Statistical Analysis of Climatic Variables and Prediction Outlook in Rwanda

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ABSTRACT: Under the anthropogenic impacts, the climate is changing and has brought about severe and possibly permanent alterations to our planets' geological, biological and ecological systems. Climate change is real and the technosphere is burdening the environment. This study covered 30 years (1980 to 2009) climate data (temperature, precipitation and humidity) to study the climate variability by using ORIGINPRO 8 software for statistical analysis. By presenting the status of climate variables (temperature, precipitation and humidity), this study presents the long term variation which shows decreased trends for precipitation and humidity while the temperature increases. However, the short –term variation showed the monthly variation of temperature to be higher in July to September (21℃ t o22℃). Finally, this study has showed that the precipitation trends in the coming years will gradually decline from nearby 80mm in 2010 to 70 mm in 2030 while the temperature will increase by 0.6 ^{0}C in these two coming decades. Finally, it is predicted that the atmospheric humidity will slightly decrease from 73.3% to 72%.

Key words: climate change, temperature, precipitation, humidity, Rwanda

1 Introduction

Climate is often defined as weather averaged over time or more rigorously as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. These relevant quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state including a statistical description of the climate system {Intergovernmental Panel on Climate Change (IPCC), 2002}. There is a lot of evidence that our climate is changing and severe consequences would occur. It is well known that the average global surface temperature has warmed by 0.8°C in the past century and 0.6°C in the past three decades,in large part because of human activities (IPCC, 2001). A recent report produced by the U.S. National Academy of Sciences confirms that the last few decades of the 20th century were in fact the warmest in the past 400 years (National Research Council of the National Academies, 2006). The Intergovernmental Panel on Climate Change (IPCC) has projected that if greenhouse gas emissions, the leading cause of climate change, continue to rise, the mean global temperatures will increase from 1.4°C to 5.8°C by the end of the 21st century (IPCC, 2001).

Overall, Africa has warmed by 0.7°C over the 20th century and general circulation

models project warming across Africa ranging from 0.2°C per decade (low scenario) to more than 0.5°C per decade (high scenario) (Hulme et al 2001; IPCC, 2001). For comparison, warming through the 20th century was at the rate of about 0.05°C per decade. Precipitation patterns in East Africa are more variable. However, historical records indicate that there has been an increase in rainfall over the last century. Hulme et al (2001) suggests that under intermediate warming scenarios, parts of equatorial East Africa will likely experience 5% to 20% increased rainfall from December to February period and 5%~10% decreased rainfall from June to August by 2050. A statistical analysis has become an indispensable technique for the study of climate changes and short- term climate prediction (Li Maicun; Yao Dirong, 1995). This study is purposely carrying a statistical data analysis of climatic data (precipitation, temperature and humidity) to present its historical and status quo and tries to estimate future climate variability so as to allow decision makers to adapt accordingly

2 Materials and Methods

The study opted to work on available data 30 years {data January 1980 to December 2009 for climate data (temperature, rainfall and relative humidity). The climate data archives were accessed from the National Meteorology office at Kigali since 1980. Meteorological data were only recorded at Kigali Airport station. It is typical in impacts assessment to use a period of years of observed meteorological data to define a "current climate baseline". This set of years can be used to calibrate impact models and to quantify baseline climate impacts. A 30-year period is likely to contain wet, dry, warm, and cool periods and is therefore considered to be sufficiently long to define a region's climate. The 30-year "normal" period as defined by the World Meteorological Organization (WMO) is recommended by the Intergovernmental Panel on Climate Change (IPCC) for use as a baseline period (**Carter et al 1994**). This study analyzed different Annual variabilities and abnormalities/anomalies using ORIGIN PRO. 8.0 software.

3 Results and discussions

Long- term variation of main climatic variables

The long-term variations of the main climatic variables such as temperature, humidity and precipitation have been studied. The main observation is that these aforementioned climatic variables change and hence it proved that climate is changing. The trends of the long term variation of the major climate variables are presented in Figure 1. Both precipitation and humidity are showing a decreasing tendency while temperature increases. The slope coefficients indicate that precipitation and humidity coefficients are negative (-0.415 and -0.067 respectively) while for the temperature, it is a positive value which equals to 0.03.

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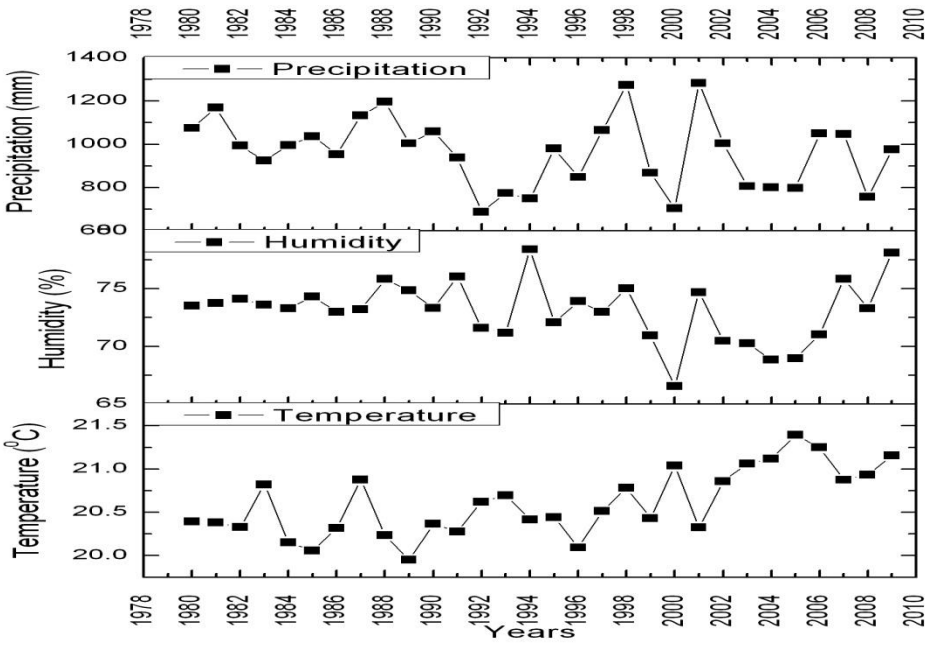

Figure 1 Annual mean variations of precipitation, temperature and humidity (1980~2009)

t is also clear that the temperature is rising notably from the year 2002. Also the year 2000 was less humid than the others. Again, precipitation has decreased as clearly remarkable in the period 1991 to 1994 and from 2003 to 2005.

Short- term variation of main climatic variables

This study has examined the trend in short term variations of the precipitation, temperature and humidity where monthly variations have been analyzed and Figure 2 gives clear trend in each climatic variable presented

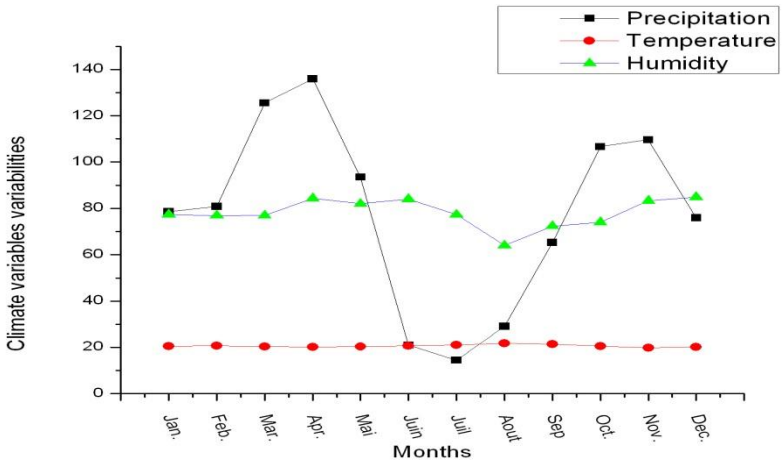

Figure 2 Mean monthly variation of climatic variables: Precipitation, temperature and humidity (period 1980~2009)

Figure 2 above shows that the temperature varies from 19.85℃ to 22℃. The hottest period is from July up to September where the mean temperature lies between 21℃ to 22℃. Humidity keeps changing from 67% to 78% and the hot the period, the less

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humidity becomes and of with little precipitation. The figure 2 shows that there are two rainy seasons during February to May and the other one in October to December. Also two sunny seasons are remarkable where the period of June to August is characterized with little and in most cases no precipitation.

Inter-annual variability and abnormalities of climatic variables

The abnormality (anomaly) is the state of something deviating from the normal or differing from the typical such as an aberration. Anomalies are obtained by subtracting the long-term means respectively for temperature, precipitation and humidity data from observed data. Anomaly is then the value above and below the long-term mean.

Standardized anomalies of total annual rainfalls, temperature and humidity have been analyzed. Therefore, pluviometric excesses and deficits, higher and lower temperatures and humidity have been considered for values of standardized anomalies, where the differences between observations and their averages are more than standard deviation (SD) or inferior to the negative value of standard deviation (-SD) (Figure 3).

Finally, Table 1 shows the descriptive statistics which have been considered when performing the aforementioned tasks.

Table 1 Descriptive statistics of precipitation, temperature and humidity in the study area (1980-2009)

	N	Minimum	Maximum	Mean	Std. Deviation
Precipitation(mm)	30	57.30	106.90	81.4673	13.19694
Temperature (^{0}C)	30	19.95	21.39	20.6050	0.38674
Humidity (%)	30	66.55	78.40	73.1040	2.62703
Valid N (listwise)	30				

The above table shows that the mean monthly values for precipitation, temperature and humidity all considered for 30 years from 1980 to 2009 are respectively 81.47 mm; 20.6℃ and 73.1% while the standard deviations are 13.2; 0.38 and 2.62 for the precipitation, temperature and humidity respectively.

Inter-annual variability and abnormalities of precipitation

The inter-annual variability and abnormalities of precipitation have been analyzed and presented in Figure 3 where excesses and deficits of precipitation correspond to the values above and below the standard deviation dotted lines. The analysis of rainfall variability for the period from 1980 to 2009 indicates that the period of 1992 up to 2008 was the driest since 1980. In fact, the study area was marked by pluviometric deficits during five years (1992, 1993, 2000, 2003, 2004, 2005 and 2008) out of which two were very remarkable (1992 and 2000). The pluviometric excesses were outstanding in the years 1981, 1988, 1998 and 2001.

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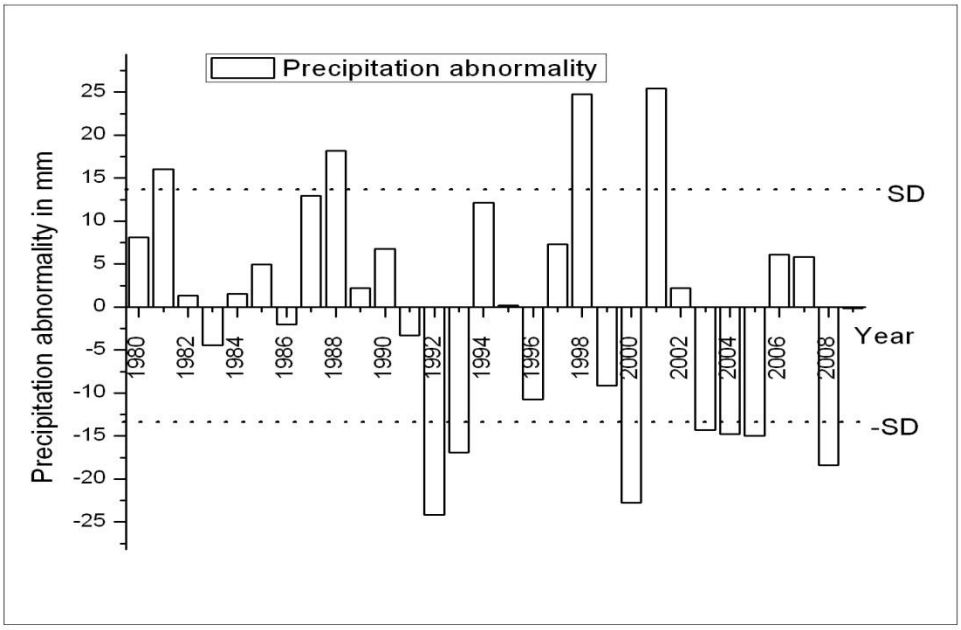

Figure 3 Trends in precipitation anomalies from 1980~2009

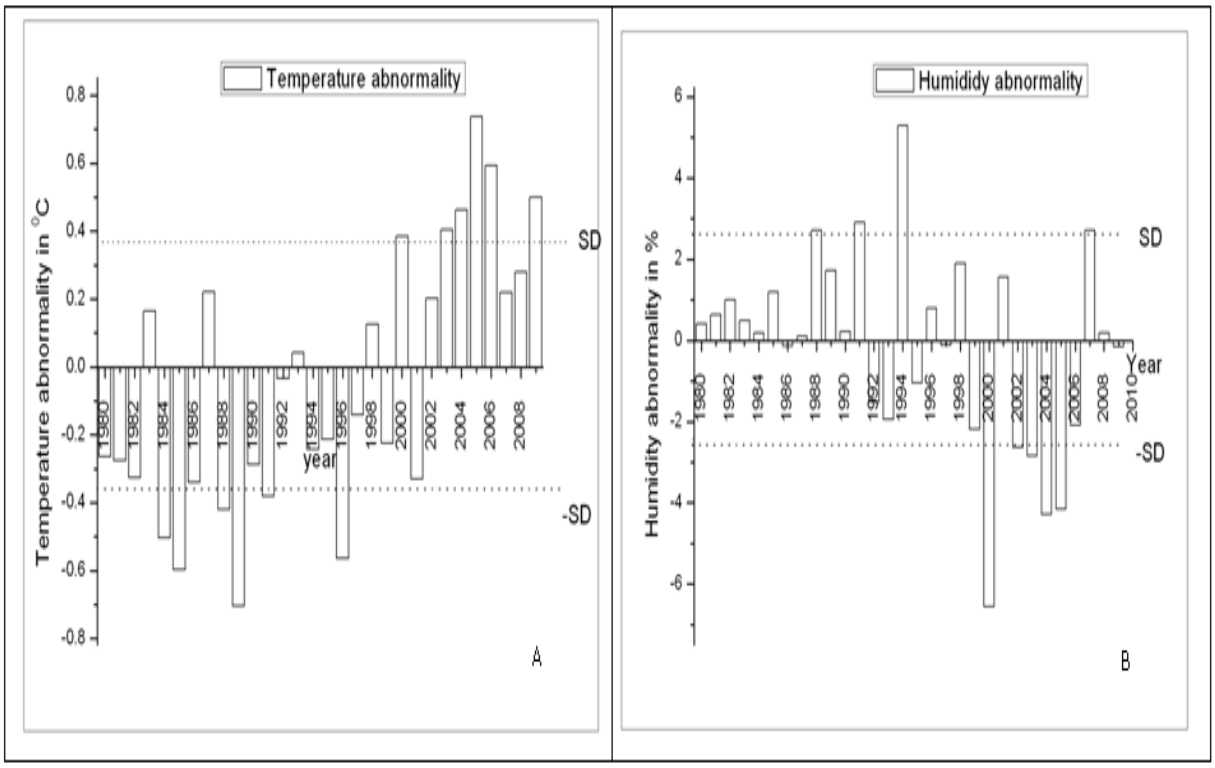

Figure 4 Trends in temperature and humidity anomalies in (A) and (B) respectively from 1980~2009

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Based on Ministry of Infrastructure, Rwanda (MININFRA, 2004), the influence of El Nino/Southern Oscillation (ENSO) on seasonal rainfalls has played a big role as remarked in the following statements:

✓ El Nino years were characterized by a pluviometry which tends to be excessive. However, some years of El Nino registered pluviometric deficits. These years are also associated to the lateness of the start of rainy seasons and some years are characterized by significant frequency of short droughts (dry spells)".

✓ "During rainy seasons, the years, which immediately followed the El Nino phenomenon, registered deficitory rainfalls marked by a significant frequency of drought short periods".

Inter-annual variability and abnormalities of temperature and humidity

The variability and abnormalities of temperature and humidity in the period of 1980 to 2009 has been analyzed and presented in Figure 4.

Figure 4 (A) shows that the variability of air temperature was marked by the increase of temperature from 2000 and higher values were attained in 2000, 2003, 2004, 2005, and 2009 and the year 2005 being the hottest one. However, the lower temperatures were observed before the year 2000 where the lowest temperature was in year of 1989.

Figure 4 (B) shows that the higher the temperature the lower the values of humidity and hence lowest values of humidity were noticed from the year 2000.

Climate variables prediction from 2010-2030

Precipitation

a) As observed from Figure 5, the precipitation trends i are showing gradual declining trends from almost 80 mm in 2010 to 70 mm in 2030.

This projection was performed using the equation derived from the used software and available data, y = -0.4156x + 910.44 where it expected to change with time x, year

Temperature

Temperature is the physical property of matter that quantitatively expresses the common notions of hot and cold.

Figure 6 presents the temperature trends as expected to occur in two coming decades

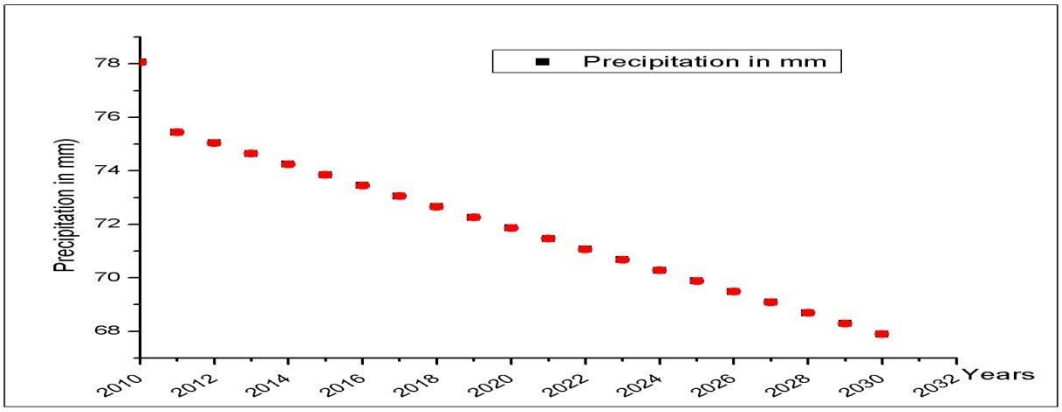

Figure 5 Mean monthly estimated precipitation projections from 2010 -2030

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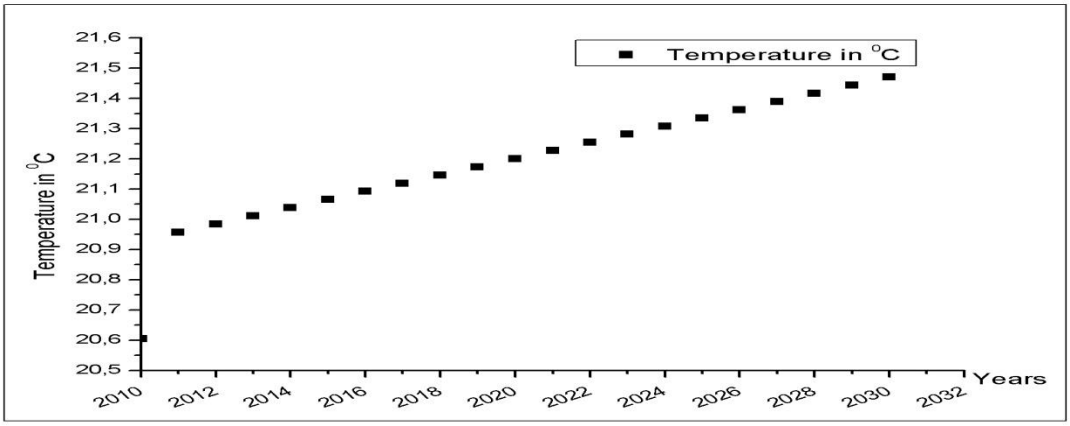

Figure 6 estimated projections in Temperatures from 2010 – 2030

Figure 6 shows how the temperature is gradually increasing. The graph shows that temperature will increase by 0.6^0C in these 2 coming decades. This is somehow similar to the prediction of Hulme et al (2001) and IPCC (2001), where according to them, the projected warming for Africa ranges from 0.2°C per decade (low scenario) to more than 0.5°C per decade (high scenario).

Atmospheric humidity

Atmospheric humidity is the amount of water vapor carried in the air.

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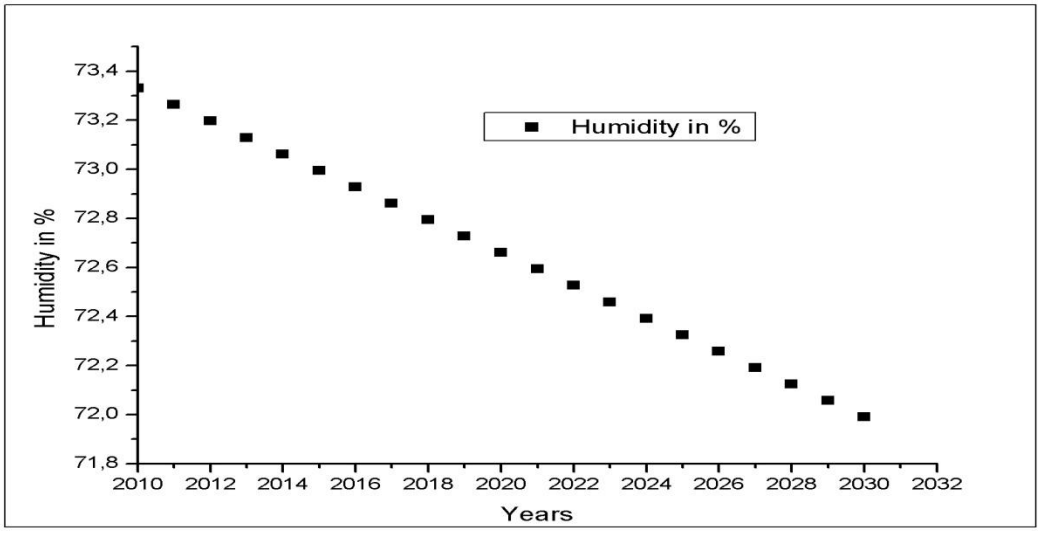

Figure 7 Estimated projections in Atmospheric humidity from 2010 - 2030

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Figure 7 shows the decrease in atmospheric humidity from 73.3% to 72%. This may be associated to the increase in temperature in the coming days as discussed earlier.

4 Conclusion

Climate change is real and the technosphere is burdening the environment. A lot of evidences prove that climate is changing and severe consequences occur and its effects are being felt and human activities are a principle cause. This study presented the status of climate variables (temperature, precipitation and humidity) and their long term variation showed a decreased trends for precipitation and humidity while the temperature increases.

The short–term variation showed the monthly variation of temperature to be higher in July to September (21℃ to 22℃) while two sunny and two rainy seasons were identified.

The inter-annual variability and abnormalities have been studied to identify the deficit in precipitation as well as excess of pluviometric values and higher temperatures. It has been observed that the driest period was 1992 to 2000 since 1980 and several years were marked by a pluviometric deficit due to El-Nino. The temperature increased from the year 2000 and the higher the temperature the lower the humidity.

The study has shown that precipitation trends in the coming years are showing gradual declining trends from nearby 80 mm in 2010 to 70 mm in 2030 while the temperature will increase by 0.6 ^{0}C in these two coming decades. Finally, it is predicted that the atmospheric humidity will slightly decrease from 73.3% to 72%.

Based on the above, climate is changing and decisions makers in all domains should consider this scenario.

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