

Original Article

Impact of Climate Change on Outdoor Thermal Comfort and Health in Tropical Wet and Hot Zone (Douala), Cameroon

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Abstract

Background and purpose: Climate change has an important role on the health and productivity of the occupant of the building. The objective of this study is to estimate the effects of climate change on thermal comfort in hot and wet areas, as in the case of the city of Douala.

Materials and Methods: The general circulation model (CSMK3 Model, Scenario B1) was adopted for this purpose. Outdoor daily parameters of temperature, sunshine, and precipitation of last 40 years were analyzed and allowed us to make forecast on this area. The past (1990-2000), the present (2001-2011), and the future (2012-2022) were considered in the hypotheses.

Results: It has been found that Douala like some large cities of Africa is already and will be severely hit of advantage by climate change if anything is not going to slow. By 2033, it is expected to have an increase of more than 0.21° C of temperature; thus, a decrease of precipitation.

Conclusion: In 2023, total discomfort will reign in the dry season, especially in January where humidex could reach 42.9. On the other hand, in the rainy season, humidex will increase of 0.91 compared to year 2013. This effect will have an increase of temperature. When we maintain relative humidity, and we increase temperature, humidex varies enormously and displays a maximum value, with maximum temperature.

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Key words: Climate Change, Thermal Comfort, Tropical Wet and Hot, Outdoor, Health

1. Introduction

The question of climate change on outdoor comfort is sustainable and installed at the first news plan and concerns of public opinions. Long confined to the scientific community, at ecological progress, it has emerged since some years at government level with recently the signing of Kyoto protocol. The global awareness about climate change is now a fact some.

This awareness has led the international community to seek a scientific consensus around for this sensitive question which can play on humanity's fate. The creation of the group on Intergovernmental Panel on Climate Change (IPCC) in 1988, was for this purpose. Several analyze and reports on this issue have been published (1). The impacts of climate change are now more visible. Various surveys conducted at the regional level on different continents show that this phenomenon is present. The different emission scenarios provided by the IPCC show that the impacts of climate change will touch all sectors and more particularly natural resources. This will make populations vulnerable 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. Aged peoples are the most vulnerable at effects of climate change. The future of humanity threatened by the effects of climate change is more explicit (2-5). and there are signs and suggestions that climate change has affected the natural systems and human. Warming of the climate system is unequivocal. There is already a global scale, a linear trend of rising average temperatures estimated at 0.6°C from 1901 to 2000, set value may vary up to 0.74°C over the next decades (6). The satellite data available since 1978 show that the annual average of ice extent has decreased by 2.7% per decade in the Arctic Ocean, with a retreat more distinct in summer (7.4%). On the other hand, the

average sea level has risen by 1.8 mm/year for 1961 and by 3.1 mm/year for 1993, due to thermal expansion and melting of glaciers.⁶ One of the most important aspects of the issue of climate change is the effect of global warming that affects the health and thermal comfort of individuals (7-10). The consequences of rise of temperature can induce human beings with cramps, fainting, heat exhaustion, dehydration, and mostly leads to death by complication (11). Indeed, global emissions of greenhouse gases have increased of 70% from 1970 to 2004, then 24% since 1990 (12). From the general circulation model (GCM) and its various components, several studies have been conducted on the effects of climate change on the health and comfort of people (13-15). The various adverse effects of climate change are visible in Africa, especially in sub-Saharan area desert encroachment, floods, etc., have been observed. According to IPCC projections, in 2020 in Africa, more than 75 million people will be exposed to hybrid stress. Furthermore, it is expected that the agricultural production and access to food in some African countries will decrease (16). According to various climate scenarios, the area of arid and semi-arid regions in Africa could increase from 5% to 8% in 2080. Rejected waste by the companies in space and in water disrupts photosynthesis and act on the outdoor climate (17-19). Douala, Cameroon's political capital, town on the edge of the sea and one of the main business centers of sub-Saharan Africa will be constantly flooded during the rainy season. The increased ($0.19 \pm 0.02^{\circ}\text{C}$) is possible within 20 years if anything is not done by the political and no-political and to ensure a supply of clean and sustainable energy consumption. This increase will contribute to warming in the region. The results also showed that the temperature is rising faster in this region in the dry season than during the rainy season; hence, the degree of heat is more observed dry season.

Precipitation decreases gradually, which sometimes explains the scarcity of rainfall in the rainy season. Researchers have proposed a model for the study of heat exchange human-environment (MENEX) (19). However, alternative methods have been tested and used in research microclimate forecast. The aim of this paper is to estimate the effects of climate change on health and outdoor thermal comfort in coastal areas, as in the case of the city of Douala. The humidex index innovated by Canada has been used for this purpose to evaluate the outdoor comfort reigning in the past, present, and future.

2. Materials and Methods

2.1. Analyzed cities

Douala is the economic capital of Cameroon, the main business center, and one of the largest cities in the country. The city is located on the Atlantic Ocean coast, between 4°03' N and 9°42' E, with an area of nearly 210 km² (Figure 1). Climate in Douala is tropical wet and hot, characterized by temperatures between 18° C and 34° C, accompanied by heavy precipitation, especially during the rainy season from June to October. The air nearly always records 99% relative humidity during the rainy season, and about 80% during the dry season from October to May.

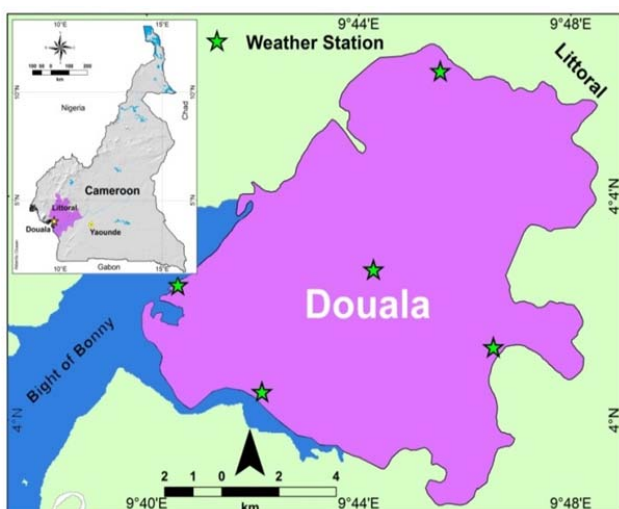


Figure 1. Study area and sampling stations

2.2. Climatic data

The outdoor daily data of the last 40 years of temperature (minimum and maximum), precipitation and sunshine was taken in five meteorological stations in Douala. Climate data were provided by local meteorological office in Douala.

The various data are measured from 3 to 10 m in height from the ground and with a frequency of 10-15 min. In these various weather stations, data: the relative and absolute humidity, wind speed evaporation, etc. are also available. These weather stations were selected for this study, because its administrative staff is qualified; they are far away buildings and measuring devices are reliable and is in a place without hindrance or other parameters that could affect the sampling data. Measurement errors on the temperature and relative humidity are estimated at $\pm 0.1^\circ\text{C}$ and 1%, respectively.

2.3. The humidex index

Humidex is a Canadian innovation. In 1979, Masterton and Richardson (20) proposed humidex as an index calculated based on air temperature and humidity. It was devised by Canadian meteorologists to describe how the average person feels in hot, humid weather (21). Humidex, thus combines temperature and humidity into one number to reflect the perceived temperature, and consequently, a measure of thermal discomfort. As it takes into account the two most important factors that affect summer comfort, it is a better measure of how stifling the air feels, rather than either temperature or humidity alone. An extremely high humidex reading is defined as one that crosses 40, as shown in table 1.

Table 1. Guide to summer comfort for the different humidex ranges (22)

Range of humidex	Degree of comfort
< 29	No discomfort
30-39	Some discomfort
40-45	Great discomfort; avoid exertion
> 45	Dangerous
> 54	Heat stroke imminent

In such conditions, all unnecessary activity should be curtailed. Humidex above 45, is again very dangerous for the life of man, outdoor medium is very uncomfortable. Despite its limitations, the humidex remains a useful, and hence popular, means of determining how hot it actually feels outside. Humidex was evaluated in this study over three periods: the past (2003), the present (2013), and future (2023 and 2033).

2.4. Model of climate change

In this study, outdoor parameter were grouped in a first time on three periods: past (1990-2000), present (2001-2011), and future (2012-2022), in the second time, thermal comfort of medium was conditioned by the past (1985-2000) and future (2013-2035). These different periods are taken to determine the effect of climate change in the environmental comfort. The version of the LARS-WG5.11 model, well-known models that produce random climatic data was used to generate data CSMK3 atmospheric general circulation model, based on the B1 scenario. This GCM is used to generate the forecasts of minimum and maximum daily temperature, precipitation, sunshine, and evaporation.

In general, data generation of the LARS-

WG model takes place in three stages: calibrating data, evaluating data, and generating meteorological data for the future period. In this study, for assessing the LARS model and forecasting the meteorological data of temperature, data from 1983 to 2005 of the five synoptic stations have been used.

It should be noted that the evaluation of the data generated by the model and that of the real sampled data for the period 1983-2005 have been undertaken using the statistical values of the co-efficient of determination ($R^2 = 0.97$), the root mean square error and the mean absolute error are inferior at 0.19. Hence, after validating the LARS-WG model using these basic data (1985-2005), the statistical period of 2013-2035 was simulated.

3. Results

From the long-term (1991-2001) average temperature, we determined increase and/or decrease in temperature and precipitation in the city of Douala. For that, we analyzed data from five weather stations and used the model CSMK3 Scenario B1 to simulate climate change in the future.

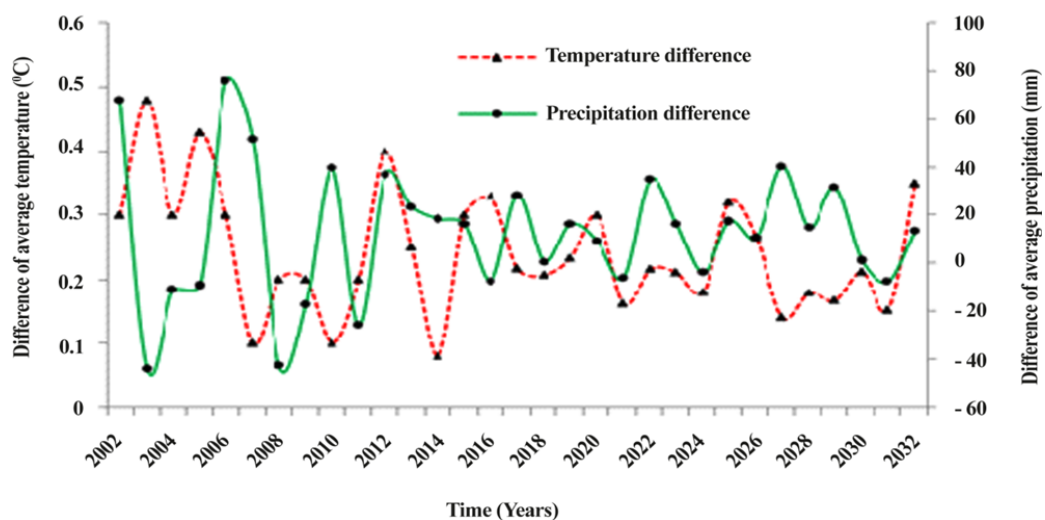


Figure 2. The temperature downfall oscillations in the city from 2002 to 2032 as compared with the long-term mean (1991-2001)

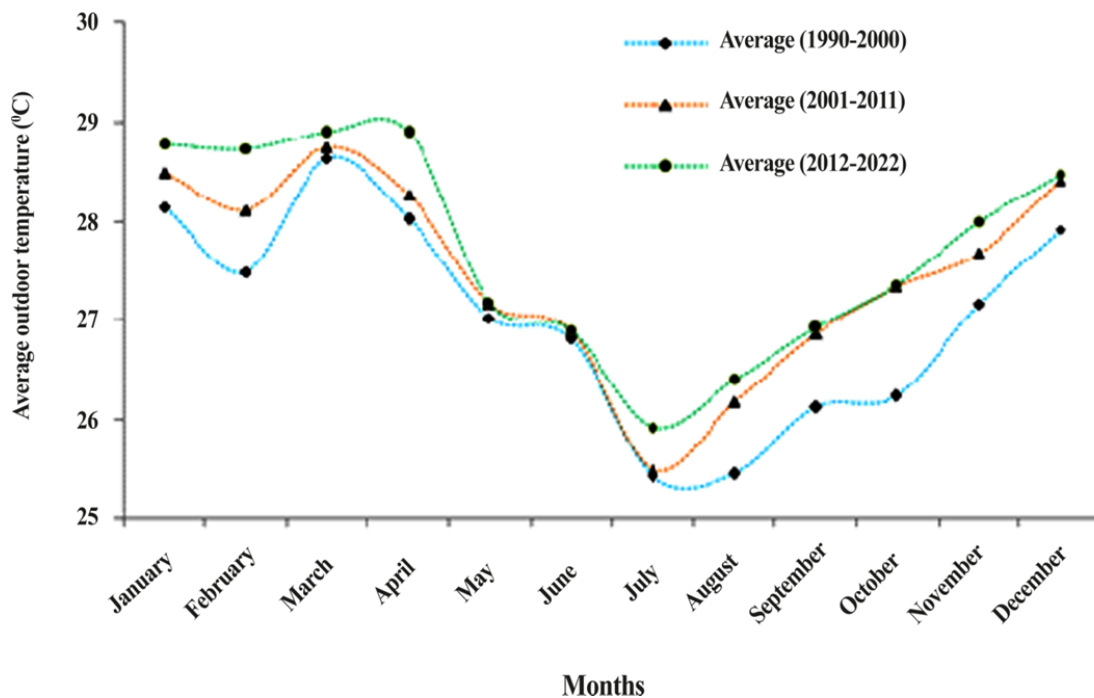


Figure 3. Average outdoor temperature in three time periods of past (1990-2000), present (2001-2011), and future (2012-2022)

It is clear from figure 2 that more the temperature increases, less precipitation decreases, less temperature decreases, more precipitation increases. The highest temperature rise of the city of Douala as compared to the average (1991-2001) is equal to 0.48°C in 2003. The average increase (2002-2032) is 0.24°C . This average is 0.23°C from 2002 to 2014 and 0.25°C for the period from 2015 to 2032. An analysis of these different averages shows that the temperature increases slightly each year. Precipitation decreases over the years. The highest increase as compared to average (1991-2001) is equal to 75.8 mm in 2006. A decrease compared to the same period was observed in 2003 and 2005, respectively of 43.8, 11.0, and 9.1 mm, also in 2008, 2011, 2016; 2021 2024, and 2031. The temperature does not always varies inversely with precipitation, this is demonstrated in the year 2012, where precipitation increases but also, temperature increases slightly compared to the average (1991-2001).

Figure 3 shows the average outdoor temperature in three periods (past, present, and future). The different average outdoor temperatures are ranged from 25.4°C to 29.2°C . From October to May (dry season), the average temperature was 27.6°C (1990-2000), 27.8°C (2001-2011), and 28.1°C (2012-2022). On the other hand, from July to October (rainy season), the average temperature was 26.0°C (1990-2000), 26.1°C (2001-2011) and 26.2°C (2012 to 2022). A careful analysis of different means obtained shows that the temperature increases in the dry season of 0.09°C and in the rainy season of 0.05°C . The hottest month is March, and the least hot is July.

Figure 4 shows the average monthly rainfall over three periods (past, present, and future). The averages obtained during three periods are 9.6, 10.2, and 9.1 mm, respectively (1990-2000, 2001-2011, and 2012-2022). The amount of precipitation has increased by 0.6 mm (2001-2011) compared to the previous period and decrease of 1.1 mm (2012-2022). Men,

fauna, and flora, without exception suffer the consequences of this decrease. The least rainy months during the periods (1990-2000 and 2001-2011) is December (0.5 and 1.2 mm), and the wettest months are July (22.9 mm) and August (26.6 mm), respectively for the same periods. In addition in period (2012-2022), it is likely that the least rainy month is January (0.6 mm) and the rainiest month is July (21.7 mm). The average outdoor relative humidity is shown in figure 5.

It can be observed in figure 5 that the humidity has increased during the period (2001-2011) compared to the previous period.

This may be a consequence of the increase in the amount of precipitation as seen above during the same period. For an average of 80.7% moisture obtained (1990-2000), 10 years later, this rate increases to 83.0% (2001-2011). This increase is significant. The operation “Green City”, consisting to sow plants in all major intersections in the city was launched this period. This can also be a cause of increased levels of moisture in the city. August is the month where the average degree of humidity is higher (around 90%). The average monthly minimum and maximum temperatures are given in figure 6.

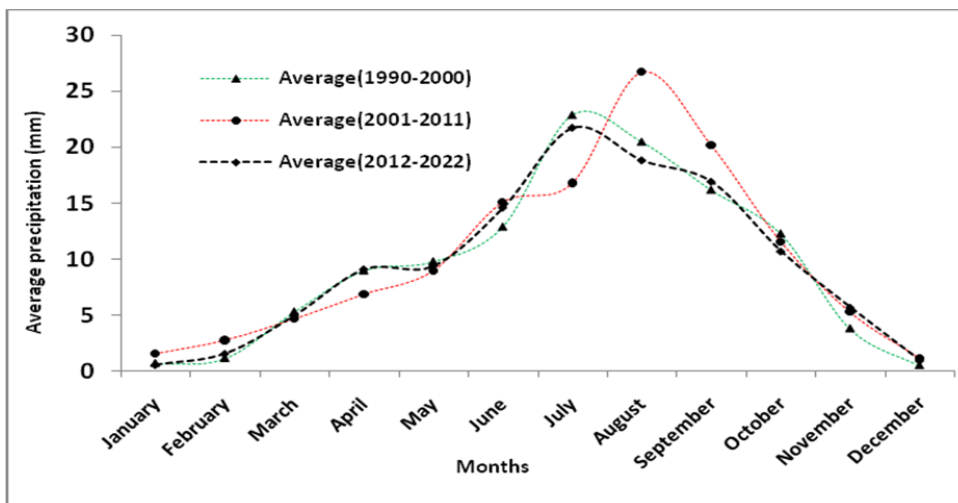


Figure 4. Average precipitation in three time periods of past (1990-2000), present (2001-2011), and future (2012-2022)

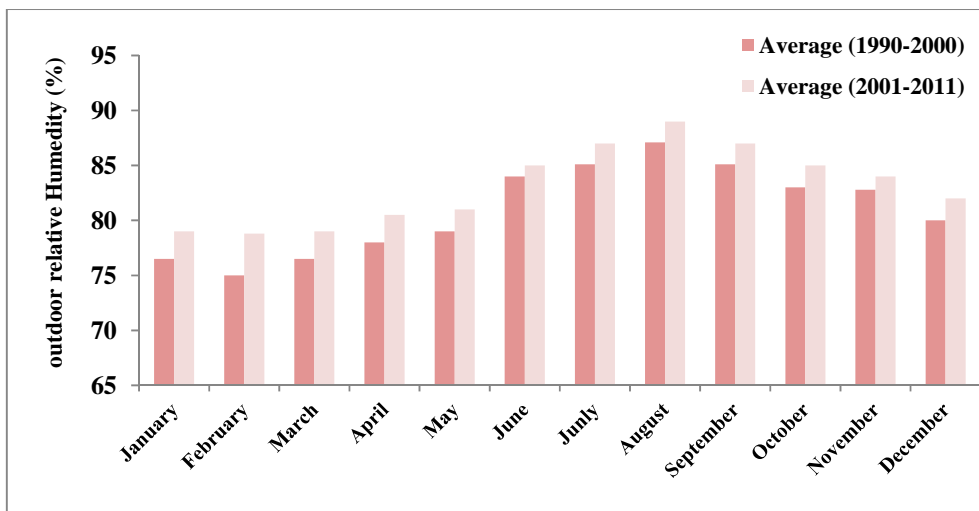


Figure 5. Average outdoor relative humidity in two time periods of past (1990-2000) and present (2001-2011)

An analysis shows that the maximum in both periods. Maximum temperatures ranged from 26° C to 35.5° C with a standard deviation (SD) = 0.71 for the period from 1985 to 2000 and also with SD = 0.46 for the period from 2013 to 2035. The peak of maximum temperatures was obtained in February 2000 (35.4° C) while the minimum of maximum temperatures (26.0° C) was obtained in the month of August 1995. In general, in both periods, the maximum temperatures are usually recorded in February and the minimum temperature in August. During the rainy season from June to October, maximum temperatures were always below 30.3° C from 1985 to 2000, it was observed that these maximum temperatures were inferior at 31.5° C, the next period. The minimum temperatures are slightly lower from 1985 to 2000 compared to the period from 2013 to 2035. An increase of 0.49° C is conceivable. The minimum temperatures are ranged from 20° C to 24.8° C, with a SD of temperature (SD = 0.61) from 1985 to 2000.

In addition, SD = 0.59 for the period from 2013 to 2035. The smallest value of minimum temperatures is obtained in August 1996 (20° C) and peak of minimum temperatures in February 2026 (24.8° C).

Figure 7 shows the average monthly values of precipitation and sunshine in the past (1985-2000) and future (2013-2035) periods.

It is observed the precipitation decrease over the years; nevertheless, sunlight increase slightly. During the period 1985 to 2000, average monthly precipitation varies from 0 to 35.1 mm. The average of this period is 9.97 mm with SD = 3.97. On the other hand, from 2013 to 2035, average monthly precipitation could varied from 0 to 36.1 mm, with an average of 8.37 mm with SD = 3.43. An analysis of these different means shows that average monthly rainfall will decrease of 1.6 mm after 32 years. The most rainy month is August 2029 (36.1 mm) and the least rainy months are December (2013; 2015; 2017; 2026; and 2029), January (1986; 1993-1994). Sunshine ranges from 2.5 to 6 kwh/m².

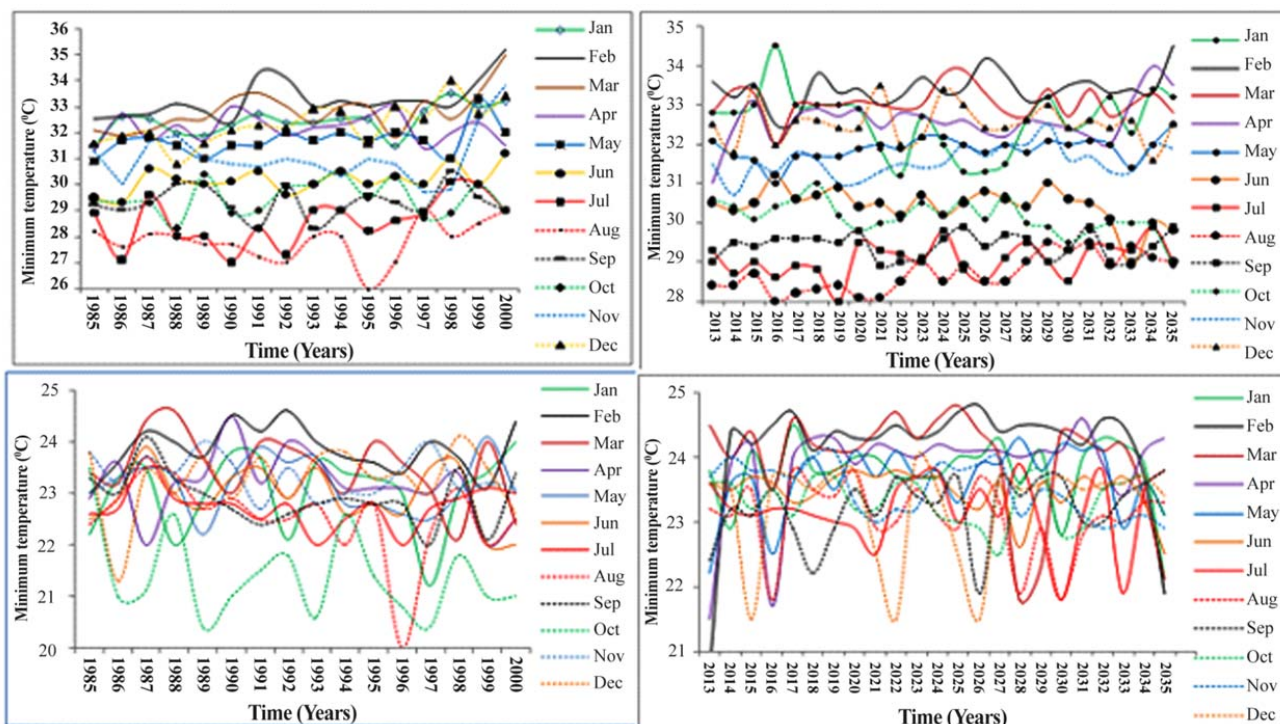


Figure 6. Comparison between the variations of the average monthly minimum and maximum outdoor temperature based on the two time scales, past and future

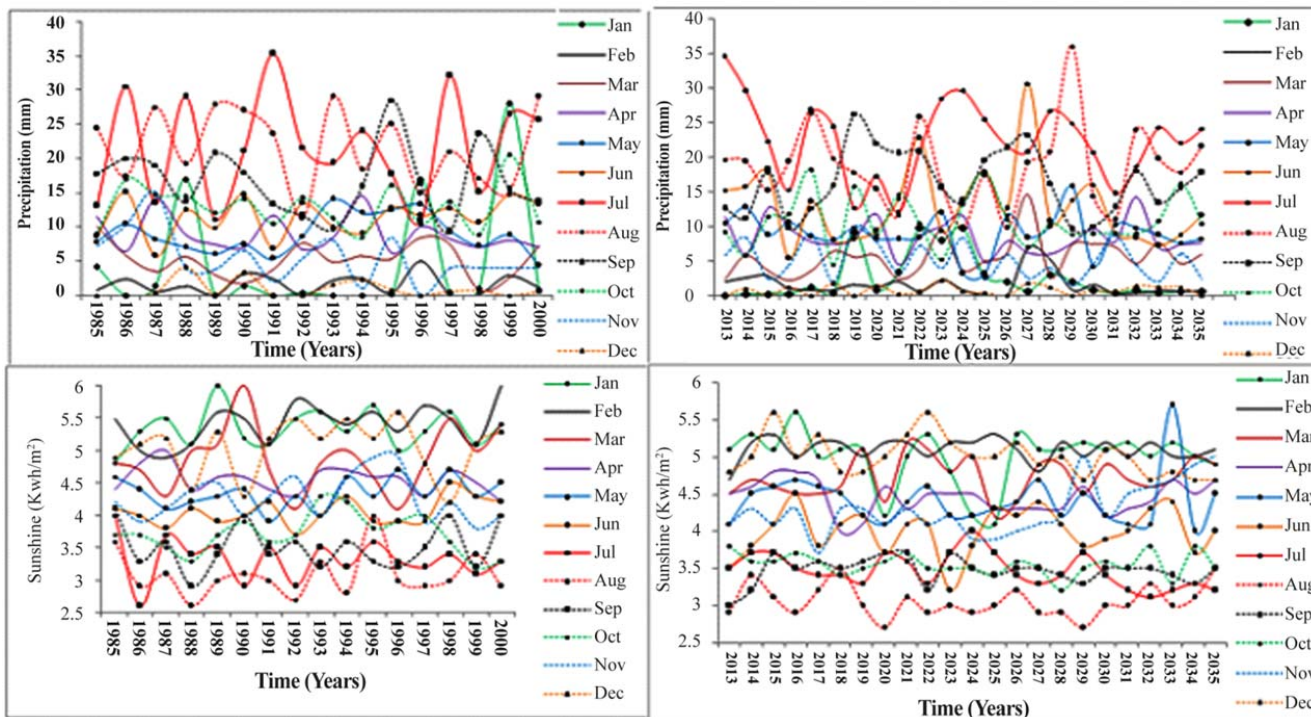


Figure 7. Comparison between the variations of the average monthly of precipitation and sunshine based on the two time scales, past and future

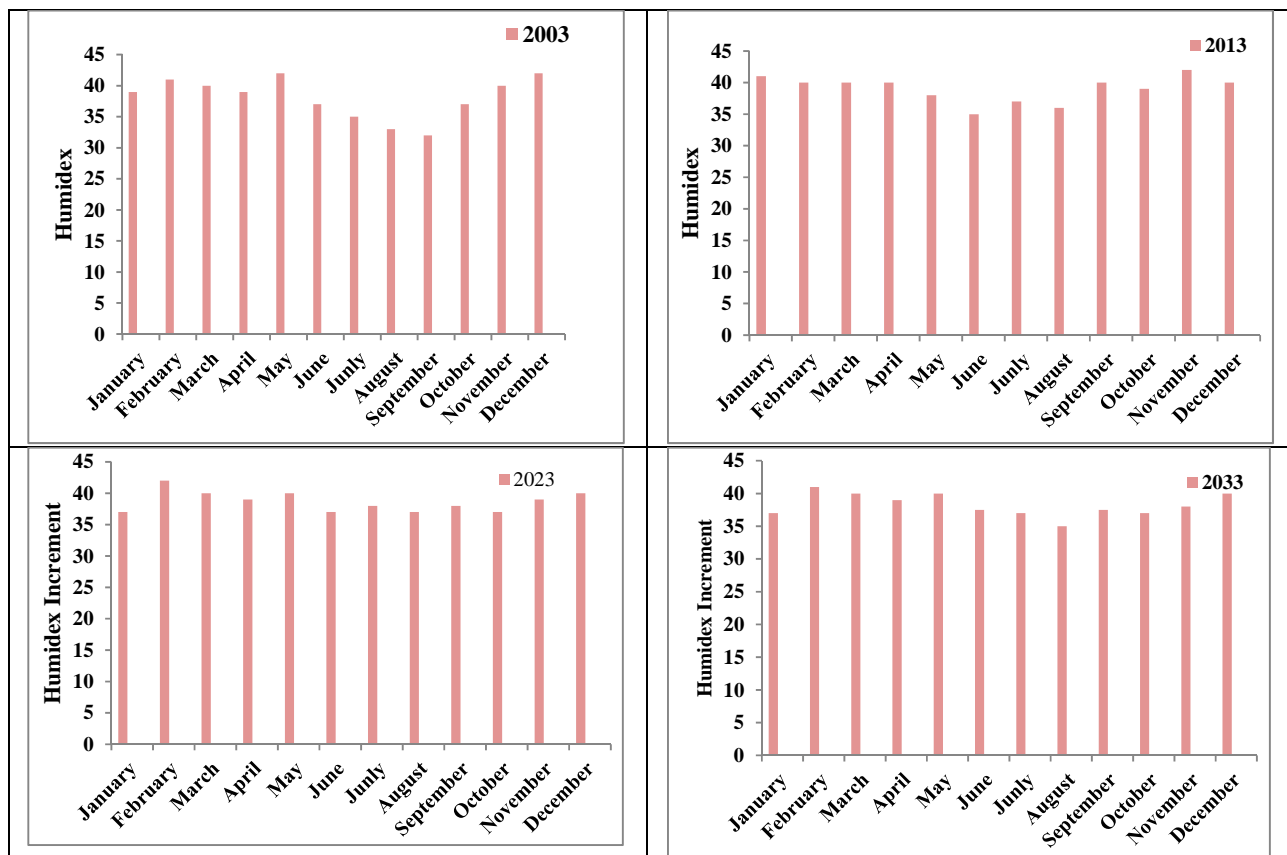


Figure 8. Yearly humidex in (2003, 2013) and yearly humidex increment (2023, 2033)

The averages are 4.2 and 4.7 kwh/m², respectively obtained in both periods (past and future). Figure 8 shows the different humidex values in three time periods: the past (2003), the present (2013), and future (2023 and 2033).

It is clear from this figure that the comfort of the outdoor environment varies according to the seasons. The geographical location of Douala, town nearest the sea, 10 m of altitude, with a wet and warm climate, sometimes its outdoor temperature was approaching 36° C. The average temperature is around 28.9° C in dry season and 26.5° C in rainy season and its high degree humidity means led to humidex values above 40 during the months of February, March, May, and December (2003). The population lives “great discomfort” during this period. In dry season (July-October) in 2003, “some discomfort” is known by town inhabitants because humidex ranged from 34 to 38.3. In 2013, in dry and rainy season, a “slight discomfort” is seen as humidex ranges from 34.5 to 39.5, except January and November where the effort should be avoided, because it recent great discomfort. In 2023, unease will grow during dry season.

4. Discussion

The proximity of Douala city of ocean has a significant influence on the different temperatures. The city is constantly traversed by hot humid winds. This sudden growth of temperature weakens the human health. During the rainy season, humidex will increase 0.91 compared at 2013. This effect is due to the increment of temperature and relative humidity. That indicates that if we increase relative humidity above 10% for the same value of the outdoor temperature, humidex shows the maximum value with the maximum relative humidity. On the contrary, if we maintain the relative humidity and increase the temperature, humidex also shows a maximum value when air temperature is maximum. These data confirm the results found by Humidex (23) and Taylor et al. (22) So, in the humid tropics, there is a clear trend for higher values humidex especially in dry season. Evolution of humidex according to temperature is given in table 2.

The effect of climate change on the outdoor environmental comfort is the main concern of all nations, because, uncomfortable environment, acts on yield or productivity of

Table 2. Evolution of humidex on three periods according to increase of the temperature (° C)

Months	Years and climate parameters							
	2003		2013		2023		2033	
	Temperature	Humidex	Temperature	Humidex	Temperature	Humidex	Temperature	Humidex
January	28.3	39.5	28.6	41.0	28.5	37.5	29.1	42.9
February	28.5	40.5	28.7	39.5	28.8	41.0	28.9	41.3
March	28.6	40.0	28.6	39.3	28.8	39.8	28.8	40.5
April	28.2	39.2	28.2	39.3	28.4	39.5	28.6	39.9
May	28.4	41.5	27.1	37.5	27.9	40.1	28.5	40.0
June	27.2	38.0	26.7	34.5	27.1	38.0	27.3	39.5
July	25.7	37.0	26.2	36.5	26.4	36.9	27.7	36.3
August	26.1	35.0	27.0	36.0	27.4	36.9	27.9	35.5
September	26.4	34.5	27.8	39.3	26.3	36.5	27.9	37.2
October	26.7	38.3	27.8	39.0	27.9	36.9	28.1	37.9
November	27.5	39.4	28.3	42.0	28.6	38.9	28.8	39.7
December	28.6	41.7	28.7	39.5	28.9	40.0	29.0	39.8

individuals (1,2,6,23). Globally, during the 10 last year, rainy season shown the conditions best slightly of comfort with average humidex of 38, while the dry season presented the uncomfortable conditions with humidex highest. A big change is expected within 20 years if nothing is done to slow climate change. An increase in temperature of more than 0.21°C is expected it implying an increase of humidex values more than 5% compared to 2013. In 2033, for example, the average humidex obtained will be 40.5 in dry season and 39.0 in rainy season. January and February humidex will be 42.9 and 41.3 respectively. This reflects the adverse conditions of outdoor environmental comfort in these months. These results are not surprising saw the temperature increase. This increase of temperature is in the beach fixed by IPCC (2,6). From these data, we conclude that the humidex clearly depends of the outdoor temperature. As a result, the global warming of the planet shows a definite effect on the external environmental comfort. Conditions become more and more unbearable in the hottest areas. Thermal comfort is very important not only for health, but also for the productivity of the occupants. In fact, thermal comfort greatly affects the efficiency of work by an individual as well as the production and social costs. Consequently, the conditions for comfort should be appropriate for the well-being, productivity, and work efficiency of the inhabitants (22). Thermal comfort heavily depends not only on environmental factors but also on physical, physiological, and psychological aspects. Satisfaction with the thermal environment is a complex topic, and the subjective responses are extremely variable. The fight against climate change involves everyone. Serious measures must be taken by the Cameroonian government to slow this problem. The Cameroonian government could, for example in the fight against climate change, preserve its forests to illegal cutting of wood, given that Cameroon

has the second potential in the Congo Basin. Mitigation measures are still possible. The effects of climate change are really negative, it is important that all the political fight against this problem. New means and software can help us to guide (24,25).

In this paper, with the daily data of minimum and maximum temperature minimal, precipitation and sunshine on 40 years, coming of five weather stations of Cameroon, forecast on outdoor climate of Douala city. The results obtained were analyzed, interpreted, and integrated. It deduce of this analysis that in wet tropical area, outdoor climate has enormously changed. Temperature will increase up to 0.21°C , while, precipitation decrease about 1.1 mm, if nothing is carried out to fight against climate change. Temperature is higher in dry season compared to rainy season. Humidity rate was high of 2.3% from 1990-2000 to 2001-2011 period. During the last 10 years, rainy season showed slightly better conditions of comfort with mean humidex of 38, and on the other hand, dry season showed discomfort conditions with humidex higher. In 2023, it appears it will be more than more "great discomfort" in dry season. In rainy season, humidex increased 0.91 as compared to 2013. That effect is due to increment of air temperature and relative humidity. In 2033, humidex values could reach 43 if nothing is carried out by political. These different results must be taken in count to preserve the future against natural disasters coming of climate change. Others researches concerning the assessment of outdoor climate in sub-Sahara Africa must be encouraged to prevent the population of climate change effects.

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