

Changing Type of Climate in Amarapura District (1983-2023)

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Abstract

Amarapura District is situated in the Dry Zone of Central Myanmar. The climate of an area is defined as the long-term change in rainfall, temperature, wind, humidity and other climatic variables. Among these climatic variables, rainfall and temperature are the most important because they are essential for the efficient management of water resources. In this research, Koppen's Climatic Classification Method, statistical method, fifteen years running mean, and fluctuation and trend line methods are mainly used to analyze the type of climate, to realize the yearly increase or decrease in temperatures and rainfalls. Based on the climatic data of the Meteorology and Hydrology Department, Mandalay (from 1983 to 2023), the mean maximum, mean and mean minimum temperatures of Amarapura District were 85.6°F, 72.5°F and 59.0°F, respectively. The range of temperature is 17.7°F. According to results, the maximum temperature decreases -0.1°F in average but the mean and minimum temperature increased 0.2°F and 0.4°F from 1983 to 2023 (41 years Records), the average annual precipitation of the Amarapura was 34.2 inches. The results show that the annual total precipitation increased at 0.3 inch per year within 41 years Records). Depending upon the mean temperature and total annual rainfall data during the 1983-2023 periods, Amarapura District enjoyed with "Tropical Savanna Type of Climate" or "Aw" using Koppen's Climatic Classification System.

Keywords: Tropical Savanna Type of Climate, fluctuation and trend line methods

Introduction

The climate is naturally variable because of the irregularity of the seasons from one year to another. Long-term climate variability is of great importance for estimating its impact on human activities and predicting the future climate. In this research, the climatic data received from the Meteorological and Hydrological Department of Mandalay are used and computed by using Koppen's climatic classification, statistical method, fifteen years running mean, and fluctuation and trend line methods. According to Koppen's climatic classification, the study area generally enjoyed "Aw" or Tropical Savanna Type of Climate. To ensure the variations of temperatures from the year 1983 to 2023, the average annual mean maximum, mean, and mean minimum temperatures of Amarapura District (1983- 2023) are calculated, and then, the fluctuation trend lines are drawn continuously.

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Study Area

Amarapura District is located in the Mandalay Region. Amarapura was the former capital city founded by King Badon of Konbaung Dynasty in 1782 CE (Moe Sat Wathan 2020: 43). The crop cultivation and weaving industries are the main economic activities in Amarapura District.

Aim and Objectives

The main aim is to analyze the temporal variation of climatic variables and climate change of Amarapura District. The objectives of the study are –

- to assess the temporal changes of the temperature during the 41 years' period (1983-2023)
- to examine the temporal changes of rainfall during the 41 years' period (1983-2023) and
- to identify the types of climates.

Data and Methodology

The temperature data for 41 years (1983-2023) were collected from the Meteorology and Hydrology Department of Mandalay. The study is based on data related to monthly and annual temperature and rainfall. The data are calculated by Köppen's Climatic Classification, the statistical method, fifteen years running mean, and fluctuation trend methods are mainly used.

Geographic Factors

Amarapura District is located in the Dry Zone of Central Myanmar. It lies between 21° 47' 24" and 21° 55' 48" of North Latitude and between 95° 12' 15" and 96° 12' 14" of East Longitude. It has an area of 207.49 sq-km (or) 51,277 acres. Amarapura District is composed of two towns (Amarapura and Myitnge) and 42 village tracts with 170 villages (Figure-1). The topographic feature of the Amarapura District is a level plain which is situated at the junction of the Ayeyarwady River and the Myitnge River. It is a flat plain with a height of about 60 meters above sea level in the west and 90 meters above sea level in the east. The topographic surface is slightly higher in the eastern part and the land gradually slopes towards the Ayeyarwady River in the west. Actually, the study area is located on the Mandalay-Kyaukse plain (Figure-2). The topographic features of Amarapura District can be divided into two portions. They are Western Alluvial Plain and Eastern Alluvial Plain. The climatic conditions of a region generally influence upon the types of natural vegetation and soil of that region and it indirectly influences upon the social and economic structures of the region. According to Köppen's Climatic Classification, Amarapura has the Tropical Savanna Type of Climate (Aw). The temperature and rainfall conditions of Amarapura are presented in Figure 3. In 2023, the total population of Amarapura District was 218,431 persons and it had increased by 24,082 persons during 9-year period from 2014 to 2023. The population growth rate during this period was 1.27 percent. The population of Amarapura District was attributed to the natural increase and migration.

Analyses of the Role of Temperature and Rainfall Conditions

Yearly Variations of Temperature Conditions

The general trends of monthly mean maximum, mean and minimum temperatures for the study period are shown in Table - 1 and Figure - 4. This figure is only a description of the temperature conditions of the study area from this description. It is not enough to understand the changing climate of the study area.

To analyze the temporal changes within the study period (1983- 2023), firstly the fluctuations of the average annual mean maximum, mean, and mean minimum temperatures should be taken into account, as shown in Table -2 and Figure -5. During the 41 years, from 1983 to 2023, the study area received an average maximum temperature of 94.88 °F, an average mean temperature of 82.73°F, and an average minimum temperature of 70.57°F. From 1983 to 1994, the maximum temperature exceeded the average maximum successively. From 1983 to 1993, the average minimum temperature decreased successively. According to the trend line, the average maximum temperature decreased at a rate of (- 0.1) °F per year. According to the trend line, the average minimum temperature was increasing (0.4) °F per year. According to the trend line, the average mean temperature had increased (0.2) °F per year.

Table-1 Average Maximum, Mean and Minimum Temperatures of Amarapura District (1983- 2023)

Temp./Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max Temp.(°F)	87.1	93.0	100.0	103.6	100.7	97.4	97.1	94.9	94.9	93.6	90.4	85.6
Mean Temp.(°F)	71.6	76.6	83.8	89.3	88.8	87.9	87.4	86.4	85.9	84.0	78.6	72.5
Mini. Temp.(°F)	56.2	60.1	67.6	74.8	76.9	78.5	77.6	77.9	77.0	74.3	66.8	59.0

Source: Meteorology and Hydrology Department, Mandalay

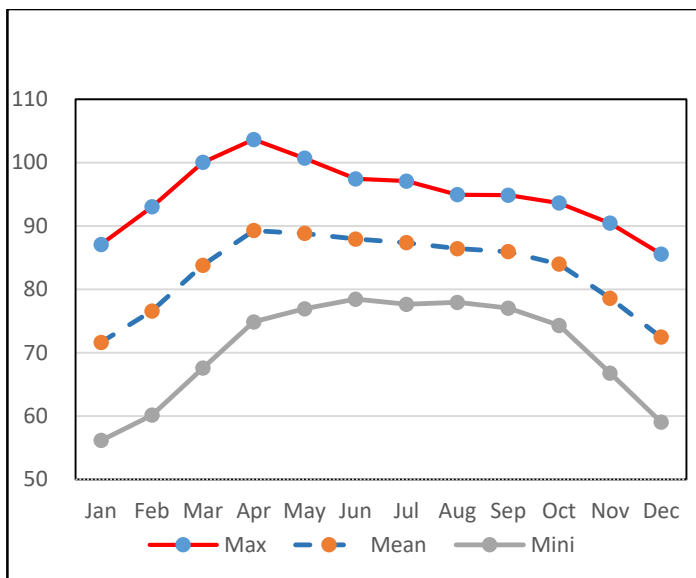


Figure- 4 Mean Monthly Maximum, Average Monthly Mean and Mean Monthly Minimum Temperature of Amarapura District (1983- 2023)

Table -2 Average Annual Maximum, Mean and Minimum Temperatures of Amarapura District (1983-2023)

Year	Max	Average Max	Mean	Average Mean	Mini	Average Mini
1983	99.0	94.9	81.8	82.7	64.6	70.6
1984	97.3	94.9	80.1	82.7	62.9	70.6
1985	98.3	94.9	82.0	82.7	65.4	70.6
1986	98.7	94.9	82.2	82.7	65.8	70.6
1987	98.7	94.9	82.3	82.7	65.8	70.6
1988	98.7	94.9	82.5	82.7	66.4	70.6
1989	98.5	94.9	81.7	82.7	65.0	70.6
1990	97.9	94.9	81.8	82.7	66.5	70.6
1991	98.7	94.9	82.7	82.7	66.6	70.6
1992	97.5	94.9	80.6	82.7	63.8	70.6
1993	98.3	94.9	80.8	82.7	63.3	70.6
1994	93.2	94.9	82.2	82.7	71.1	70.6
1995	94.0	94.9	82.9	82.7	71.8	70.6
1996	92.1	94.9	81.9	82.7	71.8	70.6
1997	92.0	94.9	81.4	82.7	70.8	70.6
1998	94.1	94.9	83.1	82.7	72.1	70.6
1999	93.3	94.9	81.9	82.7	70.5	70.6
2000	91.9	94.9	81.3	82.7	70.7	70.6
2001	93.2	94.9	82.4	82.7	71.5	70.6
2002	91.9	94.9	81.7	82.7	71.5	70.6
2003	93.5	94.9	82.7	82.7	71.9	70.6
2004	93.7	94.9	82.7	82.7	71.8	70.6
2005	94.7	94.9	83.9	82.7	73.2	70.6
2006	93.1	94.9	82.6	82.7	72.2	70.6
2007	92.1	94.9	82.1	82.7	72.1	70.6
2008	92.7	94.9	82.2	82.7	71.8	70.6
2009	95.0	94.9	83.7	82.7	72.5	70.6
2010	95.2	94.9	84.3	82.7	73.3	70.6
2011	92.2	94.9	82.2	82.7	72.3	70.6
2012	94.6	94.9	84.0	82.7	73.3	70.6
2013	93.7	94.9	83.4	82.7	73.1	70.6
2014	95.2	94.9	84.4	82.7	73.7	70.6
2015	93.7	94.9	82.9	82.7	72.2	70.6
2016	93.6	94.9	82.7	82.7	71.9	70.6
2017	93.1	94.9	82.1	82.7	71.2	70.6
2018	92.7	94.9	82.6	82.7	72.4	70.6
2019	94.9	94.9	84.1	82.7	73.2	70.6
2020	95.2	94.9	84.5	82.7	73.7	70.6
2021	95.1	94.9	84.4	82.7	73.8	70.6
2022	94.4	94.9	83.8	82.7	73.2	70.6
2023	94.6	94.9	89.1	82.7	82.7	70.6

Source: Meteorology and Hydrology Department, Mandalay

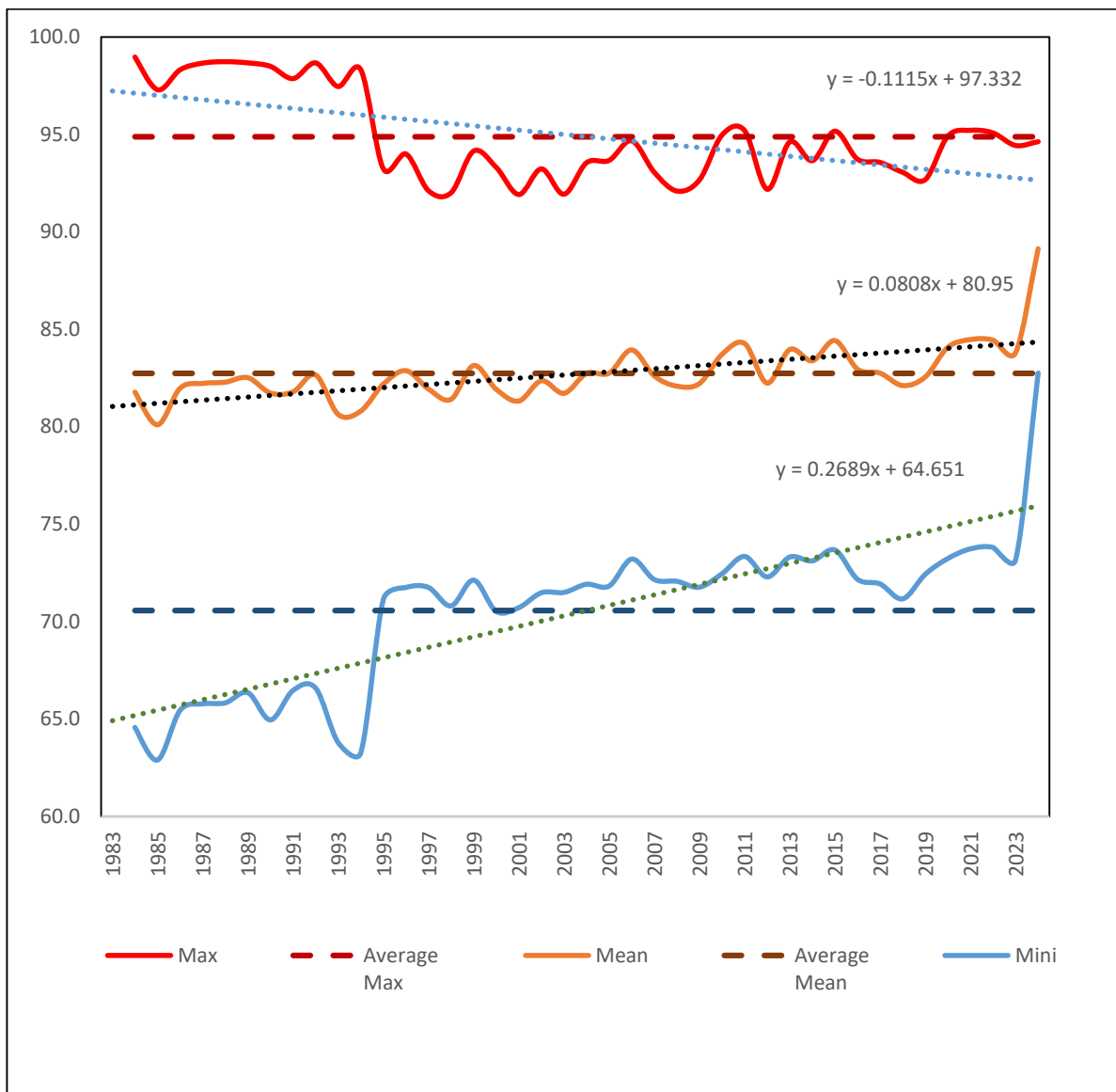


Figure - 5 Fluctuations and Trend Lines of Average Annual Maximum, Mean and Minimum Temperature of Amarapura District (1983-2023)

Yearly Variations of Rainfall

In the study area, during 41 years (1983- 2023), the average total annual rainfall was 34.2inches. The highest total annual rainfall was recorded in 2006 at 60.71inches and the lowest rainfall in 1995 at 19.0 inches. Of the 41 years, 19 years have total annual rainfall being more than the average value. The remaining 22 years have annual rainfall being less than the average value. But they have not occurred successively. Only the period between 2015 and 2018, four years have occurred successively, as shown in Table -3 and Figure -6.

Table - 3 Average Annual Total Rainfalls of Amarapura District (1983-2023)

Year	Annual Total Rainfall	Average Rainfall	Year	Annual Total Rainfall	Average Rainfall
1983	28.7	34.2	2004	28.0	34.2
1984	30.0	34.2	2005	26.3	34.2
1985	31.8	34.2	2006	60.7	34.2
1986	22.4	34.2	2007	45.9	34.2
1987	36.3	34.2	2008	28.0	34.2
1988	32.1	34.2	2009	26.9	34.2
1989	25.2	34.2	2010	40.2	34.2
1990	27.6	34.2	2011	49.0	34.2
1991	29.4	34.2	2012	25.6	34.2
1992	55.1	34.2	2013	36.6	34.2
1993	19.8	34.2	2014	24.6	34.2
1994	39.8	34.2	2015	37.6	34.2
1995	19.0	34.2	2016	52.0	34.2
1996	40.3	34.2	2017	45.6	34.2
1997	35.5	34.2	2018	35.4	34.2
1998	28.7	34.2	2019	22.7	34.2
1999	37.9	34.2	2020	26.9	34.2
2000	26.0	34.2	2021	37.1	34.2
2001	32.2	34.2	2022	31.7	34.2
2002	42.9	34.2	2023	43.9	34.2
2003	35.6	34.2			

Source: Meteorology and Hydrology Department, Mandalay

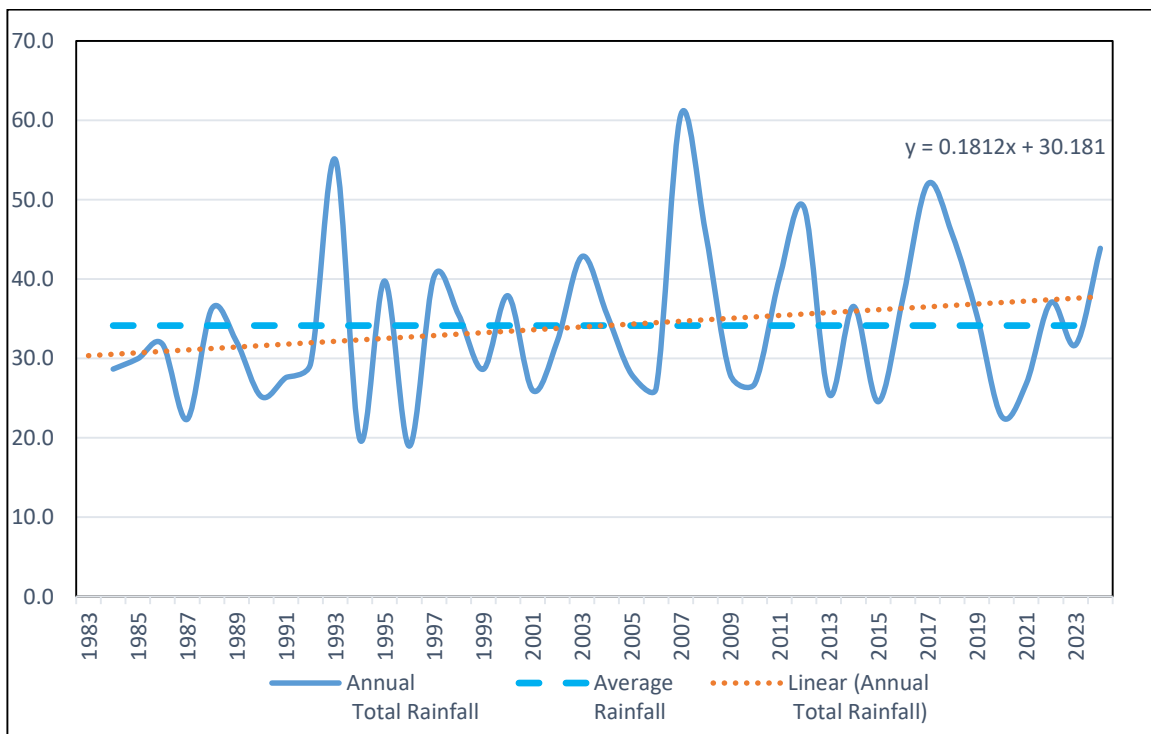


Figure - 6 Average Annual Total Rainfalls of Amarapura District (1983-2023)

Findings and Results

Analysis of types of climates in Amarapura District

In general, an area's climate type can be determined based on the average monthly temperatures and precipitation for a long period. The method of Koppen's Classification of Climate is used to classify the type of climate of the study area. To examine the successive changes in climate between 1983 and 2023, a fifteen-year running mean of average monthly temperatures and average monthly rainfall is used (Table 3). By noticing the mean monthly temperatures within 41 years (1983-2023), the coldest month of every year is January with temperatures above 64.4° F. Moreover, in terms of the fifteen-year running mean, temperatures in January have also exceeded 64.4° F. This means that the study area has enjoyed A or B type of climate. According to the rainfall data in the study period, the average annual rainfall was 34.2 inches. This indicates that the district has enjoyed an A type of climate. To determine whether the study area has either Am or Aw type of climate, mean monthly temperatures, annual rainfall data for 41 years, and Koppen's Climate Classification method are used. The driest month's rainfall is less than the calculated value, thus the study area enjoyed an "Aw" type of climate or tropical savanna.

Table - 4 Fifteen-Year Running Means of Monthly Temperature (°F) and Monthly Rainfall (Inch) of Meiktila Township (1983-2023)

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg\Total	Type of Climate
1983-1990	Temp (°F)	70.4	75.2	75.2	87.6	88.7	87.6	86.6	86.2	85.4	83.3	83.3	70.7	81.8	Aw
	RF(Inch)	0.1	0.4	0.4	1.8	4.0	4.1	2.7	5.7	5.9	5.0	2.0	0.3	48.9	
1984-1991	Temp (°F)	70.6	75.3	75.3	87.6	88.7	87.5	86.5	86.2	85.4	83.4	83.4	71.1	81.9	Aw
	RF(Inch)	0.1	0.4	0.4	1.7	4.2	4.3	2.6	5.8	6.2	4.7	1.7	0.2	51.1	
1985-1992	Temp (°F)	70.7	75.6	75.6	87.6	88.8	87.5	87.3	86.2	85.4	83.6	83.6	71.0	82.0	Aw
	RF(Inch)	0.0	0.4	0.4	1.9	4.4	4.2	2.7	5.6	6.3	4.8	1.8	0.2	54.0	
1986-1993	Temp (°F)	70.7	75.3	75.3	87.8	88.6	87.7	87.3	86.3	85.4	83.5	83.5	71.0	82.0	Aw
	RF(Inch)	0.0	0.4	0.4	1.9	4.5	4.0	2.7	5.6	6.2	4.5	1.7	0.1	55.9	
1987-1994	Temp (°F)	70.7	75.4	75.4	87.9	88.4	87.3	87.2	86.3	85.5	83.7	83.7	71.1	82.0	Aw
	RF(Inch)	0.0	0.3	0.4	1.9	5.0	4.1	2.8	5.5	6.1	4.8	1.6	0.1	58.9	
1988-1995	Temp (°F)	70.7	75.6	75.6	88.0	88.1	87.2	87.2	86.2	85.5	83.8	83.8	70.8	81.9	Aw
	RF(Inch)	0.0	0.3	0.4	1.8	5.4	4.0	2.7	5.8	6.3	4.5	1.9	0.1	61.6	
1989-1996	Temp (°F)	70.8	75.5	75.5	88.1	88.0	87.3	87.3	86.2	85.4	84.1	84.1	70.9	81.9	Aw
	RF(Inch)	0.0	0.2	0.4	1.9	5.5	3.7	2.8	5.8	6.9	4.3	1.7	0.1	64.2	
1990-1997	Temp (°F)	71.0	75.6	75.6	88.1	88.0	87.1	87.1	86.3	85.2	84.1	84.1	71.1	82.0	Aw
	RF(Inch)	0.0	0.2	0.4	1.9	5.7	4.0	2.9	5.6	7.2	3.8	1.6	0.1	66.8	
1991-1998	Temp (°F)	71.0	76.0	76.0	88.7	88.3	87.3	87.2	86.2	85.2	83.9	83.9	71.2	82.2	Aw
	RF(Inch)	0.0	0.2	0.5	2.0	5.4	3.8	2.8	5.8	7.2	3.8	1.7	0.2	66.9	
1992-1999	Temp (°F)	71.1	76.1	76.1	88.8	88.2	87.3	87.0	86.1	85.1	83.8	83.8	71.2	82.1	Aw
	RF(Inch)	0.0	0.2	0.4	1.9	5.8	4.0	2.8	6.4	8.0	4.2	1.5	0.2	69.2	
1993-2000	Temp (°F)	71.2	76.2	76.2	88.8	87.9	87.4	87.1	86.2	85.2	83.8	83.8	71.8	82.2	Aw
	RF(Inch)	0.0	0.1	0.4	1.9	5.9	4.3	2.7	5.7	7.9	4.2	1.5	0.2	68.8	
1994-2001	Temp (°F)	71.3	76.1	76.1	89.3	88.0	87.4	87.1	86.1	85.3	83.8	83.8	72.1	82.3	Aw
	RF(Inch)	0.1	0.1	0.4	1.9	6.1	4.1	3.0	5.7	7.7	4.4	1.5	0.2	69.6	
1995-2002	Temp (°F)	71.3	76.4	76.4	89.4	87.8	87.4	87.2	86.2	85.4	84.0	84.0	72.3	82.4	Aw
	RF(Inch)	0.0	0.1	0.4	2.0	6.6	3.8	2.9	5.2	7.6	4.2	1.4	0.2	69.0	
1996-2003	Temp (°F)	71.5	76.5	76.5	89.5	87.9	87.4	87.3	86.2	85.4	84.0	84.0	72.4	82.5	Aw
	RF(Inch)	0.0	0.1	0.4	2.0	6.6	3.9	3.0	5.6	7.4	5.1	1.3	0.3	70.7	

1997-2004	Temp (°F)	71.5	76.5	76.5	89.7	87.9	87.5	87.4	86.2	85.5	83.9	83.9	72.3	82.6	Aw
	RF(Inch)	0.0	0.0	0.3	1.8	7.0	3.8	3.1	6.0	7.2	5.4	1.2	0.3	71.5	
1998-2005	Temp (°F)	71.7	76.8	76.8	90.0	88.1	87.6	87.5	86.4	85.7	84.1	84.1	72.4	82.7	Aw
	RF(Inch)	0.0	0.0	0.3	1.9	6.9	3.8	2.7	5.8	7.2	5.5	1.2	0.3	71.1	
1999-2006	Temp (°F)	71.8	77.0	77.0	90.1	87.9	87.5	87.6	86.3	85.7	83.9	83.9	72.3	82.7	Aw
	RF(Inch)	0.0	0.0	0.3	1.9	7.0	3.9	2.6	5.8	7.2	6.0	1.2	0.3	71.9	
2000-2007	Temp (°F)	71.9	77.0	77.0	90.3	88.4	87.8	87.7	86.3	85.7	84.0	84.0	72.6	82.9	Aw
	RF(Inch)	0.0	0.1	0.3	1.6	6.4	3.7	2.5	6.2	7.3	5.8	1.0	0.3	71.0	
2001-2008	Temp (°F)	72.1	77.2	77.2	90.3	88.7	88.0	87.7	86.3	85.8	83.8	83.8	72.7	83.0	Aw
	RF(Inch)	0.1	0.0	0.2	1.4	6.8	3.6	2.5	6.3	7.4	6.4	1.0	0.3	71.8	
2002-2009	Temp (°F)	72.1	77.2	77.2	90.3	88.9	87.9	87.5	86.2	85.7	83.9	83.9	72.9	83.0	Aw
	RF(Inch)	0.1	0.0	0.2	1.5	6.5	3.9	2.9	6.8	7.5	6.3	1.3	0.3	73.1	
2003-2010	Temp (°F)	72.2	77.2	77.2	90.0	88.9	87.9	87.5	86.3	85.7	83.9	83.9	73.3	83.1	Aw
	RF(Inch)	0.1	0.0	0.3	1.5	6.6	3.8	3.1	6.1	7.6	7.0	1.0	0.3	71.1	
2004-2011	Temp (°F)	72.2	77.3	77.3	89.9	89.0	87.8	87.4	86.3	85.8	83.7	83.7	73.4	83.1	Aw
	RF(Inch)	0.2	0.0	0.3	1.6	6.5	3.8	3.0	6.3	7.4	7.2	1.0	0.4	68.7	
2005-2012	Temp (°F)	72.2	77.4	77.4	90.1	89.3	88.0	87.6	86.2	85.9	83.8	83.8	73.4	83.1	Aw
	RF(Inch)	0.3	0.0	0.3	1.4	6.2	3.6	2.7	6.8	7.0	7.3	1.3	0.4	65.9	
2006-2013	Temp (°F)	72.1	77.2	77.2	90.1	89.3	88.0	87.7	86.2	86.2	83.9	83.9	73.5	83.2	Aw
	RF(Inch)	0.4	0.0	0.2	1.4	6.5	3.6	2.9	6.8	6.7	7.5	1.4	0.2	63.6	
2007-2014	Temp (°F)	72.3	77.1	77.1	90.1	89.6	88.2	87.8	86.3	86.3	84.1	84.1	73.7	83.3	Aw
	RF(Inch)	0.4	0.0	0.2	1.4	6.3	3.2	2.9	6.5	5.9	7.6	1.3	0.2	59.7	
2008-2015	Temp (°F)	72.4	77.1	77.1	90.2	89.6	88.3	88.0	86.3	86.5	84.3	84.3	73.8	83.4	Aw
	RF(Inch)	0.4	0.0	0.2	1.6	6.4	2.5	2.8	6.6	5.5	7.4	1.2	0.2	56.4	
2009-2016	Temp (°F)	73.1	78.0	78.0	90.6	90.1	88.6	88.3	86.5	86.7	84.6	84.6	74.4	83.9	Aw
	RF(Inch)	0.4	0.0	0.2	1.7	6.2	2.7	2.7	7.2	5.9	7.5	1.3	0.2	55.1	

Source: Meteorology and Hydrology Department, Mandalay

Conclusion

Amarapura District is located in the Dry Zone of Central Myanmar. It has an area of 207.49 sq-km (or) 51,277 acres. In this research, the temporal variations of temperatures and rainfalls in Amarapura District were based on the climatic data recorded by the Meteorological and Hydrological Department of Amarapura District during the periods from 1983 to 2023.

Based on the climatic data of the Meteorology and Hydrology Department, Mandalay (from 1983 to 2023), the mean maximum, the average mean, and the mean minimum temperatures of Amarapura were 94.9° F, 82.7° F and 70.6° F.

Depending upon the mean temperature and total annual rainfall data during the 1983-2023 periods, Amarapura District was influenced by “Tropical Savanna Climate” or “Aw” using Koppen’s Climatic Classification System. In terms of the type of climate in Amarapura District, there is no significant change within the study period.

But Mandalay is generally classified as having an **Aw type of climate** (tropical savanna climate, characterized by distinct wet and dry seasons), **Robert R. Drummond**, in his research paper, considers additional factors such as **temperature, rainfall, and vegetation** to classify the climate. Based on these factors, Drummond described Mandalay's climate as **BSh**, which refers to a **hot semi-arid climate**. This means that Mandalay's climate is hotter and drier than the typical "Aw" and accommodated, with natural vegetation and rainfall patterns aligning more closely with semi-arid conditions.

According to the results, the temporal changes within the study period (1983-2023), the maximum temperature decreased -0.1°F on average but the mean and minimum temperature increased by 0.2°F and 0.4°F from 1983 to 2023 (41 years Records), the average annual precipitation of the Amarapura was 34.2 inches. The results show that the annual total precipitation increased at 0.3 inch per year within 41 years Records). Depending upon the mean temperature and total annual rainfall data during the 1983-2023 periods, Amarapura District was influenced by “Tropical SavannaType of Climate” or “Aw” using Koppen’s Climatic Classification System. To optimize agriculture in this climate, **drought-resisting crops, crops of shorter growing season, and perennial crops** can thrive despite the challenges of the Aw climate, ensuring food security and economic stability for farmers.

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