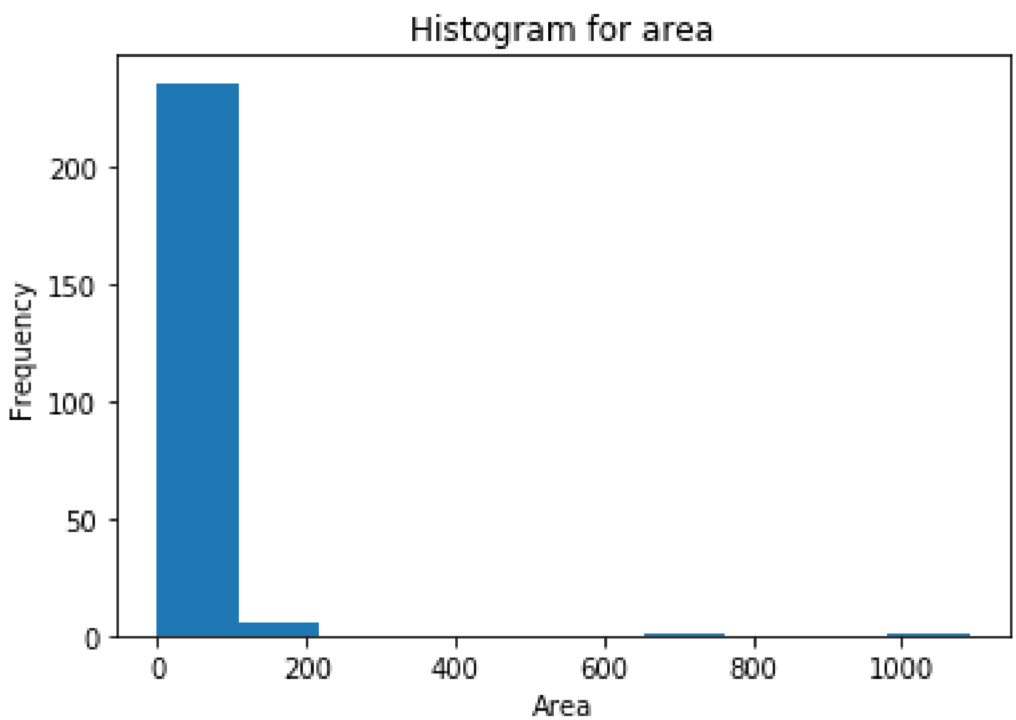


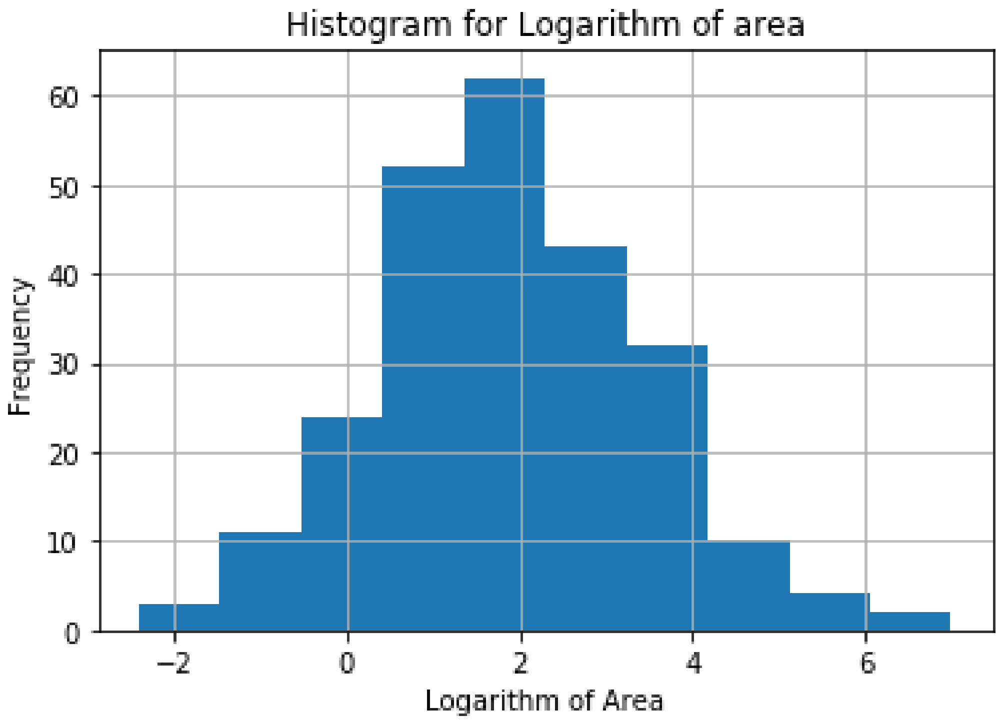

```
In [123]: # 3 b.iv)From the maximum k obtained during cross validation,
          #I am evaluating the test set using KNN and the following set of distances
          distanceMetricsList = ["euclidean","manhattan","hamming","similarity"]

          givenLabelsList = computeTestLabels(n_test_df)

          for distance_metric in distanceMetricsList:
              accuracy_list = []
              testLabelsList = KNN(max_k,n_train_df,n_test_df,distance_metric)
              accuracy = computeAccuracy(testLabelsList,givenLabelsList)
              print("Accuracy for the distance metric {} is : {}".
                    format(distance_metric, accuracy))
              accuracy_list.append(accuracy)
```

```
Accuracy for the distance metric euclidean is : 0.6470588235294118
Accuracy for the distance metric manhattan is : 0.6470588235294118
Accuracy for the distance metric hamming is : 0.5098039215686274
Accuracy for the distance metric similarity is : 0.5098039215686274
```

```
In [175]: #Linear regression
          import pandas as pd
          import matplotlib.pyplot as plt
```

```
import math
import random
import numpy as np
import math

#3 c.i) Plotting the histogram of area and Logarithm of area
train_df  = pd.read_csv("train.csv")
test_df = pd.read_csv("test.csv")

train_df = train_df.loc[train_df['area'] > 0]

#to plot the histogram of area
plt.hist(train_df.iloc[:,12])
plt.ylabel('Frequency')
plt.xlabel('Area')
plt.title('Histogram for area')
plt.show()

#to plot the logarithm of area
train_df['area'].apply(np.log).hist()
plt.ylabel('Frequency')
plt.xlabel('Logarithm of Area')
plt.title('Histogram for Logarithm of area')
plt.show()
```






```
In [176]: #Normalization of the features, last column corresponds to the output variable
          s_train_df = train_df.iloc[:,:12]
          s_test_df = test_df.iloc[:,:12]

          #Mean normalization
          n_train_df=(s_train_df-s_train_df.mean())/(s_train_df.std())
          n_test_df = (s_test_df-s_train_df.mean())/(s_train_df.std())
```

```
In [177]: # 3 c.ii) Linear regression using OLS solution
          from numpy.linalg import inv

          X_train_df = n_train_df.iloc[:, :12]
          Y_train_df = train_df.iloc[:, 12:13]

          #OLS solution: weight = inv(X.T*X)*X.T*Y
          def computeOLS(X_train, Y_train):
              product = np.matmul(X_train.T,X_train)
              inverse = np.linalg.inv(product)
              result = np.matmul(inverse,np.matmul(X_train.T,Y_train))
              return result

          weights = computeOLS(X_train_df,Y_train_df)
          print("Shape of the weight matrix is :", weights.shape)
          print("weights obtained from OLS method are: {}". format(weights))
```

```
Shape of the weight matrix is : (12, 1)
weights obtained from OLS method are: [[  6.73662115]
 [ -1.21319632]
 [  6.8050393 ]
 [  5.75928603]
 [ -0.1072859 ]
 [ 12.04084568]
 [ -9.05296087]
 [ -5.55457647]
 [  5.5875579 ]
 [-10.45906908]
 [  2.0758261 ]
 [ -0.94204314]]
```

In [178]:
```
# 3 c.iii)Compute RSS error and correlation between actual and
#predicted outcome variable

#to compute the RSS error
X_test_df = n_test_df
Y_test_df = test_df.iloc[:,12:13]

def computeRSSError(y_predict, y_actual):
    diff = y_predict - y_actual
    return np.sum(np.power(diff,2))

predicted_df = np.matmul(X_test_df,weights)
predicted_train_df = np.matmul(X_train_df,weights)


print("RSS error on test data is :", computeRSSError(predicted_df,Y_test_df).values)

corr = np.corrcoef(np.transpose(predicted_df), np.transpose(Y_test_df))

cov = np.cov(predicted_df.T, Y_test_df.T)

print("Covariance matrix:")
print(cov)

print("Correlation matrix:")
print(corr)

print("Correlation between predicted and actual outcome variable is: ", corr[0,1])
```

```
RSS error on test data is : [130284.78439442]
Covariance matrix:
[[ 363.42063238  158.92424192]
 [ 158.92424192 2228.93362549]]
```

```
Correlation matrix:
[[1.         0.17657808]
 [0.17657808 1.        ]]
Correlation between predicted and actual outcome variable is:  0.17657808014781162
```

```
In [181]: # Repeating Linear regression by taking logarithm of area as the output variable
          #to compute the RSS error
          from numpy.linalg import inv

          X_train_df = n_train_df.iloc[:, :12]
          Y_train_df = train_df.iloc[:, 12:13]
          Y_train_log_df = np.log(Y_train_df.values)

          #OLS solution: weight = inv(X.T*X)*X.T*Y
          def computeOLS(X_train, Y_train):
              product = np.matmul(X_train.T,X_train)
              inverse = np.linalg.inv(product)
              result = np.matmul(inverse,np.matmul(X_train.T,Y_train))
              return result

          weights = computeOLS(X_train_df,Y_train_log_df)
          print("Shape of the weight matrix is :", weights.shape)
          print("weights obtained from OLS method are: {}". format(weights))

          s_test_df = test_df.loc[test_df['area'] > 0]
          s_test_df = s_test_df.iloc[:,:12]

          n_test_df = (s_test_df - s_train_df.mean())/(s_train_df.std())

          X_test_df = n_test_df
          Y_test_df = test_df.iloc[:,12:13]
          Y_test_df = Y_test_df.loc[Y_test_df['area'] > 0]
          Y_test_log_df = np.log(Y_test_df.values)

          def computeRSSError(y_predict, y_actual):
              diff = y_predict - y_actual
              return np.sum(np.power(diff,2))

          predicted_df = np.matmul(X_test_df,weights)

          print("RSS error on test data with log area is: ",computeRSSError(predicted_df,Y_test_

          corr = np.corrcoef(predicted_df.T, Y_test_log_df.T)
          cov = np.cov(predicted_df.T, Y_test_log_df.T)

          print("Covariance matrix:")
          print(cov)
```

```
print("Correlation matrix:")
print(corr)

print("Correlation between predicted and actual outcome variable is: ", corr[0,1])
```

```
Shape of the weight matrix is : (12, 1)
weights obtained from OLS method are: [[ 0.02592881]
 [-0.12537356]
 [ 0.27153282]
 [ 0.17042503]
 [ 0.01022079]
 [ 0.26823179]
 [-0.38188961]
 [-0.19135272]
 [-0.10406242]
 [-0.20374163]
 [ 0.02775759]
 [ 0.06265049]]
RSS error on test data with log area is:  136.35103079050305
Covariance matrix:
[[0.09504973 0.00772395]
 [0.00772395 2.19934618]]
Correlation matrix:
[[1.         0.01689341]
 [0.01689341 1.        ]]
Correlation between predicted and actual outcome variable is:  0.016893405156312526
```

```
In [182]: # 3 c.iv) Bonus part, for experimenting with different non-linear functions of input f
          from numpy.linalg import inv
          from sklearn.preprocessing import PolynomialFeatures
          from sklearn.linear_model import LinearRegression

          train_df  = pd.read_csv("train.csv")
          test_df = pd.read_csv("test.csv")

          train_df = train_df.loc[train_df['area'] > 0]

          X_train_df = train_df.iloc[:,:12]
          Y_train_df = train_df.iloc[:,12:13]

          X_test_df = test_df.iloc[:,:12]
          Y_test_df = test_df.iloc[:,12:13]

          #Fitting polynomial regression to the data set -- degree 2
          poly = PolynomialFeatures(2)
          poly.fit_transform(X_train_df)
```

```
poly_train_df = poly.transform(X_train_df)
poly_test_df = poly.transform(X_test_df)

print("shape of train data after polynomial transformation:" ,poly_train_df.shape)
print("shape of test data after polynomial transformation:",poly_test_df.shape)

#do a normalization
n_train_df = (poly_train_df - poly_train_df.mean())/(poly_train_df.std())
n_test_df = (poly_test_df - poly_train_df.mean())/(poly_train_df.std())

lin_reg_degree_2 = LinearRegression()
lin_reg_degree_2.fit(n_train_df, Y_train_df)

predicted_df = lin_reg_degree_2.predict(n_test_df)
predicted_train_df = lin_reg_degree_2.predict(n_train_df)

polynomial_degree_list = [2,3 ,4]
RSS_error_test_list = []
RSS_error_train_list = []

RSS_error_test_list.append(computeRSSError(predicted_df,Y_test_df).values[0])
RSS_error_train_list.append(computeRSSError(predicted_train_df,Y_train_df).values[0])
print("RSS error on train is: ",
      computeRSSError(predicted_train_df,Y_train_df).values[0])
print("RSS error on test is: ",
      computeRSSError(predicted_df,Y_test_df).values[0])
```

```
shape of train data after polynomial transformation: (243, 91)
shape of test data after polynomial transformation: (51, 91)
RSS error on train is:  1488360.124120776
RSS error on test is:  404744.6917541748
```

In [183]:
```
#Fitting polynomial regression to the data set -- degree 3
poly = PolynomialFeatures(3)
poly.fit_transform(X_train_df)
poly_train_df = poly.transform(X_train_df)
poly_test_df = poly.transform(X_test_df)

print("shape of train data after polynomial transformation:" ,poly_train_df.shape)
print("shape of test data after polynomial transformation:",poly_test_df.shape)

#do a normalization
n_train_df = (poly_train_df - poly_train_df.mean())/(poly_train_df.std())
n_test_df = (poly_test_df - poly_train_df.mean())/(poly_train_df.std())

lin_reg_degree_3 = LinearRegression()
lin_reg_degree_3.fit(n_train_df, Y_train_df)
```

```
    predicted_df = lin_reg_degree_3.predict(n_test_df)
    predicted_train_df = lin_reg_degree_3.predict(n_train_df)

    RSS_error_test_list.append(computeRSSError(predicted_df,Y_test_df).values[0])
    RSS_error_train_list.append(computeRSSError(predicted_train_df,Y_train_df).values[0])

    print("RSS error on train is: ",
          computeRSSError(predicted_train_df,Y_train_df).values[0])
    print("RSS error on test is: ",
          computeRSSError(predicted_df,Y_test_df).values[0])
```

```
shape of train data after polynomial transformation: (243, 455)
shape of test data after polynomial transformation: (51, 455)
RSS error on train is:  167.28000000000003
RSS error on test is:  125566492.65370616
```

```
In [184]: #Fitting polynomial regression to the data set -- degree 4
    poly = PolynomialFeatures(4)
    poly.fit_transform(X_train_df)
    poly_train_df = poly.transform(X_train_df)
    poly_test_df = poly.transform(X_test_df)

    print("shape of train data after polynomial transformation: " ,poly_train_df.shape)
    print("shape of test data after polynomial transformation: ",poly_test_df.shape)

    #do a normalization
    n_train_df = (poly_train_df - poly_train_df.mean())/(poly_train_df.std())
    n_test_df = (poly_test_df - poly_train_df.mean())/(poly_train_df.std())

    lin_reg_degree_4 = LinearRegression()
    lin_reg_degree_4.fit(n_train_df, Y_train_df)

    predicted_df = lin_reg_degree_4.predict(n_test_df)
    predicted_train_df = lin_reg_degree_4.predict(n_train_df)

    RSS_error_test_list.append(computeRSSError(predicted_df,Y_test_df).values[0])
    RSS_error_train_list.append(computeRSSError(predicted_train_df,Y_train_df).values[0])

    print("RSS error on train is: ",
          computeRSSError(predicted_train_df,Y_train_df).values[0])
    print("RSS error on test is: ",
          computeRSSError(predicted_df,Y_test_df).values[0])
```

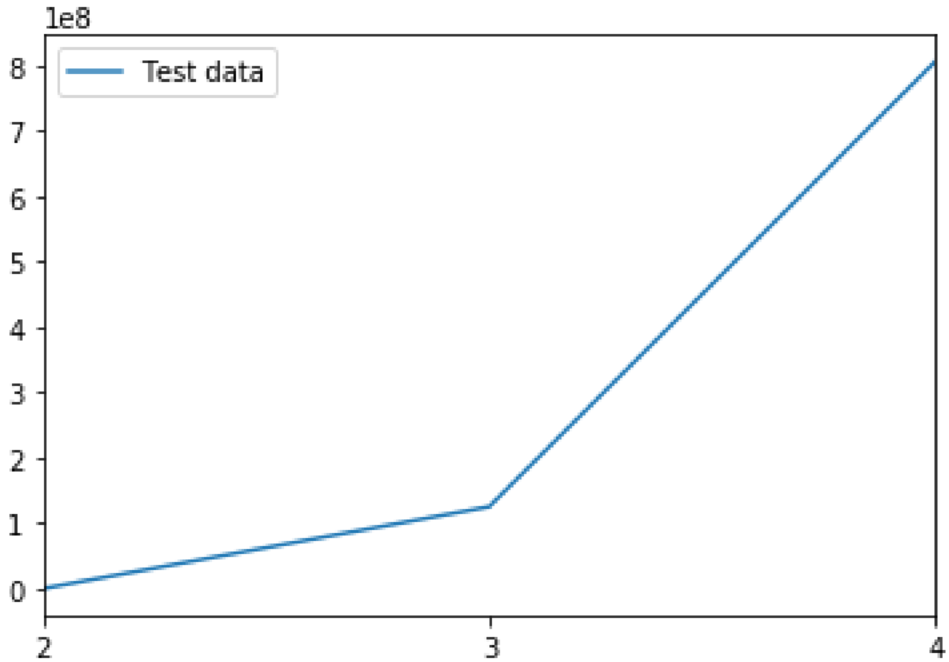
```
shape of train data after polynomial transformation:  (243, 1820)
shape of test data after polynomial transformation:  (51, 1820)
RSS error on train is:  167.2800000000098
```

```
RSS error on test is:  806139453.6862723
```

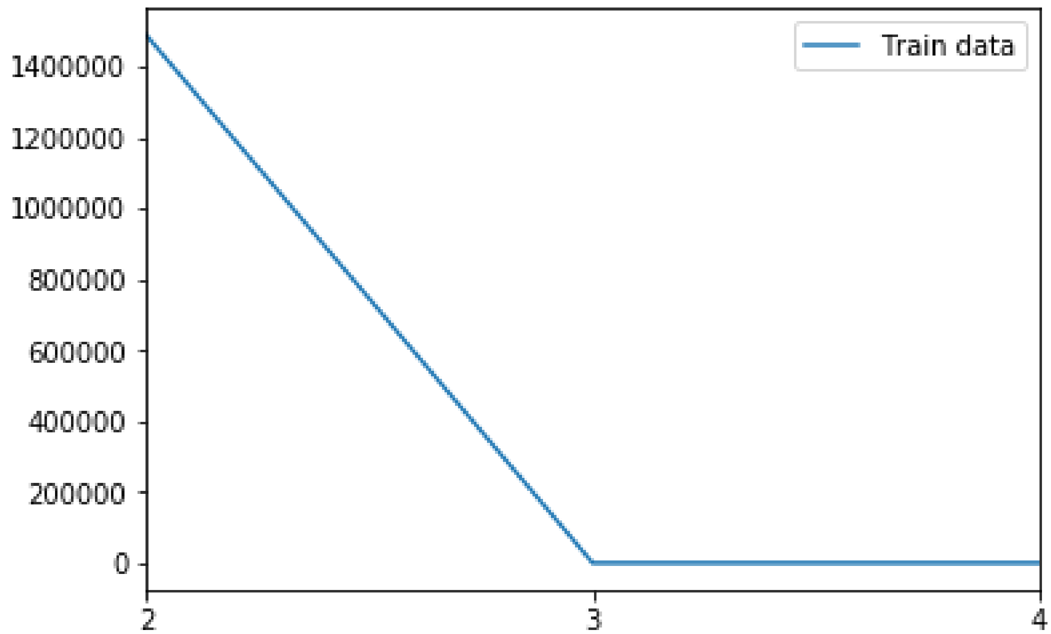
```
In [185]: print(RSS_error_test_list)
          print(RSS_error_train_list)
```

```
[404744.6917541748, 125566492.65370616, 806139453.6862723]
[1488360.124120776, 167.28000000000003, 167.2800000000098]
```

```
In [186]: plt.plot(polynomial_degree_list, RSS_error_test_list)
          plt.legend(['Test data'])
          plt.xlim([2,4])
          plt.xticks(np.arange(2,5,step=1))
          plt.show()
```




```
In [187]: plt.plot(polynomial_degree_list, RSS_error_train_list)
          plt.legend(['Train data'])
          plt.xlim([2,4])
          plt.xticks(np.arange(2,5,step=1))
          plt.show()
```


Train data
1400000
1200000
1000000
800000
600000
400000
200000
0
2
3
4

```
In [ ]:
```