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EFFECT OF RAINFALL VARIABILITY ON LAND USE/LAND COVER DYNAMICS WITHIN ENUGU URBAN

[1]Dr. Onyia, Anthonia Nkeiruka and [2]Ijomah, Jude Obinna
[1]Enugu State University of Science and Technology
[2]Federal Polytechnic, Ohodo, Enugu State
Email: *toniaim40@yahoo.com/ ijomahjude001@gmail.com*
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Abstract
The importance of rainfall variability in understanding the dynamics of climate change and land use/land cover (LULC) changes in any region cannot be overemphasized. This study examined rainfall variability in Enugu urban and metropolis as it affects land use/land cover change and climate change. Secondary rainfall data were collected from the archives of the Meteorology Unit, Enugu State University of Technology, covering the period 1971–2020. The rainfall data were tabulated and analyzed in decadal format using descriptive statistics, frequency tables, means, and graphical representations. The annual mean rainfall for the period 1971–2020 was determined using line graphs, which revealed both normal and abnormal rainfall trends. The results showed higher rainfall in years such as 1995, 1997, 2008, 2012, 2018, and 2020, with total annual amounts reaching 2,170.9 mm and 2,173.9 mm respectively. Conversely, decreases in rainfall were observed in years including 1971, 1972, 1973, 1974, 1976, and 1983, with recorded values such as 813.4 mm, 889 mm, 947 mm, and 1,104.4 mm. The findings revealed significant variations in rainfall patterns in Enugu, accompanied by notable reductions in land cover over time. Furthermore, the study established a significant relationship between rainfall trends and land cover dynamics in Enugu urban area. The study recommends further research using remotely sensed imagery and GIS techniques to confirm whether the observed decrease in land use/land cover is solely attributable to rainfall variability. It also advocates for robust education and enlightenment programs to raise public awareness of rainfall trends in the study area, thereby promoting sustainable utilization of natural resources and enhancing understanding of land use/land cover dynamics for future research.

1.1 Introduction

Rainfall variability is a key climatic feature that significantly impacts Africa's agricultural productivity and food production (Mensah et al., 2019; Ogundari & Onyeaghala, 2021; Schlenker & Lobell, 2010). It also poses a serious threat to poverty eradication and sustainable development in Nigeria, as the country has a large rural population that depends directly on rainfall-sensitive economic and development sectors as well as natural resources for subsistence and livelihood (Oladipo, 2008; Osang, 2013).

Over the years, many studies have investigated rainfall trends and variability in Nigeria, with most relying on tables and graphical plots to highlight the dynamics of rainfall changes (Adenodi, 2018; Akinsanola & Ogunjobi, 2014; Animashaun et al., 2020; Nnaji et al., 2016). Some studies have employed time-series analysis to investigate long-term fluctuations in rainfall (Ogbuene, 2010), while others adopted non-parametric tests to study rainfall trends (Obot et al., 2011).

Furthermore, there is growing evidence that climate change is exacerbating rainfall variability and increasing the frequency of extreme events such as land cover reduction, floods, droughts, and hurricanes (IPCC, 2007). Rainfall is one of the most important meteorological parameters affecting nearly all human activities (Obot, Chendo, Udo, & Ewona, 2010b). For instance, the amount of rainfall received in a region is a major determinant of the quantity of water available to meet agricultural, domestic, industrial, and power-generation needs (Sharad & Vijay, 2012).

According to Olatunde (2012), rainfall availability or non-availability is commonly used to determine the level of wetness or dryness during the growing season, making rainfall the single most important climatic element influencing agriculture and water resource management. In recent times, the reduction of land cover in parts of Enugu metropolis has raised public concern that the urban center might be experiencing serious climatic shifts. This is largely attributed to high rainfall variability, which adversely impacts agricultural productivity and economic activities in the city (Mark & Kishtawa, 2014).

Consequently, studies of rainfall variability are crucial in mitigating the impacts of extreme climate hazards such as droughts, floods, and land cover degradation (FCC, 2007). This is particularly important because the amount of water available in the soil for crop utilization depends on key rainfall characteristics such as onset, duration, and cessation, which ultimately influence the success or failure of cropping seasons (Kisaka, Mucheru-Muna, Ngetich, Mugendi, & Mairua, 2015).

2.0 Study Location

Enugu is located approximately between latitudes 6°22′30″ and 6°39′10″ N of the Equator and longitudes 7°25′35″ and 7°40′45″ E of the Greenwich Meridian. The state is administratively divided into 17 Local Government Areas (LGAs) (see Figure 2.1).

Enugu State lies in the southeastern region of Nigeria at the foot of the Udi Plateau. It shares boundaries with Abia and Imo States to the south, Ebonyi State to the east, Benue State to the northeast, Kogi State to the northwest, and Anambra State to the west (Enugu State, Nigeria, Britannica, 2022).

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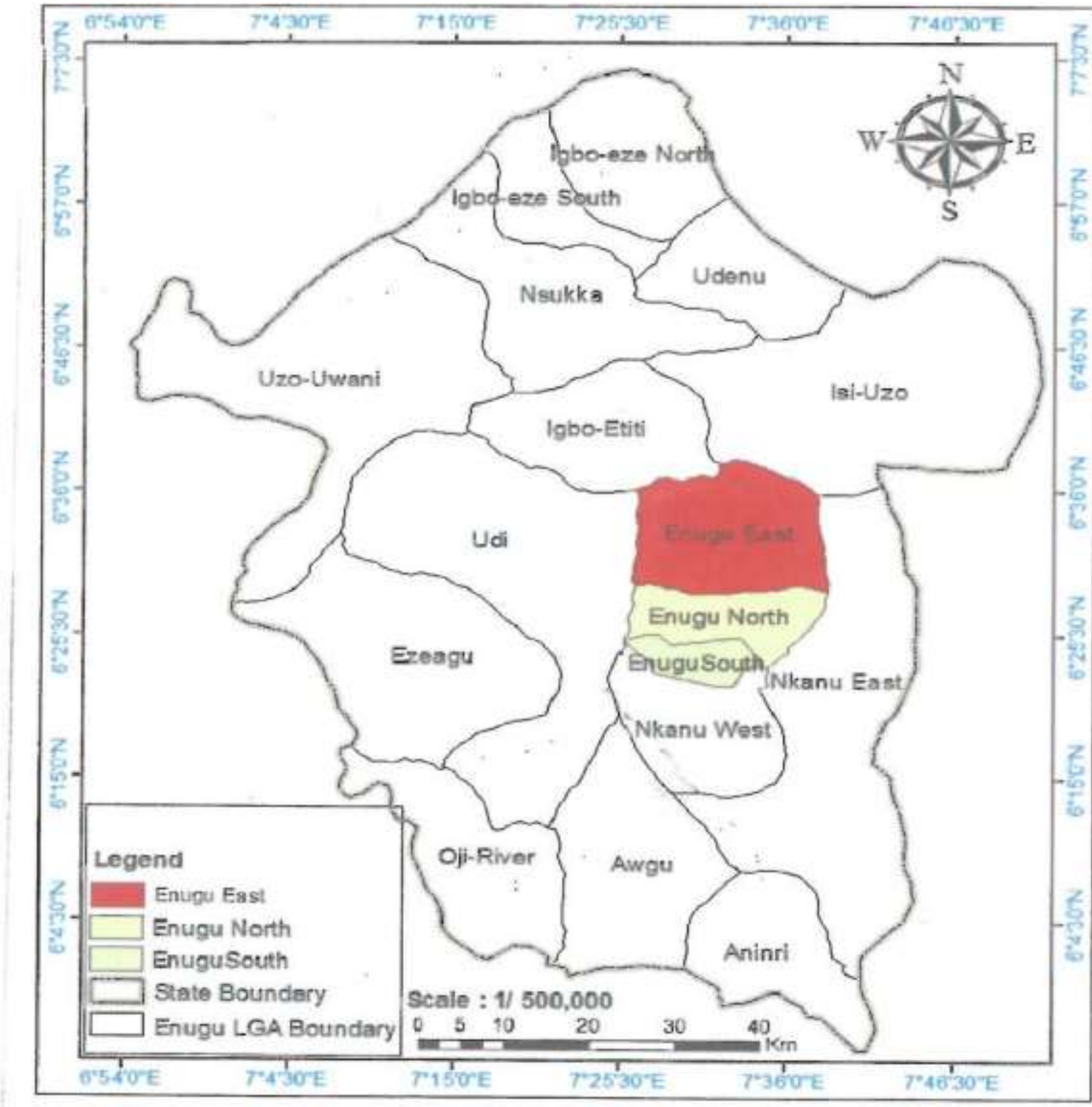

Figure 2.1: Map of Enugu State, showing the study area (Enugu Urban, comprising, Enugu East, Enugu North and Enugu South)

Source: Enugu State Ministry of Lands & Survey (2020)

2.1 Enugu Urban

Enugu urban area is centered around the capital city of Enugu State in southeastern Nigeria. Geographically, the area lies approximately between longitude 7°20′0″ E and latitude 6°40′0″ N. As the administrative and commercial hub of the state, Enugu urban plays a vital role in the socio-economic development of the region, serving as a gateway to surrounding towns and local government areas.

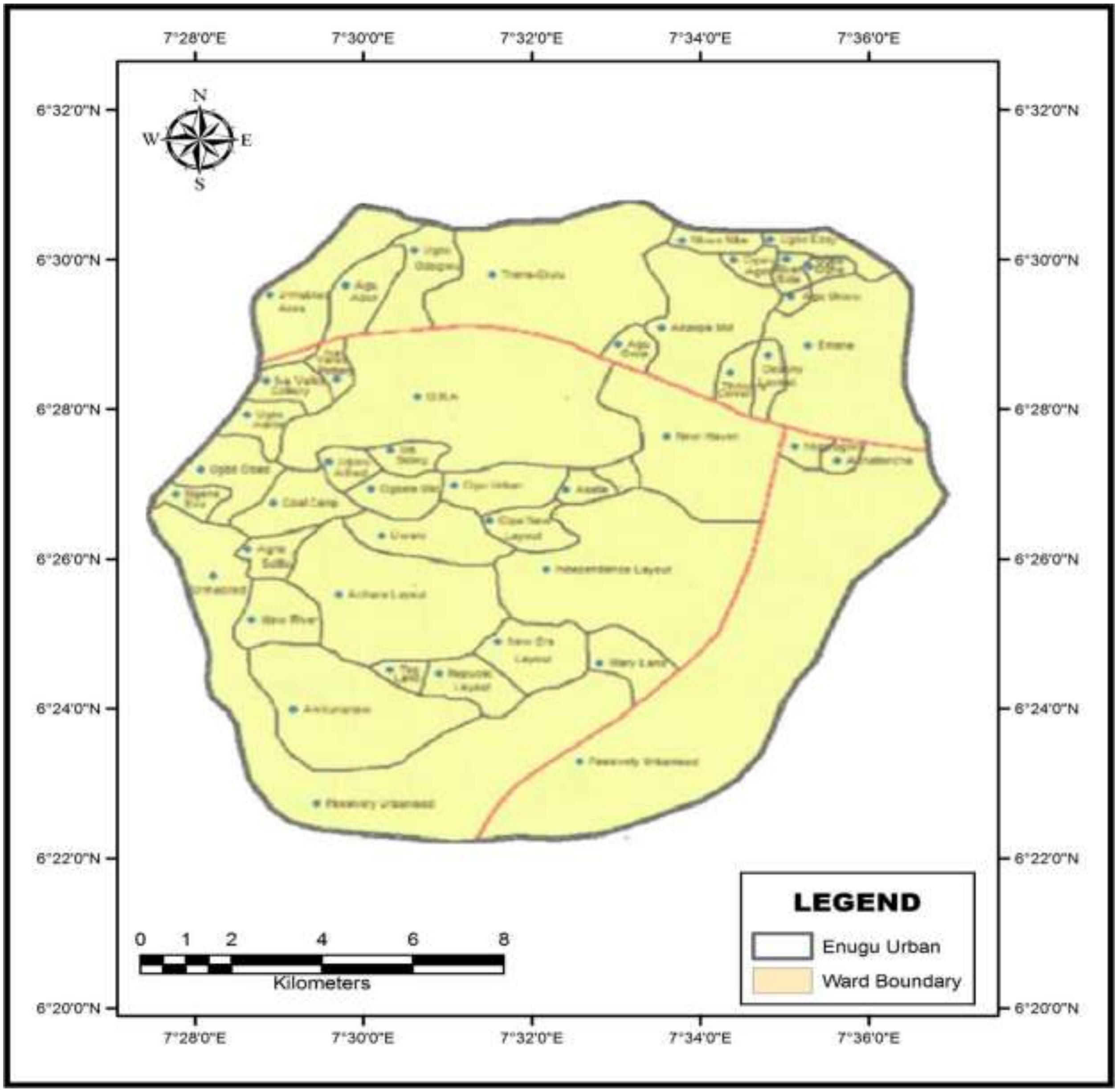

Figure 2.2: Map showing Enugu urban area.
Source: https://www.researchgate.net

Enugu, the capital city of Enugu State, lies on the railway line from Port Harcourt, about 150 miles (240 km) to the south-southwest, and sits at the intersection of major roads linking Aba, Onitsha, and Abakaliki. It is approximately a four-hour drive from Port Harcourt—historically a coal-shipping hub in Nigeria. The city is also less than an hour's drive from Onitsha, one of Africa's largest commercial centers, and about two hours from Aba, another significant trading city in southeastern Nigeria.

Enugu enjoys relatively mild climatic conditions throughout the year. Temperatures range from about 17°C (60°F) in the cooler months to 28°C (upper 80s °F) during the warmer months. The city stands at an elevation of about 223 meters (732 ft) above sea level, with well-drained soils that support agricultural activities during the rainy season. The mean temperature during the hottest month of February is approximately 30.64°C (87.16°F), while the lowest average temperature occurs in November, around 15.86°C (60.54°F). Rainfall in Enugu varies seasonally, with the lowest average of about 0.16 cm^3 (0.0098 cu in) recorded in February and the highest of about 35.7 cm^3 (2.18 cu in) in July (Enugu State, Nigeria, Encyclopedia Britannica, 2021).

3.0 Materials and Methods

This study employed descriptive statistics for data analysis. Secondary data were collected from relevant government offices and credible online sources.

3.1 Method of Data Collection

Rainfall data spanning January to December for the period 1971–2020 were obtained from the archives of the Meteorology Unit, Enugu State University of Technology, Enugu, Nigeria.

3.2 Method of Data Analysis

The collected rainfall data were analyzed using descriptive statistical techniques. Data were organized into tables and represented graphically to identify rainfall trends over time. Specifically, the annual rainfall data from 1971 to 2020 were grouped into decadal formats, enabling clearer visualization of rainfall variability across each decade. This approach also allowed for comparison with observed land use/land cover changes in the study area, providing insights into the relationship between rainfall patterns and environmental dynamics.

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4.0 Presentation of Result

4.1 Analysis and result discussion

Table 4.1 Rainfall variability from 1971 to 1980 ***(Monthly Rainfall in mm)***

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1971	0	0	69.0	3.0	94.0	161.0	122.9	334.5	235.5	32.8	0	0
1972	0	0	3.0	25.1	123.4	154.2	165.4	224.8	213.9	18.5	0	0
1973	0	0	0	42.7	11.2	98.3	151.4	305.3	158.5	46	0	0
1974	0	0	0.3	18	60.5	174.5	431.1	129.2	251.7	39.1	0	0
1975	0	0	0	37.6	81.8	158.9	252.5	224.8	186.9	31.0	0	0
1976	0	0	0	1.3	174.5	96.8	150.9	201.4	121.8	135.4	6.9	0
1977	22.1	3.1	54.8	29.9	205.6	321.4	158.5	182.9	298.6	267.1	0	2.0
1978	1.8	2.0	102.3	236.4	239.5	489.6	87.0	183.8	364.6	260.4	15.4	0.3
1979	0.5	75.1	64.3	29.4	199.0	237.1	365.2	305.4	208.1	165.8	46.9	0
1980	0	24.2	56.7	76.0	257.0	228.7	228.6	326.7	594.6	176.8	74.4	0

Source: Meteorology Unit, Enugu State University of Technology Archives (1971–1980).

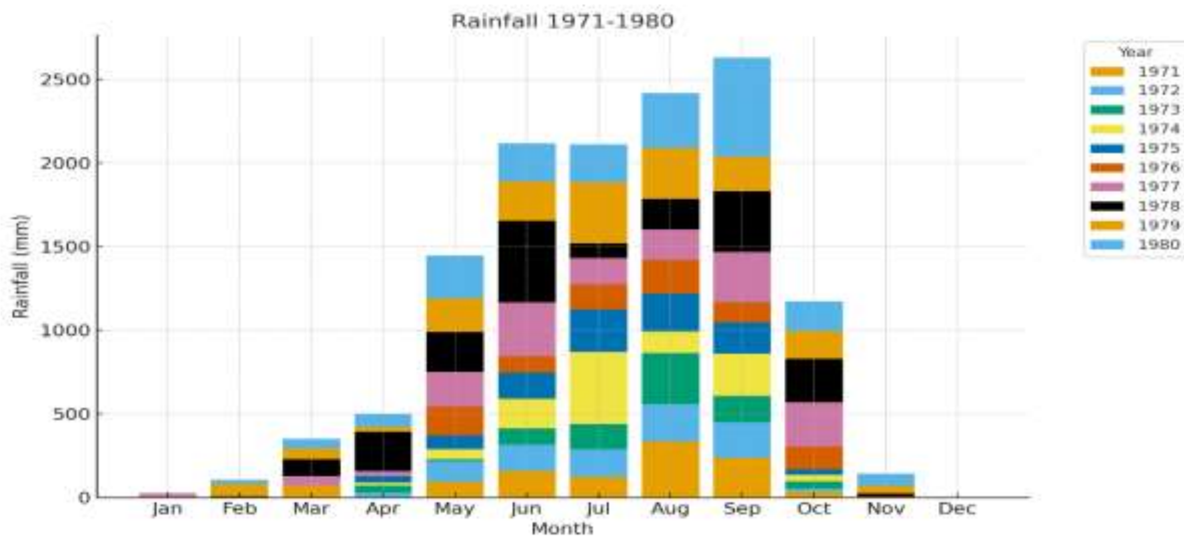

Figure 4.1: Rainfall variability graph from 1971 to 1980

Figure 4.1 illustrates the variability of rainfall in Enugu from 1971 to 1980. During this period, the lowest monthly rainfall occurred in January, with only 2.4 mm, while the highest rainfall was recorded in September, exceeding 2,500 mm. This pattern indicates that significant rainfall availability is concentrated between May and October, when monthly totals consistently rise above 1,000 mm. Conversely, from November to April, rainfall amounts generally fall below 500 mm, reflecting inadequate water supply during these months. This seasonal distribution suggests that the wet period (May–October) provides adequate water to support agricultural activities and vegetation growth, whereas the prolonged dry months (November–April) contribute to reductions in land use/land cover within the study area during the observed decade.

Table 4.2: Rainfall Variability in Enugu (1981–1990): ***(Monthly Rainfall in mm)***

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1981	4.3	1.6	30.9	83.8	194.6	219.2	270.6	182.4	395.9	327.6	0.0	0.0
1982	2.7	57.3	49.3	106.0	315.5	216.2	264.6	92.3	218.1	199.7	3.6	0.0
1983	0.0	0.0	4.0	3.3	190.0	101.1	251.4	92.2	248.2	24.2	0.0	2.7
1984	0.0	0.0	16.1	137.9	130.6	350.5	305.6	385.8	311.2	122.5	20.9	0.0
1985	16.6	0.0	206.1	127.8	291.7	202.8	193.5	462.6	259.4	157.8	21.6	0.0
1986	2.1	9.8	127.1	97.8	238.9	141.9	270.4	198.8	206.3	101.6	55.9	0.0
1987	0.0	15.7	33.0	148.7	173.6	200.5	245.1	292.3	222.7	135.7	0.0	0.0
1988	7.1	0.0	46.4	95.3	154.9	220.3	219.3	226.4	285.2	206.1	0.0	71.4
1989	0.0	0.0	4.4	167.9	278.7	182.6	162.2	413.4	217.4	217.1	0.0	0.0
1990	0.5	0.5	0.0	181.5	89.7	279.4	508.8	359.1	317.5	318.8	2.3	25.8

Source: Meteorology Unit, Enugu State University of Technology Archives (1981–1990).

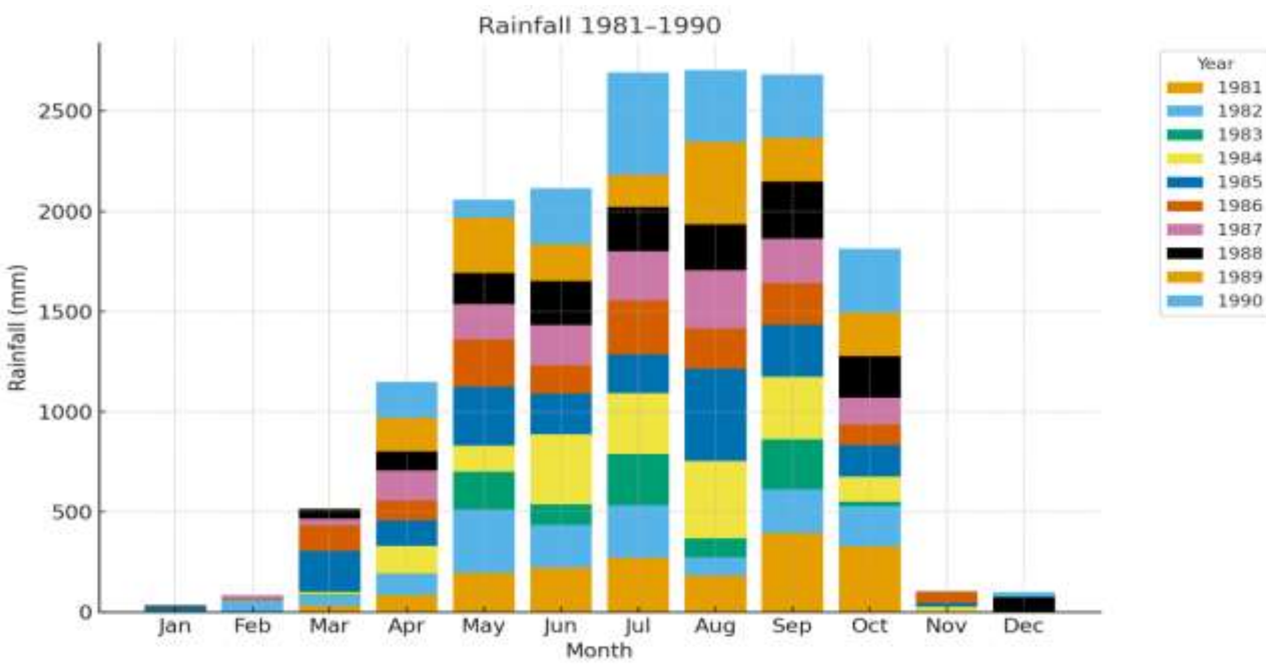

Figure 4.2: Chart showing Rainfall variability from 1981-1990

Figure 4.2 presents rainfall variability in Enugu between 1981 and 1990. The graph indicates that maximum rainfall occurred from April to October, with monthly totals consistently

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exceeding 1,000 mm. This period corresponds to the wet season, which supports vegetation growth and contributes to increases in land cover within the study area. In contrast, the months of January, February, March, November, and December recorded significantly lower rainfall, with values generally below 500 mm. This seasonal reduction reflects the prolonged dry period, which is often associated with water shortages, drought risks, and potential land degradation. Overall, the rainfall distribution highlights a distinct wet–dry seasonal cycle in Enugu during the decade, demonstrating the strong influence of rainfall variability on both land cover dynamics and ecological stability in the region.

Table 4.3: Rainfall Variability in Enugu (1991–2000): *(Monthly Rainfall in mm)*

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1991	0.0	37.6	62.4	198.1	346.4	244.8	320.2	264.5	230.5	253.5	25.0	1.4
1992	0.0	0.0	111.5	200.9	194.0	354.0	313.0	149.3	249.7	105.3	28.8	0.0
1993	0.0	5.1	62.7	148.9	109.9	263.7	186.7	389.8	243.5	72.9	82.9	11.6
1994	33.8	0.0	9.7	150.7	211.2	140.0	216.0	388.2	331.9	181.6	0.0	0.0
1995	1.6	0.0	90.2	194.1	263.9	356.7	340.2	435.1	192.4	261.7	35.0	0.0
1996	0.0	26.7	48.6	160.9	277.2	289.6	368.3	268.4	176.3	308.4	0.0	0.0
1997	0.0	0.0	111.6	261.3	376.1	345.0	226.8	235.0	392.3	264.3	68.1	4.1
1998	0.0	6.1	25.8	161.1	188.7	285.0	259.2	96.2	256.6	217.4	0.0	0.0
1999	18.4	15.7	30.0	103.6	223.5	316.8	206.4	200.2	195.1	313.4	0.0	0.0
2000	32.4	0.0	32.3	201.8	357.5	206.1	298.4	331.8	339.7	226.5	0.0	0.0

Source: Meteorology Unit, Enugu State University of Technology Archives (1991–2000).

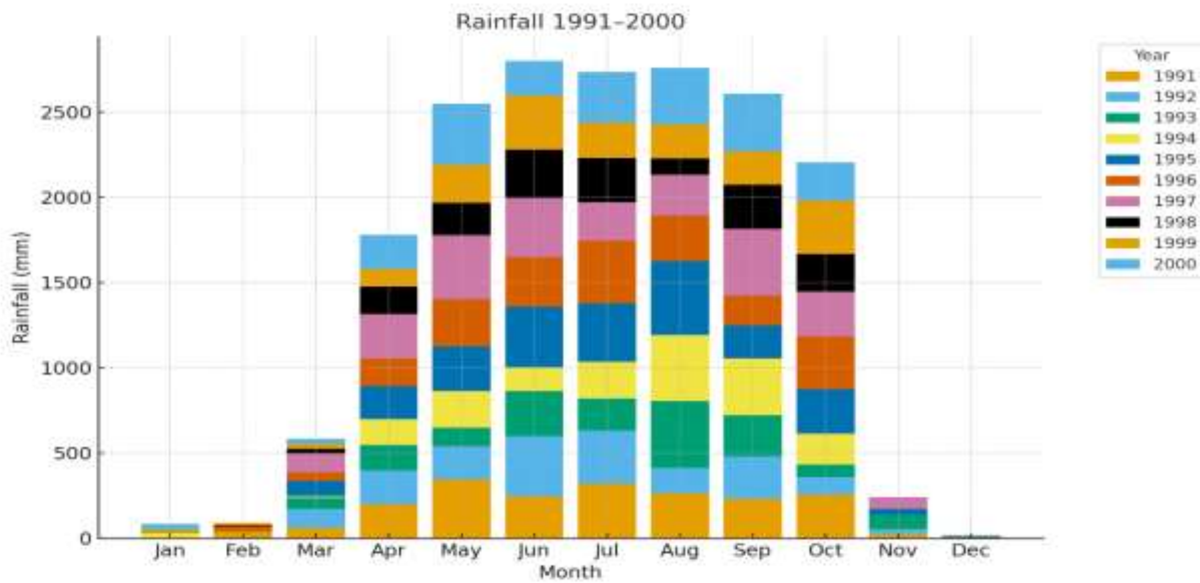

Figure 4.3 Rainfall variability graph from 1991 to 2000

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Figure 4.3 illustrates rainfall variability in Enugu between 1991 and 2000. The graph shows exceptionally high rainfall in August 1995, with totals exceeding 400 mm. Similar rainfall levels were also recorded in August 1993 (389.8 mm) and August 1994 (388.2 mm), indicating consistent peak rainfall during the late rainy season. This pattern suggests that periods of high rainfall are closely associated with rapid land cover growth and agricultural productivity, while periods of reduced rainfall correspond to declines in land cover, soil moisture stress, and possible environmental degradation.

Table 4.4: Rainfall Variability in Enugu (2001–2010): ***(Monthly Rainfall in mm)***

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2001	0.0	28.0	72.5	305.5	273.8	188.8	152.0	130.6	407.9	118.1	0.0	0.0
2002	0.0	46.5	14.0	159.1	219.7	296.4	263.3	121.9	270.9	332.5	1.5	0.0
2003	0.0	0.0	2.9	74.6	234.3	287.0	400.4	290.2	334.4	227.4	39.8	0.0
2004	0.6	6.4	4.8	186.8	305.5	222.3	284.7	174.1	272.3	258.1	22.1	33.1
2005	0.0	26.9	20.8	115.6	170.0	258.3	277.6	292.0	283.6	228.5	24.1	19.1
2006	43.9	4.6	78.9	138.4	375.0	339.2	420.5	188.3	261.8	233.7	0.0	0.0
2007	0.0	9.4	70.0	105.7	325.0	292.7	290.3	255.1	299.7	240.2	0.0	0.0
2008	1.2	0.0	56.6	191.6	281.2	244.6	196.0	328.6	332.5	96.4	235.7	205.9
2009	50.1	0.0	11.1	112.4	347.1	206.2	280.5	154.3	204.7	384.6	18.9	0.0
2010	0.0	0.0	2.2	162.8	199.3	392.5	137.6	150.0	398.1	226.0	1.0	0.0

Source: Meteorology Unit, Enugu State University of Technology Archives (2001–2010).

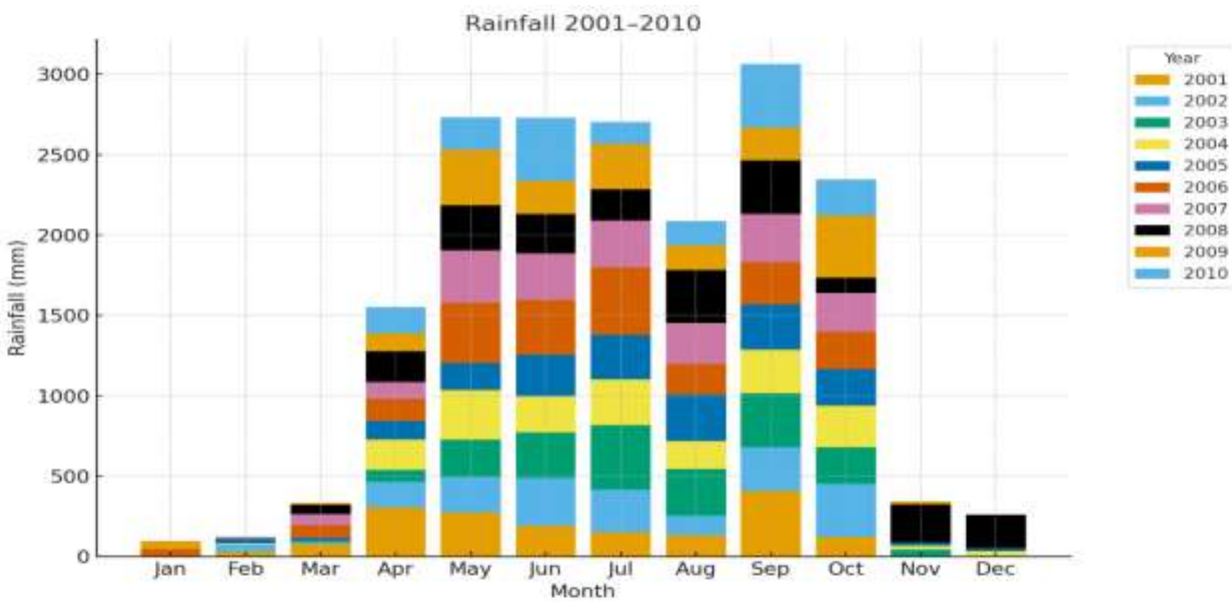

Figure 4.4: Chart showing Rainfall variability from 2001–2010 rainfall variability

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Figure 4.4 illustrates rainfall variability in Enugu from 2001 to 2010. The trend indicates generally low rainfall compared to earlier decades, posing potential hazards to the environment. During this period, the maximum monthly rainfall rarely exceeded 500 mm, with the highest values recorded in July, reaching slightly above 400 mm. Conversely, the minimum rainfall occurred in the dry-season months (typically November to March), where values dropped below 100 mm. Such prolonged low rainfall conditions may have contributed to drought occurrences, land degradation, and reductions in land use/land cover within the study area.

Table 4.5: Rainfall Variability in Enugu (2011–2020): *(Monthly Rainfall in mm)*

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2011	0.0	44.6	118.4	118.1	220.2	188.5	195.4	237.0	439.0	166.1	2.0	0.0
2012	39.0	35.7	13.0	86.9	288.7	282.5	388.0	309.1	393.2	227.7	73.9	0.0
2013	35.1	31.7	31.7	146.0	296.7	279.4	173.9	336.4	430.1	113.5	0.0	98.3
2014	1.2	5.2	120.3	183.7	241.3	229.6	308.3	311.6	297.8	172.8	57.8	0.0
2015	0.0	82.8	117.5	21.6	239.4	260.4	363.5	302.3	380.3	198.9	42.2	0.0
2016	1.0	0.0	53.8	93.3	269.7	318.0	362.4	371.0	285.6	176.3	56.3	0.0
2017	1.9	0.0	63.6	181.6	375.0	319.3	420.5	385.9	326.6	137.3	0.0	0.0
2018	6.3	0.0	63.9	230.4	250.6	362.0	389.7	302.3	434.3	311.5	83.5	0.0
2019	0.0	0.0	130.0	197.4	212.4	284.8	258.5	193.1	326.3	224.4	78.6	0.0
2020	0.0	0.0	150.0	260.6	230.8	310.2	350.3	138.0	370.0	287.6	67.0	8.8

Source: Meteorology Unit, Enugu State University of Technology Archives (2011–2020).

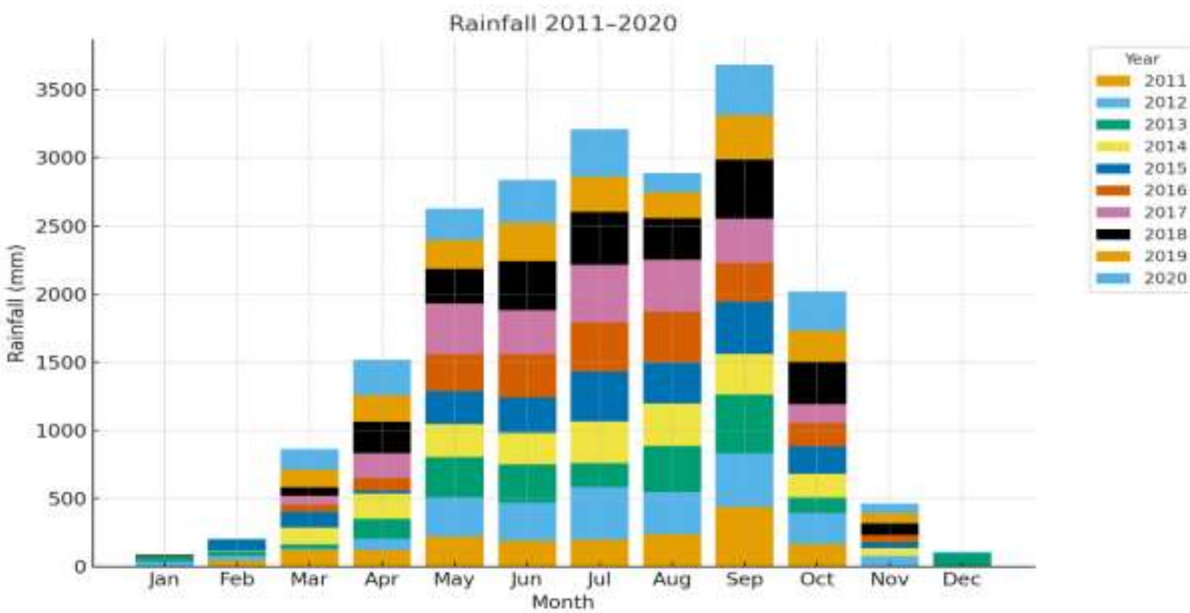

Figure 4.5 showing rainfall variability graph from 2011 to 2020

Figure 4.5 presents rainfall variability in Enugu between 2011 and 2020. The results show that peak rainfall was recorded in September, with values exceeding 350 mm, while the lowest rainfall occurred in the dry-season months of January and December, often below 100 mm. This distribution highlights the strong seasonality of rainfall in the area. Periods of high rainfall, particularly during July–September, may result in negative environmental impacts such as erosion, flooding, and disruptions to economic activities. On the other hand, the months with minimal rainfall require reliance on alternative water sources to support agriculture and land cover maintenance within the study area.

Table 4.6: Annual and Mean Rainfall Variability in Enugu (1971–2020): ***(Rainfall in mm)***

Year	Annual Rainfall	Mean Rainfall
1971	987.9	82.325
1972	928.3	77.358333
1973	813.4	67.783333
1974	1104.4	92.033333
1975	973.5	81.125
1976	889.0	74.083333
1977	1546.0	128.833333
1978	1983.1	165.258333
1979	1696.8	141.4
1980	2043.7	170.308333
1981	1710.9	142.575
1982	1549.6	129.133333
1983	917.1	76.425
1984	1781.1	148.425
1985	1939.9	161.658333
1986	1450.0	120.833333
1987	1467.3	122.275
1988	1524.4	127.7
1989	1643.9	136.975
1990	2043.1	173.616667
1991	1961.9	163.491667
1992	1706.5	142.208333
1993	1577.0	131.475
1994	1663.1	138.591667
1995	2170.9	180.908333
1996	1919.4	159.95
1997	2284.6	190.383333
1998	1496.1	124.675
1999	1623.1	135.258333
2000	2026.5	168.875

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2001	1677.2	139.766667
2002	1715.8	143.616667
2003	1891.0	157.583333
2004	1770.8	147.566667
2005	1645.4	137.116667
2006	2084.3	173.691667
2007	1891.7	157.641667
2008	2170.3	180.858333
2009	1769.7	147.475
2010	1669.5	139.125
2011	1729.3	144.108333
2012	2137.7	178.141667
2013	1941.1	161.758333
2014	1929.6	160.8
2015	2008.9	167.408333
2016	1818.8	151.567
2017	1701.8	141.816667
2018	2395.4	199.45
2019	1705.3	142.108333
2020	2173.3	181.108333

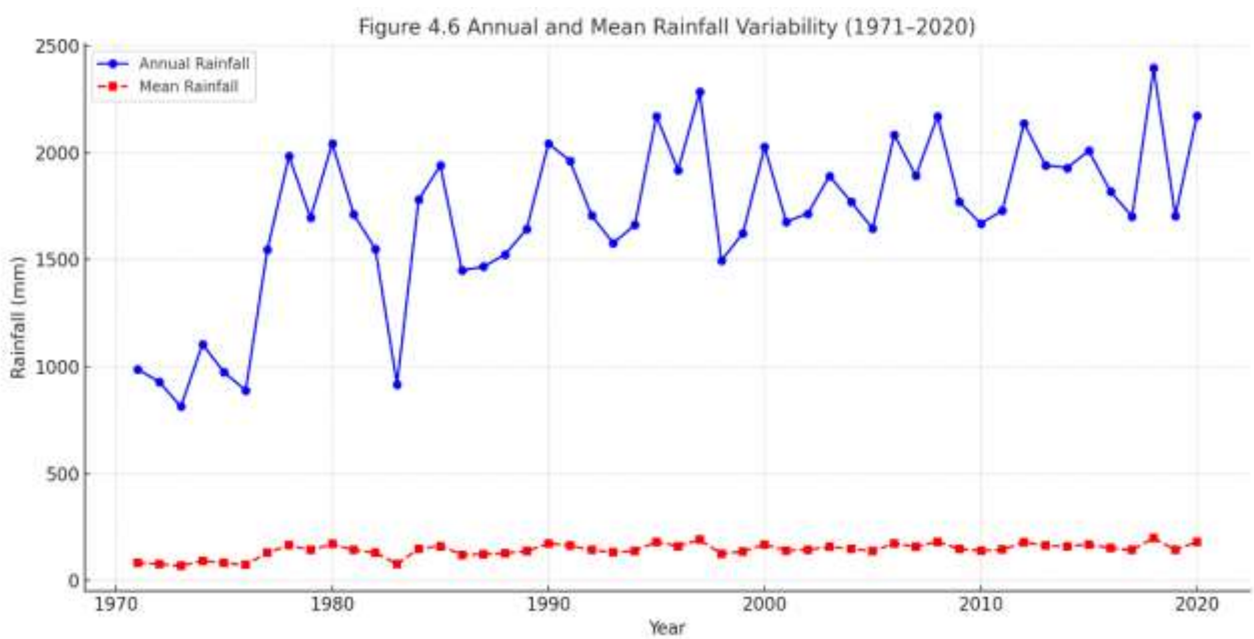

Figure 4.6 Annual and mean Rainfall variability graph from 1971 to 2020

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From Figure 4.6 above, the period of high rainfall in the urban area was recorded between the years 1977–1999 and 2002–2020. Annual rainfall during these years ranged between 1546 mm and 2395.4 mm. Notable peak years include 1977 (1546 mm), 1978 (1983.1 mm), 1980 (2043.7 mm), 1995 (2170.9 mm), 1997 (2284.6 mm), 2006 (2084.3 mm), 2008 (2170.3 mm), 2012 (2137.7 mm), 2018 (2395.4 mm), and 2020 (2173.3 mm).

Conversely, decreases in rainfall occurred in the years 1971, 1972, 1973, 1974, 1976, and 1983, with annual totals ranging from 813.4 mm to 1104.4 mm. These low rainfall years suggest periods of water stress and potential drought conditions in the study area.

5.0 Summary, Recommendations, and Conclusion

5.1 Summary of Findings

Table 4.6 and Figure 4.6 present annual and mean rainfall variability in Enugu from 1971 to 2020. Results show significant fluctuations, with higher rainfall recorded in years such as 1995, 1997, 2008, 2012, 2018, and 2020 (with totals above 2000 mm). The highest rainfall occurred in 2018 (2395.4 mm), marking it as the wettest year in the 50-year record. This extreme rainfall likely contributed to flooding, erosion, and land cover impacts in the urban area.

The lowest rainfall was observed in 1973 (813.4 mm), 1976 (889.0 mm), 1983 (917.1 mm), 1972 (928.3 mm), 1971 (987.9 mm), and 1974 (1104.4 mm). These dry years suggest possible drought conditions, land degradation, and reduced land cover in the study area.

These findings align with the study by Okwu-Delunzu, Ogbonna, and Ike (2015), who reported that increasing rainfall in Enugu contributed significantly to gully erosion and land degradation. They found that degraded areas covered 51% of total land area, with a strong positive correlation ($r = 0.8$) between cumulative rainfall and land degradation.

The observed variability may be attributed to atmospheric pollution, socio-economic activities, population growth, agricultural expansion, and technological development (Alexander, 2012). Overall, the 50-year rainfall record indicates significant variation in rainfall patterns and a reduction in land use/land cover over time in Enugu urban area.

5.2 Recommendations

1. Education and Awareness: Implement robust public education and enlightenment campaigns to raise awareness about the impact of human activities on atmospheric pollution, climate change, and rainfall variability.
2. Improved Monitoring: Establish more meteorological stations in the region to closely track changing rainfall patterns and provide accurate data for planning.
3. Flood and Drought Management: Residents of Enugu metropolis should be sensitized and encouraged to adopt adaptive strategies to cope with flooding during peak rainfall and drought during low rainfall periods, thereby sustaining agricultural and economic activities.

5.3 Conclusion

The use of descriptive statistics and graphical tools in this study confirms substantial evidence of rainfall variability in Enugu urban area (1971–2020). Results affirm that rainfall is on an upward long-term trend, contributing positively to land cover, vegetation growth, and water availability. However, the high variability indicates shifts in rainfall distribution, with extreme wet years linked to flooding and erosion, while dry years signal drought risks and reductions in land cover.

This underscores the critical need for sustainable land management, climate adaptation strategies, and improved meteorological monitoring to mitigate the environmental and socio-economic impacts of rainfall variability in Enugu.

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