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Deltares

Executive summary

Exploring adaptation options to improve the water security of Gabon

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Exploring adaptation options to improve the water security of Gabon

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Content

1 Introduction

This study focuses on the seasonal limitations of fresh water availability at the Ntoum drinking water treatment plant in the face of climate change. The study is part of the Gabonese State's cooperation with UNESCO.

Justification of the study :

On an annual base, Gabon has abundant water resources, but in the dry season the supply of drinking water is not always assured. Rising water demand and ongoing climate change could potentially cause a decrease in water availability during the dry season and possibly flood peaks during the rainy season. As a consequence the water security for the people of Gabon may be at risk.

Within this project, Deltares applied the climate risk-based decision analysis methodology, known as CRIDA (Mendoza et al., 2018) in collaboration with Victor Boumono (national consultant) and the client UNESCO. The CRIDA methodology, is internationally established in collaboration with UNESCO-IHP. It was introduced as a multi-step process to identify risks to water security under current and future climatic conditions

This project aims to seek adaptation solutions that guarantee the minimal flows and improve the water supply to the various districts of Libreville and its surroundings under changing climate conditions. The project was initiated by the Ministry of Energy and Hydraulic Resources, via the Directorate Générale de l'Eau, in collaboration with UNESCO.

The project objectives are:

- To analyse the effect of climate change on water resources in the Nzémé basin, upstream of the Ntoum drinking water plant

- To identify adaptation options to maintain or improve the water security in the future

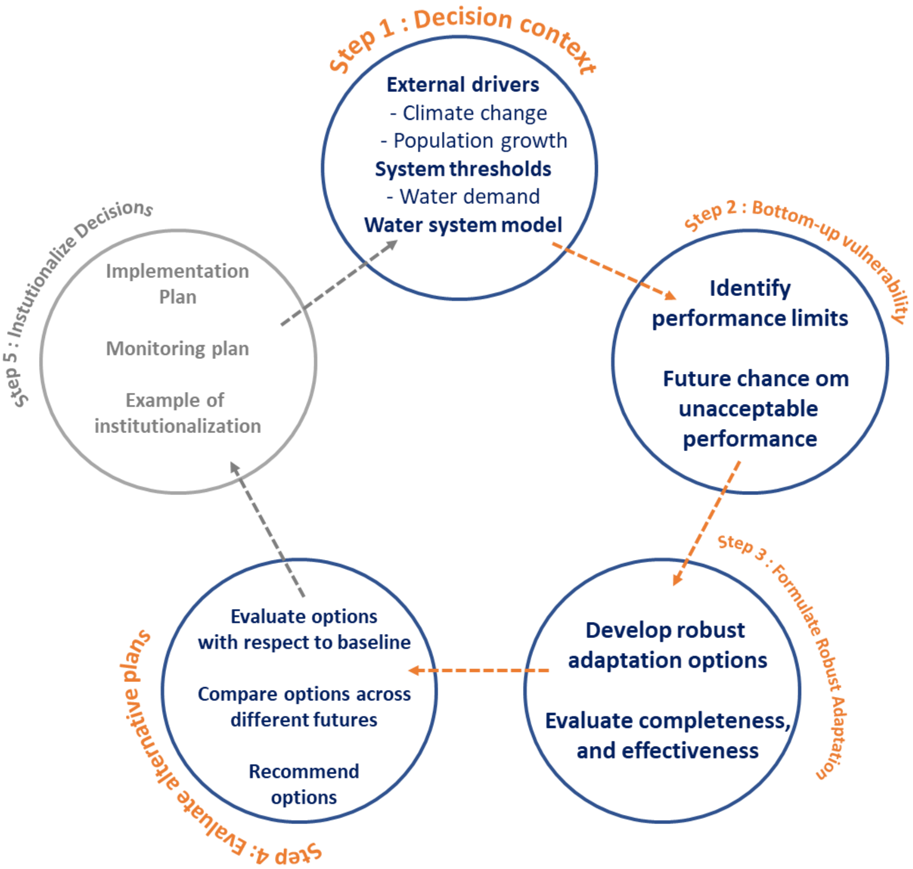
This is a summary report. The technical details are described in a more extended French report : "Développement de scénarios de changement climatique et analyse d'impact a Ntoum - rapport technique."

2 Application of the CRIDA methodology

Water security is a serious challenge in many parts of the world, especially in developing countries where the risk of climate change is exacarbated by high population and economic growth. Uncertainties related to climate, demographic and economic changes make it difficult to predict the impact on water security. Therefore it is not always possble to rely on conventional approaches used in water resources planning and management.

The Climate RIsk-based Decision Analysis (CRIDA, Mendoza et al., 2018) is developed to provide practical guidance on how climate models can be used to inform decisions on sustainable development of water resources made by local governments and water managers at the catchment scale.

CRIDA provides a collaborative process for risk-informed decision-making by effectively assessing, managing and communicating risks to stakeholders and decision makers. The process consists of five iterative steps, these are:



Our current work for water security in the Nzémé Basin focuses primarily on the first three steps of the CRIDA method, which are to identify water security issues and opportunities, and then implement a climate vulnerability analysis. We also carried out a preliminary analysis on the evaluation of possible adaptation solutions in terms of robustness and flexibility.

3 General description of Gabon and the Nzémé basin

3.1 Gabon

Gabon is located in the center of Africa at the Atlantic Ocean coast. Gabon is about 267,667 km² for an estimated population of 1.8 million inhabitants (population census, February 2013), 15% of whom live in rural areas. The annual population growth rate is about 2.3%. The density, however, has large regional disparities and a high concentration in the three main urban centers (Libreville, Port-Gentil and the Franceville-Moanda-Mounana triangle).

The topography is rarely flat and several mountain ranges reach almost 1000 meters. The Gabonese forest covers approximately 22 million hectares, including 20 million hectares of production forest. Gabon has a cultivable land potential of almost 15 million relatively fertile hectares, of which only 495,000 hectares are directly exploited. The territory of Gabon is located around the equator and has an equatorial climate, hot and humid, with abundant and frequent rainfall.

The annual precipitation cycle clearly shows a dry season for the months of June, July and August (Figure 2). However, the length of the dry season varies from year to year. The annual rainfall in Ntoum is about 2600 mm/year. The linear trend analyzes for historical annual, seasonal and monthly precipitation did not indicate a trend. Climate projections do indicate a very likely increase in mean annual temperature in the future.

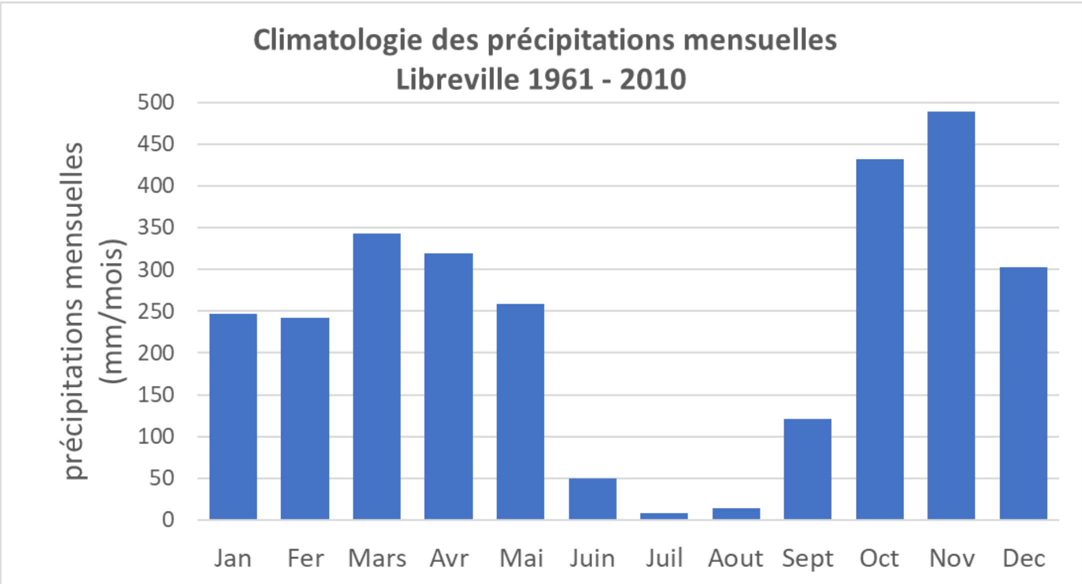


Figure 2. Annual precipitation cycle (mm/month) for Libreville for the period 1961-2010 (Boumono 2021)

3.2 Water treatment station of the Nzémé at Ntoum

The Société d'Energie et d'Eau du Gabon (SEEG) operates the Ntoum drinking water production plant using water from the Nzémé as the main source of fresh water. To increase Libreville's water supply, SEEG uses the additional sources listed hereafter and shown in Figure 3:

- Transfer of water from water courses surrounding the community of Ntoum ; the Mbè, Saza, Meba (located north of Ntoum) and Assango (east of Ntoum) rivers. The quantities of water that can be mobilized from these sources during the low flow period are estimated at a total of 124,000 m^3/d (72,000 m^3/d for the Mbé, 8,000 m^3/d for the Saza, 11,000 m^3/d for the Méba and 33,000 m^3/d for Assango ; Boumono, 2021). For the rivers in the North, significant losses have to be considered because the water transfer over the last kilometers flows over the natural terrain before returning to the natural network of a small tributary of the Nzémé. We assumed an efficiency coefficient of 60% for the transfer of water from the rivers of the sector inthe North sector and an efficiency of 80% for Assango.

- The CIM1 and CIM2 water collection stations for the treatment of water that used to flood the open-pit quarry of the former CIM Gabon cement factory. The daily maximum supply from this source is estimated at a total of 46,800 m^3/d (Boumono, 2021).

- The boreholes in the Mfoulayong. These are located in the sandstone formations that are part of the Nzémé basin and have a total capacity of 30,000 m^3/d (Boumono, 2021). The water from these boreholes is drained over natural grounds to the Nzémé water course. Most have water with a high iron content. In addition, to abstract water from these boreholes, a high-voltage electrical network has been built which does not allow for sustainable management of the resources.

- The Nzamaligué Route borehole well field which extracts groundwater from a formation called “Madiela limestones”. The contribution of this well field is approximately 22,680 m^3/d in the optimal situation where all 4 boreholes are in operation (Boumono, 2021).

- Finally, there is a water reservoir in the Nzémé at the private Exotica estate. Currently this source is used as back-up resource during the low flow period. We estimated with the national consultant that the volume of this water reservoir is about 15,000 m^3.

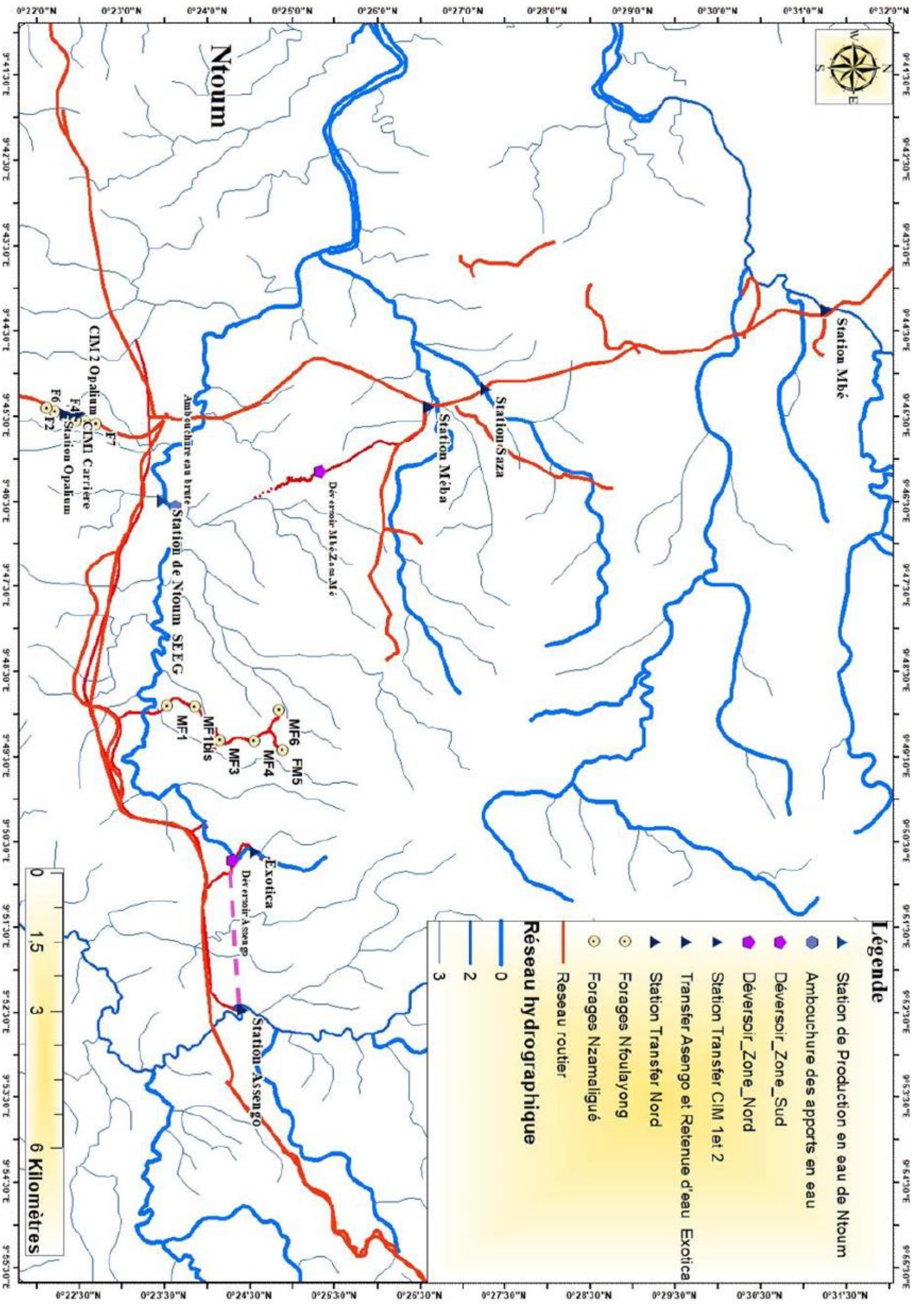


Figure 3 Overview of the drinking water production network in the area of Ntoum (Boumono 2021)

4 Climate change vulnerability analysis

4.1 Modelling chain

To analyse (1) the effects of climate change on the water resources of the Nzémé basin upstream of the Ntoum drinking water plant and (2) for the development of an adaptation strategy to maintain or improve the water security in the future, a modeling chain is set up (Figure 4).

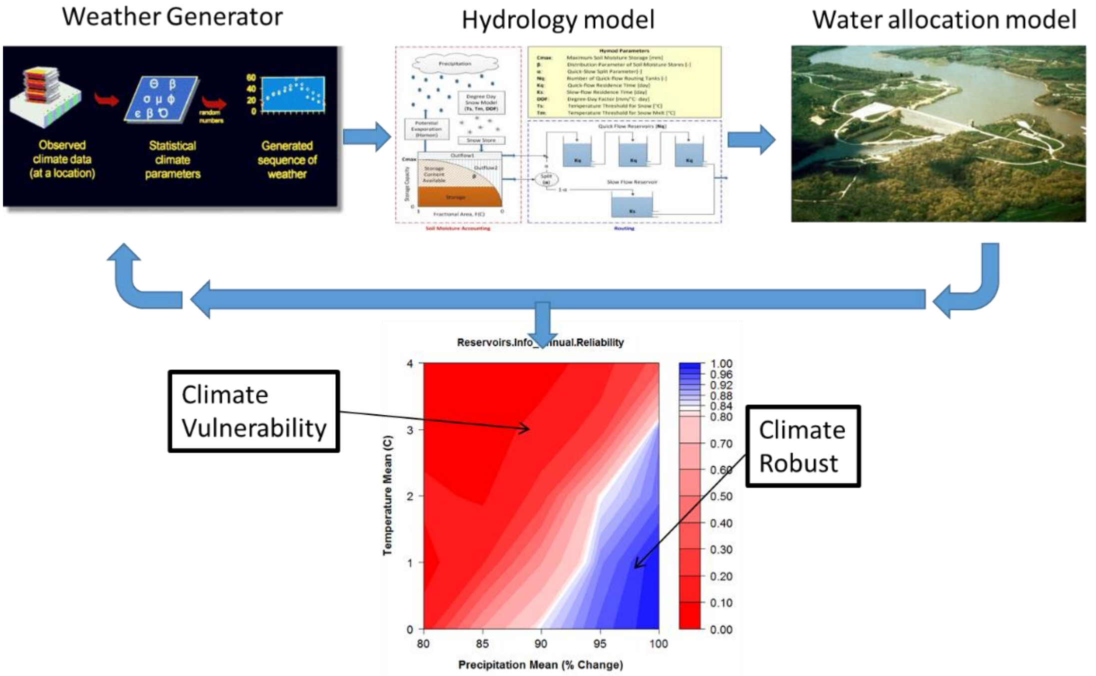


Figure 4. Overview of the modelling chain

The first step is the generation of synthetic weather data to develop a wide range of potential future climate change scenarios (change in precipitation and/or temperature). The weather generator is based on a combination of local observations, satellite data as well as climate change projections from global climate models. It takes into account both changes in variability and long-term average changes in the future climate.

In the second step, a hydrological model of the Nzémé basin was developed to assess the effects of climate change on the water resources. Finally, a water balance model of the plant's water production system was prepared to assess the vulnerability of the production system to climate change, population growth and adaptation options. The water balance model of the system includes the different sources of water that arrive at the Ntoum drinking water plant, as described in chapter 3.

The results of these analyses are represented as system climate stress tests in chapter 5.

4.2 General circulation model projections

The climate change projections used for this project are derived from 22 General Circulation Models (GCMs) used for the IPCC 5th Assessment Report for four future scenarios - Representative Concentration Pathways (RCPs). RCP2.6 represents a very sustainable world while RCP8.5 is the worst case scenario.

Overall, climate projections for the Nzémé basin indicate an increase in mean annual temperature that ranges from +0.5°C to +3.5°C (Figure 5). For precipitation, the majority of projections indicate an increase in average annual precipitation of up to nearly +20%. However, there are also models that project a decrease in average annual precipitation of almost -10% (Figure 5). Projected changes in temperature and precipitation show little intra-annual variation.

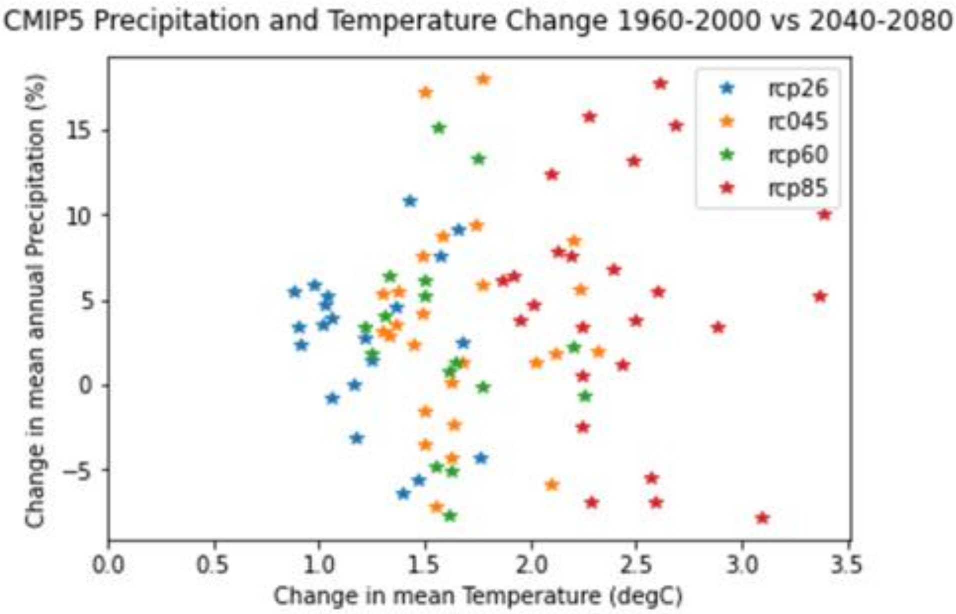


Figure 5. Range of changes in annual mean precipitation and temperature for the Nzémé basin

4.3 Historic and future water demand

Historic

Greater Libreville hosts four communities (Libreville, Akanda, Owendo and Ntoum) and has an estimated population of around 1,082,000 (Boumono, 2021). In 2015, studies on the Libreville water master plan assessed total per capita water consumption at 120 litres/person/day (Boumono, 2021). Taking these figures into account, we have estimated the current demand at a total of 129,840 m^3/d. However, in our water balance model, we also consider that only 75% of the population is connected (AFDB, 2018), which reduces the current demand to 97380 m3/s.

Future

To assess the future required drinking water production, it is necessary to take into account not only climate change, but also the increase in demand caused by population growth.

The future population scenario for the period 2020 to 2060 for the Nzémé basin is based on the United Nations population projection data (UN, 2018). Based on the growth rates of the United Nations the future demand is assumed to gradually increase over the period 2020 to 2055 to 161,303 m^3/d taking into account a consumption of 120 l/person/day and a connection rate of 75% (see Fig. 6).

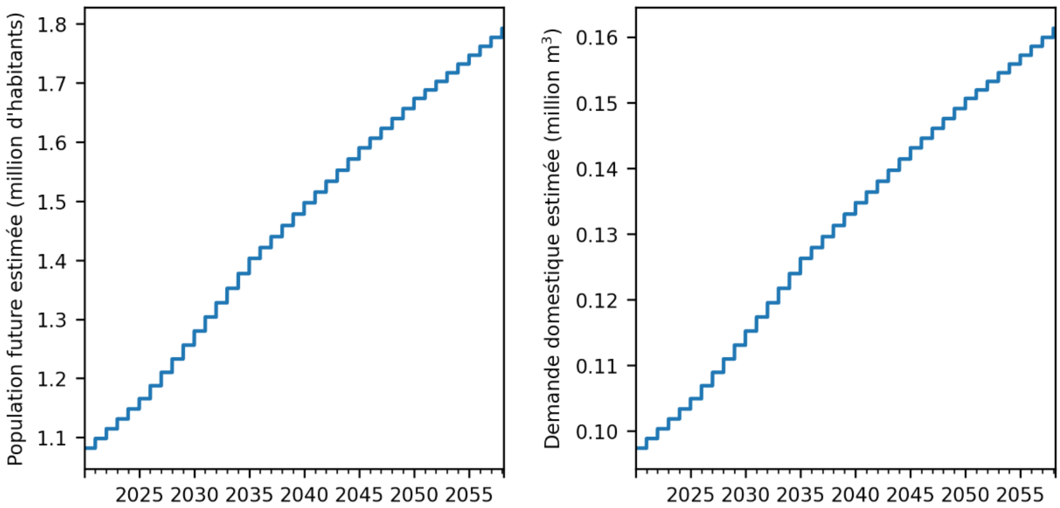


Figure 6. Estimation of population growth based on United Nations data (2018) for Greater Libreville (left); estimation of growing domestic demand (right)

5 Climate stress-test

For each of the climate scenarios, the modeling chain enables the calculation of the water supply reliability over time. This represents the percentage of time that the demand is satisfied. Figure 7 shows that there is a water demand satisfaction reliability of about 78% for the current situation.

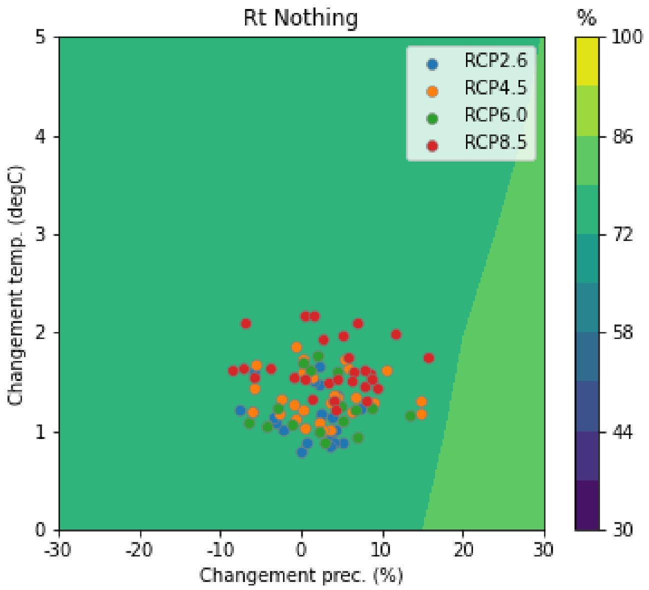


Figure 7 Temporal reliability (%) indicating that the demand is satisfied for the current system (without adaptation actions – 'Rt Nothing') taking into account the water availability for the different climate scenarios. In this graph, the values vary from 72 to 79%.

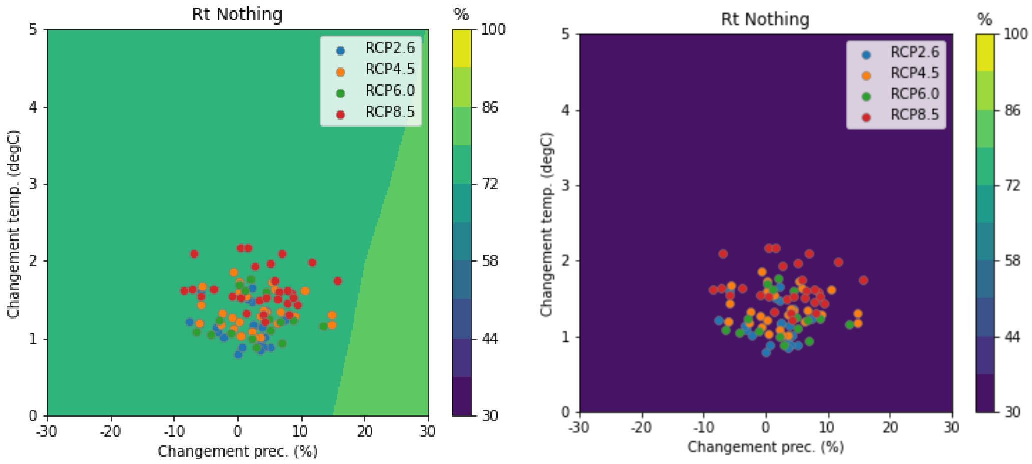
The horizontal axis of this figure shows the change in long-term average annual precipitation while the vertical axis shows the change in long-term average annual temperature. The background colors represent the temporal reliability of the request being satisfied. Next, the general circulation model (GCM) projections for the future period of interest are superimposed on the figure for the climate change context (colored dots).

For the temporal reliability presented, the performance of the system does not seem to be very sensitive to climatic changes. This is probably explained by the fact that the increase in precipitation is substantial during periods of flooding but precipitation remains low during dry periods.

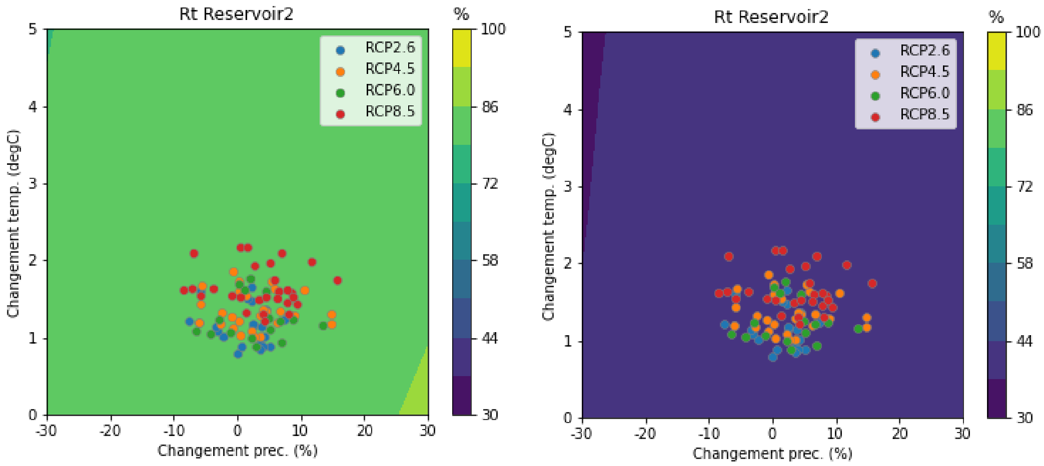
During floods, the normal operation of the drinking water production plant is prevented. Not all fresh water can be transferred to the treatment plant. Assuming that the plant cannot operate 5% of the time due to the most extreme floods, it will be necessary to take into account non-operation of the plant on average 7% of the time in the event that rainfall increases with 30 %.

6 Evaluation of adaptation actions

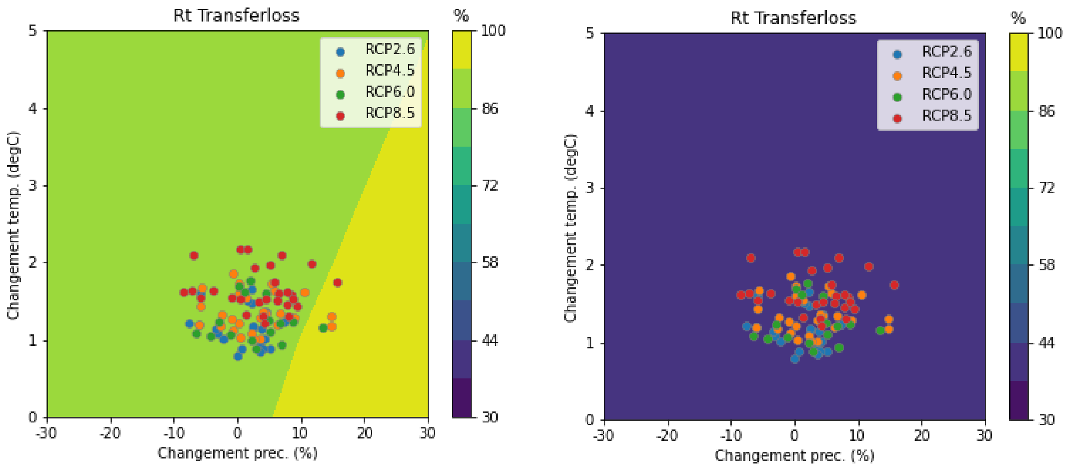
Graphs similar to Figure 7 were also derived for future climate change conditions (left) and the combination of future climate change and future increases in water demand related to population growth (right). The graphs indicate the percentage of time the water demand can be met by the Ntoum water plant. The color scale is from blue (30%) to yellow (100%). Blue indicates that the situation will get worse in the future, yellow indicates that the situation may improve in the future after the given adaptation option is implemented.



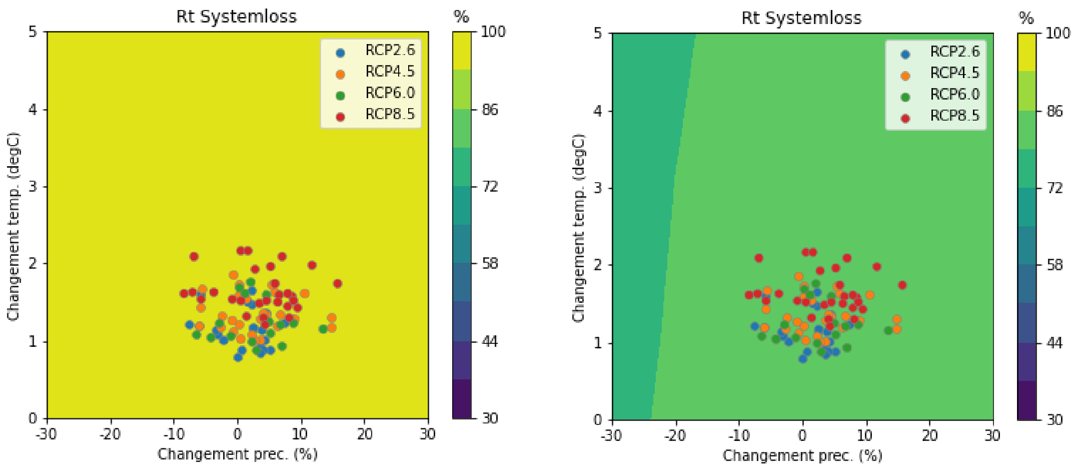
Climate change may slightly increase the percentage of time that water demand cannot be met (+1%). However, the figure on the right, which includes the future increase in population and hence water demand, shows that when the population increases, the percentage of time that future water demand can be satisfied decreases sharply (by ~ 78% to ~35%). Future population growth will have a larger impact on per capita water availability than climate change.



The graphs above provide the same information but now for the situation where a large reservoir upstream of Ntoum is build within the river system. The change to slightly lighter colors indicates that the reservoir will improve water availability a bit. The request can be satisfied for an additional 5% of time. Here only the results for this large[1] reservoir are shown because the proposed small reservoir similar to the existing reservoir shows almost no difference.

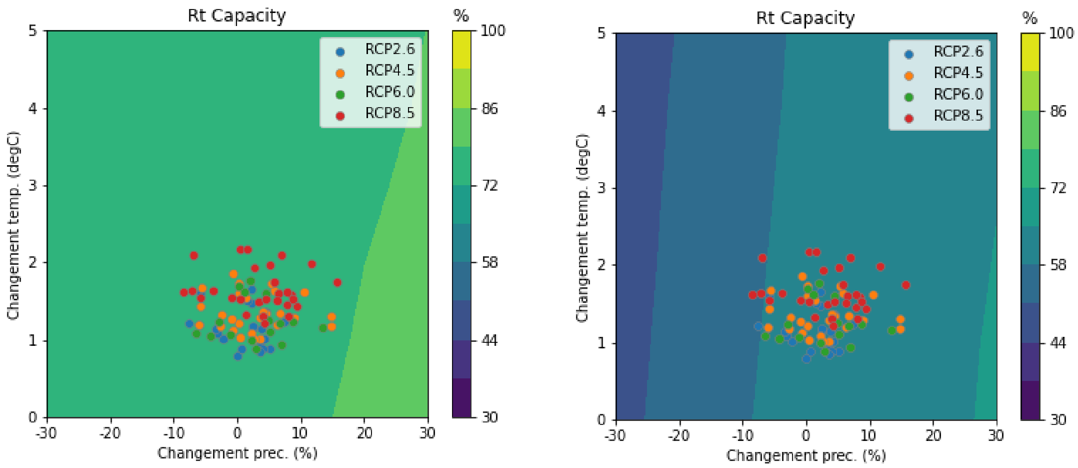


When the transfer system is optimized (i.e. new pipelines, no transfer over open land etc) the transfer losses from the various sources to the Nzémé River and the Ntoum plant can be decreased, demand can be met for approximately an additional 7% of time.



The largest improvement can be achieved by decreasing the losses of the distribution system from the Ntoum treatment plant to the city of Libreville and its inhabitants. In the improved situation where the efficiency of the distribution network is increased from 52% to 71%, the demand can be satisfied (100% of time) by only considering future climate change (left). When the future increasing demand is also considered, demand can be satisfied for at least 82% of the time (right).

[1] A reservoir of 1.000.000 m^3 which is 65 times the existing reservoir at Exotica.



An increase in production capacity from 258,000 m^3/d to 370,000 m^3/d as already planned is unavoidable if we consider a strong increase in population and water demand.

7 Recommended adaptation options

The results of the climate stress test indicate that optimizing the distribution network facilities to reduce distribution losses contributes substantially to the improvement of the water supply reliability rate. However, considering the future growing demand, this adaptation action alone is not enough to achieve a temporal reliability of more than 82%. It is therefore necessary to combine this action with other adaptation actions to increase the temporal reliability rate beyond 90% taking into account both climate change and population growth.

The recommended adaptation options are :

- Optimization of the distribution network to increase the efficiency from approximately 52% to 71%. It is worth noting that the African Development Bank has already initiated steps for the implementation of this system improvement (AFDB, 2018).

- Optimization of the facilities in the northern sector this reduces transfer losses that and could potentially increase the efficiency by 60% to 80%.

- Increasing water stock by building reservoirs in the river network. It should be noted that depending on their location and their operational scheme, the reservoirs can also be used during flood periods to reduce the system's vulnerability to a potential increase in extreme flows. However, the reservoirs should have a large volume (>1,000,000 m3) to have a noticeable effect on water availability in the dry period.

- The planned increase in the production capacity is unavoidable if one considers the projected strong increase in the population and the related increase in water demand.

The actions below are no-regrets actions that will help (1) improve the system understanding / knowledge and (2) the conditions of the current water system.

- Establishment of a surveillance and monitoring network for the water resources to improve the knowledge of temporal variations in rivier flow of the Nzémé and its surrounding water courses.

- Improved estimates of current and future drinking water needs for domestic and industrial use.

- Maintenance of the transfer network, facitilies and monitoring network: during the field visits of this project, it was noted that some of the equipment was malfunctioning.

- Forest conservation in the Nzémé basin to improve infiltration and maintain base flows.

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