*Research Article*

# An assessment of impacts of climate change on available water resources and security in Cameroon

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## ABSTRACT

Water is the first sector to be affected by changes in climate. The prediction is that with climate change, the climate will be more variable with more intense storms which will increase the risks of flooding and droughts. Attaining and sustaining water security will therefore be more challenging than it has been up to now. The objectives of this paper were to determine the impact of climate change on water resources in Cameroon based on historical data; to predict the impact of climate change on water resources and on the water available per capita and to recommend changes required in water management to ensure and sustain water security in a changing climate.

Statistical analyses were used to determine the trends and the variability in the rainfall and runoff of stations with at least 40 years of data. Projections were then made for internal renewable water resources for the various basins in 2025 and 2050 and the per capita available water resources calculated for each basin**.** The study concludes that during the period 1968 to 2006, the surface water resources in the northern part of Cameroon reduced by about 30 % while in the southern parts, the reduction was about 14%. However, up till the year 2050, there will still be adequate available water resources in all river basins even when the impacts of climate change are taken into consideration but there will be increased variability. To ensure water security under these circumstances, the construction of more water storage dams will be required.

**Keywords:** climate change, water resources, per capita available water, water security

## RÉSUMÉ

Le secteur de l'eau est le premier à être touchés par les changements climatiques. Avec le changement climatique, il est prévu que le climat sera plus variable avec des tempêtes plus intenses qui accroîtront les risques d'inondation et de sécheresse. Atteindre et maintenir la sécurité de l'eau sera donc plus difficile qu'elle ne l'a été jusqu'à présent. Les objectifs de ce travail étaient de déterminer l'impact du changement climatique sur les ressources en eau au Cameroun sur la base des données historiques, de prédire l'impact du changement climatique sur les ressources en eau et sur l'eau disponible par habitant et de recommander les changements nécessaires dans la gestion de l'eau pour assurer et maintenir la sécurité de l'eau dans un contexte de climat changeant.

Les analyses statistiques ont été utilisées pour déterminer les tendances et la variabilité de la pluviométrie et des écoulements avec au moins 40 années de données collectées dans diverses stations. Des projections ont donc été faites sur les ressources en eau internes renouvelables pour les différents bassins en 2025 et 2050 et les ressources en eau disponibles par habitant calculées pour chaque bassin. L'étude conclut que durant la période 1968-2006, les ressources en eau de surface dans la partie septentrionale du Cameroun ont été réduites d'environ 30 %, tandis que dans les régions méridionales, la réduction était d'environ 14 %. Toutefois, jusqu'à l'année 2050, les ressources en eau disponibles sont suffisantes dans tous les bassins fluviaux, même si les impacts du changement climatique sont pris en compte, mais il y aura augmentation de la variabilité. Pour assurer la sécurité de l'eau dans un climat plus variable, la construction d'autres barrages de stockage d'eau sera nécessaire.

Mots-clés: changement climatique, ressources en eau, l'eau disponible par habitant, la sécurité de l'eau.

## INTRODUCTION

Water is a critical but often overlooked element in sustainable development. In most countries, water related problems stem from poor management rather than actual water shortage (GWP-TEC, 2004). Natural and human factors contribute to its scarcity and, significant sections of the population in many countries today have insufficient water. Water is essential for socio-economic development and for maintaining healthy ecosystems. Sustainable development is possible only when there is water security. There is no generally accepted definition of water security. For this paper the definition suggested by Mason and Calow (2012) and that adopted by AMCOW and GWP (2012) were combined. Water security is defined as "having sufficient water, in quantity and quality, for the needs of humans (health, livelihoods and productive economic activities) and ecosystems, matched by the capacity (financial, social and legal) to access and use it, resolve trade-offs, and manage water-related risks, including flood, drought and pollution".

The Intergovernmental Panel on Climate Change (IPCC) defines climate in a narrow sense as the average weather, 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 (Bates *et al.,* 2008). The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Climate change on the other hand refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.

Water is the first sector to be affected by changes in climate and predictions are that this will lead to intensification of the hydrological cycle and impact the quantity of water resources available. Impacts of this include: changes in the frequency, intensity and spatial distribution of precipitation; changes in the amounts of precipitation; increases in evaporation due to increasing temperatures; changes in runoff; variations in ground water recharge rates; rise in sea level in coastal areas; increase in floods and droughts and increased variability of water resources.

One of the major factors influencing water security is the per capita available water resources in a country or region. This indicator can be used to determine the abundance or scarcity of water. Based on the population in 2007, Cameroon has abundant renewable water resources estimated at about 15 000 $m^3$/year per capita (MINEE and GWP, 2009a) with variations from one river basin to another. The amount of fresh water resources in the world is finite but its distribution is projected to be affected by climate change with rainfall increasing in some areas and decreasing in others. The IPCC has concluded that globally there will be a negative impact on freshwater resources as a result of climate change (Bates *et al.*, 2008). Predictions are however uncertain especially at local levels where decision making is more relevant. For example Giannini *et. al.,* (2008) indicated that, for West Africa current climate change model projections have good agreement on the direction of change in temperature (increase) but are inconclusive with respect to precipitation with nearly as many models projecting increases in precipitation as decreases.

How climate change will affect the available water resources in various river basins will have an important bearing on water security. Previous studies on the impact of climate change on water resources have not gone far enough to determine the impact on water security within various basins. The aim of this study was therefore to investigate the impacts of climate change on per capita available water resources in the various river basins in Cameroon in an attempt to enhance the sustainable management of this resource as a contribution to the socio-economic development of the country. The specific objectives were to determine the trends and variabilities of rainfall and quantity of water resources; evaluate the state of water security and determine the current water resources per capita in river basins. The impact of projected climate variability on the available water resources was also determined.

## MATERIALS AND METHODS

### Study Sites

The annual rainfall for locations with at least 40 years of data was obtained from the Department of National Meteorology in Douala, Cameroon (DMN, 2009). The annual rainfall data were for 11 locations namely; Bafoussam, Bamenda, Bertoua, Douala, Ebolowa, Edea, Garoua, Kribi, Maroua, Ngaoundere and Yaoundé. Data of the mean annual runoff for four locations namely; River Sanaga at Edea; River Logone at Baikoum and at Bangor; and River Chari at Chagoua were obtained from the National Electricity Cooperation. The choice of data sites was guided by the availability of sufficiently long data series and a desire to cover the entire country. The rainfall data covers all the ecological regions of Cameroon and is therefore representative of the country. The data on the flow rate of rivers was available only for four locations. However, this is also considered to be representative because the basins they represent are large. For example, the basin area of the flow rate of the Sanaga River at Edea, represents about a quarter of the surface area of Cameroon. In addition, the data gives a good indication of the variability between the flow rates in the northern and southern parts of the country.

### Analysis of trends and variability

A Microsoft Excel spread sheet was used to analyze the trend and the variability in the rainfall and runoff data. The trends were obtained by fitting a linear model trend line using all the available data and determining the equation of the line. Because of the different durations of the available data used to determine the trends, the percentage change with time in each variable was determined for the same time period to permit comparisons.

In order to determine the change in the variability, the data series was divided into two periods each of at least 20 years and the coefficient of variation (CoV) determined for each period. The coefficients of variations of the two periods were then used to assess the change in variability. The coefficient of variation gives a normalized measure of spread about the mean and was estimated as the ratio of the standard deviation to the mean. The greater the CoV, the greater the variability in a property. Wilding (1985) proposed a classification scheme for identifying the extent of variability based on the CoV values. Values of the CoV up to 15; greater than 15 but less than or equal to 35; and greater than 35% indicate low, moderate and high variability, respectively. This classification was used to classify the variability of rainfall and runoff between two time periods.

### Indicator of water security

The Water Poverty Index (WPI) developed by NERC (2002) was used to assess the status of water security. WPI combines both the physical quantities relating to water availability and the socio-economic factors relating to poverty, to produce an indicator that addresses the diverse factors that affect water resource management. It is a measure, for a given country, of the impact of water scarcity and water provision on human populations. WPI is a number between 0 and 100, where a low score indicates water poverty and a high score indicates good water provision. The value of the WPI was correlated with secondary data on; access to water and sanitation of the population in Cameroon and the number of water related disasters especially floods.

**Projected per capita available water resources**

The linear trend lines obtained were used to estimate the flow rate of four rivers in 2025 and 2050 assuming the linear trends continued. The current estimated surface water resource of 268 km$^3$ in Cameroon (MINEE and GWP, 2009a) was considered to be data for the year 1992. The percentage change in the surface flow rate in the north of Cameroon was determined as well as that for the flow in the south (River Sanaga) for 2025 and 2050 as compared to the year 1992. These changes were then assumed to apply to all river basins in the respective parts of the country.

MINEE and GWP (2009b) estimated the population in each river basin in Cameroon based on the population of 2007. The Population Reference Bureau (2012) estimates that the population of Cameroon was 20.9 million in 2012 and projects that it will attain 28 million in 2025 and 44.6 million in 2050. With a knowledge of the total projected population in 2025 and 2050, the projected population in the various river basins was obtained by distributing the total population in 2025 and 2050 respectively in the five basins using the same proportion as that obtained in 2007. With the projected population and surface water resources, it was now possible to determine the available water resources per capita for each river basin as the ratio of the projected internal renewable water resources to the projected population in 2025 and 2050 respectively.

## RESULTS AND DISCUSSION

**Trends and variability of mean annual rainfall**

An example of the variability and the trend in the mean annual rainfall for Bafoussam for the period 1940 to 2007 is shown in figure 1 which indicates that the mean annual rainfall has been decreasing as illustrated by the linear model trend equation at a rate of about 1.6 mm per year, with a net decrease of about 107 mm equivalent to 5.8% of the 1940 value.

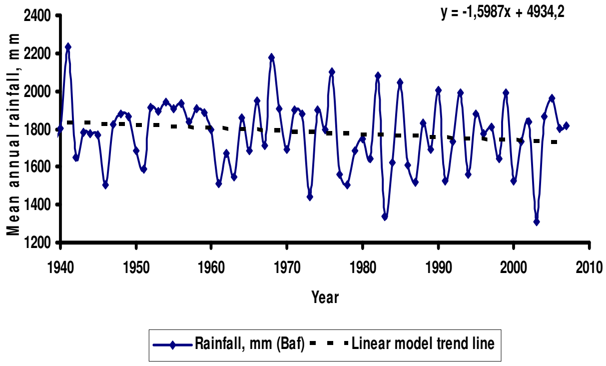


Figure 1: Variability and the trend in the mean annual rainfall for Bafoussam from 1940 to 2007.

Table 1 summaries the trend lines and the percentage change in the rainfall over the period 1962-2006 for the 11 locations analyzed. With the exception of Kribi where the increase in the trend is about 15%, all other locations show decreasing trends with Douala manifesting the greatest drop of about 16% while the smallest (0.1 %) is at Ebolowa.

**Table 1**: Changes in the amount of rainfall in the different regions of Cameroon

| Location | Period used to determine trend line | Equation of trend line | Change in rainfall from 1962-2006 (mm) | % change from 1962-2006 |
|---|---|---|---|---|
| Douala | 1951-2007 | R= - 15.474Y + 34520 | -681 | -16.4 |
| Bamenda | 1923-2007 | R= - 7.11Y + 16404 | -313 | -12.7 |
| Yaoundé | 1951-2007 | R= - 3.745Y + 9002 | -165 | -10.0 |
| Edea | 1960-2006 | R= - 5.725Y + 13767 | -252 | -9.9 |
| Ngaoundere | 1941-2007 | R= - 2.878Y + 7180 | -127 | -8.3 |
| Maroua | 1953-2004 | R= - 1.358Y + 3512 | -60 | -7.0 |
| Garoua | 1951-2007 | R= - 1.25Y + 3495 | -55 | -5.3 |
| Bertoua | 1939-2007 | R= - 1.61Y + 4683 | -71 | -4.6 |
| Bafoussam | 1934-2007 | R= - 1.6Y + 4934 | -70 | -3.9 |
| Ebolowa | 1926-2007 | R= - 0.046Y + 1848 | -2 | -0.1 |
| Kribi | 1962-2006 | R= 9.05Y-15048 | 398 | 14.7 |

Note: In the linear trend line equation, R is the mean annual rainfall in mm while Y is the year.

Table 2 summarizes the change of the variability in the mean annual rainfall for 11 locations over two periods each of at least 20 years. The time periods are not identical because of the differences in the duration of the data sets. However, what is important is to demonstrate if the variability at any location has changed and not a comparison between stations. Out of the 11 locations studied, nine indicate an increasing variability in the amount of the mean annual rainfall. In four locations (Garoua, Maroua, Yaoundé and Edea), the variability has changed from low to moderate using the classification of Wilding (1985) during the two time periods analyzed. For the other five locations with increasing variability, the characterization has remained low. Two locations (Bamenda and Bertoua) indicate a decreasing variability. For Bamenda the variability has remained low while in Bertoua, it has changed from moderate to low.

**Table 2**: Changes in the variability of the mean annual rainfall in different regions of Cameroon

| Location | Period for CoV | CoV, (%) | Change in CoV, (%) |
|---|---|---|---|
| Bafoussam | 1946-1976 | 9.39 | 2.1 |
| | 1977-2007 | 11.44 | |
| Bertoua | 1946-1976 | 15.66 | -3.7 |
| | 1977-2007 | 11.99 | |
| Douala | 1951-1981 | 11.92 | 2.1 |
| | 1982-2007 | 14.06 | |
| Garoua | 1951-1981 | 14.20 | 1.1 |
| | 1982-2007 | 15.25 | |
| Maroua | 1953-1973 | 14.89 | 4.8 |
| | 1974-2004 | 19.72 | |
| Yaoundé | 1951-1981 | 11.95 | 4.4 |
| | 1982-2007 | 16.40 | |
| Ebolowa | 1946-1976 | 11.75 | 1.5 |
| | 1977-2007 | 13.26 | |
| Ngaoundere | 1946-1976 | 10.19 | 1.2 |
| | 1977-2007 | 11.41 | |
| Bamenda | 1946-1976 | 11.42 | -3.3 |
| | 1977-2007 | 8.10 | |
| Edea | 1960-1983 | 13.28 | 3.7 |
| | 1984-2006 | 16.93 | |
| Kribi | 1960-1983 | 16.12 | 4.0 |
| | 1984-2006 | 20.1 | |

In general, the mean annual rainfall shows a decreasing trend for the stations studied, while the variability is on the increase. The trend in the mean annual rainfall is in line with an analysis by MINEPDEP and UNDP (2012) with data from 1961-2008. The study concluded that in Douala (unimodal humid forest zone), and in Garoua (sudano sahelien zone), the annual rainfall has been decreasing since 1961. Studies by Sighomnou (2004) and MINEPDED and UNDP (2012), have also concluded that the spatial distribution of rainfall is also changing. For example, the normalized rainfall for the period 1971-2000 shows an overall southward shift in the isohyets. This is another indication of the decreasing rainfall trend in the country. A study by Odgugo (2010) in Nigeria using data from 1901 to 2005 came to a similar conclusion that in general the temperature is increasing while the rainfall is showing a decreasing trend.

## Trends and variability in surface water resources

Figure 2 shows an example of the variability and the trend in the mean annual flow rate in the River Sanaga at Edea from 1945 to 2006. The flow rate has been decreasing as illustrated by the linear model trend equation at a rate of about 6.8 $m^3/s$ every year. Over the period in question, the flow rate has reduced from about 2086 to 1668 $m^3/s$. This is a reduction of about 20 percent compared to the linear model trend line value in 1945.

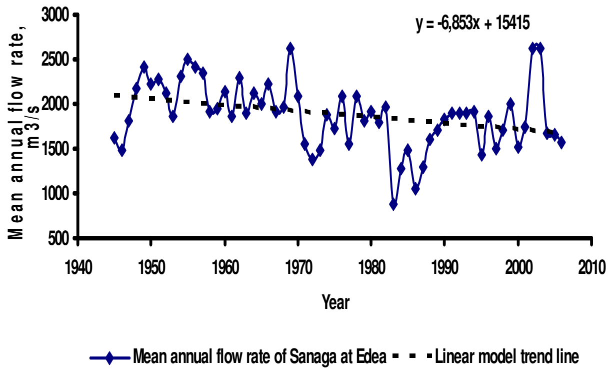


Figure 2: Variation and trend in the mean annual flow rate of the Sanaga River at Edea from 1945 to 2006

Table 3 summaries the linear model trend equations and the percentage changes in the mean annual flow rate for some locations from 1968-2006. In all the locations, the flow rate has been reducing with the highest percentage change observed at the River Logone (32%), followed by the River Chari (21%) and then the River Sanaga with the lowest value of 14%. Munang (2010) also found decreasing trends of precipitation and river runoff in the River Sanaga. However, climate change only could not be blamed for the decreasing trend. Human influences too were considered to play a great role.

**Table 3**: Changes in the mean annual flow rate of some rivers in Cameroon

| Location | Period used to determine trend line | Equation of trend line | Change in the flow rate from 1968-2006, ($m^3/s$) | % change in flow rate from 1968-2006 |
|---|---|---|---|---|
| River Chari at Chagoua | 1968-2008 | F= - 2.9107Y + 6246.7 | -111 | -21.3 |
| Logone at Baikoum | 1953-2008 | F= - 2.597Y + 5422 | -99 | -31.7 |
| Logone at Bongnor | 1953-2008 | F= - 4.3646Y + 9088.2 | -166 | -33.3 |
| Sanaga at Edea | 1945-2006 | F= - 6.853Y + 15415 | -260 | -13.5 |

On the average, in northern Cameroon, the flow rates in the rivers have reduced by about 30% during the period 1968-2006. In the Sanaga river basin which occupies about 25% of the surface area of Cameroon and located in the south of Cameroon, over the same period, the flow has reduced by about 14%. These results are in line with those obtained by Sighomnou (2004) who concluded that the flow rates of Cameroonian rivers had dropped by 15-35% in the 70s compared to the period 1941-1970. It should be noted that although the rainfall has been reducing, the effect on the reduction on the mean annual flow rate is much greater. Although the Sanaga River has the greatest absolute reduction in the flow rate, due to its much greater flow rate, the percentage reduction is the smallest amongst the rivers analysed. The greatest reductions are found in the northern parts of the country. Table 4 summaries the change in the variability in the mean annual flow rate for some locations in Cameroon. At three of these locations, (River Sanaga at Edea; River Logone at Baikoum and at Bangor) the variability around the inter-annual flow rate has increased. However, the variations have not changed their classification and have remained moderate. On the other hand, at the River Chari at Chagoua the variability has reduced considerably changing from high to moderate even though the flow rate shows a decreasing trend.

Table 4: Indications of the changes in the variability of the mean annual flow rate of some rivers in Cameroon.

| Location | Period for the coefficient of variation | Coefficient of variation, (%) | Change in CoV, (%) |
|---|---|---|---|
| River Chari at Chagoua | 1968-1988 | 41.3 | -11.8 |
| | 1989-2008 | 29.5 | |
| Logone at Baikoum | 1953-1983 | 27.5 | 4.5 |
| | 1984-2008 | 32.0 | |
| Logone at Bongnor | 1953-1983 | 19.7 | 12.1 |
| | 1984-2008 | 31.8 | |
| Sanaga at Edea | 1945-1975 | 15.6 | 5.6 |
| | 1976-2006 | 21.2 | |

It can therefore be concluded that in Cameroon the surface water resources are decreasing, with greater percentage decreases observed in the northern part of the country. In general, variability in the long term mean annual flow rate in the rivers is increasing as a result of climate change. The increasing variability suggests there will be likely more extremes with increasing possibilities of droughts and floods. The increasing variability of water resources has implications on how the water is to be managed if there is to be water in adequate quantity to ensure water security. More dams will have to be constructed to mobilize water to be used for socio-economic development as well as for managing water related risks.

**Indications of water security in Cameron**

The ultimate aim of water management is to ensure water security. Lawrence *et al.,* (2003), determined the WPI index which is an indicator of water security. The index was determined using five major components, each with several subcomponents. The main components were availability of water resources, access, capacity, use and environment. For Cameroon the WPI was determined to be 53.6%. Cameroon does not suffer from physical water scarcity but from economic scarcity as defined by IWMI (2005). Economic scarcity results from inadequate investment and is characterized by poor infrastructure and unequal distribution of water. Unreliability or inadequately mobilized water resources is one of the causes of water insecurity in Cameroon and is a major constraint to socio-economic development.

Poor access to water and sanitation and poor management of water related risks are other indicators which can be used to illustrate the fact that Cameroon is water insecure. In 2007 it was estimated that only about 44 % of Cameroonians had access to adequate drinking water (INS, 2008). In urban areas, the situation was much better with a percentage access of about 75 %. The situation in rural areas was worse with a percentage access of 28 %. The percentage of the total population with access to adequate sanitation was about 37 %; with 66.4 % in urban areas and only 14.4 % in rural areas. The national water utility company has a mandate to provide potable water only to urban centres with a population of at least 5 000 persons. In 2009, only 98 such towns had a functional water distribution network (MINEE and GWP, 2009a) giving a national coverage of about 32 % of towns with a population of at least 5 000 persons.

Management of water related risks is another good indicator of water insecurity because a single water related disaster can easily roll back many years of socio-economic development. According to the IPCC, more droughts and heavy rainstorms are likely to result in future due to climate change (Bates *et al.*, 2008). Heavy rains would lead to greater flooding compounded by rising sea levels. Fonteh *et al.,* (2010) reported that between 1984 and 2009, there were about 23 major water-related disasters in Cameroon. This corresponds to an average of one disaster per year. Flooding is the most frequent water-related disaster and occurs mainly in urban areas in the Northern, Littoral and Centre Regions. For example, from 1983 to 2008, six major floods occurred in Yaoundé causing significant material damage, losses in human life and leaving many persons homeless (Numbessi, 2011). Major floods have also been recorded in Maroua and Douala and caused significant damage. The 2012 floods in northern Cameroon are further indications of the water insecurity in Cameroon.

The above suggests that despite abundant water resources there is water insecurity in Cameroon because this water is not adequately mobilized for socio-economic development.

**Currently available and predicted quantities of water in Cameroon**

Table 5 shows the internal, external and the total renewable water resources of Cameroon. The total available water resources are the sum of the internal and external renewable water resources. Internal renewable water resources (IRWR) originate from within the national boundary whereas the external resources (ERWR) are those originating from outside the national frontiers. About 96 % of Cameroon's total renewable water resources are internal and hence the contribution of the external renewable water resources can be ignored. Since there is overlap between surface and groundwater, the surface and groundwater resources cannot simply be added together else there will be double counting. According to FAO (2010), the overlap is about 95 % i.e. only about 5% of the groundwater needs to be added to the surface water. The total renewable water resources (TRWR) of Cameroon are therefore 283.18 $km^3$ per year as indicated on Table 5.

**Table 5**: The total renewable water resources of Cameroon

| Origin of renewable resources | Quantity, ($m^3$x$10^9$) | | |
|---|---|---|---|
| | Surface water | Ground water | Total |
| Internal | 267.88 | 55.98 | 270.68 |
| External | 12.50 | 0 | 12.50 |
| TOTAL | 280.38 | 55.98 | 283.18 |

Source: adapted from MINEE and GWP, (2009a) and FAO (2010)

Table 6 presents the contribution of the various river basins in Cameroon to the IRWR ignoring the contribution from groundwater. The greatest contribution of the surface flow is from the Nyong & coastal basins which accounts for more than a third of the flow (35.4%). This is followed by the Sanaga basin (24%), Niger basin (16.39), Congo basin (12.59) and the lowest contribution (12.14%) is from the Lake Chad basin.

Table 6: Availability of IRWR in Cameroon in 2007

| Entity | IRWR ($m^3$x$10^9$) | Population | Available water, ($m^3$/year/per capita) |
|---|---|---|---|
| Lake Chad | 32.52 | 2,602,736 | 12,495 |
| Niger | 43.10 | 3,575,256 | 12,055 |
| Sanaga | 63.18 | 4,185,620 | 15,095 |
| Congo | 33.45 | 824,976 | 40,547 |
| Nyong and Coastal Basins | 94.82 | 7,393,268 | 12,825 |
| Cameroon | 267.88 | 17,900,000 | 14,965 |

Source: Adapted from MINEE and GWP (2009a, 2009b) and INS (2008)

Because of the overlap between ground water and surface water and the negligible contribution of external renewable water resources, the available water per year per capita was calculated using only the surface water resources. This was also because the distribution of ground water in the different river basins cannot be determined with certainty based on existing information. Table 6 also shows the available per capita renewable water resources in the various river basins. A country or region is defined to have physical water scarcity when the available water is less than 1000 $m^3$/year/capita (UNDP *et al.*, 2000). When the amount is between 1000 and 1700, the area is considered to be water stressed. A country is defined to be adequate in water if the available water is greater than 1700 $m^3$/year/capita. Based on these definitions and the data on Table 6, Cameroon has adequate water resources in all its river basins with the Congo basin having the highest available water resources of about 40 000 $m^3$/year/capita.

**Predicted quantity of available water in Cameroon**

Water is the primary medium through which climate change will impact people, ecosystems and economies (Sadoff and Muller, 2009). While the connection between increased temperatures and changes in rainfall has been modelled in detail, the same is not true for the effect on river flows and the recharge of ground water. Based on the findings of the IPCC, it's difficult to make predictions about the future of rainfall and storms. It's even more difficult to predict the impact of changing temperature and rainfall on water availability from rivers, lakes and ground water because the physical science of relating climate changes to the hydrological cycle is very complex and is still at its infancy. While the amount and timing of rainfall is very important to some water users like farmers, most water users draw their water from surface and ground water resources (Sadoff and Muller, 2008). These sources are fed by rainfall, but the relationship between the amount of rainfall and the amount of water available in rivers, lakes or ground water is a complex one and depends on the specificities of each location.

Table 7 presents the projected percentage reduction in the flow rate of some rivers in the northern and southern portions of Cameroon in 2025 and 2050 compared to the situation in the year 1992. This is based on the assumption that the linear trend of decreasing flow continues to hold. In 2025, the average reduction in the northern section of Cameroon will be about 30 % while for the Sanaga basin it would be about 13%. In 2050, the projected reduction will be about 54 % and 23 % in the northern and southern portions of the country respectively.

Table 7: Projected percentage reduction in the annual flow rate of some rivers in Cameroon based on the linear trend model.

| River | Percentage change in flow rate from 1992 | |
|---|---|---|
| | 2025 | 2050 |
| River Chari at Chagoua | -21.4 | -37.6 |
| Logone at Baikoum | -34.4 | -60.5 |
| Logone at Bongnor | -36.6 | -64.3 |
| Sanaga at Edea | -12.8 | -22.5 |

Table 8 shows the available water resources per capita in various river basins in Cameroon considering only projected increases in the population in 2025 and 2050. On the other hand, Table 9 presents the available water per capita in the same river basins considering the projected increases in the population and decreases in flow rate due to climate change. It can be observed that with or without climate change, up to the year 2050, Cameroon will still have adequate water resources in all its river basins since the available water resources per capita in all basins is greater than 1700 $m^3$. As such, attaining and sustaining water security in Cameroon will not be constrained by insufficient water quantity.

**Table 8**: Available water resources in various river basins in Cameroon considering only projected increases in the population.

| River Basin | 1992 estimates IRWR ($m^3$x$10^9$) | Population | | | | Available water ($m^3$/year/capita) | |
|---|---|---|---|---|---|---|---|
| | | 2007 | 2012 | 2025 | 2050 | 2025 | 2050 |
| Lake Chad | 32.52 | 2 510 652 | 2 931 312 | 3 927 117 | 6 255 336 | 8 281 | 5 199 |
| Niger | 43.10 | 3 443 472 | 4 020 427 | 5 386 218 | 8 579 476 | 8 002 | 5 024 |
| Sanaga | 63.18 | 4 031 338 | 4 706 790 | 6 305 747 | 10 044 155 | 10 019 | 6 290 |
| Congo | 33.45 | 794 513 | 927 634 | 1 242 764 | 1 979 545 | 26 916 | 16 898 |
| Nyong & Coastal Basins | 94.82 | 7 120 752 | 8 313 836 | 11 138 154 | 17 741 488 | 8 513 | 5 345 |
| National | 267.88 | 17 900 727 | 20 900 000 | 28 000 000 | 44 600 000 | 9 567 | 6 006 |

Source: Adapted from MINEE and GWP (2009a, 2009b), and Population Reference Bureau (2012)

**Table 9**: Available water in various river basins in Cameroon considering the projected increases in the population and decreases in flow rate due to climate change**.**

| River Basin | 1992 estimates IRWR ($m^3$x$10^9$) | Projected IRWR per basin ($m^3$x$10^9$) | | Projected population | | Projected available water ($m^3$/year/capita) | |
|---|---|---|---|---|---|---|---|
| | | 2025 | 2050 | 2025 | 2050 | 2025 | 2050 |
| Lake Chad | 32.52 | 22.76 | 14.96 | 3 927 117 | 6 255 336 | 5 797 | 2 391 |
| Niger | 43.10 | 30.17 | 19.83 | 5 386 218 | 8 579 476 | 5 601 | 2 311 |
| Sanaga | 63.18 | 54.97 | 48.65 | 6 305 747 | 10 044 155 | 8 717 | 4 843 |
| Congo | 33.45 | 29.10 | 25.76 | 1 242 764 | 1 979 545 | 23 417 | 13 011 |
| Nyong & Coastal Basins | 94.82 | 82.49 | 73.01 | 11 138 154 | 17 741 488 | 7 406 | 4 115 |
| National | 267.88 | 219.50 | 182.20 | 28 000 000 | 44 600 000 | 7 839 | 4 085 |

Source: Adapted from MINEE and GWP (2009a, 2009b), and Population Reference Bureau (2012)

## CONCLUSIONS AND RECOMMENDATIONS

In general, the trend in Cameroon is that the mean annual rainfall is decreasing while there is increasing variability in the amount of rainfall. During the period 1968 to 2006, the surface water resources in the northern part of Cameroon reduced by about 30% while in the southern parts of Cameroon, the reduction was about 14%. Up till the year 2050, there will still be adequate quantities of internal renewable water resources in all river basins even when the impact of climate change is taken into consideration. However, there will be increased variability in water resources. The increasing variability in mean annual rainfall and in the long term mean annual flow rate in the rivers suggests there will be likely more extreme events with increasing possibilities of droughts and floods. This has implications on how water is to be managed if there is to be water in adequate quantity to ensure water security. More water storage dams will have to be constructed to mobilize water to be used for socio-economic development as well as for managing water related risks such as droughts and floods.

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