 doi:10.20944/preprints201801.0151.v1

Peer-reviewed version available at *Hydrology* **2018**, *5*, 12; doi:10.3390/hydrology5010012

Article

Impact of Climate Change on Water Resources Availability in a Trans-Boundary Basin in West Africa: Case of Sassandra

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Abstract: In the context of climate change in West Africa characterized by a reduction of precipitation, this study was conducted to evaluate the impact of climate change on water resources from now to the end of the 21st century in the transboundary watershed of the Sassandra River shared by Guinea and Côte d'Ivoire. Historical and future climate (Representative Concentration Pathways or RCPs 4.5 and 8.5 scenarios) data were projected with the model. The Abdus Salam ICTP RegCM4 was used. The hydrological modeling of the river basin was carried out with the conceptual hydrological model, GR2M. This model is a monthly time steps model that allows the assessment of the discharge of the Sassandra River for each climate scenario according to the 2030 (2021–2040), 2050 (2041–2060), 2070 (2061–2080), and 2090 (2081–2100) horizons. The results showed a reduction of the annual discharge when compared to the baseline (1961–1980). For the RCP 4.5, the observed values went from –1.2% in 2030 to –2.3% in 2070 and rose to –2.1% in 2090. Concerning the RCP 8.5, we saw a variation from –4.2% to –7.9% in the 2030 and 2090 horizons, respectively. With the general decrease of rainfall in West Africa, it is appropriate to assess the impact on water resources on the largest rivers (Niger, Gambia, and Senegal) that irrigate the Sahelo-Saharian zone.

Keywords: climate change; GR2M; hydrologic modeling; transboundary river; West Africa.

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1. Introduction

West Africa is relatively well endowed with water resources that are renewed each year through the normal hydrological cycle [1]. Thus, the problem with water is not so much the total quantity of water availability in the region, but its unequal distribution in space and time. In this context, Guinea has the particularity of being the main water provider for many countries in the region, hence the name of Guinea as the water tower of West Africa. Indeed, Guinea possesses 14 transboundary rivers and the springs of this river system are based in this country [2]. According to the study of Sidibé and Oulaye [3], 130 km^3 of water leaves the territory of Guinea annually to supply the biggest rivers of West Africa (Niger, Senegal, and the Gambia), flowing to the sahelian countries (Mali, Mauritania, Niger) and to many rivers in Côte d'Ivoire, Guinea-Bissau, Sierra Leone, and Liberia (namely the Makona, Loffa, Cavaly, Bafing, Bagbé, and Sassandra Rivers).

Climate change caused by the increase of greenhouse gasses in the atmosphere has significantly influenced the water balance by causing changes in evapotranspiration rates, temperature, and rainfall [4]. In West Africa, these changes have had a negative impact on the water resource availability as water resources are dwindling in the region due to the overall decline of rainfall [5–14].

Several studies have been carried out in the transboundary river basin of Sassandra concerning the assessment and management of water resources [15–22], particularly, Ardoin et al. [19], Rescan, [20] and Yao [22], who used the Génie Rural à 2 paramètres Mensuel (GR2M) hydrological model.

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The works of Ardoin et al. [19] and Rescan [20] showed that the Sassandra River runoff and water availability would increase from 10% to 13% during the first half of the 21st century (horizon 2050) before decreasing to horizon 2080 when compared to the reference period 1971–1995. The latter in their studies modeled climate from the HadCM3 global climate model of spatial resolution, 2.5° x 3.75° with the greenhouse gas emission scenario A2. Recently, Yao [22] worked on the hydrologic modeling of a tributary of the Sassandra River (the Lobo). This study was carried out using the regional climate model RegCM3 of spatial resolution of 0.44 ° x 0.44 ° under the A1B emission scenario. Yao [22] improved a deficiency by reducing the scale of climate modeling to better appreciate local specificities.

This study, which concerns almost all of the watershed of Sassandra, used climate data generated from the RegCM version 4 model under the Representative Concentration Pathways (RCPs) 4.5 and 8.5 (spatial resolution: 0.25° x 0.25°) to first, evaluate climate change in West Africa and its impact on the natural discharge of Sassandra River at Soubré; and second, estimate the headwater inflow from Guinea, the water tower of West Africa, to Côte d'Ivoire.

2. Materials and Methods

2.1. Study Area

The Sassandra River is a transboundary river located in West Africa that has its spring in the Forest Guinea (Guinea) and Denguélé (Côte d'Ivoire) regions. It crosses the western part of Côte d’Ivoire and flows into the Gulf of Guinea at the city of Sassandra. It extends from 5.5°N to 10.5°N with an area of 62,700 km^2 of which Guinea possess 13% and a length of 650 km (Figure 1). Elongated with Kc equal to 1.39, the Sassandra River Basin has no pronounced topography, except in the Guinean part where the peaks are around 1300 m and in the Man region where Mount Tonkpi peaks at 1190 m. The mean of the basin altitude is 385 m.

The Sassandra Basin spreads over three different climatic regions where hydrological regimes are quite similar to precipitation regimes [23]. In the south, a humid tropical climate is observed and corresponds to the region of Soubré-Gagnoa. It is characterized by two rainy seasons from March to June and from September and October, and two dry seasons that go from November to February and from July to August. The northern part of the river basin is characterized by a transitional tropical climate or Sudanese climate (station of Odienné) where the most abundant annual precipitation occurs mostly during the months of July, August, and September. From November to March-April there is drought. The mountain climate is located in the center-west of the basin in the mountains of Man. This climate is characterized by a short dry season (November to February) and a rainy season that extends from March to October with the precipitation peak in September. The Forest Guinea region is characterized by a long rainy season of nine to ten months. The annual rainfall varies between 1700 and 2500 mm. Figure 2 and Table 1 summarize the characteristics of the basin's climate.

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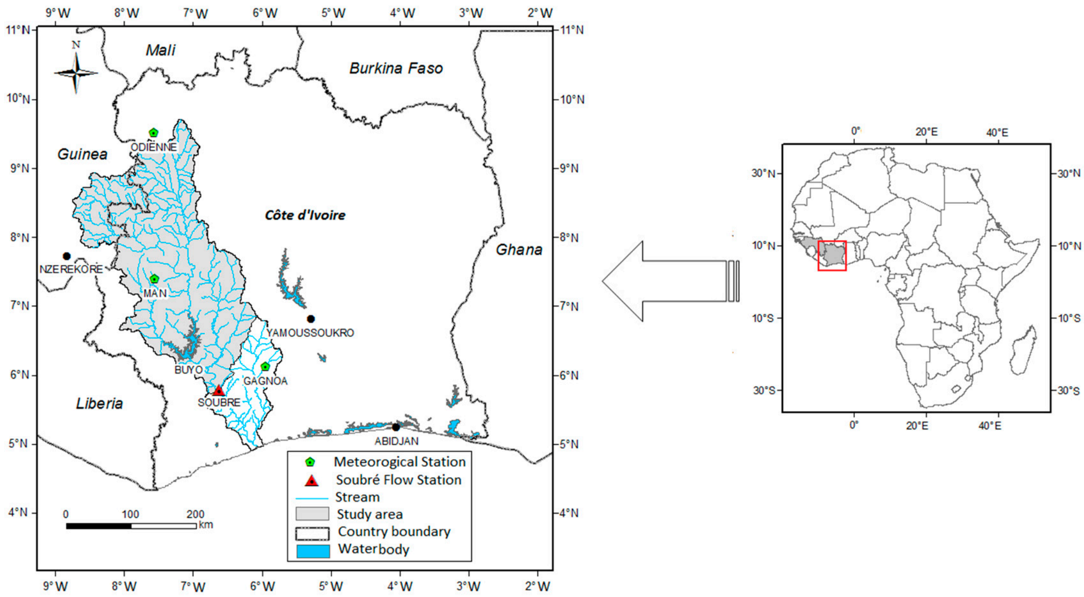

Figure 1. Sassandra River Basin at Soubré.

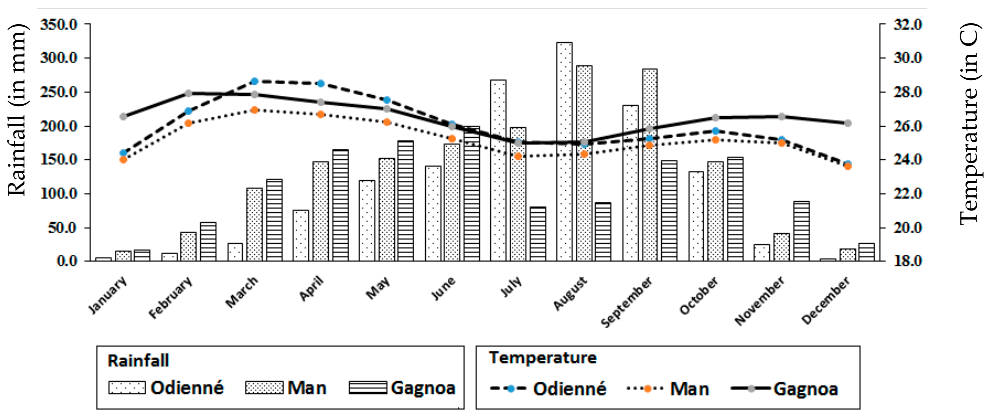

Figure 2. Monthly averages over 30 years (1961–1990).

Table 1. Annual averages over 30 years (1961–1990).

	Longitude (Decimal Degree)	Latitude (Decimal Degree)	Temperature (in °C)	Rainfall (in mm)	PET (in mm)
Odienné	–7.5660	9.5000	26.0	1365.9	1559.9
Man	–7.5167	7.4000	25.2	1617.8	1411.0
Gagnoa	–5.9500	6.1333	26.5	1322.7	1632.4
Average	-	-	25.9	1435.5	1534.4

The Sassandra possess two hydroelectric dams: Buyo, built in 1980 (capacity, 165 MW), and Soubré (capacity, 270 MW) whose construction was completed in 2017. The annual mean discharge at the station of Soubré before 1980 (1954–1980) was about 500 m³/s and 331 m³/s after (1981–2005). Regarding vegetation, the natural ecosystems in the basin are shared between the wooded savannah in the northeast and the humid dense forest in the center and south of the basin [24]. Since the 1960s, in the Ivorian part of the basin, human activities have been conducted such as timber extraction for export and the mobilization of vast territories for cash crops and industries (cotton, cocoa, coffee, rubber and palm oil), then to the shifting cultivation on slash-and-burn [25]. Today, with the economic recovery and its opening to the outside world, the annual deforestation rate in Guinea is

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estimated at 0.5%, i.e., about 35,000 hectares of forests lost every year due to agriculture, mining exploitation (bauxite and other minerals), fuelwood and service harvesting [26]. The geology consists essentially of the Precambrian basement. The soils are ferralitic type and not very permeable, but have a significant retention capacity [27].

2.2. Available Data

2.2.1. Historical Data

The monthly observed climatic data (precipitation and temperature) from 1956 to 1980, used in this study was provided by the Société d'Exploitation et de Développement Aéroportuaire, Aéronautique et Météorologique (SODEXAM).

The river discharge data at the station of Soubré were from the database of the Office National d'Eau potable (ONEP). These were the monthly flows from 1956 to 1980 as after 1980, the Buyo dam located upstream of the Soubré station no longer allowed a natural flow. These flows were converted into depth of runoff flowed for the calibration and validation of the hydrological model.

The soil characteristics or the Water Holding Capacity (WHC) of the soil reservoir (S) of the hydrological model GR2M corresponded to the soil water capacity. This information was estimated using the FAO Soil Map (FAO-UNESCO 1974–1981). This consisted in calculating the average of the capacities of all soil types in the watershed through weighting with their respective superficies.

2.2.2. Future Climate Simulated Data

The future climate data were provided by the United Nations University Institute for Natural Resources in Africa (UNU-INRA) in Accra (Ghana). These data include daily temperature, precipitation, and potential evapotranspiration (PET) of the Economic Community of West African States (ECOWAS) zone projected by Sylla [28] up to 2100. The methodology used to simulate these climate data was the Abdus Salam International Centre for Theoretical Physics (ICTP) Regional Climate Model version 4 (RegCM4; [29]). Indeed, RegCM4 has been used at a resolution of 0.25° x 0.25° (25 km x 25 km) to dynamically downscale a set of CMIP5 ESMs over West Africa for the two Intergovernmental Panel on Climate Change (IPCC) core RCPs (RCP4.5 and RCP8.5). The driving data were derived from the CMIP5 Global Climate Models (GCMs).

The basic strategy has been to use the GCMs to simulate the response of the global circulation to large-scale forcings and the RCM to (a) account for sub-GCM grid scale forcings (e.g., complex topographical features and land cover heterogeneities) in a physically-based way; and (b) enhance the simulation of atmospheric circulations and climatic variables at fine spatial scales. This technique therefore constitutes the most appropriate tool to generate regional climate change data for West Africa and has been used extensively over the region (e.g., [30–34]). For more details about the CMIP5 models, see Taylor et al. [35].

2.3. Climate Change Analysis

We compared the annual simulated climate data up to 2100 according to RCPs 4.5 and 8.5 with observation values in a baseline period (1961–1980). Thus, the variations of mean precipitation, temperature, or basin discharge at different horizons were calculated in relation to the baseline period (1961–1980). The four horizons were: 2021–2040 (2030), 2041–2060 (2050), 2061–2080 (2070), and 2081–2100 (2090). The variations are expressed as a percentage and are calculated according to the following formula:

$$\Delta_i^{hori} = 100 \times \frac{(\overline{X_i^{hor}} - \overline{X^{ref}})}{\overline{X^{ref}}} \quad (1)$$

where $\overline{\Delta_i^{hor}}$ is the annual mean value calculated over the specified horizon; $\overline{X^{ref}}$ is the annual mean value calculated over the reference period; and i the time step {2030, 2050, 2070, 2090}.

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This rate of change represents the relative increase or decrease in annual precipitation, temperature, or basin discharge for the future.

2.4. Bias Correction or Delta Approach

Climate models often have biases in climate simulation. This was the case for the projected climate data used in this study. Indeed, rainfall is significantly underestimated and to a lesser extent, temperatures. Thus, before using these data for the hydrological modeling, we corrected these errors using the Delta approach. This approach was applied to the most relevant climate variables in hydrology, notably rainfall, temperature, and ET_0 [36]. It defines some correction factors by comparing the statistical properties of simulated variables during the reference period to those of the historical observations. These factors were then applied to the climate simulations to correct the biases. The method permits to correct two types of disturbances:

- "Additive" disturbances for temperatures

$$T_{scen,j,h} = T_{obs,j} + (T_{scen,m,h} - T_{réf,m}) \quad (2)$$

where $\boldsymbol{T_{scen,j,h}}$ is the daily temperature of the considered horizon; $\boldsymbol{T_{obs,j}}$ is the daily observed temperature; $\boldsymbol{T_{scen,m,h}}$ is the monthly inter-annual mean temperature of the horizon considered; $\boldsymbol{T_{ref,m}}$ is the monthly inter-annual mean temperature of the reference period; and $\boldsymbol{T_{scen,m,h} - T_{ref,m}}$ is Delta T.

- "Multiplicative" disturbances for the precipitations

$$P_{scen,j,h} = P_{obs,j} \times (P_{scen,m,h} / P_{réf,m}) \quad (3)$$

where $\boldsymbol{P_{scen,j,h}}$ is the daily precipitation of the considered horizon; $\boldsymbol{P_{obs,j}}$ is the daily precipitation observed; $\boldsymbol{P_{scen,m,h}}$ is the monthly inter-annual mean precipitation of the horizon considered; $\boldsymbol{P_{ref,m}}$ is the monthly inter-annual mean precipitation of the reference period; and$\boldsymbol{P_{scen,m,h}}/\mathrm{P}_{ref,m}$ is the Delta P/P or ΔP or ratio.

2.5. Hydrological Model, GR2M

For the hydrological modeling of the Sassandra watershed, the *Génie Rural à 2 paramètres Mensuel* (or GR2M) model was used in this study. GR2M is a conceptual rainfall-flow model with two reservoirs. The reservoir S has a capacity maximum X_1 that carries out the simulation of discharge on a monthly basis from rainfall data and mean monthly evapotranspiration over a basin. The concept pattern of the model is shown in Figure 3 and described has follow [37]. In the GR2M model, the production function relies on a soil moisture store (S). Given a precipitation P, the level S in the store becomes S_1. The parameter X_1, the maximum capacity of the store, is positive and is given in mm. The excess precipitation is given by P_1. Given the potential evapotranspiration E, the level S_1 becomes S_2. The production store (X1) then empties with a percolation P_2 and its level, ready for the computations of the following month, given by S.

The total precipitation that reaches the routing store is given by P_3. The level R in the routing store then becomes R_1. The parameter X_2 is positive and has no dimension. The level in the store becomes R_2. The store, with a fixed capacity equal to 60 mm, empties following a quadratic function. The streamflow is given by Q. The model has two parameters to optimize during its calibration:

- $X1$: the capacity of the production store (mm);
- $X2$: the exchange coefficient (no dimension).

The use of the GR2M model has yielded good results on several basins in West Africa [13,19,20,22,38].

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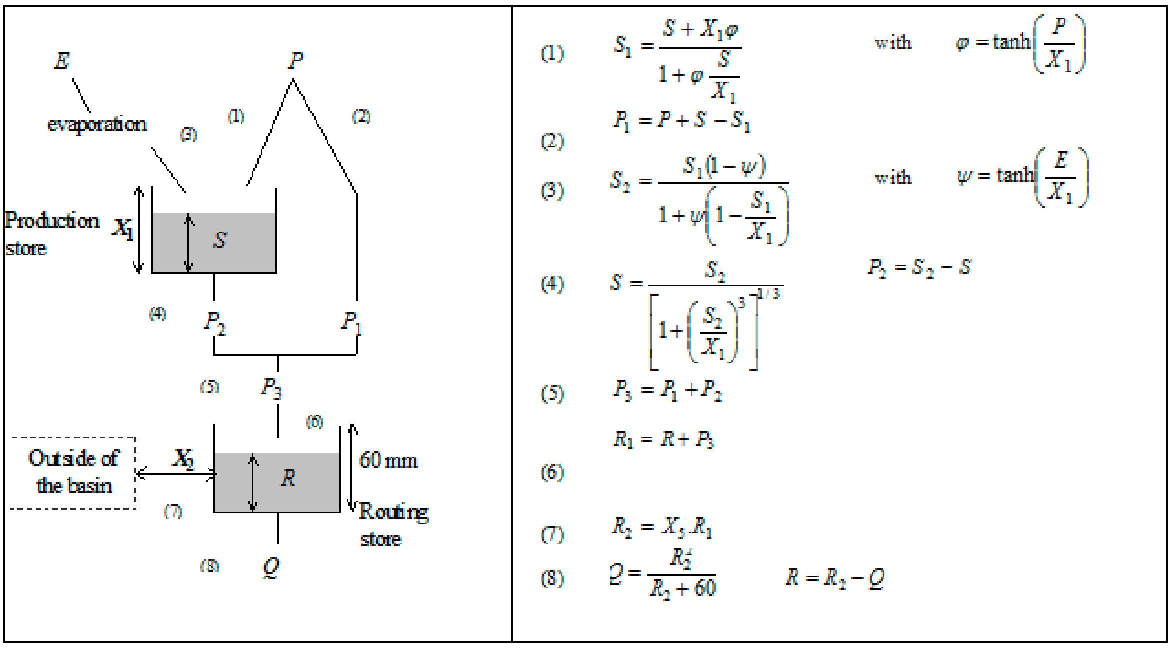

Figure 3. Scheme of the conceptual the model GR2M (Source, [37]).

For calibration and validation of the model, testing of the different sub-divisions of the discharge series was conducted using the method described by Mouelhi et al. [37]. The best periods were 1961–1967 and 1971–1977 for calibration and validation, respectively. In order to use the optimization criteria, we chose the objective form proposed by Perrin [39], which is a modification of the explanation coefficient for Nash and Sutcliffe [40], called "Nash":

$$NASH = \left[1 - \frac{\sum_i (Q_o^i - Q_c^i)^2}{\sum_i (Q_o^i - Q_m)^2}\right] \quad (4)$$

where Q_o^i and Q_c^i indicate the observed and calculated flows, respectively; and the Q_m is the observed mean flow over the whole period of observation without any missing data. The model is considered to be performing well when the estimated flows approach the observed flow, that is, when the NASH criterion value is close to 1. We can affirm that values less than 0.6 indicate an important difference between the observed and simulated discharge by the model.

The simulation of future discharge was carried out over the period 2021 to 2100. The input data, precipitation, and potential evapotranspiration (PET.) were simulated according to the climate scenarios RCP 4.5 and 8.5. Ultimately, nine simulations were carried out: one simulation for the historical period of 1961–1980, and eight simulations for the RCP 4.5 and 8.5 scenarios for the four horizons 2040, 2060, 2080, and 2100. To make simulation possible, the parameters (X1 and X2) used for calibration and validation over the periods already observed were kept constant.

2.6. Headwater Inflows from Guinea Assessment

To evaluate the quantity of water coming from Guinea, which supplies the Sassandra River, we were confronted by a lack of data for modeling with GR2M. We estimated the variation of this quantity based on the results of Roudier et al. [41]. Indeed, according to the study, the change in runoff is a function of the variation in precipitation in the Sassandra Basin according to Equation (5). Thus, the projected flows were calculated from Equation (5) and the projected precipitation data on the Guinean part of the basin according to RCP 4.5 and 8.5 scenarios.

$$\text{Runoff change} = 2.0 \times \text{rainfall change} + 7.7 \quad (5)$$

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This equation has established with a Pearson coefficient of correlation equal to 0.68 for the Sassandra River Basin.

3. Results and Discussions

3.1. Climate Change Analysis

3.1.1. Temperatures

Figure 4 presents the inter-annual monthly mean temperatures of the Sassandra catchment obtained from projected climate data according to RCPs Scenarios 4.5 and 8.5. It shows a continuous increase of the projected temperatures up to 2090 when compared to the value observed during the baseline period (1961–1980) i.e., 25.9 °C, regardless of the climate scenario. This increase in temperature was more marked in the RCP 8.5 scenario, which was the most pessimistic scenario [42]. Indeed, the highest temperatures were observed during RCP 8.5. Thus, by the 2090 horizon, the mean temperature in the watershed will be 32.9 °C during the month of March (hottest month) and 29.6 °C in July (coolest month). For RCP 4.5, the temperatures will be 30.2 °C and 27.2 °C for the months of March and July, respectively. According to the conclusions of Sylla [28] for the West African region, our analysis for the Sassandra Basin showed significant variations in extreme values (low and high temperatures). Thus, for the extreme months (March and July), we observed average variations around +5.1 °C and the other months showed average increases +4.8 °C on the horizon 2090.

These results confirmed the analysis of Sylla [43] and the last IPCC report concerning the projected temperatures in West Africa. Indeed, West Africa is expected to be strongly impacted by temperature increase. The latest IPCC report showed a warming range of 3–6 °C above the late 20th century baseline.

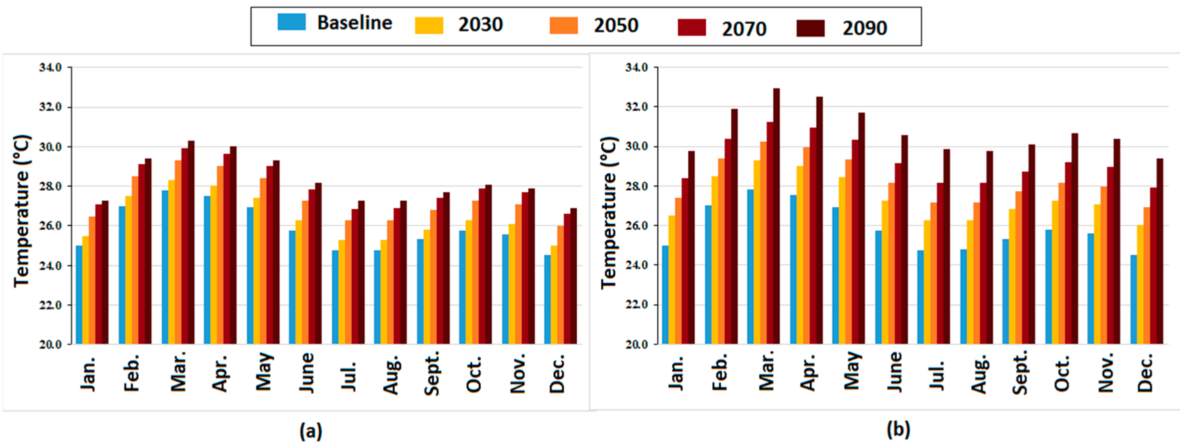

Figure 4. Variation of the monthly interannual mean temperatures for 2030, 2050, 2070, and 2090 horizons in the Sassandra River Basin: (**a**) RCP 4.5; and (**b**) RCP 8.5.

The analysis of the projected annual mean temperatures under scenarios RCP 4.5 and 8.5 showed a rising temperature trend when compared to the baseline (1961–1980) in the Sassandra River Basin (Table 2). The maximal increase, 17.4% (+5 °C) was observed at horizon 2090 and for scenario RCP 8.5. For the same scenario, temperatures will increase by 5.9%, 9.3%, and 13.3% for the 2030, 2050, and 2070 horizons, respectively. For the RCP 4.5, we will reach an increase of 2.1 °C by 2090 (i.e., +9.1%). The variations observed in this study were close to the results of Ardoin et al. [19] and Soro et al. [44]. Soro et al. [44] obtained a temperature increasing 20% for the horizon 2075 under the RCP 8.5 in the Bandama River Basin (Côte d'Ivoire) and Ardoin et al. [19] obtained the same augmentation using for the future climate projection, the HadCM3 model, and the A2 greenhouse gas emission scenario in West Africa.

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Table 2. Projected changes of temperature and rainfall for the 21st century in the Sassandra River Basin under RCPs 4.5 and 8.5.

		Baseline	2030		2050		2070		2090	
			Average	Change	Average	Change	Average	Change	Average	Change
Temperature	RCP 4.5	25.9 °C	26.4 °C	+2%	27.4 °C	+6%	28 °C	+8%	28.3 °C	+9%
	RCP 8.5		27.4 °C	+6%	28.3 °C	+9%	29.3 °C	+13%	30.8 °C	+19%
Rainfall	RCP 4.5	1435.5 mm	1330.1 mm	−7%	1310.2 mm	−9%	1295.4 mm	−10%	1296.6 mm	−10%
	RCP 8.5		1224.7 mm	−15%	1185 mm	−17%	1155.3 mm	−20%	1088.8 mm	−24%

3.1.2. Rainfall

The monthly inter-annual rainfall observed in the baseline period and projected under RCPs 4.5 and 8.5 for the four horizons 2030, 2050, 2070, and 2090 is presented in Figure 5. For both climate scenarios, there was an overall decrease in average monthly precipitation when compared to the values observed during the reference period (1435.5 mm). Additionally, the diagrams of monthly rainfall of the Sassandra watershed had different courses according to RCPs 4.5 and 8.5. Indeed, at the baseline, the monthly inter-annual average of precipitation of the watershed was similar to the mountain climate (Figure 2) located around the locality of Man and was characterized by a long rainy season. These characteristics kept constant during RCP 4.5 (Figure 5a). Furthermore, this scenario showed a decrease in rainfall until the 2070s and a slight recovery in 2090. For RCP 8.5, the seasonal variation evolved towards a Sudanese climate (Figure 2) type materialized by a shortening of the rainy season and an elongation of the dry season (Figure 5b).

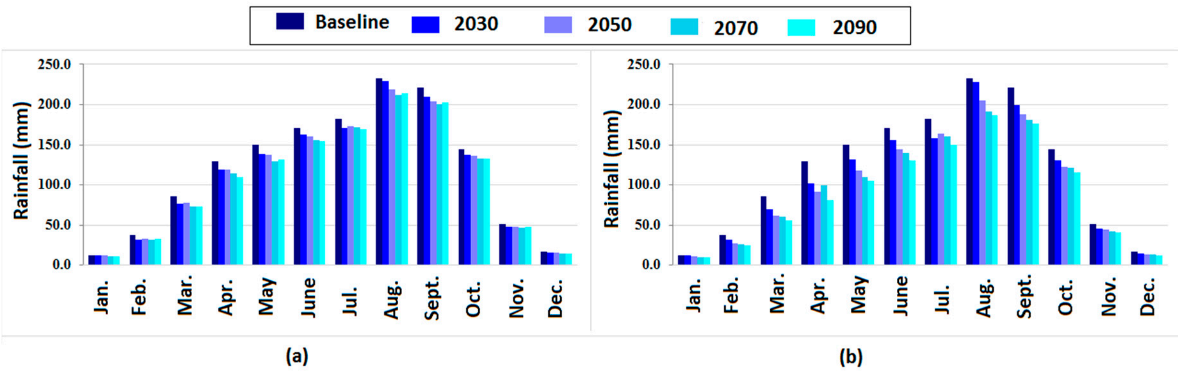

Figure 5. Monthly inter-annual mean rainfall for 2030, 2050, 2070, and 2090 horizons in the Sassandra River Basin: (**a**) RCP 4.5; and (**b**) RCP 8.5.

For annual mean rainfall, Table 2 shows a decrease for the two scenarios in the basin with a more pronounced reduction for RCP 8.5. RCP 8.5 will therefore create the worst situation when compared to the baseline (1961–1980) with a reduction of 24% at the 2090 horizon. The annual mean rainfall for the baseline period was 1435.5 mm. We will have 1330.1 mm (-7%), 1310.2 mm (-9%), 1295.5 mm (-10%), and 1296.6 mm (-10%) for RCP4.5 and 1224.7 mm (-15%), 1185 mm (-17%), 1155.3 mm (-20%), and 1088.8 mm (-24%) for RCP8.5, respectively, for the 2030, 2050, 2070, and 2090 horizons. This rainfall deficit situation had already been observed by several authors in West Africa for RCP scenarios 4.5 and 8.5 [44,45].

The future climate data (temperature and precipitation) analysis conformed to those of Sylla [28], which clearly indicates that anthropogenic climate change will substantially impact extreme precipitation and temperature events and cause shifts of the different moisture zones.

3.2. Calibration and Validation of River Discharge Simulations

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The results at the end of the calibration and validation tests of the GR2M model are presented in Figure 6. The Nash values obtained were 0.94 and 0.79 for calibration and validation, respectively. The observed and calculated hydrographs showed stumps (flow degradation). The reproduction of the observed and calculated hydrographs shows the low Nash values obtained in validation.

Indeed, the low flows were poorly reproduced and the flood flows underestimated. In the calibration or validation phase, there was a slight delay (delay or advance) between the simulated hydrograph and the observed hydrograph. However, on the whole, the calculated monthly average water slices reproduced the seasonal variations satisfactorily on the calibration sample and validation.

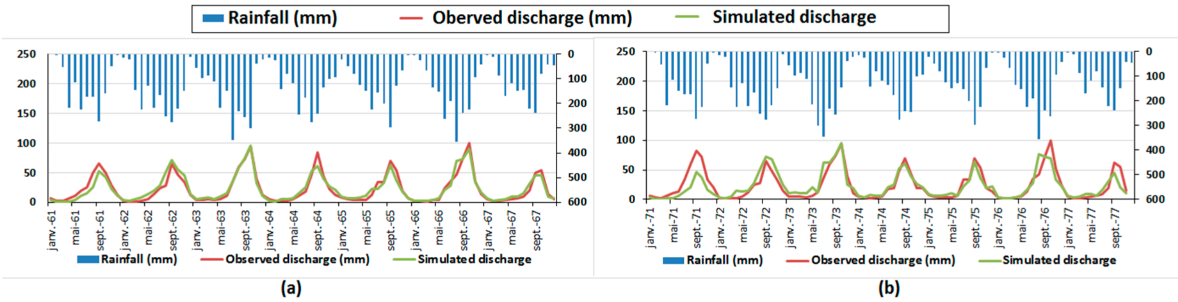

Figure 6. Hydrograms observed and simulated by the GR2M model at Soubré: (**a**) Calibration; and (**b**) Validation.

3.3. Impact of Climate Change on Natural River Discharge

This section presents the impact of climate change on the watercourses run-off for 2040, 2060, 2080, and 2100 in the Sassandra watershed (Figure 7). Indeed, the flows simulated using the climatic parameters projected by the RCP 4.5 and RCP 8.5 scenarios with the GR2M model showed a great variability with respect to the reference period.

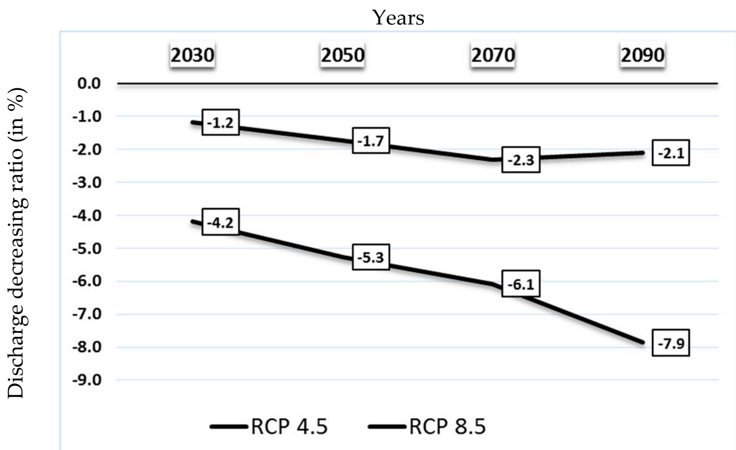

Figure 7. Future variations of the Sassandra natural river discharge when compared to the baseline per climate scenarios (RCP 4.5 and 8.5).

Compared to the baseline (1961–1980), the discharge variation until 2100 was negative. For the RCP 4.5 scenario, the reduction rate went from –1.2% for the 2030 horizon to a maximum decrease of –2.1% in 2070, followed by a slight rise to –2.3% by 2090. Discharges of the scenario RCP 8.5 decreased hopelessly until it reached a rate of –7.9% by 2090. Thus, we could see that the simulated annual mean discharges varied (decreased) in the same sense as the projected rainfall with the RegCM4 model.

The decline of the observed discharge in this study corroborated the results found by [46], who conducted a study to assess the potential of the climate change impacts on water inflows at the Manantali Dam (in the Senegal River watershed) by 2050. They used data from the CMIP5 climate

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model under scenarios RCP 4.5 and RCP 8.5 and the hydrological model GR4J. However, Soro et al. [44] observed an increase in runoff for the RCP4.5 scenario in the Bandama River Basin (Côte d'Ivoire).

3.4. Impact of Climate Change on Headwater Inflows from Guinea

Based on future rainfall on the Guinean part of the Sassandra River Basin, we evaluated the water quantity that flowed towards Côte d'Ivoire using Equation (5). Table 3 shows the reduction rate of the mean annual runoff and the total quantity of water transiting through the Guinean border for the Ivorian part of the Sassandra downstream. The results indicated that for the RCP 4.5, the variation will be –48.3 x 10^6 m^3/year in 2030 to –86.5 x 10^6 m^3/year in 2090. The highest decrease would be observed in 2070 and will be –95.2 x 10^6 m^3/year. Scenario 8.5, which had the highest reductions comparatively to RCP 4.5, showed (in millions of m^3/year) 173.3, 217.6, 250.7, and 324.8 for the 2030, 2050, 2070 and 2090 horizons, respectively.

Table 3. Runoff variation for the next decades of the 21st century.

Headwater inflows from Guinea		2030	2050	2070	2090
RCP 4.5	Runoff change (in %)	–6.9	–8.3	–9.8	–9.3
	Volume change (10^6 m^3/year)	–48.3	–71.6	–95.2	–86.5
RCP 8.5	Runoff change (in %)	–14.7	–17.5	–19.5	–24.1
	Volume change (10^6 m^3/year)	–173.3	–217.6	–250.7	–324.8

Even if this evaluation was roughly estimated, it provides an indication of the evolution of this parameter until 2090, which must be taken with some precaution given that the equation of Roudier et al. [41] (used for the assessment) was determined for the entire basin and not for a part of the basin. However, an assessment of water resources from Guinea, the West African water tower, with a distributed hydrological model could refine this assessment in the actual and future socio-economic development context in Guinea. The obtained discharges change using the equation of Roudier et al. [41], are almost similar the values obtained by Bio [47] (decrease with the magnitude ranging from -15% to -37%) under the scenarios RCPs 4.5 and 8.5 using two region climate models rainfall data in Oueme River Basin in Benin (West Africa). On the other hand, the works of Kouakou et al. [48] in the trans-boundary Comoé River Basin (shared by Burkina Faso, Côte d'Ivoire, Ghana and Mali) using the GR2M and ReGcm model and A1 scenario climate data, revealed a decrease in runoff from -18.8% to +34% in 2031-2040 and from -40% to +73% in the 2091-2100 horizon. Because, the Comoé and Sassandra Rivers are the same climate zone in West Africa these significant variations can be explained by the projected climate data particularly the rainfall data. Indeed, as mentioned by Rowell [49] and Orlowsky and Seneviratne [50] the models agree almost everywhere and for all seasons on the sign of changes of temperature indices and quantiles, but changes in precipitation are more uncertain.

4. Conclusions

This study proposed a methodology to assess the potential impacts of climate change on the natural discharge of the Sassandra trans-boundary watershed shared by Côte d'Ivoire and Guinea. Based on the future climate data projected to 2100 under scenarios RCP 4.5 and RCP 8.5 with the Reg-CM4-MPI-ESM-MR model, the situation for the coming decades of the 21st century was evaluated using the GR2M hydrological model. For both scenarios, we observed a reduction of the natural discharge for the following time periods or horizons: 2030, 2050, 2070, and 2090. This reduction was related to the decrease in rainfall associated with the increase in PET. The decrease was more important for RCP8.5. However, the results also mainly depended on the global hydrological model used (GR2M), which was relatively simple and worked with two parameters. Thus, these results can be improved by using a distributed hydrological model with a higher number of parameters. Furthermore, it is necessary to study the impact of climate change on the hydrology of West African trans-boundary rivers for their integrated management.

Acknowledgments: The authors thank the Société d'Exploitation et de Développement Aéroportuaire, Aéronautique et Météorologique (SODEXAM) for historical climate data, the Office National d'Eau potable (ONEP) of Côte d'Ivoire for the river discharge data, and the United Nations University Institute for Natural Resources in Africa (UNU-INRA) in Accra (Ghana) for data acquisition.

Author Contributions: Coulibaly Naga developed the ideas, prepared data, and did the modelling. Coulibaly Naga, Coulibaly Talnan J. H. contributed to the analyses, interpretation of results, and wrote the paper. Ziyanda Mpakama and Savané Issiaka revised the paper.

Conflicts of Interest: The authors declare no conflict of interest.

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