Global Journal of Ecology, Environment and Alternate Energy Technologies
https://eurekajournals.com/GJEEAET.html

An Examination of the Annual Average Rainfall in Jamaica, 1999-2018

Paul Andrew Bourne[1], Peta-gay Forbes[2], Shantel McFarlane[2], Dwayne Pusey[2], Jay Anna Roach[2], Peta-Gaye Thompson[2], Tommy-gay Gayle[2], James Fallah[3], Calvin Campbell[4], Clifton Foster[5], Caroline McLean[2], Tabitha Muchee[6], Advella L. Meikle[2], Barbara Biira[7]

[1]Department of Institutional Research, Northern Caribbean University, Mandeville, Manchester, Jamaica, WI.
[2]Department of Nursing, Northern Caribbean University, Mandeville, Manchester, Jamaica, WI.
[3]Department of Dental Hygiene, Northern Caribbean University, Mandeville, Manchester, Jamaica, WI.
[4]Department of Mathematics and Engineering, Northern Caribbean University, Mandeville, Manchester, Jamaica, WI.
[5]Department of Biology, Chemistry, and Environmental Sciences, Northern Caribbean University, Mandeville, Manchester, Jamaica, WI.
[6]Department of Nutrition and Dietetics, Northern Caribbean University, Mandeville, Manchester, Jamaica, WI.
[7]Department of Psychology, Northern Caribbean University, Mandeville, Manchester, Jamaica, WI.

Abstract

Introduction: The meteorological processes that control rainfall is studied intensely to learn more about how rainfall is distributed locally and globally. ("Rainfall | Encyclopedia.com", 2022). Mean Annual Rainfall means the average total amount of rainfall recorded during a year in a particular place. Between the years 1999 and 2018; 2010 was recorded as the highest mean rainfall with an annual average of 2597mm in Jamaica.

Objective: This research aimed to provide information on the impact of climate change that affected rainfall in Jamaica, whether negatively or positively during the period 1999 to 2018.

Methods and materials: This study utilized data series for a period of 20 years (1999 - 2018). The data was gathered from and published by The Statistical Institute of Jamaica (STATIN) and sourced from the Meteorological Services of Jamaica. The MET's Weather Branch is concerned with observing and forecasting weather conditions over and around the island. (MET, 2021). The Secondary time series data analysis refers to the use of existing research data to find answers to a question that was different from the original work. The data that was sourced was then listed, reserved, recovered, and processed using the Statistical Packages for the Social Sciences (SPSS), Version 28.0 for Windows 11 operating systems. The methods of analysis include descriptive statistics, a measure of central tendency, a measure of dispersion, tables that are being used to

observe trends in the data set and histograms. However specific data points could be taken directly from the initial table that includes a mean value for the rainfall each year of 20 years (1999 - 2018). Additionally, scatter plot graphs were done to determine the function of the data collected and bar graphs were created using Microsoft Excel LTSC 2021.

Findings: The results indicated that the annual mean rainfall in Jamaica from 1999 to 2018 has declined steadily. The researchers felt there was a need to raise public awareness about the annual mean rainfall in Jamaica. The research has shown that increased temperatures, hurricanes, and prevailing winds from the northeast trade winds were just some of the factors that affected the distribution of rainfall in Jamaica. One limitation of this research was the limited access to information locally to match the hypothesis of our research, nonetheless, we persevered. Further studies will be needed to fully resolve the impact of climate change on rainfall in Jamaica

Conclusion: The data collected for the period of 20 years from 1999-2018 was retrieved from The Statistical Institute of Jamaica on the Annual Mean Rainfall in Jamaica. Jamaica heavily depends on rainfall for a variety of purposes, including domestic, commercial, and crop irrigation. For the past two decades, there has been a -12.3985 per cent change in the Annual Average Rainfall for 20 years in Jamaica. This suggests that the average rainfall for the 20 years under investigation has decreased over the past 2 decades.

Keywords: Rainfall, Annual, Tropics.

Introduction

Do not be angry at the rain; it simply does not know how to fall upwards. Rainfall is the amount of precipitation, in the form of rain (water from clouds), that descends onto the surface of the Earth, whether it is on land or water (McSweeney, & Thornton, 2020). It develops when air masses travel over warm water bodies or wetland surfaces (Baum, 2014; Black et al., 2021). Falling rain is usually composed of droplets with diameters of about 0.02 in (0.5 mm) or greater. A group of smaller raindrops is called drizzle. It is not considered rainfall when precipitation from clouds evaporates on the way down and fails to reach Earth's surface. The meteorological processes that control rainfall are studied intensely to learn more about how rainfall is distributed locally and globally (Baum, 2014; Black et al. (2021; Encyclopedia.com, 2022). Mean Annual Rainfall means the average total amount of rainfall recorded during a year in a particular place. Between the years 1999 and 2018; 2010 was recorded as the highest mean rainfall with an annual average of 2597mm in Jamaica.

Theoretical Framework

Collision Coalescence theory mostly applies to warm conventional clouds in tropical and subtropical regions. Langmuir's (1974) coalescence theory suggests that the small droplets in the clouds grow larger by coalescence until they are heavy enough to fall(Mayhew, 2009; Sigwart, 2009). Upon falling, the large droplets are ripped apart by conventional currents and air friction which disintegrates them into new droplets which fall as rainfall(Kunaka,2020). Precipitation can include all forms of falling moisture, such as drizzle, hail, rain, sleet, snow, and snow pallets. During the summer, evaporation loss is accelerated from all types of free water surfaces. The

water lost finds room in an air mass and adds to the atmospheric vapour storage. This large quantity of vapour makes the air mass moist, making it more able to hold water (Sen, 2015).

Rainfall records are maintained on a daily, monthly, seasonally, or yearly basis. At each rain gauging station, the rainfall is measured after 24 hours. Generally, the measurement is taken at 8:30 in the morning. The first obvious total rainfall that occurred in the past 24 hours is entered against the date on which the measurement is done. The rainfall varies from year to year but the average of the series of yearly records gives the mean rainfall value. The long-term mean is called normal rainfall (Sen, 2015).

Climate change is already having visible effects on the world. With the earth's warming, rainfall patterns are changing, and sea levels are rising. These changes can increase the risk of heat waves, floods, droughts and fires (MetOffice,2022). This study seeks to evaluate the annual average rainfall in Jamaica for a period of 20 years; that is from 1999-2018. In particular, we evaluate how climate change might be affecting the amount of rainfall Jamaica experiences annually.

Literature Review

The global distribution of precipitation is influenced by the general circulation of the atmosphere, proximity to large bodies of water, and topography (Pacific, n.d.).Rodgers & Streluk (2007) write that precipitation is most abundant where air risesand least abundant where it sinks with rainfallbeing the amount of precipitationin the form of rain that descends onto the surface of Earth. Rainfall develops when air masses travel over warm water bodies or wetlandsurfaces (Genio, A. del, Dai, A., & Fung, I. (1997). The atmospheric turbulence and convection carry the water vapour upward into the air masses where they form clouds and the clouds eventually release the water vapour, which then drops as rainfall.

Jamaica, among several other Caribbean countries, is located in the tropical zone.Although climate conditions are somewhat similar across countries in the region, the elevation/topography of each country significantly moderates them(*Climate: the Caribbean*, n.d.). May to October is the long rainy season, and December to March is the dry season. In Jamaica, a wet day is one with at least 1 millimetre of liquid or liquid-equivalent precipitation (Encyclopedia.com, nd). The chance of wet days in Jamaica varies significantly throughout the year. The wetter season lasts 6.1 months, from 13 May to 16 November, with a greater than 33% chance of a given day being a wet day. The month with the wettest days in Jamaica in September, with an average of 15.5 days with at least 1 millimetre of precipitation. The most common form of precipitation throughout the year is rain alone, with a peak probability of 55% on the 28th of September. (Weather Spark, n.d.).

Jamaica experiences extreme seasonal variation in monthly rainfall. Rain falls throughout the year in Jamaica. The month with the most rain in Jamaica in October, with an average rainfall of 132 millimetres. The month with the least rain in Jamaica is January, with an average rainfall of 19 millimetres(*Climate: the Caribbean*, n.d.). The average annual rainfall for the entire island is about 82 inches (2,100 mm), but regional variations are considerable (Ferguson et al., n.d.).

In Trinidad and Tobago, Trinidad receives an average of 2100 millimetres (82.6 inches) of rain and the smaller island of Tobago is slightly wetter with an average of 2500 mm (98.4 inches). The rainy season of Trinidad and Tobago falls between May to December (World Weather & Climate Information, n.d.). On average, July is the wettest month with 10.5 inches (266 mm) of precipitation and March is the driest month with 1.3 inches (34 mm) of precipitation(World Weather & Climate Information, n.d.). While in Barbados, the wet season runs from June to December and the dry season from January to May. The wet season is prone to heavy rainfall and tropical storms. The wettest period is from September to November, while the driest is from February to April. Barbados receives abundant rainfall in the range of 1016mm (40") or 2286mm (90") annually (World Weather & Climate Information, n.d.; Weather Atlas, 2022).). With the data previously provided, amongst the three mentioned countries; Barbados has the highest rainfall annually.

Recent data suggest that climate change can affect the intensity and frequency of precipitation (EPA, 2021). The Meteorological Services of Jamaica specifies the number of changes that are possible during times of climate change:

Research has shown that the increase in mean global temperatures of the last century, otherwise called global warming, has been primarily due to human activity. Projected impacts for Small Island Developing States, the grouping in which Jamaica falls, due to global warming include but are not limited to sea level rise, increasing temperatures, more frequent droughts, longer dry periods and more intense rainfall episodes (Meteorological Service of Jamaica*, nd*.)

As oceans warm, there is an increase in the amount of water that evaporates into the air. When more moisture-laden air moves over land or converges into a storm system, it can produce more intense precipitation, such as heavier rainfall. The potential impacts of heavy precipitation include crop damage, soil erosion, and an increase in flood risk due to heavy rains, which in turn can lead to displacement, injury, deaths, and other flooding-related effects on health (EPA, 2021).One of the most damaging flash floods in Jamaica in recent years occurred outside the “normal” wet season. The deadly flash flood occurred in northeastern Jamaica on 3–4 January 1998 leaving the region inundated by heavy rainfall, flash floods, and mudslides that caused five fatalities and over nine million U.S. dollars in damage to property, agriculture, and infrastructure(Laing, 2004).

Materials and Methods

This study utilized data series for a period of 20 years (1999 - 2018). The data was gathered from and published by The Statistical Institute of Jamaica (STATIN) and sourced from the Meteorological Services of Jamaica. The Met Service’s Weather Branch is concerned with the CBSE observing and forecasting conditions over and around the island(*Meteorological Service of Jamaica*, n.d.).

Secondary time series data analysis uses existing research data to find answers to a question that was different from the original work. The data that was sourced for this study was listed, reserved, recovered, and processed using the Statistical Packages for the Social Sciences (SPSS), Version 28.0 for Windows 11. The methods of analysis include descriptive statistics, a measure

of central tendency, a measure of dispersion, tables that are being used to observe trends in the data set and histograms. However specific data points could be taken directly from the initial table that includes a mean value for the rainfall each year of 20 years (1999 - 2018). Additionally, scatter plot graphs were done to determine the function of the data collected and bar graphs were created using Microsoft ExcelLTSC 2021.

Findings

Table 1 presents the annual average rainfall for 20 years between 1999 to 2018. In 1999, the average rainfall was 1805mm; in 2018, it was 1684 mm in Jamaica. The difference in the amount of rainfall between these two years is-121mm, with this we can say that the amount of rainfall within the 20 years has declined.

Table 1: Annual Average Rainfall (mm) in Jamaica for over 20 years (1999-2018)

Year	Annual Average Rainfall (mm)
1999	1805
2000	1547
2001	1857
2002	2159
2003	1861
2004	1807
2005	2412
2006	1665
2007	2139
2008	1960
2009	1621
2010	2597
2011	1839
2012	1682
2013	1473
2014	1519
2015	1313
2016	1759
2017	2160
2018	1684

Figure 1 shows a scatter plot graph of the Annual Average Rainfall for 20 years. The average amount of rain fell from 1805mm in 1999 to 1547mm in 2000. It then rose in 2004 with an average of 2412mm, fell by 747mm in 2006, rose by 474mm in 2007, and then fell by 518mm again in 2009. By 2010, there had been a considerable increase of 976 mm. With 1284mm of rainfall between 2010 and 2015, it thereafter gradually decreased. In 2018, it decreased by 476mm after rising by 847mm in 2015 and 2017.

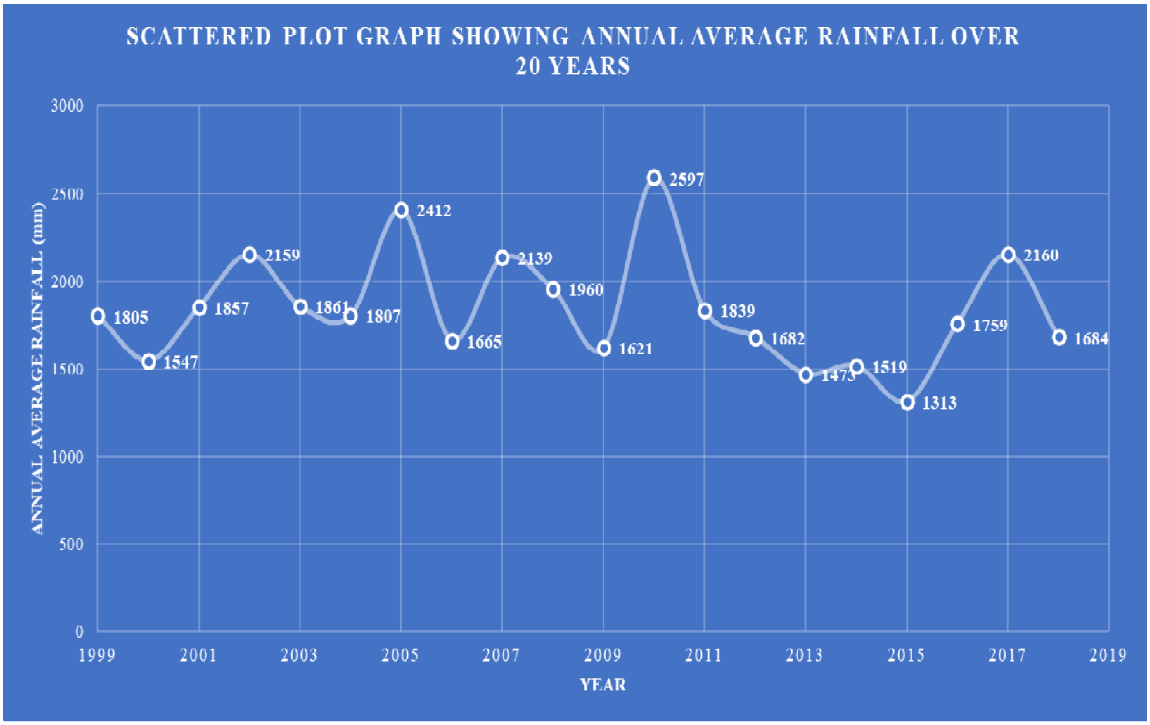

Figure 1: Scatter Plot Graph showing Annual Average Rainfall, 1999-2018

Table 2 shows the descriptive statistics for the Annual Average Rainfall for 20 years (1999-2018). The skewness is 0.747, which is moderately skewed and not accepted. Therefore, the mean of 1842.95 cannot represent the average. As such, the median of 1806 would be used as the average, with a standard deviation of 320.10039. The median is 1806 which represents the median value. There is a 95% confidence interval for the mean which range from 1693.1384-1992.7616. For approximately 18/100 or 9/50 years, Jamaica experienced moderate rainfall. **Figure 2** shows a frequency distribution polygon of the Annual Average Rainfall for 20 years, 1999-2018, which is a relatively good distribution as seen by the representation of the curve that appears to be normal with a skewness of 0.747. This skewness is not ideal but moderately good.

Table 2: Descriptive data for the Annual Average Rainfall over 20 years

			Statistic	Std. Error
Annual Average Rainfall	Mean		1842.9500	71.57662
	95% Confidence Interval for Mean	Lower Bound	1693.1384	
		Upper Bound	1992.7616	
	5% Trimmed Mean		1830.5000	
	Median		1806.0000	
	Variance		102464.261	
	Std. Deviation		320.10039	
	Minimum		1313.00	
	Maximum		2597.00	
	Range		1284.00	
	Interquartile Range		462.25	
	Skewness		.747	.512
	Kurtosis		.432	.992

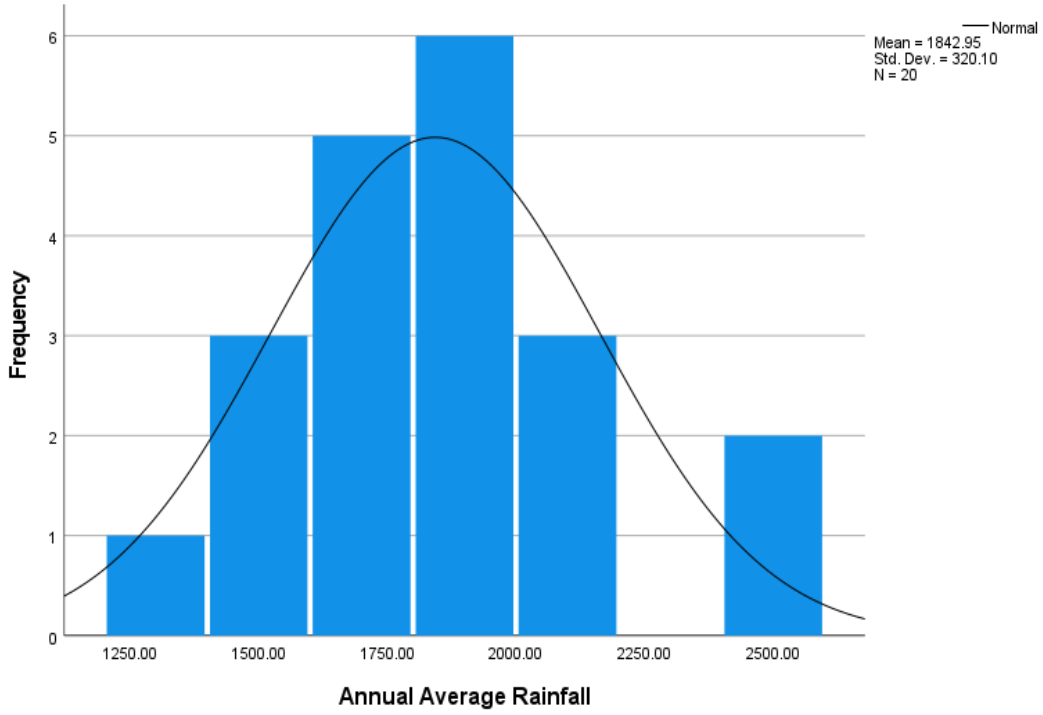

Figure 2: Frequency distribution polygon of Annual Average Rainfall, 1999-2018

Annual Average Rainfall

Table 3 shows the descriptive statistics for the first 10 years (1999-2008) for the Annual Average Rainfall of 20 years. The skewness is 0.579 which is acceptable and the mean of 1921.2 is best used to represent the average for this period, with a standard deviation of 255.24054. The mean of 1921.2 represents the middle value. There is a 95% confidence interval for the mean ranging from 1738.6119 to 2103.7881. The skewness of 0.579 shows a normal distribution curve as seen in **Figure 3. Table 4** shows the descriptive statistics for the second 10 years (2009-2018) for the Annual Average Rainfall of 20 years. The skewness is 1.369, which indicates that the mean of 1764.7 is influenced by extremely large values (outliers). Hence, the median of 1683 is best used to represent the average, with a standard deviation of 370.88934. The median is 1683 which would represent the median value. The 95% confidence interval of the mean ranges from 1499.3818 to 2030.0182. The skewness of 1.369 shows a curve skewed to the left or positively skewed as seen in **Figure 4**, which indicates that the average rainfall in this period (2009-2018) was not moderately distributed. **Figure 5** shows a bar graph representing the averages for the periods of the first 10 years (1999-2008) and the second 10 years (2009-2018) for the Annual Average Rainfall for 20 years in Jamaica. The average for the first and second ten years is respectively 1921.2 and 1683. For the past two decades, there has been a -12.3985 per cent change. This suggests that the average rainfall for the 20 years under investigation has decreased over the past two decades.

Table 3: Descriptive Statistics of the first 10 years (1999-2008) of the Annual Average Rainfall for 20 years

			Statistic	Std. Error
Annual Average Rainfall	Mean		1921.2	80.7142
	95% Confidence Interval for Mean	Lower Bound	1738.61	
		Upper Bound	2103.79	
	5% Trimmed Mean		1914.72	
	Median		1859	
	Variance		65147.7	
	Std. Deviation		255.241	
	Minimum		1547	
	Maximum		2412	
	Range		865	
	Interquartile Range		374	
	Skewness		0.579	0.687
	Kurtosis		0.174	1.334

Table 4: Descriptive statistics of the second 10 years of Annual Average Rainfall for 20 Years

			Statistic	Std. Error
Annual Average Rainfall	Mean		1764.7	117.286
	95% Confidence Interval for Mean	Lower Bound	1499.38	
		Upper Bound	2030.02	
	5% Trimmed Mean		1743.56	
	Median		1683	
	Variance		137559	
	Std. Deviation		370.889	
	Minimum		1313	
	Maximum		2597	
	Range		1284	
	Interquartile Range		411.75	
	Skewness		1.369	0.687
	Kurtosis		2.089	1.334

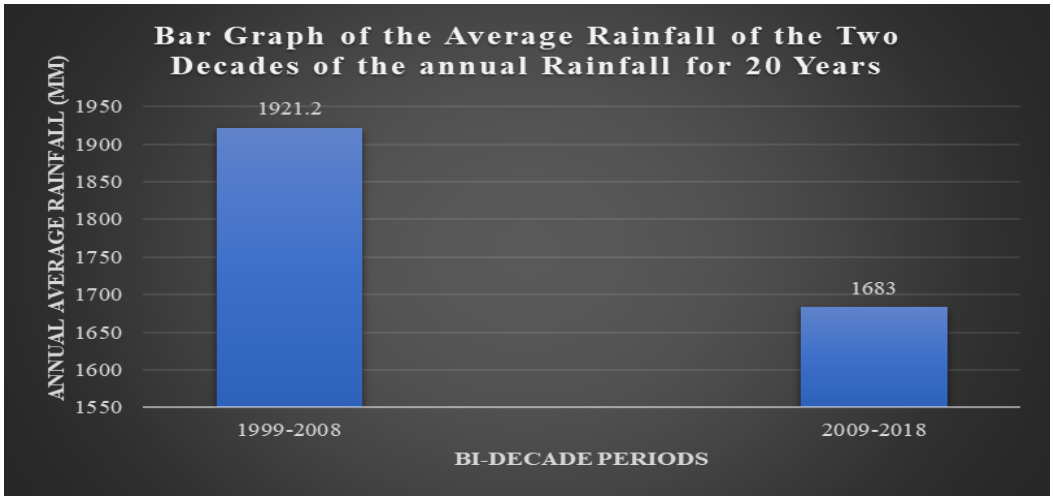

Figure 5: Bar Graph of the Average of the Bi-Decades period of the Annual Average Rainfall for 20 years, (1999-2018)

Table 5 shows the descriptive statistics for the first 5 years (1999-2003) of Annual Average Rainfall for 20 years shows a skewness of 0.161, which is close to being an ideal skewness, therefore the mean of 1845.8 is best to represent the average for this period. **Table 6** represents the descriptive statistics for the second 5 years (2004-2008) of Annual Average Rainfall for 20 years, which shows a skewness of 0.525, which is an accepted skewness, therefore the mean of 1996.6 is best to represent the average for this period. **Table 7** represents the descriptive statistics for the third 5 years (2009-2013) of Annual Average Rainfall for 20 years, which shows a skewness of 1.761, which indicates the mean of 1842.4 is highly influenced by extreme values, therefore the median of 1682 is best to represent the average for this period. And finally, **Table 8** represents the descriptive statistics for the fourth 5 years (2014-2018) of the Annual Average Rainfall for 20 years, which shows a skewness of 0.655, which is moderately skewed, and the mean of 1687 is not best used to represent the average. The median of 1684 is best to represent the average for this period. **Figure 6** is a bar graph representation of the averages for every 5 years for the Annual Average Rainfall of 20 years.

The second 5-year span (2004–2008) with a 1996.6 average, when compared to the third 5-year period (2009–2013), which had an average rainfall of 1682mm, as shown in **Figure 6**, is the time in which Jamaica had the highest rainfall throughout the previous 20 years.

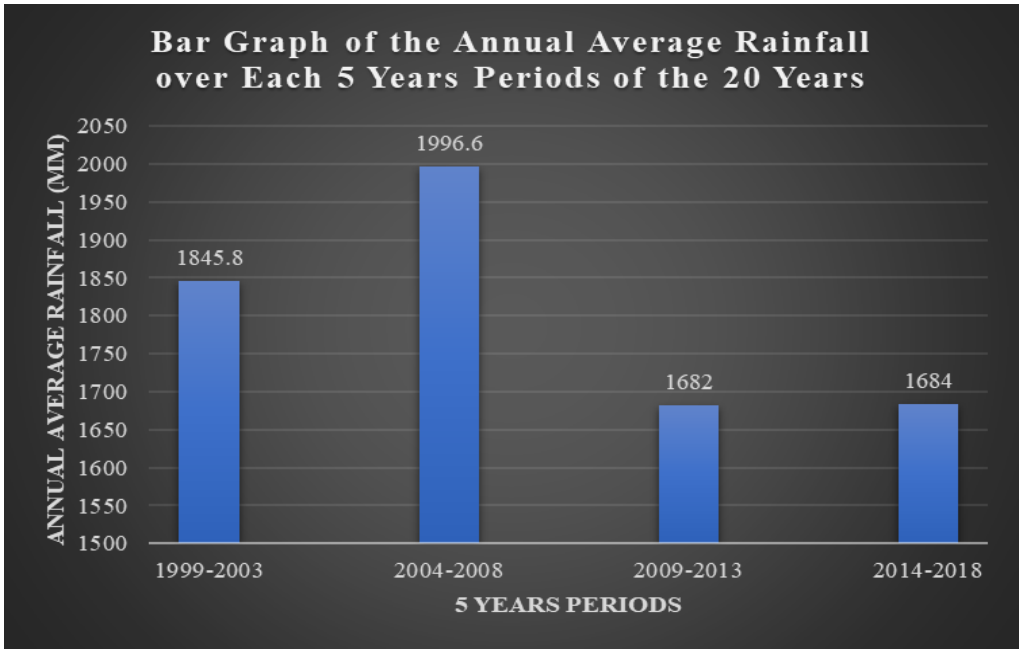

Figure 6: Bar Graph of the Averages for the 5 Years Periods of the Annual Average Rainfall for 20 years, (1999-2018)

Determining the Annual Average Rainfall Function

Figures 7-10 depict various scatter points fitted by particular functions. Those functions range from linear to 6-degree polynomials. Using the squared R values, it can be deduced from the curves that annual average rainfall in Jamaica for 20 years can be fitted by a 6-degree polynomial (i.e., **Figure 8**). The 6-degree polynomial accounts for 28.2% of the scatter values compared to the other functions, with a linear function accounting for the least explanation (i.e., 3.96%). The ideal function, the 6-degree polynomial is expressed as an equation, below:

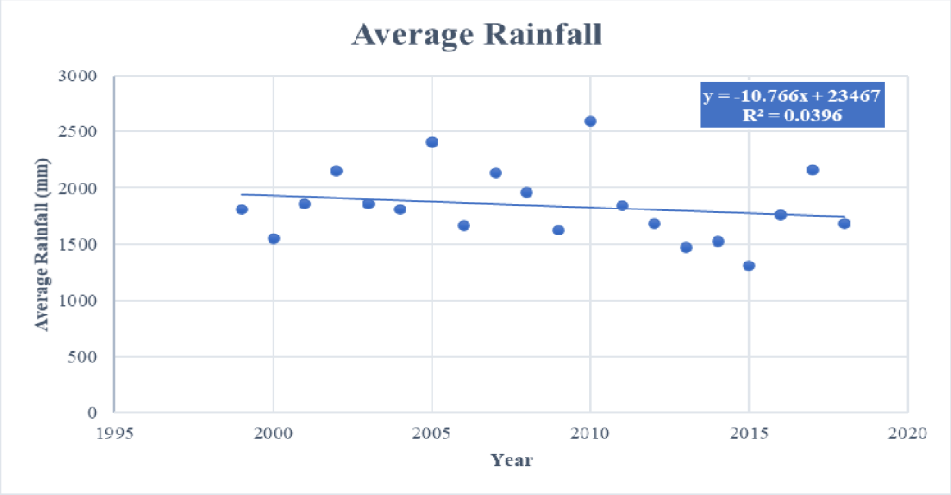

Figure 7: Annual Average Rainfall function, Linear

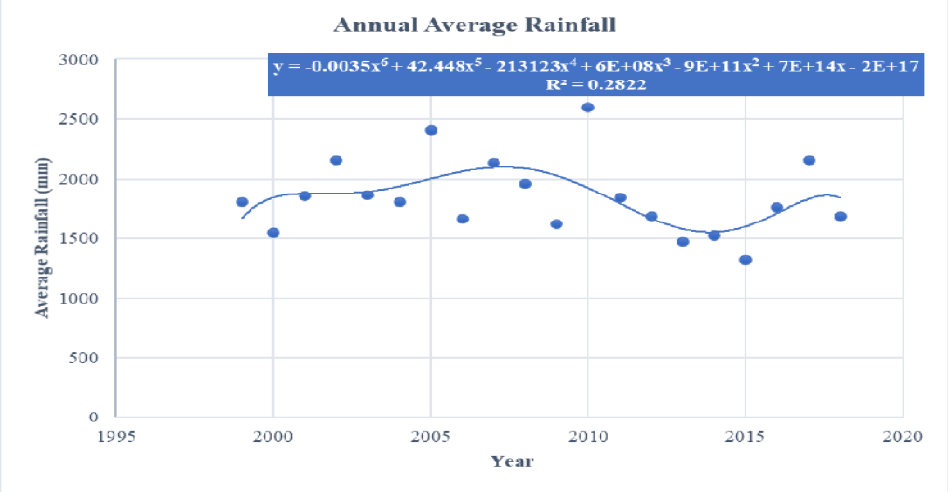

Figure 10: Annual Average Rainfall, 6-degree polynomial

$Y_i = -0.0035x^6 + 42.448x^5 - 213123x^4 + 6E+08x^3 - 9E+11x^2 + 7E+14x - 2E+17$ [1]

Where Y_i represents the annual average rainfall for the period I and X_i symbolize the year.

The annual average rainfall in Jamaica for 20 years is, therefore, a cyclical function and this suggests that rainfall is a complex phenomenon.

Discussion

Changes in the earth's hydrologic cycle in response to climate change have been observed as early as the 1990s (Genio et al., 1997). Jamaica and other Caribbean countries are located in tropical regions and they experience moderate rainfall annually. Findings of theannual mean rainfall of Jamaica over 20 years will be discussed.

Data were retrieved from STATIN on Annual Mean Rainfall in Jamaica for the period of 20 years (1999-2018).With a combined global land and ocean surface temperature of0.2°C (1.12°F) above the 13.9°C (57.0° F) average for the 20th century, 2010 tied with 2005 as the warmest such period on record. At 0.60°C (1.08° F) above the 20th-century norm, 1998 ranks third among

all years on record for warmth (NCEI, 2011). Based on this information, it can be inferred that 2005 and 2010 being two of the warmest years, is one of the reasons for the most rainfall experienced in Jamaica from the period of 1999-2018. As seen in **Figure 1,** the graph shows 2010, as the highest Annual mean of rainfall in Jamaica was 2597mm.

CDEMA's situation report (2010) on Tropical Storm Nicole, outlined the storm's impact over the western Caribbean and stated that Jamaica experienced rainfall with some sections of the island having up to 9 inches of rainfall over 12 hours. A total of 78 communities were impactedby flooding, landslides, casualties and missing people (CDEMA, 2010).

Between 2014 and 2015, Jamaica experienced one of the worst seasons of drought in recent history(Neufville, 2016). Jamaica's economy, especially rural livelihoods, was badly affected.During that period, annual agricultural production declined by 30 per cent from 2013 to 2014 and when combined with subsequent bush fires, economic losses were estimated to be about JMD1 billion (the US $6.5 million)(Weller, 2022). The drought coincides with data utilized for this study; there was 1313mm of rainfall in Jamaica in 2015, which was the lowest amount in recorded history.

Jamaica heavily depends on rainfall for a variety of purposes, including domestic, commercial, and crop irrigation. For the past two decades, there has been a -12.3985 per cent change in the Annual Average Rainfall for 20 years in Jamaica (Figure #). This suggests that the average rainfall for the 20 years under investigation has decreased over the past 2 decades.

Conclusion

Rain is synonymous with water and water is synonymous with life. Rain brings several benefits, such as watering wild plants and crops, forming streams and rivers, replenishing water tables, and producing healthy negative ions (Reference, n.d.). Observing changes in the earth's hydrologic cycles is imperative, especially in these times given climate change.This study aimed to evaluate the annual average rainfall in Jamaica for a period of 20 years; that is from 1999-2018. In particular, we evaluated how climate change might be affecting the amount of rainfall Jamaica experiences annually. The results indicated that the annual mean rainfall in Jamaica from 1999 to 2018 declined steadily. The researchers believe there is a need to raise public awareness about the annual mean rainfall in Jamaica. Data was collected from the Statistical Institute of Jamaica (STATIN) and the Meteorological Services of Jamaica (Met Service). Research has shown that increased temperatures, hurricanes, and prevailing winds from the northeast trade winds were just some of the factors that affected the distribution of rainfall in Jamaica. One limitation of this research was the limited access to information locally to test the hypothesis of our research, nonetheless, we persevered. Further studies will be needed to fully investigate the impact of climate change on rainfall in Jamaica.

Recommendations

Based on the findings and the conclusions, the following recommendations are presented: Awareness is needed among members of the public on declining rainfall and climate change. Informing citizens about changes in weather patterns should not only be limited to hurricane

season.Citizens should also be encouraged to participate in mitigating behaviours such as tree replanting behaviours has as been shown to contribute to rainfall in an area(Davies, 2021).The government, non-governmental organizations, and entertainersmusttake a collectiveeffort to continually improve public education on climate change.FurtherFurther research must be on climate change in Jamaica and the wider Caribbean to understand tongues occurring on tongue sends as a result.

References

Baum, D. (2014, June 1). How to (Try to) Make It Rain. Scientific American. Retrieved June 26, 2022, from https://www.scientificamerican.com/article/rain-how-to-try-to-make-it-rain/?error=cookies_not_supported&code=3c5915bb-8b22-493a-916e-edb58714a1fd.

Black, C. V., Buisseret, David J., Bryan, Patrick and Ferguson, James A. (2021, March 10). Jamaica. Encyclopedia Britannica. Retrieved June 12, 2022, from https://www.britannica.com/place/Jamaica/Climate.

Climate: Caribbean. (n.d.). SKYbrary Aviation Safety. Retrieved October 1, 2022, from https://skybrary.aero/articles/climate-caribbean..

Davies, P. (2021, July 8). More trees, more rainfall? Why increased tree planting could save Europe from climate change. *Euro News*. https://www.euronews.com/green/2021/07/06/more-trees-more-rainfall-why-increased-tree-planting-could-save-europe-from-climate-change.

Encyclopedia.com. (nd). Climate of Jamaica. https://www.britannica.com/place/Jamaica/Economy.

Encyclopedia.com. (2022). "Rainfall." Climate Change: In Context. Encyclopedia.com: https://www.encyclopedia.com/environment/energy-government-and-defense-magazines/rainfall.

Ferguson, J. A., Bryan, P., Buisseret, D. J., & Black, C. v. (n.d.). *Jamaica : Climate*. Brittanica. Retrieved October 1, 2022, from https://www.britannica.com/place/Jamaica/additional-info#contributors.

Genio, A. del, Dai, A., & Fung, I. (1997, December). *Science Briefs: Precipitation Trends in the 20th Century*. NASA: Goddard Institute for Space Studies. https://www.giss.nasa.gov/research/briefs/1997_delgenio_02/.

Kunaka, D. (2020, November 13). Rainfall Formation Theories (Collision Coalescence and the Bergeron Findeisen theory). The Geo Room. Retrieved June 28, 2022, from https://thegeoroom.co.zw/climatology/rainfall-formation-theories/#2

Laing, A. (2004). Cases of heavy precipitation and flash floods in the Caribbean during El Niño winters. *Journal of Hydrometeorology*, 577–594. https://doi.org/10.1175/1525-7541(2004)005.

Mayhew, S. (2009). coalescence theory. Oxford Reference. https://www.oxfordreference.com/view/10.1093/oi/authority.20111012183815621#:%7E:text=Langmuir's%20coalescence%20theory%20(1974)%20suggests,with%20other%20droplets%2C%20growing%20more.

McSweeney, K. (2020, August 14). Making it Rain: The Science of Weather Manipulation-Now. Powered by Northrop Grumman. Retrieved June 26, 2022, from https://now.NorthropGrumman.com/making-rain-science-weather-manipulation/.

Met Office. (2022, June 10). Effects of climate change. Retrieved June 27, 2022, from https://www.metoffice.gov.uk/weather/climate-change/effects-of-climate-change.

Meteorological Service of Jamaica. (n.d.). Retrieved October 1, 2022, from https://metservice.gov.jm/about-us/.

Meteorological Service of Jamaica. *(nd). What is Climate Change?* https://metservice.gov.jm/what-is-climate-change/.

Neufville, Z. (2016, January 28). *Jamaica's Drought Tool Could Turn Table on Climate Change.* Climate Links. https://www.climatelinks.org/blog/jamaicas-drought-tool-could-turn-table-climate-change.

Pacific. (n.d.). Precipitation, Global Distribution of - building, oceans, temperature, Water Encyclopedia. Retrieved June 10, 2022, from http://www.waterencyclopedia.com.

Reference.Com. (2020, April 3). What Are Some Advantages of Rain? Retrieved June 27, 2022, from https://www.reference.com/science/advantages-rain-f2b26e230356ff0a.

Rodgers, A., &Streluk, A. (2007). *Precipitation*. Heinemann.

Sen, S. (2015, June 27). Precipitation: Theory, Types and Uses (With Diagram). Your Article Library. Retrieved June 23, 2022, from https://www.yourarticlelibrary.com/water/rainfall/precipitation-theory-types-and-uses-with-diagram/60418.

Sigwart, J. (2009). Coalescent Theory: An Introduction, *Systematic Biology*, 58(1): 162-165, https://doi.org/10.1093/schbul/syp004.

US EPA. (2021, July 21). Climate Change Indicators: Heavy Precipitation. https://www.epa.gov/climate-indicators/climate-change-indicators-heavy-precipitation.

Weather Atlas. (2022). *Barbados-Climate & Monthly weather forecast*. From https://www.weather-atlas.com/en/barbados-climate.

Weather Spark. (n.d.-b). Jamaica Climate, Weather By Month, Average Temperature (Jamaica) - Weather Spark. Retrieved June 10, 2022, from https://weatherspark.com.

Weatherspark.com. (nd). Climate and average weather year round in Jamaica. https://weatherspark.com/y/150241/Average-Weather-in-Jamaica-Year-Round.

Weller, K. (2021, May 11). Still Standing, Still Serving in the Midst of Extreme Weather. U.S. Agency for International Development. Retrieved June 28, 2022, from https://www.usaid.gov/jamaica/news/still-standing-still-serving-midst-extreme-weather.

World Weather & Climate Information. (n.d.). Climate and average weather in Trinidad & Tobago. https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine-in-Trinidad-Tobago.

Annexes

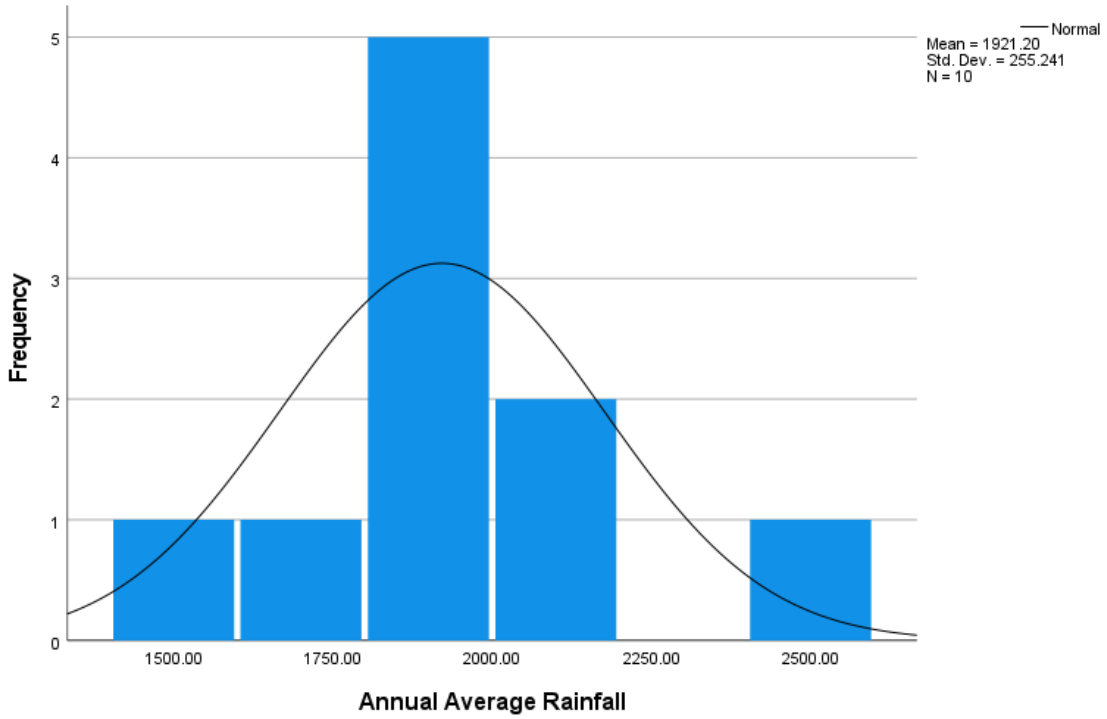

Figure 3: Frequency distribution polygon of Annual Average Rainfall for the first 10-year period (1999-2008) for 20 years

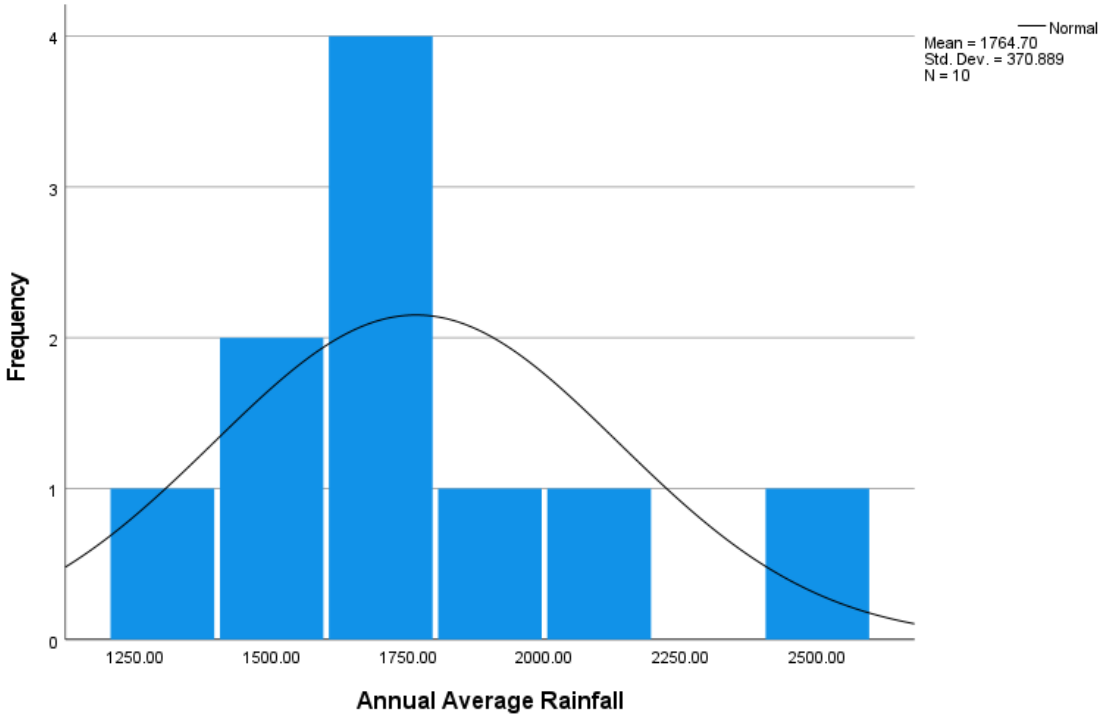

Figure 4: Frequency distribution polygon of Annual Average Rainfall for the second 10-year period (2009-2018) for 20 years

Table 5: Descriptive Statistics of the first 5 Years period (1999-2004) of the Annual Average Rainfall for 20 Years

			Statistic	Std. Error
Annual Average Rainfall	Mean		1845.8000	97.31310
	95% Confidence Interval for Mean	Lower Bound	1575.6155	
		Upper Bound	2115.9845	
	5% Trimmed Mean		1845.0000	
	Median		1857.0000	
	Variance		47349.200	
	Std. Deviation		217.59871	
	Minimum		1547.00	
	Maximum		2159.00	
	Range		612.00	
	Interquartile Range		334.00	
	Skewness		.161	.913
	Kurtosis		1.811	2.000

Table 6: Descriptive Statistics of the second 5 Years period (2004-2008) of the Annual Average Rainfall for 20 Years

			Statistic	Std. Error
Annual Average Rainfall	Mean		1996.6000	130.39962
	95% Confidence Interval for Mean	Lower Bound	1634.5526	
		Upper Bound	2358.6474	
	5% Trimmed Mean		1991.9444	
	Median		1960.0000	
	Variance		85020.300	
	Std. Deviation		291.58241	
	Minimum		1665.00	
	Maximum		2412.00	
	Range		747.00	
	Interquartile Range		539.50	
	Skewness		.525	.913
	Kurtosis		-.465	2.000

Table 7: Descriptive Statistics of the third 5 years period (2009-2013) of the Annual Average Rainfall for 20 Years

			Statistic	Std. Error
Annual Average Rainfall	Mean		1842.4000	197.56457
	95% Confidence Interval for Mean	Lower Bound	1293.8728	
		Upper Bound	2390.9272	
	5% Trimmed Mean		1821.0000	
	Median		1682.0000	
	Variance		195158.800	
	Std. Deviation		441.76781	
	Minimum		1473.00	
	Maximum		2597.00	
	Range		1124.00	
	Interquartile Range		671.00	
	Skewness		1.761	.913
	Kurtosis		3.353	2.000

Table 8: Descriptive Statistics for the fourth 5 Years Period (2014-2018) of the Annual Average Rainfall for 20 Years

			Statistic	Std. Error
Annual Average Rainfall	Mean		1687.0000	140.89393
	95% Confidence Interval for Mean	Lower Bound	1295.8157	
		Upper Bound	2078.1843	
	5% Trimmed Mean		1681.5000	
	Median		1684.0000	
	Variance		99255.500	
	Std. Deviation		315.04841	
	Minimum		1313.00	
	Maximum		2160.00	
	Range		847.00	
	Interquartile Range		543.50	
	Skewness		.655	.913
	Kurtosis		.938	2.000

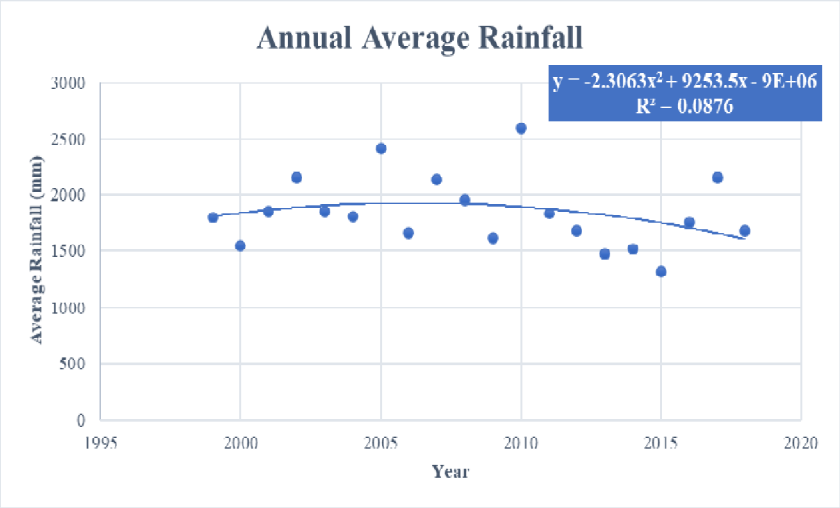

Figure 8: Annual Average Rainfall function, 2-degree polynomial

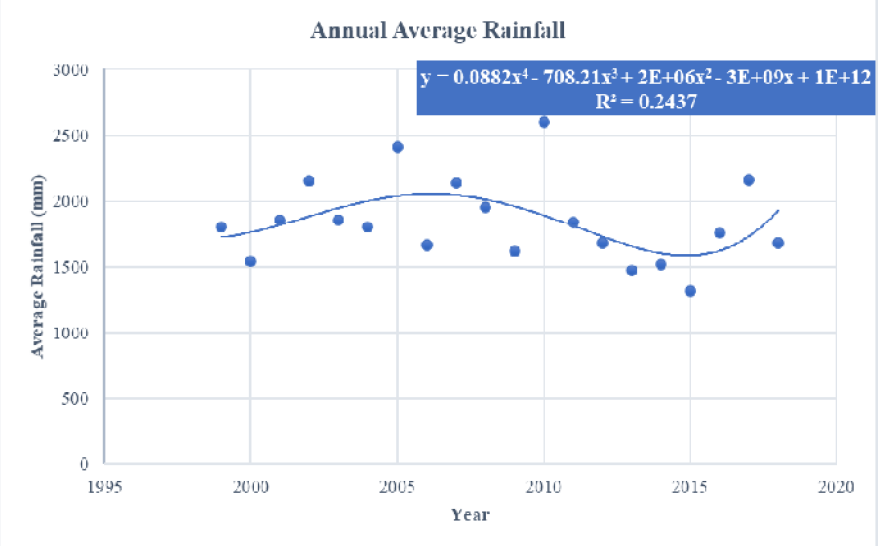

Figure 9: Annual Average Rainfall function, 4-degree polynomial

Definition of Terms

Atmospheric Turbulence: Atmospheric turbulence is irregular fluctuations occurring in atmospheric airflow. These fluctuations are random and continuously changing and are superimposed on the mean motion of the air.

Degree polynomial: The degree of polynomials is defined as the highest power of the variable in it. Mathematically, the degree of a polynomial is the highest of the degrees of the monomials (individual terms) with non-zero coefficients in the polynomial.

Coalescence: The act or process of coming together to form one larger group or substance.

Collision Coalescence Theory: Langmuir's coalescence theory (1974) suggests that the small droplets in clouds grow larger by coalescence until they are heavy enough to fall. As they fall, they collide with other droplets, growing more.

Climate: Climate is the long-term pattern of weather in a particular area.

Climate Change: A study dealing with variations in climate on many different time scales, from decades to millions of years, and the possible causes of such variations.

Confidence Interval: A confidence interval, in statistics, refers to the probability that a population parameter will fall between a set of values for a certain proportion of times**.**

Convection: Convection is a way for heat to move, also referred to as a heat transfer mechanism.

Descriptive statistics: Descriptive statistics are brief descriptive coefficients that summarize a given data set, which can be either a representation of the entire population or a sample of a population. Descriptive statistics are broken down into measures of central tendency and measures of variability (spread). Measures of central tendency include the mean, median, and mode, while measures of variability include standard deviation, variance, minimum and maximum variables, kurtosis, and skewness.

El Niño: El Niño is a climate pattern that describes the unusual warming of surface waters in the eastern equatorial Pacific Ocean. Trade winds and the atmosphere are also impacted by El Niño.

Interquartile Range: The interquartile range defines the difference between the third and the first quartile. Quartiles are the partitioned values that divide the whole series into 4 equal parts.

Kurtosis: Kurtosis is a statistical measure that defines how heavily the tails of a distribution differ from the tails of a normal distribution. In other words, kurtosis identifies whether the tails of a given distribution contain extreme values.

Linear: Linear refers to an equation or function that is the equation of a straight line and takes the form y = MX + b, where "m" is equal to the slope, and "b" is equal to the y-intercept.

Long-Term Service (LTS): Long-term support (LTS) is a product lifecycle management policy in which a stable release of computer software is maintained for a longer period than the standard edition.

Mean: Mean is an essential concept in mathematics and statistics. The mean is the average or the most common value in a collection of numbers. In statistics, it is a measure of the central tendency of a probability distribution along median and mode. It is also referred to as an expected value.

Median: The median is the middle number in a sorted, ascending or descending list of numbers and can be more descriptive of that data set than the average.

MET: Meteorological Services of Jamaica.

Millimetre (mm): A millimetre (abbreviated as mm and sometimes spelt as millimetre) is a small unit of displacement (length/distance) in the metric system.

NOAA: National Oceanic and Atmospheric Administration.

NWS: National Weather Service.

ODPEM: Office of Disaster Preparedness and Emergency Management.

Outlier: An outlier, in statistics, can be defined as a value that is distant from the majority of the values in a data set.

PIOJ: Planning Institute of Jamaica.

Precipitation: Any or all of the forms of water particles, whether liquid or solid, that fall from the atmosphere (e.g., rain, hail, snow or sleet). It is a major class of hydrometeor, but it is distinguished from the cloud, fog, dew, rime, frost, etc., in that it must fall. It is distinguished from cloud and virga in that it must reach the ground**.**

R values: In Statistics, the Pearson's Correlation Coefficient is also referred to as Pearson's r, the Pearson product-moment correlation coefficient (PPMCC), or bivariate correlation. It is a statistic that measures the linear correlation between two variables. Like all correlations, it also has a numerical value that lies between -1.0 and +1.0.

Range: In math, the range is a statistical measurement of dispersion, or how much a given data set is stretched out from smallest to largest. In a set of data, the range is the difference between the greatest and smallest value.

Skewness: Skewness refers to a distortion or asymmetry that deviates from the symmetrical bell curve, or normal distribution, in a set of data. If the curve is shifted to the left or the right, it is said to be skewed. Skewness can be quantified as a representation of the extent to which a given distribution varies from a normal distribution.

SPSS: Statistical Package for the Social Sciences.

Standard Deviation: The standard deviation is a statistic that measures the dispersion of a dataset relative to its mean and is calculated as the square root of the variance. The standard deviation is calculated as the square root of variance by determining each data point's deviation relative to the mean.

STATIN: Statistical Institute of Jamaica.

Statistics: It is the science of collecting, analyzing, presenting, and interpreting empirical data. Statistics is a highly interdisciplinary field.

Temperature: This is the measure of hotness or coldness expressed in terms of any of several scales, including Fahrenheit and Celsius.

Topography: The study or detailed description of the surface features of a region.

Trimmed Mean: A trimmed mean (sometimes called a truncated mean) is similar to a "regular" mean (average), but it trims any outliers. Outliers can affect the mean (especially if there are just one or two very large values), so a trimmed mean can often be a better fit for data sets with erratic high or low values or extremely skewed distributions.

USEPA: the United States Environmental Protection Agency.

Variance: The variance is a measure of variability. It is calculated by taking the average of squared deviations from the mean. Variance tells you the degree of spread in your data set. The more spread the data, the larger the variance is about the mean.

WHO: World Meteorological Organization: Established by the United Nations, the WMO consists of more than 130 nations. The organization is responsible for coordinating, standardizing and improving meteorological activities throughout the world and for encouraging and facilitating the efficient exchange of information between countries, in the interest of various human activities.