TRENDS OF SURFACE AIR TEMPERATURE AND PRECIPITATION OVER TORORO-UGANDA

BY

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DECLARATION

I **Chebet Difas** hereby declare that the research work contained in this report is my original work, and that it has never been submitted to any university or other higher education institution for the purpose of conferring a degree or another credential.

Signature..

Date...14/10/2024...

APPROVAL

The research work that has culminated into this report was done under the supervision of the following supervisor.

Dr. Andima Geoffrey.

Signature………………………………………………………………………………………

Date…14-10-2024……………………………………………………………………………

DEDICATION

I dedicate this research report to my father, **Soyekwo Clive** and mother, **Chelangat Beatrice** for the unfailing support and parental advice they bestowed to me throughout the course of study. I also dedicate it to my little sister **Chemutai Trasila** and all those who believe God can raise them from the ashes.

ACKOWLEDGEMENT

I am immensely thankful to the Almighty God for the gift of life he has rendered to us and for the far He has brought us. This research was as a result of a collective effort from a number of people.

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May God bless you all!

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LIST OF ACRONYMS AND ABREVIATIONS

TAHMO- Trans African Hydro Meteorological Observatory

UNMA – Uganda National Meteorological Authority

SAT- Surface Air Temperature

UMD – Uganda Meteorological Department

ITCZ – Inter-Tropical Convergence Zone

ABSTRACT

Surface air temperature (SAT) and precipitation are important variables, the coupling of which is crucial in understanding the variation in the Earth's climate under the effects of global warming. It is known that these two variables vary differently overtime in different regions of the world. This research is aimed at determining the diurnal and seasonal trend of surface air temperature and precipitation, and also the correlation that exists between the two climatic variables. Climate data from the meteorological station in Tororo were collected and the data set consisted of average values of surface air temperature and precipitation for two years, 2017 and 2018. The results show that the surface air temperature has a clear diurnal trend with a maximum at 29.3 ˚C and a minimum at 17.1 ˚C. similarly the precipitation over Tororo has a diurnal pattern characterized by a maximum at 3.6mm and a minimum at 0.02mm. The seasonal pattern reveals that Tororo has two seasons, the dry season which stretches from around November to March while the wet season extends from April to around October.

With focus on 2018, the correlation between surface air temperature and precipitation was calculated using the spearman's rank correlation method with the help of the JASP software. A strong negative correlation between the two variables was obtained.

1 CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

Climate change is a global phenomenon that has far-reaching implications for various regions around the world. One of the most important aspects affected by climate change is surface air temperature, which plays a major role in shaping local weather patterns and precipitation.

Environmental changes associated with global warming have been investigated from various research perspectives. Various studies have examined trends and inter-annual variations of rainfall. Such studies are particularly important in Tororo, a town located in eastern Uganda, which experiences tropical savanna climate characterized by hot conditions with distinct wet and dry seasons.

Surface air temperature and precipitation are fundamental measurements for describing the climate, and have wide-ranging impacts on human life and ecosystems. For example, increases in air temperature lead to more intense heat waves, which cause illness and death, especially in vulnerable populations. Rainfall, snowfall, and the timing of snowmelt can all affect the amount of water available for drinking, irrigation, and industry. Diurnal and seasonal temperature and precipitation patterns determine the types of animals and plants (including crops) that survive in particular locations. Variations in temperature and precipitation disrupt a wide range of natural processes, particularly if these changes occur more quickly than plant and animal species can adapt.

Concentrations of heat-trapping greenhouse gases are increasing in the Earth's atmosphere. In response, average temperatures at the Earth's surface are rising and are expected to continue rising (USGCRP, 2017). As average temperatures at the Earth's surface rise, more evaporation occurs, which, in turn, increases overall precipitation. Therefore, a warming climate is expected to increase precipitation in many areas including Tororo. (Averages & Data, n.d.)

However, because climate change causes changes in wind patterns and ocean currents that drive the world's climate system, some areas are warming more than others, some have experienced cooling, and precipitation patterns will vary across the world. In addition, higher temperatures lead to more evaporation, so increased precipitation will not necessarily increase the amount of water available for drinking, irrigation, and industry. Increased evaporation can also produce more intense precipitation events for instance; heavier rain and hailstorms that can damage crops and increase flood risk even if the total amount of precipitation in an area does not increase.

In this study, I reconfirm recent trends of diurnal and seasonal surface air temperature and precipitation trends and clarify the correlation that exists between these two variables. I particularly focus on the inter-seasonal and diurnal trends of surface air temperature and precipitation over this specific region of Tororo.

1.2 PROBLEM STATEMENT

The harsh climate changes coupled with the unknown trends of surface air temperature and precipitation over Tororo, a district in Eastern Uganda has become an increasingly pressing issue in recent years, this has made it difficult for the scientists to accurately predict future climate conditions. This has posed a significant challenge on the policy makers and planners to make informed decisions about adaptation and mitigation strategies. The changes in surface air temperature and precipitation have also led to an increase in the frequency and intensity of extreme weather events including heat waves, droughts, floods and storms within the region leading to a devastating impact on human health and agriculture. However, there is lack of comprehensive understanding of how surface air temperature and precipitation vary over this specific region. This calls for an in-depth investigation to analyze the trends and determine the correlation between the two climatic events.

1.3 AIM

The aim is to study the trends of surface air temperature and precipitation over Tororo, Uganda.

1.4 OBJECTIVES

1. To determine the diurnal trend surface air temperature and precipitation over Tororo
2. To determine the seasonal trend of surface air temperature and precipitation over Tororo
3. To determine the correlation between surface air temperature and precipitation

1.5 SCOPE

This research study examined the trends of surface air temperature and precipitation over Tororo, Uganda and determined the correlation between these two climate variables. The research focused on data for two years 2017 and 2018. The data was collected from the TAHMO weather station located at the UNMA headquarters in Tororo district.

Location in Uganda

Coordinates: 00°41′34″N 34°10′54″E

Country	Uganda
Region	Eastern Region of Uganda
District	Tororo District
Elevation	4,193 ft (1,278 m)

Figure 1 The location of Tororo

1.6 SIGNIFICANCE

The findings of this research study will help the people of Tororo, Uganda to be fully equipped with the information about the trends of surface air temperature and precipitation. This will enable them make informed decisions that will be crucial for developing effective adaptation and mitigation strategies to safeguard the socio-economic and environmental well-being of Tororo, Uganda as well as other similar regions facing climate change challenges. This will help policy makers and contribute to the existing body of knowledge in weather forecasting and draught projection.

2 CHAPTER TWO: LITERATURE REVIEW

2.1 Surface air temperature and precipitation

Surface air temperature is how hot air is near the surface of the earth, measured at 2 meters above the ground or the ocean surface. Surface air temperature has profound and widespread impacts on both natural systems and on human lives and activities. It affects health, agriculture, energy demand and much more. Extremes of surface air temperature, both heat waves and extreme cold periods, are particular important for human health. Surface air temperature provides a key indicator of climate change, contributing to "global surface air temperature record" (Jones et al., 1999).

Research conducted by Nsubuga et al., about the Variability and trends in daily and monthly near-surface temperatures in Uganda, collected over the period 1960 to 2008 (49 years), were analyzed. Daily observational temperature records from eight selected stations in Uganda were acquired from the Uganda Meteorological Department (UMD). Data collected by the UMD are quality controlled through a rigorous process before being archived. The data received were tested for homogeneity, gaps were filled and simple correlation analyses were used for validation during the analysis.

They employed statistical techniques (Mann-Kendall and linear regression) to analyze temperature variability and to obtain temperature trends. Findings indicate that intra-annual temperature shows reduced variability over recent decades, but which is not statistically significant. An examination of intra-monthly trends in daily maximum and minimum temperatures revealed a general decline of intra-annual variance of monthly temperature means. Results also demonstrated that maximum temperatures are more variable compared to minimum temperatures in Uganda. An increasing trend in hot days, hot nights, warm nights and warm spells were also detected. At seven of the stations, annual temperature range and diurnal temperature range trends were found to be negative. The finding that intra-annual and intra-monthly variance is declining suggests that fewer anomalously extreme temperature episodes occur. The gap between maximum and minimum extremes is reducing, which supports the observation that minimum temperatures are on the increase (Nsubuga, 2008).

The present study by Ayugi and Tan in 2019 characterizes recent temporal evolution of surface air temperature over Kenya during 1971–2010. The study utilized Climatic Research Unit reanalysis datasets for monthly minimum, maximum and mean average temperatures. Linear regression is utilized in determining statistical significance of trends, while Sequential Mann–

Kendall rank test is employed in evaluating abrupt changes in temperature during the study period. Spatial analysis of mean temperature during the last four decades reveals evidence of rising temperature on annual and seasonal bases. Positive trends dominate western and central parts of Kenya, whereas insignificant positive trends are observed over northern and eastern parts of the study domain. Similarly, linear trends exhibit rising temperatures at the rate of 0.09 °C/decade, with an abrupt change in annual mean being detected in 1992. Overall, significant increase at 99% confidence level is observed during March–May season, while 95% confidence level is witnessed during October–December season (Ayugi & Tan, 2019).

Over millions of years, changes in the distribution of continents and oceans can alter where and how much sunlight is absorbed or reflected by the surface of the earth. This differential heating influences the direction and strength of wind precipitation patterns. The frequency and size of fires, regions that experience dry seasons are susceptible to fires. In many of these regions, climate change due to global warming is making their dry seasons longer (Mubialiwo et al., 2021).

Data from a number of countries provide evidence of increased intensity of daily precipitation, generally manifested through increased frequency of wet days and an increased proportion of total precipitation occurring during the heaviest events. Over most land areas there has also been an increase in the persistence of wet spells (New et al., 2001).

According to a study conducted by Ye and Ahammed.,(2020), the empirical relationship between annual daily maximum temperature (ADMT) and annual daily maximum rainfall (ADMR) was investigated. The data were collected from four weather stations located in Adelaide, South Australia, from 1988 to 2017. Due to the influence of sea surface temperature on rainfall and temperature, the distance from the weather station to the sea was considered in the selection of weather stations. Two weather stations near the sea and two inland weather stations were selected. Three non-parametric statistical tests (Kruskal–Wallis, Mann–Whitney, and correlation) were applied to perform statistical analysis on the ADMT and ADMR data. It was revealed that the temperature and rainfall in South Australia varies according to weather station location. The distance from the sea to the weather station was found to have limited influence on temperature and rainfall. Meanwhile, with the 0.05 level of significance, the association between ADMT and ADMR near sea stations is not as significant as the association between the two inland weather stations. It is relatively unrealistic to use ADMR to predict ADMT, or vice versa, since their correlation is not statistically significant (Spearman's rank correlation coefficient: −0.106) (Ye & Ahammed, 2020).

According to Nsubuga (2018), the climate of Uganda is tropical in nature and influenced by the Inter-Tropical Convergence Zone (ITCZ), varied relief, geo-location and inland lakes, among other factors. The impacts of severe weather and climate trends and variability have been documented substantially in the past 20-30 years. Most studies indicated a rainfall decline. Daily maximum and minimum temperatures are on the rise, while projections indicate a decrease in rainfall and increase in temperature both in the near and far future. The implication of these changes on society and the economy are discussed herein. Cost of inaction were expected to become huge, given factors like, the growing rate of the population and the slow expanding economy experienced in Uganda. Varied forms of adaptation to the impacts of climate change are being implemented, especially in the agricultural sector and at house hold level, though not systematically (Nsubuga, 2018).

According to a study conducted in South Africa by Monographs, to investigate seasonal trends of surface temperature and rainfall from 1979 to 2007 in southern Africa. It was found out that in recent years, annual rainfall has decreased over the African continent from the equator to 20ºS, as well as in Madagascar. On the other hand, annual mean surface temperature has shown an increasing trend across the whole region, with particularly large rates of increase in Namibia and Angola. The spatial and temporal structures of trends in rainfall and surface temperature have apparent seasonality, with rainfall in Angola, Zambia, and Namibia tending to decrease from December to March, and surface temperature from Namibia to southeastern South Africa tending to increase from July to October (Monographs, 2010).

2.2 Global warming

According to a study conducted by Sara, et al (2021)., Global warming, climate change, and environmental pollution present plants with unique combinations of different abiotic and biotic stresses. Although much is known about how plants acclimate to each of these individual stresses, little is known about how they respond to a combination of many of these stress factors occurring together, namely a multi-factorial stress combination. Recent studies revealed that increasing the number of different co-occurring multi-factorial stress factors causes a severe decline in plant growth and survival, as well as in the micro-biome biodiversity that plants depend upon. This effect should serve as a dire warning to our society and prompt us to decisively act to reduce pollutants, fight global warming, and augment the tolerance of crops to multi-factorial stress combinations Sara et al, (2021).

3 CHAPTER THREE: METHODOLGY

3.1 DATA COLLECTION

The surface air temperature and precipitation for the years 2017 and 2018 were collected from the Trans African Hydro Meteorological Observatory (TAHMO) located at Tororo (00°41’34”N 34° 10’54”E).

Figure 2 TAHMO weather station at the UNMA headquarters in Tororo

The instrument shown on the figure 2 above is the ATMOS41. The ATMOS 41 All-in-One Weather Station is designed for continuous monitoring of environmental variables, including all standard weather measurements. All sensors are integrated into a single, small form-factor unit, requiring minimal installation effort. ATMOS 41 can be used for a variety of applications including determining the surface air temperature and precipitation.

3.1.1 Diurnal trend of surface air temperature and precipitation

The hourly averages of surface air temperature and precipitation were calculated to determine their diurnal trends; bar graphs of surface air temperature, and precipitation against time were separately drawn respectively.

3.1.2 Seasonal trend of surface air temperature and precipitation

The monthly average values of surface air temperature and precipitation were calculated to determine their seasonal variation, bar graphs were drawn respectively.

3.1.3 Correlation between surface air temperature and precipitation

Spearman's rank correlation between surface air temperature and precipitation was calculated using the average monthly values and analyzed using the JASP software.

4 CHAPTER FOUR: RESULTS AND DISCUSSIONS

In this chapter, the results of data as derived from Trans African Hydro Meteorological observatory (TAHMO) for Tororo weather station are presented and interpreted.

4.1 DATA ANALYSIS

4.1.1 Diurnal trend of surface air temperature and precipitation

4.1.1.1 Diurnal trend of surface air temperature

The hourly average values were recorded and the information obtained has been shown in the figure 3 and figure 4.

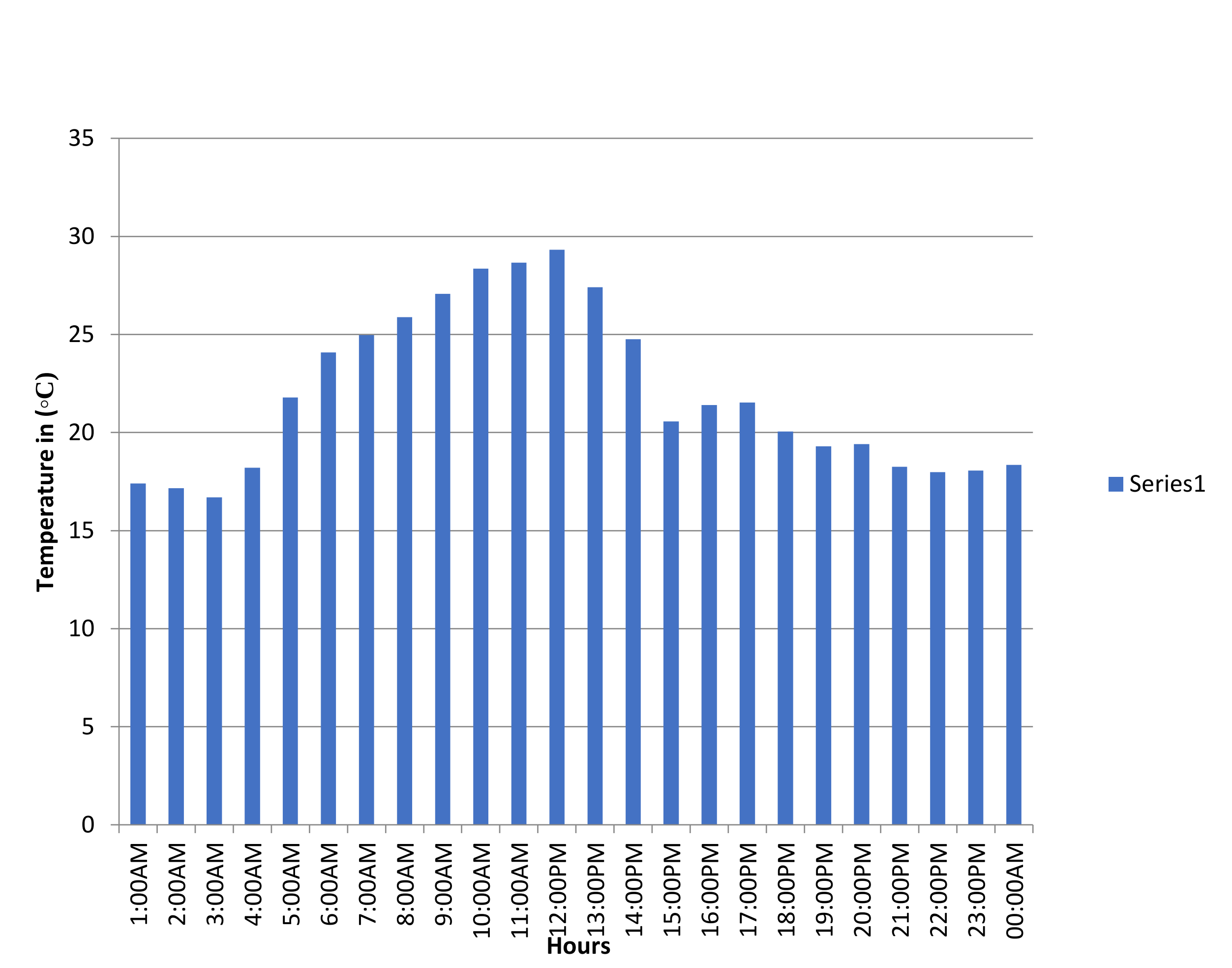

Figure 3 Average hourly values of surface air temperature for 2017

From figure 3 above, there is a normal distribution of surface air temperature characterized by a maximum at 29.3 ˚C around 12:00 pm and a minimum at 17.1 ˚C around 3:00 am. It is observed that night hours have low temperatures compared to daytime. This is attributed to the fact that there is a less cloud cover during daytime which causes more sunlight to reach the earth's surface, hence leading to higher daytime temperatures compared to night hours.

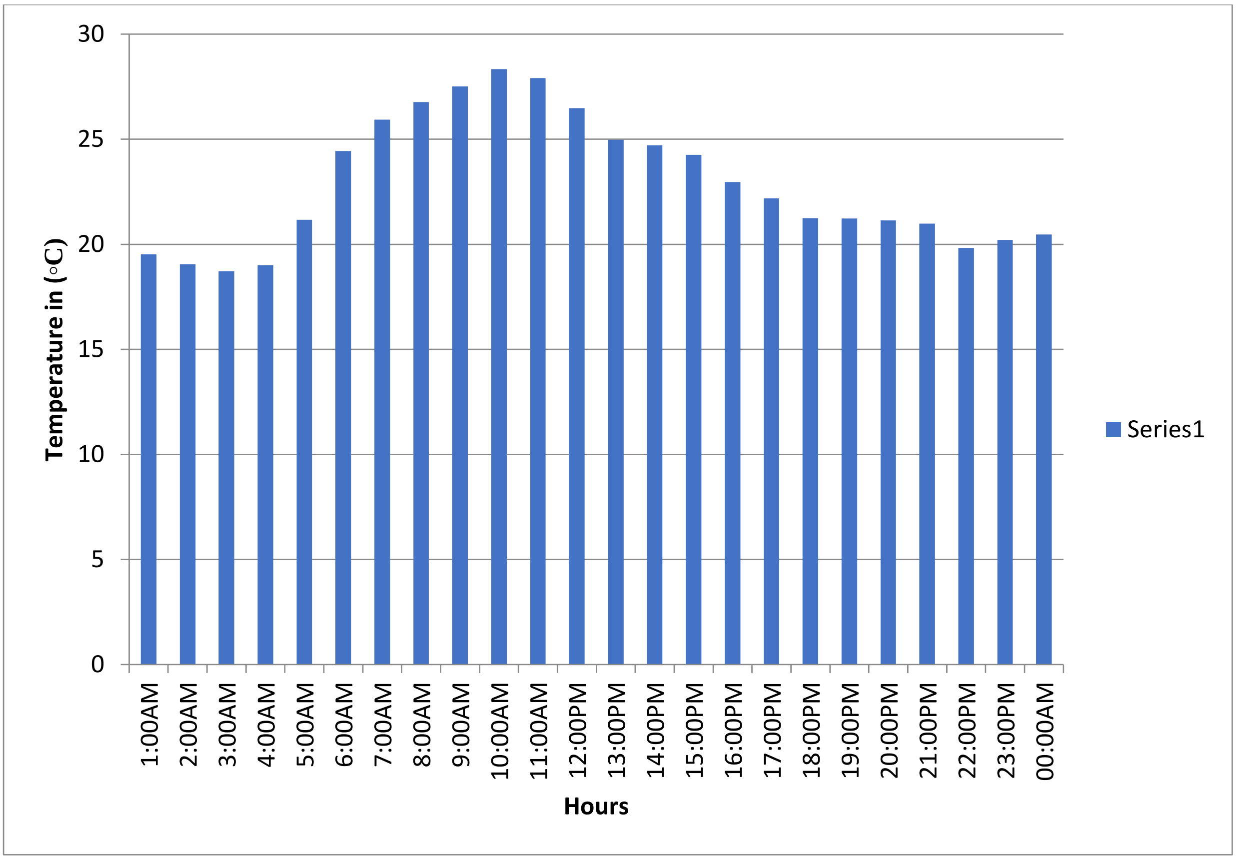

Figure 4 Average hourly temperatures for Tororo, 2018

The figure 4 above shows that there is a normal distribution of surface air temperature characterized by a maximum at 28.4 ˚C around 10:00 am and a minimum at 18.1 ˚C around 3:00 am. It is observed that night hours have low temperatures compared to daytime. This is because of the less cloud cover during daytime which causes more sunlight to reach the earth's surface, hence leading to higher daytime temperatures compared to night hours. The temperatures eventually reduce in the evening hours as the sun reaches the horizon.

4.1.1.2 The diurnal trend of precipitation

The average hourly values of precipitation were recorded and the information obtained was recorded in figure 5 and figure 6 as shown below.

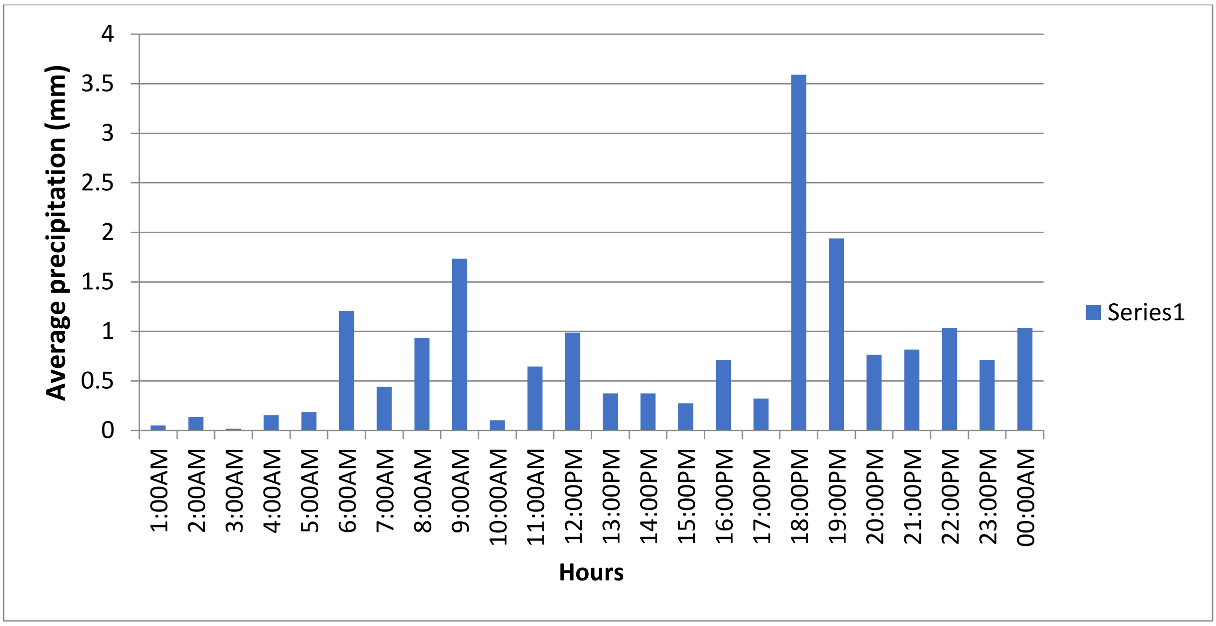

Figure 5 Average hourly precipitation for Tororo, 2017

There is a significant amount of hourly precipitation characterized by a maximum at 3.6 mm and a minimum at 0.02 mm as shown in figure 5 above. Even the direst hours during the day time still receive some amount of rainfall. This can be attributed to the fact that, during day, the sun's energy heats the earth's surface and this causes the air near the ground to rise, creating convection currents. The convection lifts the air upward leading to cloud formation which in turn leads to precipitation.

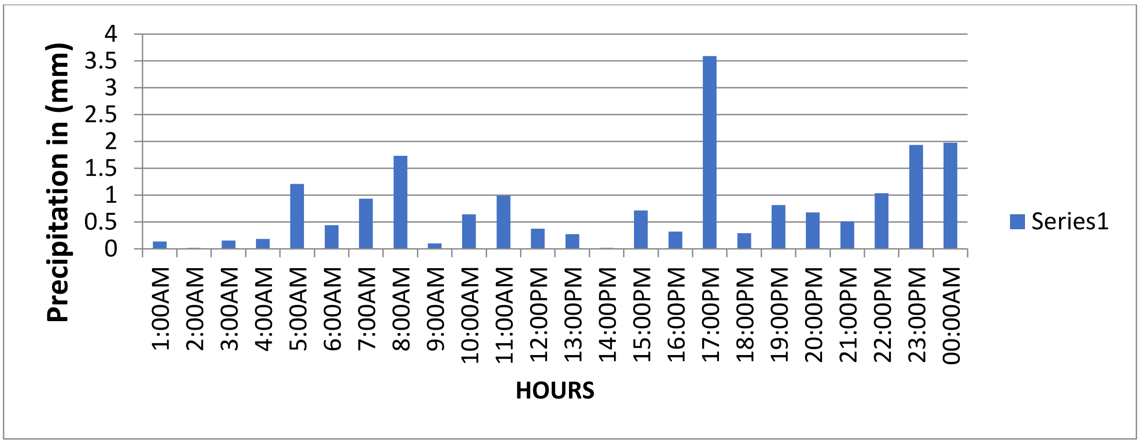

Figure 6. Average hourly precipitation for Tororo, 2018

There was a similar trend of rainfall received in the area for the two consecutive years.

4.1.2 Seasonal trend of surface air temperature and precipitation

4.1.2.1 Seasonal trend of surface air temperature

Average monthly values of surface air temperature were recorded and the information shown in figure 7 and figure 8 was obtained.

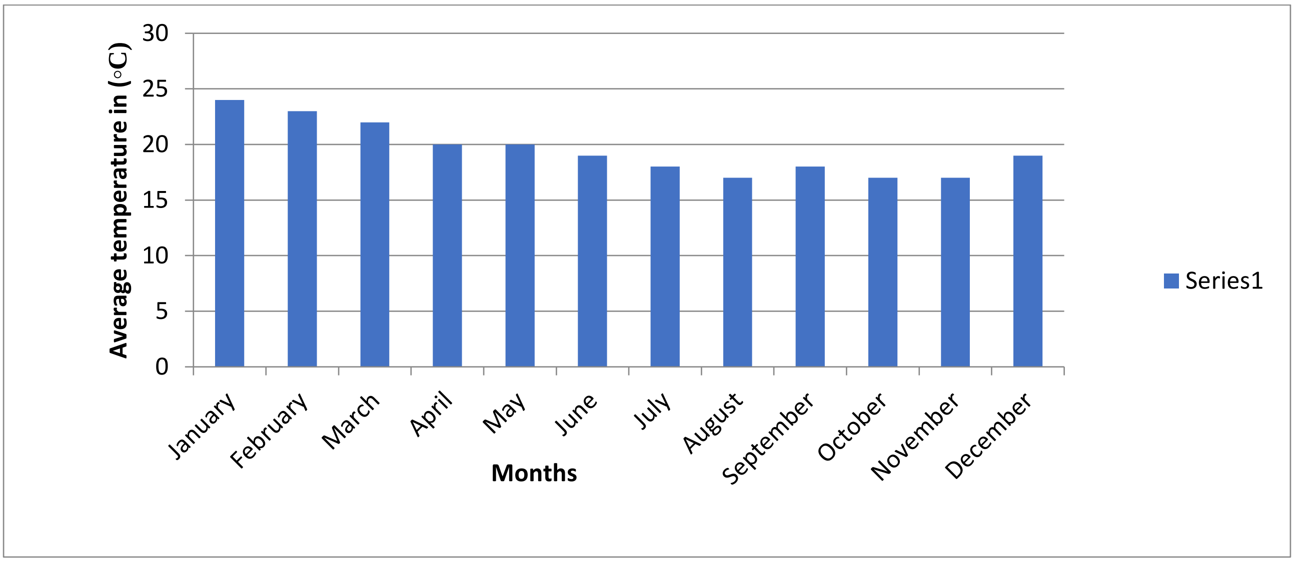

Figure 7 Average monthly temperatures for Tororo, 2017

From figure 7 above, it is observed that Tororo experiences distinct wet and dry seasons due to its location near the equator. January falls within the dry season, characterized by minimal rainfall and fewer clouds. During this time, there is less atmospheric moisture and cloud cover to block the sun's rays. As a result, more sunlight reaches the Earth's surface, leading to higher temperatures. There is an average temperature of 24°C in January which reflects its period of intense solar radiation and reduced cooling from precipitation.

August, September, October, and November are months within Tororo's wet season characterized by a minimum at 17 ◦C. During these months, the region typically experiences higher rainfall amounts and more frequent cloud cover. Clouds act as a natural barrier, reflecting some of the incoming solar radiation back into space and reducing the amount of sunlight that reaches the surface.

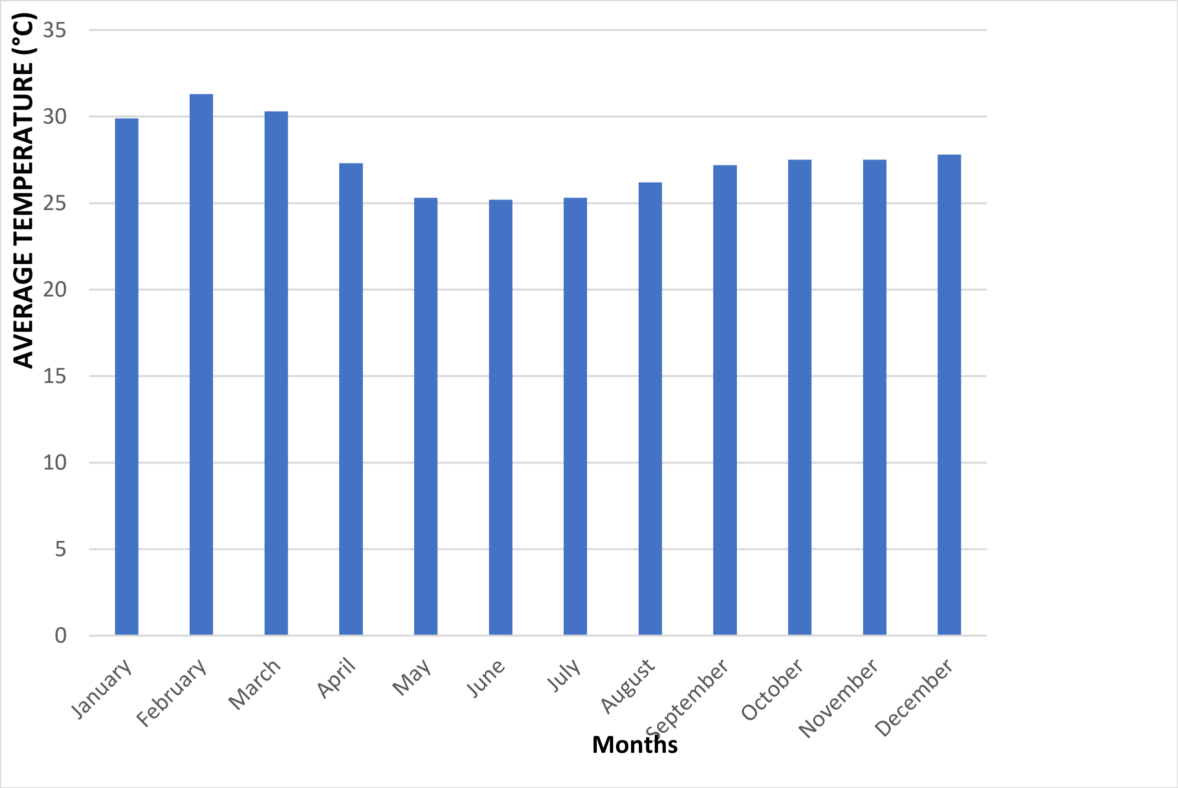

Figure 8 Average monthly temperatures for Tororo, 2018

From figure 8 above, Tororo received hot temperatures with an average value of about 30.6°**C** between January and February while the coolest month was June with an average temperature of 25.2°**C** in 2018**.** The hotter temperatures observed between January and February, and the cooler temperatures in June for 2018 are primarily driven by seasonal shifts related to the position of the ITCZ and the associated patterns of solar radiation, precipitation, and cloud cover.

4.1.2.2 The seasonal trend of precipitation

The average monthly values of precipitation were recorded and the information obtained is represented in figure 9 and figure 10 below.

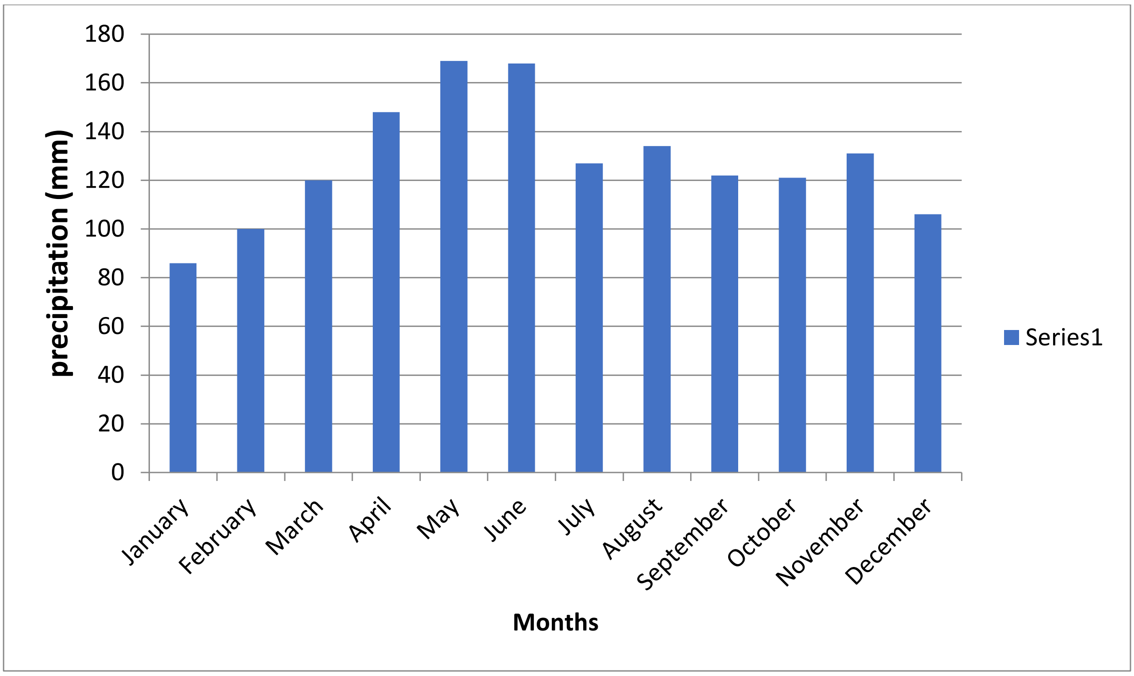

Figure 9 Average monthly precipitation of Tororo, 2017

The graph on figure 9 above shows peaks between May and June with precipitation of about 168.5mm while the lowest amount of precipitation of about 86mm is received in Tororo in January 2017. Tororo, like many equatorial regions, experiences distinct wet and dry seasons. The peak in precipitation between May and June aligns with the onset of the wet season in this area. During these months, the Inter-tropical Convergence Zone (ITCZ) typically moves northward towards the equator, bringing with it increased moisture and rainfall. This period represents a transition from the dry season characterized by lower precipitation to the wet season characterized by higher precipitation. The Inter-tropical Convergence Zone is a belt of low pressure near the equator where trade winds from the northern and southern hemispheres come together. When the ITCZ is positioned over or near Tororo, it brings abundant moisture and rainfall, leading to the observed peak in precipitation during May and June. January falls within the dry season in Tororo. During this time, the ITCZ is typically located farther south, reducing the influx of moisture-laden air and thereby decreasing rainfall amounts. The lower precipitation observed in January 2017 (about 86mm) reflects these dry season conditions when rainfall is minimal.

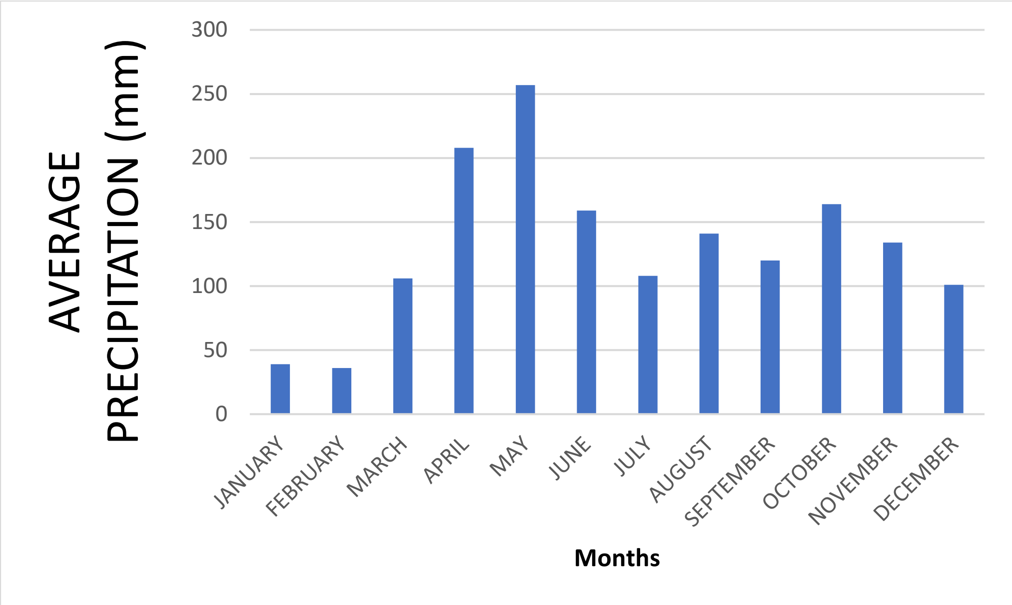

Figure 8 Average monthly Precipitation for Tororo, 2018

From figure 10 above, it is observed that the monthly precipitation patterns have been normally distributed throughout the year showing peaks at the month of May (157mm and 257mm). The normally distributed monthly precipitation patterns observed in Tororo throughout 2018, with peaks in May (157mm and 257mm), are largely attributed to the seasonal movement of the ITCZ and its influence on rainfall dynamics in equatorial regions including Tororo.

However, Tororo's proximity to Lake Victoria makes it receive cool winds and thus low temperatures and a slightly higher amount of precipitation compared to other areas in Uganda.

4.1.3 Correlation between surface air temperature and precipitation

Average monthly values of surface air temperature and precipitation for 2018 were recorded and spearman's rank correlation was calculated using the JASP software. The following results were obtained.

Correlation

Spearman's Correlations

Variable		.
1. precipitation (mm)	N	.
	Spearman's rho	.
	p-value	.

Spearman's Correlations

Variable		precipitation (mm)	surface air temperature °C
1. precipitation (mm)	N	—	
	Spearman's rho	—	
	p-value	—	
	Upper 95% CI	—	
	Lower 95% CI	—	
2. surface air temperature °C	N	12	—
	Spearman's rho	-0.681 *	—
	p-value	0.015	—
	Upper 95% CI	-0.175	—
	Lower 95% CI	-0.902	—

* p < .05, ** p < .01, *** p < .001

4.1.4 Pattern of distribution and strength of the correlation between the two variables

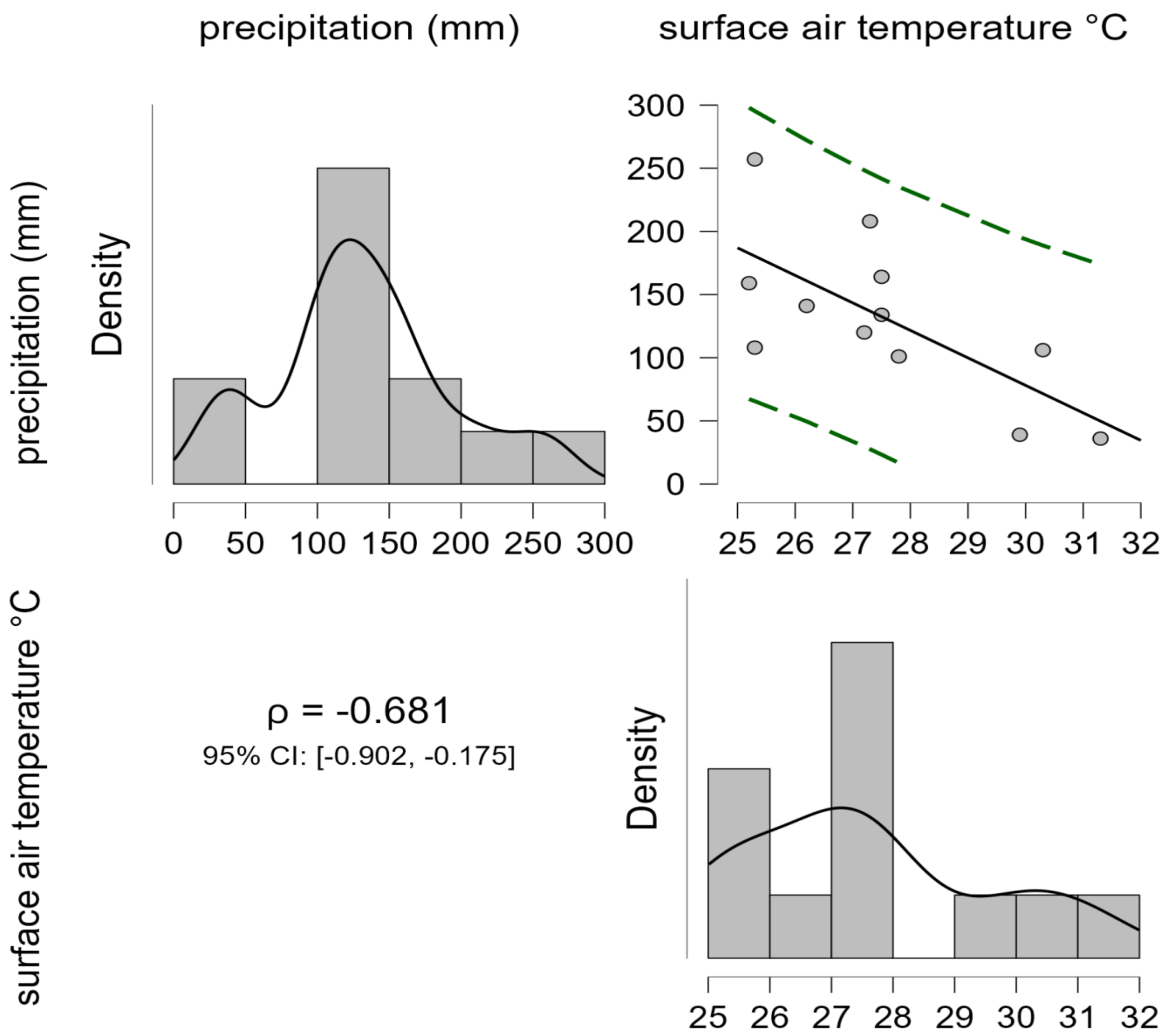

Figure 9 Correlation plot

The result showed that there is a strong negative correlation between surface air temperature and precipitation indicated by the trend line in the scatter graph on figure 11 above. This indicates a robust statistical relationship where higher surface air temperatures are associated with lower precipitation levels, and lower temperatures are associated with higher precipitation levels. This implies that during months or periods when surface air temperatures are higher than usual, there tends to be less precipitation. This could imply drier conditions or reduced rainfall during warmer periods.

Conversely, when temperatures are lower, precipitation tends to be higher. This suggests that colder periods are associated with more precipitation, potentially more rainfall or snowfall.

5 CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

In conclusion, the surface air temperature of Tororo has a clear diurnal trend with a maximum at 29.3 ˚C and a minimum at 17.1 ˚C. similarly the precipitation over Tororo has a diurnal pattern characterized by a maximum at 3.6mm and a minimum at 0.02mm. The seasonal pattern reveals that Tororo has two seasons, the dry season which stretches from around November to March while the wet season extends from April to around October and there is a strong negative correlation between surface air temperature and precipitation with a rank correlation coefficient of -0.681.

5.2 RECOMMENDATION

To further build on this research, I propose the following recommendations.

Research should be carried out on how to utilize the collected data and develop predictive models like linear regression, time series analysis and other modeling techniques, which will enable forecast of future temperature and precipitation trends, and supporting proactive planning and adaptation measures.

A comprehensive research should be conducted to assess how changing temperature-precipitation relationships will affect local ecosystems, biodiversity, and agricultural productivity.

There should be studies that try to investigate the implications of the observed trends on local climate change, including the potential consequences of biodiversity, food security, human health and other climate change related impacts.

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