The Impact of Climate Change on the Rainfall Distribution in Suriname

by

Nurmohamed Riad J.[1]

[1] *Anton de Kom University of Suriname, Department Infrastructure, Leysweg, POB 9212, Paramaribo, Suriname (S.A), Phone:+597-465558 ext 351, Fax: +597-495005, Website: www.uvs.edu or http://www.geocities.com/ftew_infra/index.htm, E-mail: riadnur@hotmail.com, Homepage: www.geocities.com/riadnur/Index.htm)*

Abstract

From the several climate variables, rainfall shows the greatest variability in Suriname during the year and determines therefore in general the variability of freshwater resources over space and time. Analysis of historical and future rainfall data are therefore of great importance for management and planning purposes of water related projects. This paper presents the first results of such analysis. Rainfall and temperature data of 11 meteorological stations were analyzed for this purpose. Linear regression analysis and the 5-year moving average were used, determining whether there is climate change. The future rainfall and temperature predictions in Suriname are made through extrapolation of historical trends and the use of Global Circulation Models.

The analysis of historical rainfall data shows a negative tendency for stations Cultuurtuin, Friendshiptotness, Moengo, Tafelberg, Sipaliwini and NwNickerie. A positive tendency is found for the stations Albina, Brownsweg, Coeroeni, Kabalebo and Stoelmanseiland. Analysis of the historical temperature data shows a positive tendency for stations Coeroeni, Cultuurtuin, Kabalebo, Tafelberg, Sipaliwini, NwNickerie and Stoelmanseiland. However, these results do not match with those of the GCM's. Different models predict different values for the future annual average rainfall, whilst extrapolation of the historical trends shows a definite decrease by 2100. Temperature, however, shows a positive tendency. Here, results from GCMs and extrapolation of historical trends coincide for annual average change in temperature tendency.

Keywords: Climate Change; Rainfall; Modeling; Scenarios; Temperature

1. Introduction

Carbon dioxide (CO_2), the most important greenhouse gas along with methane (CH_4), nitrous oxide (N_2O), halo- and chlorofluor carbon (CFCs), is expected to double by 2100, causing global warming at high rate and consequently to dramatic changes in the world's climate. Climate change is defined as a significant variation in the mean state of the climate or its variability persisting for decade or longer. The Intergovernmental Panel on Climate Change (IPCC), refers climate change to any change in climate over time, whether due to natural variability or as a result of human activity.

According to this organization the earth's average global surface temperature has increased $0.6\pm0.2^{o}C$ in the 20^{th} century and under CO_2 doubling, the temperature is predicted to rise 1.5 to $4.5^{o}C$ by 2100, relative to 1990 levels. For the Latin American region, changes between 0.2 and $2^{o}C$ under low climate change scenarios and 2 to $6^{o}C$ under high climate change scenarios, are projected by 2100.

Together with the temperature, change in the global precipitation will take place, inclusive the intensity and frequency of rainfalls, the location and patterns of extreme weather events. GCMs simulations also have shown an increase in precipitation over the tropical areas ($10^{o}N$ to $10^{o}S$) by 0.2 to 0.3% per decade. This increase is mainly expected in highlands of the tropics where already sufficient precipitation falls. (Lozan J, Grabl H *et al*, 1998; Albritton D, Allen M *et al*, 2001; Bergkamp B and Orlando B, 1999).

Global climate change is also the main cause of sea level rise, resulting in flooding of low lying areas and salt water intrusion in coastal wetlands its tributaries and aquifers. World's respond to this global warming has resulted in signature of the United Nations

Convention on Climate Change in Rio de Janeiro in 1992. Suriname became a party to this Convention on October 1997.

As Suriname is richly endowed with freshwater resources (rivers, swamps, wetlands, lakes, aquifers), climate change will have significant impacts on the environment and socio-economy of the country. A decrease in rainfall will result in a decrease of river runoff and intrusion of saltwater in the lower parts of our main rivers. Together with sea level rise, coastal groundwater's will also be affected by saltwater intrusion. Since most of our agricultural and fisheries activities are concentrated in the coastal zone, changes in freshwater resources may finally enhance the poverty level of the country. Further more, less rainfall will also have negative impacts on the biodiversity, coastal and marine ecosystems and forestry. The combine effect of these changes will further disrupt the entire hydrological cycle of the region, causing on its own turn natural disasters as extreme draughts and forest fires.

This concern has been viewed generally in some publications, showing statistically the negative trend of rainfall and its distribution. Becker C. (1993) mentioned a decrease in precipitation of 4 mm annually over the past 100 years at Paramaribo. Amatali M. and Naipal S. (1999) analyzed rainfall stations along the coast of Suriname and have showed, except for some locations, a general decrease in average annual rainfall in the coastal area of Suriname. In summary, a change in the quantity and distribution of rainfall, will immediately affect the availability of freshwater, its use, planning and management of water related projects.

This paper will discuss the following issues:

- analysis of the historical monthly and annual rainfall time series to identify trends,
- analysis of historical monthly and annual temperature time series to identify trends, and
- predictions of future rainfall and temperature quantity and distribution.

2. Description of the Study Area

The study area covers the entire land area of Suriname, located on the northeastern coast of South America and covers an area of approximately 163,800km^2. About 67% of all rainfall in Suriname returns to the atmosphere by evapotranspiration and about 33% flows into the Atlantic ocean. About 30% of the area, mainly the coastal plain, rises only a few meters above mean sea level. The southern mountain range and some mountainous areas in the center of the country (20% of the area), rises above 300m above sea level, some of those above 500m, and few peaks exceed 1000m (Tafelberg 1080m and Julianatop 1280m). The rest of the country (45%) has altitudes between 100-300m. The country is for ±85% covered with tropical forest.

Climate of Suriname is classified as tropical humid, according to Koppen and is moderated by trade winds. Four seasons are observed, statistically, during the year: (a) the long rain season (April-mid August), (b) the long dry season (mid August – December), (c) the short rain season (December- February) and (d) the small dry season (February- April). The mean wind speed averages between 1-3m/s in coastal areas and decreases rapidly land inward. Relative humidity averages about 75-90% in the coastal areas and lowers in the central and southern regions of the country. The mean sunshine is about 58% during the year. Daily temperature varies in average between 23-31^{o}C. Average annual rainfall in the country varies from less than 1500mm in the coastal area to 3000mm/year and more in the central part of the country. Average annual evaporation in the country varies from about 1600 mm to 1900 mm/year. (SPS/OAS, 1988; Duba D., 1971; Tan T.B, 1989).

3. Data Availability

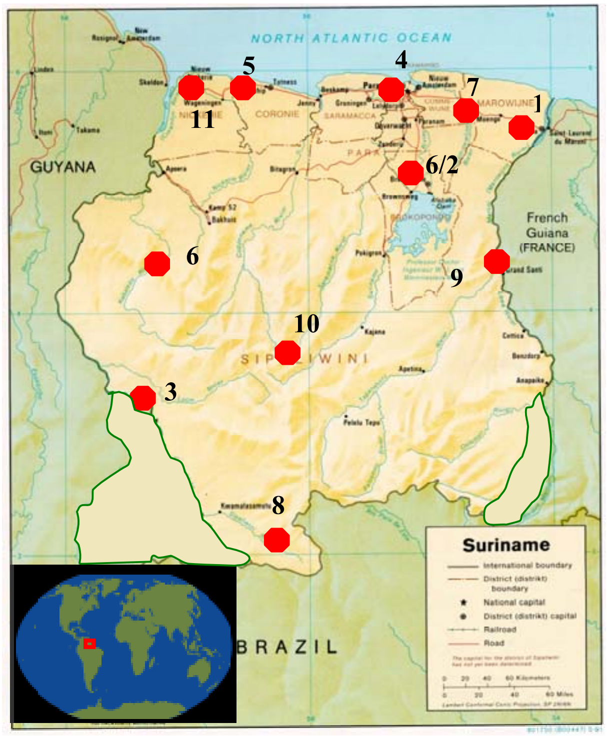
For determination of climate change and its impact on the rainfall distribution within the country, 11 meteorological stations were selected, based on record lengths ($\geq$15 years) and precision and reliability of data. Table 1 below presents the meteorological stations selected for this study and figure 1 the locations of the stations. It should be noted that due to the civil war, most of the stations located in the hinterland, were closed in 1985/86.

Table 1. Station name, WMO number, position and available data

Station	Name - WMO Name	Position	Precipitation Data (period (years))	Temperature Data (period (years))
1. Albina	803 KALBI - 81208	05.39N-54.03W	1915-1985 (71)	-
2. Brownsweg	64 BROW - *	05.01N-55.09W	1911-1986 (76)	-
3. Coeroeni	109 KCOER - 81253	03.22N-57.20W	1961-1985 (25)	1971-1986 (16)
4. Cultuurtuin	602 KCULT - 81201	05.50N-55.10W	1900-1999 (100)	1971-1999 (29)
5. Friendshiptotness	301 FRIE - *	05.52N-56.20W	1904-1985 (82)	-
6. Kabalebo	110KKABA - 81260	04.24N-57.13W	1961-1985 (25)	1971-1986 (16)
7. Moengo	701 MOEN - 81206	05.37N-54.24W	1919-1985 (67)	-
8. Sipaliwini	112SIPA - *	02.02N-56.07W	1961-1986 (26)	1971-1985 (15)
9. Stoelmanseiland	805 KSTOE - 81209	04.21N-54.25W	1959-1986 (28)	1971-1999 (29)
10. Tafelberg	513 KTAF - 81250	03.47N-56.09W	1959-1986 (28)	1971-1986 (16)
11. NwNickerie	209 KNICK - 81202	05.56N-57.00W	1960-1999 (40)	1971-1986 (16)

* The stations without WMO number are rainfall stations

Figure 1. Locations of rainfall and temperature stations



* The red circle in de map shows the location of the station and the number is corresponding with the number presented in table 1

4. Methodology

The methods used for analyzing long term annual and monthly data of rainfall, temperature and climate change impacts are:

- linear regression analysis,

- the 5-year moving average, and

- extrapolation of historical trends and simulations of Global Circulation Models.

Two periods have been defined for the above analysis: a short period (for rainfall: 1961-1985 (25 years), for temperature: 1971-1985 (15 years)), and a long period (1900-1999) for rainfall only.

5. Description of Climate Change Scenarios

To predict future rainfall and temperature developments, historical trends along with physically based GCMs simulations were used. GCMs are complex, gridded with a resolution of 250x250km horizontal, 1km vertical, three dimensional computer models of the climate system, developed from numerical weather forecasting models. They are considered to provide the best basis for construction of climate change scenarios, but are still not yet suitable for estimating regional or local changes.

To simulate baseline climatic data (1 x CO_2) from world climatic data (1961-1990) and data for year 2030, 2060 and 2100 (2 x CO_2), 5 GCMs were selected from the MAGICC/SCENGEN model (2000), a global and regional climate change scenario generator. These are: HadCM2 (UK Hadley Centre for Climate Prediction and Research), ECHAM4 (German Climate Research Centre), CGCM1 (Canadian Centre for Climate Modeling and Analysis), GFDL-TR (US Geophysical Fluid Dynamics Laboratory), CSIRO2-EQ (Commonwealth Scientific and Ind. Research Organization) and CCSR-NIES (Japanese Centre for Climate Systems Research).

The future monthly and annual precipitation and temperature, under climate change conditions for Suriname, were calculated as follows: for precipitation the quotient (2 x CO_2/1 x CO_2) was multiplied with the observed baseline data and for temperature the difference (2 x CO_2 - 1 x CO_2) was added to the observed baseline data (1961/1971-1985) for whole Suriname.

6. Results and Analysis

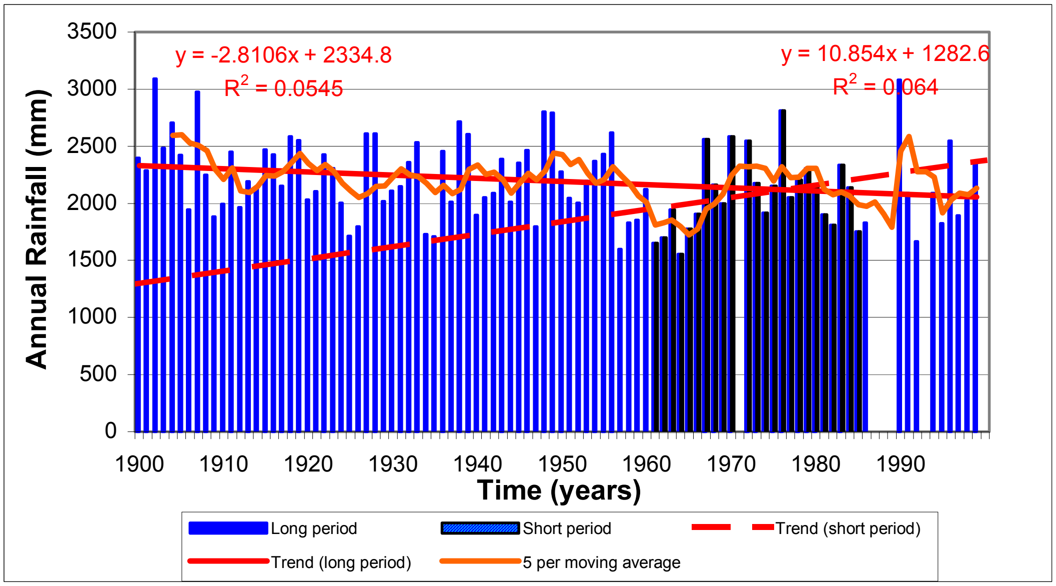
6.1 Rainfall Analysis and Trends

The time series of monthly and annual average precipitation have been examined both graphically and numerically, as they provide a great opportunity for detecting and describing climate variability. Long term trends (1900-1999) and short term (1961-1985) trends derived from linear regressions of annual average rainfall shows clearly that rainfall is increasing and decreasing at different locations. The short period analysis shows that at 8 stations (Albina, Brownsweg, Coeroeni, Cultuurtuin, Kabalebo, Moengo, NwNickerie, Stoelmanseiland) the annual average rainfall is increasing by 3 to 41 mm a year and at least at 3 stations (Friendshiptotness, Sipaliwini, Tafelberg) is decreasing with 2.4 to 14.5 mm a year. The highest rate of increase was identified at Albina and Stoelmanseiland and the lowest increase at NwNickerie. Again, the highest rate of decrease was identified at Tafelberg but the lowest rate at Sipaliwini. The long period trend analysis shows that annual average rainfall is increasing at 5 stations (Albina, Brownsweg, Coeroeni, Kabalebo, Stoelmanseiland) with 0.83 to 16.34 mm a year and is decreasing at 6 stations (Cultuurtuin, Friendshiptotness, Moengo, NwNickerie, Sipaliwini, Tafelberg) with 2.4 to 14.34 mm a year. The highest rate of increase was identified at Stoelmanseiland and the lowest increase at Albina. The highest rate of decrease was identified at Tafelberg and the lowest rate at Sipaliwini. From these analysis, clearly follows that increase in historical annual rainfall is concentrated in the east and Westside of Suriname whilst a decrease is observed in central part from the northt to the south of Suriname.

It appears moreover that between the trends analysis for the short and long period at a particular rainfall station no clear relation exist. For some stations such as NwNickerie, Moengo, Cultuurtuin, positive trends are identified in the short period analysis, while for the long period analysis, negative trends are found. In general, it is also found that rates from long term period analysis are lower than for short period analysis such as in Albina, 41mm/year (1961-1986) compared with 0.83mm/year (1915-1985). When using moving average techniques, it is concluded that similar results are found as the regression analysis. However, shifts in the mean, can be better identified using this technique. At Moengo for example, the moving average identified 3 different trend parts, within the observed data: a constant trend from 1918 to 1955, a decreasing trend from 1955 to 1963 and an increasing trend from 1963 to 1985. At Brownsweg, a constant trend is identified during 1911-1950 and 1970-1985, while between 1950-1970 the annual average rainfall is decreasing.

Figure 2 shows the recession tendencies and moving mean of annual rainfall at Cultuurtuin for the short period and long period.

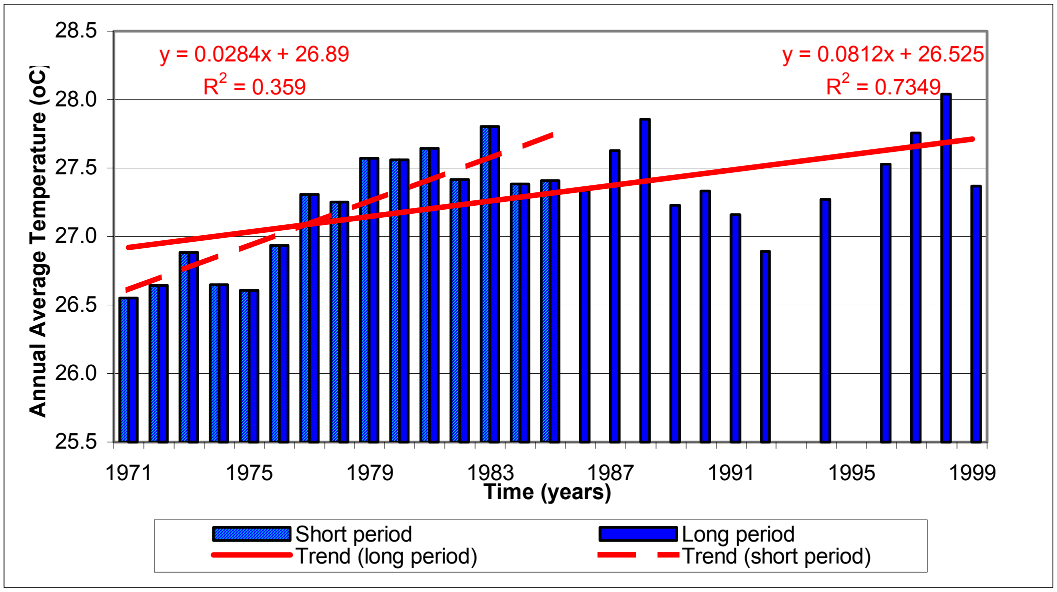
Figure 2. Trend for annual average rainfall at station Cultuurtuin during a 25 year period (1961-1985) and 100 year period (1900-1999)



6.2 Temperature Analysis and Trends

Both long-term (1900-1999) and short term trends (1971-1985) shows that the annual average temperature in Suriname is increasing at stations Coeroeni, Cultuurtuin, Kabalebo, NwNickerie, Sipaliwini, Stoelmanseiland and Tafelberg. The short period analysis shows an increase of 0.001 to 0.081°C/year and long period trend analysis shows an increase of 0.001 to 0.063°C/year. The highest rates of increase in temperature is found at Sipaliwini followed by Cultuurtuin and the lowest rate of increase at Coeroeni followed by Kabalebo. Analysis in trends of both periods does not show much difference. However, analysis of monthly maximum temperature at the stations indicate a positive trend, varying from 0.001 to 0.005°C/year for maximum temperature and a positive trend, varying from 0.001 to 0.004°C/year for minimum temperature. Figure 3 shows the positive tendency of annual temperature at station Cultuurtuin for the short period and long period.

Figure 3. Trend for annual average temperature at station Cultuurtuin during a 15 year period (1971-1985) and 28 year period (1971-1999)



6.3 Climate Change Impact on the Rainfall Quantity and Distribution

Results from the 5 GCMs do not differ much from the observed data and therefore represent the yearly pattern well. However, their prediction differ from each of them by year 2030, 2060 and 2100.

The highest estimates is given by the CCSR-NIES model, predicting changes of -35 to 188% for average monthly rainfall during the year by 2100. HadCM2 predicts changes of –3 to –50%, ECHAM4, -50 to 35% and GFDL-TR, -27 to 40%. The CSIRO2-EQ model predicts the lowest changes, -4 to 7%. The highest rates of monthly increase and decrease are found in the short (December till February) and long wet seasons (June till August).

From the average annual rainfall analysis it was found that the highest decrease is predicted by the HadCM2 model, accounting for about 11% by 2030, 20% by 2060 and 33% by year 2100, reference to 1961-1985 values. The highest increase is predicted by the CCSR-NIES model, 7% by 2030, 40% by 2060 and 31% by year 2100. The other models predict slight increases or decreases in average annual precipitation, varying from –3 to 0.4 by 2030, -0.5 to 1.4 by 2060 and –5 to 1 by year 2100.

When using historical trend analysis, it is found that the average annual precipitation for Suriname will be decreasing with 1% by 2030, 1.6% by 2060 and 2.5% by 2100. This result is close to the predictions of the GFDL-TR, ECHAM4 and CSIRO2-EQ model.

6.4 Climate Change Impact on the Temperature Quantity and Distribution

Here also the GCMs results are used as they represent the baseline observed data rather good. It is found that all models predict an increase in average monthly temperature by year 2100.

The highest estimates are given by HadCM2, 3.2 to 4.2^{o}C a year, and ECHAM4, 2.2 to 4.3^{o}C a year, and the lowest estimates by CSIRO2-EQ, 1.3 to 1.7^{o}C a year. GFDL-TR predict changes between 1.4 to 2.8^{o}C a year and CCSR-NIES, 1 to 2.9^{o}C a year. The highest rates are in general predicted in the period December till January and May till August.

From the average annual temperature analysis, it was found that the highest increase in average annual temperature is predicted by the HadCM2 model, about 1.2^{o}C by 2030, 2.2^{o}C by 2060 and 3.5^{o}C by 2100, reference to 1971-1985 values. The lowest increase is predicted by the CSIRO2-EQ model with values of 0.5^{o}C by 2030, 1.8^{o}C by 2060 and 1.5^{o}C by 2100. ECHAM4 predicts changes of 1.1^{o}C by 2030, 2^{o}C by 2060 and 3.2^{o}C by 2100, GFDL-TR 0.7^{o}C by 2030, 1.3^{o}C by 2060 and 2.1^{o}C by 2100, CCSR-NIES 0.7^{o}C by 2030, 1.4^{o}C by 2060 and 2.3^{o}C by 2100.

Again using historical trend analysis, it is found that the average annual temperature will increase with about 1.1^{o}C by 2030, 1.8^{o}C by 2060 and 2.8^{o}C by 2100. These projections in temperature change are within the range of the different models and were also projected by the IPCC under low and high case scenarios.

7. Conclusions and Recommendations

Basic conclusions and recommendations drawn from this study are:

- Historical trend analyses of annual average rainfall during the period 1961-1985 have shown a decreasing tendency in central part of Suriname from the north to the south and an increasing tendency in the east and west part of Suriname. Reason(s) for this change has yet to be investigated.
- Historical trend analyses of annual average temperature during the period 1971-1985 have shown that there has been an increasing tendency over Suriname. Reason(s) for this change also need to be investigated.
- Results of regression analysis based on short and long-term periods do not match with each other. For this purpose, long-term data ($\geq$ 30 years) for trend analysis is advised.
- Application of linear regression analysis and moving averages results, generally, in similar trends. However, moving average could be a better indicator for detail trend analyses, as it provides more information about the course of the trend over the period.
- An obvious correlation between the historical annual average rainfall tendency and temperature tendency was not found. Therefore, the relation between observed temperature and rainfall at a particular location and their distribution need to be analyzed further.

- The changes in annual average rainfall and temperature, based on GCM outputs are not the same for all models. Some models predict an increase or decrease or both, in monthly and annual average rainfall and temperature by 2030, 2060 and 2100. Extrapolation of historical annual average rainfall trends shows only a decrease, whilst extrapolation of historical annual average temperature trends shows only an increase, for Suriname by 2030, 2060 and 2100. The predictions are however within the range of those predicted by the IPCC for the tropics.
- For further studies, regional climate change scenarios are needed. For this purpose additional data are required, not only from Suriname but also from the neighboring countries, La Guiane in the east and Guyana in the west.

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Note on the author

Nurmohamed Riad J. studied at the University of Suriname (BSc in Infrastructure) and the Free University Brussel, Belgium (MSc in Water Resources Engineering). He is presently senior lecturer and researcher at the Department Infrastructure at the University of Suriname. At present, he is doing a PhD research about "The Impact of Climate Change on the Water Resources of Suriname" at the University of Suriname in cooperation with the Free University of Brussels, Belgium.