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Climate change and effect on frequency curves of precipitation and radiation: An statistical study in equatorial area, Cameroon

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A B S T R A C T

Human being intensify global warming as we are the reason for higher temperature level and lower precipitation rate. Phenomena such as flood and drought are just few consequences of climate change. This sudden change affects health and wellbeing of mankind. In this paper, the analysis of outdoor climate and forecast on precipitation and radiation intensity has been carried out in two regions of Cameroon. General Circulation Model (INCM3) and scenario A2 were used. The results show that as air temperature and radiation increase, precipitation quantity decreases. There is a great concentration of precipitation for the cooling period of year (rainy season) and the decrease of annual precipitation by the amount of 15.23mm for future period. The radiation intensity rises faster in the warm region, Douala than the wet region, Yaounde. Meanwhile, in wet region, precipitation's concentration decreases faster than that of warm region. Moreover, the analysis of all data show that radiation increases 5% every year in wet and hot climate, Douala.

Keywords: c*limate change, precipitation, radiation, scenario, equatorial area*

1. Introduction

The global awareness about climate change is now a fact some. Long confined to the scientific community, at ecological progress, it has emerged since few years at government level with recently the signing of many protocols. The main effect of climate change may be the increase of earth's temperature which is called global warming. Increasing global surface temperatures are very likely to lead changing in precipitation, sunshine and atmospheric moisture. A warmer atmosphere can hold more moisture, and globally water vapour increases of 7% for every degree centigrade of warming. How this will translate into changes in global precipitation is less clear cut but the total volume of precipitation is likely to increase of 1-2% per degree of warming. The different emission scenarios provided by the Intergovernmental Panel on Climate Change (IPCC) show that the impacts of climate change will touch all sectors and more particularly natural resources (Nematchouaet al., 2014). This will make the vulnerable populations in areas where the adjustment will be made as it takes. The consequences of this phenomenon are stayed some positive times in some countries of Asia and America, but in the majority of cases, they are negative. There's evidence to show that regions that are already wet are likely to get wetter, but details on how much wetter and what impacts there will be on a local scale are more difficult to ascertain (Ellen, 2008). The dry regions of the subtropics are likely to get drier and will shift towards the poles. Aged peoples are the most vulnerable at effects of climate change. Changes in rain and snowfall can result in a number of impacts for water resource managers that depend on snowpack for water supply, including increases in flooding, decreases in summer water supply, and changes to both groundwater and surface water quality (Ellen, 2008). Precipitation is much more difficult to predict than temperature but there are some statements that scientists can make with confidence about the future. Assessing the relevant vulnerability requires a thorough knowledge about the climatic conditions of each region in the future (Roshan et al., 2013). Dore (2005), in his study was obtained as result a decreasing trend in annual precipitation for the last period. Meanwhile according to work of

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(Chaudhari et al., 1994) in Pakistan, several stations was shown a tendency toward increasing precipitation during monsoon season. Many other works can explain climate effect on precipitation (Zarghami et al., 2001; Zhi, 2011; Zhao, 2012; Xu, 2012). These last centuries, a decrease of precipitation has been observed in some regions of Cameroon and also in many Africa's countries. In this work, was studied thank to fourteen GCM model associated to three scenarios, the effect of climate change on frequency curves of precipitation and sunshine.

2. Materials and methods

2.1 Study Case

The study area is constituted of five climatic zones. This study was carried out in warm and wet zone in sub-Saharan Africa (Cameroon). Cameroon stretches in length from 2 to 13 degree of North latitude, and spreads in large from 9 to 16 degree of East longitude. It covers 475,442 km2 of area and presents various climatic nuances summarizing all bioclimatic of African continent. This diversity is simplified by the distribution of different climatic nuances: in north of 6^{th} parallel, the dry tropical climate dominates; while in the south, equatorial climate becomes more and more humid towards the coastline and Mount Cameroon. Cameroon is divided into three climatic zones, namely, the Sudanese, the Sudano−Sahelian, and the equatorial regions. Cameroon is characterized by an equatorial climate with two main seasons of equal amplitudes: a long rainy season from mid-March to mid-November (8 months) and a short dry season from mid-November to mid-March (4 months). The study was conducted in the equatorial cities of Douala and Yaounde.

Douala is the economic capital of Cameroon, the main business centre and one of the largest cities in the country. It is the most industrialized city in central Africa. It is proven that the industries, the cars, and the buildings emit more than 60% of the total CO2 in the atmosphere. Douala's port is the main place of entry of cars not only in Cameroon, but also in Chad, and in Republic of central Africa (RCA). This city is located on the Atlantic Ocean coast, from 4◦ to 4◦4N of latitude and from 9◦40to 9◦48E of longitude, with an area of nearly 210 km2. Climate in Douala is tropical wet and hot, characterized by temperatures between 18◦and 34◦C, accompanied by heavy precipitation, especially during the rainy season from June to October. The air almost always records 99% relative humidity during the rainy season, and about 80% during the dry season from October to May.

Yaounde is the Cameroon political capital and is located approximately 300 km from the Atlantic coast and enjoys a sub-equatorial climate with four seasons; a large dry season from mid-November to late March, a short rainy season from April to mid-June, a short dry season from mid-June to mid-August and a long rainy season from mid-August to mid-November. Its altitude is between 600 - 800 m. Yaounde city has relatively fresh climate. The maximum temperature is ranged between 30°C and 35°C and the minimum is 15°C. Geographically, it is between 3°52'N latitude and 11°32'E longitude. Its population was about 2.5 million of inhabitants in 2011 due to the early 90s rural exodus which increased its population with a growth rate estimated at 7 % per year. As a consequence of this fast exodus, several suburbs were created at the western and the-north parts of the Yaounde city.

2.2 Climatic data

Outdoor daily data of the last 30 years of temperature (minimum and maximum), precipitation and sunshine was taken in five meteorological stations within the study area. Some outdoor data are given in table 1. The various data are measured from 3 to 10 m in height from the ground and with a frequency of 10–15 min.

Table1. Characteristics of location and observed climatic data for Douala and Yaounde

City	Douala	Yaounde	Total Both types
Latitude (°N)	4.01--4.42	3.52—3.85	-
Longitude (°E)	9.40--9.48	11.32—11.75	-
Altitude(m)	10	600—800	-
Available data (years)	1961--2002	1973—2002	1961--2002
Temperature (°C)			
Maximum	35.7	35.5	35.7
Minimum	17.3	14.7	14.7
Relative humidity (%)			
Maximum	100	98	100
Minimum	49	55	49
Sunshine (Kwh/m^2)			
Maximum	7.34	7.54	7.54
Minimum	0.24	0.33	0.24
Precipitation (mm)			
Mean yearly	3870.2	1530.7	2700.0
Area (Km^2)	210	180	-

In selected weather stations, data like the relative and absolute humidity, wind speed, and evaporation are also available. The mentioned stations are selected because their administrative staff was qualified, measuring devices were reliable and also installed in a place far from any type of hindrance. Measurement errors on the temperature and relative humidity are estimated to be ± 0.1◦C and 1%, respectively.

2.3 Climate change models

In the present research, 14 GCM models and three scenarios have been used (B1, A2, A1B). The most significant input of these models is the rate of emission of greenhouse gases in the future eras. However, a precise final determination is not possible. Accordingly, different emission scenarios with a variety of gas qualities in future have been offered. On the other hand, to define the effect of global warming by means of the rise in global temperature, it was necessary to employ a LARS-WG model. LARS-WG is one of the most well-known meteorological stochastic data-generating models used for generation of the quantities of rainfall, solar radiation, and daily maximum and minimum temperatures in both present and future climates of a meteorological station (Racsko, 1991; Semenov, 2002). The first version of the above-mentioned model was invented as a tool for statistical exponential micro scaling in Budapest (Racsko, 1991). In a LARS-WG model, some complex statistical distributions are used for modeling of meteorological variables. Fourier's series estimates the temperature. Daily maximum and minimum temperatures are simulated as stochastic processes with daily standard deviations and means, depending on dry or wet conditions of the relevant day (Orosa, 2014). In this assessment, Douala's and Yaounde's temperature data in the time intervals of 1975–2000, were chosen as the basic data and temperature changes for the years 1985–2005 were studied based on the proposed scenario, so that the proper model accords with the experimental data of temperature in the proposed years. After testing the best model with Pearson correlation coefficient, the changes in Douala's and Yaounde's temperature components were predicted in the worldwide heating bed for the periods 2010–2035 and 2040–2065. Based upon these changes, the degree day index values were calculated and compared with those in the past and present periods.

3. Results and Discussions

The variation of temperature every year in different regions is given in following figure.

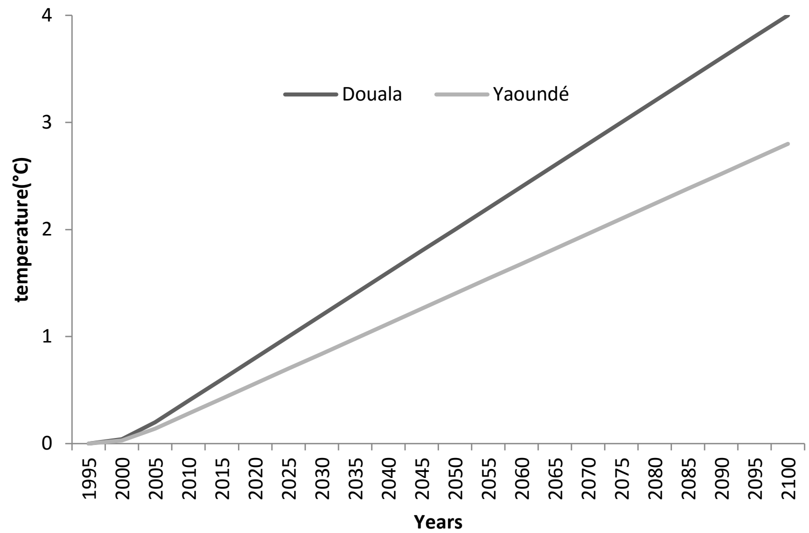

Figure 1. Annual temperature increment for Douala and Yaounde

In figure 1, it is seen that the temperature varies more in hot region (Douala) than in humid region(Yaounde). The following equations have been established after analysis of the evolution of different temperatures:

$\Delta t = 0.040 \cdot \theta$	in Douala	(1)
$\Delta t = 0.028 \cdot \theta$	in Yaoundé	(2)

where Δt is the mean annual temperature increment (°C) and θ is the time (years).

So, during the next 50 years, the outdoor air temperature of Douala will can to vary of (2°C) and Yaounde of (1.4°C). According to IPCC (at the time of COP21), a variation of more than 2°C will to observe in Africa if nothing is doing now for struggle against climate change.

Figure 2 showed the comparison of the observed and estimated annual mean precipitation and radiation. The average and standard deviation values of both observed and estimated data for the period 1985–2005 are shown in Fig.2, for Douala (fig.2a, 2c) and Yaounde (fig.2b, 2d). In (figure1a), from January to December for mean air temperature between 23.9°C to 28.1°C, mean of observation data, varied from 23.52mm to 700.29mm with standard deviation ($15.53<SD<248.97$), while the mean of generated data varied from 32.66mm to 656.70 mm ($30.11<SD<185.48$). We can observe that only in (April and May), the mean of generated data (263.64 and 283.4mm) is the highest compare to the mean of observation data (262.52 and 273.82mm). Precipitation's quantity is superior to 450mm only from July to September during this period. Meanwhile, in figure2b, mean of observation data, varied from 48.05mm to 106.85mm with standard deviation ($24.73<SD<46.79$), the mean of generated data was between 43.76mm and 103.35mm ($18.83<SD<42.28$). The rain is higher between April and June, but too, from August to October. In (figure 2c), the mean of observation data of radiation was between 3.05 and 5.40Kwh/m^2, with($0.19<SD<0.40$), while the mean of generated data was from 3.19 to 5.37KWh/m^2, with ($SD<0.29$). August is month the least sunny and January the sunniest. Meanwhile, in Yaounde (see figure 2d), the mean of observation data varied from 3.74 to 5.87 KWh/m^2 with standard deviation ($0.33<SD<2.21$). While, the mean of generated data varied from 2.88 to 5.65 Kwh/m^2. The radiation is the highest in December (5.65 Kwh/m^2) and the weakest in October (2.88 Kwh/m^2).

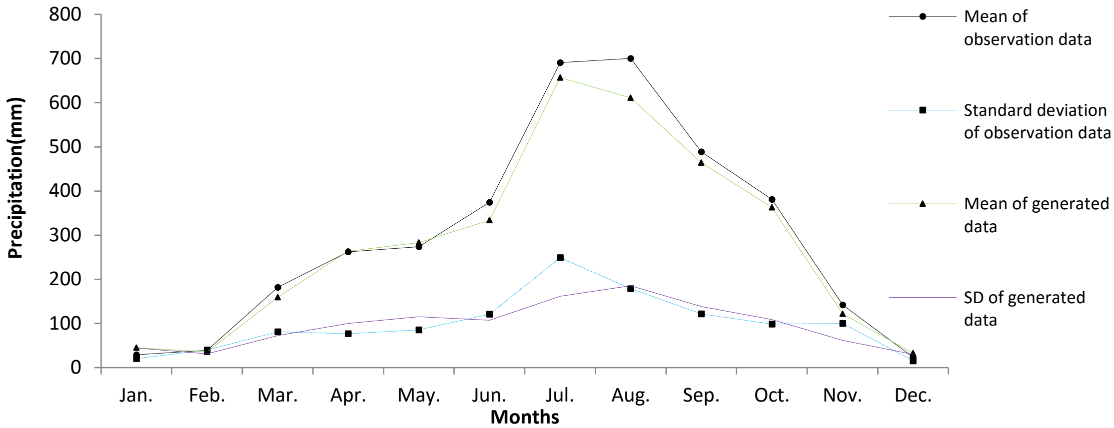

Figure 2a. Comparison of the observed and estimated annual mean precipitation in Douala

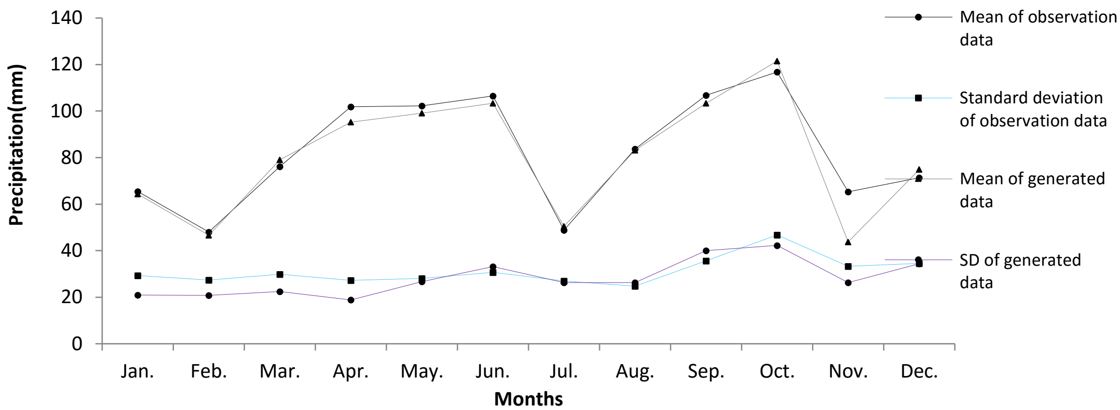

Figure 2b. Comparison of the observed and estimated annual mean precipitation in Yaounde

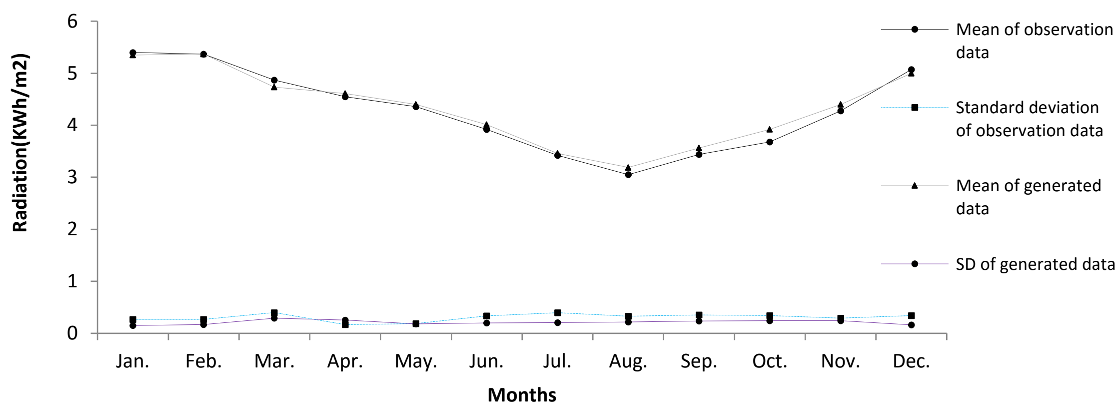

Figure 2c. Comparison of the observed and estimated annual mean Radiation in Douala

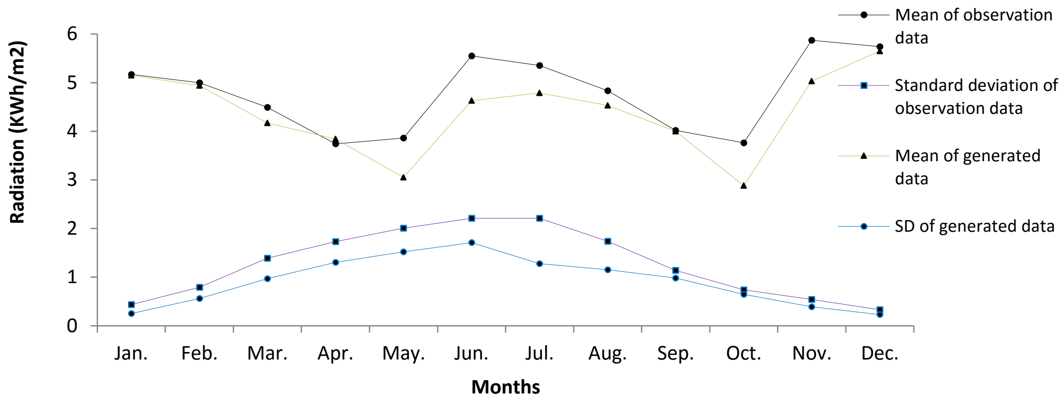

Figure 2d. Comparison of the observed and estimated annual mean Radiation in Yaounde

The above figures also show a fast increase of radiation in tropical region (Douala) compare to equatorial climate (Yaoundé). Precipitation decreases rapidly in tropical region.

Figure 3 shows simulated precipitation with the observational data in Douala. We can observe that the precipitation varied according to the periods. In the past (1975-2000), the mean of monthly precipitation was 291.98mm for a total of 3503.81mm. Moreover, in 2010-2035, the mean of monthly precipitation will be 285.65mm, either a decrease of 6.31mm, compare to the first period. The total precipitation during this period shall be 3428.1mm. In contrast, between 2040 and 2065, the mean of monthly precipitation will be 278.15mm for a total of 3337.82mm. A decrease of 5% of precipitation was obtained between periods (1975-2000) and (2040-2065). These results confirm the different conclusions found by (Dore, 2005). As shown in figure 4, the simulated precipitation with the observational data in Yaounde, precipitation is no wide compare to Douala. The averages were 127.2mm, 124.1 and 118.9mm, on the periods: (1975-2000), (2010-2035) and (2040 -2065), respectively. That means less rain as the time goes by.

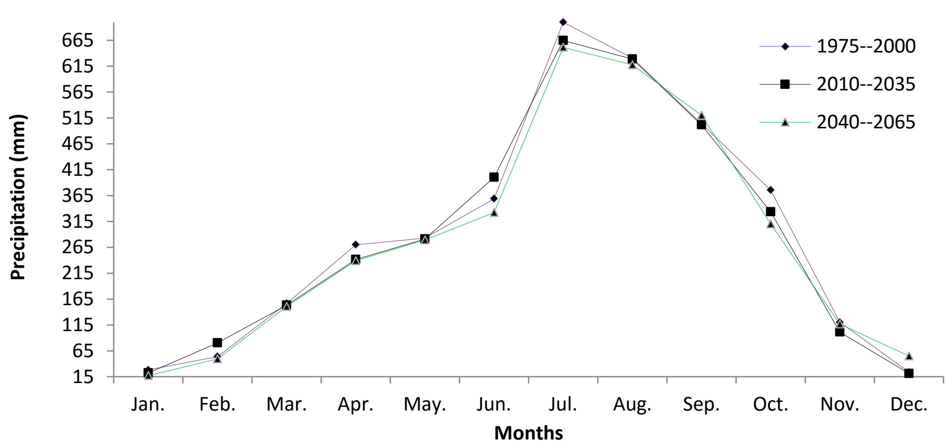

Figure 3. Simulation precipitation with the observational data in Douala

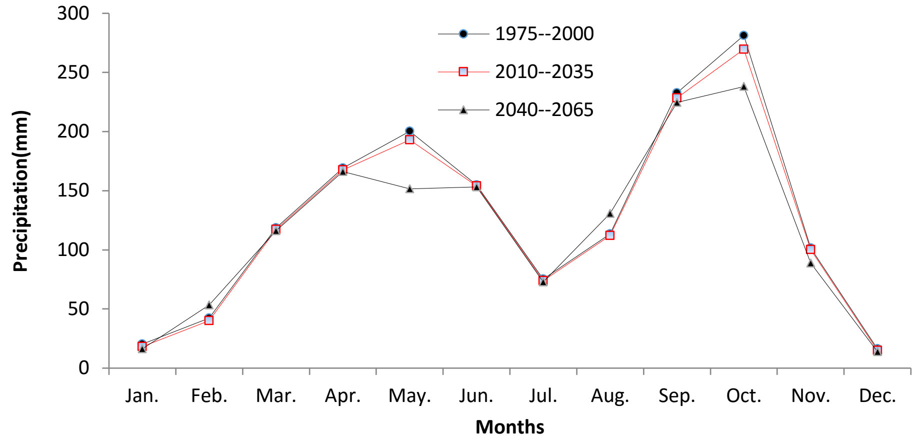

Figure 4. Simulation precipitation with the observational data in Yaounde

In figure 5 between 2040 and 2065, the radiation should be from 3.8 to 6.8 Kwh/m^2 (standard deviation, SD=0.93), with 4.72 Kwh/m^2, as average during all this period. Moreover, between 2010 and 2035, radiation varied from 3.4 to 6.4 Kwh/m^2 (SD=0.47), with an average of 4.41 Kwh/m^2, Meanwhile, between 1985 and 2000, radiation varied from 3.2 to 5.3 Kwh/m^2 (SD=0.67). An analysis of all the data showed that radiation increases of 5% every year in wet and hot climate(Douala). In equatorial climate (Yaounde), see figure6, radiation is also very important, particularly in dry season from November to March. Between 1975 and 2000, sunshine varied from 4.2 to 5.6 Kwh/m^2 (SD=0.51), with average of 4.71 Kwh/m^2. On the other hand, 5.3 Kwh/m^2 will be the average for the period (2010-2035), with sunshine between 4.1 and 6.1 Kwh/m^2 (SD=0.56). Finally, between 2040 and 2065, sunshine will be between 5.2 and 7.1 Kwh/m^2 (SD=0.43).

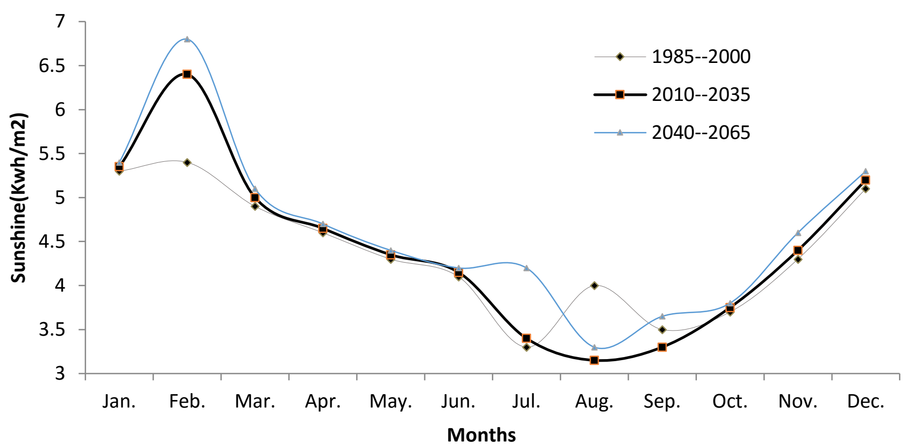

Figure 5. Simulation radiation with the observational data in Douala

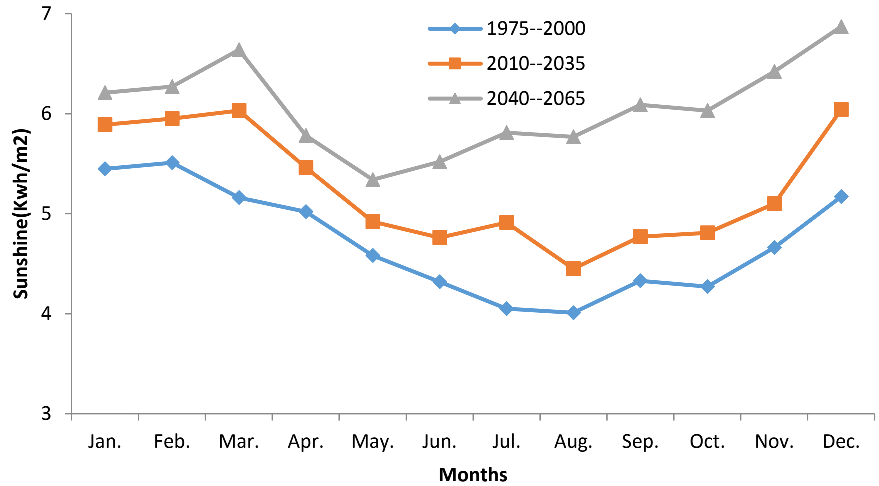

Figure 6. Simulation Radiation with the observational data in Yaounde

The figures (7, 8 and 9) showed the frequency of precipitation during three periods in different cities. Between 1975 and 2000, the months with the most rain are July (19.97%), August (17.99%), September (14.37%) and October (10.35%) in Douala, meanwhile, in Yaounde, intensity of rain is the highest on October (18.54%). It also rains abundantly in September (15.31%), May (12.78%) and April (11.12%). The months the least rainy are December and January with an average of 0.74% and 1.2% respectively in Douala and Yaounde. Moreover, between 2010 and 2035, the month with the most rain staying July and October for Douala and Yaounde, but with a decrease of 3% and 1% compare to last period (1975-2000). Between 2040 and 2065, July (19.37%) and August (18.1%) will be the rainiest months in Douala.

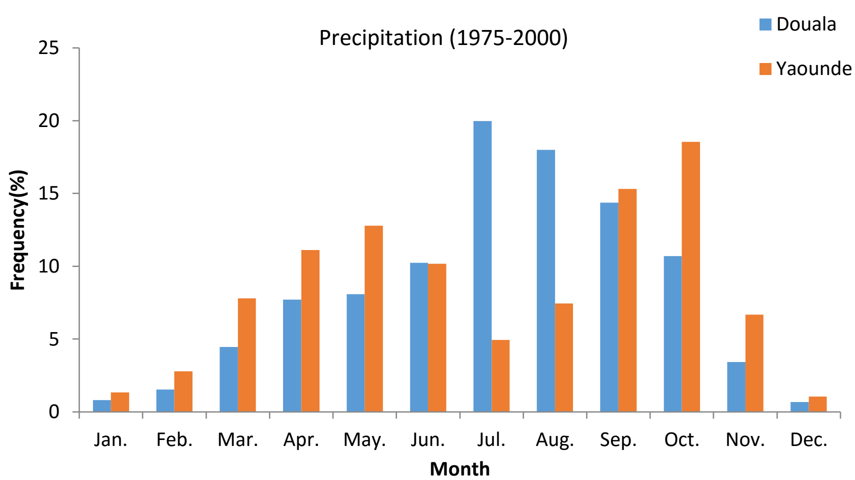

Figure 7. Comparison of percentage of monthly precipitation in two regions for observational (1975–2000) period

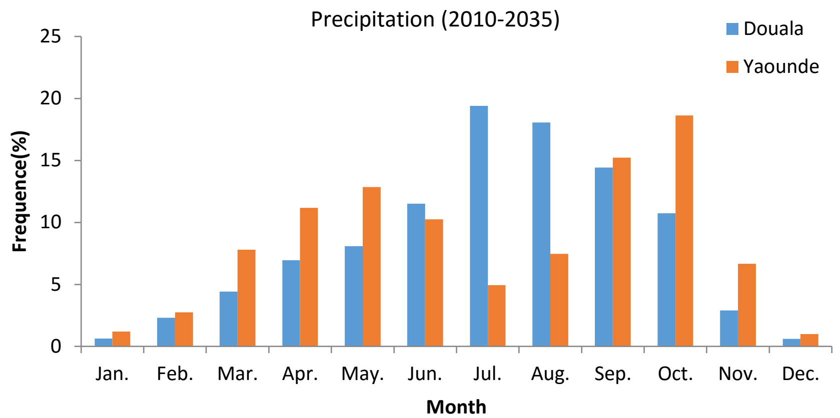

Figure 8. Comparison of the frequency percentage of monthly precipitation in two regions for simulated (2010–2035) period

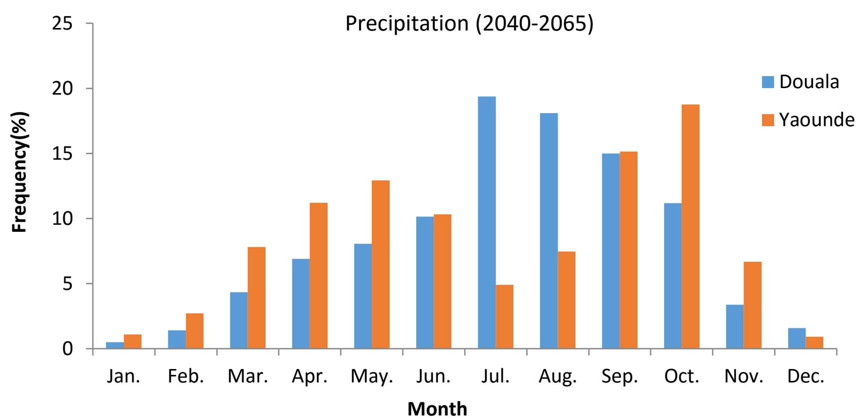

Figure 9. Comparison of the frequency percentage of monthly precipitation in two regions for simulated (2040–2065) period

The rate shall be stay higher on October. Figures 10, 11 and 12 show frequency of radiation on three periods studied. January, February and December were and will be still the months the hottest in the two regions (Roshan et al., 2014), have rather found an increase of annual precipitation by the amount of 20.62mm for future period.

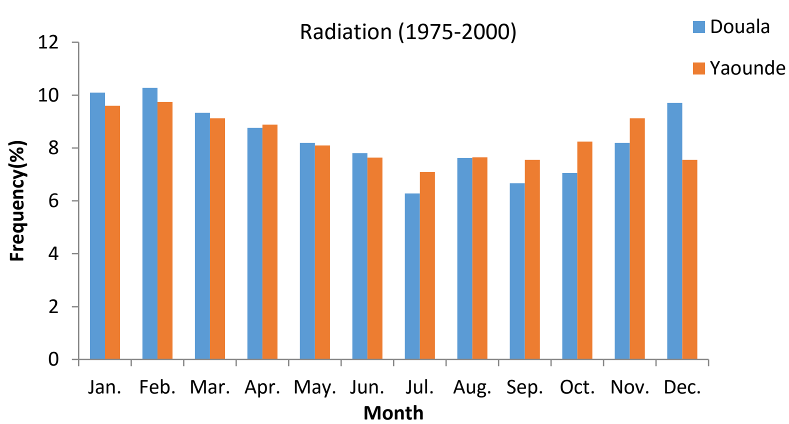

Figure 10. Comparison of percentage of monthly sunshine in two regions for observational (1975–2000) period

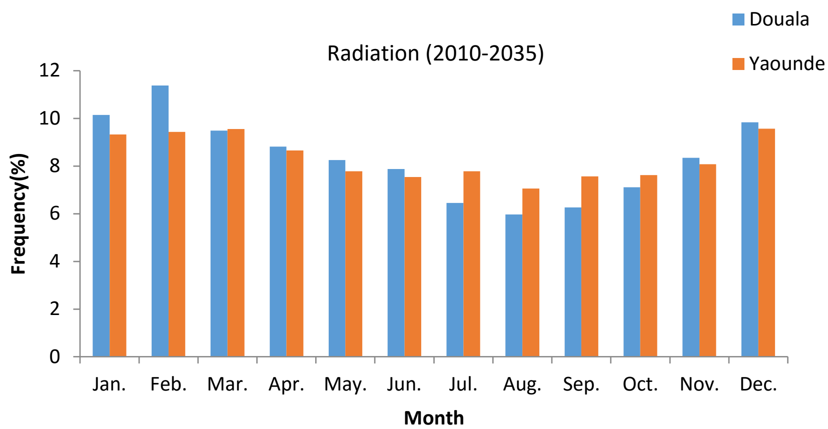

Figure 11. Comparison of the frequency percentage of monthly sunshine in two regions for simulated (2010–2035) period

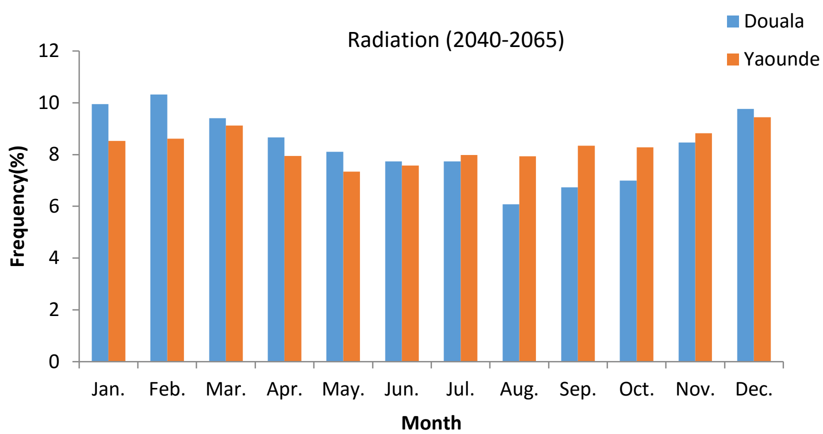

Figure 12. Comparison of the frequency percentage of monthly sunshine in two regions for simulated (2040–2065) period

This result shows that the consequences of climate change vary according to regions and their geographic situation. In (2040-2060) period, total discomfort will reign in the dry and rainy season, especially between November to February. Precipitation moved inversely to air temperature and radiation. The decrease of precipitation and increasing of radiation can to have many consequences on health of citizens and farming.

4. Conclusion

This research investigates and predicts the intensity of precipitation and sunshine of cities in Cameroon. The underlying data (the minimum, maximum temperature minimal, precipitation and sunshine) is collected from five weather stations in Cameron for past 30 years. The results were analyzed, interpreted, and integrated. It is concluded that in the past (1975-2000), the mean of monthly precipitation was 291.98mm. Moreover, between 2010 and 2035, the mean monthly precipitation will be 285.65mm, either a decrease of 6.31mm, compared to the first period. In addition, between 2040 and 2065, the mean of monthly precipitation will be 278.15mm for a total of 3337.82mm, therefore precipitation will decrease in the future in both regions. It is noteworthy that the total annual precipitation increase within the area is more evident for the humid period of the year (rainy season). Furthermore, August is the least sunny and January is the sunniest in warm region. Also it is vital not to forget that decrease in precipitation causes many diseases and illnesses for men, mammals, and other animals.

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