ASSIGNMENT 1

ANDREW ID: parmenin

18-788: Big Data Science

3/25/23

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I, the undersigned, have read the entire contents of the syllabus for course 18-788 (Big Data Science) and agree with the terms and conditions of participating in this course, including adherence to CMU's AIV policy.

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LIBRARIES USED

- import numpy as np
- import pandas as pd
- import matplotlib.pyplot as plt
- import warnings
- # %pip install haversine
- from haversine import haversine
- from scipy.optimize import curve_fit
- from sklearn.metrics import r2_score
- from sklearn.metrics import mean_squared_error
- from sklearn.model_selection import train_test_split
- from sklearn.neighbors import KNeighborsRegressor
- from sklearn.tree import DecisionTreeRegressor
- warnings.filterwarnings("ignore")

QUESTION 1:

It was asked to load into the environment (Jupyter notebook), the two historical monthly datasets (RwandaDistrictRainfall.csv and RwandaDistrictVegetation.csv) for each of the thirty districts in Rwanda. The data they offer includes measurements of rainfall and enhanced vegetation index, which are derived from data obtained through satellite imaging. This was done by downloading them and using the pandas' read_cv function[1] to read from them.

QUESTION 2:

It was now required to graph two, time series for both rainfall and vegetation index with 6x5 subplots each for all the districts. Preprocessing the data frame was done by first transposing it, and inserting the date range to it to ease the plotting of the time. Next, the subplots were plotted for both rainfall and vegetation using the matplotlib.pyplot's subplots function[2] for plotting and subplots_adjust[3] for adding margins to the plot and the following two graphs were produced.

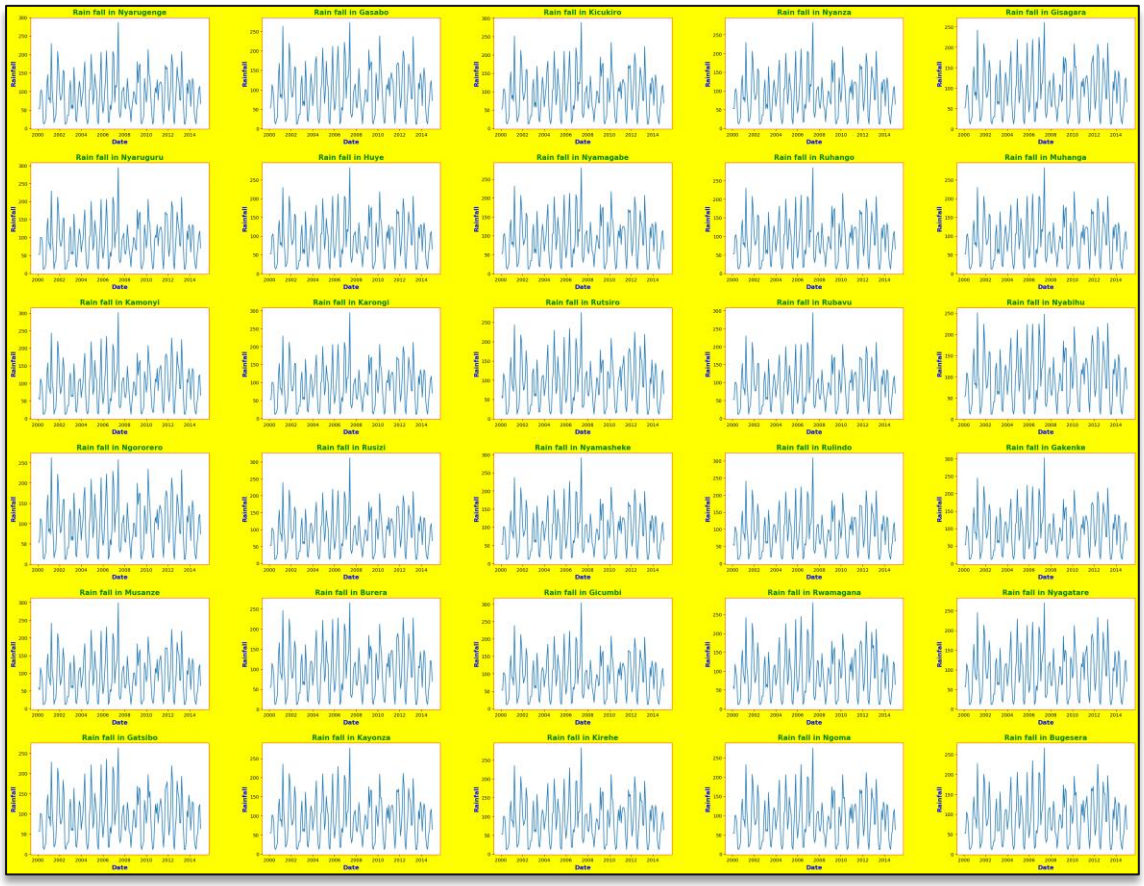
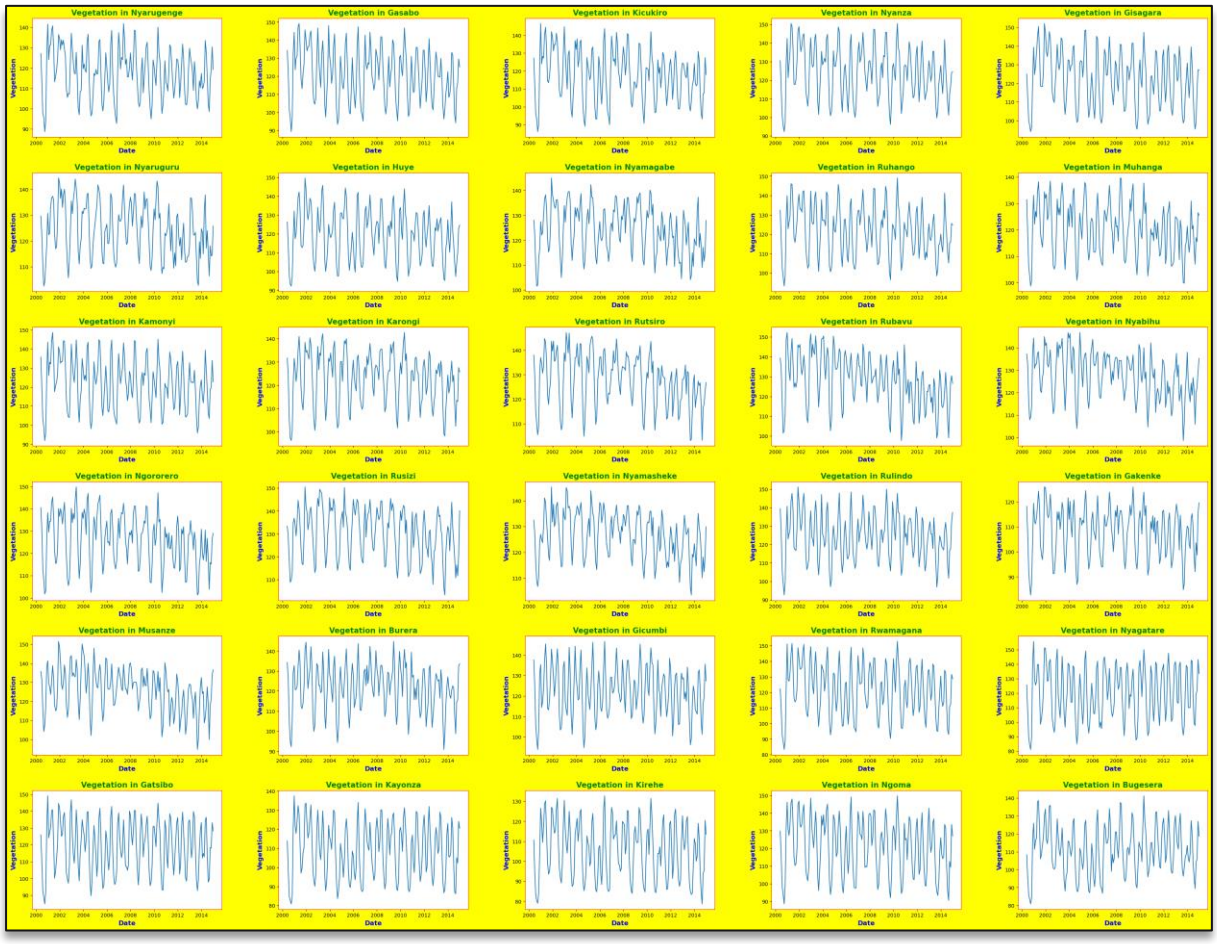


Figure 1: The subplots for rainfall in 30 districts

We can infer from the graph that the highest quantity of rain had fallen first, in 2007 and second, in 2001 in most of the districts of the country.



<u>Figure 2:</u> The subplots for vegetation index in 30 districts

We can infer from the graph that, as the highest quantity of rain had fallen first, in 2007 and second, in 2001 in most of the districts of the country caused the vegetation index to go high in 2001 and 2002 as well, even though the lowest quantity of vegetation index was found in the year 2001 for the most of the districts.

<u>QUESTION 3:</u>

It was required to calculate the mean, median, minimum, and maximum of both the rain fall and vegetation index for each month of the year, i.e., 12 monthly values and to plot them against the month of the year. These were calculated and stored inside the following data frame and plotted as of below.

	Mean	Median	Minimum	Maximum
0	69.083333	68.70	46.9	105.9
1	100.239778	86.50	52.9	238.4
2	139.459333	135.30	52.9	263.5
3	148.915556	141.20	97.4	244.7
4	112.469111	100.65	36.2	311.8
5	24.529333	20.30	11.8	52.9
6	15.152667	11.80	11.8	29.4
7	41.829778	41.20	14.7	80.9
8	85.049111	94.10	23.5	182.7
9	126.871111	114.05	29.4	236.5
10	135.926667	117.60	76.5	229.4
11	100.438444	94.10	41.2	200.0

Figure 3: The mean, median, minimum, and maximum data frame for rainfall

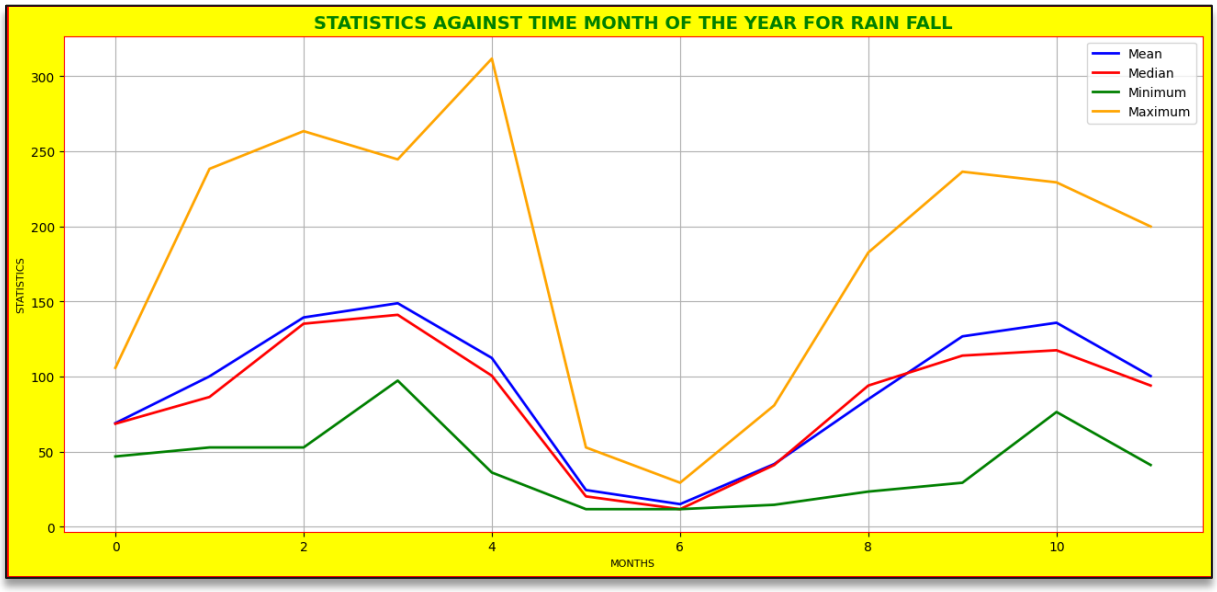


Figure 4: The mean, median, minimum, and maximum graph for rainfall

We can infer from the above plot and data frame that the low precipitation in Rwanda is seen in the month of July and the highest rainfall is seen in the month of April.

	Mean	Median	Minimum	Maximum
0	124.140874	123.987221	93.649422	150.495856
1	120.469059	121.296982	88.375662	149.525034
2	124.236352	125.807144	98.306588	150.224410
3	133.260526	136.536959	100.691685	152.635095
4	135.315459	138.384247	108.315401	151.328737
5	125.576479	127.417296	95.024470	143.043877
6	110.991302	111.805282	83.192432	130.992456
7	103.655364	103.049909	78.661577	129.470863
8	105.528631	106.236392	78.962225	126.923562
9	113.553146	114.049997	84.074041	139.933869
10	128.385639	128.324193	98.071576	152.008141
11	130.453648	130.134722	103.750315	155.625355

Figure 3: The mean, median, minimum, and maximum data frame for vegetation index

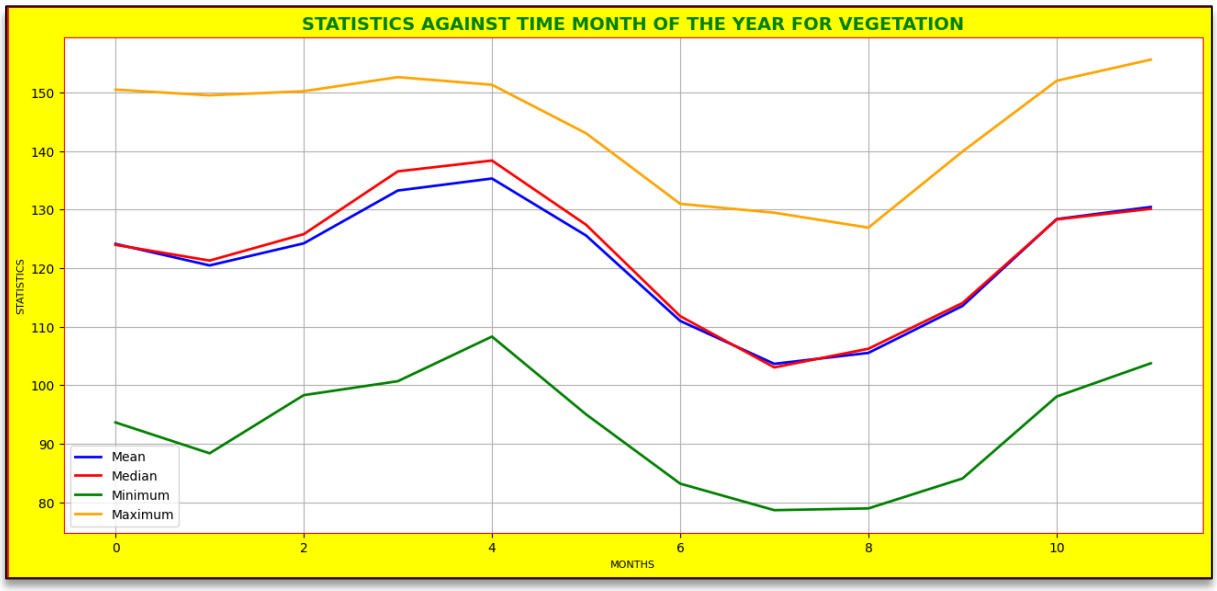


Figure 4: The mean, median, minimum, and maximum graph for vegetation index

From the above data frame and graph we can infer that the low vegetation index in Rwanda is seen in the month of August and the highest vegetation index is seen in the month of May.

QUESTION 4:

It is needed to compute the correlation coefficient (C) for rainfall between all pairs of districts and create a graph that shows the correlation against distance in kilometers. The graph should use the C(d) = C0exp(-ad) model to fit the data and plot a curve that illustrates the decline in correlation with distance. Finally, we needed to estimate the values of C0 and the decay constant (a) for the model.

This was done by first, loading the "RwandaDistrictCentroidsLongitude_Latitude.csv" data set, calculating the correlation coefficient **C** for rainfall between each pair of districts, computing the distance **d** between the pair. This was performed by the help of the haversine library which calculate the great-circle distance between two points on the Earth surface[4] and found to be **34.693078998302425 km**. After that, the following graph is made to show the correlation values versus the distance.

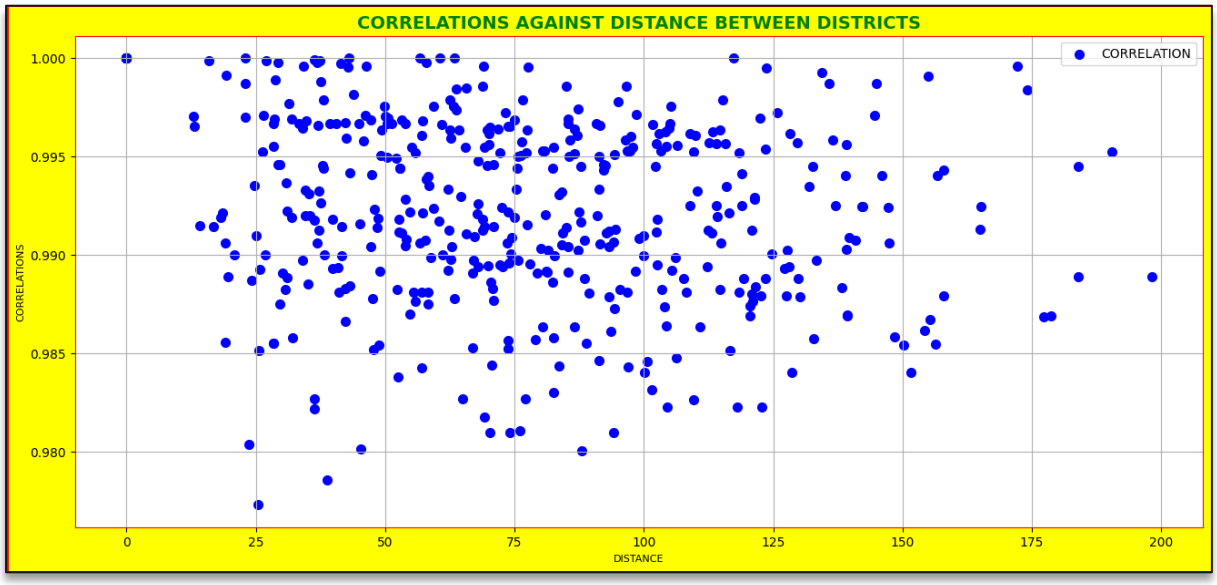
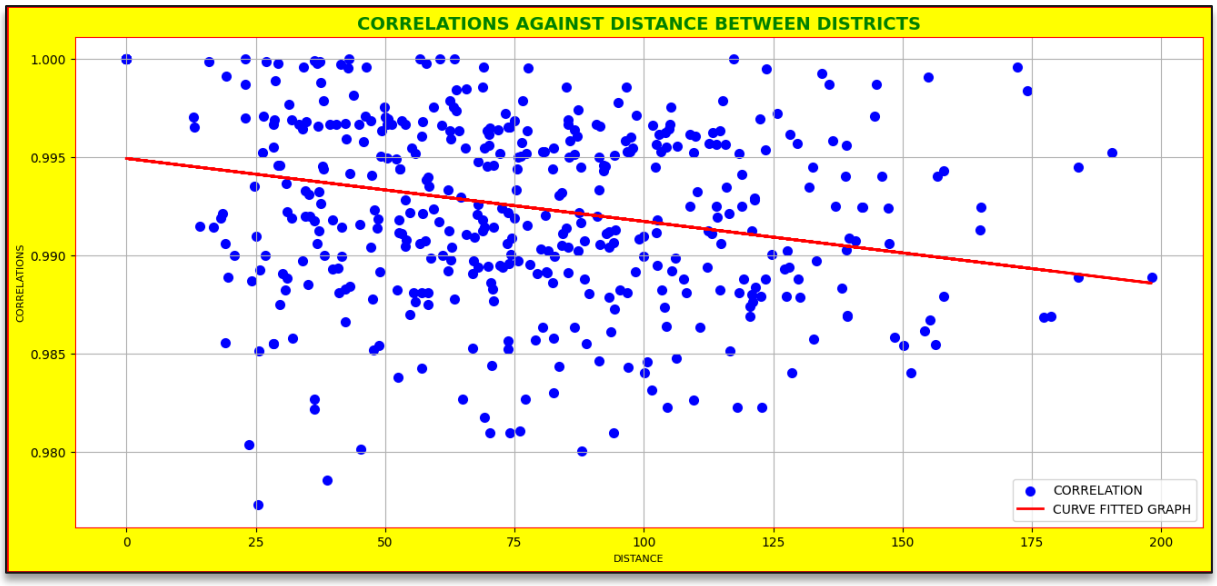


Figure 5: The graph to show the correlation values versus the distance.

Next, the model **C(d) = C0exp(-ad)** is fit, and the **curve_fit**[5] function is fit to the model, distances and correlations to provide the params (**C0)** and the decay constant (**a)** are estimated and they are **0.9949362375041936** and **3.234477915376383e-05** respectively.

Finally, this curve is plotted below to show how quickly the correlation declines with distance.



<u>Figure 6:</u> The graph to show how quickly the correlation declines with distance

From the graph, we may deduce that the more remote the districts are from one another, the less their data are correlated, and the closer the districts are to one another, the more correlated their data are.

<u>QUESTION 5:</u>

For this question, it was required to synchronize the dates for both rainfall and vegetation index and make a scatter plot for the same months and use colors and symbols to create a legend for the graph. This was done by first dropping the first four rows in the rainfall data set to match the shape with vegetation index. Then synchronizing the dates by making the date column as the index. After that, the following labelled plot is sketched show the vegetation index against rainfall.

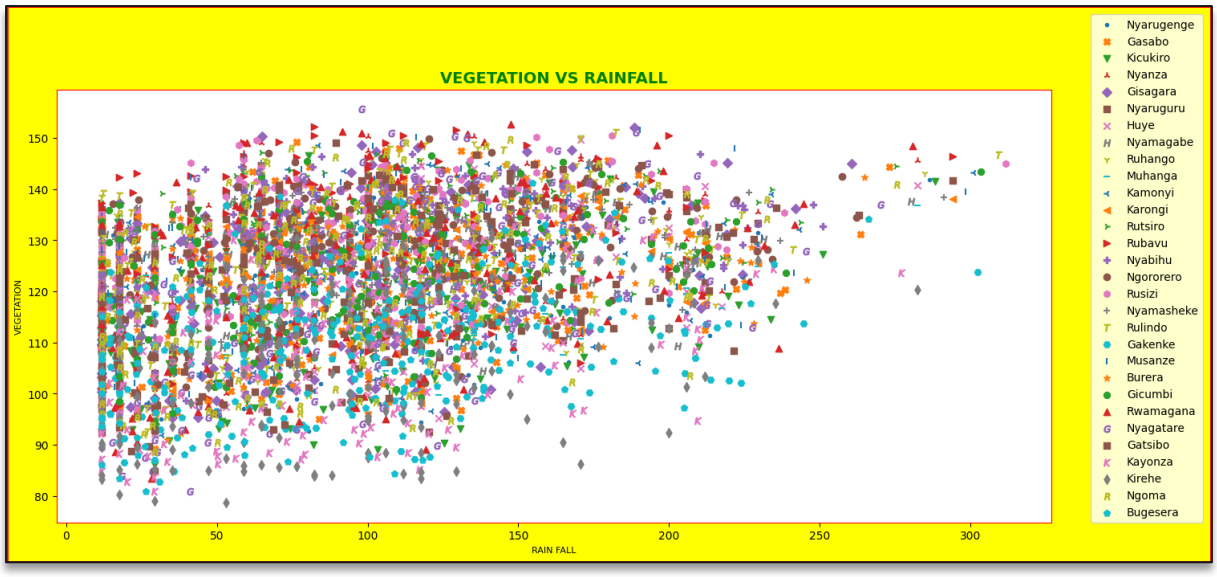


Figure 7: The graph for vegetation index against rainfall

We can infer from the graph that there is a strong correlation between rainfall and vegetation.

QUESTION 6:

As the optimal K is 1, therefore the rainfall has a considerable effect on vegetation after one month.

QUESTION 7:

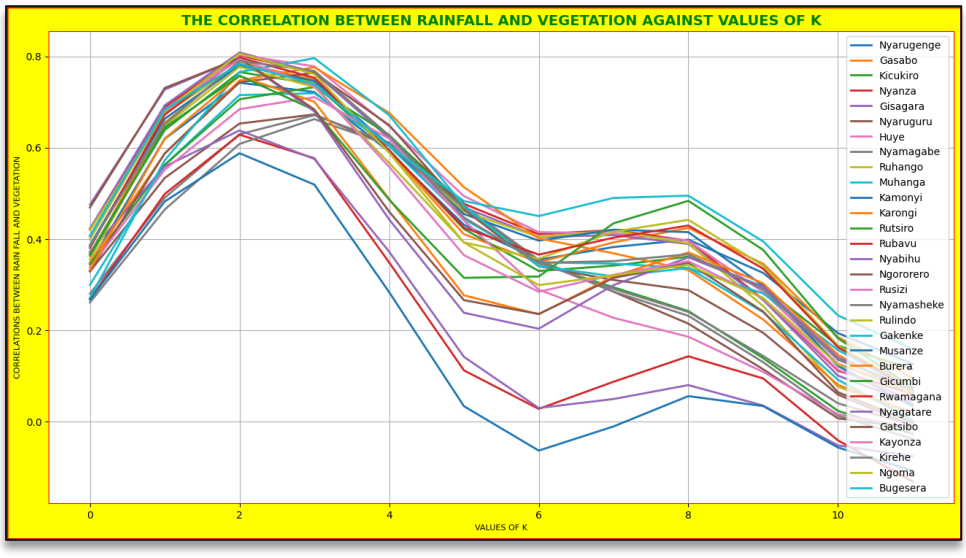


Figure 8: The correlation vs values of k

The value of K that gives the highest correlation is 2 because it has repeated many times.

QUESTION 8:

	LINEAR	QUADRATIC	CUBIC
R2 FOR RAINFALL	0.109453	0.116198	0.118972
R2 FOR DELAYED RAINFALL	0.388732	0.446825	0.449767
R2 FOR SMA FOR RAINFALL	0.453645	0.471145	0.471967

Figure 9: The r squared table.

	LINEAR	QUADRATIC	CUBIC
ADJUSTED R2 FOR RAINFALL	0.109284	0.116030	0.118805
ADJUSTED R2 FOR DELAYED RAINFALL	0.388615	0.446719	0.449662
ADJUSTED R2 FOR SMA FOR RAINFALL	0.453540	0.471043	0.471866

Figure 10: The adjusted r squared table.

	LINEAR	QUADRATIC	CUBIC
RMSE FOR RAINFALL	13.197640	13.147566	13.126912
RMSE FOR DELAYED RAINFALL	10.944063	10.411039	10.383314
RMSE FOR SMA FOR RAINFALL	10.358588	10.191343	10.183412

Figure 11: The root mean squared error table.

The best model is the cubic table as it has low errors and has larger r square and adjusted r squared scores.

QUESTION 9:

	LINEAR	QUADRATIC	CUBIC
RAINFALL	0.096467	0.098395	0.098415
DELAYED RAINFALL	0.386211	0.438682	0.440549
SMA FOR RAINFALL	0.435076	0.446277	0.447589
SMA FOR DELAYED RAINFALL	0.249434	0.268109	0.270667

Figure 12: **The r squared table.**

	LINEAR	QUADRATIC	CUBIC
RAINFALL	0.095610	0.097540	0.097560
DELAYED RAINFALL	0.385626	0.438146	0.440015
SMA FOR RAINFALL	0.434534	0.445745	0.447059
DELAYED SMA RAINFALL	0.248710	0.267403	0.269963

Figure 13: **The adjusted r squared table.**

	LINEAR	QUADRATIC	CUBIC
RAINFALL	13.081383	13.067421	13.067272
DELAYED RAINFALL	10.848912	10.374837	10.357573
SMA FOR RAINFALL	10.247044	10.144953	10.132926
SMA FOR DELAYED RAINFALL	11.827096	11.679034	11.658604

Figure 14: **The root mean squared error table.**

We can infer from the above tables that the best model is the cubic model.

QUESTION 10:

	LINEAR	QUADRATIC	CUBIC	DECISION TREE	KNN REGRESSOR
R2 SCORE	0.435076	0.446277	0.447589	0.225599	0.401993
RMSE SCORE	10.247044	10.144953	10.132926	11.997385	10.542822

By looking to the above to table, we can infer that the cubic model is the best performing model as it has the lowest root mean squared error.

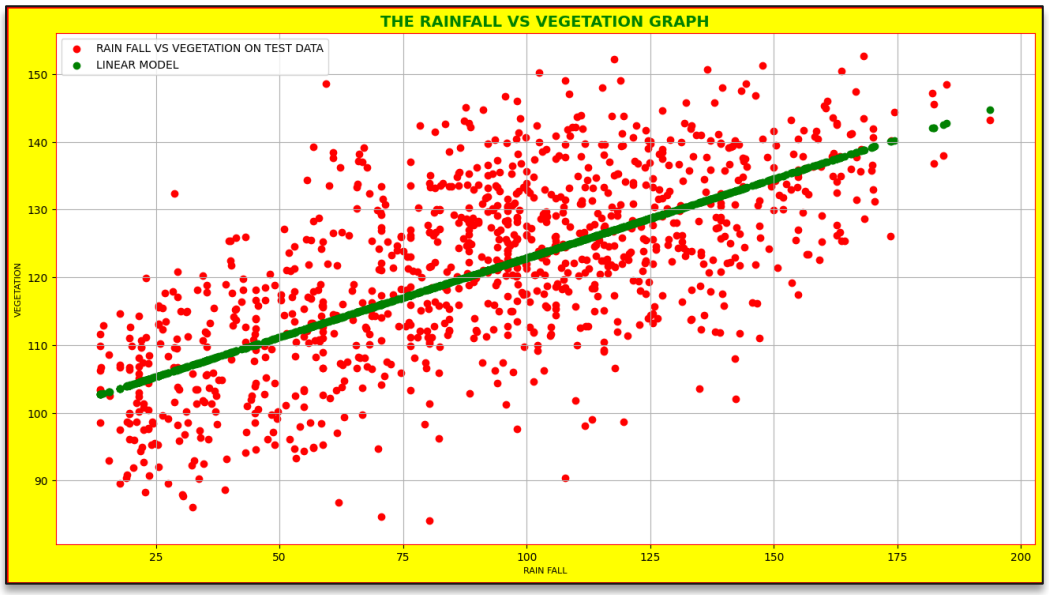


Figure 15: Linear model for vegetation vs rainfall

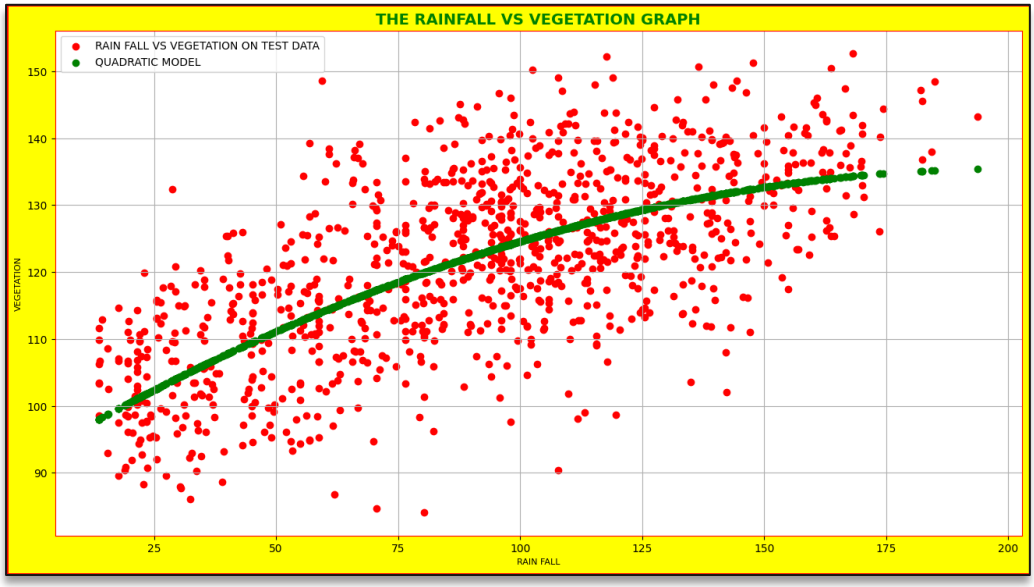


Figure 16: Quadratic model for vegetation vs rainfall

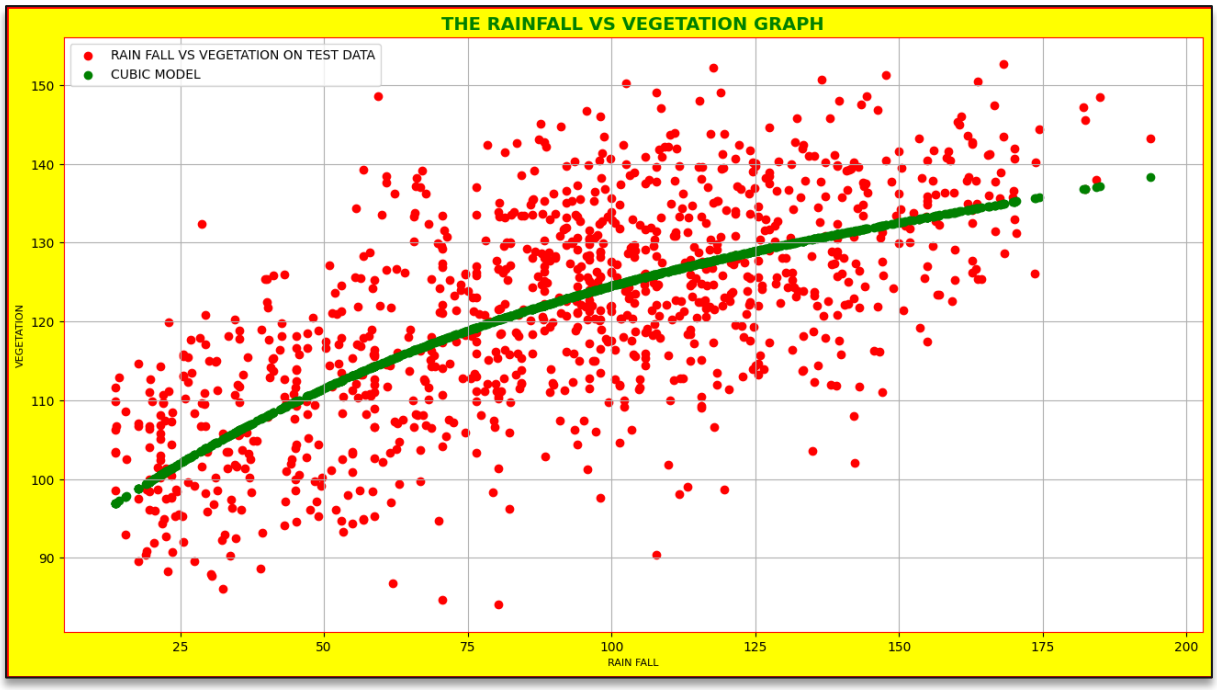


Figure 17: Cubic model for vegetation vs rainfall

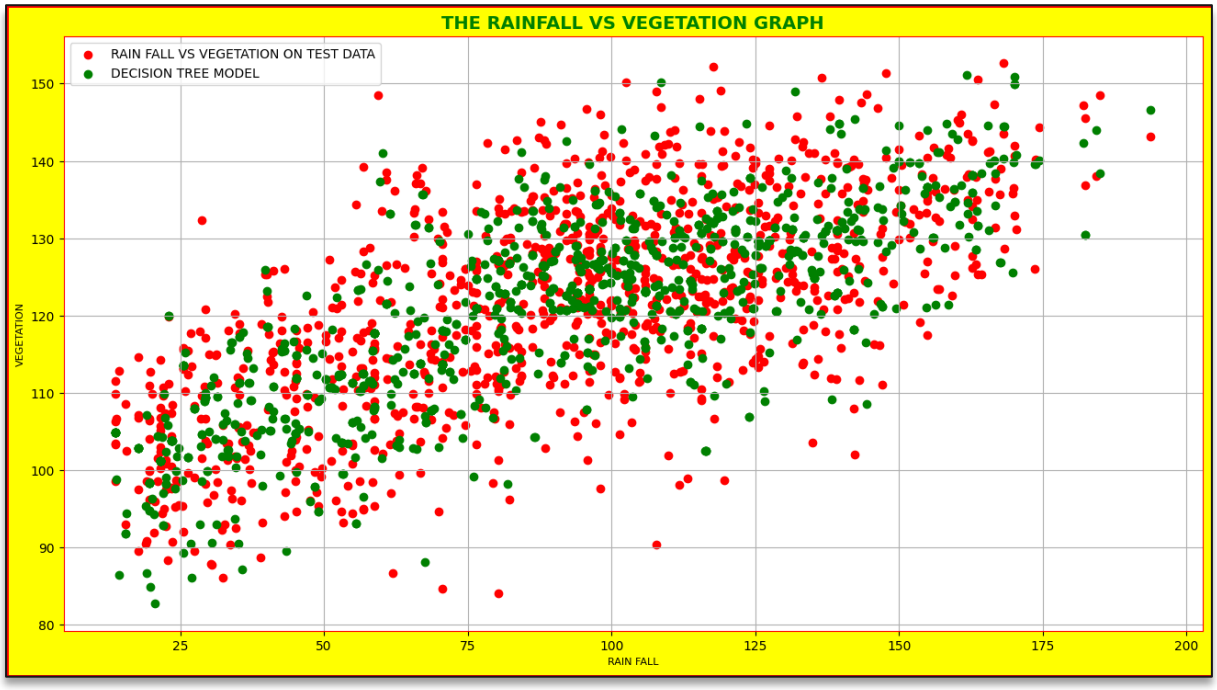


Figure 18: Decision tree model for vegetation vs rainfall

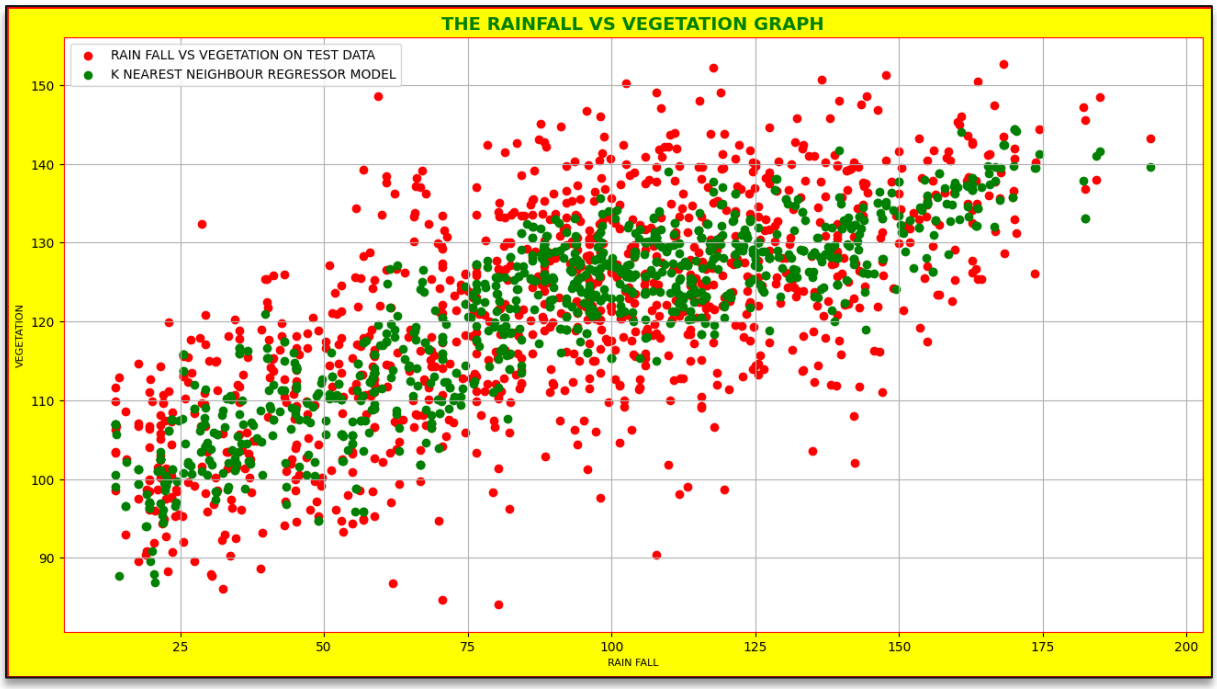


Figure 19: KNN model for vegetation vs rainfall

REFERENCES

[1] ‘pandas.read_csv — pandas 1.5.3 documentation’. https://pandas.pydata.org/docs/reference/api/pandas.read_csv.html (accessed Mar. 25, 2023).

[2] ‘17. Creating Subplots in Matplotlib | Numerical Programming’. https://python-course.eu/numerical-programming/creating-subplots-in-matplotlib.php (accessed Mar. 25, 2023).

[3] ‘Matplotlib Subplots_adjust - Python Guides’, Sep. 16, 2021. https://pythonguides.com/matplotlib-subplots_adjust/ (accessed Mar. 25, 2023).

[4] ‘haversine: Calculate the distance between 2 points on Earth.’ Accessed: Mar. 25, 2023. [Online]. Available: https://github.com/mapado/haversine

[5] ‘scipy.optimize.curve_fit — SciPy v1.10.1 Manual’. https://docs.scipy.org/doc/scipy/reference/generated/scipy.optimize.curve_fit.html (accessed Mar. 25, 2023).