Rainfall Analysis Report (2018–2022)

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Women in Data Science Fellowship Application

Date: 7/28/2025

Title: Rainfall Analysis of Five African Countries Using CHIRPS Data
Period Covered: January 2018 – December 2022
Data Source: Digital Earth Africa – CHIRPS Monthly Rainfall
Tools Used: Python (pandas, seaborn, matplotlib)

Purpose:
This analysis aims to assess rainfall trends and anomalies across selected African countries over a five-year period and explore how rainfall variability could influence agriculture and climate resilience strategies.

Introduction

Rainfall patterns play a central role in determining agricultural output and food security, especially in Sub-Saharan Africa where farming is predominantly rain-fed. Understanding these patterns is crucial for guiding crop planning, irrigation needs, and resilience strategies in the face of climate variability.

This analysis uses rainfall data from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), as provided by Digital Earth Africa. The dataset includes monthly rainfall totals (in millimeters) for various regions across five African countries from 2018 to 2022.

The goal of this report is to:

- Identify trends, seasonal patterns, and anomalies in rainfall across regions and years;

- Discuss the implications of rainfall variability on agriculture and food systems;
- Recommend an additional dataset that can enhance decision-making in climate or agrifood policy.

In [105…
```
# Import necessary libraries
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np

# Set styles for better visualization
sns.set_style("whitegrid")
plt.rcParams['figure.figsize'] = (14, 8)
```

Load the Dataset

In [106…
```
 #Step 1: Load the dataset
rainfall_data = pd.read_csv('CHIRPS_5_Countries_2018_2022.csv', encoding='latin1')
#rainfall_data.to_csv('CHIRPS_5_Countries_2018_2022_clean.csv', index=False, encoding='utf-8')
rainfall_data.head()
```

Out[106…

	Country	Region	Year	Month	Rainfall_mm
0	Kenya	Nairobi	2018	1	25.41
1	Kenya	Nairobi	2018	2	214.89
2	Kenya	Nairobi	2018	3	218.55
3	Kenya	Nairobi	2018	4	256.78
4	Kenya	Nairobi	2018	5	291.81

In [107…
```
rainfall_data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 900 entries, 0 to 899
Data columns (total 5 columns):
 #   Column       Non-Null Count  Dtype  
---  ------       --------------  -----  
 0   Country      900 non-null    object 
 1   Region       900 non-null    object 
 2   Year         900 non-null    int64  
 3   Month        900 non-null    int64  
 4   Rainfall_mm  900 non-null    float64
dtypes: float64(1), int64(2), object(2)
memory usage: 35.3+ KB
```

In [108…
```
rainfall_data.shape
```

Out[108…
```
(900, 5)
```

The dataset contains 5 variables (see below) and 900 entries of data

Variable	Type	Description
Country	Categorical	Name of the country where rainfall was recorded (e.g., Kenya, Nigeria).
Region	Categorical	Specific region or administrative unit within the country.
Year	Integer	Calendar year of the rainfall observation (2018 to 2022).
Month	Integer	Month of the observation (1 = January, 12 = December).
Rainfall_mm	Float	Recorded rainfall amount in millimeters (mm) for the region and month.

In [109…
```
rainfall_data["Country"].unique()
```

Out[109…
```
array(['Kenya', 'Ethiopia', 'Malawi', 'Benin', 'Côte d\x92Ivoire'],
      dtype=object)
```

In [110…
```
rainfall_data['Country'] = rainfall_data['Country'].replace("Côte d\x92Ivoire", "Côte d'Ivoire")

# Confirm the replacement was successful
rainfall_data['Country'].unique()
```

Out[110…
```
array(['Kenya', 'Ethiopia', 'Malawi', 'Benin', "Côte d'Ivoire"],
      dtype=object)
```

Data Cleaning

In [111…
```
rainfall_data.isna().sum()
```

Out[111…
```
Country        0
Region         0
Year           0
Month          0
Rainfall_mm    0
dtype: int64
```

The dataset contains no null values.

In [112…
```
# Convert Month to actual month names for better plotting
month_names = {1: 'Jan', 2: 'Feb', 3: 'Mar', 4: 'Apr', 5: 'May', 6: 'Jun',
               7: 'Jul', 8: 'Aug', 9: 'Sep', 10: 'Oct', 11: 'Nov', 12: 'Dec'}
rainfall_data['month_name'] = rainfall_data['Month'].map(month_names)
```

In [113…
```
rainfall_data.head()
```

Out[113…

	Country	Region	Year	Month	Rainfall_mm	month_name
0	Kenya	Nairobi	2018	1	25.41	Jan
1	Kenya	Nairobi	2018	2	214.89	Feb
2	Kenya	Nairobi	2018	3	218.55	Mar
3	Kenya	Nairobi	2018	4	256.78	Apr
4	Kenya	Nairobi	2018	5	291.81	May

In [114…
```
# Create a date
rainfall_data['Date'] = pd.to_datetime(rainfall_data['Year'].astype(str) + '-' + rainfall_data['Month'].astype(str) +


# Sort by date for time series
```

```
rainfall_data.sort_values('Date', inplace=True)

rainfall_data.head()
```

Out[114...

	Country	Region	Year	Month	Rainfall_mm	month_name	Date
0	Kenya	Nairobi	2018	1	25.41	Jan	2018-01-01
360	Malawi	Lilongwe	2018	1	145.66	Jan	2018-01-01
540	Benin	Cotonou	2018	1	10.17	Jan	2018-01-01
780	Côte d'Ivoire	Bouaké	2018	1	315.61	Jan	2018-01-01
120	Kenya	Mombasa	2018	1	317.67	Jan	2018-01-01

In [115...

```
# Monthly average rainfall per country
monthly_avg = rainfall_data.groupby(['Country', 'Date', 'month_name'])['Rainfall_mm'].mean().reset_index()
monthly_avg.head()
```

Out[115...

	Country	Date	month_name	Rainfall_mm
0	Benin	2018-01-01	Jan	45.000000
1	Benin	2018-02-01	Feb	175.276667
2	Benin	2018-03-01	Mar	84.633333
3	Benin	2018-04-01	Apr	259.563333
4	Benin	2018-05-01	May	118.070000

In [116...

```
monthly_avg_sorted = monthly_avg.sort_values(by='Rainfall_mm', ascending=False)

#top 10 average monthly rainfall
top_10_monthly_avg = monthly_avg_sorted.groupby('Country').head(10)
```

In [117...

```
top_10_monthly_avg.head()
```

Out[117…

	Country	Date	month_name	Rainfall_mm
231	Kenya	2022-04-01	Apr	370.560000
255	Malawi	2019-04-01	Apr	364.673333
100	Côte d'Ivoire	2021-05-01	May	363.846667
238	Kenya	2022-11-01	Nov	344.966667
138	Ethiopia	2019-07-01	Jul	338.873333

Exploratory Data Analysis

In [118…

```
# Sort the DataFrame by Country, Region, and Date
rainfall_sorted = rainfall_data.sort_values(by=['Country', 'Region', 'Date'])

# Get unique countries and regions
unique_countries = rainfall_sorted['Country'].unique()
unique_regions = rainfall_sorted['Region'].unique()
```

In [119…

```
unique_countries
```

Out[119…

```
array(['Benin', "Côte d'Ivoire", 'Ethiopia', 'Kenya', 'Malawi'],
      dtype=object)
```

In [120…

```
unique_regions
```

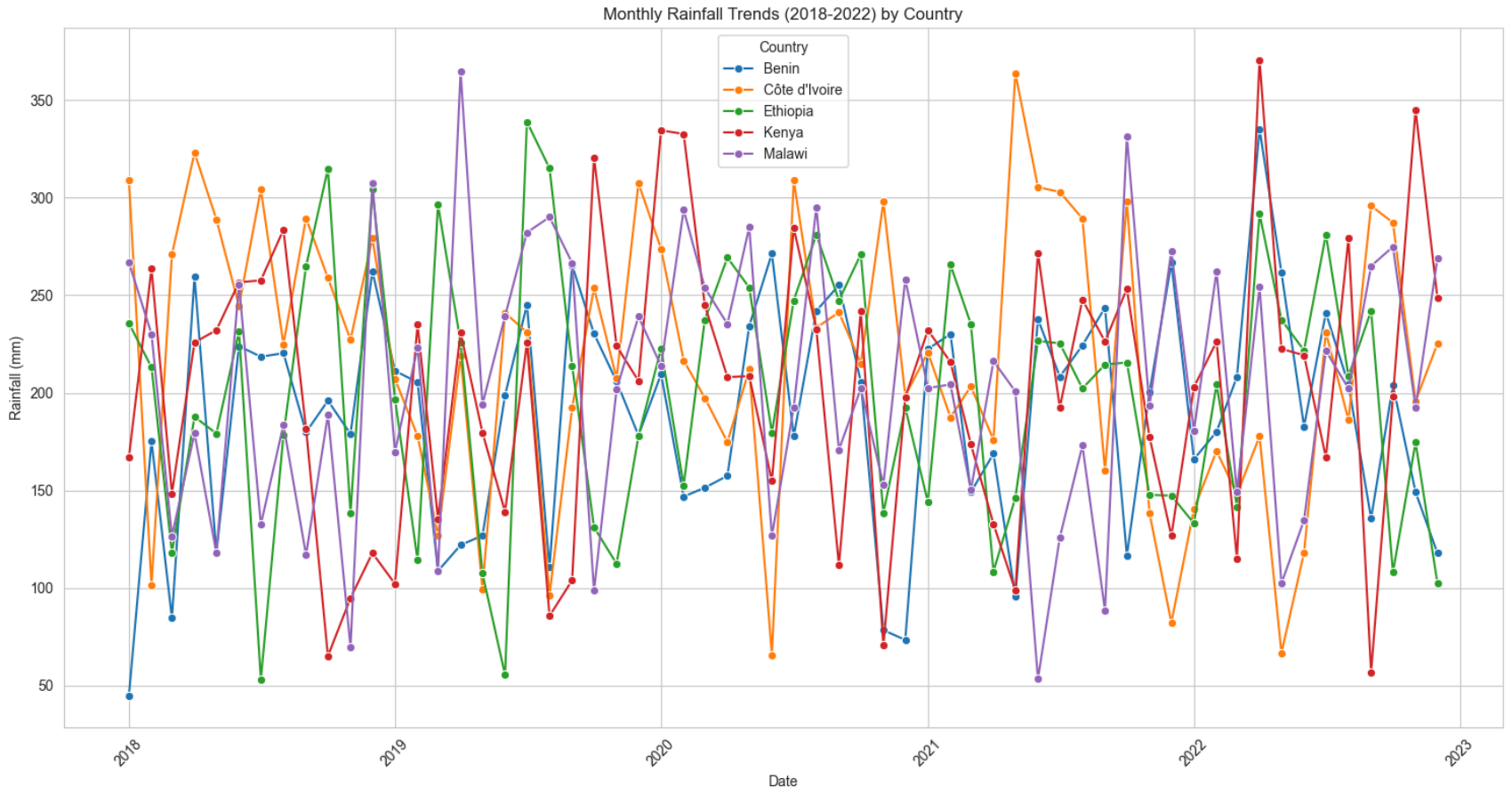
Out[120…

```
array(['Abomey', 'Cotonou', 'Parakou', 'Abidjan', 'Bouaké', 'Korhogo',
       'Addis Ababa', 'Hawassa', 'Mekelle', 'Kisumu', 'Mombasa',
       'Nairobi', 'Blantyre', 'Lilongwe', 'Mzuzu'], dtype=object)
```

In [121…

```
# Plotting monthly rainfall for each country
plt.figure(figsize=(15, 8))
sns.lineplot(data=rainfall_sorted, x='Date', y='Rainfall_mm', hue='Country', errorbar=None, marker='o')
plt.title('Monthly Rainfall Trends (2018-2022) by Country')
plt.xlabel('Date')
plt.ylabel('Rainfall (mm)')
plt.grid(True)
plt.legend(title='Country')
```

```
plt.xticks(rotation=45)
plt.tight_layout()
plt.savefig('monthly_rainfall_by_country_trend.png')
plt.show()
```

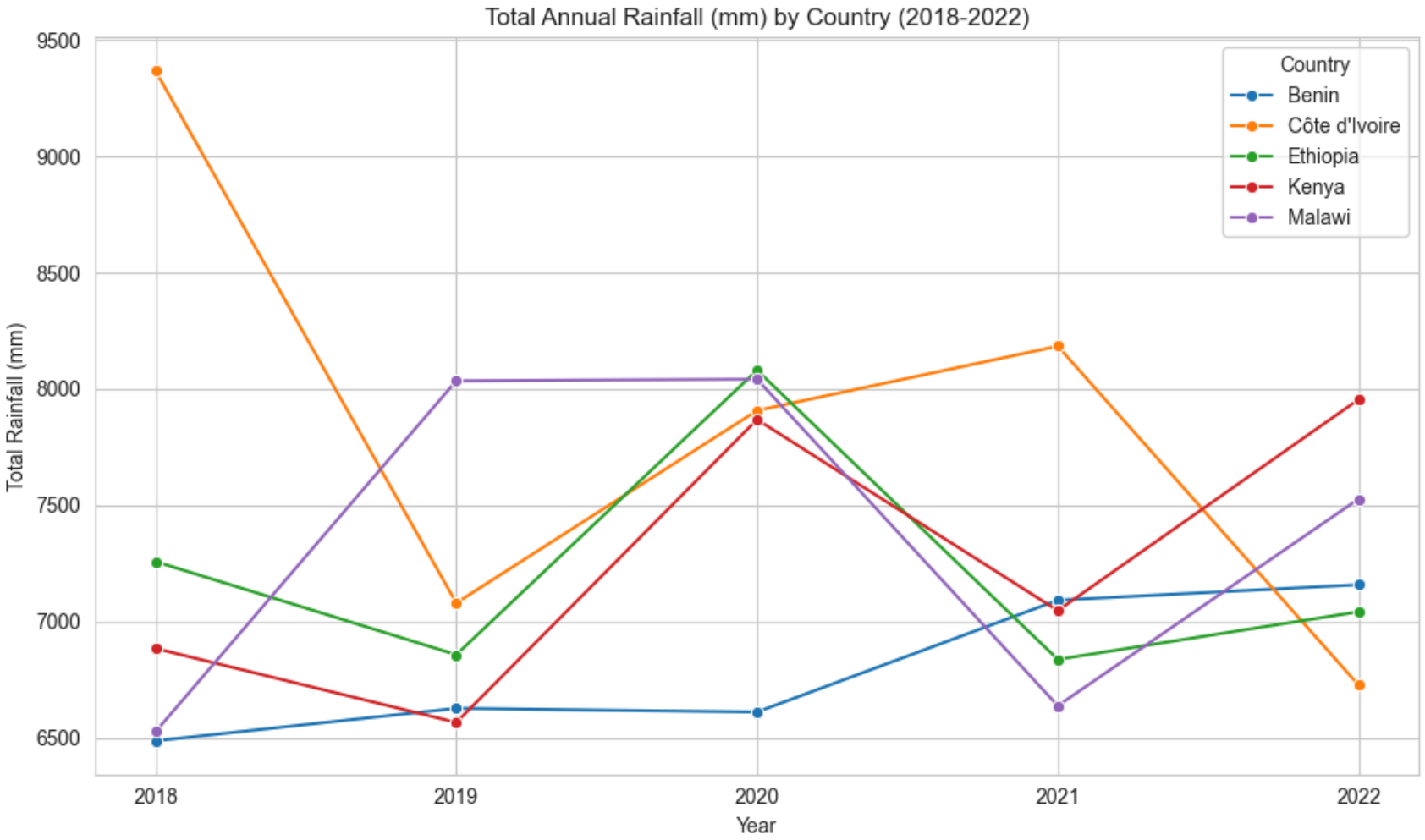


In [154…

```
# Calculate total annual rainfall for each country
annual_rainfall_country = rainfall_data.groupby(['Country', 'Year'])['Rainfall_mm'].sum().reset_index()

# Plotting the annual rainfall for each country
plt.figure(figsize=(10, 6))
sns.lineplot(data=annual_rainfall_country, x='Year', y='Rainfall_mm', hue='Country', marker='o')
plt.title('Total Annual Rainfall (mm) by Country (2018-2022)')
plt.xlabel('Year')
plt.ylabel('Total Rainfall (mm)')
plt.xticks(annual_rainfall_country['Year'].unique())
```

```
plt.grid(True)
plt.legend(title='Country')
plt.tight_layout()
plt.savefig('annual_rainfall_by_country.png')
plt.show()
```



Key Observations:

- Côte d'Ivoire :

Shows the highest total annual rainfall in 2018 (~9500 mm). Experiences a significant decline in rainfall from 2018 to 2019, followed by fluctuations but generally lower totals compared to 2018.

- Malawi :

Consistently high rainfall throughout the period. Peaks at around 8000 mm in 2020, making it one of the wettest years for Malawi.

- Ethiopia :

Relatively stable rainfall pattern with slight increases over time. Reaches its peak in 2020 (~8000 mm), similar to Malawi.

- Kenya :

Moderate rainfall levels compared to other countries. Shows an increasing trend from 2019 to 2022, with a notable rise in 2022.

- Benin :

The lowest total annual rainfall among the five countries. Exhibits a gradual increase from 2018 to 2022, stabilizing around 7000 mm.

Insights:

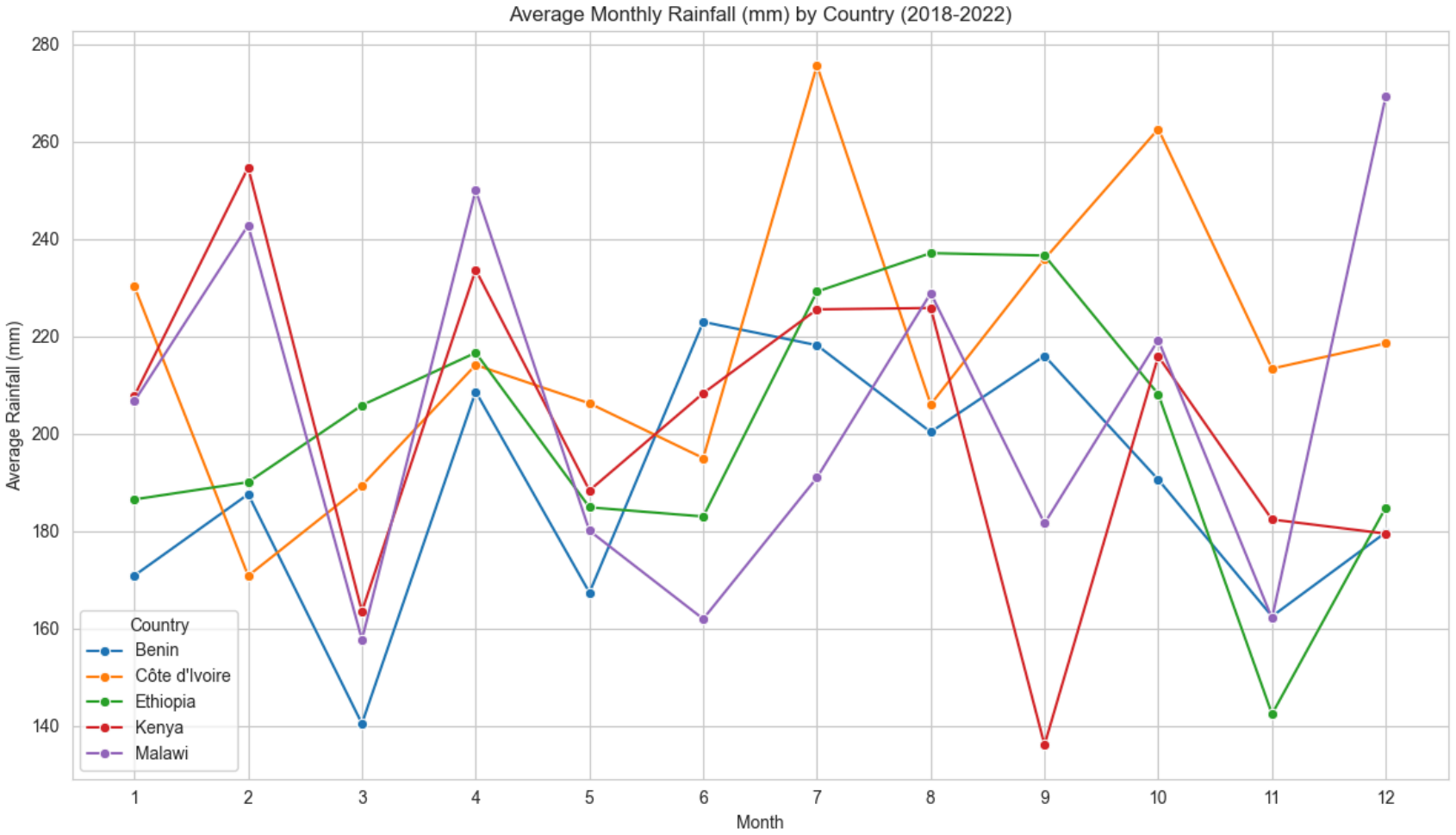
- Côte d'Ivoire had an exceptionally wet year in 2018, which sharply declined afterward.
- Malawi and Ethiopia are consistently wetter than the other countries, with peaks in 2020.
- Kenya shows a recovery trend after a dry period in 2019.
- Benin remains the driest country overall but has shown improvement in recent years.

In [126…

```
# Calculate average monthly rainfall across all years for each country to observe seasonal patterns
monthly_avg_rainfall_country = rainfall_data.groupby(['Country', 'Month'])['Rainfall_mm'].mean().reset_index()

# Plotting the average monthly rainfall for each country
plt.figure(figsize=(12, 7))
sns.lineplot(data=monthly_avg_rainfall_country, x='Month', y='Rainfall_mm', hue='Country', marker='o')
plt.title('Average Monthly Rainfall (mm) by Country (2018-2022)')
plt.xlabel('Month')
plt.ylabel('Average Rainfall (mm)')
plt.xticks(range(1, 13))
plt.grid(True)
plt.legend(title='Country')
```

```
plt.tight_layout()
plt.savefig('average_monthly_rainfall_by_country.png')
plt.show()
```



Interpretation:

Distinct Seasonal Patterns:

- **Bimodal Pattern** (East Africa: Kenya, Uganda, Malawi): Countries like Kenya and Uganda exhibit a "bimodal" pattern with two distinct rainy seasons. The first peak typically occurs around March-May (Long Rains), and the second, generally shorter, peak

occurs around October-December (Short Rains). This pattern is characteristic of regions influenced by the bi-annual movement of the Intertropical Convergence Zone (ITCZ).

- **Unimodal Pattern** (West Africa: Mali, Niger, Côte d'Ivoire): Countries in West Africa generally show a "unimodal" pattern, with a single, extended rainy season that typically peaks between July and September. This aligns with the ITCZ's northward movement during the Northern Hemisphere's summer.

Rainfall Intensity: The intensity of rainfall during peak months varies significantly among countries. For example, Côte d'Ivoire often shows higher average monthly rainfall during its peak season compared to more arid countries like Niger.

Dry Seasons: Conversely, periods with very low average monthly rainfall are also clearly visible, representing the dry seasons that impact planting decisions and necessitate water conservation strategies.

Implication: Understanding these distinct monthly and seasonal patterns is fundamental for farmers to determine optimal planting and harvesting times, manage irrigation, and select appropriate crop varieties. Deviations from these average patterns can lead to agricultural challenges, as discussed in the anomalies section.

Anomalies

In [145…
```
# Define the new anomaly thresholds
max_threshold = 350
min_threshold = 30

# Identify very high rainfall anomalies based on the new threshold
high_anomalies_fixed = rainfall_data[rainfall_data['Rainfall_mm'] > max_threshold]

# Identify very low rainfall anomalies based on the new threshold
low_anomalies_fixed = rainfall_data[rainfall_data['Rainfall_mm'] < min_threshold]
```

In [146…
```
print(f"Rainfall Anomalies: Months with Rainfall Greater than {max_threshold} mm:")
print(high_anomalies_fixed[['Country', 'Region', 'Year', 'Month', 'Rainfall_mm']].sort_values(by='Rainfall_mm', asce

print(f"\nRainfall Anomalies: Months with Rainfall Less than {min_threshold} mm:")
print(low_anomalies_fixed[['Country', 'Region', 'Year', 'Month', 'Rainfall_mm']].sort_values(by='Rainfall_mm', ascen
```

```
Rainfall Anomalies: Months with Rainfall Greater than 350 mm:
           Country       Region  Year  Month  Rainfall_mm
231       Ethiopia  Addis Ababa  2022      4       399.89
754  Côte d'Ivoire      Abidjan  2020     11       399.18
547          Benin      Cotonou  2018      8       398.77
232       Ethiopia  Addis Ababa  2022      5       398.67
804  Côte d'Ivoire       Bouaké  2020      1       397.99
..             ...          ...   ...    ...          ...
254       Ethiopia      Mekelle  2019      3       351.28
750  Côte d'Ivoire      Abidjan  2020      7       350.51
648          Benin      Parakou  2022      1       350.19
760  Côte d'Ivoire      Abidjan  2021      5       350.10
314       Ethiopia      Hawassa  2019      3       350.06

[125 rows x 5 columns]

Rainfall Anomalies: Months with Rainfall Less than 30 mm:
           Country       Region  Year  Month  Rainfall_mm
521         Malawi        Mzuzu  2021      6         6.83
868  Côte d'Ivoire      Korhogo  2020      5         7.52
107          Kenya       Kisumu  2021     12         9.28
645          Benin      Parakou  2021     10         9.34
156          Kenya      Mombasa  2021      1         9.48
170          Kenya      Mombasa  2022      3         9.80
598          Benin      Cotonou  2022     11        10.14
540          Benin      Cotonou  2018      1        10.17
32           Kenya      Nairobi  2020      9        10.69
263       Ethiopia      Mekelle  2019     12        10.75
773  Côte d'Ivoire      Abidjan  2022      6        12.06
494         Malawi        Mzuzu  2019      3        12.15
71           Kenya       Kisumu  2018     12        12.20
636          Benin      Parakou  2021      1        12.26
582          Benin      Cotonou  2021      7        12.79
340       Ethiopia      Hawassa  2021      5        12.93
749  Côte d'Ivoire      Abidjan  2020      6        13.40
625          Benin      Parakou  2020      2        13.88
77           Kenya       Kisumu  2019      6        14.19
747  Côte d'Ivoire      Abidjan  2020      4        14.64
12           Kenya      Nairobi  2019      1        15.01
574          Benin      Cotonou  2020     11        15.03
215       Ethiopia  Addis Ababa  2020     12        15.41
56           Kenya      Nairobi  2022      9        15.47
```

601	Benin	Parakou	2018	2	15.48
578	Benin	Cotonou	2021	3	15.70
257	Ethiopia	Mekelle	2019	6	16.37
859	Côte d'Ivoire	Korhogo	2019	8	16.55
674	Benin	Abomey	2019	3	17.32
464	Malawi	Blantyre	2021	9	18.25
719	Benin	Abomey	2022	12	18.41
556	Benin	Cotonou	2019	5	19.44
328	Ethiopia	Hawassa	2020	5	19.49
730	Côte d'Ivoire	Abidjan	2018	11	19.62
310	Ethiopia	Hawassa	2018	11	20.53
713	Benin	Abomey	2022	6	20.57
35	Kenya	Nairobi	2020	12	21.09
299	Ethiopia	Mekelle	2022	12	21.14
772	Côte d'Ivoire	Abidjan	2022	5	21.63
172	Kenya	Mombasa	2022	5	22.05
214	Ethiopia	Addis Ababa	2020	11	22.86
47	Kenya	Nairobi	2021	12	22.90
186	Ethiopia	Addis Ababa	2018	7	22.95
894	Côte d'Ivoire	Korhogo	2022	7	23.07
34	Kenya	Nairobi	2020	11	23.17
657	Benin	Parakou	2022	10	23.55
677	Benin	Abomey	2019	6	25.31
0	Kenya	Nairobi	2018	1	25.41
401	Malawi	Lilongwe	2021	6	25.47
518	Malawi	Mzuzu	2021	3	26.63
158	Kenya	Mombasa	2021	3	27.24
228	Ethiopia	Addis Ababa	2022	1	27.27
124	Kenya	Mombasa	2018	5	27.74
800	Côte d'Ivoire	Bouaké	2019	9	27.85
316	Ethiopia	Hawassa	2019	5	29.13

In [148…
```
high_anomalies_fixed.count()
```

Out[148…
```
Country        125
Region         125
Year           125
Month          125
Rainfall_mm    125
month_name     125
Date           125
dtype: int64
```

In [152…
```
low_anomalies_fixed.count()
```

Out[152…
```
Country        55
Region         55
Year           55
Month          55
Rainfall_mm    55
month_name     55
Date           55
dtype: int64
```

Anomalies

- Anomalies, defined as months with rainfall exceeding 350 mm (very high) or falling below 30 mm (very low), were identified. A total of 125 entries recorded very high rainfall events, such as Addis Ababa, Ethiopia in April 2022 (399.89 mm) and Abidjan, Côte d'Ivoire in November 2020 (399.18 mm). Conversely, 55 months experienced very low rainfall, with instances like Mzuzu, Malawi in June 2021 (6.83 mm) and Korhogo, Côte d'Ivoire in May 2020 (7.52 mm). These extreme events represent significant variations from typical conditions.

Anomalies Using Standard Deviation

In [ ]:
```
# Sort the DataFrame by Rainfall_mm to find the highest and lowest
df_sorted_high = rainfall_data.sort_values(by='Rainfall_mm', ascending=False)
df_sorted_low = rainfall_data.sort_values(by='Rainfall_mm', ascending=True)

# Get the top 5 highest rainfall events
top_5_high_rainfall = df_sorted_high.head(5)
print("Top 5 Highest Rainfall Events:")
print(top_5_high_rainfall)

# Get the top 5 lowest rainfall events
top_5_low_rainfall = df_sorted_low[df_sorted_low['Rainfall_mm'] > 0].head(5)
if top_5_low_rainfall.empty and (df_sorted_low['Rainfall_mm'] == 0).any():
    top_5_low_rainfall = df_sorted_low[df_sorted_low['Rainfall_mm'] == 0].head(5)
print("\nTop 5 Lowest Rainfall Events (excluding 0 unless all are 0):")
print(top_5_low_rainfall)
```

```
# Calculate monthly average and standard deviation for each Country and Region
monthly_stats = rainfall_data.groupby(['Country', 'Region', 'Month'])['Rainfall_mm'].agg(['mean', 'std']).reset_index
monthly_stats.rename(columns={'mean': 'Mean_Rainfall', 'std': 'Std_Dev_Rainfall'}, inplace=True)

# Merge the monthly statistics with the original DataFrame
df_merged = pd.merge(rainfall_data, monthly_stats, on=['Country', 'Region', 'Month'], how='left')

# Define a threshold for anomalies
n_std_flexible = 1.5

# Identify very high rainfall 'outliers' (more than n_std_flexible standard deviations above the mean)
df_merged['Outlier_High'] = (df_merged['Rainfall_mm'] > (df_merged['Mean_Rainfall'] + n_std_flexible * df_merged['Std

# Identify very low rainfall 'outliers' (more than n_std_flexible standard deviations below the mean)
df_merged['Outlier_Low'] = (df_merged['Rainfall_mm'] < (df_merged['Mean_Rainfall'] - n_std_flexible * df_merged['Std_

# Filter for rows that are considered 'outliers' (either high or low)
outliers = df_merged[df_merged['Outlier_High'] | df_merged['Outlier_Low']]

print("\nIdentified Rainfall Outliers (using 1.5 standard deviations from monthly regional mean):")
print(outliers[['Country', 'Region', 'Year', 'Month', 'Rainfall_mm', 'Mean_Rainfall', 'Std_Dev_Rainfall', 'Outlier_Hi

print("\nSummary of Outliers by Country and Region:")
outlier_counts = outliers.groupby(['Country', 'Region']).size().reset_index(name='Outlier_Count')
print(outlier_counts.sort_values(by='Outlier_Count', ascending=False))
```

```
Top 5 Highest Rainfall Events:
          Country       Region  Year  Month  Rainfall_mm month_name  \
231       Ethiopia  Addis Ababa  2022      4       399.89        Apr
754  Côte d'Ivoire      Abidjan  2020     11       399.18        Nov
547          Benin      Cotonou  2018      8       398.77        Aug
232       Ethiopia  Addis Ababa  2022      5       398.67        May
804  Côte d'Ivoire       Bouaké  2020      1       397.99        Jan

          Date
231 2022-04-01
754 2020-11-01
547 2018-08-01
232 2022-05-01
804 2020-01-01

Top 5 Lowest Rainfall Events (excluding 0 unless all are 0):
          Country   Region  Year  Month  Rainfall_mm month_name       Date
521         Malawi    Mzuzu  2021      6         6.83        Jun 2021-06-01
868  Côte d'Ivoire  Korhogo  2020      5         7.52        May 2020-05-01
107          Kenya   Kisumu  2021     12         9.28        Dec 2021-12-01
645          Benin  Parakou  2021     10         9.34        Oct 2021-10-01
156          Kenya  Mombasa  2021      1         9.48        Jan 2021-01-01

Identified Rainfall Outliers (using 1.5 standard deviations from monthly regional mean):
          Country    Region  Year  Month  Rainfall_mm  Mean_Rainfall  \
5         Ethiopia   Hawassa  2018      1        71.73        221.212
13        Ethiopia   Mekelle  2018      1       381.85        173.400
24          Malawi  Lilongwe  2018      2       394.67        268.110
35   Côte d'Ivoire   Abidjan  2018      3       370.14        163.830
80           Kenya   Nairobi  2018      6       390.46        165.628
..             ...       ...   ...    ...          ...            ...
796       Ethiopia   Hawassa  2022      6       299.45        167.552
810         Malawi  Blantyre  2022      7       319.93        142.584
822  Côte d'Ivoire   Korhogo  2022      7        23.07        239.202
876          Kenya   Mombasa  2022     11       387.87        153.794
897          Kenya   Nairobi  2022     12       232.31         85.572

     Std_Dev_Rainfall  Outlier_High  Outlier_Low
5           91.236363         False         True
13         134.959825          True        False
24          74.450540          True        False
35         128.658248          True        False
```

```
80         135.047542          True        False
..                ...           ...          ...
796         80.314209          True        False
810        111.170732          True        False
822        128.173178         False         True
876        137.481059          True        False
897         90.796480          True        False

[70 rows x 9 columns]

Summary of Outliers by Country and Region:
          Country       Region  Outlier_Count
10          Kenya      Mombasa              8
5   Côte d'Ivoire      Korhogo              7
4   Côte d'Ivoire       Bouaké              6
11          Kenya      Nairobi              6
13         Malawi     Lilongwe              6
1           Benin      Cotonou              6
3   Côte d'Ivoire      Abidjan              5
8         Ethiopia      Mekelle              5
7         Ethiopia      Hawassa              4
0           Benin       Abomey              4
6         Ethiopia  Addis Ababa              3
14          Malawi        Mzuzu              3
12          Malawi     Blantyre              3
2           Benin      Parakou              2
9           Kenya       Kisumu              2
```

In [140…

```
# Define countries for East and West Africa
east_africa_countries = ['Kenya', 'Ethiopia', 'Malawi']
west_africa_countries = ['Benin', 'Côte d’Ivoire']
```

In [142…

```
# Calculate seasonal totals for East African countries
# Long Rains (Mar-May)
long_rains_ea = rainfall_data[rainfall_data['Country'].isin(east_africa_countries) & rainfall_data['Month'].isin([3,
long_rains_ea_total = long_rains_ea.groupby(['Country', 'Region', 'Year'])['Rainfall_mm'].sum().reset_index()
long_rains_ea_total.rename(columns={'Rainfall_mm': 'Long_Rains_mm'}, inplace=True)

# Short Rains (Oct-Dec)
short_rains_ea = rainfall_data[rainfall_data['Country'].isin(east_africa_countries) & rainfall_data['Month'].isin([10
short_rains_ea_total = short_rains_ea.groupby(['Country', 'Region', 'Year'])['Rainfall_mm'].sum().reset_index()
short_rains_ea_total.rename(columns={'Rainfall_mm': 'Short_Rains_mm'}, inplace=True)
```

```
print("East Africa - Long Rains (Mar-May) Totals:")
print(long_rains_ea_total.head())
print("\nEast Africa - Short Rains (Oct-Dec) Totals:")
print(short_rains_ea_total.head())
```

```
East Africa - Long Rains (Mar-May) Totals:
    Country       Region  Year  Long_Rains_mm
0  Ethiopia  Addis Ababa  2018         673.23
1  Ethiopia  Addis Ababa  2019         568.27
2  Ethiopia  Addis Ababa  2020        1074.89
3  Ethiopia  Addis Ababa  2021         699.06
4  Ethiopia  Addis Ababa  2022        1124.66

East Africa - Short Rains (Oct-Dec) Totals:
    Country       Region  Year  Short_Rains_mm
0  Ethiopia  Addis Ababa  2018          791.58
1  Ethiopia  Addis Ababa  2019          670.47
2  Ethiopia  Addis Ababa  2020          385.37
3  Ethiopia  Addis Ababa  2021          471.98
4  Ethiopia  Addis Ababa  2022          341.68
```

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```
# Calculate seasonal totals for West African countries (Main Rainy Season: Jun-Sep)
main_rainy_season_wa = rainfall_data[rainfall_data['Country'].isin(west_africa_countries) & rainfall_data['Month'].is
main_rainy_season_wa_total = main_rainy_season_wa.groupby(['Country', 'Region', 'Year'])['Rainfall_mm'].sum().reset_i
main_rainy_season_wa_total.rename(columns={'Rainfall_mm': 'Main_Rainy_Season_mm'}, inplace=True)

print("\nWest Africa - Main Rainy Season (Jun-Sep) Totals:")
print(main_rainy_season_wa_total.head())
```

```
West Africa - Main Rainy Season (Jun-Sep) Totals:
  Country  Region  Year  Main_Rainy_Season_mm
0   Benin  Abomey  2018                785.60
1   Benin  Abomey  2019                604.15
2   Benin  Abomey  2020               1041.23
3   Benin  Abomey  2021               1186.68
4   Benin  Abomey  2022                751.07
```

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