State of the Climate Report: Suriname

Climate Change Division

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List of abbreviations

ABS	*Algemeen Bureau voor de Statistiek* General Bureau of Statistics
ADEKUS	*Anton de Kom Universiteit van Suriname* Anton de Kom University of Suriname
AFOLU	Agriculture, Forestry and Land Use
AORI	Atmosphere and Ocean Research Institute
ATM	*Ministerie van Arbeid, Technologische Ontwikkeling en Milieu* Ministry of Labor, Technological Development and Environment
BOG	*Bureau voor Openbare Gezondheidszorg* Bureau of Public Health
CARICOM	Caribbean Community
CCRIF	Caribbean Catastrophic Risk Insurance Facility
CCSR-NIES	Center for Climate System Research – National Institute for Environmental Studies
CDF	Cumulative Distribution Function
CELOS	Center for Agricultural Research Suriname
CIFOR	Center for International Forestry Research
CMIP	Coupled Model Intercomparison Project
COSIPLAN	*Consejo Suramericano de Infraestructura y Planeamiento* South American Council for Infrastructure and Planning
CREEBC	CARICOM Regional Energy Efficiency Building Code
C3S	Copernicus Climate Change Service
DEV	*Dienst Electriciteits Voorziening* Department of Rural Energy
DFID	Department for International Development
DRM	Disaster Risk Management
DWV	*Dienst Water Voorziening* Water Supply Service
ECMWF	European Centre for Medium-Range Weather Forecasts
ECMWF IFS	Integrated Forecasting System
EITI	Extractive's Industry Transparency Initiative
ENIC	Electricity Nickerie
ENSO	El Niño Southern Oscillation
EPAR	Electricity Paramaribo
FAO	Food and Agriculture Organization of the United States
FOB	*Fonds Ontwikkeling Binnenland* Foundation Funding Development Interior
FREL	Forest Reference Emission Levels
GAP	Good Agricultural Practices
GCM	General Circulation Model
GCCA+	Global Climate Change Alliance Plus Initiative
GDP	Gross Domestic Product
GEF	Global Environment Facility

GNP	Gross National Product
HFLD	High Forest cover and Low Deforestation
IDB	Inter-American Development Bank
IEA	International Energy Agency
IICA	Inter-American Institute for Cooperation on Agriculture
IITA	International Tropical Timber Agreement
IPCC	Intergovernmental Panel on Climate Change
IPSL	Institut Pierre Simon Laplace
ITCZ	Inter-Tropical Convergence Zone
ITP	Indigenous and Tribal People
IWW	Interdepartmental Water Workgroup
IWRM	Integrated water resources management
JCI	Junior Chamber International
LEED	Leadership in Energy and Environmental Design
LVV	*Ministerie van Landbouw, Veeteelt en Visserij* Ministry of Agriculture, Animal Husbandry, and Fisheries
LPG	Liquified Petroleum Gas
MERSD	Sustainable Education and Research in Sustainable Development
MUMA	Multiple Use Management Areas
NAP	National Adaptation Plan
NASA	National Aeronautics and Space Administration
NCCPSAP	National Climate Change Policy, Strategy and Action Plan
NCCR	*Nationaal Coördinatiecentrum voor Rampenbeheersing* National Coordination Center for Disaster Management
NDC	Nationally Determined Contribution
NFMS	National Forest Monitoring System
NFP	National Forest Policy
NH	*Ministerie van Natuurlijke Hulpbronnen* Ministry of Natural Resources
NIMOS	Nationaal Instituut voor Milieu en Ontwikkeling in Suriname National Institute for Environment and Development in Suriname
NMA	National Environmental Authority
NRW	Non-Revenue Water
NMS	National Mangrove Strategy
NTFP	Non-Timber Forest Products
NV EBS	*N.V. Energie Bedrijven Suriname* Energy Company of Suriname
OAS	Organization of American States
OP	*Ontwikkelingsplan* National Development Plan
OW	*Ministerie van Openbare Werken* Ministry of Public Works
PCP	Precipitation
PES	Payment for Ecosystem Services
PV	Photovoltaic

Q-Q	Quantile-Quantile
RCP	Representative Concentration Pathway
RD	Ministry of Regional Development
R&D	Research and Development
REDD+	Reducing emissions from deforestation and forest degradation in developing countries, and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries
ROM	*Ministerie van Ruimtelijke Ordening en Milieu* Ministry of Spatial Planning and Environment
SAMAP	Suriname Agricultural Market Access Project
SBB	*Stichting voor Bosbeheer en Bostoezicht* Foundation for Forest Management and Production Control
ScenarioMIP	Scenario Model Intercomparison Project
SFM	Sustainable Forest Management
SMNR	Sustainable Agricultural Management of Natural Resources
SNC	Second National Communication
SOC	State of the Climate
SPS	*Stichting Planbureau Suriname* Planning Office Suriname
SPSC	Staatsolie Power Company Suriname
SSP	Shared Socioeconomic Pathway
Suralco	Suriname Aluminum Company
SWM	Suriname Watersupply Company
SWOT	Strengths, Weaknesses, Opportunities, Threats
SWRIS	Suriname Water Resources Information System
UNDP	United Nations Development Program
UNFCCC	United Nations Framework on Climate Change
USACE	United States Army of Corps of Engineers
WLA	*Waterloopkundige Afdeling* Hydraulic Research Division
WWF	World Wildlife Fund

Executive summary

Several factors contribute to Suriname's particular vulnerability to the effects of climate change. It is dependent on fossil fuels, has forests liable to decay, fragile ecosystems, and its low-lying coastal area accounts for 87% of the population and most of the country's economic activity. Many sectors are at risk of suffering losses and damage caused by gradual changes and extreme events related to climate change.

For Suriname to develop sustainably it must incorporate climate change and its effects into the country's policies and laws. However, there were no in-depth studies of what Suriname's future climate might look like on the subnational level, or the impacts it would have on different sectors or in different districts, which makes evidence-based decision-making difficult. Therefore, the Inter-American Development Bank (IDB) and Government of Suriname decided to collaborate on the project *Mainstreaming Climate Change in Sustainable Decision-Making tools*. One of the project's products is this State of the Climate (SOC) Report.

Following a short introduction, Chapter 2 of the report provides the data and methodologies that were used to obtain the results in chapters 3-5.

The SOC Report analyzes Suriname's historical climate data (1990-2014) in Chapter 3 and provides climate projections for three time horizons (2020-2044, 2045-2069, 2070-2094) through two emissions scenarios (intermediate/SSP2-4.5 and severe/SSP5-8.5) in Chapter 4. The analysis focuses on changes in sea-level, temperature, precipitation, relative humidity, and winds for the seven subnational locations of Paramaribo, Albina, Bigi Pan MUMA, Brokopondo, Kwamalasamutu, Tafelberg Natural Reserve, and Upper Tapanahony. The variables that form part of the analysis and its outcomes on the country-level are summarized in Table 1.

For Paramaribo, the capital and most populous district, the climate is expected to become hotter and drier. According to scenario SSP2-4.5, the historical average temperature of 27.3°C is expected to increase to 28.9°C by mid-century and to 29.4°C by the end of the century. In line with this, minimum and maximum temperatures are expected to increase from 24.4°C to 26.4°C and from 30.2°C to 32.4°C in the long term. Consequently, the number of hot days and nights per year are expected to increase to 295 and 364 per year by the end of the century, while cold days and nights disappear altogether. Rain is expected to decrease for all seasons, with precipitation episodes becoming rarer and more intense. In the SSP5-8.5 scenario the trends are similar, but heightened. Maximum wind speed is expected to increase moderately in all scenarios.

Table 1- Climate variables analyzed and projected, their historical trends and future projections

Variables	Historical trend	Future trend
Mean, maximum, and minimum daily temperature	These indicators are similar throughout the country and slightly lower in the south. In the north, temperatures are increasing, while in the south they are decreasing.	Daily mean, minimum, and maximum temperatures are projected to increase in the entire country, although less at the coast and more in the southwest.
Frequency of hot days and hot nights	The frequencies of these days are very homogeneous throughout the country.	The frequencies of the two increase throughout the country.
Frequency of cold days and cold nights		The frequencies of these two decrease and cold days and nights almost disappear.
Accumulated yearly precipitation	Precipitation shows a strong increasing trend throughout the country.	Yearly accumulated rainfall is expected to decrease strongly. In general, the decrease could surpass 20% of the historical average.
Number of rainy days per year	These are more frequent on the coast, the center and southwest of the country, and less so on higher grounds towards the southeast.	The number of rainy days decreases, especially on the coast.
Maximum precipitation in five days	These indicators are even across the entire country.	Both indicators increase greatly for all locations. This, together with the decrease in the number of rainy days, points to a change of rain regime towards fewer but more intense precipitation events.
Maximum precipitation in one day		
Short dry season precipitation	The interior is rainier than at the coast, increasingly so. However, in general precipitation is more even and seasons are less pronounced.	These seasons become drier throughout the country.
Dry season precipitation		
Short rainy season precipitation		
Rainy season precipitation		This season becomes drier at the coast but wetter in the interior.
Maximum daily winds	These are highest just off the coast and over the higher ground in the southeast. They show a descending trend.	Wind indicators are projected to vary little. The main patterns visible in the historical map change very

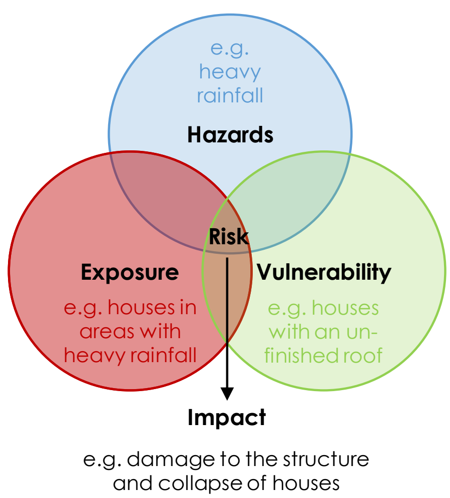
Variables	Historical trend	Future trend
Gale wind days	These are very rare, with less than two per year.	little in all scenarios and time horizons.
Strong wind days	These occur mostly at the coast and in the center and southeast of the country.	
Relative humidity	This indicator is high for all of Suriname and has a latitudinal gradient, with maximum values at the coast and slightly lower ones further inland.	The climate in Suriname is expected to become drier, particularly in the southwest of the country.
Sea-level rise	NA	Sea-level increases by 0.25 m in the severe scenario by the end of the century, causing the erosion of coastal mangroves, affecting coastal infrastructure, and damaging harbors.

Source: SOC Report team elaboration

The SOC analyzes climate risk in Chapter 5. Risk is the product of climate **hazards**, **exposure** to these climate hazards, and **vulnerability** of the exposed elements to the climate hazards (Figure 1). The materialization of risk results in impacts.

To define climate risk for Suriname, the country's ten districts and four important sectors (agriculture, water, forestry, infrastructure) were examined for factors which increase their exposure and vulnerability. These were then combined with data for the historical and projected climate hazards. The outcomes of the analysis are summarized in Table 2.

***Figure 1**: Climate risk and impacts are the product of climate hazards, exposure, and vulnerability.*



Source: SOC Report team elaboration

***Table 2**- Summary of climate risk, hazards, exposure, and vulnerability throughout the districts for the historical trend and the future*

<table>
<tr><th></th><th>Historical (1990-2014)</th><th>Future (-2094)</th></tr>
<tr><td>Risk</td><td colspan="2">Paramaribo, Sipaliwini, and Wanica are the districts most at risk, and Coronie and Nickerie those least at risk.</td></tr>
<tr><td>Hazards</td><td>Paramaribo and Wanica face the most climate hazards, and Nickerie the least.</td><td>Nickerie will remain the district with the least hazards. Sipaliwini will become one of the districts with the most hazards.</td></tr>
<tr><td>Exposure</td><td colspan="2">Commewijne and Paramaribo are the most exposed districts due to their exposed agriculture, water, and forestry sectors (Commewijne) as well as infrastructure sector (Paramaribo). Brokopondo is the least exposed district due to its little-exposed agriculture and infrastructure sectors.</td></tr>
<tr><td>Vulnerability</td><td colspan="2">Sipaliwini and Brokopondo are the most vulnerable districts due to their vulnerable agriculture and infrastructure sectors. Coronie is the least vulnerable district due to its less vulnerable forestry and infrastructure sector.</td></tr>
</table>

Source: SOC Report team elaboration

The results imply the following actions be taken:

- In Paramaribo and Wanica, infrastructure assets such as roads and bridges should be protected from climate hazards, particularly sea-level rise and intense precipitation events like flooding.
- In Sipaliwini and Brokopondo an improved infrastructure would offer more and better goods and services to its citizens.
- Agricultural land and livestock In Commewijne, and the people whose livelihoods depend on them, should be protected from the negative impacts of climate change. The high mangrove cover in Commewijne demands attention in light of sea-level rise and increased erosion.

Chapter 6 of the Report offers conclusions and recommendations on how Suriname can reduce its climate risk:

- The Environmental Framework Act should be fully enforced.
- Climate change mitigation and adaptation should be mainstreamed into sectoral legislation.
- Governmental mainstreaming should be participatory and include tribal and local organizations, the private sector, and nongovernmental organizations.
- Institutions should strengthen their data and process management in order to ameliorate the negative effects of staff turnover.
- Human, financial, and technological capacity should be strengthened across the board.
- International cooperation projects should include a component on capacity building to foster the sustainability of results and continuity of inter-institutional cooperation mechanisms after the end of a project.

- Roles and responsibilities between cooperating actors should be clear. The National Environment Authority (NMA) should become a strong coordinating entity that assures functions are executed in a concerted manner.
- There should be strengthened cooperation between government institutions, research institutes, and between each other, including on the sharing of information.
- There should be more finance for research and development, including studying the impacts of climate change.
- As this study does not go into detail on climate change impacts such as water shortages on extractive industries (oil, mining), the main drivers of the Surinamese economy. More research on this topic is highly recommended.
- Further investigation into changes in the position of the Inter-Tropical Convergence Zone (ITCZ) and in the El Niño Southern Oscillation (ENSO) cycle and their impacts on precipitation and temperature regimes is highly recommended.
- A study on the economics of climate change effects in Suriname would help to ascertain the specific sectoral impacts from an economic standpoint, as well as to provide the basis for the development of a cost-benefit analysis of adaptation options.
- The risk index should be updated whenever new indicators and data are available.
- A detailed study on coastal risk to sea-level rise, including more precise data on sea-level rise and the geomorphology of the coast, shoreline change rates through erosion and accretion, the coastal slope, wave height and tidal range is also recommended
- Activities that raise awareness for the public, and general education of the effects of climate change would be helpful.
- The government should increasingly collaborate with the private sector, which can offer technological solutions and decrease climate change impacts by protecting its assets.
- As a High Forest cover and Low Deforestation (HFLD) country, Suriname should make use of the carbon market.
- The government should improve the institutional framework of Disaster Risk Management (DRM) and develop a disaster risk financing and insurance strategy.
- The synergies between adaptation and mitigation should be fully taken advantage of, and possible trade-offs should be addressed.
- More climatological observation stations should be installed to have a continuous data collection in space and time. Automatic recording instruments should be employed in remote areas.
- Data storage and dissemination must be improved, using a consistent and open file and data format.

INTRODUCTION

1.1. Context

Suriname's contribution to climate change is relatively small, as the country's 2008 greenhouse gas inventory demonstrated that it was a net carbon sink due to its large forest cover. However, Suriname is particularly vulnerable to the effects of climate change. Today, the Surinamese people experience extensive coastal erosion, prolonged dry seasons, and flooding.

Suriname is fully committed to a transparent implementation of the United Nations Framework Convention on Climate Change (UNFCCC), which it ratified on 14 October 1997, and the Paris Agreement, which it ratified on 13 February 2019. In 2006 the country submitted its first National Communication and in 2016 its second one. Both documents not only served to systematize the country's progress and challenges in mitigating and adapting to climate change, but also brought climate change concerns to the attention of the Surinamese people and policymakers that are making increasing efforts to consider the objective of the UNFCCC in their development strategies. The National Communications also highlight the need for more research and capacity-building to be done on climate models, projections, and impact assessments to validate and complement existing assumptions on the effects of climate change and support decision making in favor of a sustainable development. Suriname's National Development Plan (OP) for 2017-2021 prioritized the utilization and protection of the environment, but more studies and data are needed to further progress. The National Climate Change Policy, Strategy and Action Plan (NCCPSAP) for Suriname (2014-2021) has identified the lack of climate change data as a limitation for effective planning and decision making.

1.2. The project *Mainstreaming Climate Change in Sustainable Decision-Making Tools*

To mainstream climate change means to integrate the mitigation and adaptation to the effects and concerns of climate change. Mainstreaming climate change into Suriname's OP enables evidenced-based decision-making that is inclusive, transparent, and takes the impacts of climate variability in multiple sectors into consideration. To facilitate this, the Inter-American Development Bank (IDB) and Government of Suriname decided to collaborate on the project *Mainstreaming Climate Change in Sustainable Decision-Making Tools*. One of the project's products is this State of the Climate Report. Other parts of the project include the implementation of a capacity building program, the development of training material for local technical experts on the production of near to long-term climate projections and the possible impacts based on their results, and gathering feedback from and raising awareness with shareholders.

The overall objective of the State of the Climate Report is to comprehensively analyze the likely impacts of climate change on the four key sectors Agriculture, Water, Forestry, and Infrastructure, and for diverse geographic areas based on the analysis of historical climate trends, and to produce projections at subnational level details.

Suriname's State of the Climate Report provides a comprehensive analysis of the climate risks the country faces and on how it can ameliorate these. The report not only serves stakeholders and policymakers in development planning, but also supports the country's efforts to fulfill its reporting obligations to the UNFCCC by providing up-to-date information on adaptation and vulnerability based on state-of-the-art climate projections. Suriname follows in the footsteps of countries such as Jamaica, which has developed a similar report every three years since 1995 in order to meet the country's 2030 vision, and matches the State of the Caribbean Climate Report, which was prepared by the Climate Studies Group Mona of the University of the West Indies for the Caribbean Development Bank in April 2020, with country-specific data.

DATA AND METHODOLOGIES

2.1. Climate analysis

The aim of this chapter is to present the data and methodologies used to analyze the historical climate and produce future climate projections, as well as to analyze climate risk.

To analyze the historical climate, measurements from 35 stations run by the Meteorological Service of Suriname were complemented with satellite data from the ERA5 dataset. For the future projections, a multi-model approach based on three CMIP6 General Circulation Models (GCMs) (HadGEM3-GC31, MIROC6 and IPSL-CM6A) was employed. The future climate was projected for three different time horizons (near 2020-2044, medium-term 2045-2069, and long-term 2070-2094) and two emissions scenarios (intermediate/SSP2-4.5 and severe/SSP5-8.5). Both historical and future climate data was downscaled to a 10 km resolution and presented on the country level and for seven points of interest (Paramaribo, Albina, Bigi Pan MUMA, Brokopondo, Tafelberg Natural Reserve, Kwamalasamutu, and Upper Tapanahony).

To analyze climate risk, a risk index was constructed based on a five-step procedure: 1) selection of indicators, 2) data quality check, 3) normalization, 4) weighing, and 5) aggregation. The risk index considers four sectors and the country's ten districts.

2.1.1. Data sources

The Meteorological Service of Suriname operates a wide range of meteorological stations across the country, most of which measure only precipitation, with a small number of stations measuring temperature, wind, and precipitation. The Meteorological Service provided the historical daily data for these station for the period from 1990 to 2019.

The analysis of this dataset has been especially challenging[1]. For this work 35 measurement stations were used, which were chosen based on the length of available data series. Among the stations used, six measured temperature, precipitation, wind, and humidity, among other variables that were not used in this study, and 29 measured only rainfall. Of these, some lacked several years of data at the beginning of the period, and coverage varied depending on each variable and location. The most complete variable was mean temperature, for which 92.7% of all possible data was available. Maximum daily temperature and minimum daily temperature each covered 90.1% and 90.0% of the total data, respectively. Relative humidity was available for 92.5% of all data, while the coverage was significantly less for precipitation, of which 60.7% of the spatiotemporal data series was available. Best practices for data storage and dissemination are included in the recommendations at the end of this report.

This dataset from Suriname was used in combination with the historical data provided by ERA5, which covers the entire country at a spatial resolution of 0.25° with temporal continuity. The Copernicus Climate Change Service (C3S) ERA5 dataset is highly accurate and helps to conduct

[1] The existing observations were very dense, but the data series in many cases lacked integrity and coherence, therefore many hours were spent in the interpretation and translation of the original data into usable data by various ways of logging precipitation and wind data.

climate change studies when data series from conventional meteorological observations are unavailable or incomplete for a given region. ERA5 is part of the European Union Earth monitoring program and is implemented by the European Center for Medium-range Weather Forecasts (ECMWF.) It has data on meteorological conditions from 1979 to the present back for the entire Earth's surface. The dataset comes from a combination of a meteorological models, the ECMWF Integrated Forecasting System (IFS) satellite observation data, and ground sensors to create a consistent long-term record of our climate. Reanalysis data provides the best possible understanding of past weather, what happened during a particular weather event and why, and to link current and past weather events. ERA5 provides estimates of many atmospheric, terrestrial, and oceanic climatic variables in hourly time resolution. The data covers the Earth in 30 km grid cells and divides the atmosphere into 137 levels from the Earth's surface to 80 km above ground. ERA5 includes information on uncertainties for all variables with reduced spatial and temporal resolutions.

The station data was used to calibrate the ERA5 reanalysis data. By applying the probability matching technique to the ERA5 data in relation to the observed data, a dense and regular grid of observation-validated reanalysis data could be obtained and used as the historical reference. One lasting result of this work was creating a multivariable database which can be used as a reliable pseudo-observational reference in future studies of Suriname's climate. The only exception was the ERA5 wind observations, which could not be used as this data was provided as average values on the Beaufort scale, whose low resolution made it unsuitable for the purposes of calibrating the historical dataset.

The probability matching technique (Calheiros and Zawadzki, 1987) adjusts the probability of an event happening in the reanalysis dataset to the probability of the same event happening in the observed dataset. First, a probability distribution function was computed for the observed dataset by calculating how many events of any intensity are found in the observed data. Then the cumulative distribution function (CDF), ranging from 0 to 1, was computed. This provided the probability of events occurring at any given intensity. This probability was then applied at the reanalysis dataset, where the data was matched with the observed data, and the distribution of events was similar in both datasets.

Using the ERA5 dataset and the observations recorded by the Meteorological Service of Suriname, a large number of climatic variables could be analyzed: temperature, maximum wind, and precipitation, in addition to the climate indices of summer days, frost days, tropical nights, heatwaves, rainy days, and moderate to strong wind or higher. Table 3 details the variables analyzed in this study.

Table 3*- Variables and indices used and their description and unit*

Abbreviation	Variable/ index	Description	Units
tmean	Variable	Average daily temperature	°C
tmax	Variable	Maximum daily temperature	°C
tmin	Variable	Minimum daily temperature	°C

Abbreviation	Variable/ index	Description	Units
TX90	index	Days when the mean temperature exceeds the mean temperature of 10% of the hottest days	days/year
TX10	index	Days when the mean temperature drops below the mean temperature of 10% of the coldest days	days/year
TN90	index	Nights when the mean temperature does not reach the mean temperature of 10% of the hottest nights	days/year
TN10	index	Nights when the mean temperature drops below the mean temperature of 10% of the coldest nights	days/year
Accumulated pcp	Variable	Accumulated rain	mm/year
Rainy days	index	Number of days with more than 1 mm of rain	days/year
RX1day	index	Value of maximum accumulated precipitation in 1 day	mm
RX5day	index	Value of maximum accumulated precipitation in 5 days	mm
Maximum wind	Variable	Average of maximum daily wind	Km/h
Strong wind days	index	Number of days with maximum wind stronger than 40 Km/h and lower or equal to 60 Km/h	days/year
Gale wind days	index	Number of days with maximum wind stronger than 60 Km/h	days/year
SLA	Variable	Increase of sea level above sea height	m
Humidity	Variable	Average relative humidity	%

Source: SOC Report team elaboration

2.1.2. Obtaining future projections from models

2.1.2.1. General Circulation Models

General Circulation Models (GCM) are numerical representations of the climate system that reproduce its components' (hydrosphere, cryosphere, atmosphere) dynamics at different spatial and temporal scales. They are versatile and extremely useful tools, since they include a complex group of processes based on the physical, chemical, and biological properties of each component of the climate system, their interactions, and existing feedback processes. In this way, each GCM can simulate responses to different radiative forcing (i.e. the total net radiation the system receives, which depends, among other factors, on the concentration of greenhouse gases) and scenarios, and each GCM models different atmospheric processes and feedback. GCMs can thus be forced to follow different scenarios and radiative forcings, thereby providing projections on how climate could evolve in the future.

An analysis of the scope and limitations of different GCMs is conducted by the renowned Coupled Model Intercomparison Project (CMIP), in which numerous climate modeling centers participate. This collaborative framework designed to study the outputs of climate models and improve our knowledge about climate change is the basis for the assessment reports elaborated by the Intergovernmental Panel on Climate Change (IPCC). The IPCC is a multinational UN-led body that constitutes the main advisory panel on climate change, and which elaborates periodical reports on the state of the climate and possible paths for it to develop. The CMIP ensures all the GCMs' information undergoes a robust data quality control procedure. The project is currently in its sixth phase (CMIP6).

In order to produce climatic trends, the most recent and currently available climate models of the CMIP6 were used. As these are still under development, there are only few model outputs available compared to CMIP5, on which the fifth IPCC assessment report is based. However, the number of available models was still considered to be suitable for a multi-model approach. In addition, CMIP6 projections, based on historical simulations from 1850-2014, are particularly useful in the context of Suriname, whose data record for the purpose of this report starts in 1990.

The multi-model approach of this study was based on the following CMIP6 GCMs (table 4):

***Table 4**- CMIP6 GCMs used in the multi-model approach*

GCM acronym	Centre
HadGEM3-GC31	Met Office Hadley Centre for Climate Change
MIROC6	Atmosphere and Ocean Research Institute (AORI), Centre for Climate System Research - National Institute for Environmental Studies (CCSR-NIES)
IPSL-CM6A	Institut Pierre-Simon Laplace (IPSL)

Source: SOC Report team elaboration

The models were selected based on the following criteria:

- A renowned climate study conducted in the region used the HadGEM2-ES and MIROC5 models (Almagro et al., 2017). The choice of these two models was based on their satisfactory simulation of precipitation and atmospheric circulation over South America. The State of the Climate report uses the new version of these models under CMIP6: HadGEM3-GC31 and MIROC6. In addition, the HadGEM3-GC31 and HadGEM2-ES models were created by the Met Office Hadley Centre for Climate Change that also developed the regional model PRECIS, which was used in Suriname's Second National Communication to the UNFCCC.

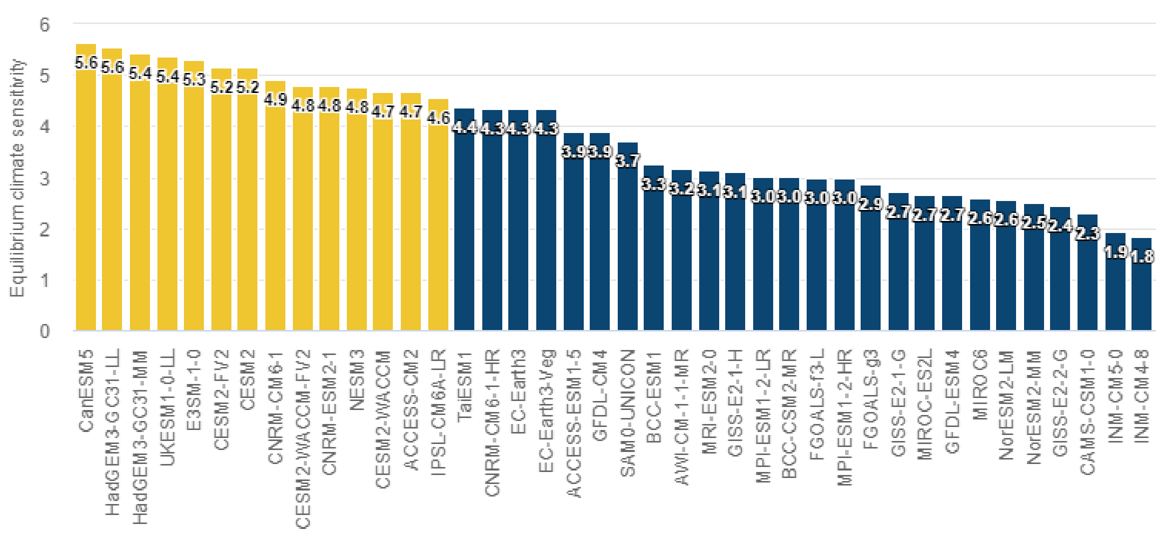
- IPSL-CM6A was added to the multi-model analysis based on the suggestion of local experts from the Anton de Kom University of Suriname (ADEKUS). Together with the other two models they cover a wide range of climate sensitivities. Climate sensitivity is the average change in the planet's surface temperature in response to changes in radiative forcing, for instance, how much it will warm from double the carbon dioxide concentration. A multi-model approach which analyzes a wide range of sensitivities covers the statistics for each variable and provides an error calculation that contains all possible climatic variations (Table 5, Figure 2).

Table 5- *Climate sensitivity in CIMP6 models*

Climate sensitivity	Model
High	HadGEM3-GC31
Medium	IPSL-CM6A
Low	MIROC6

Source: Rogelj et al. (2018)

Figure 2- *Climate sensitivity in CIMP6 models*



Source: Rogelj et al. (2018)

- In addition, the three models selected have undergone rigorous analysis and validation for the region. The earlier version (CMIP5) was used for the generation of the regional models of the CORDEX project for the Central American region. To sample the range of potential outcomes, and uncertainty associated with particular GCMs, it is necessary to provide ensemble simulations combining different models, as it is done within the CORDEX framework. These simulations give a robust model ensemble, from which models which have undergone rigorous analysis for the region can be selected.

2.1.2.2. Emissions scenarios

The Scenario Model Intercomparison Project (ScenarioMIP), one of the main activities of CMIP6, provides climate projections of multiple models based on a new set of emission scenarios and different paths of social development.

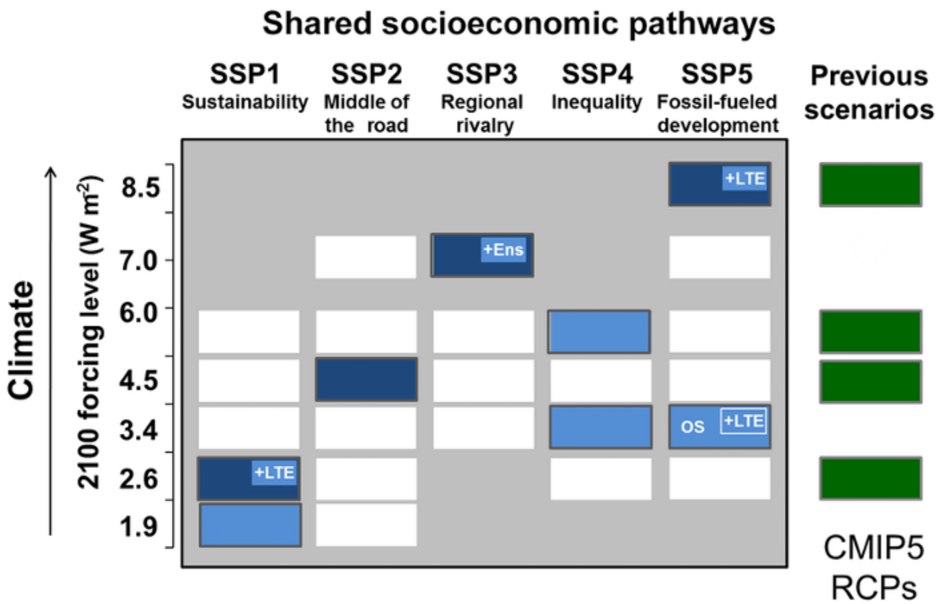
For the last available IPCC assessment report, Representative Concentration Pathways (RCP) were developed, based on an approximate calculation of the total radiative forcing in the year 2100 in relation to 1750, which can be 2.6 Wm^{-2} (RCP2.6 scenario), 4.5 Wm^{-2} (SSP2-4.5 scenario), 6.0 Wm^{-2} (RCP2.6 scenario), or 8.5 Wm^{-2} (RCP2.6 scenario). However, these were not accompanied by a socioeconomic narrative, but based purely on radiative forcing.

In recent years, a series of new trajectories have been constructed that examine the way in which global society, demography, and the economy could change in the next century, including aspects such as population and economic growth, education, urbanization, and technological development. These Shared Socioeconomic Paths (SSP) analyze five different ways in which the world could evolve in the absence of a climate policy: a world of growth and equality centered on sustainability (SSP1); a world where trends broadly follow their historical patterns (SSP2); a fragmented world of "resurgent nationalism" (SSP3); a world of increasing inequality (SSP4); and a world of rapid and unrestricted growth in economic production and energy use (SSP5). These narratives describe alternative pathways for society. They represent benchmarks on how things would look in the absence of a climate policy and allow researchers to examine barriers and opportunities for climate mitigation and adaptation.

Although not simultaneously, both efforts have been designed to be complementary. RCPs have established trajectories for greenhouse gas concentrations and the extent of warming that could occur at the end of the century. Meanwhile, the SSPs establish the intensity and timing of any emission reductions due to the different possible paths of global economic development. Compared to RCPs only, the combination of RCPs and SSPs offers a broader and more complex vision.

Both types of trajectories form a matrix in which each cell represents a different combination of situations that pose opportunities and challenges for the mitigation and adaptation to climate change (Figure 3).

Figure 3- Matrix of SSP-RCP scenarios



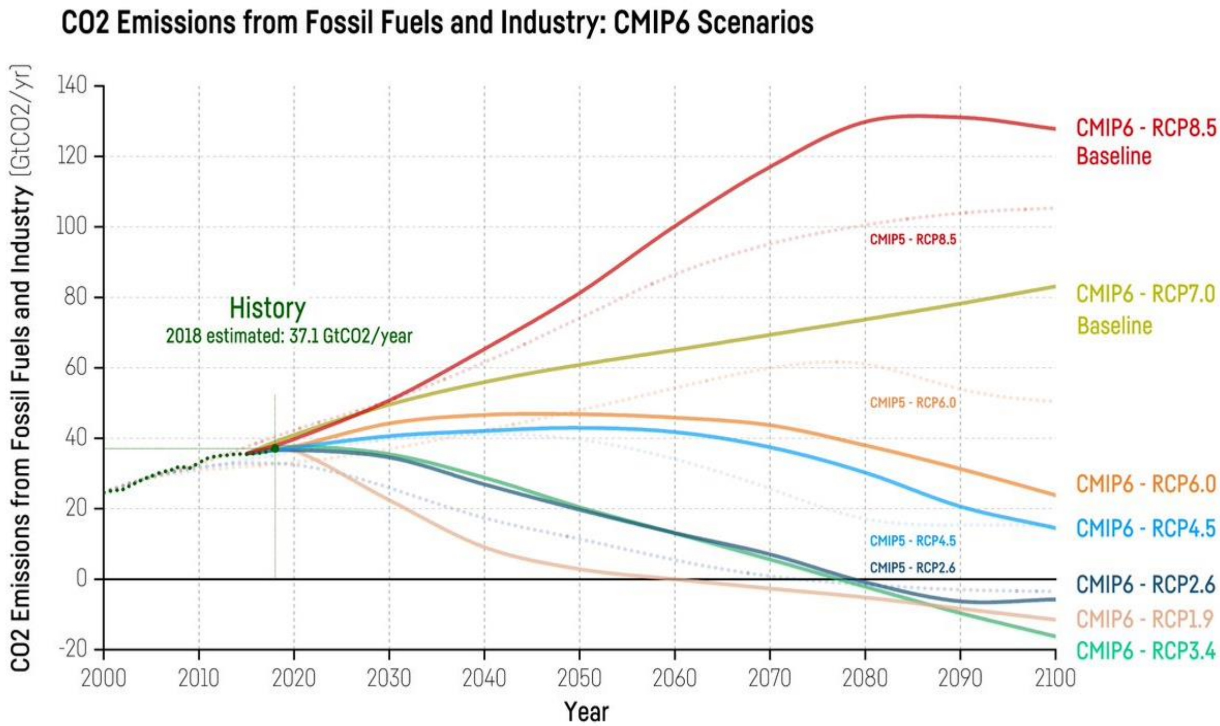
Source: Rogelj et al. (2018)

In this study, the scenarios SSP2-4.5 (a combination of RCP4.5 and SSP2) and SSP5-8.5 (a combination of RCP8.5 and SSP5) have been selected:

- SSP2-4.5 represents the intermediate level in the range of paths contemplated and updates the RCP-4.5 path. It is a scenario that combines an intermediate society and forcing level.
- SSP5-8.5: This scenario represents the higher end of the range of paths. It includes an update of the RCP8.5 trajectory with an increase in CO_2 emissions much faster after 2030 compared to the previous version used in the fifth assessment report. Since the RCP8.5 trajectory had very high expectations for other greenhouse gases that were not supported by observations, more CO_2 had to be released to reach 8.5 Wm^{-2} in 80 years. This is the only scenario with emissions high enough to produce a radiative forcing of 8.5 Wm^{-2} in 2100.

The scenarios have been approved for use in the development of the CMIP6 project and are considered the best available to generate simulations of the past, present, and future climate. The CMIP6 climate projections differ from those of CMIP5 not only because they are generated by updated versions of climate models, but also because they are based on updated scenarios and recent emissions trends, a significant improvement (Figure 4).

***Figure 4**- Evolution of CO2 emissions from fossil fuels and industry, comparing the scenarios of CMIP5 (dashed line) and CMIP6 (continuous line)*



Source: Ritchie (2018)

2.1.2.3. Statistical downscaling model

GCMs have a coarse spatial resolution that limits the assessment of climate change impacts on a more regional and local scale. In addition, many physical processes, such as those related to clouds, occur on smaller spatial scales than those used by GCMs, and are not simulated. GCMs also have limitations when simulating feedback mechanisms such as the greenhouse effect of water vapor, radiation of clouds, ice in ocean circulation, or the albedo effect of snow. Although uncertainties are inherent to the modeling process, GCMs are particularly prone to generating deviations or errors when representing specificities at more regional or local scales.

The climate of a region is determined by the interaction of forcings and circulations that occur on a planetary, regional, and local scale, as well as by a wide range of timescales, ranging from sub-daily to multi-decadal. Forcings on a planetary scale regulate the general circulation of the atmosphere. Incorporated within the general circulation, local and regional forcings and smaller-scale circulations modulate the spatial and temporal structure of the regional and local climatic signal. Local and regional forcings refer to spatial scales below 10^4 and 10^7 km^2, respectively. Above this limit one refers to the continental scale. Forcings on smaller spatial scales consider the marked climatic heterogeneity that exists within the continental scales. Some examples of forcings on a local and regional scale are the complex orography of a region, the characteristics of land use, the distribution of lakes and rivers, the distribution and contrasts between land and ocean, and snow. Until now regional forcings were resolved using regional climate models.

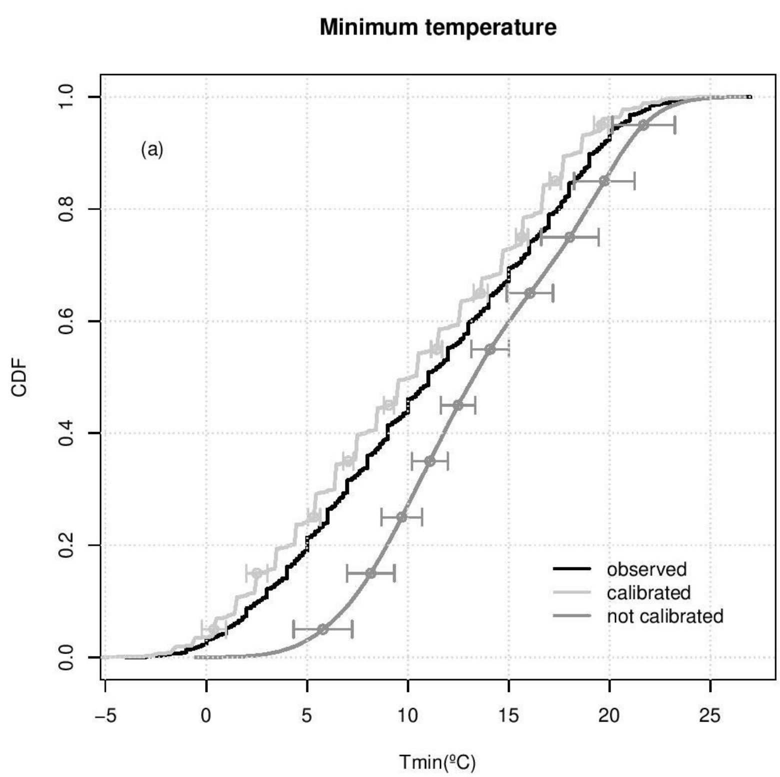
There are several procedures for adjusting climate projections considering either regional or local forcings, a correcting process known as downscaling:

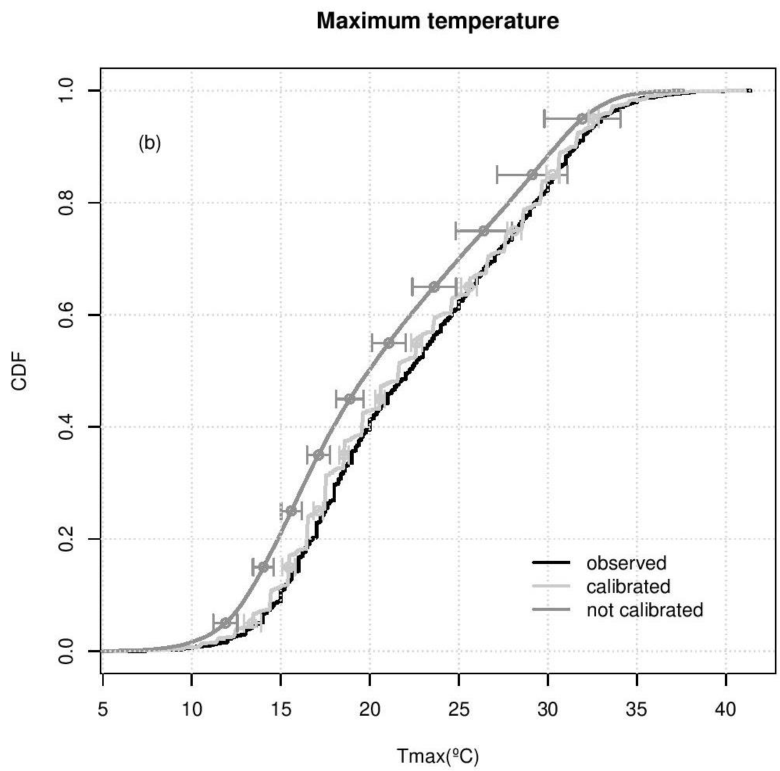
- Adding the climatological difference between the future and historical simulations of the RCPs to the observed historical data, called the delta method
- Eliminating the existing bias in the future simulations of CGMs by applying the difference between the observed and simulated historical datasets, called the unbiasing method

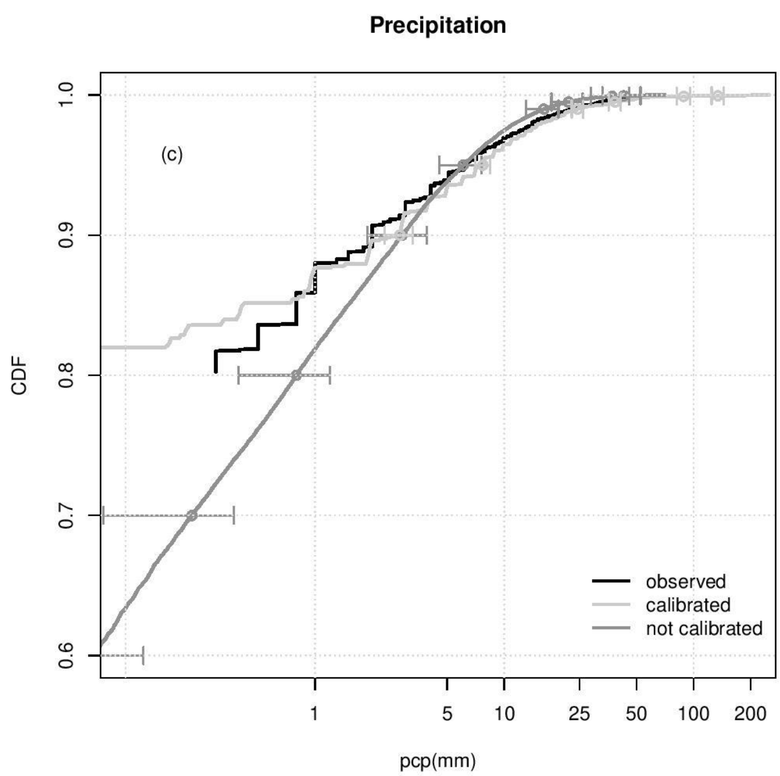
The first correction assumes that the variability of climatic variables in future scenarios remains unchanged, while the second assumes that such variability is identical to that observed, both of which are very restrictive. Therefore, in this study we apply a more complex statistical downscaling method, the quantile-to-quantile method (Q-Q) (Amengual et al., 2012a and b).

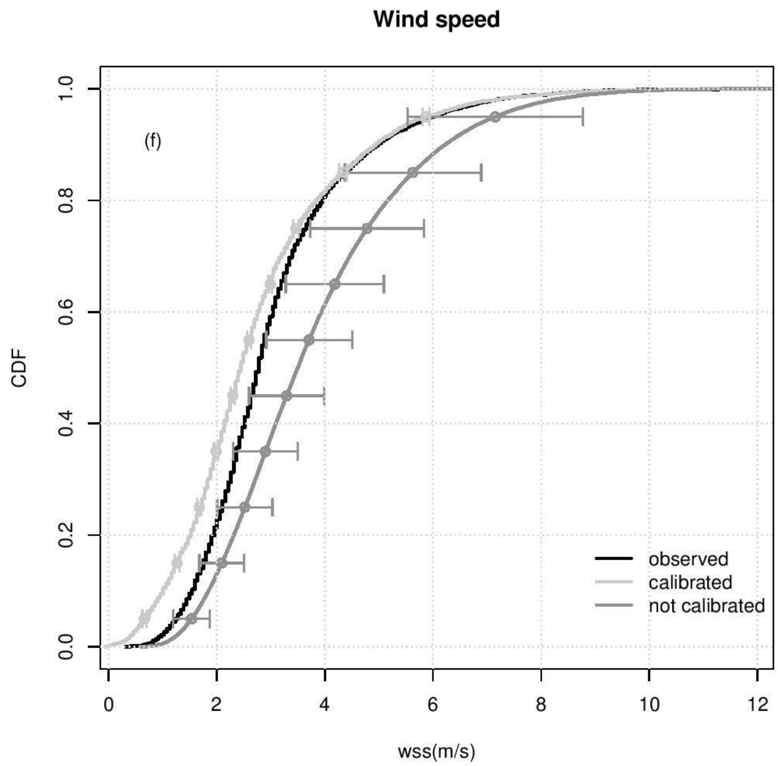
In the Q-Q adjustment, all climatic variables are adjusted to consider regional forcings (Figure 5). The method considers the same historical period or baseline for the observed (black line) and simulated variables (dark grey line). It then determines the differences between the two series of data and corrects the variables for future periods, considering these differences (light grey line).

Figure 5*- Application of the quantile-to-quantile adjustment: cumulative distribution function (CDF) is the probability of the variable having a value equal to or smaller than x at each point of a) minimum temperature, b) maximum temperature, c) precipitation, and d) wind speed in Palma de Mallorca, Spain*




Maximum temperature
(b)
CDF
0.0
0.2
0.4
0.6
0.8
1.0
5
10
15
20
25
30
35
40
Tmax(ºC)
observed
calibrated
not calibrated


Precipitation
(c)
CDF
0.6
0.7
0.8
0.9
1.0
1
5
10
25
50
100
200
pcp(mm)
observed
calibrated
not calibrated



Source: SOC Report team elaboration

This statistical adjustment allows to use climatic characteristics in global climate simulations, correcting and adapting them to the local scale.

In summary, this method not only corrects the projections according to the differences between the simulated climatic parameters in the future and present scenarios, but also the errors in the mean, as well as the variability and the distribution of the future climatic variables of interest.

2.1.2.4. Reference period and future climatological standard normal

Under the World Meteorological Organization's (WMO) current technical regulations, which recognize the reality of a changing climate, climatological standard normal is defined as the average of climatological data computed for successive 30-year periods. A 30-year period is long enough to filter out any interannual variation or anomalies, but also short enough to be able to show longer climatic trends. Averaging over shorter time periods may lead to misleading interpretations of the results. Climatological standard normal periods should be adhered to whenever possible to allow for a uniform basis for international comparison.

However, the analysis provided in this report was restricted by the current available future model periods, which sometimes only cover up to the year 2099. As the aim of his study was to analyze three future time periods, near future, medium-term, and long-term from 2020 onwards, 25-year periods were defined - a compromise to obtain robust results and cover three time horizons.

Accordingly, the following periods of 25 years were established: Near future (2020-2044), medium-term (2045-2069), and long-term (2070-2094).

From a historical viewpoint, a reference period of 25 years from 1 January 1990 to 31 December 2014 was used. This drew on the most recent observation data available in Suriname that matches climate models (which reach up to the year 2014), allowing for Q-Q adjustments.

2.1.2.5. Presenting the data

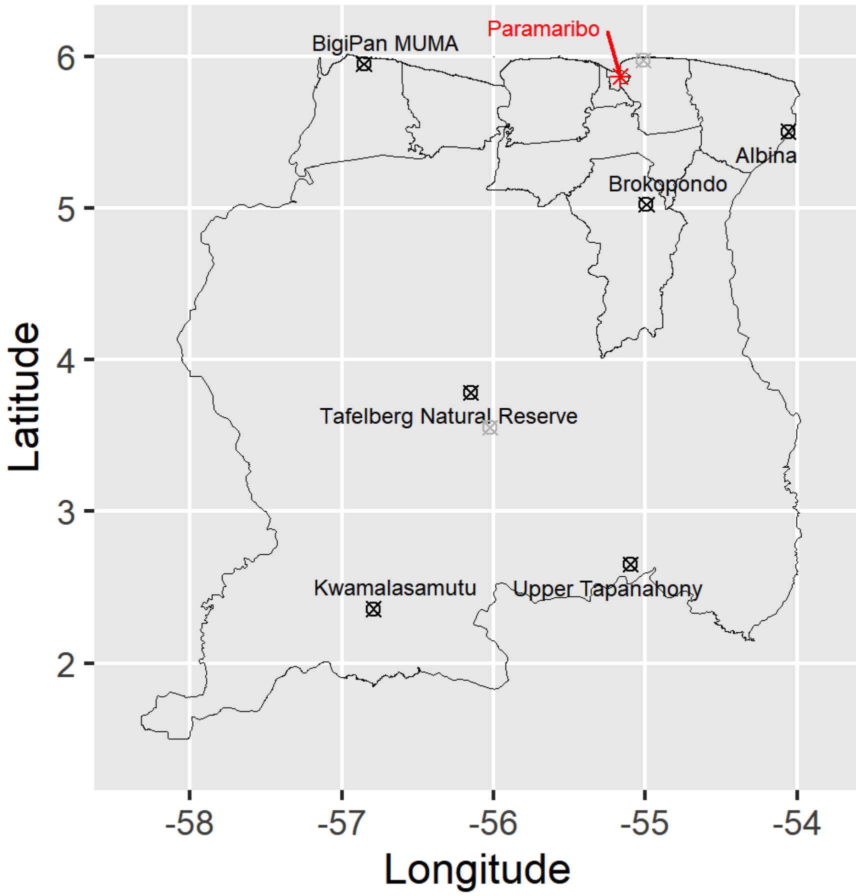
This study provides an analysis at a regional scale, presented in maps that cover the entire country at a resolution of 10 km.

In addition, it also provides an analysis at the local scale, presented in figures and tables for seven pre-selected points of interest:

1. Bigi Pan MUMA
2. Paramaribo
3. Brokopondo
4. Albina
5. Tafelberg Natural Reserve
6. Kwamalasamutu
7. Upper Tapanahony

These points of interest are shown in Figure 6 and have been chosen based on locations of high population, important economic activity, or representation of a wider unpopulated region as drawn from the regional results. Half the points are in the coastal area, among them the capital of Suriname, Paramaribo, while the rest are located further south in the interior of the country.

Figure 6- Location of the points of interest used in this study



Source: SOC Report team elaboration

2.2. Risk analysis

2.2.1. The concept of risk

In their latest, fifth assessment report on Impacts, Adaptation and Vulnerability, the Intergovernmental Panel on Climate Change (IPCC) defines risk as "the potential for consequences where something of value is at stake and where the outcome is uncertain (…) Risk results from the interaction of vulnerability, exposure, and hazard" (IPCC, 2014a).

Moreover, the IPCC (2014a) defines vulnerability, exposure, and hazard as follows:

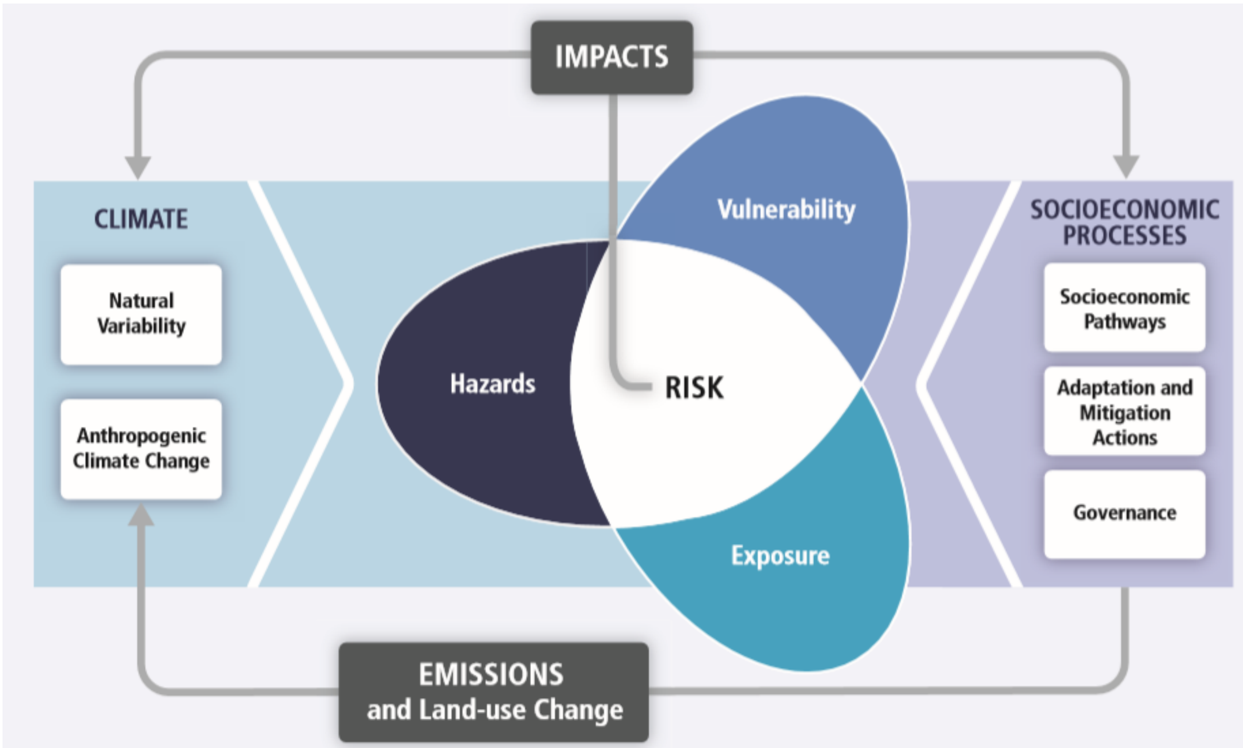
- Vulnerability- The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (…)
- Exposure- The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.
- Hazard- **The** potential occurrence of a (…) physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources (…)

Climate hazards may stem from gradual changes in climate variables such as precipitation and temperature, or from extreme events such as floods and droughts. Notably, anthropogenic climate change adds to already existing natural climate variability and can lead to an increase in gradual changes and extreme events.

Vulnerability and exposure to climate hazards depend on several socioeconomic factors, such as income, education, governance, access to public goods and services, and adaptation measures that have been adopted to reduce exposure and vulnerability. Importantly, without hazards, there is no exposure, and without exposure, there is no vulnerability.

Risk is the product of Hazards, Exposure and Vulnerability, and materializes as an impact which creates feedback into existing hazards in the climate system and the socioeconomic system responsible for vulnerability and exposure.

Figure 7- *Climate risk is the product of climate hazards, exposure, and vulnerability*



Source: IPCC (2014b)

2.2.2. Risk indicators and indices

Climate risk is a complex idea, so it is advantageous to analyze climate hazards first, then exposure and vulnerability, and later assess their results and interactions in one metric. This is best done using indicators which can later comprise an easy-to-understand risk index. The selection of indicators is subjective and depends on expert opinion. Risk indices are elaborated using the following five-step procedure (Nardo, Saisana, Saltelli, Tarantolla, Hoffman & Govannini, 2005; Saisana & Tarantola, 2002).

i. Selection of indicators

ii. Data quality check

iii. Normalization

iv. Assigning weights to the indicators

v. Aggregation

2.2.2.1. Selection of indicators

The selection of indicators is the first step to be taken. It is conditioned by several factors:

- The theoretical framework- the definitions of hazard, exposure and vulnerability underlying the indicators

- The availability of data
- The quality of the data (see step 2.2.2.2.)

Hazards

The hazard indicators correspond to the following 18 climate variables of the climate analysis:

- Temperature
    - Average annual temperatures (mean, minimum, maximum)
    - Frequency of cold days- number of days per year in which the maximum temperature falls below the threshold of the 10th percentile of the average maximum temperature.
    - Frequency of cold nights- number of days per year in which the minimum temperature falls below the threshold of the 10th percentile of the average minimum temperatures.
    - Frequency of hot days- number of days per year in which the maximum temperature falls above the threshold of the 90th percentile of the average maximum temperatures.
    - Frequency of hot nights- number of days per year in which the minimum temperature falls above the threshold of the 90th percentile of the average minimum temperatures.

- Precipitation
    - Number of rainy days per year (R> 1mm)
    - Mean accumulated annual rainfall
    - Annual maximum rainfall recorded on one day
    - Annual maximum rainfall recorded on five consecutive days
    - Dry season rainfall (16 August - 30 November)
    - Short dry season rainfall (01 February - 15 April)
    - Rainy season rainfall (16 April - 15 August)
    - Short rainy season rainfall (01 December - 31January)

- Relative humidity

- Wind
    - Number of days per year with strong wind (maximum wind 40 km/h-60 km/h).
    - Number of days per year with gale wind (maximum wind >60 km/h).
    - Maximum wind speed per year (km/h)

- Sea-surface height above the geoid

Exposure and vulnerability

The indicators for exposure and vulnerability were selected based on the characteristics of the sectors that formed part of this analysis (agriculture, water, forestry, infrastructure) and are presented in tables 6-9.

Table 6- Indicators for exposure and vulnerability in the Agriculture sector

Unit	Year	Description
Exposure		
Number of family farms as a percentage of the total number of households	2008-2009	99.6% of farms are family farms (managed by one or more people belonging to the same household). Only 0.4% of farms are managed alternatively (corporations, non-governmental organizations, companies belonging to the government, institutions, religious organizations).
Number of animals (cattle, sheep, goats, pigs) per farm on average	2008-2009	
Agricultural land as a percentage of the total area of the district	2008 and 2018-2019	
Number of hired workers on farms (2008) as a percentage of the total population (2012)	2008 and 2012	The more people are employed on farms, the more people will be negatively affected by climate change. Hired employees do not form a part of the household the farm is managed by.
Number of farms with less than two hectares of agricultural land as a percentage of all farms	2008-2009	Smallholders are often subsistence farmers which are more likely to practice their profession in areas prone to climate hazards (riverbanks, flood plains etc.). Moreover, they often have limited physical capacity and assets to cope with risks and are unable to switch to other livelihood strategies.
Percentage of population whose income is less than half of GNI per capita of the district (2009)	2009	Low-income people are more likely to suffer from food insecurity as they are less able to compensate for higher food prices.
Percentage of children under the age of 5 that are stunted (-2 SD) (2018)	2018	People who already suffer from food insecurity are likely to suffer most from an increase in food insecurity. Stunting refers to a child who is too short for their age. Stunting is the failure to grow both physically and cognitively and is the result of chronic or recurrent malnutrition. Wasting refers to a child who is too thin for his or her height. Wasting, or acute malnutrition, is the result of recent rapid weight loss or the failure to gain weight. A child who is moderately or severely wasted has an increased risk of death, but treatment is possible.
Percentage of children under the age of 5 that are wasted (-2 SD) (2018)		

Unit	Year	Description
Vulnerability		
Number of family farms with the farmer having received no formal education as a percentage of all family farms	2008-2009	More educated farmers show higher adaptive capacity to cope with changing conditions and to find solutions to problems.
Number of family farms run by women as a percentage of the total number of family farms	2008-2009	Female farmers and fishers are likely to have less access to the services of finance institutions to improve their production means or to protect themselves against the negative impacts of climate change. Therefore, the fewer male farmers and fishers and more female ones, the higher the sector's risk. This indicator highlights the financial exclusion that women face and affects the inclusiveness of the sector.
Number of farms with irrigation infrastructure as a percentage of the total number of farms (inverted)	2008	Coastal agriculture relies on irrigation infrastructure as rainfall is seasonal. Less irrigation infrastructure indicates that production systems will suffer from water shortage. This indicator only concerns the coastal districts (excluding Sipaliwini and Brokopondo), where irrigation infrastructure is important due to less rainfall.

Source: SOC Report team elaboration from Ministry of Social Affairs and Public Housing (2019), Ministry of Social Affairs and Public Housing (2020), Ministry of Agriculture, Animal Husbandry, and Fisheries (LVV), UNDP (2013), Lowder, Sánchez, & Vertini (2019), and the General Bureau of Statistics (ABS)

Table 7- Indicators for exposure and vulnerability in the Water sector

Description	Year	Description
Exposure		
Population as a percentage of the total number of households not using improved drinking water sources	2018	Improved drinking water sources include piped water into a dwelling, compound, yard, or plot, a neighbor, public tap/standpipe, tube well/borehole, protected dug well, protected spring, rainwater collection, and packaged or delivered water.
Number of households as a percentage without adequate waste-water disposal	2018	Improved sanitation facilities include flush or pour flush to piped sewer systems, septic tanks, or pit latrines, ventilated improved pit latrines, pit latrines with slabs, and composting toilets. People without improved sanitation facilities will be more affected by water quality deterioration.
Number of households with in-adequate water availability, as a percentage of the total number of households	2018	The more people do not have sufficient drinking water available; the more people are affected by further reductions in drinking water availability.
Number of household members as a percentage of the total number of household members without access to drinking water on premises	2018	People with less access to drinking water are the most affected by further reductions in drinking water accessibility.
Vulnerability		
Inverted SWM and DWV water production (m3/day) per capita	2015 and 2012	The less water per capita, the more likely shortages are to arise due to decreases in drinking water availability.
Inverted storage capacity (m3/day) per capita	2017 and 2012	The less water storage, the less water availability during drought periods.

Number of households whose main source of drinking water is not rainwater collection, as a percentage of the total number of households	2018	The fewer alternative water resources such as rainwater collection, the more people rely on groundwater, most of which is not renewable in Suriname and whose availability decreases further over time.

Source: SOC Report team elaboration, information provided by the Ministry of Social Affairs and Public Housing (2019), and the General Bureau of Statistics (ABS)

Table 8- *Indicators for exposure and vulnerability in the Forestry sector*

Description of unit	Year	Description
Exposure		
Area of mangroves as a percentage of the total area of the district	2018	The more area covered by coastal mangroves, the higher the risk of coastal mangroves being negatively affected.
Area of open savanna and swamp as a percentage of the total area of the district	2017	The complete list of SBB LULUC categories is: Abandoned areas, agriculture, buildings, infrastructure, water bodies, mining, open savanna, open swamp, forest.
Area of forest (excluding savannas and swamps) as a percentage of the total area of the district	2017	The more area covered by forests, the higher the risk of forests being negatively affected.
Area of community (HKV) and company concessions as a percentage of the forested area of the district	2018	The more area of the forest forms part of concessions, the more people are employed in the forestry sector and negatively impacted by declines in forest production.
Vulnerability		

Number of Amerindian and Maroon settlements per km² district area	No date	All land used by ITP is contested. The more forested land with contested rights, the more unsustainable land-use practices, deforestation, and the less ecosystem management.
Inverted number of SBB logging checkpoints per km² forest	2020	The smaller the density of logging check points, the more likely illegal logging and forest degradation exist.
Deforested area between 2000 and 2015 as a percentage of the total forested area	2000	The more deforestation, the more floods and droughts.
Volume (m³) of roundwood produced per km² forest	2018 and 2017	Logging causes forest degradation. The higher the roundwood production, the higher the forest degradation.

Source: SOC Report team elaboration, information provided by Foundation for Forest Management and Production Control (SBB), www.gonini.org, and the and the General Bureau of Statistics (ABS).

Table 9- *Indicators for exposure and vulnerability in the Infrastructure sector*

Unit	Year	Description
Exposure		
Km of road per km² area	2018	The more roads, bridges, and ports, the more likely economic and physical losses and damage.
Number of bridges per km² area	2018	
Number of certified harbors per capita (x 100.000)	2017	
Number of electricity connections as a percentage of the total number of people	2018 and 2012	The more electricity connections, the more likely economic and physical losses and damage to transmission lines. This indicator concerns EBS electricity connections.
Coastline (km) per area (km2)	2020	The more coastline a district has in relation to its area, the more it is exposed to sea-level rise, waves, high winds, and floods.

Unit	Year	Description
District population as a percentage of the total population in Suriname	2012	The more people that live in a district, the more people can be adversely affected.
Vulnerability		
Percentage of household members that rely on fuel for lighting	2018	The more people rely on fuel for lighting, combined with the fewer people that are connected to the grid, the more people may suffer from energy insecurity when road or boat transport of fuels is interrupted.
Inverted number of water-related data gathering stations per km^2 area	2020	The less water data stations there are, the less water management can be performed to prevent and mitigate floods. This indicator uses the water-related data gathering stations of the Maritime Authority Suriname and the Hydraulic Research Division.
Percentage of dwellings without finished flooring	2018	Climate hazards affect the durability of the exterior of buildings such as walls and roofs. Water entry may also lead to moisture-related problems inside of buildings. The less weather-resistant the material and design of buildings, the more likely they are to suffer from losses and damage due to climate hazards.
Percentage of dwellings without finished roof		
Percentage of dwellings without finished walls		
Length of non-novel roads as a percentage of all roads	2018	The more non-novel material roads (sand and laterite roads), the less long-lived the road system. Under conditions of frequent rainfall and with little resources for regular maintenance, asphalt and paved roads are the most long-lived.
Number of non-novel bridges as a percentage of all bridges	2018	The more non-novel material bridges (wood, steel/wood, and fiber bridges), the less long-lived the bridge system. Concrete and steel are considered novel materials.
Inverted primary completion rate	2018	Education can be a powerful tool in enabling effective adaptation to climate change (IPCC, 2014) by conditioning housing and other infrastructure so they cope with climate stresses. Therefore, the less education, the higher the losses and damage due to climate hazards.

Source: SOC Report team elaboration, information provided by the Ministry of Social Affairs and Public Housing (2019, 2020), ABS (2018, 2019), SWRIS Suriname Water Resources Information System SWRIS (2020a, 2020b), Gonini (2020), and the General Bureau of Statistics (ABS)

2.2.2.2. Data quality check

The indicators and risk index can only be as good as the data which compose them. Therefore, the indicators were screened for outliers and missing data and redundancy due to correlation.

Importantly, the data quality check does not account for the uncertainty of the future climate. This is accounted for by employing state-of-the-art methods to make the projections, including Q-Q statistical downscaling, ERA5 reanalysis data and models from the CMIP6, and by constructing risk indices for various emission scenarios (SSP2-4.5 and SSP5-8.5).

- Outliers: Data points whose standardized z-value is bigger than -/+ 3 classify as outliers. By contrasting outliers with other sources of information they can be distinguished into those:
    - caused by an error which can be corrected
    - caused by an error which cannot be corrected, in which case the data point must be deleted from the series (see data missing at random below)
    - not caused by an error, in which case they are substituted with the maximum permittable value (z = 3)

  There were no outliers detected in the variables on vulnerability and exposure. The hazard variables were not analyzed for outliers, as these were projected and may include outliers due to fundamental changes in the future climate.

- Missing data: Missing data can be distinguished into:
    - Data missing at random, whose absence does not introduce bias into the analysis
    - Data missing not at random (e.g. higher incomes not declared by wealthy households), whose absence introduces bias into the analysis. Preferably, indicators without data missing not at random were used in the analysis.
    - The variable on SWM storage capacity (m^3/day) per capita (related to the vulnerability of the water sector) only had data for the four districts served by SWM (Para, Paramaribo, Saramacca, Wanica).
    - The variable of irrigation infrastructure (related to the vulnerability of the agriculture sector) was applied only in the coastal districts, excluding Sipaliwini and Brokopondo. In the interior of the country shifting cultivation is practiced, and this does not rely on irrigation infrastructure.
    - The variable of the proportion of non-novel bridges (related to the vulnerability of the infrastructure sector) did not yield data for Coronie, as this district did not have any bridges on record.

No missing data introduced bias into the analysis and all indicators could be retained in the analysis. The hazard variables were complete for all scenarios, time periods, and districts.

2.2.2.2.1 Correlation between indicators for each sector

Agriculture

The number of family farms correlates positively and significantly with the farmer having received no formal education ($p<0.05$) and the number of female farmers ($p<0.01$) (table 10). Family farming, which is the most prevalent form of farming in Suriname, is an economic activity that does not generate a high income. It is more likely to be conducted by less educated people, who cannot execute a more lucrative profession. As women have less access to education, this also implies that the more farming, the more women will be farmers, and they will be less educated farmers, as the significant positive correlation between the number of female farmers and the farmer having received no formal education ($p<0.001$) implies.

- The number of animals per farm is inversely and significantly related to the farmer having received no formal education ($p<0.05$), and the number of female farmers ($p<0.001$). Less educated (often female) farmers are less likely to have the human and financial capital to buy and hold animals, thus the inverse correlation. Due to the multiple correlations between female farmers and other variables, the indicator was excluded from the analysis to avoid redundancy.

- Other correlations concern those between irrigation infrastructure and wasted children ($p<0.001$).

Water

Unimproved sanitation facilities, unimproved drinking water sources, access to drinking water, and rainwater collection all correlate significantly and positively with one another, except for rainwater collection, which is inversely related to the rest of variables (table 11). This is because rainwater collection is a source of improved drinking water. In the hinterland, unimproved sanitation facilities (e.g. defecation in rivers) and rainwater collection are frequent. As water and wastewater connections are often installed simultaneously, these two variables correlate very strongly, and the indicator on improved sanitation facilities was excluded from the analysis to avoid redundancy.

Forestry

The SBB logging checkpoint density, deforestation rate, and forested area all correlate significantly with one another ($p<0.01$) (table 12). The higher the proportion of forested area of the total district area, the smaller the logging checkpoint density and the smaller the deforestation rate. Therefore, the indicator on the number of SBB logging checkpoints was excluded from the analysis to avoid redundancy. Moreover, the concession area as a percentage of the total forested area correlated positively and significantly with SBB logging checkpoint density ($p<0.01$) and the volume of roundwood produced per km^2 forest ($p<0.01$). There is a casual link between concession area and roundwood production, thus the indicator on concession area was removed from the analysis, as roundwood production gives a better idea of the actual economic output of concessions, both in terms of primary products as well as employment of forest dependent people.

Infrastructure

The road network density correlates significantly and positively with multiple variables (table 13): the number of bridges ($p<0.001$), the proportion of coastline of each district ($p<0.05$), and the number of water-related data gathering stations ($p<0.01$). The proportion of coastline of each district and the number of water-related data gathering stations also correlate significantly and positively ($p<0.001$), and both correlate to a lesser extent and negatively with the proportion of dwellings with unfinished walls ($p<0.05$). The indicator on the number of water-related data gathering stations was excluded from the analysis to avoid redundancy, and because of its strong correlation with several other variables, and the importance of those indicators on the road network and coastline for estimating infrastructure related losses and damage, particularly from sea-level rise.

- The number of electricity connections also correlates significantly with several other variables: the number of households using fuel for lighting (negative correlation, $p<0.01$), the proportion of bridges of non-novel material (negative correlation, $p<0.05$), dwellings without finished walls (negative correlation, $p<0.05$) and the primary completion rate (positive correlation, $p<0.05$).

- The number of households using fuel for lighting correlates significantly and positively with the proportion of dwellings that have an unfinished flooring and roof ($p<0.05$). As the indicator on electricity connections provides information on both socioeconomic conditions as well as infrastructure assets, it was retained in the analysis. However, the indicator on households using fuel for lighting was excluded from the analysis to avoid redundancy.

- Out of the three indicators on dwellings (with an unfinished roof, flooring, or walls), the two on dwellings with an unfinished flooring and roof correlate significantly and positively with each other ($p<0.03$). As the indicator on dwellings with an unfinished floor had the strongest average correlation with other indicators, it was excluded from the analysis to avoid redundancy.

__Table 10__- P-values of Pearson correlations are shown between variables of vulnerability and exposure for Agriculture. Statistically significant values are underlined, exposure variables are highlighted in red and vulnerability variables are highlighted in yellow.

	Number of animals (cattle, sheep, goats, pigs) per farm on average	Agricultural land as a percentage of the total area of the district	Number of hired workers as a percentage of the total population	Number of farms with less than 2 ha of agricultural land as a percentage of all farms	Percentage of population whose income is less than half of GNI per capita of the district	Percentage of children under the age of 5 that are stunted (-2 SD)	Percentage of children under the age of 5 that are wasted (-2 SD)	Number of family farms with the farmer having received no formal education as a percentage of all family farms	**Number of family farms run by women as a percentage of the total number of family farms**	Number of farms with irrigation infrastructure as a percentage of the total number of farms
Number of family farms as a percentage of the total number of households	0,068	0,165	0,588	0,448	0,842	0,571	0,312	0,016	0,005	0,269
Number of animals (cattle, sheep, goats, pigs) per farm on average		0,172	0,751	0,554	0,916	0,704	0,176	0,019	0,001	0,282
Agricultural land as a percentage of the total area of the district			0,998	0,846	0,590	0,995	0,155	0,366	0,126	0,207
Number of hired workers as a percentage of the total population				0,219	0,105	0,458	0,065	0,596	0,498	0,103
Number of farms with less than 2 ha of agricultural land as a percentage of all farms					0,612	0,254	0,715	0,163	0,221	0,482
Percentage of population whose income is less than half of GNI per capita of the district						0,123	0,277	0,467	0,371	0,239
Percentage of children under the age of 5 that are stunted (-2 SD)							0,797	0,359	0,654	0,092
Percentage of children under the age of 5 that are wasted (-2 SD)								0,491	0,066	0,000
Number of family farms with the farmer having received no formal education as a percentage of all family farms									0,001	0,495
Number of family farms run by women as a percentage of the total number of family farms										0,073

Source: SOC Report team elaboration

Table 11- P-values of Pearson correlations are shown between variables of vulnerability and exposure for Water. Statistically significant values are underlined, exposure variables are highlighted in red, and vulnerability variables are highlighted in yellow.

	Number of households not using improved sanitation facilities as a percentage of the total number of households	Number of households without drinking water available in sufficient quantities as a percentage of the total number of households	Number of household members without access to drinking water on premises as a percentage of the total number of household members	SWM and DWV water production (m^3/day) per capita	Number of households which main source of drinking water is not rainwater collection as a percentage of the total number of households
Number of households not using improved drinking water sources as a percentage of the total number of households	0,000	0,772	0,000	0,166	0,017
Number of households not using improved sanitation facilities as a percentage of the total number of households		0,969	0,000	0,091	0,005
Number of households without drinking water available in sufficient quantities as a percentage of the total number of households			0,793	0,320	0,414
Number of household members without access to drinking water on premises as a percentage of the total number of household members				0,371	0,027
SWM and DWV water production (m^3/day) per capita					0,078

Source: SOC Report team elaboration

***Table 12**- P-values of Pearson correlations are shown between variables of vulnerability and exposure for Forestry. Statistically significant values are underlined, exposure variables are highlighted in red, and vulnerability variables are highlighted in yellow.*

	Area of open savanna and swamp as a percentage of the total area of the district	Area of forest as a percentage of the total area of the district	**Number of SBB logging checkpoints per km² forest**	**Concession area as a percentage of the total forested area**	Deforested area between 2000 and 2015 as a percentage of the total forested area	Number of Amerindian and Maroon settlements per km²	Volume (m³) of roundwood produced per km² forest
Area of mangroves as a percentage of the total area of the district	0,714	0,625	0,924	0,685	0,986	0,486	0,301
Area of open savanna and swamp as a percentage of the total area of the district		0,715	0,274	0,244	0,230	0,545	0,460
Area of forest as a percentage of the total area of the district			<u>0,000</u>	0,653	<u>0,006</u>	0,061	0,176
Number of SBB logging checkpoints per km² forest				<u>0,009</u>	<u>0,000</u>	0,117	0,278
Concession area as a percentage of the total forested area					0,259	0,101	<u>0,002</u>
Deforested area between 2000 and 2015 as a percentage of the total forested area						0,506	0,493
Number of Amerindian and Maroon settlements per km²							0,663

Source: SOC Report team elaboration

Table 13- P-values of Pearson correlations are shown between variables of vulnerability and exposure for Infrastructure. Statistically significant values are underlined, exposure variables are highlighted in red, and vulnerability variables are highlighted in yellow

	Number of bridges per km² area	Number of certified harbors per capita (x 100.000)	Number of electricity connections as a percentage of the total number of people	Coastline (km) per area (km²)	Number of people as a percentage of the total population of Suriname	**Percentage of household members that rely on fuel for lighting**	**Number of water-related data-gathering stations per km² area**	Length of non-novel roads as a percentage of all roads	Number of non-novel bridges as a percentage of all bridges	**Percentage of dwellings without finished flooring**	Percentage of dwellings without finished roof	Percentage of dwellings without finished walls	Primary completion rate
Km of road per km2 area	0,000	0,259	0,187	0,039	0,293	0,074	0,008	0,676	0,987	0,229	0,372	0,074	0,726
Number of bridges per km² area		0,243	0,446	0,133	0,200	0,200	0,043	0,987	0,580	0,365	0,662	0,200	0,489
Number of certified harbors per capita (x 100.000)			0,986	0,957	0,415	0,682	0,708	0,845	0,762	0,295	0,527	0,873	0,554
Number of electricity connections as a percentage of the total number of people				0,270	0,726	0,005	0,229	0,651	0,011	0,082	0,159	0,043	0,025
Coastline (km) per area (km²)					0,774	0,322	0,000	0,063	0,748	0,853	0,437	0,012	0,800
Number of people as a percentage of the total population of Suriname						0,229	0,907	0,029	0,855	0,138	0,325	0,556	0,829
Percentage of household members that rely on fuel for lighting							0,244	0,676	0,098	0,043	0,030	0,174	0,347
Number of water-related data-gathering stations per km² area								0,098	0,726	0,603	0,343	0,013	0,829
Length of non-novel roads as a percentage of all roads									0,701	0,347	0,987	0,043	0,651
Number of non-novel bridges as a percentage of all bridges										0,067	0,061	0,405	0,004
Percentage of dwellings without finished flooring											0,003	0,907	0,128
Percentage of dwellings without finished roof												0,973	0,257
Percentage of dwellings without finished walls													0,803

Source: SOC Report team elaboration

2.2.2.3. Normalization

To compare and summarize indicators with different units, the data of each indicator is normalized using the minimum-maximum normalization. Normalization conserves the ranks of data points in the dataset and correlation between indicators. Indicators with a positive impact and which reduce risk are inverted at this point, as their higher values correspond to less climate risk.

The context of the four sectors provides important insights into whether the projected changes in climate hazard indicators are going to decrease or increase climate risk. Table 14 provides an overview. The trends and projections of almost all hazard indicators have a negative impact on the country. The only exception is relative humidity, where a decrease can be observed. As a high relative humidity increases the sensation of hot temperatures, a decrease in relative humidity can be regarded a positive impact. Table 14 also informs on which hazard indicators were inverted upon entering them into the risk index: higher numbers in the frequency of cold days and nights, the accumulated yearly precipitation, the number of rainy days per year, and the precipitation in the short dry and rainy seasons have a positive impact on the sectors in the context of their expected evolution in future scenarios, so these indicators were inverted. The righthand column of the table provides an explanation.

Table 14*- Hazard indicators, their historical trends and future projections, the impacts these have on the sectors, how the indicator values influence the risk index and underlying reasons*

Indicator	Historical trend	Future trend	Positive or negative impact	Increases or decreases the climate risk index	Explanation
Average, minimum, and maximum daily temperature	These indicators are similar throughout almost all of the country and slightly lower in the south. In the north, these indicators are increasing, while in the south they are decreasing.	Daily mean, minimum, and maximum temperatures are projected to increase in the entire country, although less at the coast and more in the southwest.	Negative	Increases	Temperature is increasing across all locations, scenarios, and time periods. As cold temperature and its effects such as frost are not a hazard in Suriname, those locations with cooler temperatures have an advantage over those locations with higher temperatures.

Indicator	Historical trend	Future trend	Positive or negative impact	Increases or decreases the climate risk index	Explanation
Frequency of hot days and nights	These indices are very homogeneous throughout the country.	The two indices increase everywhere.	Negative	Increases	Days which can be dangerously hot and nights during which sleeping is difficult pose a threat to human health. The higher the frequency, the bigger the hazard.
Frequency of cold days and nights		These decrease and almost disappear and are less important in a tropical climate.	Negative	Decreases	Days and nights which can be dangerously cold do not occur in Suriname. As cold days and nights are the counterweight to hot days and nights, their increase is advantageous and their decrease harmful in terms of climate risk.
Accumulated yearly precipitation	This indicator reaches its maximum in the southwest and the coastal region. Precipitation shows a strong increasing trend throughout the country.	This indicator is expected to decrease strongly. In general, the decrease could surpass 20% of the historical average.	Negative	Decreases	Accumulated precipitation is expected to decrease strongly in the future, though districts with a higher accumulated yearly precipitation are less likely to suffer impacts.
Number of rainy days per year	These are more frequent on the coast, the center and southwest of the country, and less so on higher grounds towards the southeast.	This indicator decreases, especially on the coast.	Negative	Decreases	Rainy days decrease climate risk by acting as the counterweight to intense precipitation events (one or five days) which can cause losses and damage.

Indicator	Historical trend	Future trend	Positive or negative impact	Increases or decreases the climate risk index	Explanation
Maximum precipitation in one/five days	These indicators are even across the entire country.	Both indicators increase greatly for all locations. This, together with the decrease in the number of rainy days, points to a change of rain regime toward fewer but more intense precipitation events.	Negative	Increases	These indicators represent intense precipitation events, which can cause losses and damage due to flooding.
Short dry season precipitation	The coast has two distinct wet seasons and two distinct dry seasons. In the interior, the rainy season is rainier than at the coast, increasingly so. Precipitation is more even, and seasons are less pronounced.	These seasons become drier throughout the country.	Negative	Decrease	In the southern side of the country (Sipaliwini) the regime of precipitation shifts to a wetter rainy season and drier seasons the rest of the year. That leads to more concentrated precipitation that could impact the flow of rivers throughout the year. In the coastal and agricultural zones, the decline in precipitation occurs for all seasons. Dry seasons become very dry, which could impact water availability for food production.
Dry season precipitation			Negative	Decrease	
Short rainy season precipitation			Negative	Decrease	
Rainy season precipitation		This season becomes drier at the coast but wetter in the interior.	Negative	<u>Coast:</u> Decrease <u>Interior:</u> Increase	
Maximum daily winds	These are highest just off the coast and over the higher ground in the southeast.	These indicators are projected to vary little. The main patterns visible	Negative	Increase	Winds can cause damage to infrastructure, housing, and crops. Thus, the higher the

Indicator	Historical trend	Future trend	Positive or negative impact	Increases or decreases the climate risk index	Explanation
	They show a descending trend.	in the historical map change very little in all scenarios and timeframes.			winds, the higher the climate risk.
Gale wind days	These are exceedingly rare (less than two per year).		Negative	Increase	
Strong wind days	These occur mostly at the coast and in the center and southeast of the country.		Negative	Increase	
Relative humidity	This indicator is very high for all of Suriname and has a latitudinal gradient, with maximum values at the coast and slightly lower ones further inland.	The climate in Suriname is expected to become dryer, particularly in the southwest of the country.	Positive	Increase	Higher temperatures with higher humidity imply a greater feeling of temperature, which implies a higher health risk for the population.
Sea-level rise	N/A	This indicator increases the same for all districts, more so in scenario SSP5-8.5 and the further into the XXI century.	Negative	Increase	The more district surface below the sea level, the more likely flooding, lack of drainage, and salinization. This affects especially those districts close to the coast.

Source: SOC Report team elaboration

2.2.2.4. Assigning weights to the indicators

When resuming different indicators in an index, one may choose to weigh them according to their relative importance. The majority of climate risk and vulnerability indices are constructed using equal weights for indicators and the three risk components of hazards, exposure, and vulnerability (Tonmoy, El-Zein & Hinkel, 2014). In this report, the same equal weights were employed. In order to compensate for different numbers of indicators in the sub-indices we apply the following formula:

$$H = H_1{}^{1/m} \times H_2{}^{1/m} \times \dots \times H_m{}^{1/m}$$

H: Hazard sub-index
$H_{1\text{-}m}$: Hazard indicators
m: number of hazard indicators

$$E = E_1{}^{1/n} \times E_2{}^{1/n} \times \dots \times E_n{}^{1/n}$$

E: Exposure sub-index
$E_{1\text{-}n}$: Exposure indicators
n: Number of exposure indicators

$$V = V_1{}^{1/p} \times V_2{}^{1/p} \times \dots \times V_p{}^{1/p}$$

V: Vulnerability sub-index
$V_{1\text{-}p}$: Vulnerability indicators
p: Number of vulnerability indicators

When the sub-indices (H, E, V) are evaluated without aggregating them into the risk index, they are minimum-maximum normalized to produce values on the range of 0-1, as a percent.

2.2.2.5. Aggregation

Aggregation of the risk component sub-indices (H, E, V) into the risk index proceeds using the following formula, stressing climate hazards to emphasize impacts:

$$R = H^{1/2} \times E^{1/4} \times V^{1/4}$$

R: Risk index

The index is then minimum-maximum normalized to produce values on the range of 0-1, as a percent.

HISTORICAL CLIMATE DATA AND TRENDS

The aim of this chapter is to analyze the historical climate to subsequently elaborate future climate projections. This chapter first provides a brief introduction to the overall climate of Suriname. It then provides the results obtained from the ERA5 reanalysis data calibrated with in-situ observations for four variables: precipitation, temperature, wind, and relative humidity. For each variable, their overall climatology was characterized, followed by an evaluation of historical trends in seven locations, as well as an analysis of the occurrence of extreme events. The historical trends are characterized by their probability of occurrence according to the following table (Table 15).

***Table 15**- Probability of occurrence defined*

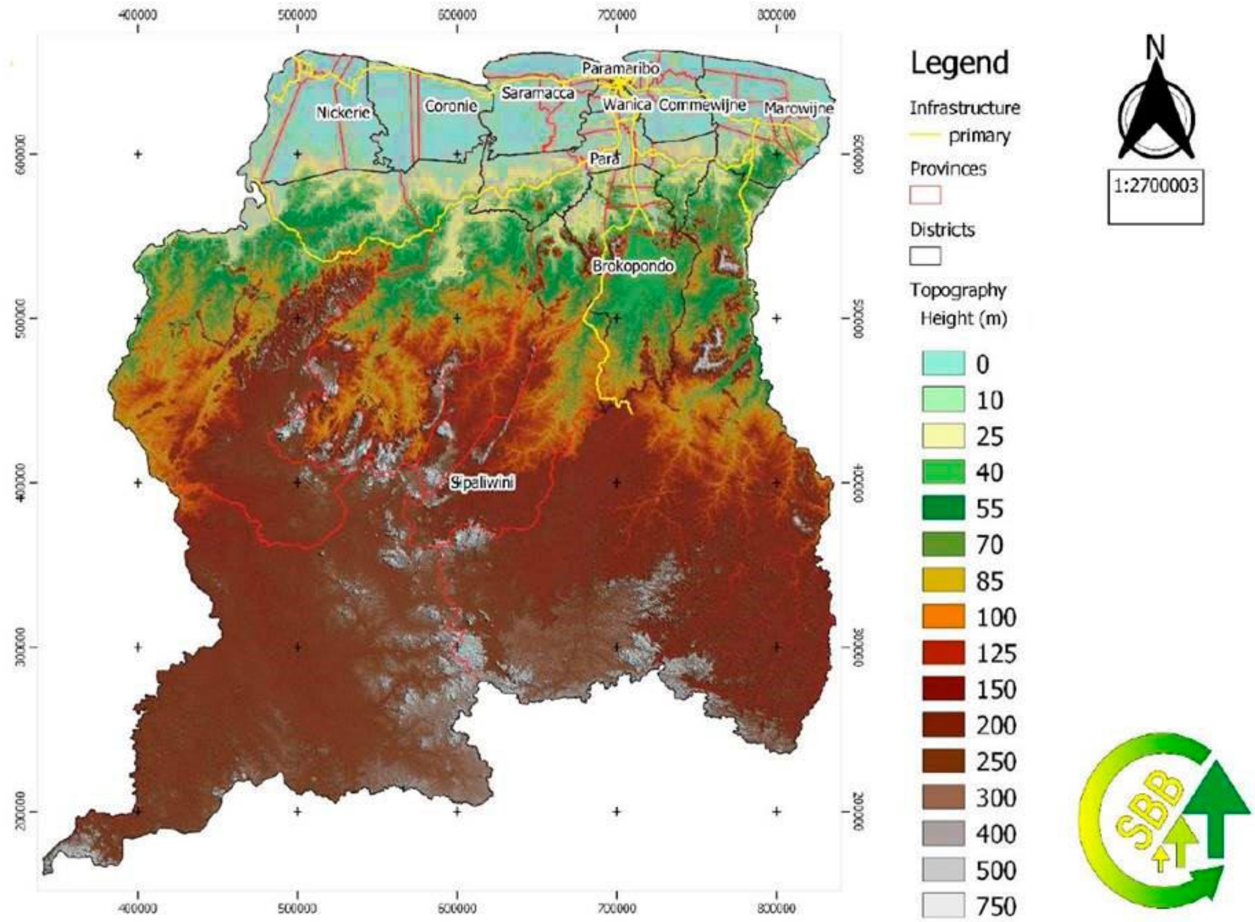
Definition	Probability of occurrence
Extremely likely	>95%
Very likely	>90%
Likely	>66%
More likely than unlikely	>50%
More unlikely than likely	<50%
Very unlikely	<10%
Extremely unlikely	<5%

Source: IPCC (2019)

3.1 Introduction

Suriname is located at the north of the equator on the northeastern coast of South America, between 4^0-6^0 north latitude and 54^0-58^0 west longitude. Suriname has a tropical climate with abundant rainfall, uniform temperature, and high humidity. The country shows a smooth orography, with height ascending as we move southwards from the only coast in the north (Figure 8). This difference in altitude leads to diverging coastal and interior climates. The topography of the northern half of the country is composed of flat coastal plains, and low hills further inland. The overall pattern of the hinterland, the southern half of the country, is composed of the central highlands, with a few locations rising to slightly over 1000 m above sea level (Boedhram & Baldew, 1988), like Tafelberg at 1026 m above sea level, and Suriname's highest mountain Juliana Top which sits at 1230 m above sea level (Boedhoe, 2004).

Figure 8- Orography of Suriname



Source: Simpson et al. (2012)

The average daily temperature in the coastal region is 27.6°C, with an average daily variation of 4°C. There is relatively little variation in temperature between the seasons in the coastal region. January is the coldest month with an average temperature of 27.5°C, and October is the warmest with an average temperature of 29.2°C. The annual variation of the average temperature is 2-3°C. The interior has similar figures, with an even smaller annual variation of average temperatures.

Precipitation amounts vary across the country. On average, Paramaribo receives 1,756 mm of rainfall annually, Bigi Pan in the northwestern coast receives 1,796 mm/year, Kwamalasamutu in southern Suriname receives 2,392 mm/year, and Tafelberg in central Suriname receives 1,851 mm/year. Variation in monthly rainfall results in two wet and two dry seasons in the northern part of Suriname. In the south, one wet and one dry season are distinguished.

Winds in Suriname generally move in a northeasterly direction. Maximum average wind speed ranges from 30-42 km/h on the coast to about 30 km/h in the interior. Wind is highest during the dry seasons, with up to 40 km/h in March, and a second stronger peak in September and October. Wind speeds are relatively high along the seashore and decrease as one moves inland. Wind speeds of 20 to 30 km/h generally occur during the day and drop dramatically during the evening and night, especially in the interior.

Although Suriname lies outside of the hurricane belt, the country's weather is occasionally affected by hurricane tails. Local gales called *sibibusi* occur before storms, usually at the end of the rainy seasons. During such gales, maximum wind speeds of 20-30 m/s have been recorded. Such gales occur over the entire country and may destroy trees and houses. This happens on average less than three days a year. Strong winds are more frequent and can happen up to 100 days a year in the coastal region.

Daily humidity is on average 80-90% in the coastal regions. It is lower in the central and southern regions of the country, with an average of 75%. In forested areas, air humidity depends, among other things, on the penetration of sun radiation. Variations of relative humidity are between 70-100% in forested areas and between 50-100% in open areas.

The El Niño-Southern Oscillation (ENSO) is a recurring climate pattern based on changing temperatures of the tropical central and eastern Pacific Ocean. It occurs every two to seven years where the ocean waters warm or cool by 1-3 ^{0}C. The ENSO cycle directly affects the rainfall distribution in the tropics and can strongly influence weather conditions. La Niña and El Niño are the extreme phases of the ENSO cycle.

El Niño is associated with a warming of the ocean surface above average in the central and Eastern Tropical Pacific Ocean. The warmer the ocean temperature anomalies, the stronger El Niño. La Niña is associated with a cooling of the ocean surface below average in the central and eastern tropical Pacific Ocean. The cooler the ocean temperature anomalies, the stronger La Niña (Columbia University, 2020).

Following a study conducted by Nurmohamed, Naipal, and Becker (2006), Suriname's amount of rainfall correlates with ENSO, and changes of sea surface temperatures in the Tropical North Atlantic and the Tropical South Atlantic. Therefore, ENSO may cause changes in precipitation, leading to more rainfall variability during the seasons. This can, in some years, cause the usual regime of two dry seasons and two wet seasons to turn into a regime of just one wet and one dry season.

The Inter-Tropical Convergence Zone (ITCZ) is an area near the equator, between the northern and southern hemisphere, where the northeast and the southeast trade winds meet. The ITCZ is seasonal and moves between the 45th parallels north and south of the equator, according to the sun and the land mass it heats. The movements of the ITCZ affect rainfall and determine wet and dry seasons in the tropics. Changes in the ITCZ can result in severe droughts or flooding (NASA, 2020).

The annual migration of the ITCZ and passage of its centerline across Suriname twice annually (from south to north and back over the equator again) determines much of the country's climate and spatiotemporal rainfall variability (Figure 9) (Nurmohamed, Naipal & Becker, 2006). The ITCZ is pushed back and forth by the northeast and southeast trade winds that have an average speed of 3 m/s but may range from 0-15 m/s (Meteorologische Dienst, 1998). Most of the climatological elements, such as temperature, humidity, and rainfall, manifest a strong semi-annual oscillation, causing two wet seasons and two dry seasons (Emanuels, 1968):

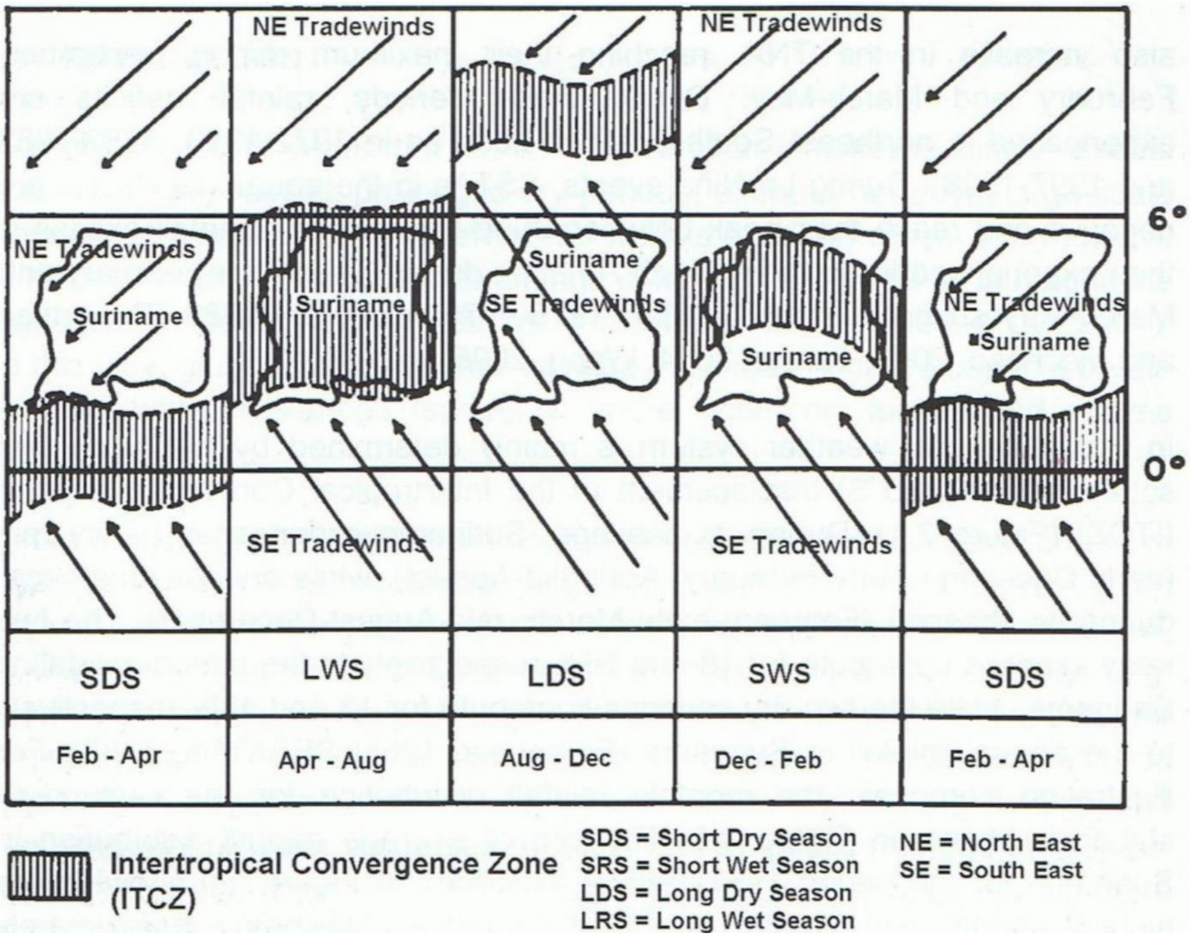
- The short dry season is two and a half months and starts at the beginning of February and lasts until mid-April. During this season, the ITCZ moves further towards the south. The area with low atmospheric pressure is in its southernmost position during these months (Boedhram & Baldew, 1988).

- The long wet season lasts four months and starts in mid-April and lasts until mid-August. During this season, the ITCZ moves back up north across Suriname. In most areas monthly rainfall amounts to at least 200 mm. Suriname's wettest month is May with a monthly average rainfall of about 325 mm. The average monthly total rainfall of the wet season is about 260 mm. Seasonal rainfall is less at the coast and in the south of the country and more in the inland regions (Mitro, 2008).

- The long dry season is three and a half months and starts mid-August and ends at the beginning of December. By this time, the ITCZ has migrated northwards across Suriname and reached its final and most northern location, the Atlantic Ocean, before migrating back southwards. The average monthly total rainfall of the dry season is about 120 mm. September and particularly October are the driest months of the year, with a monthly average rainfall of less than 100 mm. The average monthly rainfall in the central highlands, the hinterland, and some areas at the coast is less than 50 mm. The long dry season records the highest temperatures and lowest relative humidity values in Suriname (Meteorologische Dienst, 1998; Emanuels, 1968).

- The shorter wet season lasts two months and starts at the beginning of December and lasts until the beginning of February. During this season, the ITCZ moves towards the south and across Suriname and northeast trade winds prevail. Monthly rainfall is about 200 mm. Sometimes the shorter wet season does not occur (Boedhram & Baldew, 1988).

Figure 9- Movement of the ITCZ above Suriname



Source: SPS/OAS (1988)

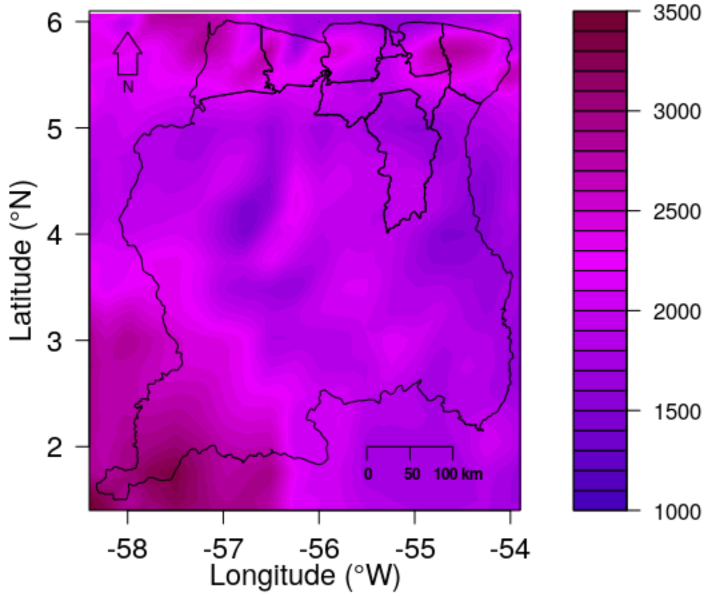
3.2 Rainfall

3.2.1. Rainfall climatology

3.2.1.1. Regional results

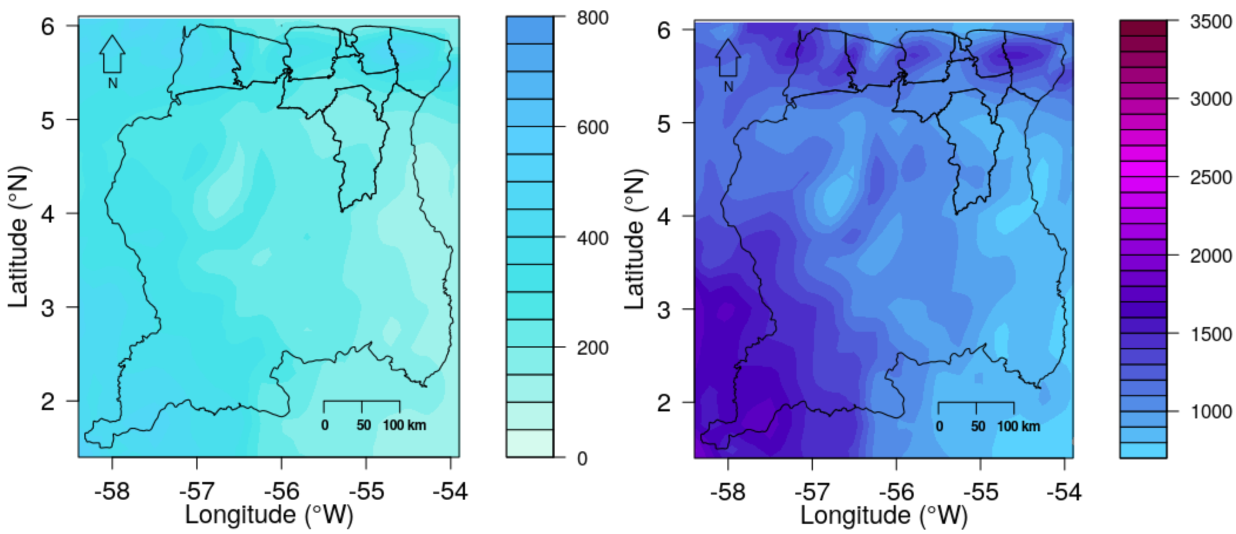
Accumulated yearly precipitation is over 1,500 mm for all of Suriname, with maximums in the southwest receiving more than 3,000 mm/year, and the coastal region with more than 2,500 mm/year (Figure 10). Most of the rain falls during the wet season (Figure 11).

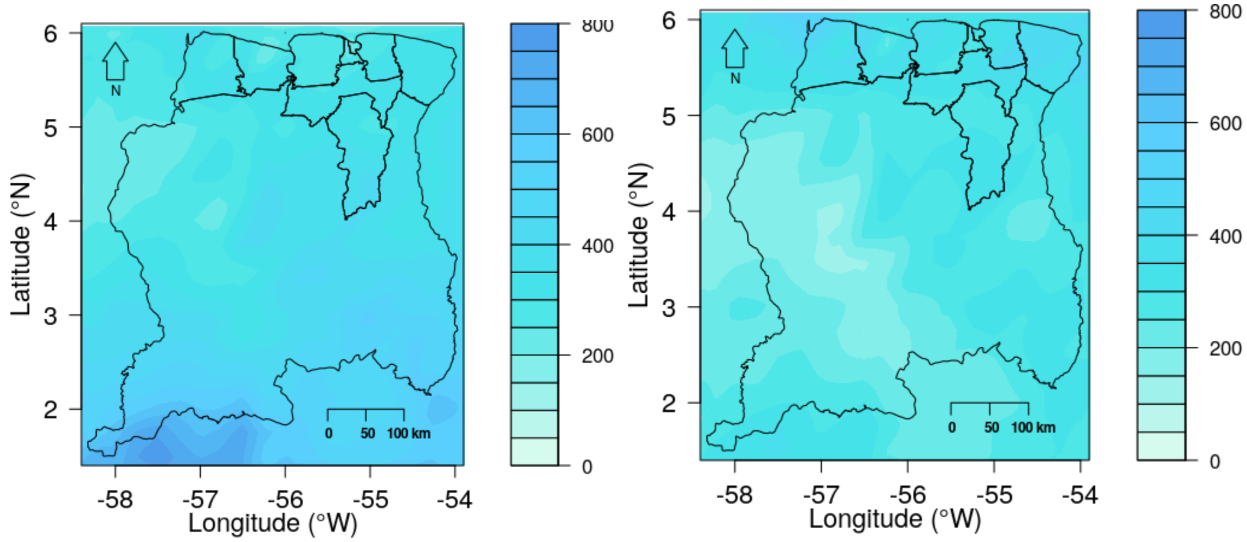
Figure 10*- Average accumulated yearly precipitation (mm/y) for the period 1990-2014*



Source: SOC Report team elaboration

Figure 11*- Average accumulated precipitation (mm) during the dry season (top left), rainy season (top right), short dry season (bottom left), and short rainy season (bottom right) for the period 1990-2014*





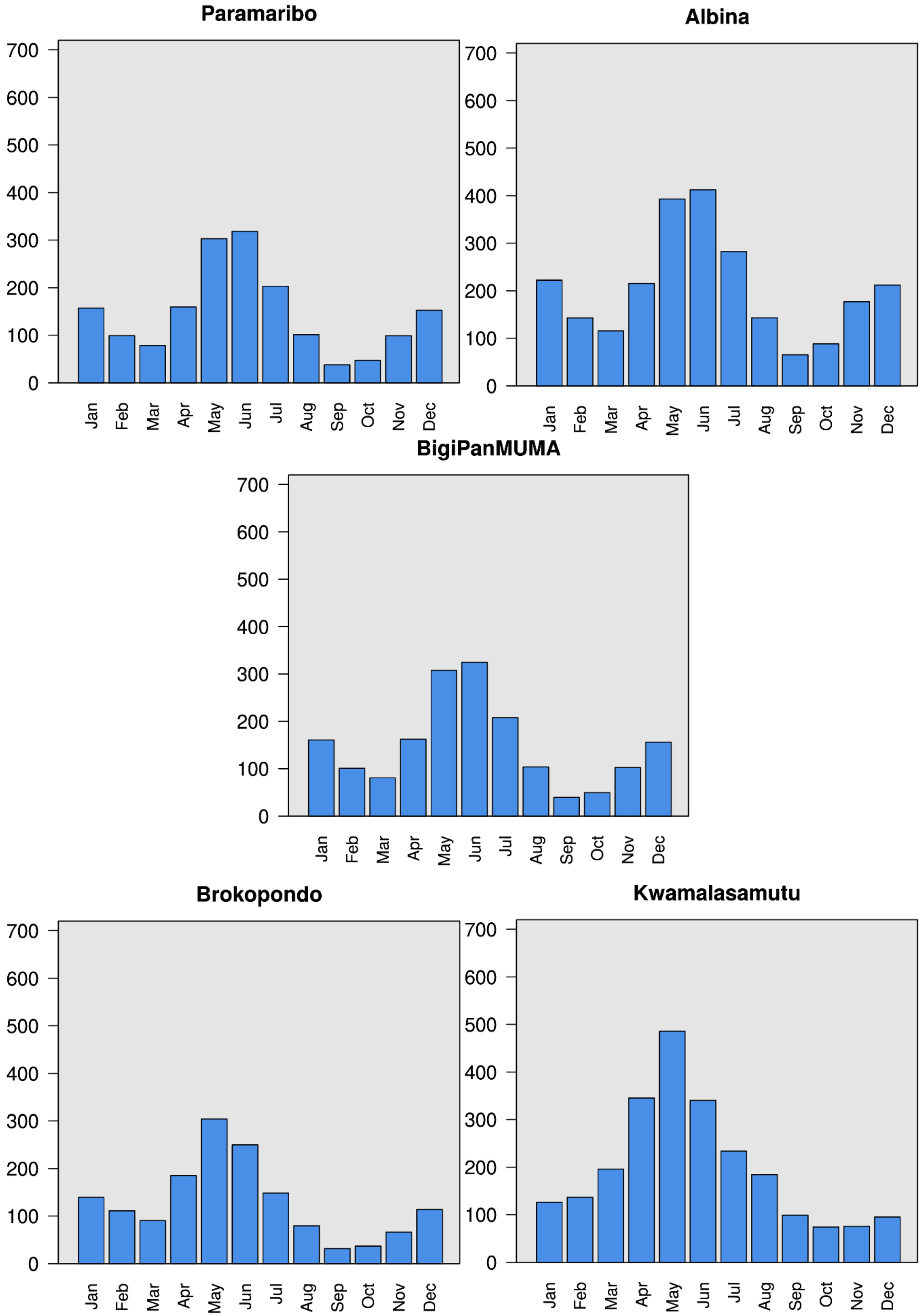
Source: SOC Report team elaboration

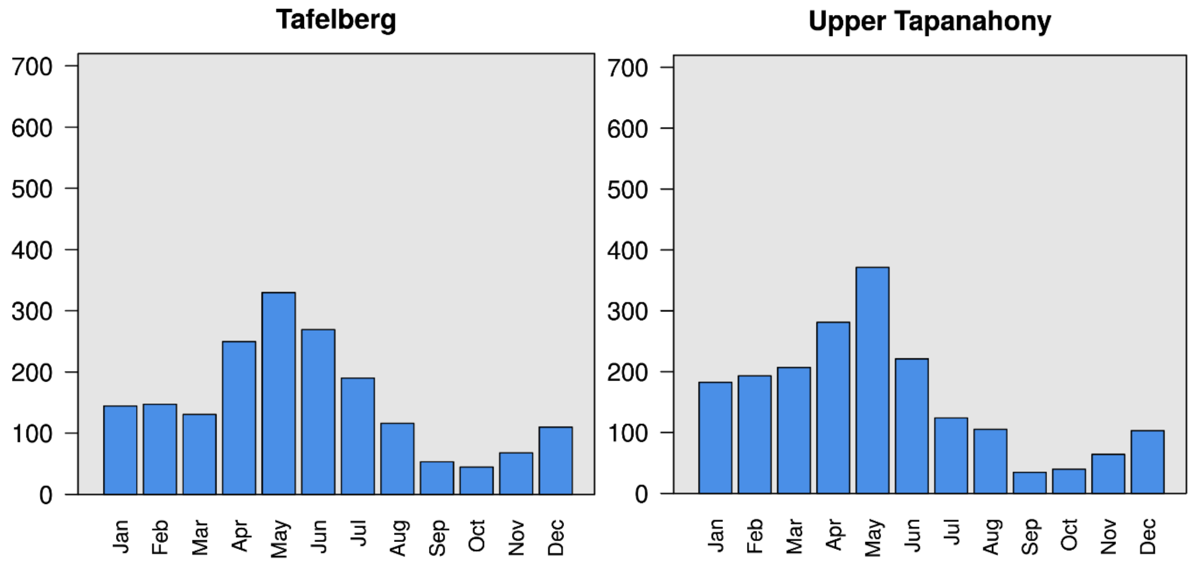
The main driver of the differences in precipitation regimes between the north and the south of the country, apart from the proximity to the sea and elevation, is the annual cycle of the ITCZ. This belt reaches its southernmost position for Suriname in March, when its effect is felt in the south of the country, but not in the north. It then moves north until September, when it is beyond any point in Suriname, creating the long dry season in the north, and the only dry season in the south.

3.2.1.2. Local results

Paramaribo has two distinct wet seasons and two distinct dry seasons (Figure 12). This regime is shared by the points of interest closer to the coast, Albina, Bigi Pan MUMA and, to a lesser extent, Brokopondo. The further inland, the more evenly distributed the precipitation. Kwamalasamutu, Tafelberg and Upper Tapanahony show a wet season generally rainier than the coast that goes from April to August in Kwamalasamutu and from January to June in Upper Tapanahony. The dry season lasts from September to December in all cases. Minimum temperatures are lowest in February in Tafelberg and Upper Tapanahony, the highest point of interest, or July in Kwamalasamutu.

***Figure 12**- Monthly accumulated precipitation (mm) for seven locations averaged over the historical period 1990-2014*





Source: SOC Report team elaboration

3.2.2. Rainfall trends

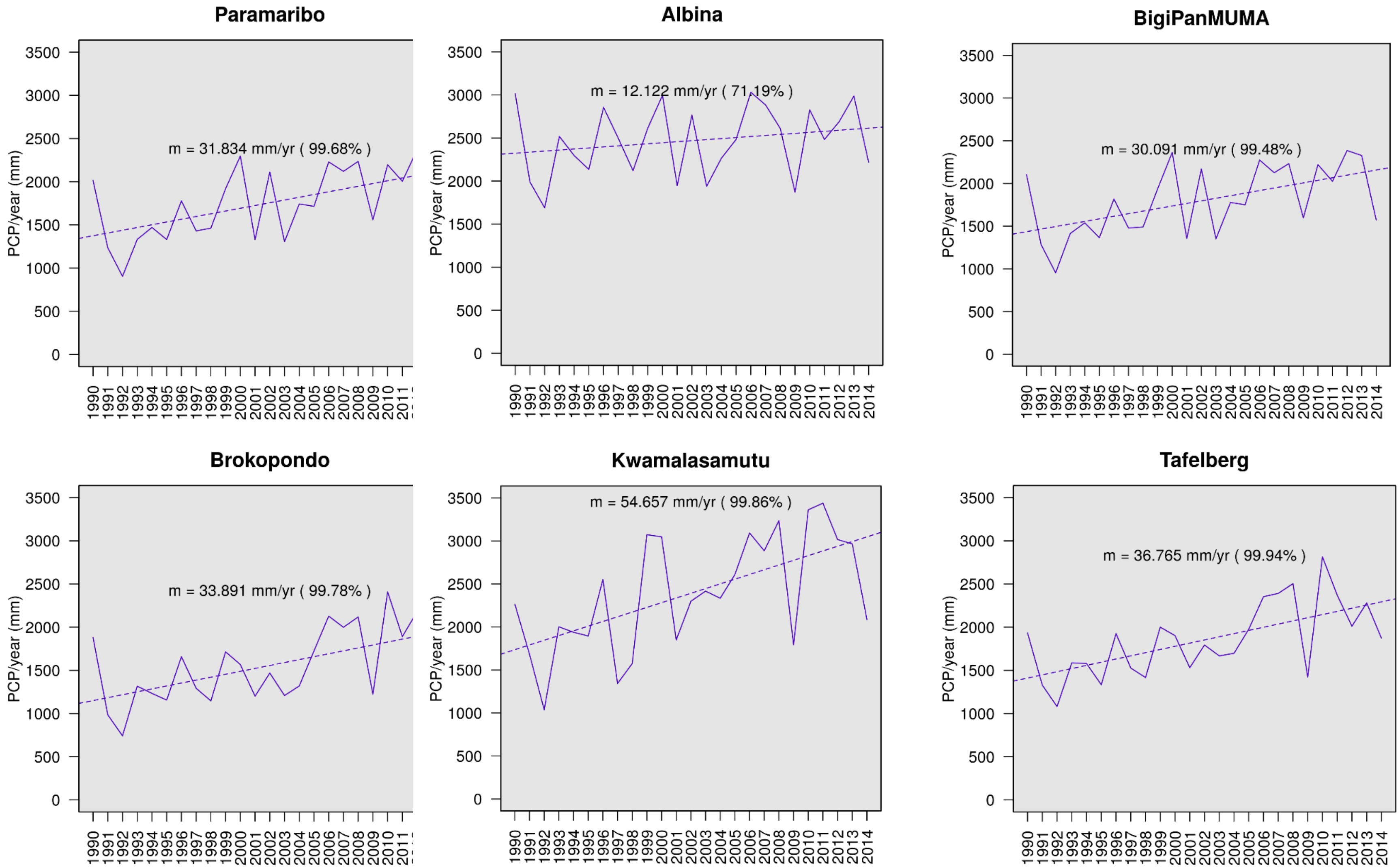
Precipitation shows a strong increasing trend in all seven points of interest, including up to 546.6 mm/decade in Kwamalasamutu (Table 16, Figure 13). The confidence of these results is high or very high.

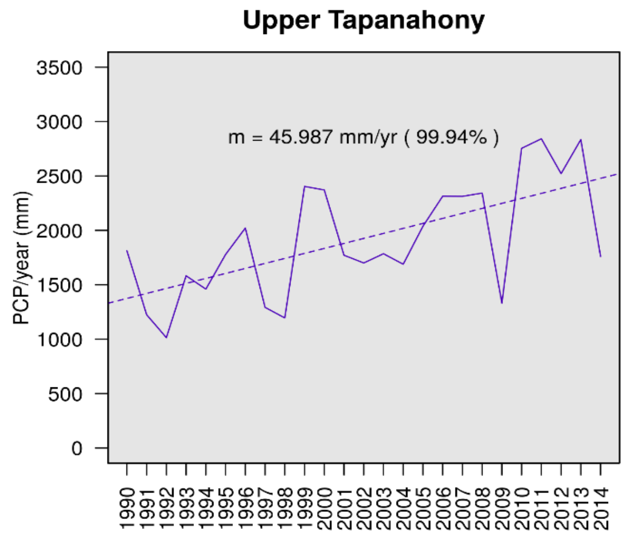
***Table 16**- Annual average value, decadal rate of change and probability of occurrence for accumulated precipitation in the seven locations*

Location	Average value (mm/y)	Rate of change per decade	Probability of occurrence
Paramaribo	1,756.1	+319.3	extremely likely
Albina	2,469.4	+121.2	likely
Bigi Pan MUMA	1,796.4	+300.9	extremely likely
Brokopondo	1,556.4	+318.3	extremely likely
Kwamalasamutu	2,391.6	+546.6	Extremely likely
Tafelberg	1,851.9	+367.6	extremely likely
Upper Tapanahony	1,926.3	+459.9	extremely likely

Source: SOC Report team elaboration

Figure 13- Observed annual trends (m) and their probability of occurrence for the yearly mean precipitation during the period 1990-2014 in seven locations



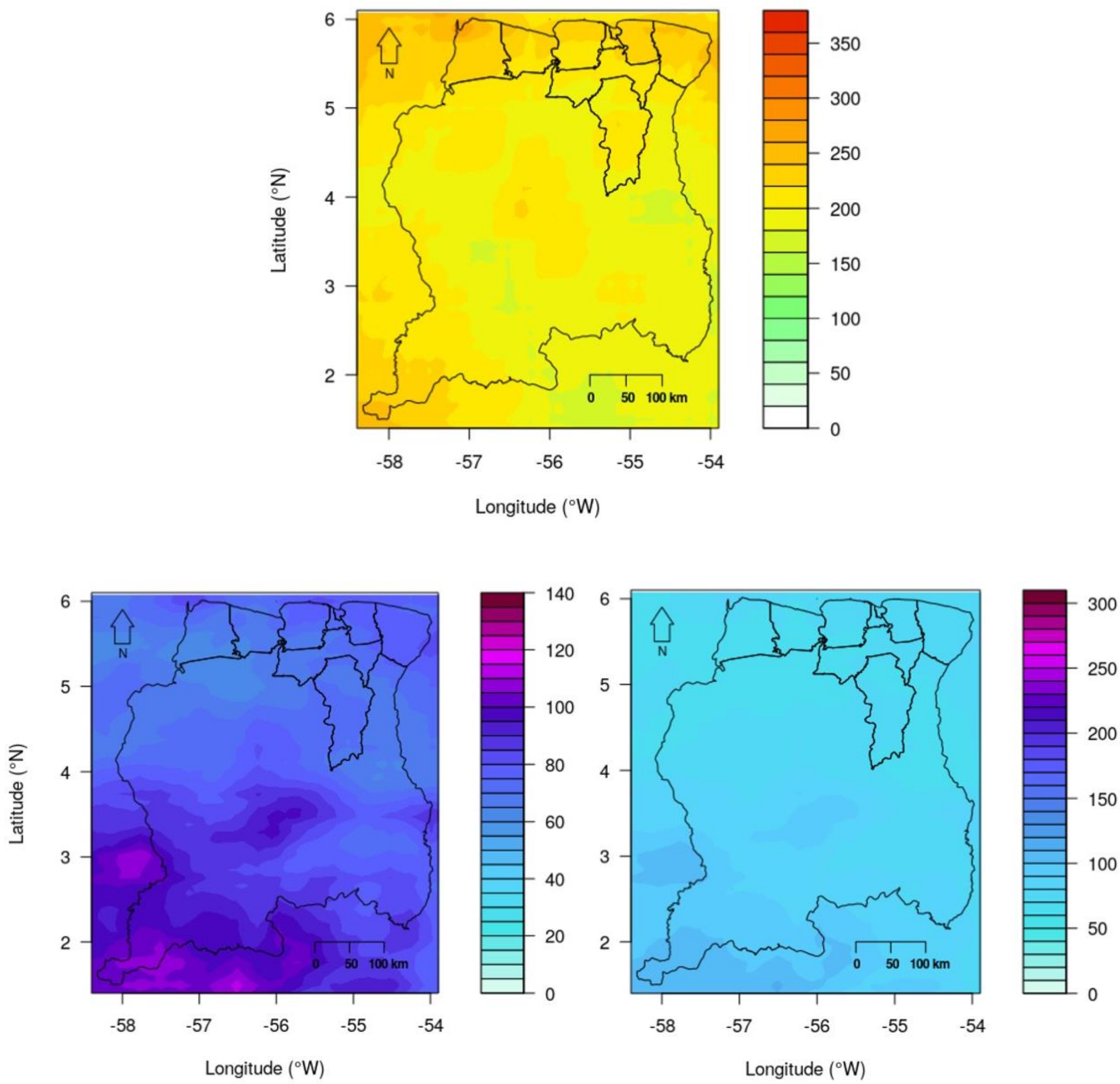


Source: SOC Report team elaboration

3.2.3. Rainfall extremes

A high number of rainy days are the counterweight to days with extreme rainfall. Rainy days are more frequent on the coast, the center, and southwest of the country, and less so on higher ground towards the southeast (Figure 14). The maximum value in daily precipitation is also higher in these regions. Maximum values of precipitation for a single day lie around 110 mm.

Figure 14*- Maps of the average values in the period 1990-2014 of number of yearly rainy days (top), maximum daily precipitation in mm/day (bottom left) and maximum five-daily precipitation in mm/day (bottom right)*



Source: SOC Report team elaboration

3.3. Temperature

3.3.1. Temperature climatology

3.3.1.1. Regional results

Average daily temperature is similar throughout most of the country (Figure 15). It is around 27°C except for the southern border, in which higher elevations lead to slightly lower mean temperatures. Maximum daily temperature averages 32°C for most of Suriname, and its maximum values are found slightly inland and on the eastern border, around 33°C. Minimum temperatures show a slightly different pattern, where they are higher in the coastal region around 25°C, and decrease constantly going south and towards higher ground, reaching 21°C in the highest point of the country.

Figure 15- Average mean (top), maximum (bottom left) and minimum (bottom right) temperature (ºC) for the period 1990-2014

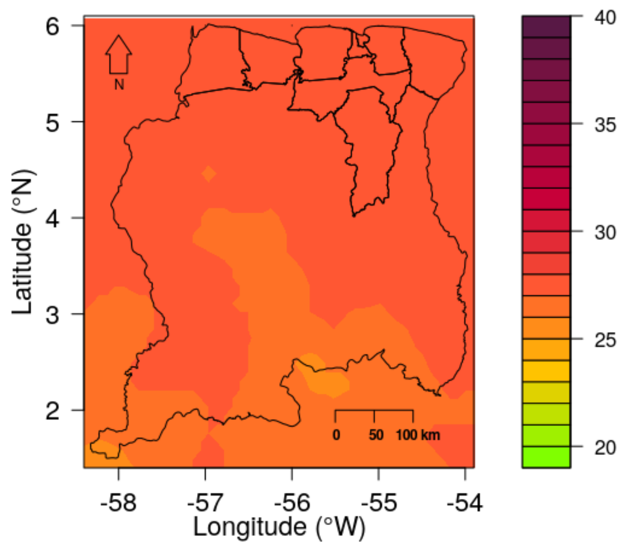
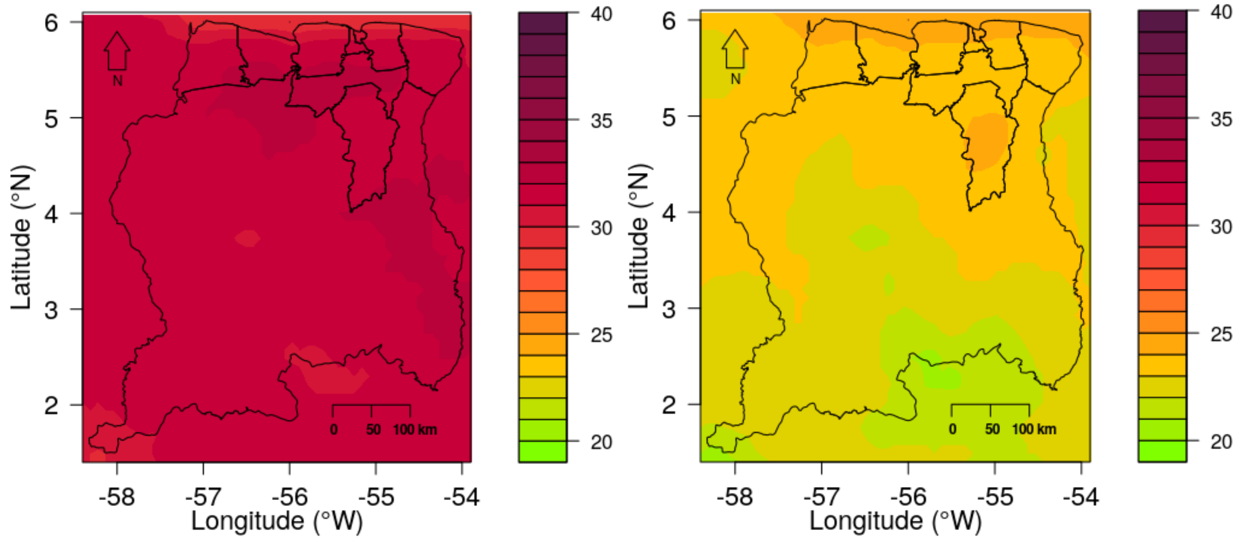


Figure 16- Average mean (top), maximum (bottom left) and minimum (bottom right) temperature (ºC) for the period 1990-2014

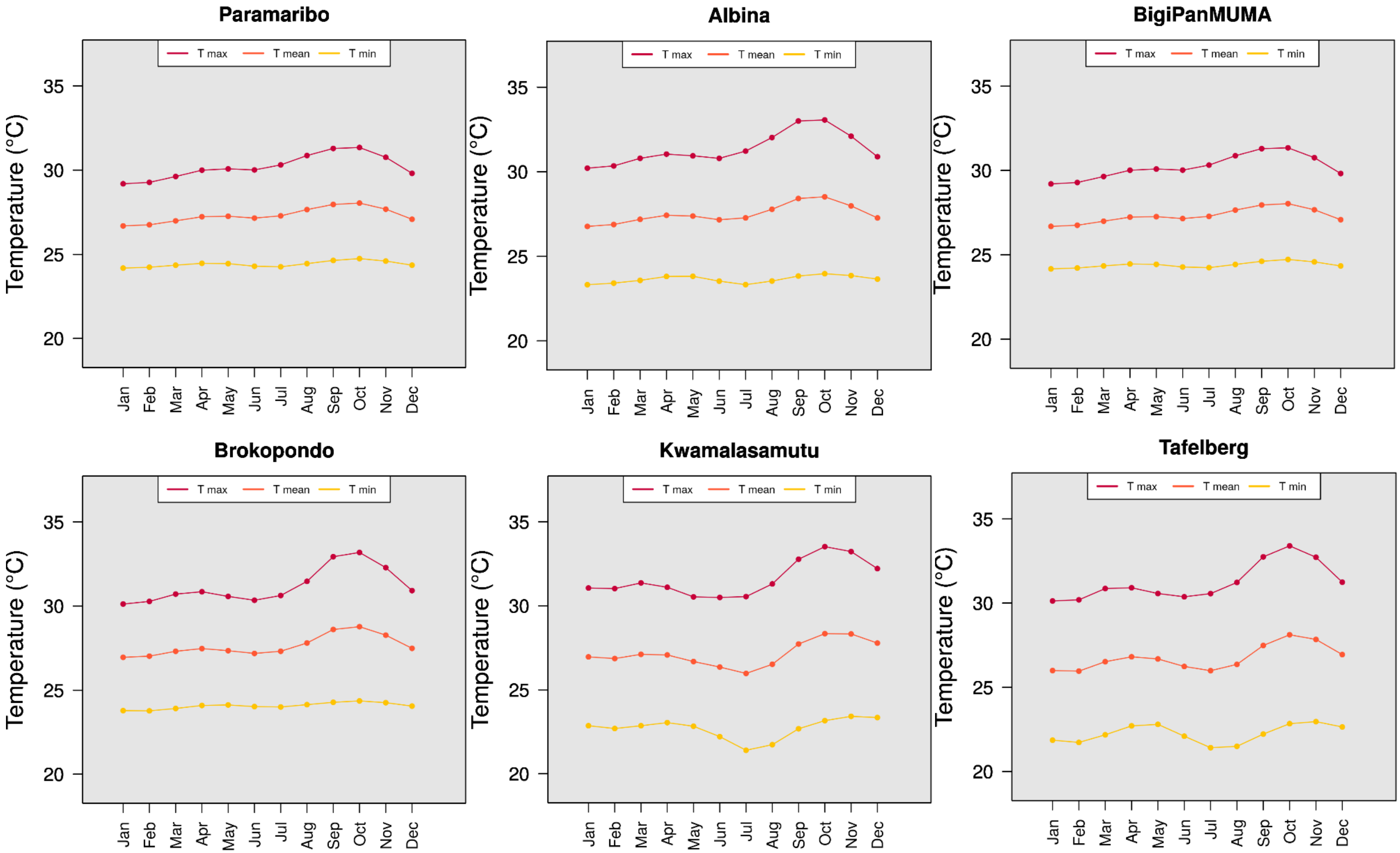


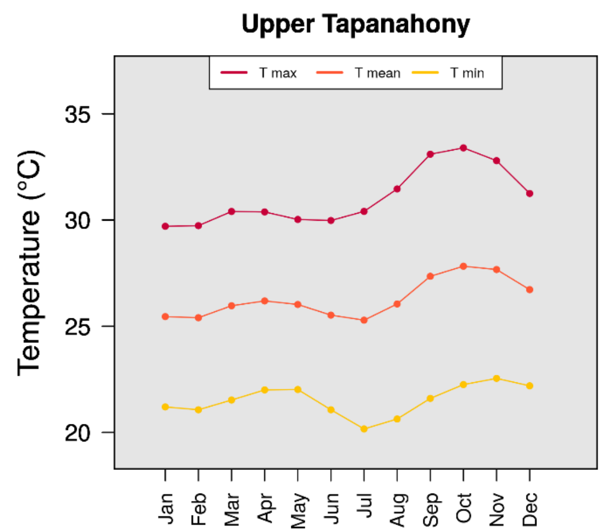
Source: SOC Report team elaboration

3.3.2.2. Local results

In all points of interest, temperature is higher during the long dry season, particularly in October, and has two minimums during the wet seasons (Figure 16). Maximum temperatures show the same monthly behavior, with a strong maximum in October. Minimum temperatures show a similar cycle, although smoother.

Figure 17- Average mean (top), maximum (bottom left), and minimum (bottom right) temperature (ºC) in all seven locations for the period 1990-2014





Source: SOC Report team elaboration

3.3.2. Temperature timescale decomposition and trends

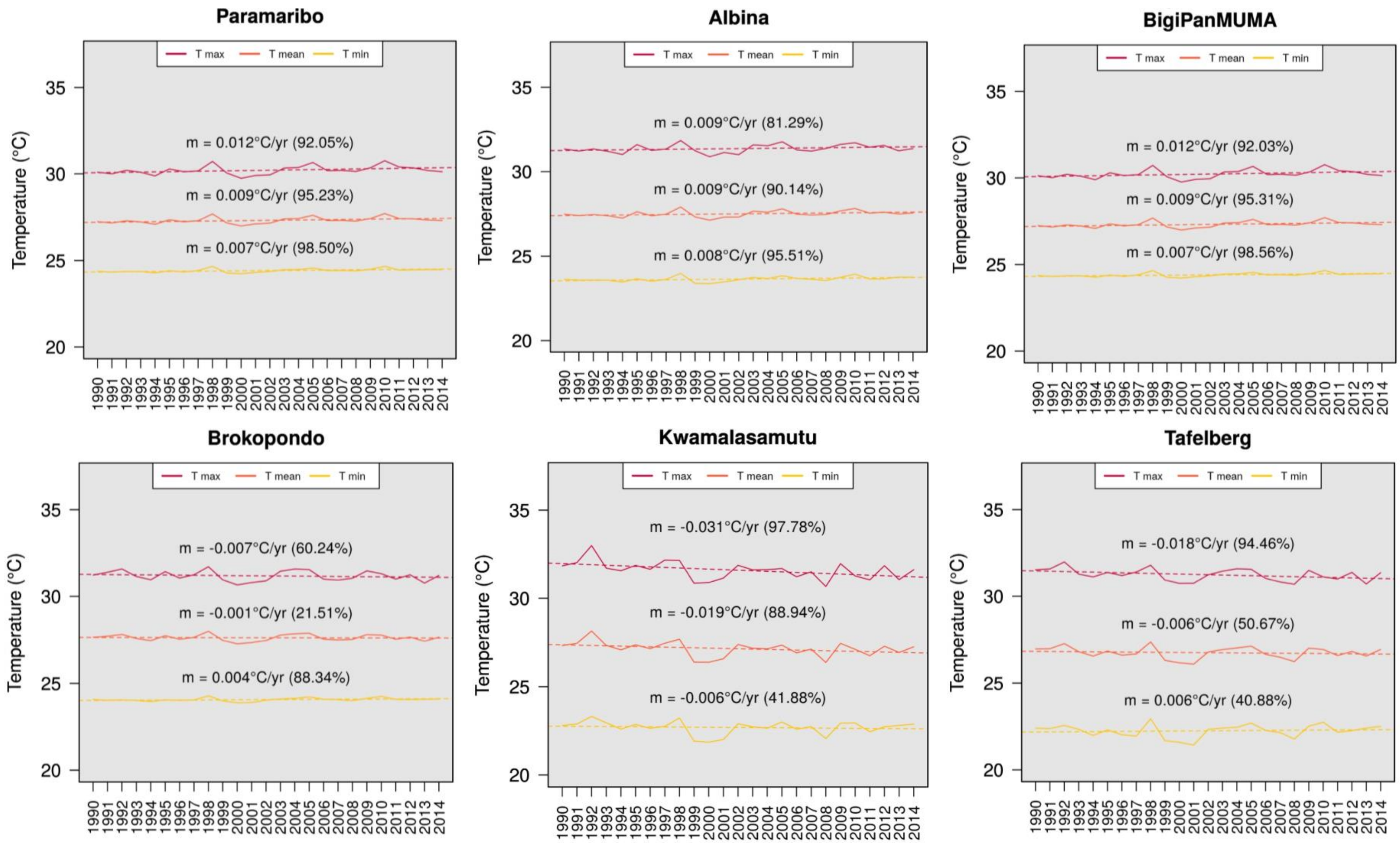
Minimum temperatures are increasing except in Kwamalasamutu. In the north in Paramaribo, Albina, and Bigi Pan MUMA, maximum temperatures are increasing, while in the center and south they show a cooling trend (Table 17, Figure 17). The two extreme cases are Kwamalasamutu (-0.31°C/decade) and Bigi Pan MUMA (+0.13°C/decade). Mean temperatures also show the north is warming, and the south is cooling. The confidence on these results is generally high or very high, with the exception of temperature trends in the southern locations, which are less reliable.

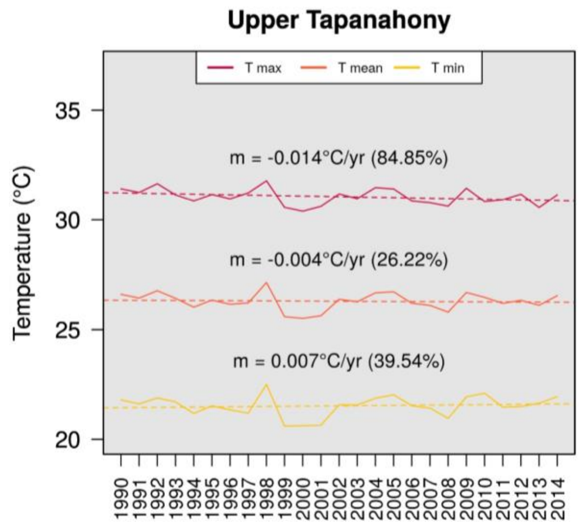
Table 17- Annual average value, decadal rate of change and probability of occurrence for minimum, mean and maximum temperature in the seven locations

Location	Average value (°C)			Rate of change per decade			Probability of occurrence		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
Paramaribo	27.3	30.2	24.4	+0.09	+0.12	+0.07	Extremely likely	Very likely	Extremely likely
Albina	27.5	31.4	23.6	+0.09	+0.09	+0.07	Very likely	Likely	Extremely likely
Bigi Pan MUMA	27.3	30.2	24.1	+0.09	+0.12	+0.07	Extremely likely	Very likely	Extremely likely
Brokopondo	27.6	31.2	24.1	-0.01	-0.07	+0.04	More unlikely than likely	More likely than unlikely	Likely
Kwamalasa mutu	27.1	31.6	22.7	-0.19	-0.31	-0.06	Likely	Extremely likely	More unlikely than likely
Tafelberg	26.8	31.2	22.2	-0.06	-0.18	+0.06	More likely than unlikely	Very likely	More unlikely than likely
Upper Tapanahony	26.3	31.1	21.5	-0.04	-0.14	+0.07	More unlikely than likely	likely	More unlikely than likely

Source: SOC Report team elaboration

***Figure 18**- Observed annual trends (m) and their probability of occurrence for the average mean, maximum, and minimum temperature during the period 1990-2014 in the seven locations*



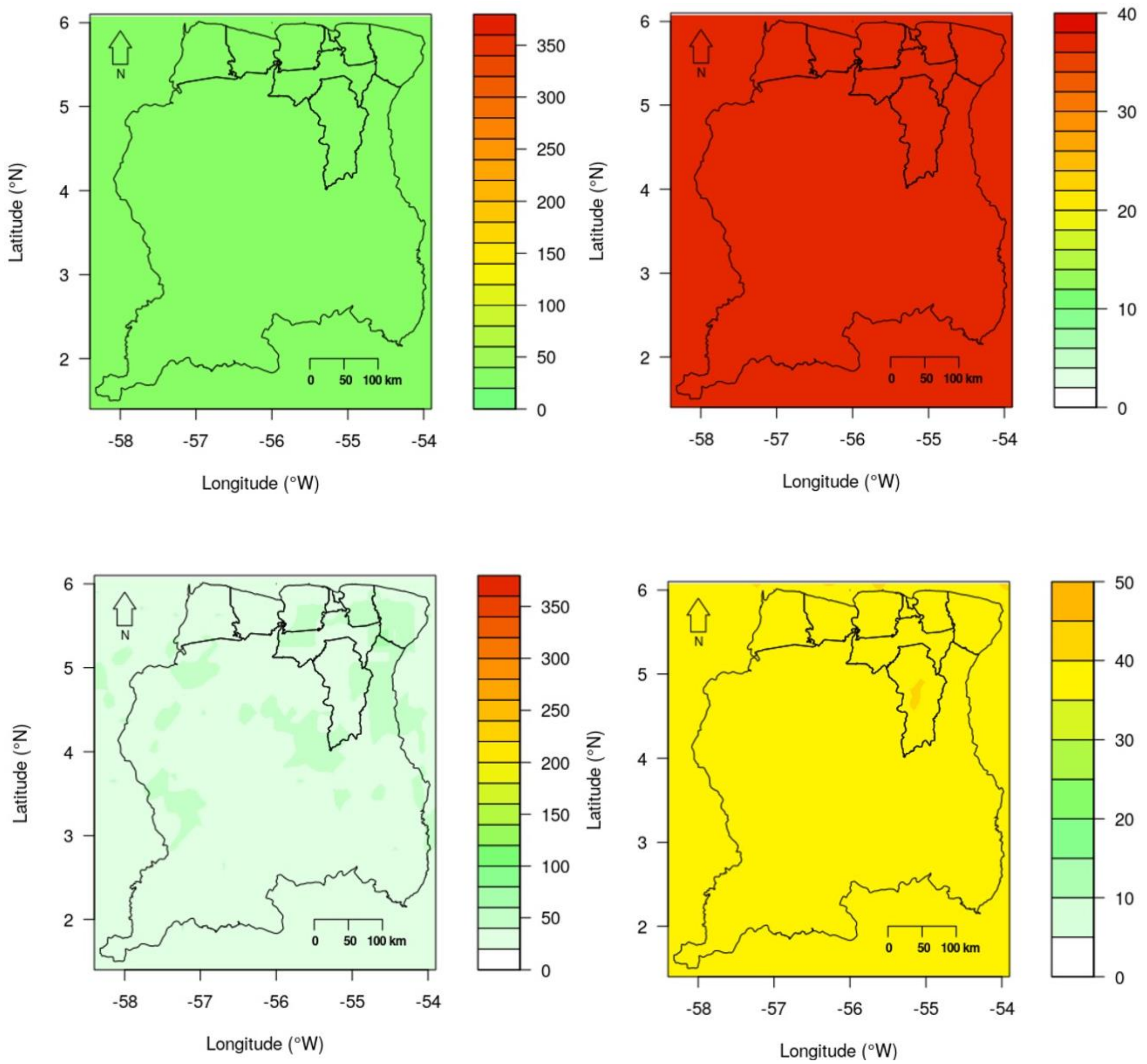


Source: SOC Report team elaboration

3.3.3. Temperature extremes

Hot days (TX90p), cold days (TX10p), hot nights (TN90p), and cold nights (TN10p) is defined as days and nights in which temperature is above or below the 10% hottest and coldest in the climatology. The maps of these four indices are very homogeneous (Figure 18).

Figure 19- *Maps of the average yearly values in the period 1990-2014 for frequency of days in which temperature surpasses p90 (90th percentile) (top left), days in which temperature is below p10 (10th percentile) (top right), nights in which temperature surpasses p90 (bottom left) and nights in which temperature is below p10 (bottom right)*



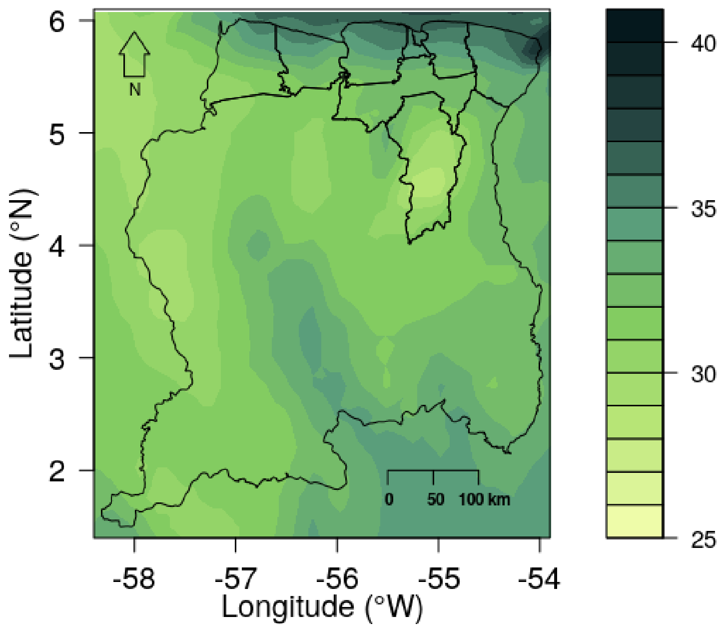
Source: SOC Report team elaboration

3.4. Wind

3.4.1. Wind climatology

Maximum daily winds reach their maximum value of 40 km/h just off the coast, and the local maximum over the higher ground in the southeastern region of the country is around 35 km/h (Figure 19). For the rest of the country the values vary between 25 km/h and 32 km/h.

Figure 20*- Average maximum wind speed (km/h) for the period 1990-2014*



Source: SOC Report team elaboration

3.4.2. Wind timescale decomposition and trends

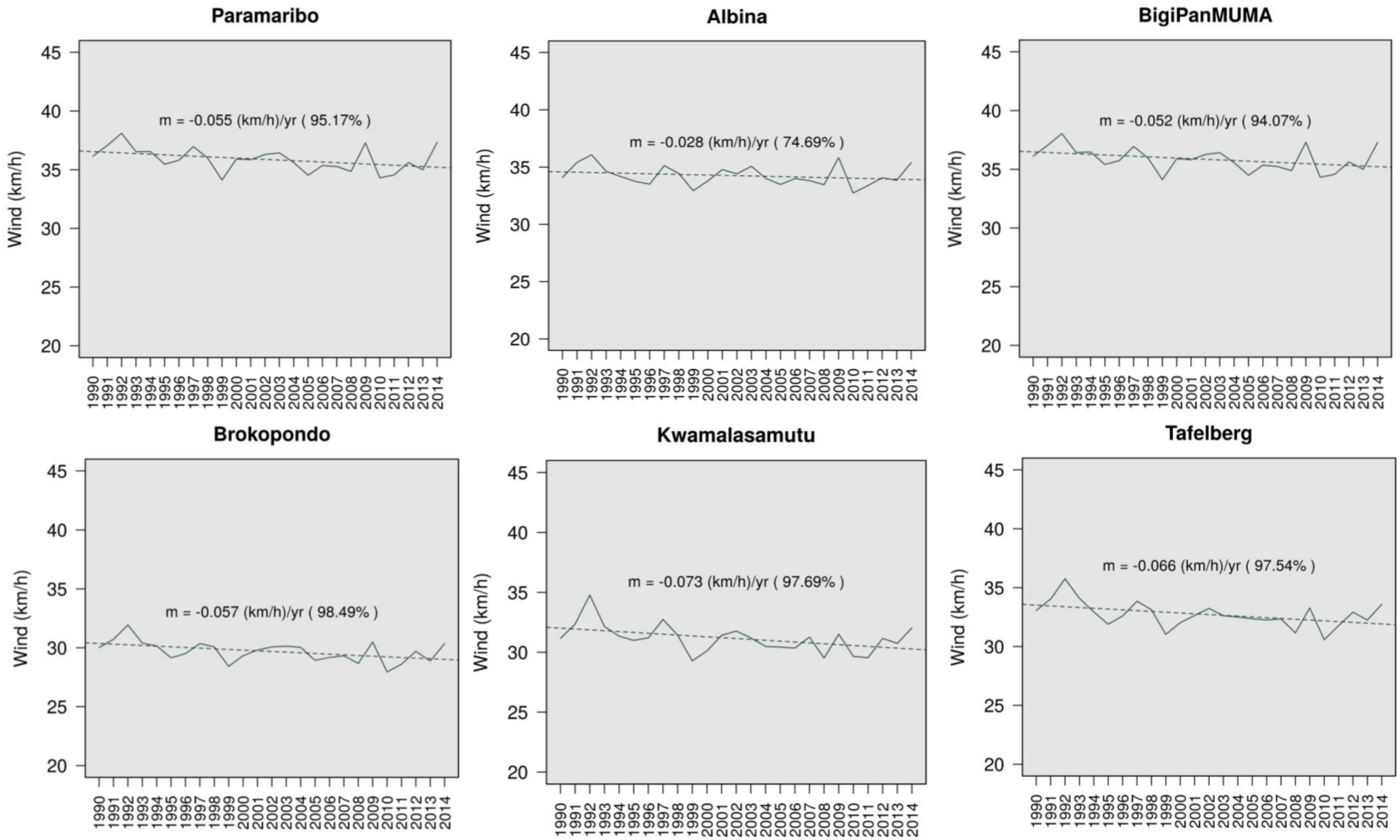
Maximum wind speed shows a descending trend, ranging from -0.28 km/h per decade in Bigi Pan MUMA to -0.8 km/h per decade in Upper Tapanahony (Table 18, Figure 20). The confidence on these results is generally high or very high, with the exception of wind trends on the coast, which are less reliable.

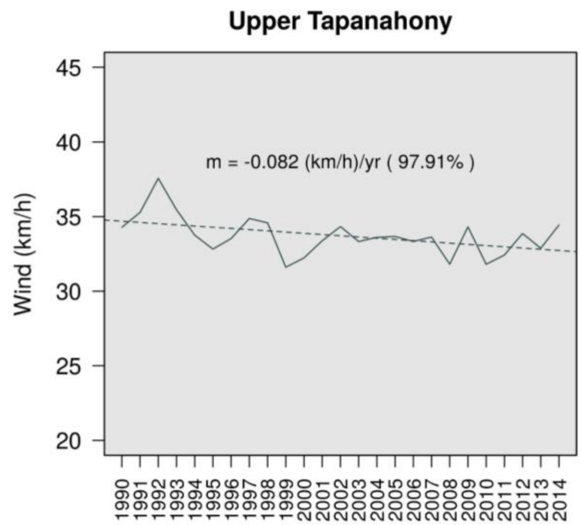
Table 18*- Annual average value, decadal rate of change and probability of occurrence for maximum wind*

Location	Average value (km/h)	Rate of change per decade	Probability of occurrence
Paramaribo	35.9	-0.5	very likely
Albina	34.25	-0.28	likely
Bigi Pan MUMA	35.85	-0.52	very likely
Brokopondo	29.69	-0.57	extremely likely
Kwamalasamutu	31.15	-0.73	extremely likely
Tafelberg	32.7	-0.66	extremely likely
Upper Tapanahony	33.7	-0.8	extremely likely

Source: SOC Report team elaboration

Figure 21- Observed annual trends (m) and their probability of occurrence for the mean maximum wind speed during the period 1990-2014 for the seven locations



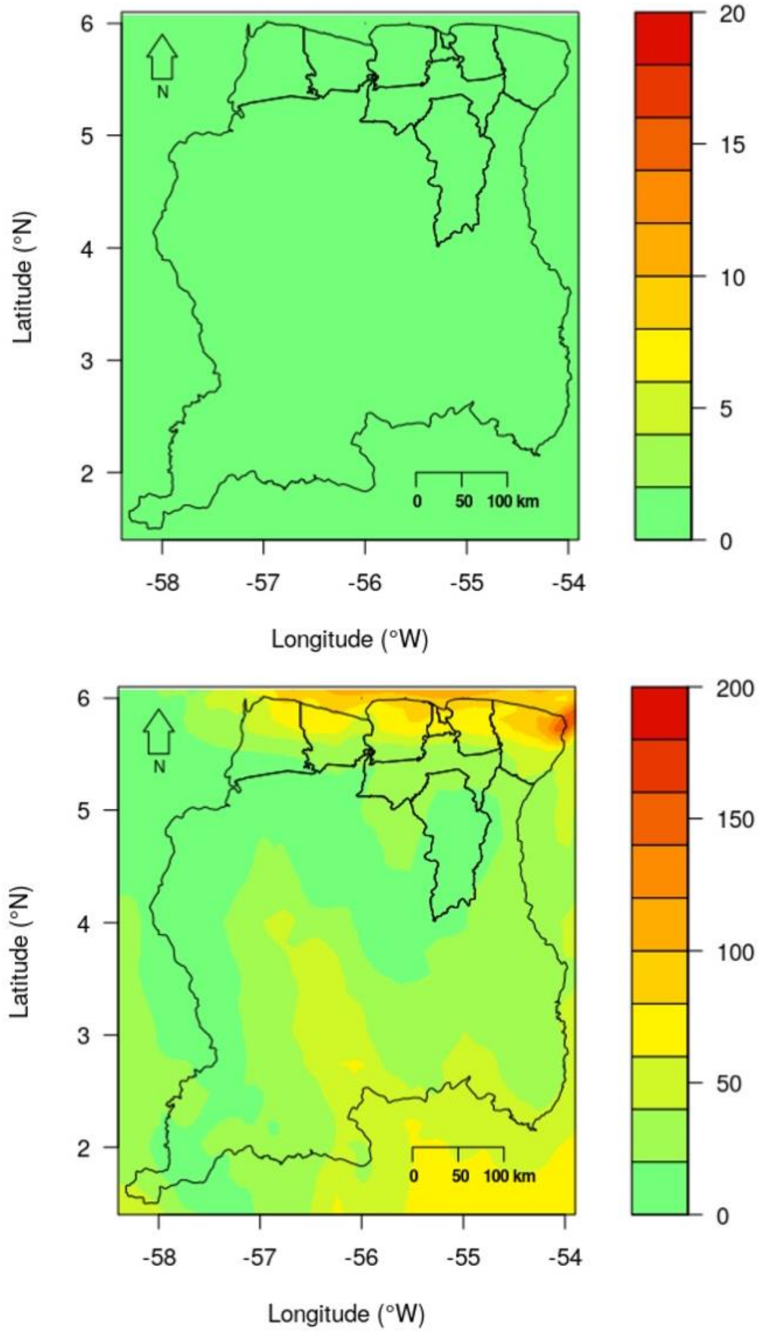


Source: SOC Report team elaboration

3.4.3. Wind extremes

Gale wind days are exceedingly rare in Suriname with fewer than two per year, while strong wind days occur more than fifty times a year in the center and southeast of the country, and more than a hundred days per year on the coast (Figure 21).

Figure 22*- Maps of the average yearly values in the period 1990-2014 of frequency of days in which maximum wind speed surpasses 60 km/h, a gale wind, (top) and days in which maximum wind speed surpasses 40 km/h (bottom)*



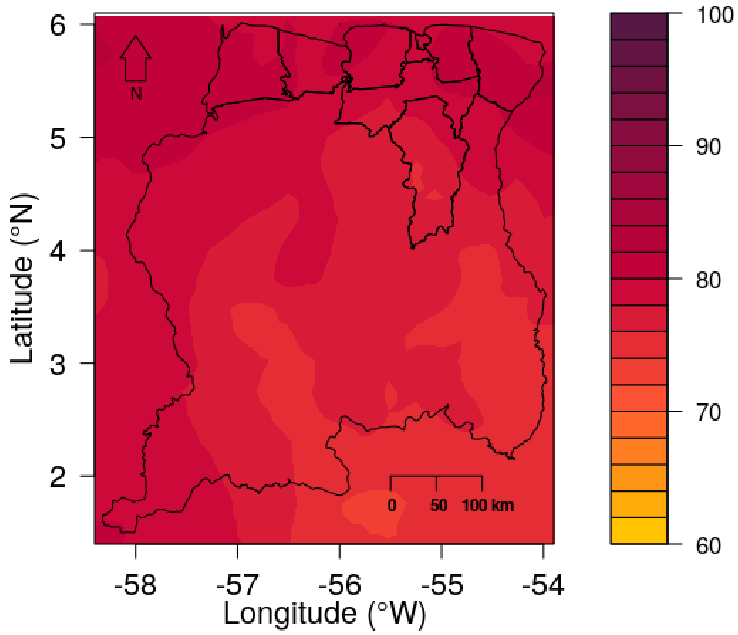
Source: SOC Report team elaboration

3.5. Humidity

3.5.1. Humidity climatology

Relative humidity is very high for all of Suriname, 80% or higher, and has a latitudinal gradient, with the maximum values found at the coast and slightly lower values further inland (Figure 22).

Figure 23- Average relative humidity (%) for the period 1990-2014



Source: SOC Report team elaboration

CLIMATE PROJECTIONS

The aim of this chapter is to present the results of the future climate projections. The projections have been obtained from a multi-model analysis, combining the climate models HadGEM3-GC31, IPSL-CM6A, and MIROC6 for three time horizons (2020-2044, 2045-2069, and 2070-2094), and the two scenarios (SSP2-4.5 and SSP5-8.5). As in the previous chapter, the results concern rainfall, temperature, wind, and relative humidity. In addition, sea-level rise was considered.

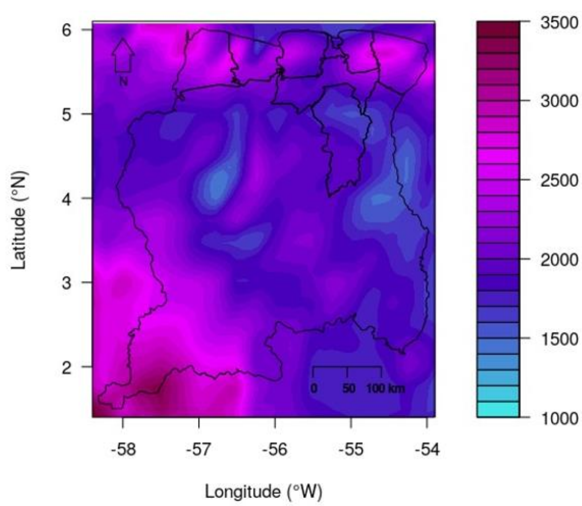
4.1. Rainfall

4.1.1. Rainfall climatology

4.1.1.1. Regional results

Accumulated precipitation in Suriname is expected to decrease strongly as the mean position of the ITCZ shifts northwards (Figures 23-24). The ITCZ is expected to shift northwards due to the northern hemisphere warming faster than the southern hemisphere (Park et al. 2015). The ITCZ position depends on radiative balances and heat fluxes (Schneider et al. 2014) and its mean position has varied over long periods of time, such as the transition from the Medieval Climate Anomaly to the Little Ice Age (Higley et al. 2018). The maximum values of up to 3,500 mm/year of precipitation in the historical record are reached in the southwest and could be reduced by up to 500 mm/year by the end of the century in the SSP2-4.5, reaching values of just over 3,000 mm/year. In the RCP 8.5 scenario, those values could decrease by 900 mm/year, for a maximum accumulated precipitation of 2,600 mm/year. The projected decrease in precipitation is also very strong in the coastal region, especially in the SSP5-8.5 scenario, which points to a decreasing trend in accumulated precipitation from around 2,500 mm/year to just over 2,000 mm/year. In general, the decreases in precipitation for the country could surpass 20% of the historical climatological accumulated precipitation.

***Figure 24**- Average accumulated precipitation during the historical period (top) and projections for the indicated periods and scenarios*



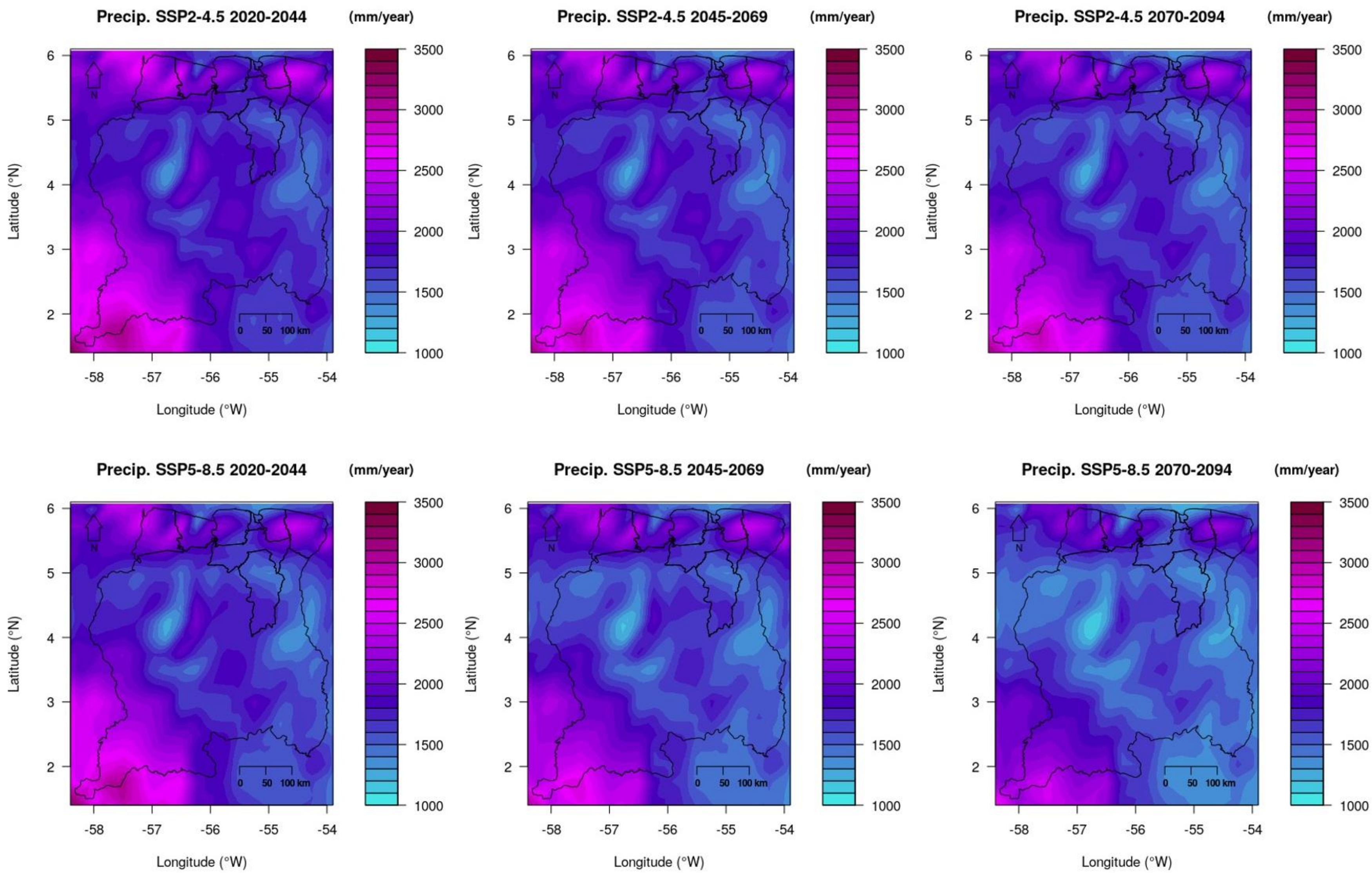
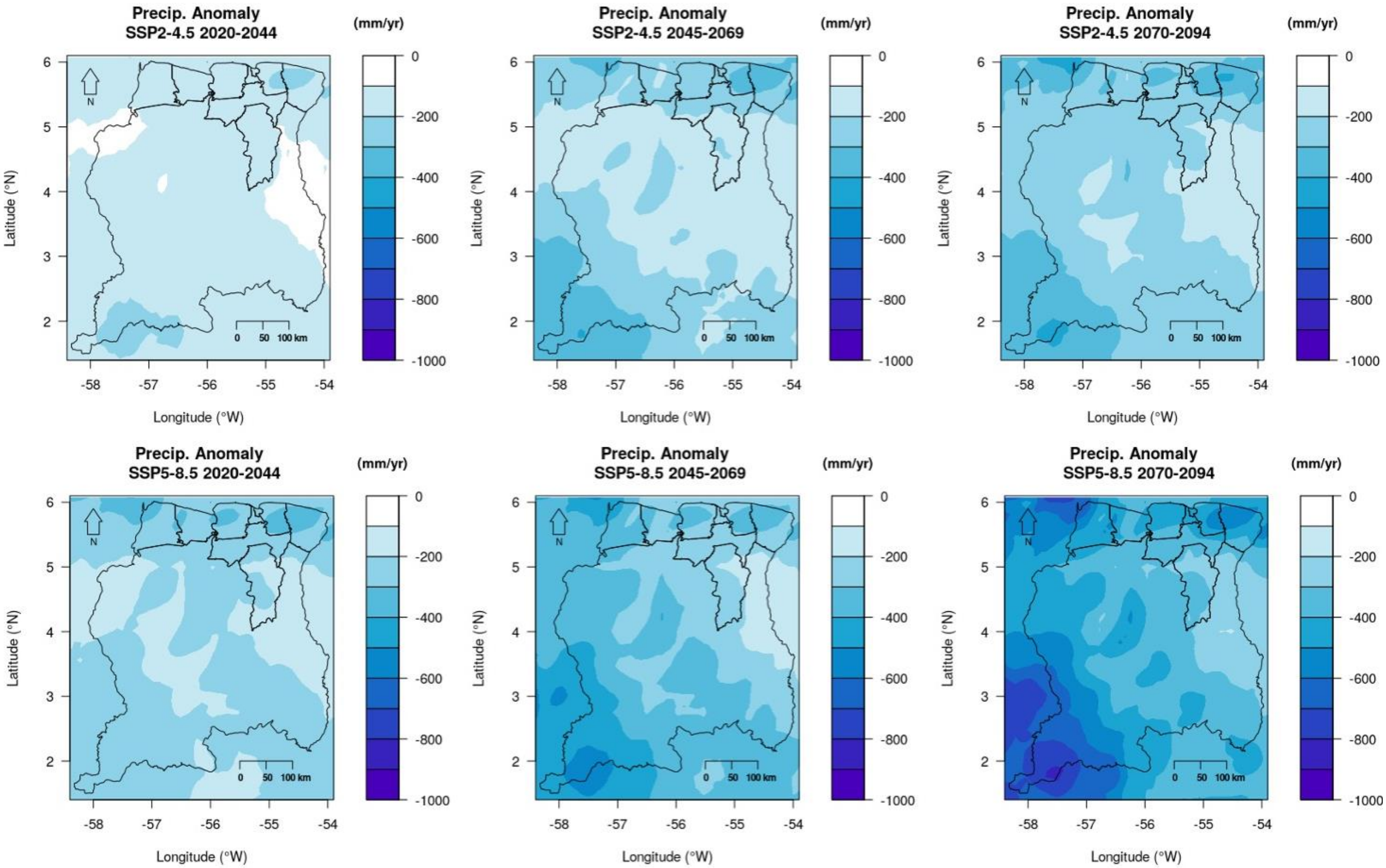

Precip. SSP2-4.5 2020-2044
(mm/year)
Precip. SSP2-4.5 2045-2069
(mm/year)
Precip. SSP2-4.5 2070-2094
(mm/year)
Precip. SSP5-8.5 2020-2044
(mm/year)
Precip. SSP5-8.5 2045-2069
(mm/year)
Precip. SSP5-8.5 2070-2094
(mm/year)
Latitude (°N)
Longitude (°W)
6
5
4
3
2
-58
-57
-56
-55
-54
3500
3000
2500
2000
1500
1000
0 50 100 km
N

Figure 25- Average accumulated precipitation anomalies (each period minus the historical period 1990-2014) projected for the indicated periods and scenarios



Source: SOC Report team elaboration

4.1.1.2. Local results

As on the regional level, yearly mean accumulated precipitation is projected to decrease strongly in all seven points of interest and by more than a 20% in almost all locations of the country for SSP5-8.5 by the end of the century (Table 19).

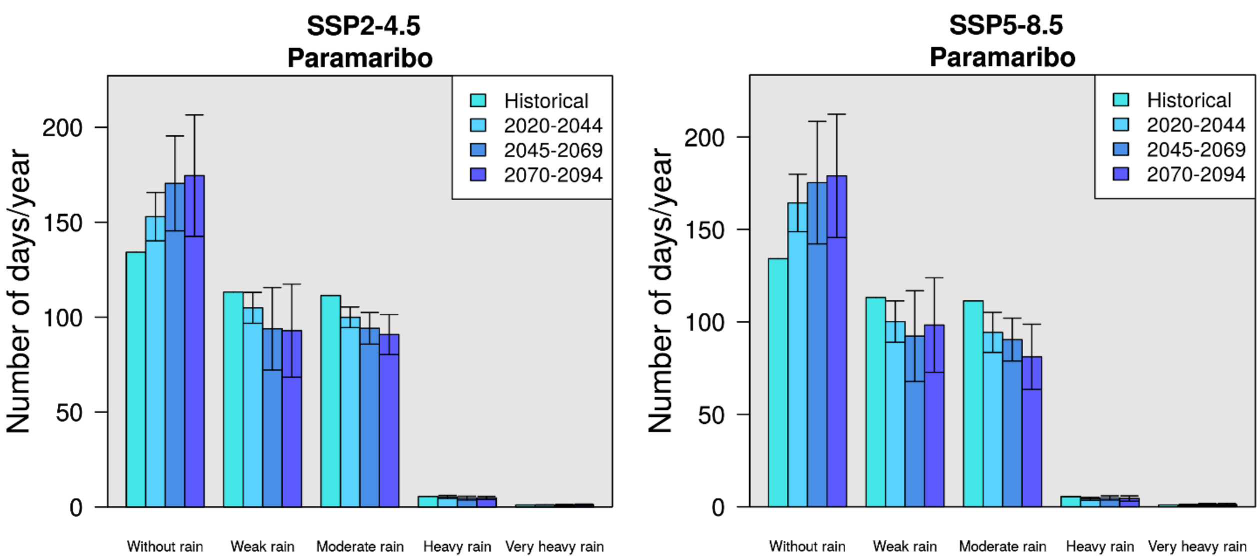
Table 19- Mean accumulated precipitation values (mm/y) for each scenario and period in seven locations

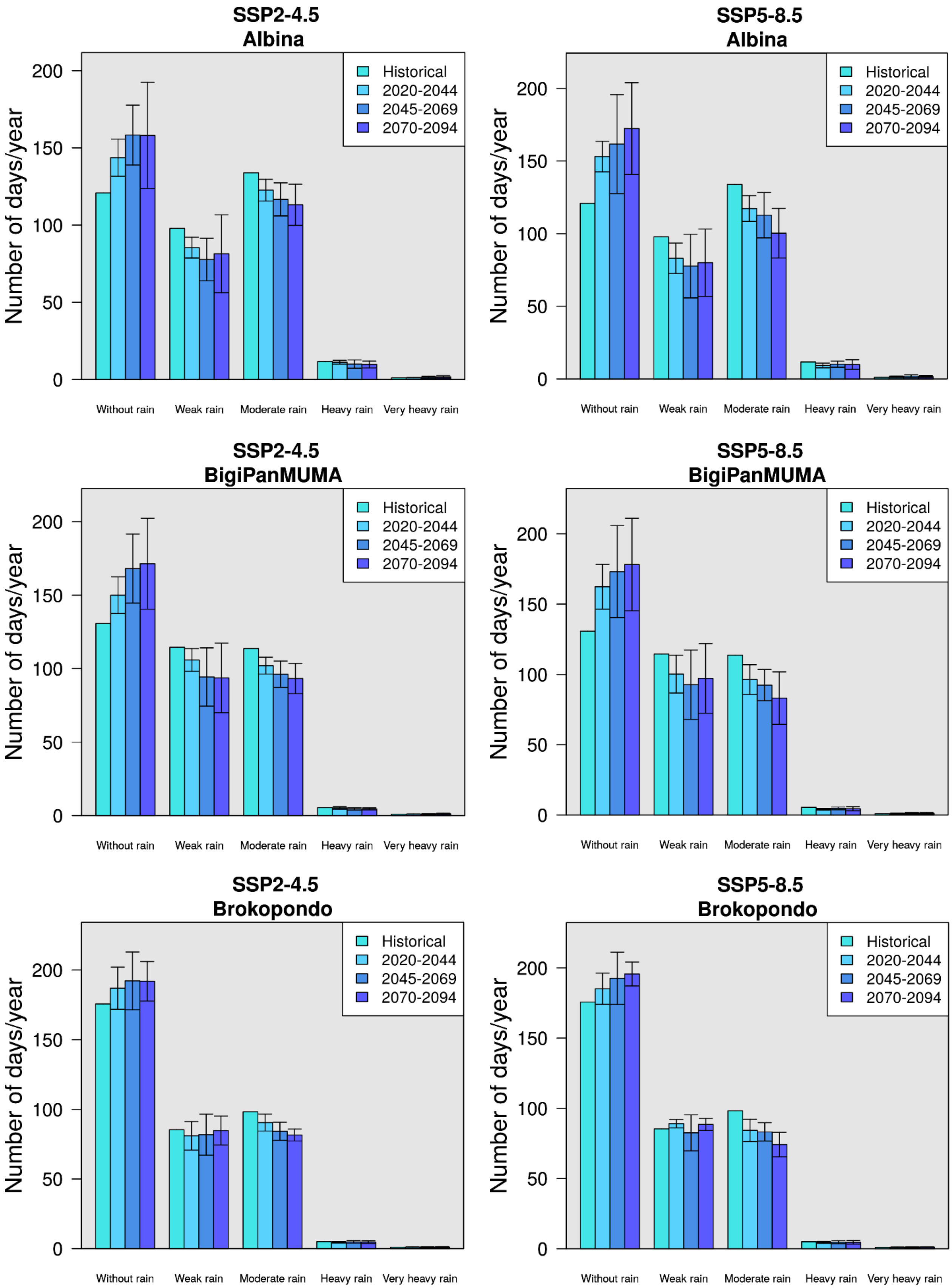
Locations	1990-2014	2020-2044		2045-2069		2070-2094	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Paramaribo	1,756	1,596	1,496	1,493	1,486	1,476	1,350
Albina	2,470	2,270	2,161	2,156	2,160	2,128	1,970
Bigi Pan MUMA	1,796	1,633	1,531	1,525	1,522	1,510	1,379
Brokopondo	1,556	1,457	1,387	1,397	1,387	1,379	1,306
Kwamalasamutu	2,392	2,219	2,166	2,130	2,002	2,108	1,849
Tafelberg	1,852	1,718	1,651	1,667	1,541	1,634	1,458
Tapanahony	1,926	1,782	1,686	1,718	1,588	1,692	1,520

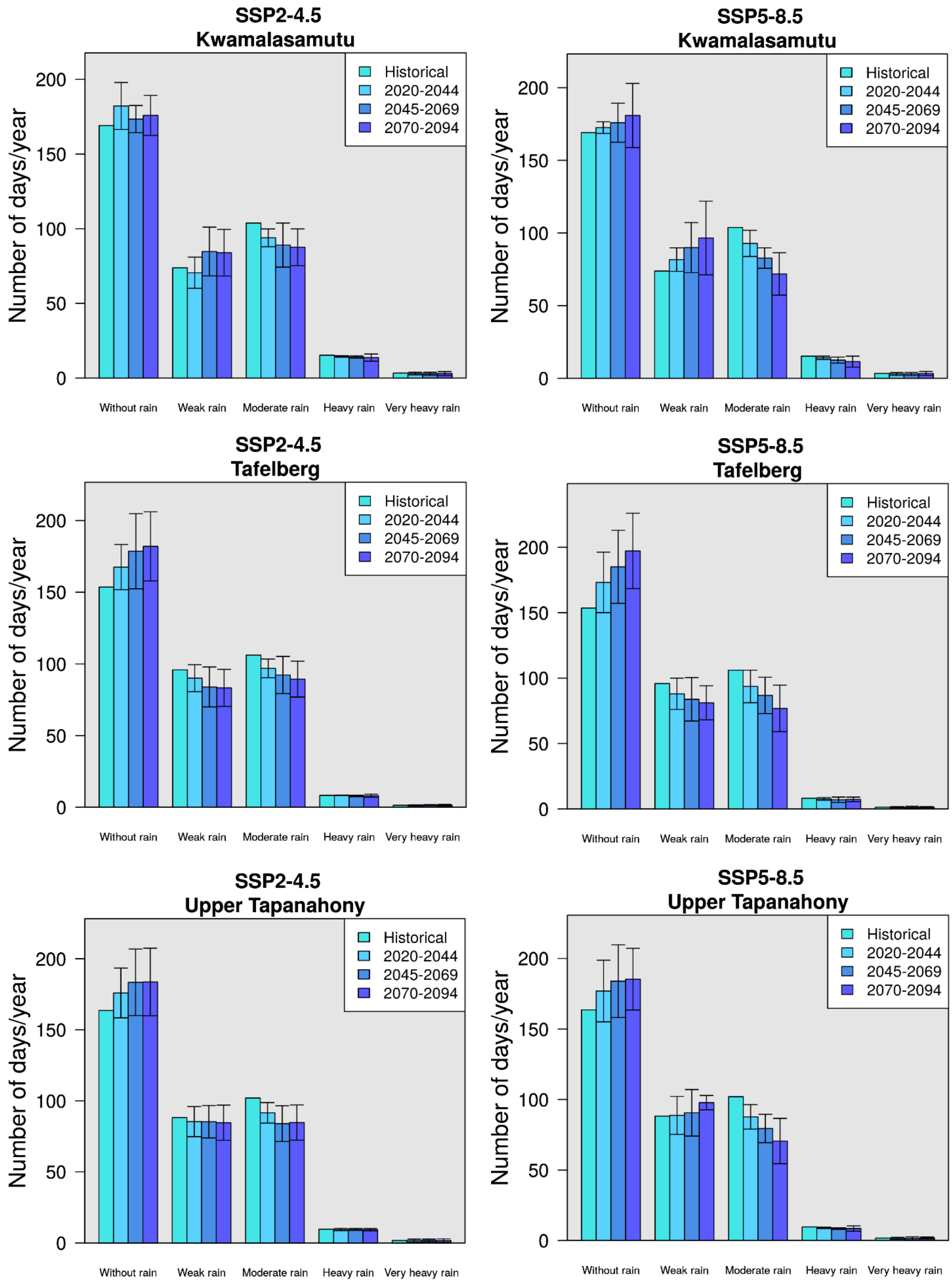
Source: SOC Report team elaboration

Annual precipitation regimes throughout Suriname are projected to change similarly, showing the number of days without rain expected to increase everywhere (Figure 25). In most timeframes through both scenarios, all of Suriname will have more dry days. This is most evident in the long term and for the coastal points of interest but can also be observed in the interior and for the short and medium term. This change in the number of days without rain contributes significantly to the reversal of the historical trend of more cumulative rain per year, changing totals to a lower amount as time progresses. Episodes of weak and moderate rain are expected to decrease in Paramaribo, Albina, Bigi Pan MUMA, Brokopondo, and Tafelberg, and increase in Kwamalasamutu. Extreme events might also increase in Kwamalasamutu, Albina, or Bigi Pan MUMA.

Figure 26- Average annual precipitation regime projected for the indicated periods and scenarios in the seven locations




SSP2-4.5
Albina
SSP5-8.5
Albina
SSP2-4.5
BigiPanMUMA
SSP5-8.5
BigiPanMUMA
SSP2-4.5
Brokopondo
SSP5-8.5
Brokopondo
Number of days/year
0
50
100
150
200
Historical
2020-2044
2045-2069
2070-2094
Without rain
Weak rain
Moderate rain
Heavy rain
Very heavy rain



Source: SOC Report team elaboration

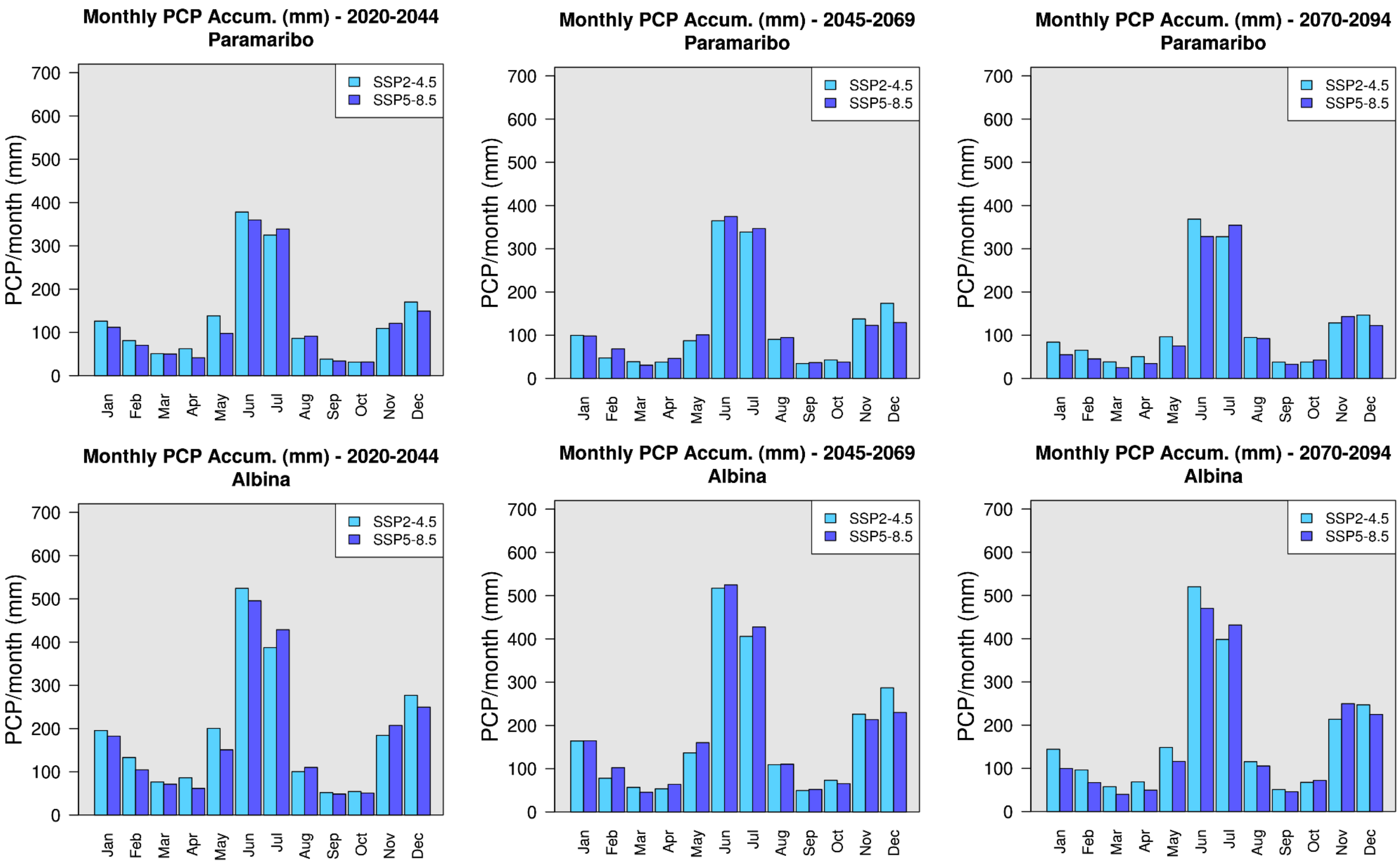
Seasonally, climate regimes in Suriname go from the two wet and two dry seasons of the coastal region, to only one rainy and one dry in the southern part of the country. Figures 26-27[2] show that this regime is expected to persist in most points, and for both the SSP2-4.5 and SSP5-8.5 scenarios.

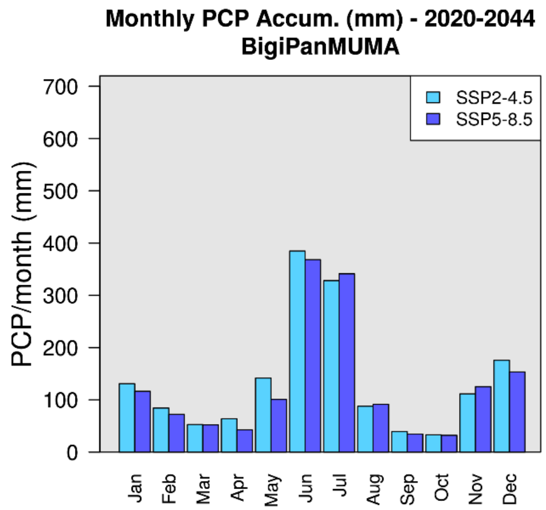
For the northernmost locations of Paramaribo, Albina, Brokopondo and Bigi Pan MUMA, the total precipitation is expected to decrease, especially during the short dry season. However, the longer dry season shows a small increase in precipitation for these locations, which points to a displacement of seasons, as noted previously in the climographs. The ITCZ area of influence over Suriname is expected to narrow throughout the century, which diminishes the length of time it causes Surinamese rains. This is supported by the projected evolution of the rains in cities located in the interior. In Kwamalasamutu, Upper Tapanahony, and Tafelberg the shorter rainy and shorter dry seasons become much drier in both scenarios and for all timeframes. Meanwhile, the rainy season becomes rainier. The ITCZ leaves more precipitation in the months it affects these locations, and much less the rest of the year.

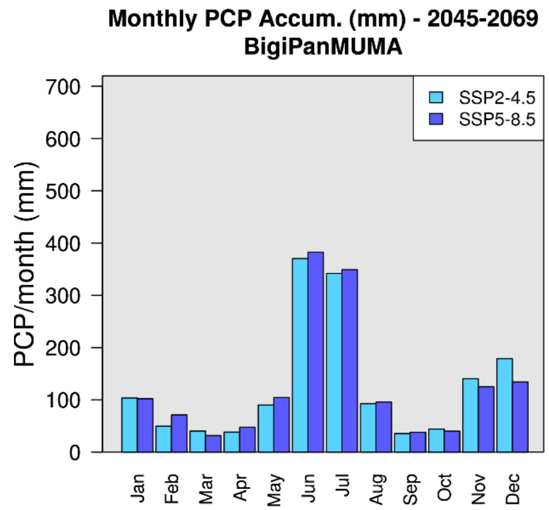
The main takeaway of these projections, when talking about seasonally accumulated precipitation in Suriname, is that seasons, as defined by accumulated rain, are likely to shift in time.

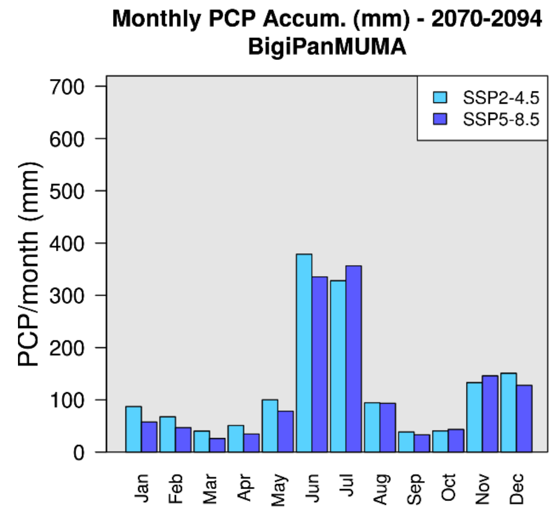
[2] Figure 27 shows accumulated precipitation. As the time span of the seasons differs greatly, the shorter rainy season may accumulate less rainfall than the dry season.

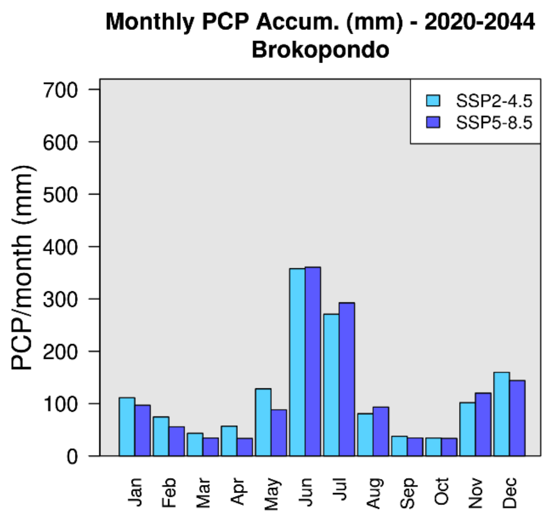
Figure 27- Graphs for seven locations showing the monthly accumulated precipitation (mm) projected for the indicated periods and scenarios in the seven locations

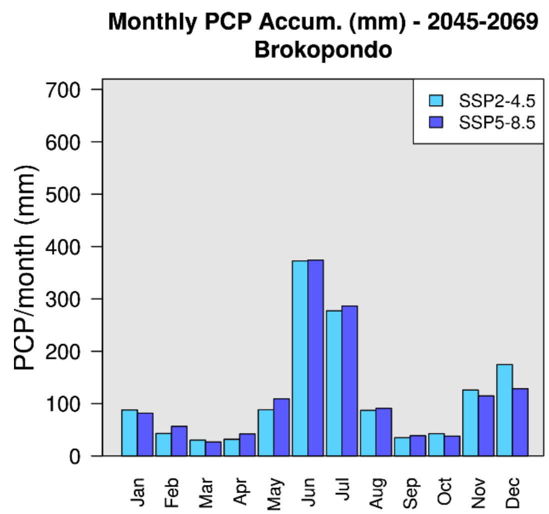


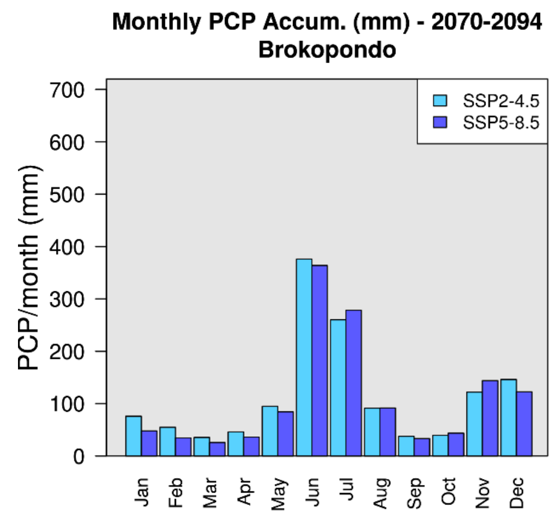

Monthly PCP Accum. (mm) - 2020-2044
BigiPanMUMA
SSP2-4.5
SSP5-8.5
PCP/month (mm)
0
100
200
300
400
500
600
700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

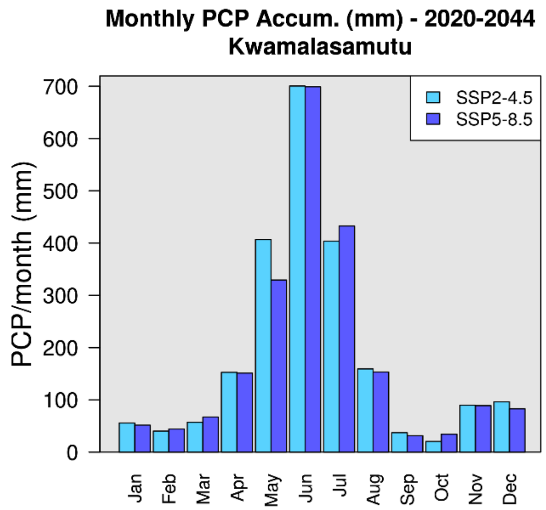

Monthly PCP Accum. (mm) - 2045-2069
BigiPanMUMA
SSP2-4.5
SSP5-8.5
PCP/month (mm)
0
100
200
300
400
500
600
700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

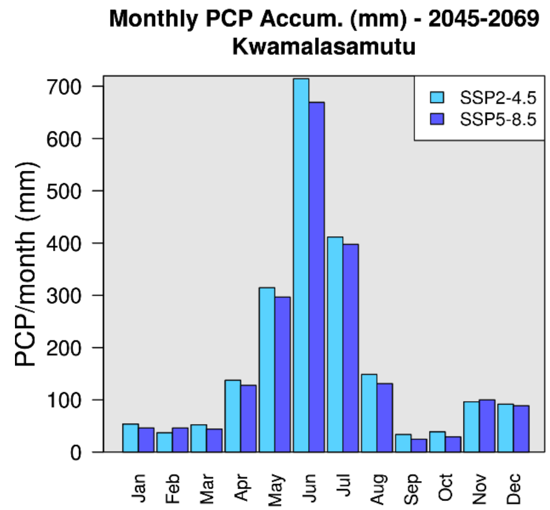

Monthly PCP Accum. (mm) - 2070-2094
BigiPanMUMA
SSP2-4.5
SSP5-8.5
PCP/month (mm)
0
100
200
300
400
500
600
700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

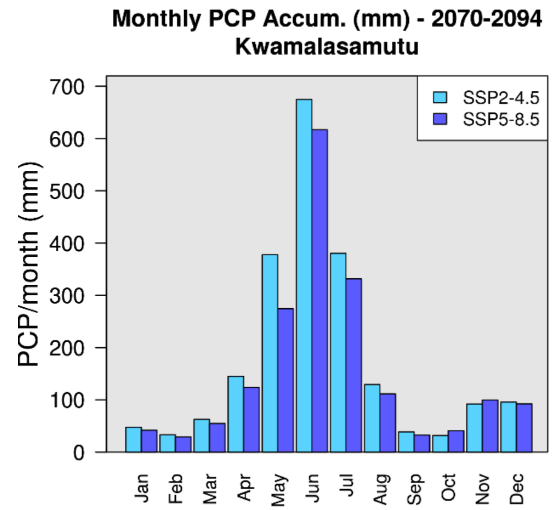

Monthly PCP Accum. (mm) - 2020-2044
Brokopondo
SSP2-4.5
SSP5-8.5
PCP/month (mm)
0
100
200
300
400
500
600
700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

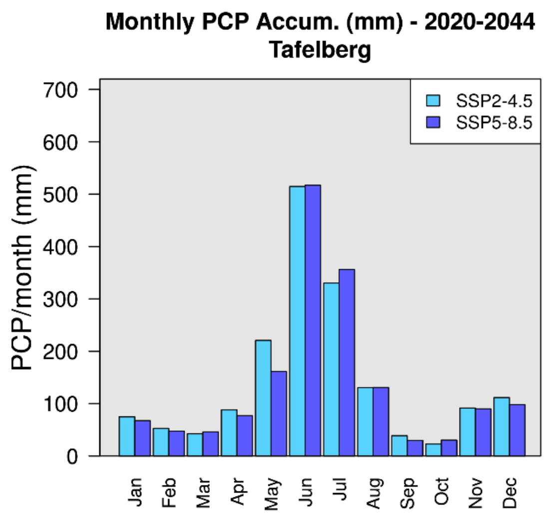

Monthly PCP Accum. (mm) - 2045-2069
Brokopondo
SSP2-4.5
SSP5-8.5
PCP/month (mm)
0
100
200
300
400
500
600
700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

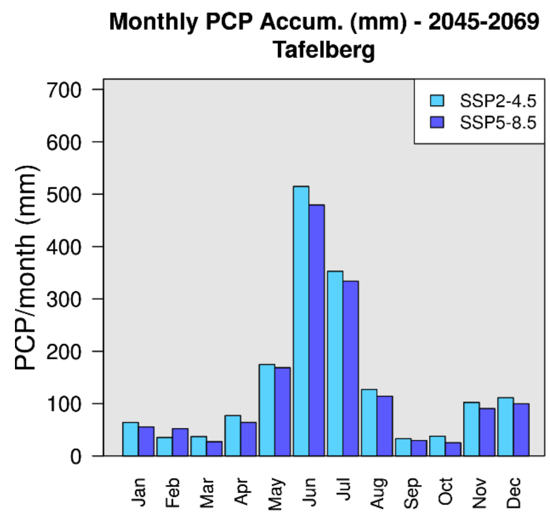

Monthly PCP Accum. (mm) - 2070-2094
Brokopondo
SSP2-4.5
SSP5-8.5
PCP/month (mm)
0
100
200
300
400
500
600
700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

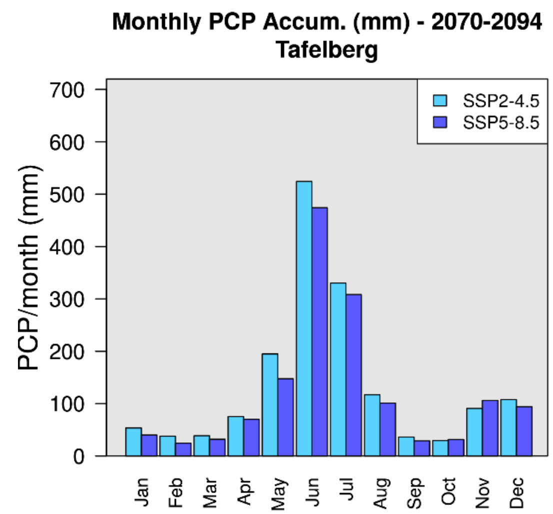

Monthly PCP Accum. (mm) - 2020-2044
Kwamalasamutu
PCP/month (mm)
SSP2-4.5
SSP5-8.5
0
100
200
300
400
500
600
700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

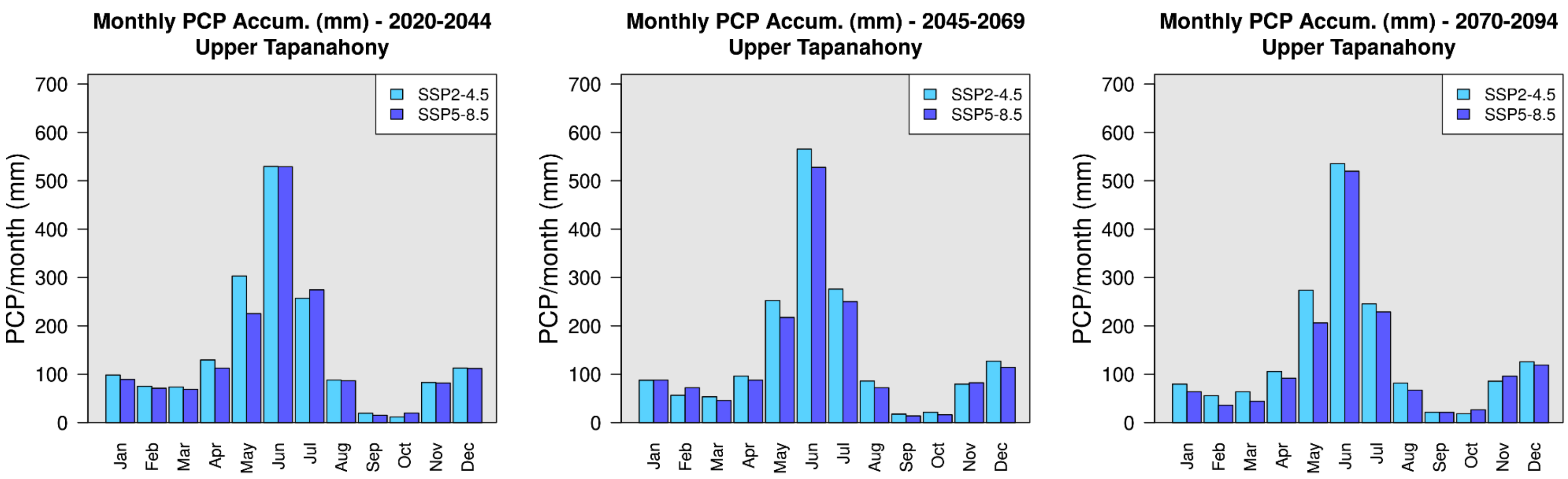

Monthly PCP Accum. (mm) - 2045-2069
Kwamalasamutu
PCP/month (mm)
SSP2-4.5
SSP5-8.5
0
100
200
300
400
500
600
700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Monthly PCP Accum. (mm) - 2070-2094
Kwamalasamutu
PCP/month (mm)
SSP2-4.5
SSP5-8.5
0
100
200
300
400
500
600
700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Monthly PCP Accum. (mm) - 2020-2044
Tafelberg
PCP/month (mm)
SSP2-4.5
SSP5-8.5
0
100
200
300
400
500
600
700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

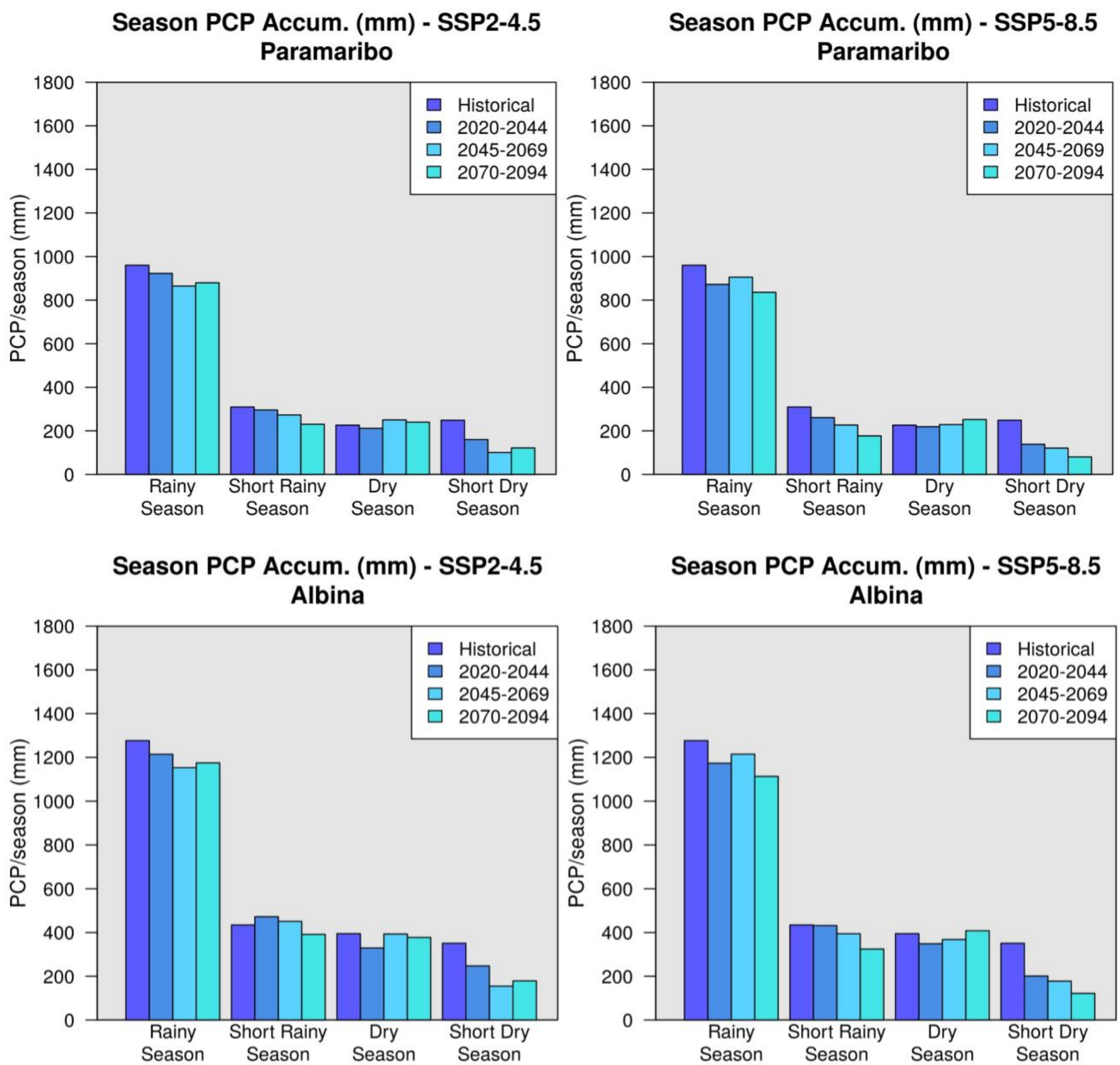

Monthly PCP Accum. (mm) - 2045-2069
Tafelberg
PCP/month (mm)
SSP2-4.5
SSP5-8.5
0
100
200
300
400
500
600
700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

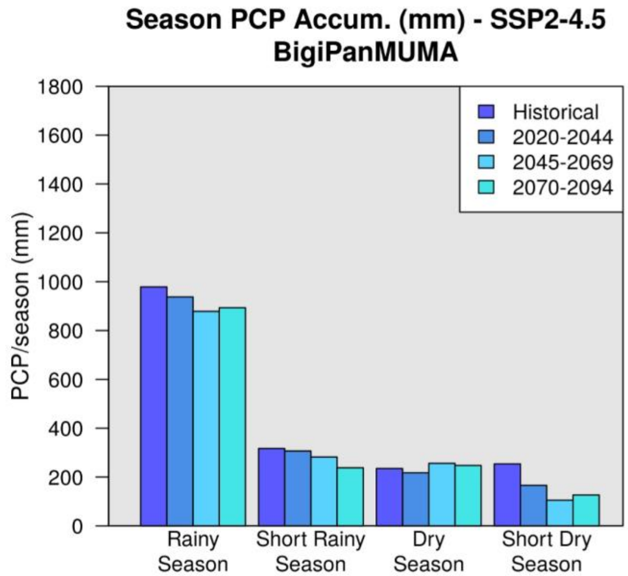

Monthly PCP Accum. (mm) - 2070-2094
Tafelberg
PCP/month (mm)
SSP2-4.5
SSP5-8.5
0
100
200
300
400
500
600
700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

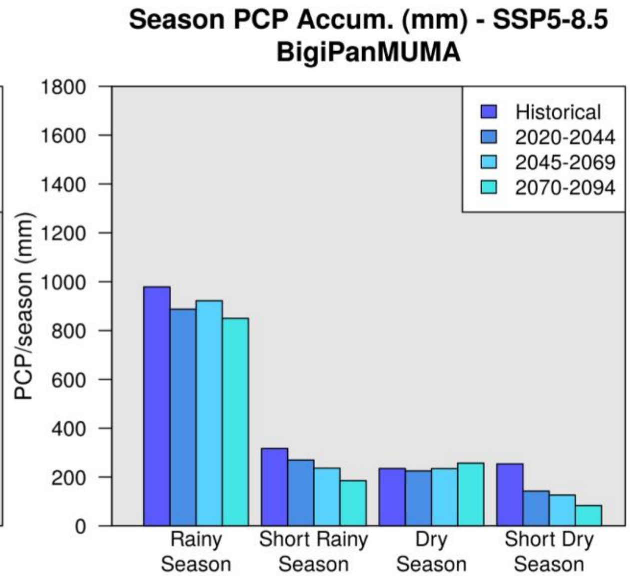


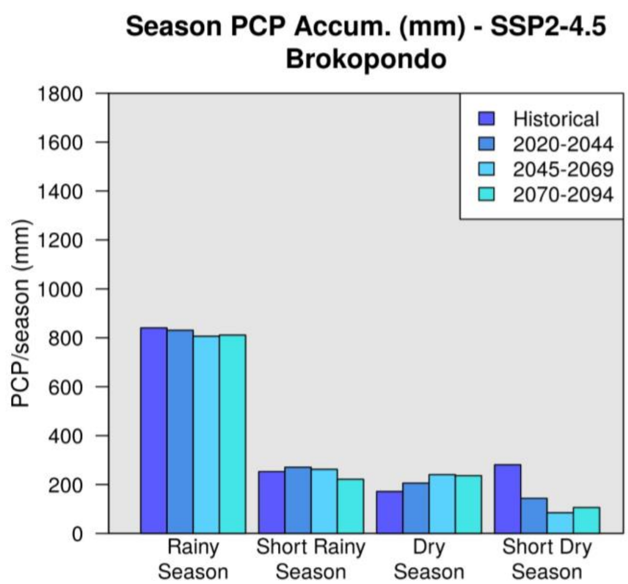
Source: SOC Report team elaboration

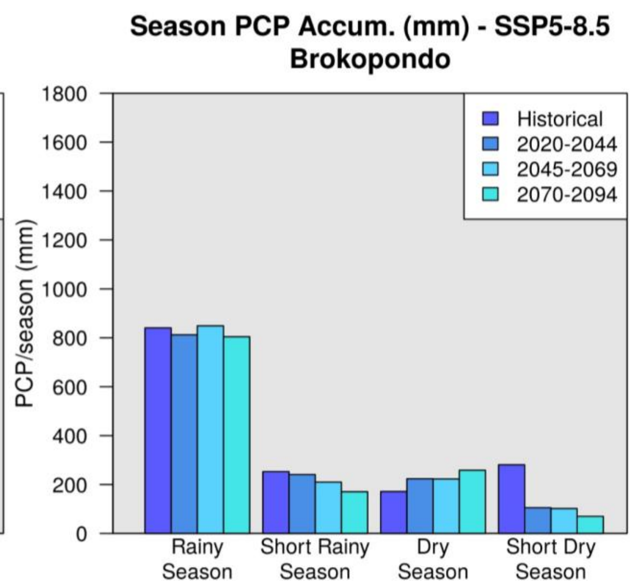
***Figure 28**- Seasonal accumulated precipitation regime projected for the indicated periods and scenarios in the seven locations*

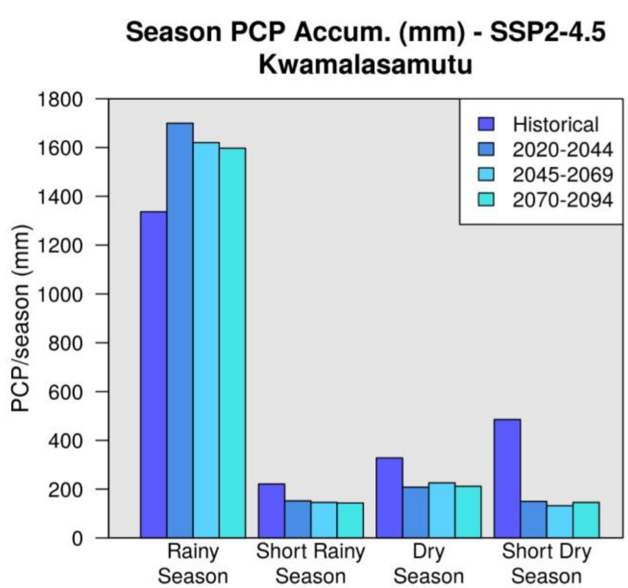


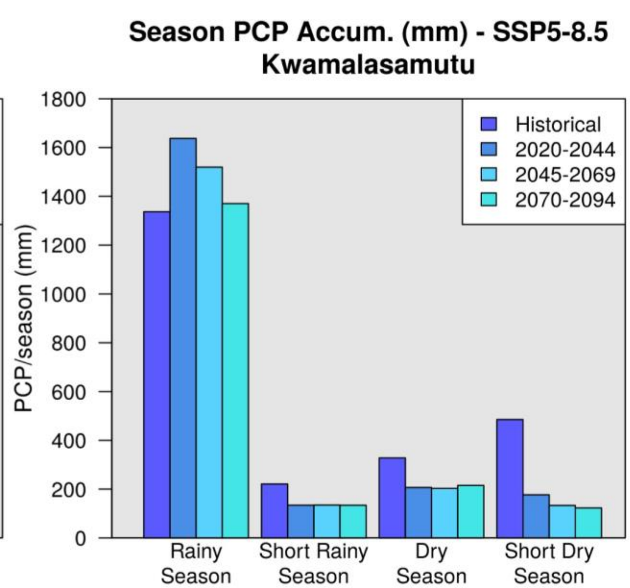

Season PCP Accum. (mm) - SSP2-4.5
BigiPanMUMA
PCP/season (mm)
1800
1600
1400
1200
1000
800
600
400
200
0
Historical
2020-2044
2045-2069
2070-2094
Rainy Season
Short Rainy Season
Dry Season
Short Dry Season

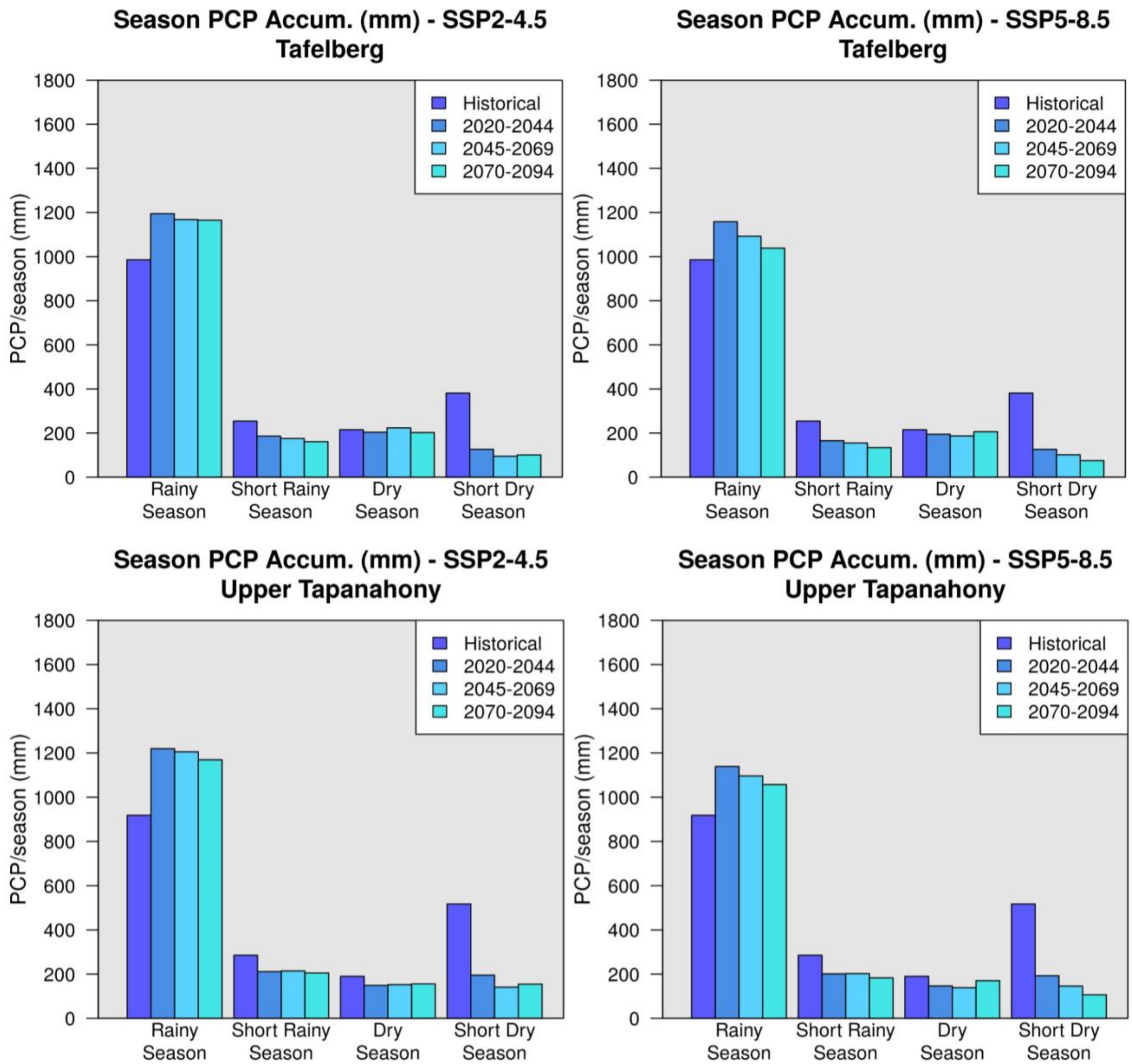

Season PCP Accum. (mm) - SSP5-8.5
BigiPanMUMA
PCP/season (mm)
1800
1600
1400
1200
1000
800
600
400
200
0
Historical
2020-2044
2045-2069
2070-2094
Rainy Season
Short Rainy Season
Dry Season
Short Dry Season


Season PCP Accum. (mm) - SSP2-4.5
Brokopondo
PCP/season (mm)
1800
1600
1400
1200
1000
800
600
400
200
0
Historical
2020-2044
2045-2069
2070-2094
Rainy Season
Short Rainy Season
Dry Season
Short Dry Season


Season PCP Accum. (mm) - SSP5-8.5
Brokopondo
PCP/season (mm)
1800
1600
1400
1200
1000
800
600
400
200
0
Historical
2020-2044
2045-2069
2070-2094
Rainy Season
Short Rainy Season
Dry Season
Short Dry Season


Season PCP Accum. (mm) - SSP2-4.5
Kwamalasamutu
PCP/season (mm)
1800
1600
1400
1200
1000
800
600
400
200
0
Historical
2020-2044
2045-2069
2070-2094
Rainy Season
Short Rainy Season
Dry Season
Short Dry Season


Season PCP Accum. (mm) - SSP5-8.5
Kwamalasamutu
PCP/season (mm)
1800
1600
1400
1200
1000
800
600
400
200
0
Historical
2020-2044
2045-2069
2070-2094
Rainy Season
Short Rainy Season
Dry Season
Short Dry Season



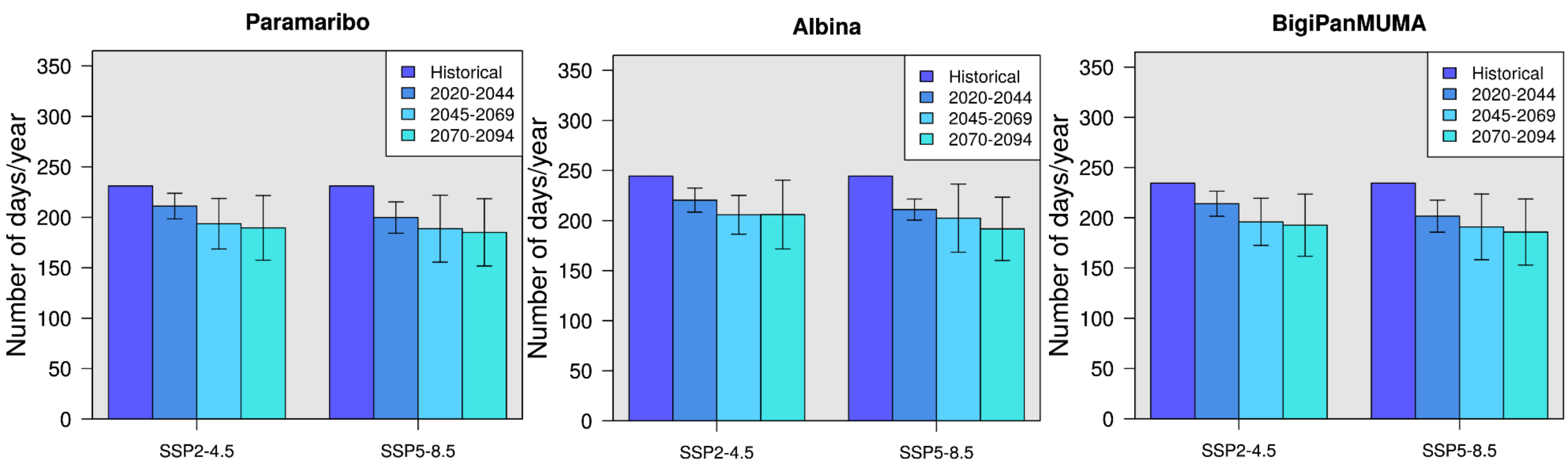
Source: SOC Report team elaboration

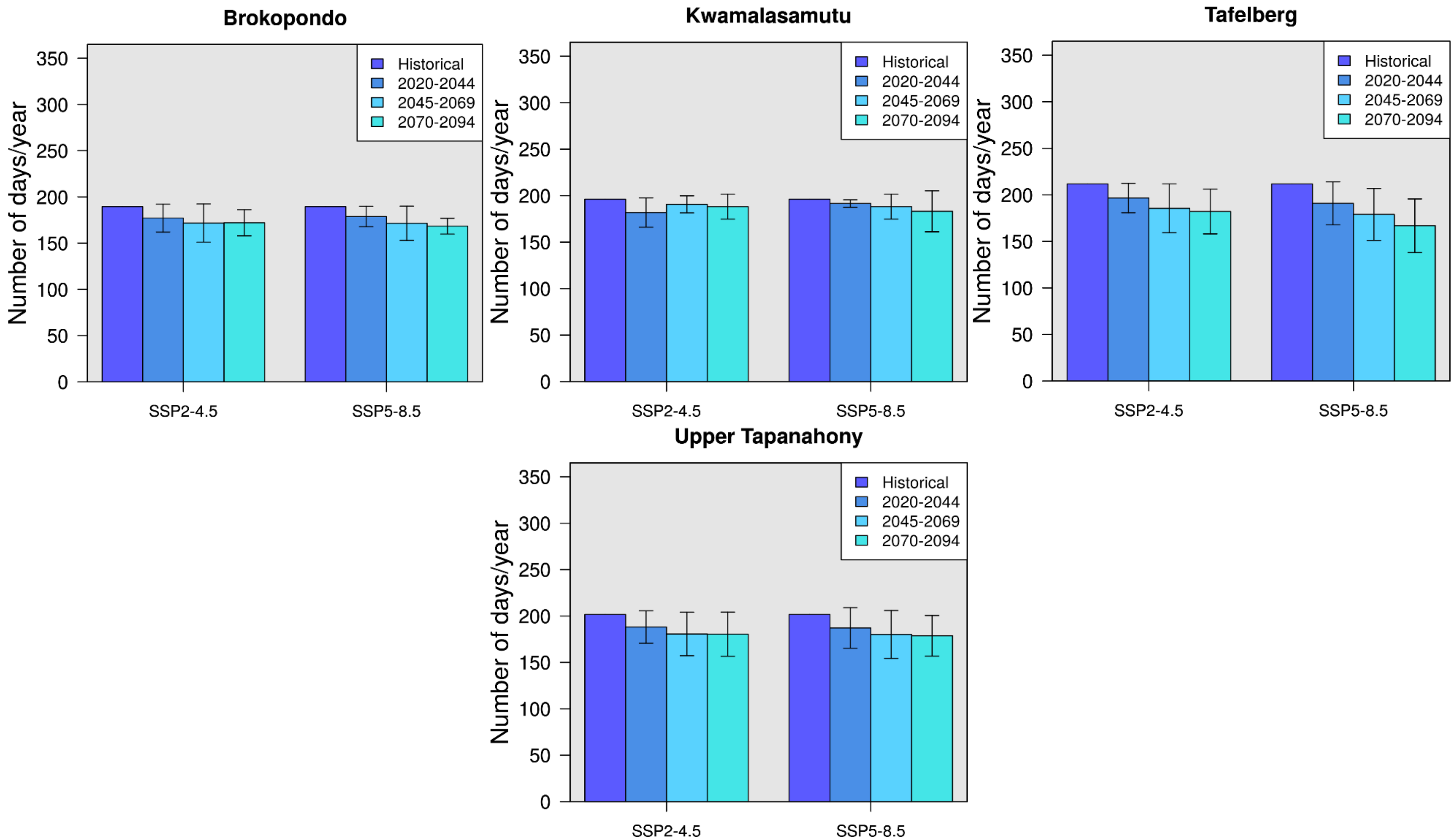
4.1.2. Rainfall extremes

The number of rainy days is projected to decrease on the coast and does not project significant change in the interior. Paramaribo and Albina suffer a decrease of more than 15% in the number of rainy days by the end of the century in SSP5-8.5, while in Kwamalasamutu the decrease is smaller than 5% (Figure 28, Table 20).

Maximum precipitation in one day and in five days are projected to increase greatly for all locations, especially for maximum precipitation in five days (Figures 29-30, Tables 21-22). This, together with the decrease in the number of rainy days, point to a change of rain regime towards fewer but more intense precipitation events.

Figure 29- *Average number of rainy days per year projected for the indicated periods and scenarios in the seven locations*





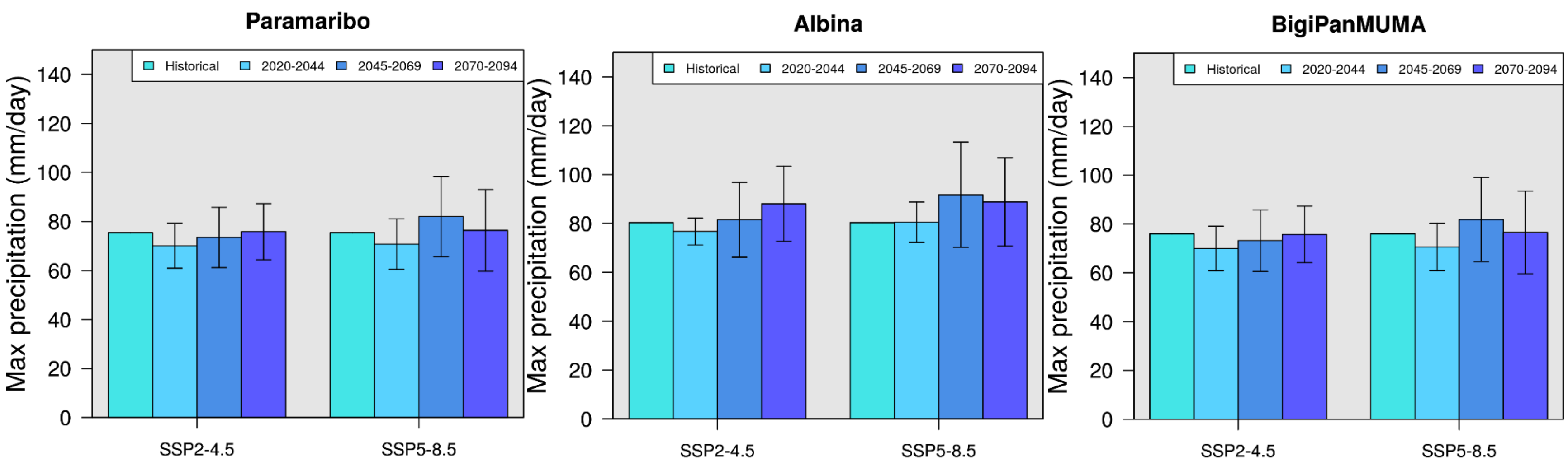
Source: SOC Report team elaboration

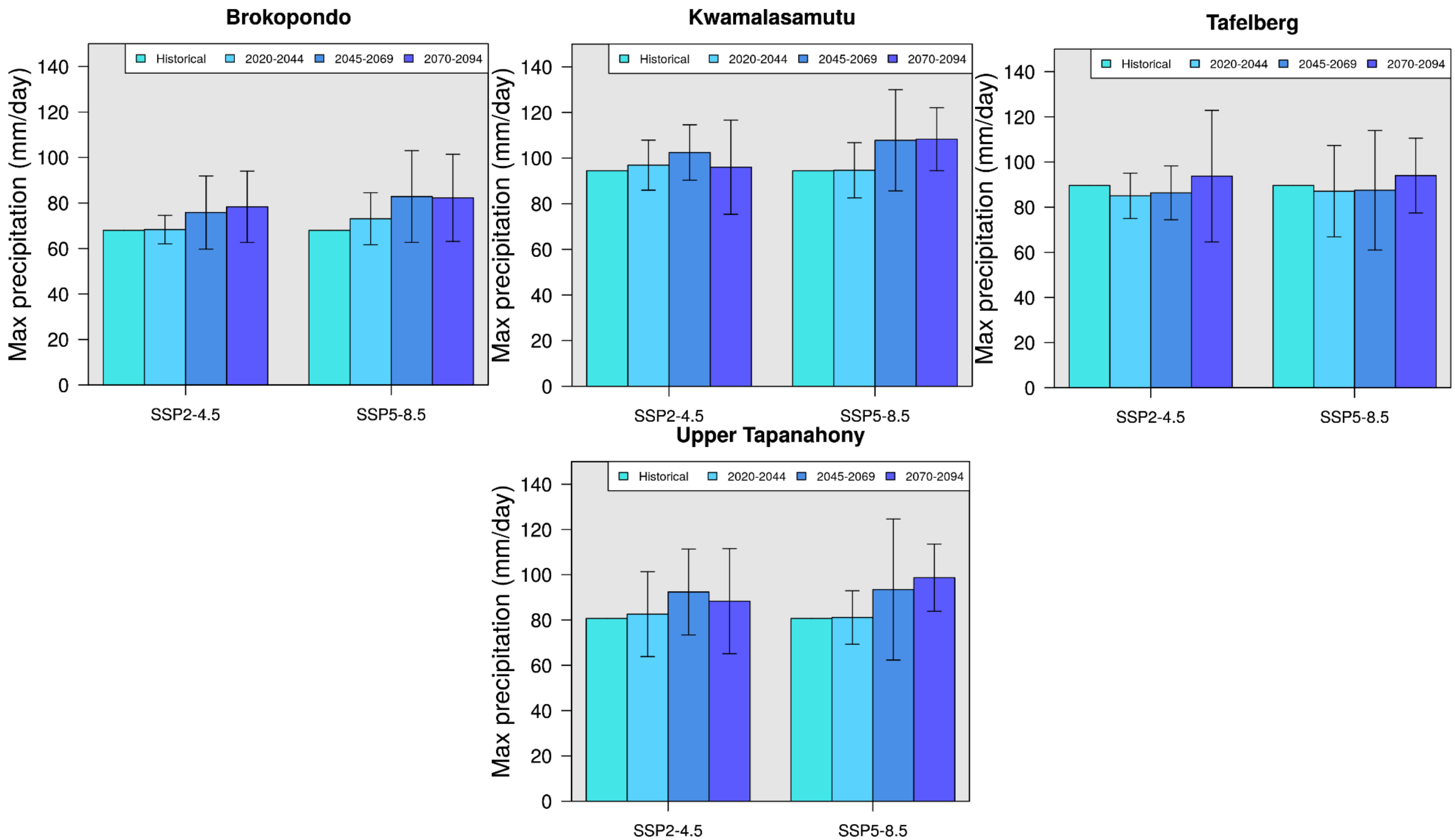
Table 20- Average rainy days per year and variations projected for the indicated periods and scenarios, obtained from the regionalized daily series at seven locations

Location	1990-2014	2020-2039		2040-2069		2070-2094	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Paramaribo	231	211.1	199.7	193.6	188.7	189.5	185.1
Albina	244.4	220.4	211.0	205.7	202.4	206.0	191.7
Bigi Pan MUMA	234.5	214.1	201.1	196	190.9	192.7	185.8
Brokopondo	190	177.1	179	171.8	171.5	172.1	168.4
Kwamalasamutu	196.2	181.8	191.5	191	188.1	188.1	183.1
Tafelberg	211.7	196.5	191	185.5	179	182.1	167
Tapanahony	202	188.1	187.1	181	180	180.3	179

Source: SOC Report team elaboration

Figure 30- Average precipitation in one day (RX1) projected for the indicated periods and scenarios in the seven locations





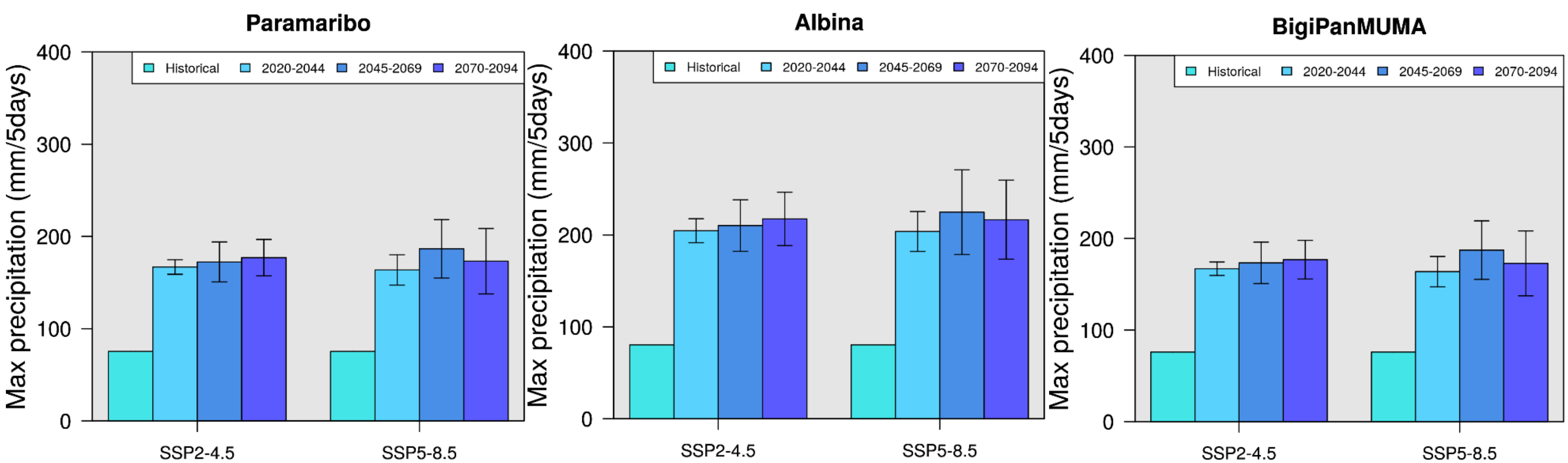
Source: SOC Report team elaboration

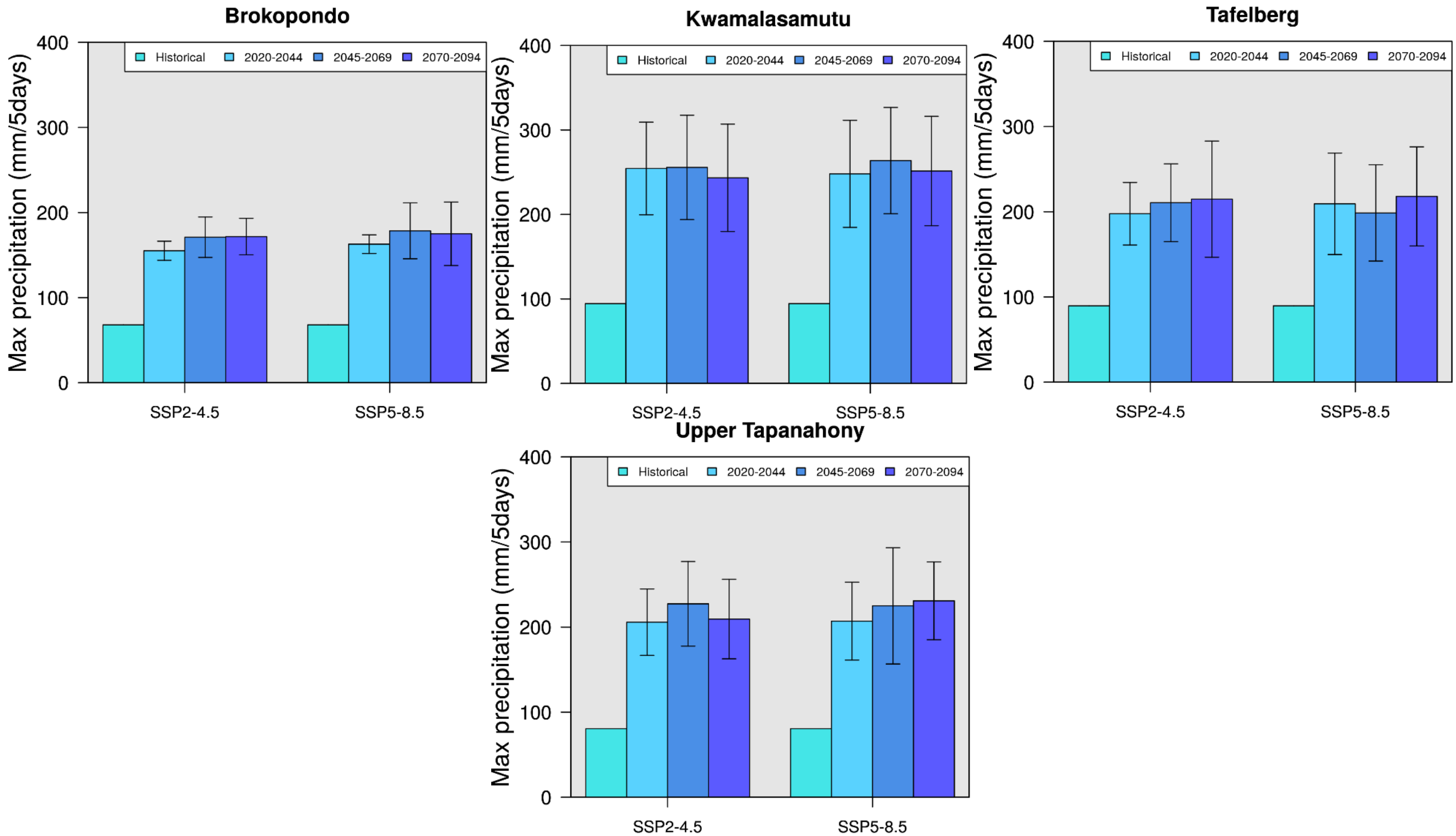
Table 21- Average precipitation in one day (RX1day climate index) and variations projected for the indicated periods and scenarios, obtained from the regionalized daily series at the seven locations

Location	1990-2014	2020-2044		2040-2069		2070-2094	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Paramaribo	75.4	70.0	70.8	73.5	82.0	75.8	76.3
Albina	80.4	76.7	80.5	81.5	91.7	88.1	88.8
Bigi Pan MUMA	76	70	70.1	73.2	81.8	75.7	76.5
Brokopondo	68	68.3	73.1	75.8	82.8	78.3	82.3
Kwamalasamutu	94.4	97	97	102.4	108	96	108.3
Tafelberg	90	85	87	86.3	87.5	93.7	94
Tapanahony	81	83	81.1	92.4	93.5	88.3	99

Source: SOC Report team elaboration

Figure 31- Average precipitation in five days (RX5) for the historical period and projected for the indicated periods and scenarios in the seven locations





Source: SOC Report team elaboration

***Table 22**- Average precipitation in five days (RX5day climate index) and variations projected for the indicated periods and scenarios, obtained from the regionalized daily series at seven locations*

Location	1990-2014	2020-2044 SSP2-4.5	2020-2044 SSP5-8.5	2045-2069 SSP2-4.5	2045-2069 SSP5-8.5	2070-2094 SSP2-4.5	2070-2094 SSP5-8.5
Paramaribo	75.4	166.9	163.6	172.4	186.6	177.0	173.2
Albina	80.4	204.5	203.7	210.2	224.8	217.4	216.6
Bigi Pan MUMA	76	167	164	173.4	187.3	176.8	172.8
Brokopondo	68	155.1	163	171	178.5	171.7	175.1
Kwamalasamutu	94	254	248.1	256	264	243.4	251.4
Tafelberg	90	198	209.3	210.6	199	215	218
Tapanahony	81	206	207	277.3	225	209.4	231

Source: SOC Report team elaboration

4.2. Temperature

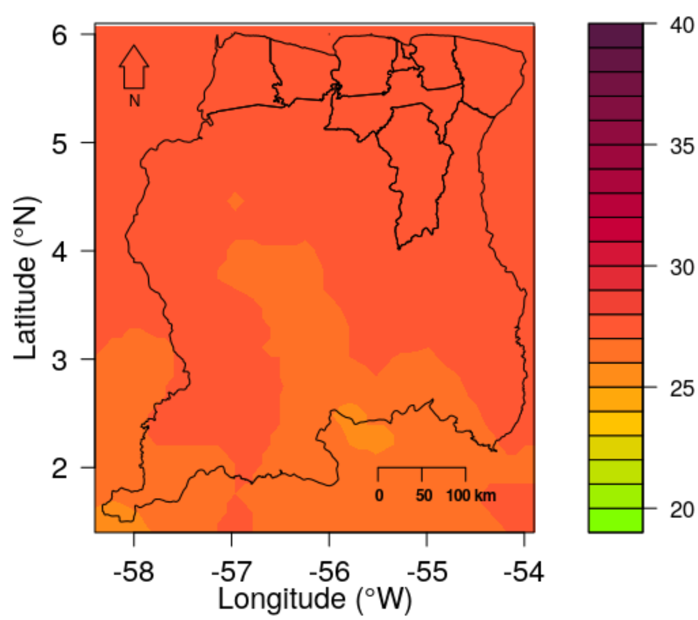
4.2.1. Temperature climatology

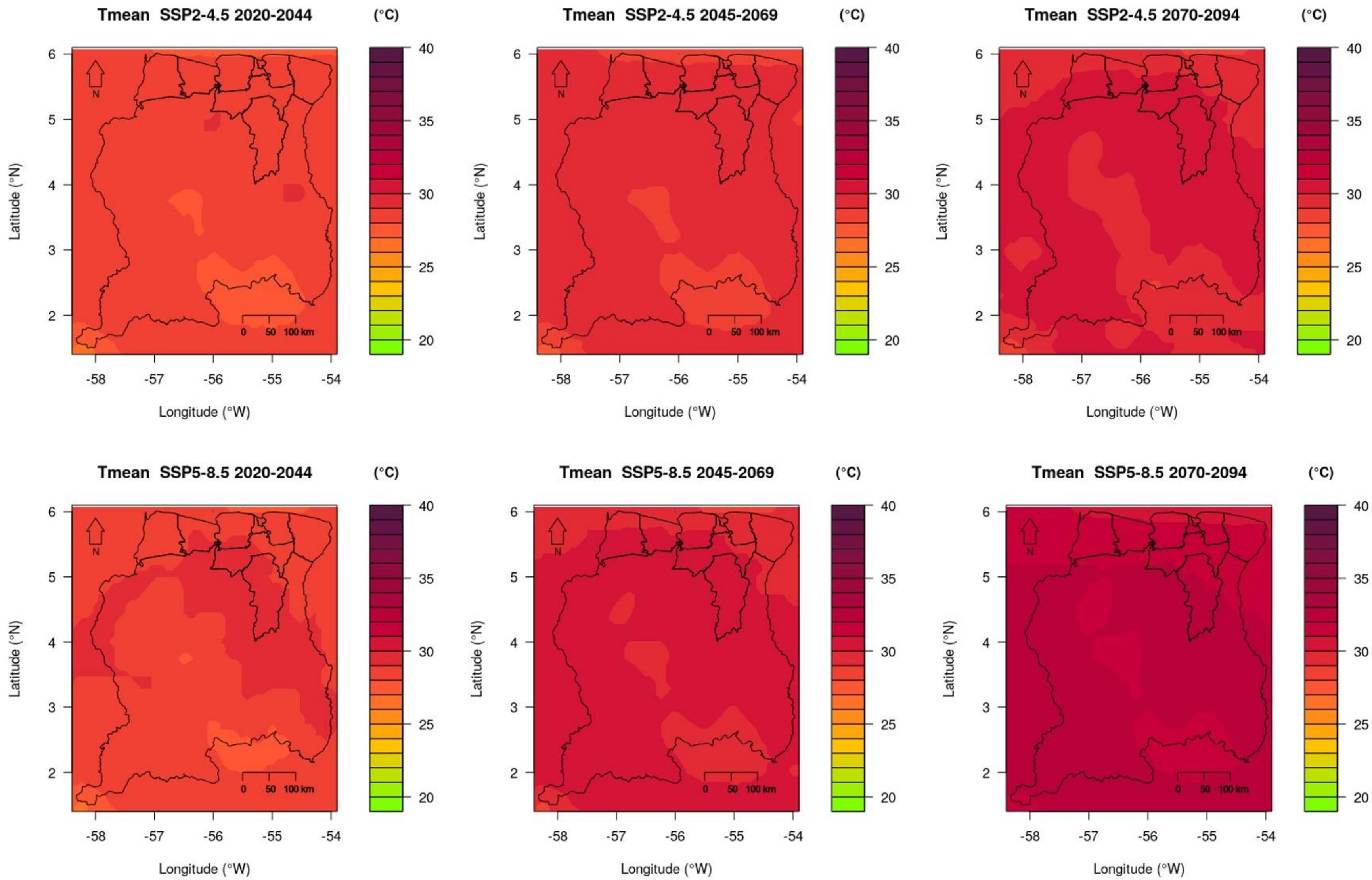
4.2.1.1. Regional results

Daily mean, minimum, and maximum temperatures are projected to increase in both climate scenarios and for all periods over the entire country (Figures 31-36). The increase in all fields is expected to be less pronounced at the coast and more pronounced in the southwest region of Suriname. Depending on the scenario, mean temperature is projected to change from around 27°C to 32°C (SSP2-4.5) or 33°C (SSP5-8.5) by the end of the 21st century. Maximum temperature for most of the country would increase from 32°C to 37°C (SSP2-4.5) or 39°C (SSP2-4.5). Minimum temperature is reached in the southeast of the country (20°C) and is expected to increase to 24°C (SSP2-4.5) or 26°C (SSP5-8.5).

The range of mean temperature increase on the coast goes from 0.5°C in the short term for the SSP2-4.5 scenario to more than 3°C at the end of the century for the SSP5-8.5 scenario. This range is similar to that observed for minimum and maximum temperatures. In the central region of the country the range of mean and minimum temperature increase goes from 1.5°C in the short term SSP2-4.5 scenario to 5°C in the long term SSP5-8.5 scenario. This range is even wider for the maximum temperature, which is projected to increase by up to 6°C by the end of the century in the SSP5-8.5 scenario.

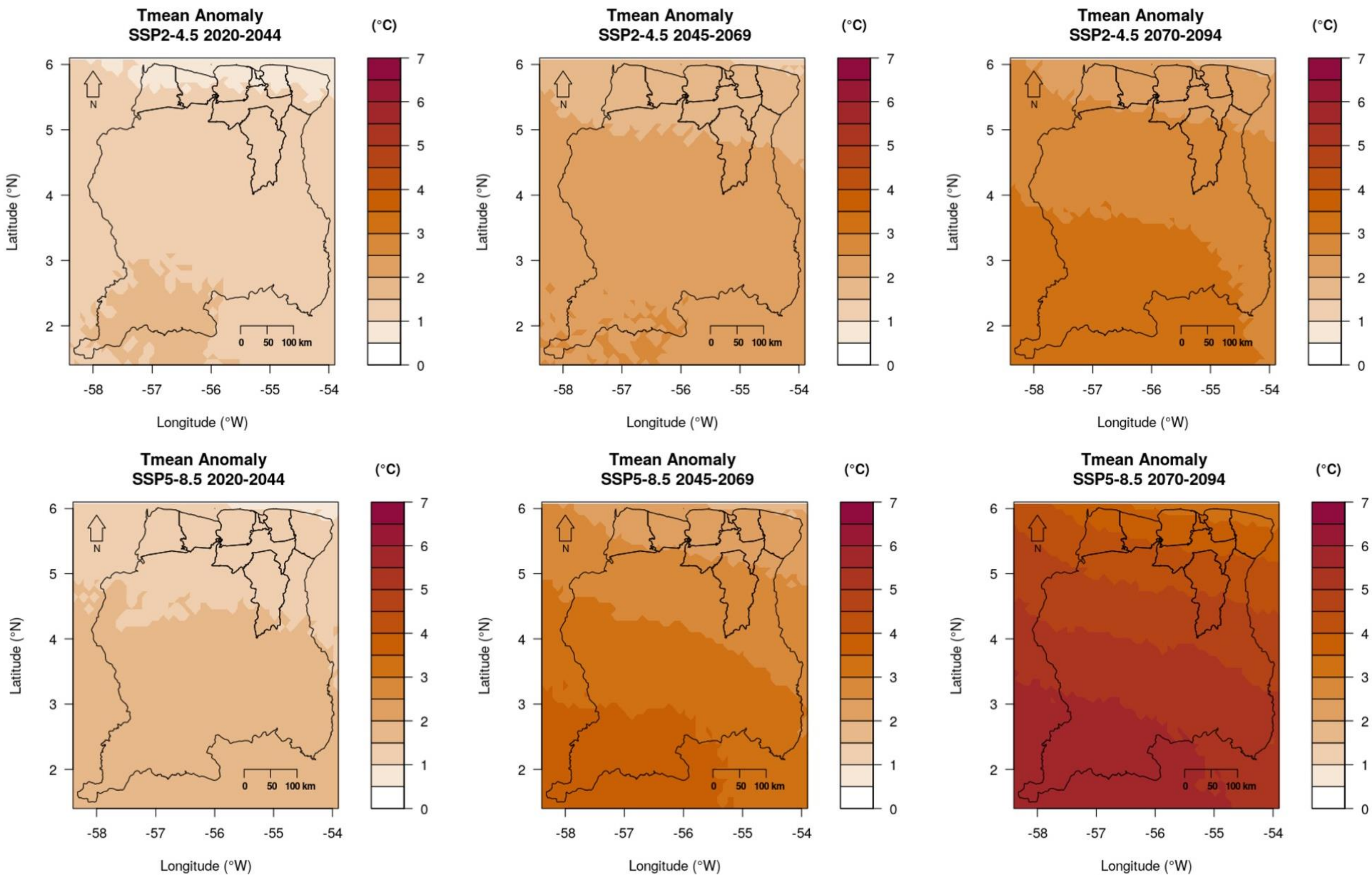
Figure 32- Average mean temperature for the historical period and projected for the indicated periods and scenarios





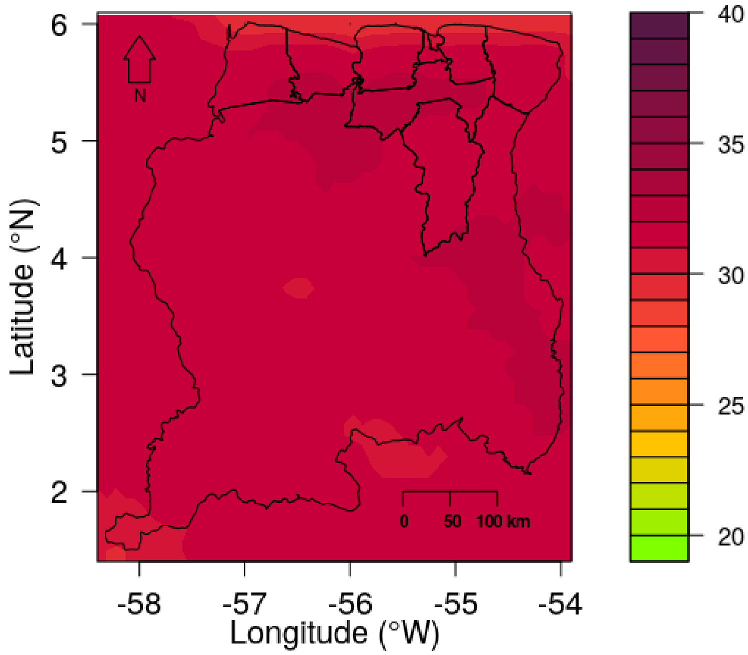
Source: SOC Report team elaboration

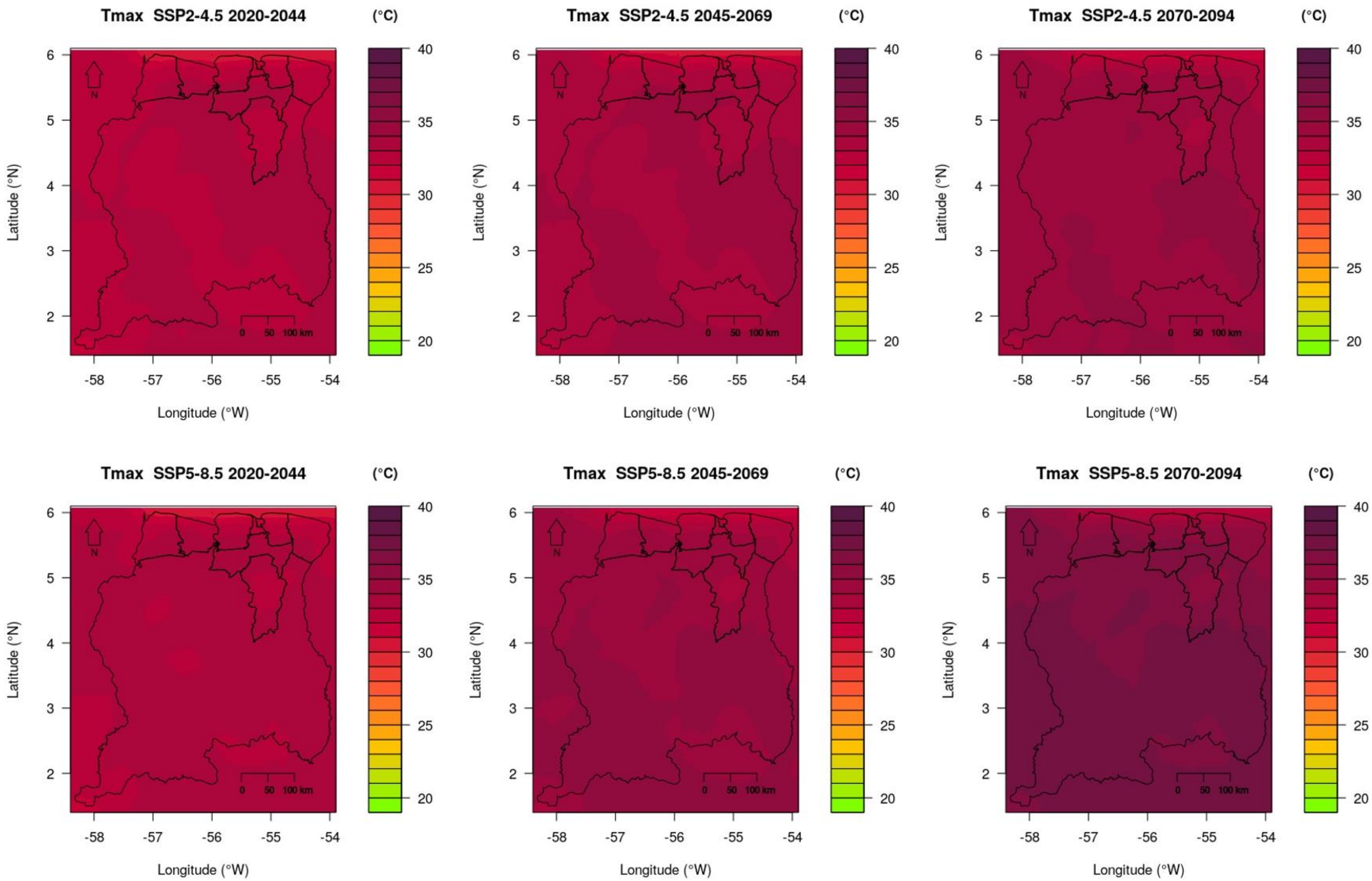
Figure 33- Average mean temperature anomalies projected for the indicated periods and scenarios



Source: SOC Report team elaboration

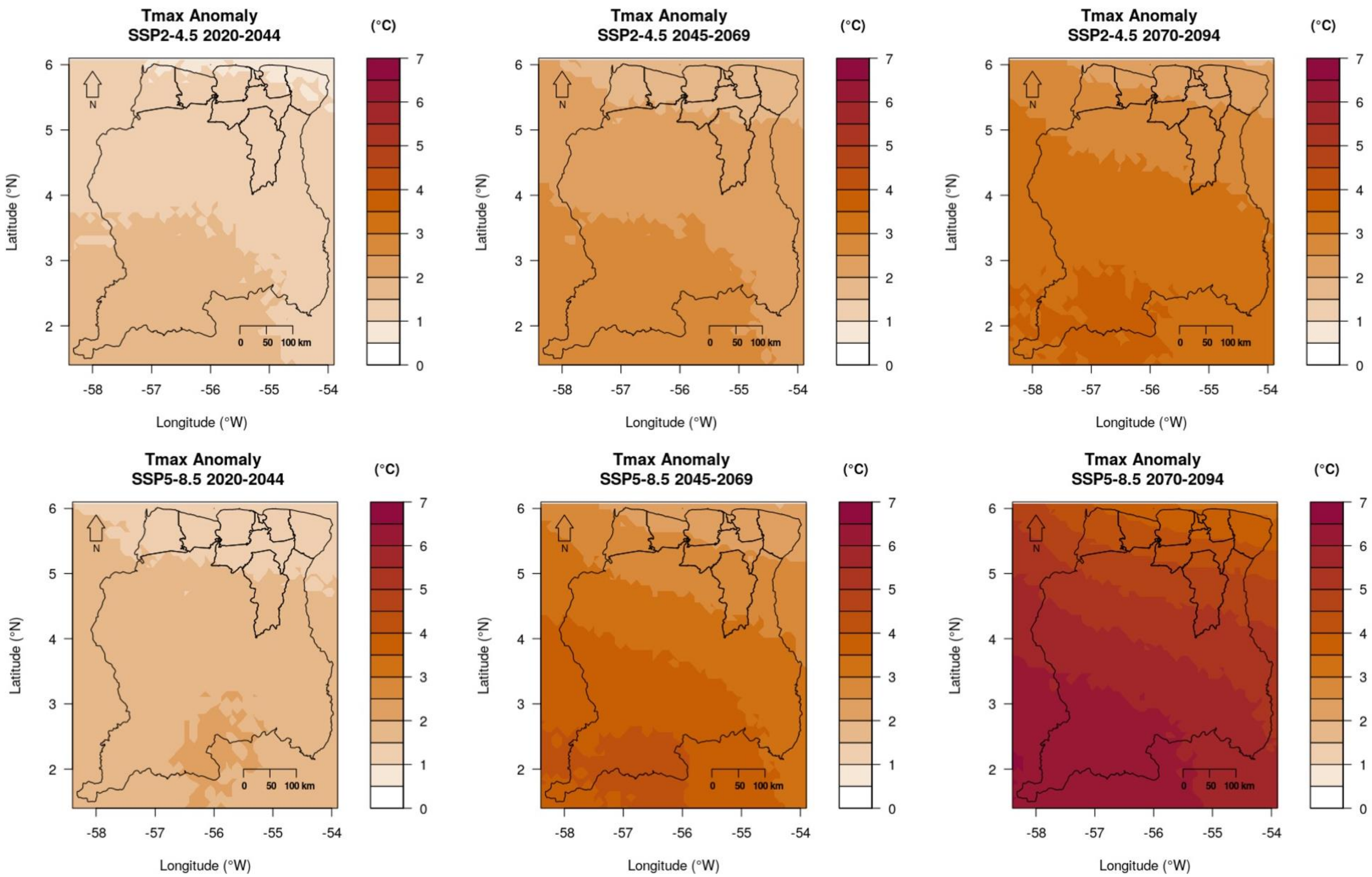
Figure 34- Average maximum temperature for the historical period and projections for the indicated periods and scenarios





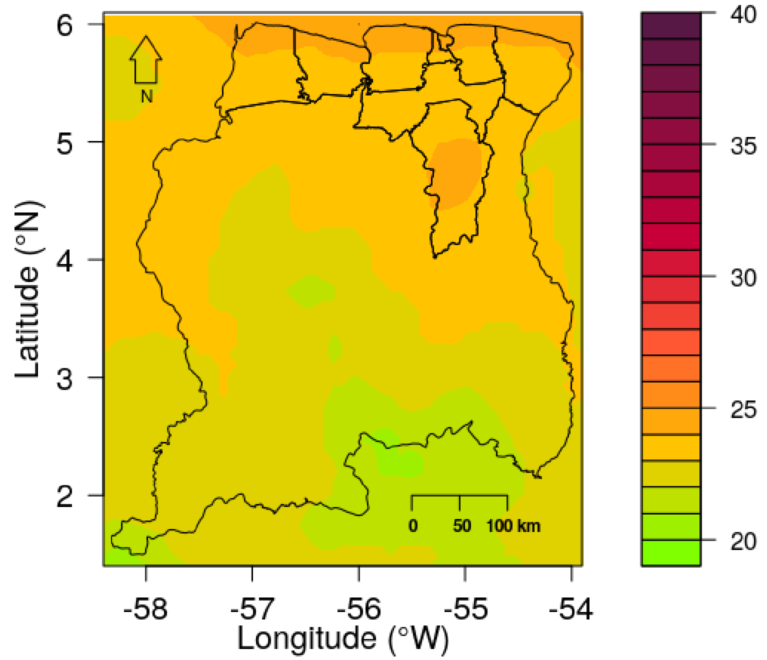
Source: SOC Report team elaboration

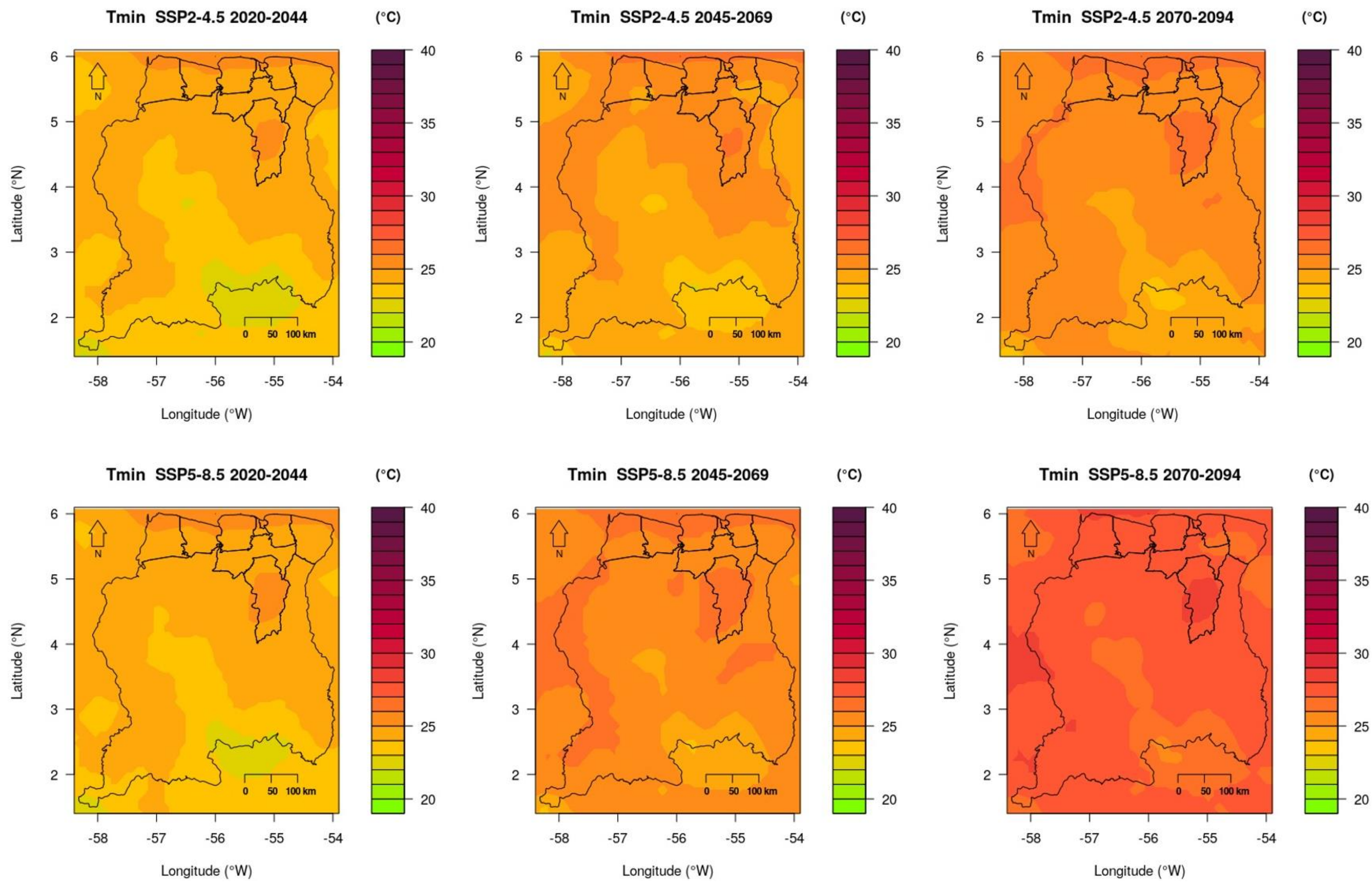
Figure 35- Average maximum temperature anomalies projected for the indicated periods and scenarios



Source: SOC Report team elaboration

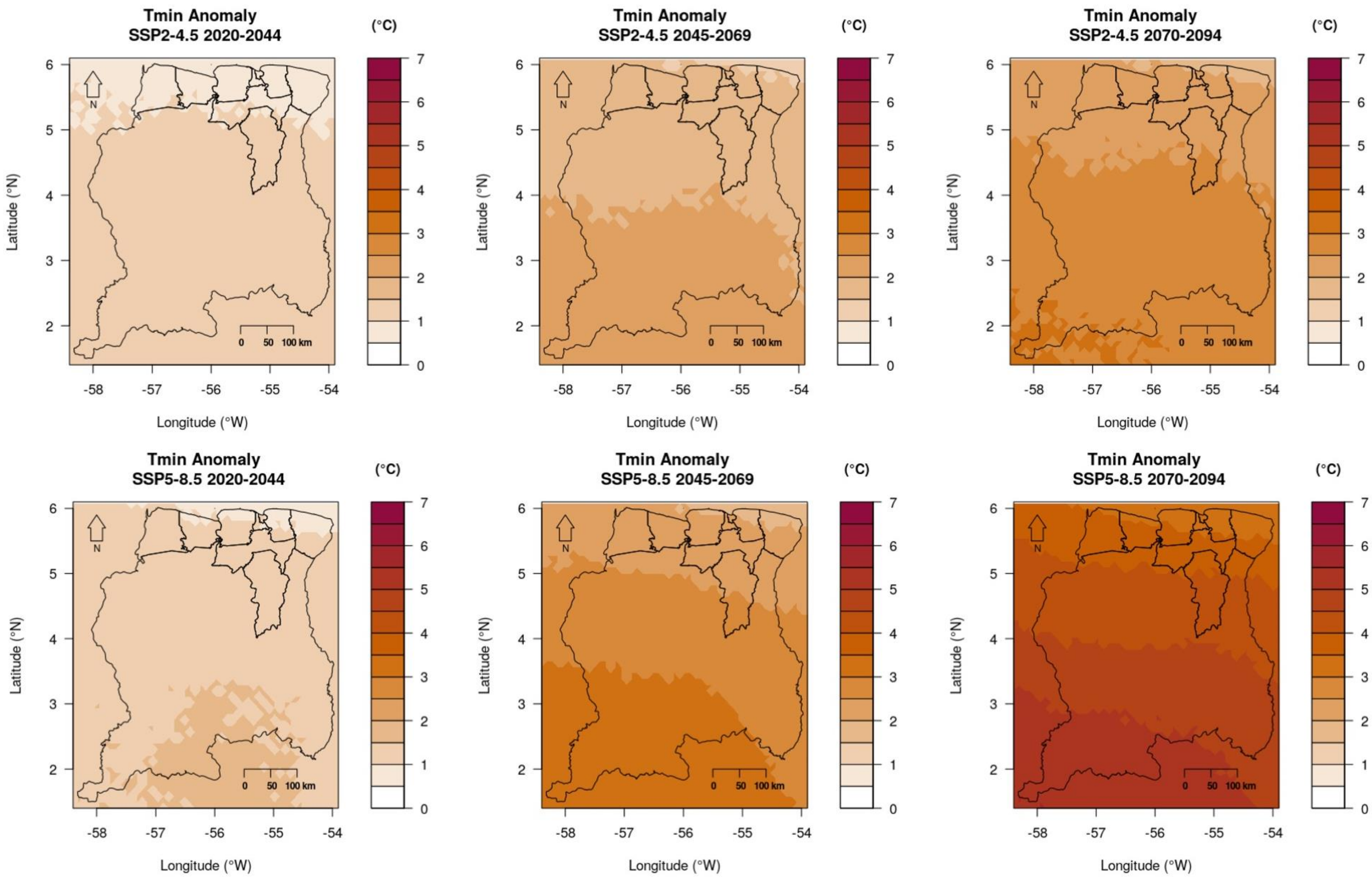
***Figure 36**- Average minimum temperature for the historical period and projections for the indicated periods and scenarios*





Source: SOC Report team elaboration

Figure 37- Average minimum temperature anomalies projected for the indicated periods and scenarios



Source: SOC Report team elaboration

4.2.1.2. Local results

Figure 37 shows that there is no projected change in the distribution of the hottest and coldest months in Suriname. The annual cycle of mean, maximum, and minimum temperatures is expected to continue as it is now, albeit enhanced, as shown by the average mean, maximum, and minimum temperature in Tables 23-25. In the SSP2-4.5 scenario, temperatures are expected to increase by more than 0.3ºC per decade in Tafelberg, Upper Tapanahony, and Kwamalasamutu. This rate increases to 0.5ºC in the SSP5-8.5 scenario. Maximum and minimum temperatures also increase strongly in the south, and slightly less so in Albina, Paramaribo and Bigi Pan MUMA.

Table 23*- Average mean temperature values (°C) for each scenario and period in the seven locations*

Locations	1990-2014	2020-2044		2045-2069		2070-2094	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Paramaribo	27.3	28.2	28.3	28.9	29.4	29.4	30.7
Albina	27.5	28.4	28.6	29.2	29.7	29.7	31.2
Bigi Pan MUMA	27.3	28.2	28.3	28.9	29.3	29.4	30.7
Brokopondo	24.1	25.1	25.2	25.8	26.4	26.4	28
Kwamalasamutu	22.7	24	24.2	24.9	25.9	25.6	27.8
Tafelberg	22.2	23.4	23.6	24.2	25.1	24.9	26.8
Tapanahony	21.5	22.7	23	23.6	24.5	24.3	26.4

Source: SOC Report team elaboration

Table 24*- Average maximum temperature values (°C) for each scenario and period in the seven locations*

Locations	1990-2014	2020-2044		2045-2069		2070-2094	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Paramaribo	30.2	31.2	31.3	31.9	32.4	32.4	33.8
Albina	31.4	32.4	32.6	33.1	33.6	33.7	35.2
Bigi Pan MUMA	30.2	31.2	31.3	31.9	32.3	32.4	33.8
Brokopondo	31.2	32.4	32.7	33.3	33.9	33.9	35.8
Kwamalasamutu	31.6	33.2	33.5	34.3	35.6	35.1	37.8
Tafelberg	31.2	32.7	33.1	33.7	34.7	34.5	36.9
Tapanahony	31.1	32.5	33	33.6	34.6	34.4	36.8

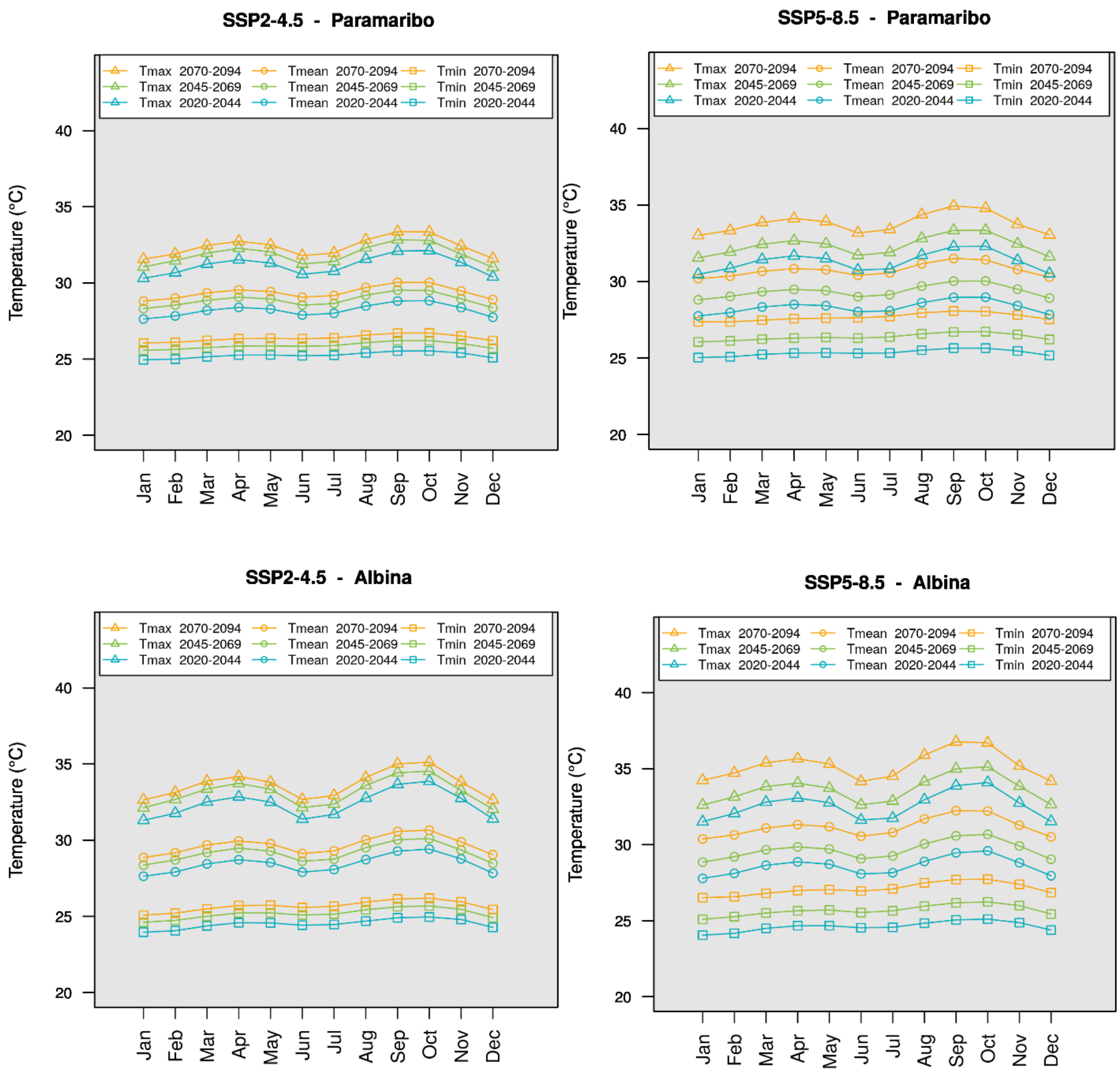
Source: SOC Report team elaboration

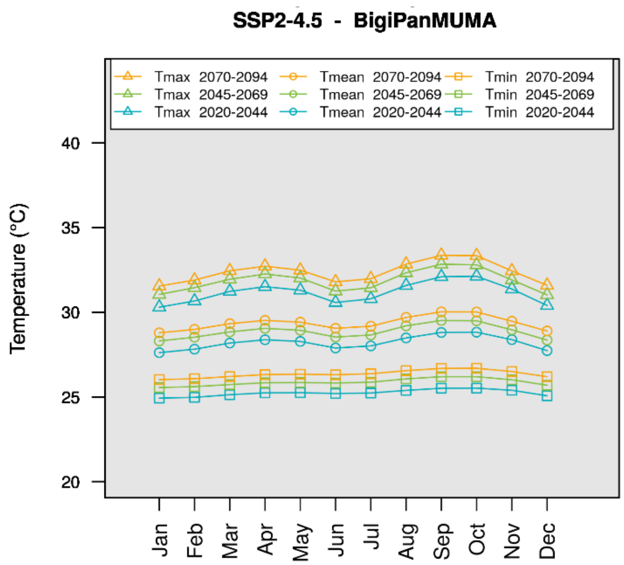
Table 25*- Average minimum temperature values (°C) for each scenario and period in the seven locations*

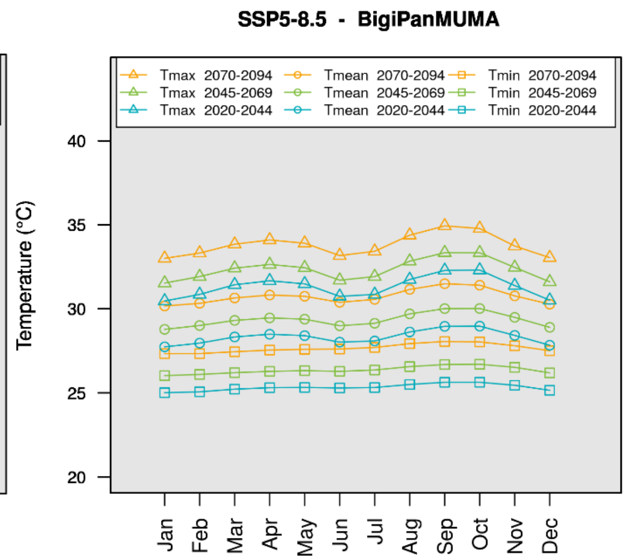
Locations	1990-2014	2020-2044		2045-2069		2070-2094	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Paramaribo	24.4	25.3	25.3	25.9	26.4	26.4	27.7
Albina	23.6	24.5	24.6	25.2	25.7	25.7	27.1
Bigi Pan MUMA	24.4	25.2	25.3	25.9	26.4	26.4	27.7
Brokopondo	24.1	25.1	25.2	25.8	26.4	26.4	28
Kwamalasamutu	22.7	24	24.2	24.9	25.9	25.6	27.8
Tafelberg	22.2	23.4	23.6	24.2	25.1	24.9	26.8
Tapanahony	21.5	22.7	23	23.6	24.5	24.3	26.4

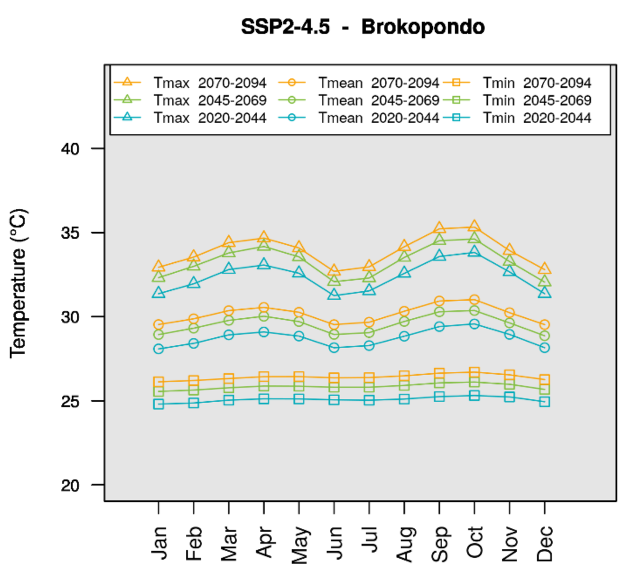
Source: SOC Report team elaboration

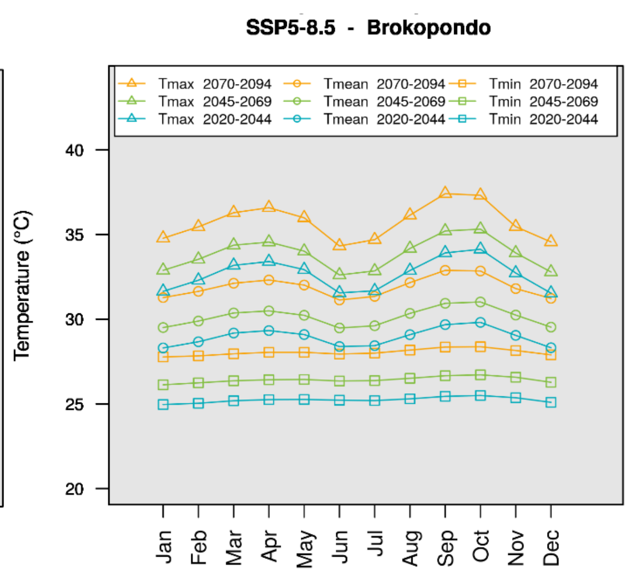
Figure 38- Average mean, minimum, and maximum temperature for each scenario and period in the seven locations

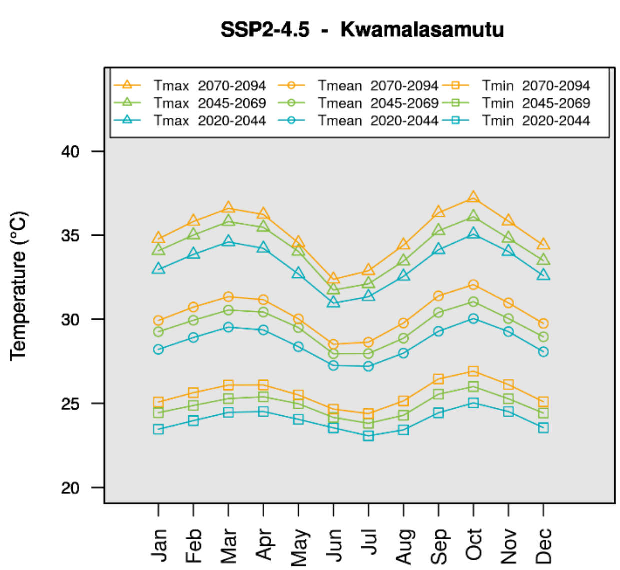


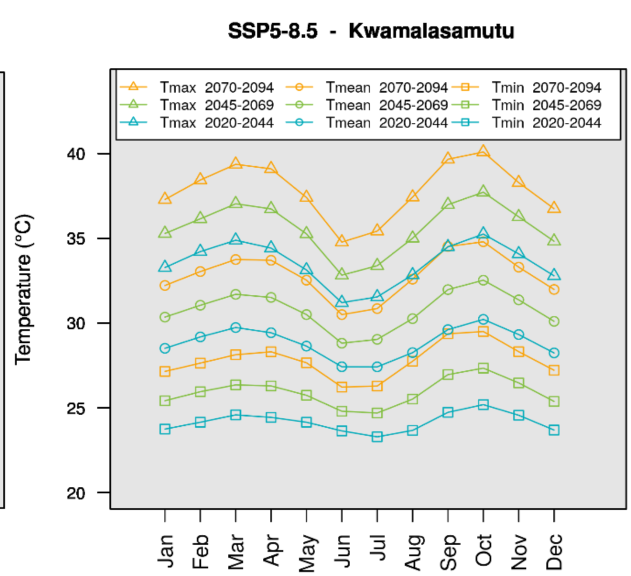

SSP2-4.5 - BigiPanMUMA
Tmax 2070-2094
Tmax 2045-2069
Tmax 2020-2044
Tmean 2070-2094
Tmean 2045-2069
Tmean 2020-2044
Tmin 2070-2094
Tmin 2045-2069
Tmin 2020-2044
Temperature (°C)
20 25 30 35 40
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

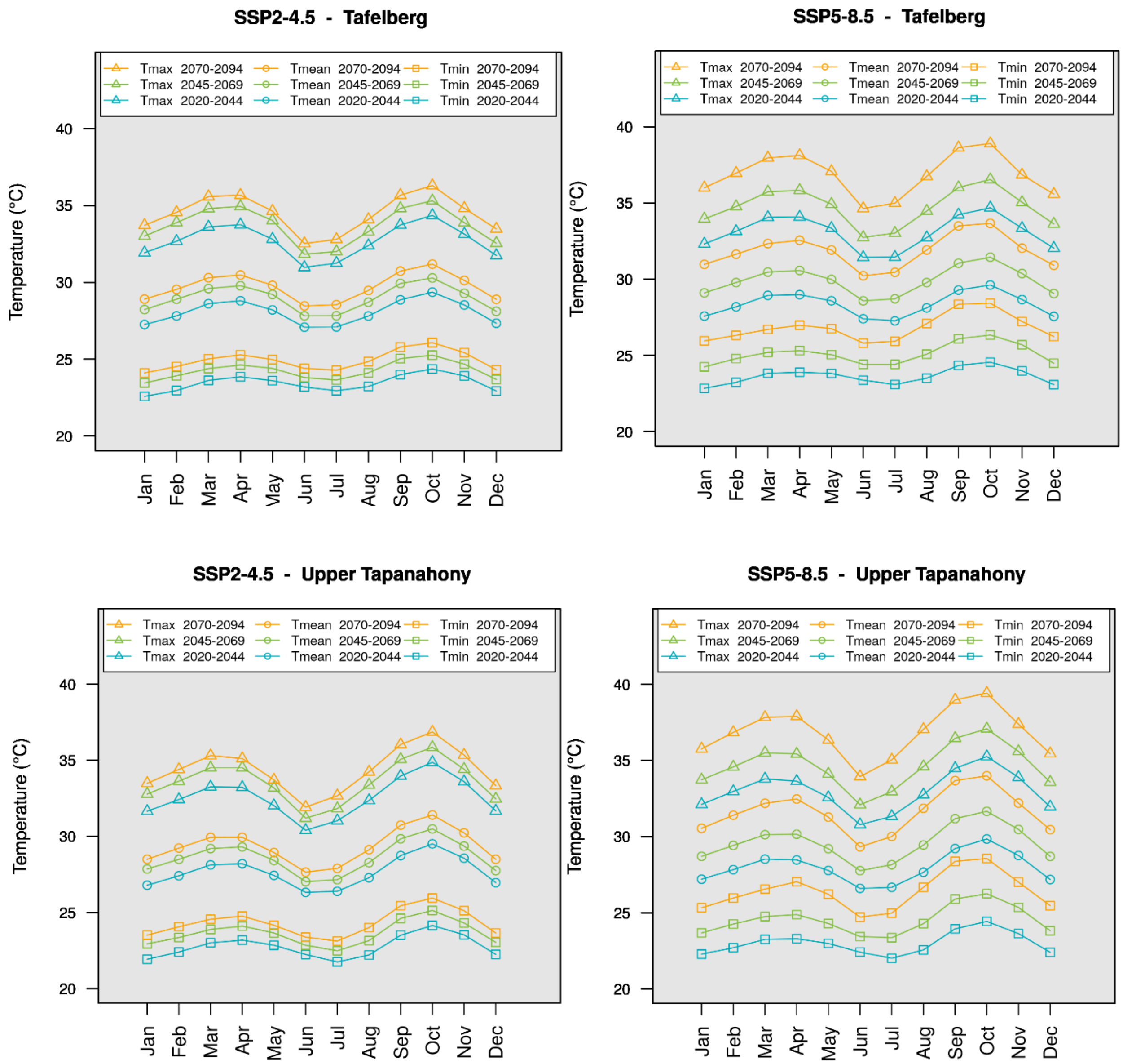

SSP5-8.5 - BigiPanMUMA
Tmax 2070-2094
Tmax 2045-2069
Tmax 2020-2044
Tmean 2070-2094
Tmean 2045-2069
Tmean 2020-2044
Tmin 2070-2094
Tmin 2045-2069
Tmin 2020-2044
Temperature (°C)
20 25 30 35 40
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


SSP2-4.5 - Brokopondo
Tmax 2070-2094
Tmax 2045-2069
Tmax 2020-2044
Tmean 2070-2094
Tmean 2045-2069
Tmean 2020-2044
Tmin 2070-2094
Tmin 2045-2069
Tmin 2020-2044
Temperature (°C)
20 25 30 35 40
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


SSP5-8.5 - Brokopondo
Tmax 2070-2094
Tmax 2045-2069
Tmax 2020-2044
Tmean 2070-2094
Tmean 2045-2069
Tmean 2020-2044
Tmin 2070-2094
Tmin 2045-2069
Tmin 2020-2044
Temperature (°C)
20 25 30 35 40
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


SSP2-4.5 - Kwamalasamutu
Tmax 2070-2094
Tmax 2045-2069
Tmax 2020-2044
Tmean 2070-2094
Tmean 2045-2069
Tmean 2020-2044
Tmin 2070-2094
Tmin 2045-2069
Tmin 2020-2044
Temperature (°C)
20 25 30 35 40
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


SSP5-8.5 - Kwamalasamutu
Tmax 2070-2094
Tmax 2045-2069
Tmax 2020-2044
Tmean 2070-2094
Tmean 2045-2069
Tmean 2020-2044
Tmin 2070-2094
Tmin 2045-2069
Tmin 2020-2044
Temperature (°C)
20 25 30 35 40
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec



Source: SOC Report team elaboration

4.2.2. Temperature extremes

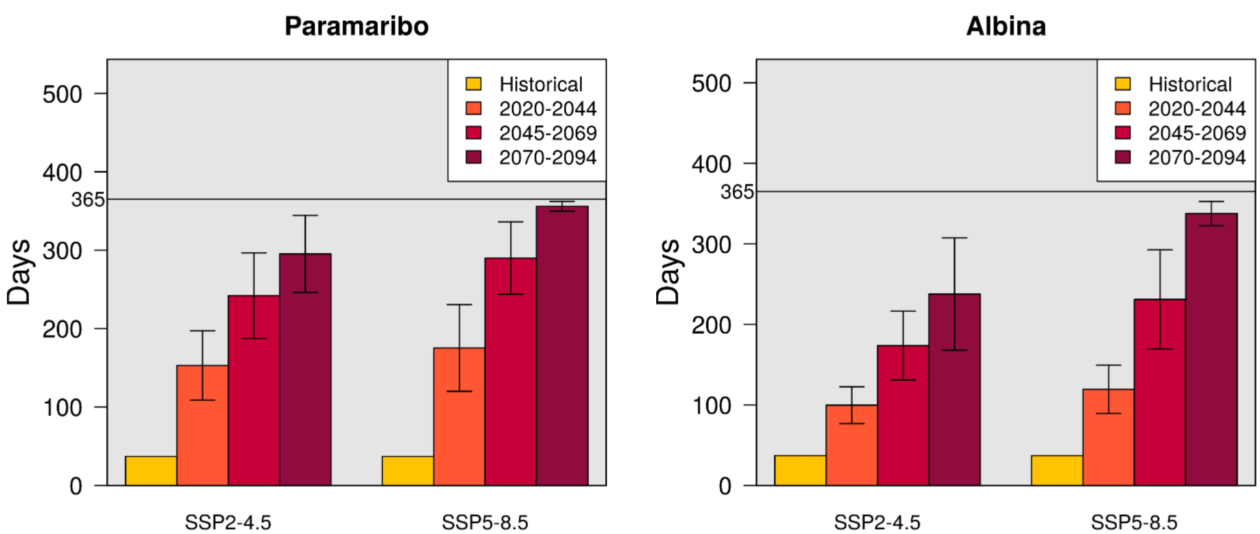
The number of days per year on which p90 temperature is exceeded increases particularly fast in Bigi Pan MUMA, where it could reach half the days of the year sooner than 2040 in SSP5-8.5, and sooner than 2060 in SSP2-4.5 (Figure 38, Table 26). By the end of the century more than half of the days of the year exceed p90 temperature everywhere in Suriname.

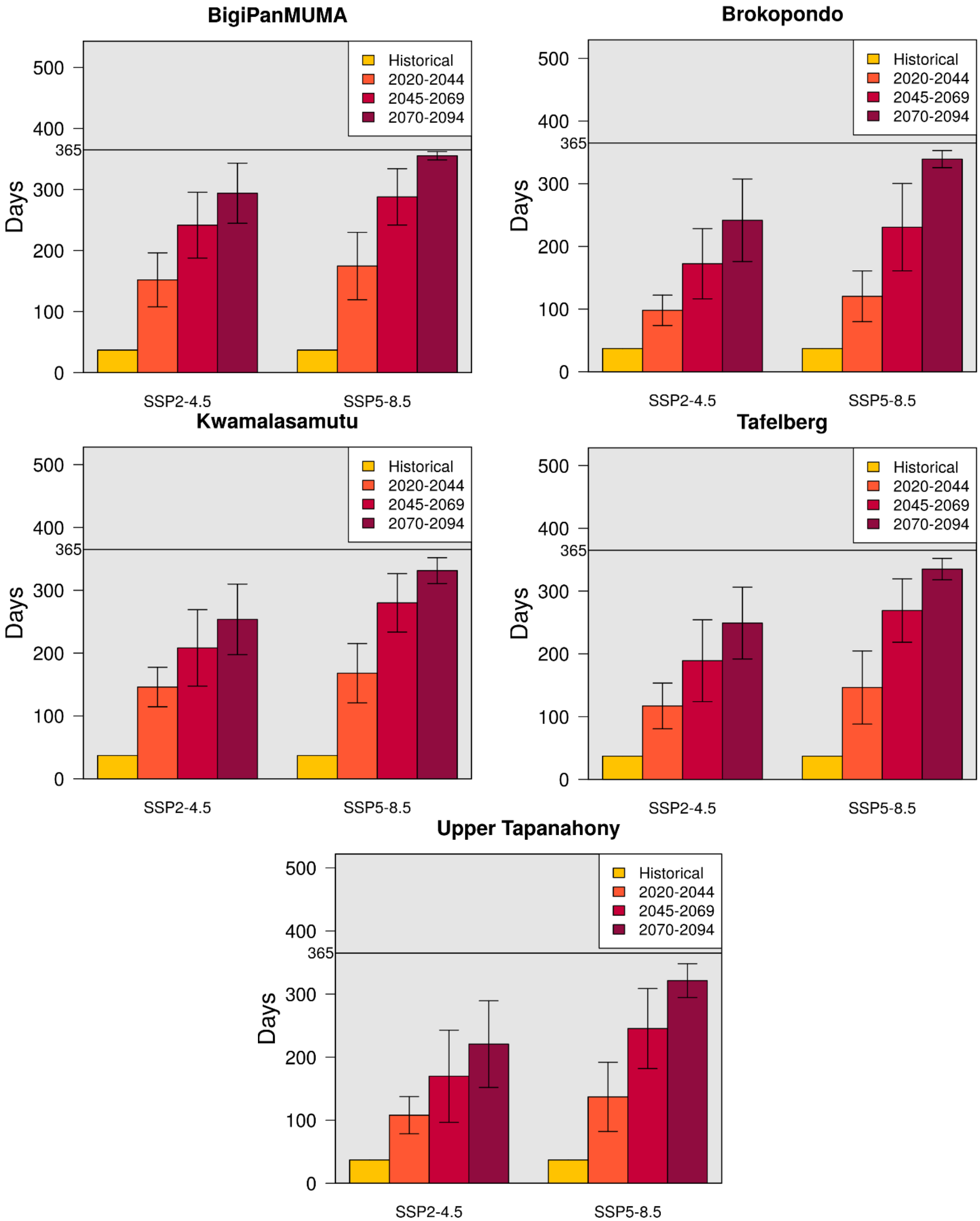
The number of days per year on which p10 temperature is not reached decreases strongly everywhere (Figure 39, Table 27). The decrease is faster for SSP5-8.5 and in coastal cities and areas, where it reaches zero by mid-century in both scenarios.

The number of nights per year in which p90 temperature is exceeded increases for all locations (Figure 40, Table 28). The greatest increase is found in Brokopondo, Paramaribo, Albina and Bigi Pan MUMA, which might suffer from more than 90% of nights exceeding p90 temperature by the end of the century, and by mid-century in the SSP5-8.5 scenario.

The number of nights per year in which p10 temperature is not reached, as with the number of days below p10 temperature, decreases strongly for all scenarios and time periods, more so for SSP5-8.5 and in coastal places (Figure 41, Table 29). It is virtually zero by the end of the century in all cases.

Figure 39- Number of days per year on which p90 temperature is exceeded for each scenario and period in the seven locations





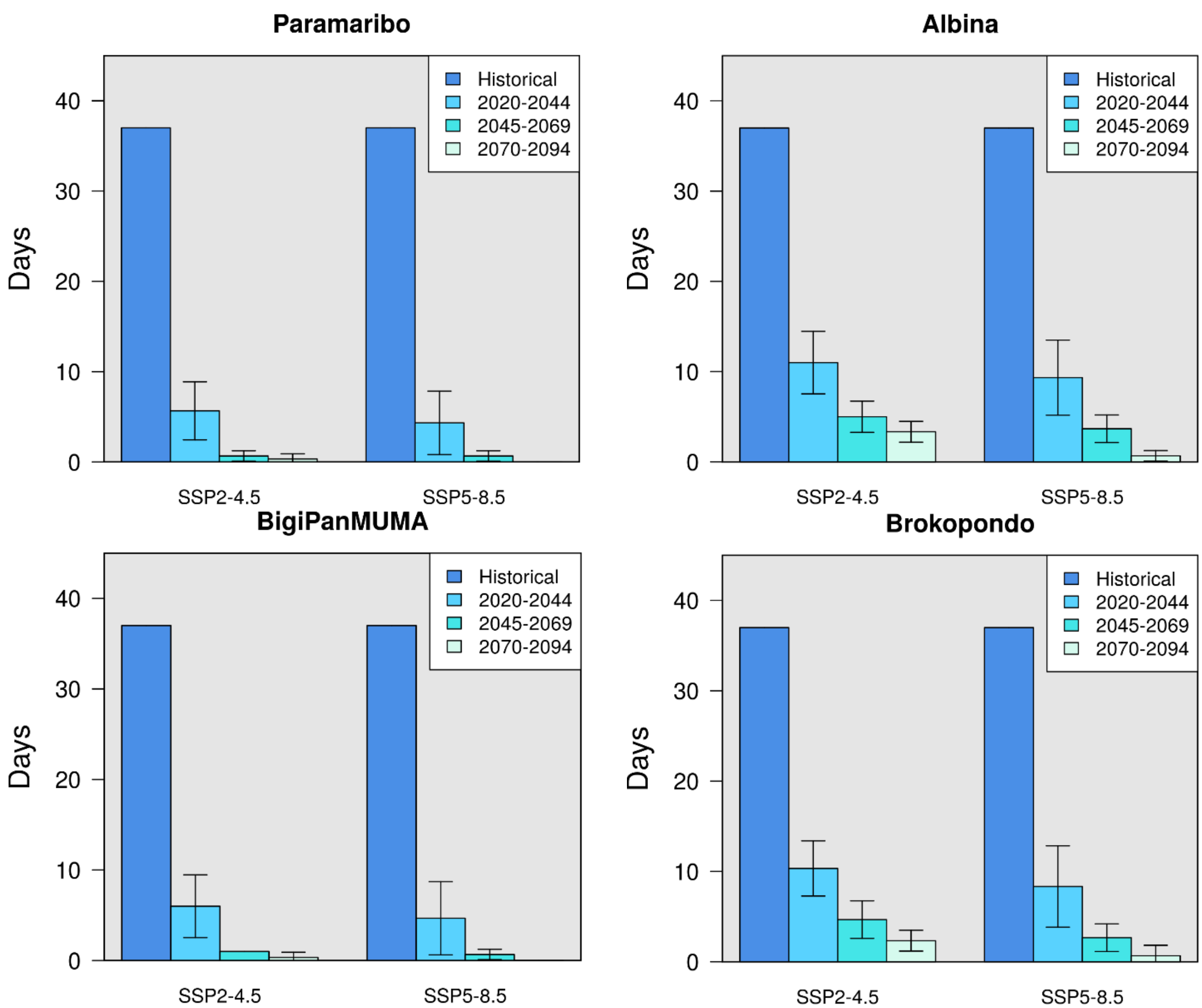
Source: SOC Report team elaboration

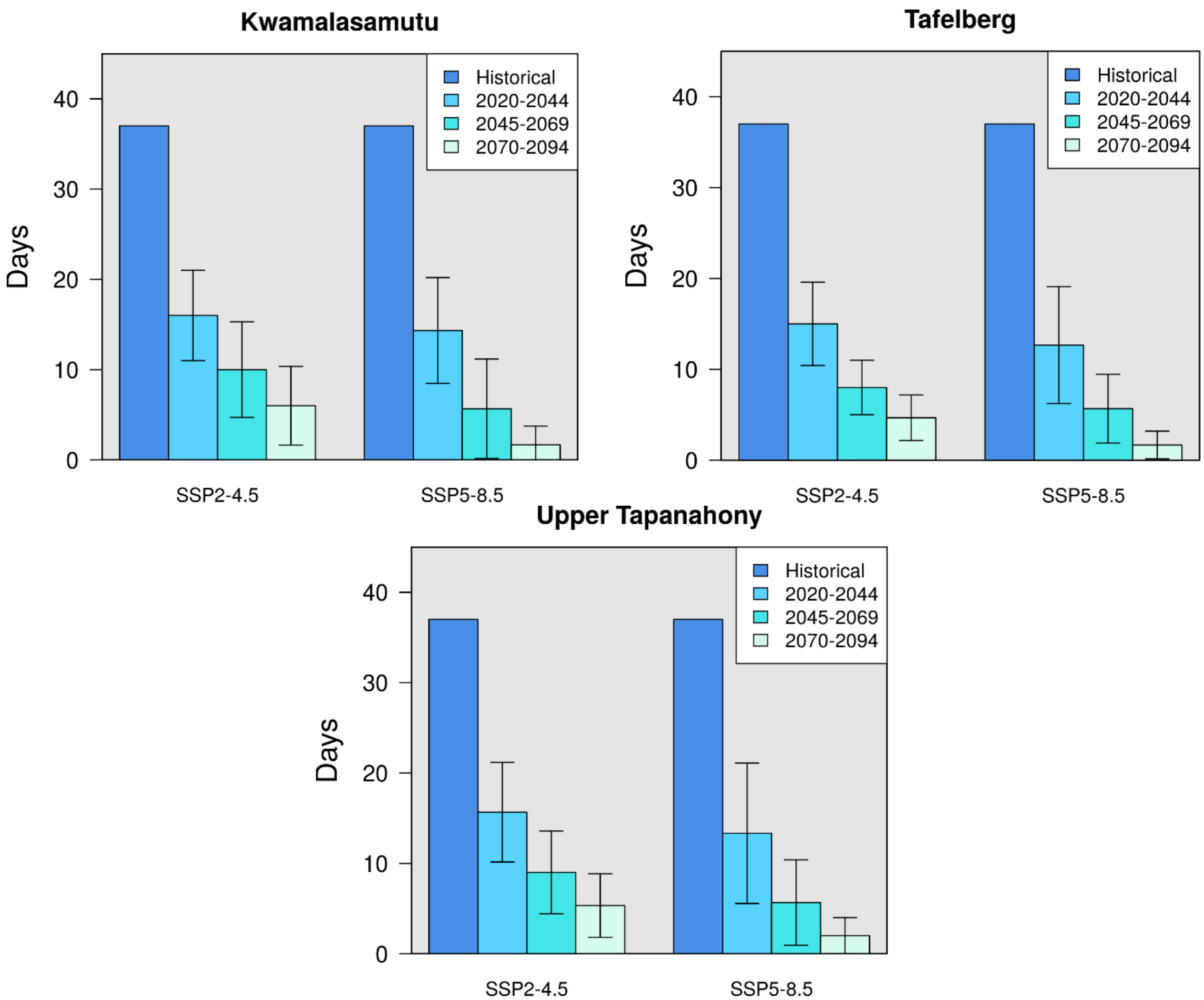
Table 26- Average days per year of the TX90 climate index and variations projected for the indicated periods, obtained from the regionalized daily series at seven locations

Location	1990-2014	2020-2044		2045-2069		2070-2094	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Paramaribo	37	153	175.3	242	290	295.3	356
Albina	37	99.7	119.3	173.7	231	237.7	337.7
Bigi Pan MUMA	37	152	174.7	241.6	288	294	355.3
Brokopondo	37	98	120.3	172.3	230.7	241.7	339.3
Kwamalasamutu	37	146	168	208.3	280	253.7	331.3
Tafelberg	37	117	146.3	189	269	249	335
Tapanahony	37	108	137	169.7	245.3	220.7	321.3

Source: SOC Report team elaboration

Figure 40- Number of days per year on which p10 temperature is not reached for each scenario and period in the seven locations





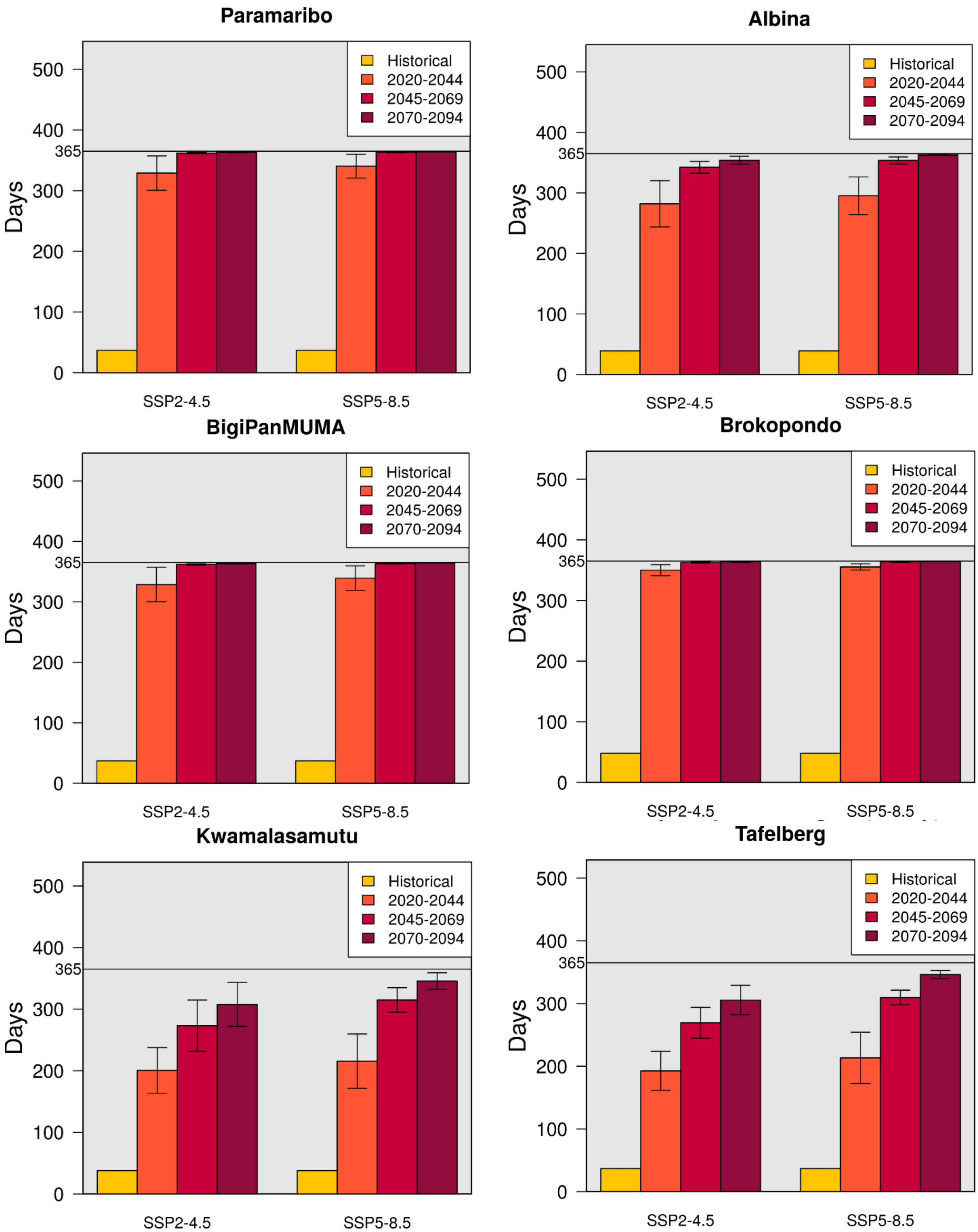
Source: SOC Report team elaboration

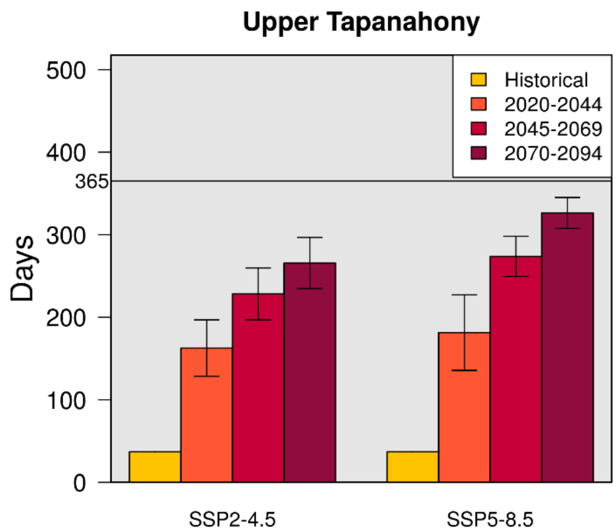
***Table 27**- Average days per year of the TX10 climate index and variations projected for the indicated periods, obtained from the regionalized daily series at seven locations*

Location	1990-2014	2020-2044		2045-2069		2070-2094	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Paramaribo	37	5.7	4.3	0.7	0.7	0.3	0
Albina	37	11	9.3	5	3.7	3.3	0.7
Bigi Pan MUMA	37	6	4.7	1	0.7	0.3	0
Brokopondo	37	10.3	8.3	4.7	2.7	2.3	0.7
Kwamalasamutu	37	16	14.3	10	5.7	6	1.7
Tafelberg	37	15	12.7	8	5.7	4.7	1.7
Tapanahony	37	15.7	13.3	9	5.7	5.3	2

Source: SOC Report team elaboration

__Figure 41__- Number of nights per year on which p90 temperature is exceeded for each scenario and period in the seven locations





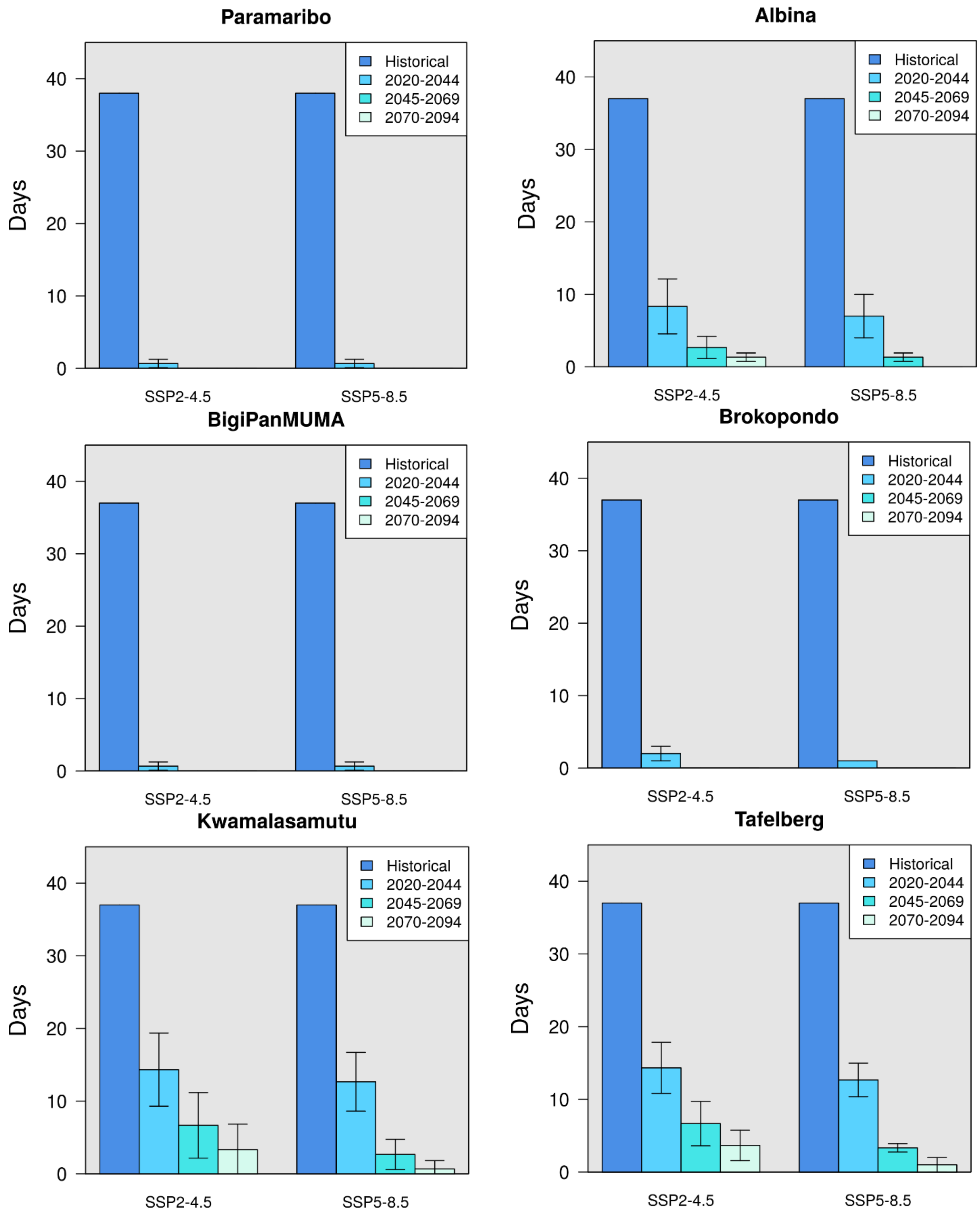
Source: SOC Report team elaboration

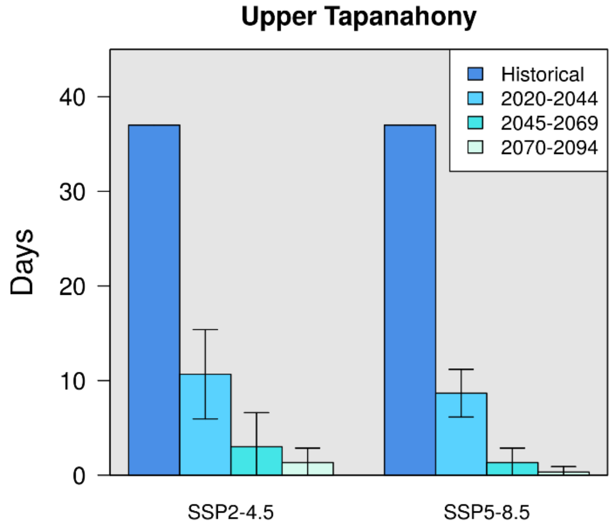
Table 28- *Average days per year of the TN90 climate index and variations projected for the indicated periods, obtained from the regionalized daily series at seven locations*

Location	1990-2014	2020-2044		2045-2069		2070-2094	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Paramaribo	37	329	340	362	363.3	363.3	364
Albina	39	282	295.3	342.3	353.7	354	363.7
Bigi Pan MUMA	37	328.7	339.3	362	363.3	363.3	364
Brokopondo	37	350	355.3	362.7	363.7	363.7	364
Kwamalasamutu	38	200.7	215.7	273.3	315	307.7	345.7
Tafelberg	37	192.7	213.3	269.3	309.7	305.7	346.3
Tapanahony	37	162.7	181.3	228.3	273.7	265.7	326.3

Source: SOC Report team elaboration

Figure 42- Number of nights per year on which p10 temperature is not reached for each scenario and period in the seven locations





Source: SOC Report team elaboration

Table 29*- Average days per year of the TN10 climate index and variations projected for the indicated periods, obtained from the regionalized daily series at seven locations*

Location	1990-2014	2020-2044		2045-2069		2070-2094	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Paramaribo	38	0.7	0.7	0	0	0	0
Albina	37	8.3	7	2.7	1.3	1.3	0
Bigi Pan MUMA	37	0.7	0.7	0	0	0	0
Brokopondo	37	2	1	0	0	0	0
Kwamalasamutu	37	14.3	12.7	6.7	2.7	3.3	0.7
Tafelberg	37	14.3	12.7	6.7	3.3	3.7	1
Tapanahony	37	10.7	8.7	3	1.3	1.3	0.3

Source: SOC Report team elaboration

4.3. Wind

4.3.1. Wind climatology

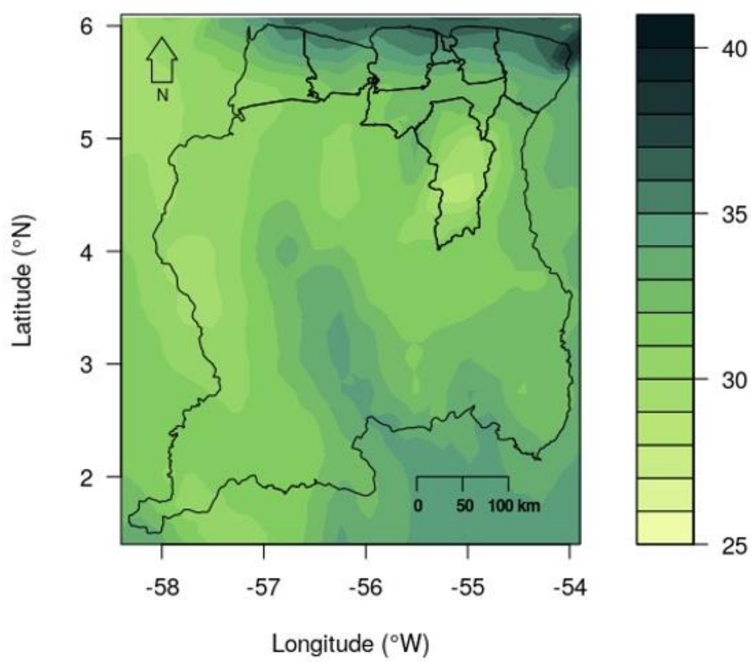
4.3.1.1. Regional results

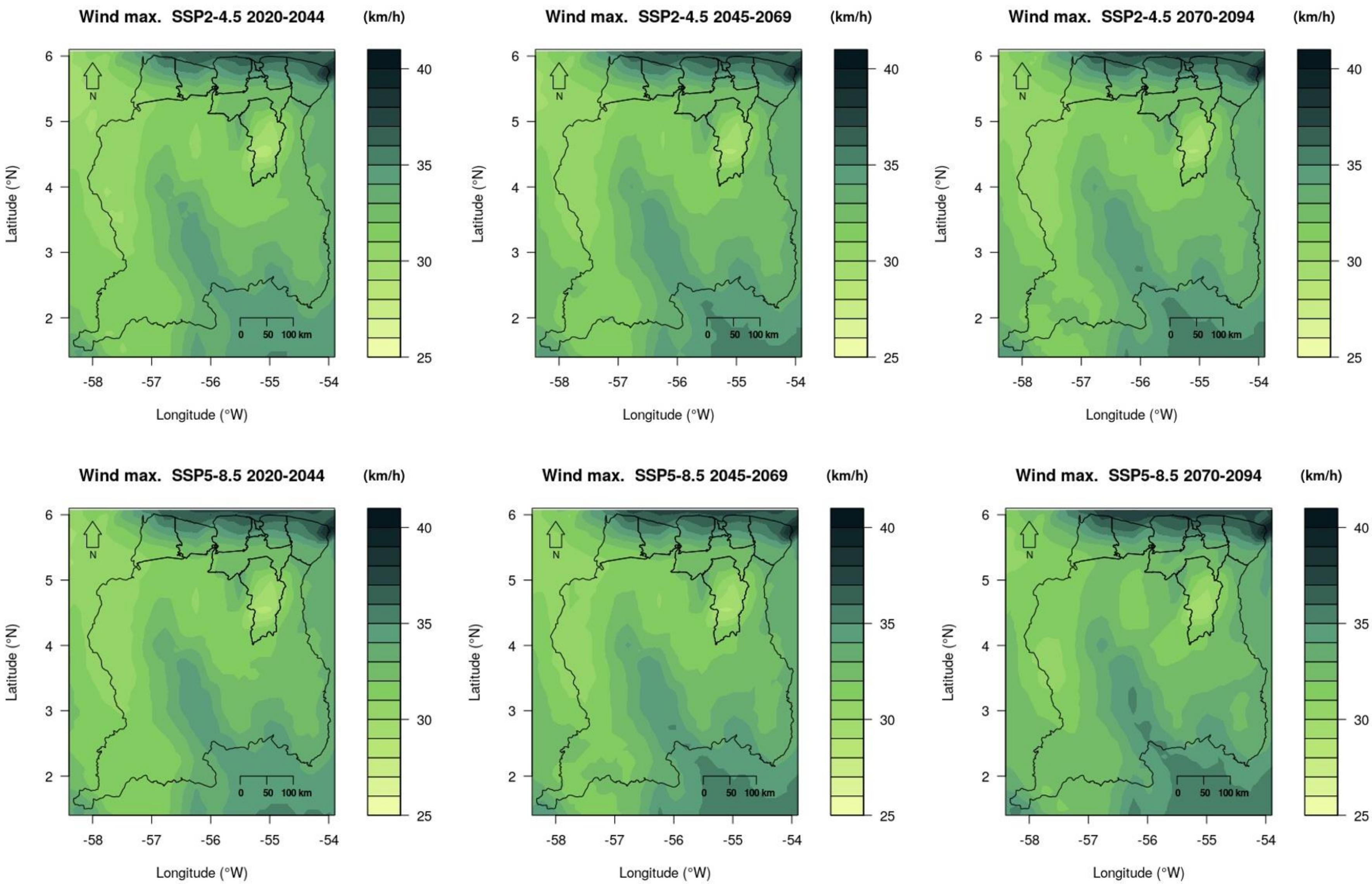
Maximum daily wind speed is projected to vary little (Figures 42-43). SSP5-8.5 shows slightly stronger winds along the coast, but this variable does not show any remarkable trends in the future. The main patterns visible in the historical map show strong values along the coast and the center of the country and slower winds over the Brokopondo reserve, and change very little in all scenarios and timeframes.

Hurricanes play a very small role in Suriname, as its location in the south of the Caribbean protects it from the worst effects of these phenomena. Hurricanes in the Caribbean are expected to increase, but there is no evidence pointing to them affecting South America any more than they do now.

Although wind direction is of interest to Suriname, it was not analyzed as part of this report.

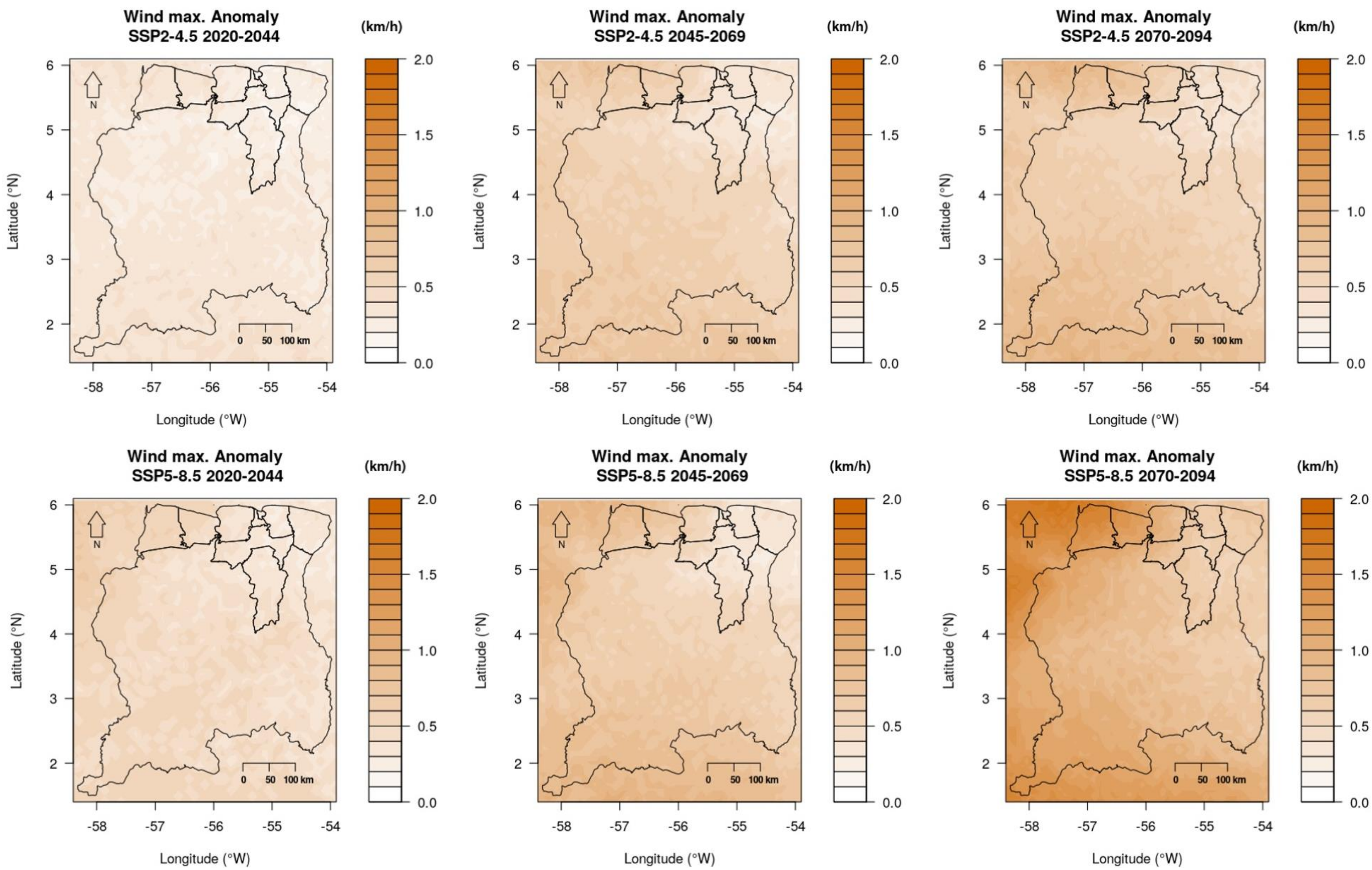
Figure 43- *Average maximum wind for each scenario and period in the seven locations*





Source: SOC Report team elaboration

Figure 44*- Average maximum wind anomalies for each scenario and period in the seven locations*



Source: SOC Report team elaboration

4.3.1.1. Local results

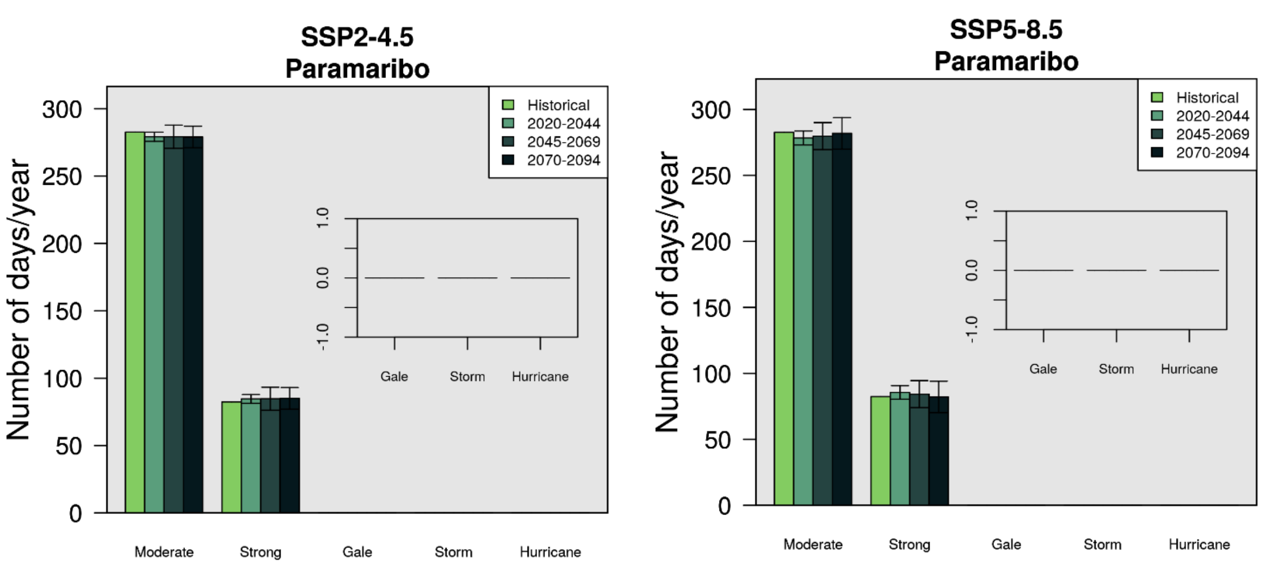
There is almost no change at all in the wind regime for Brokopondo, Paramaribo, Albina, Kwamalasamutu, or Bigi Pan MUMA. Tafelberg shows little change, with the exception of hurricane force winds, which become slightly more likely in this location, and in Upper Tapanahony there is an increase in strong winds while moderate winds become slightly rarer (Figure 44). Average mean wind speed, however, shows an increase in all projections and periods, for all locations, but the increase is very similar for the near-term and for the long-term and in both scenarios (Table 30). This, together with the unreliable decreasing trend in wind speed shown in the present climate assessment makes a strong case for taking these results with some caution.

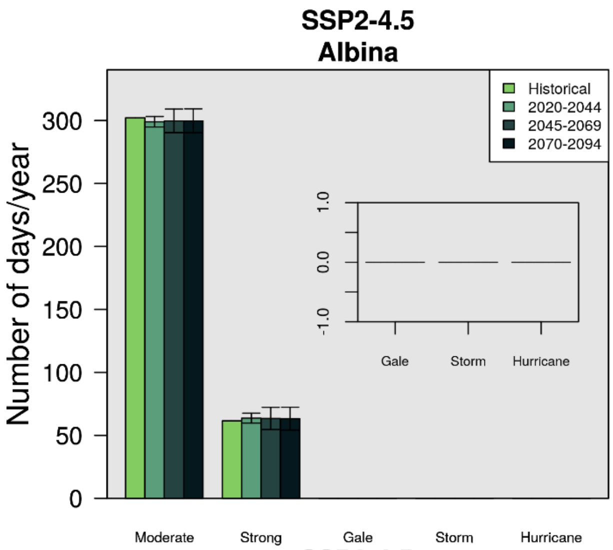
***Table 30**- Mean maximum wind speed (km/h) for each scenario and period in the seven locations*

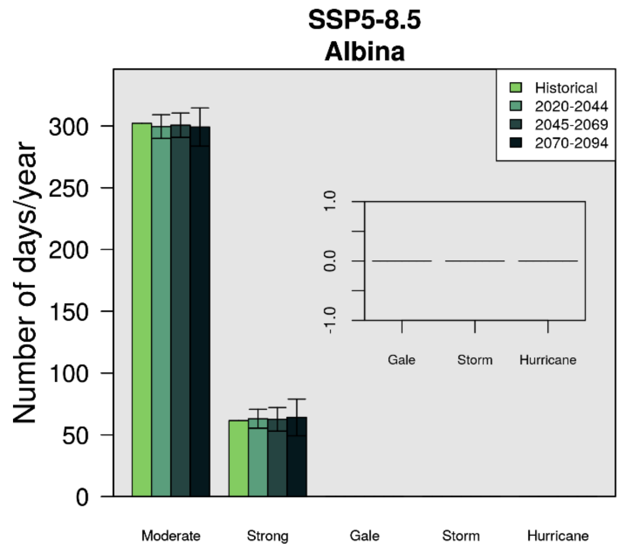
Locations	1990-2014	2020-2044		2045-2069		2070-2094	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Paramaribo	26.3	36.1	36.2	36.3	36.3	36.4	36.6
Albina	23.2	34.5	34.6	34.6	34.6	34.7	34.9
Bigi Pan MUMA	26.2	36.1	36.2	36.2	36.2	36.3	36.5
Brokopondo	14.6	29.9	30	30	30	30.1	30.3
Kwamalasamutu	17.5	31.5	31.6	31.8	31.9	31.9	32.2
Tafelberg	21.5	33	33.2	33.3	33.3	33.3	33.5
Tapanahony	22.8	34	34.1	34.3	34.4	34.4	34.5

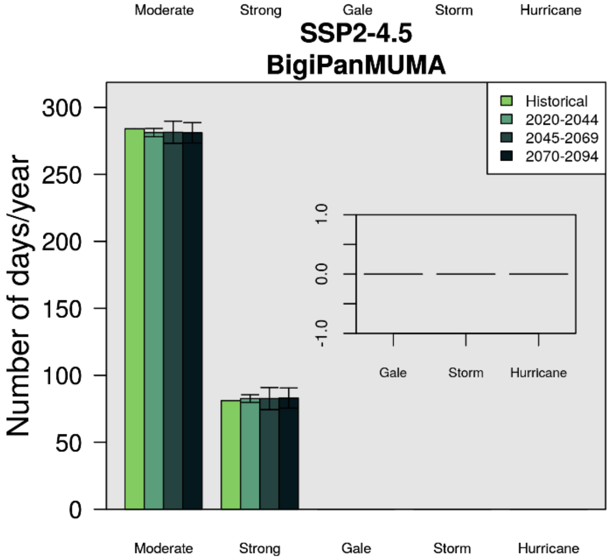
Source: SOC Report team elaboration

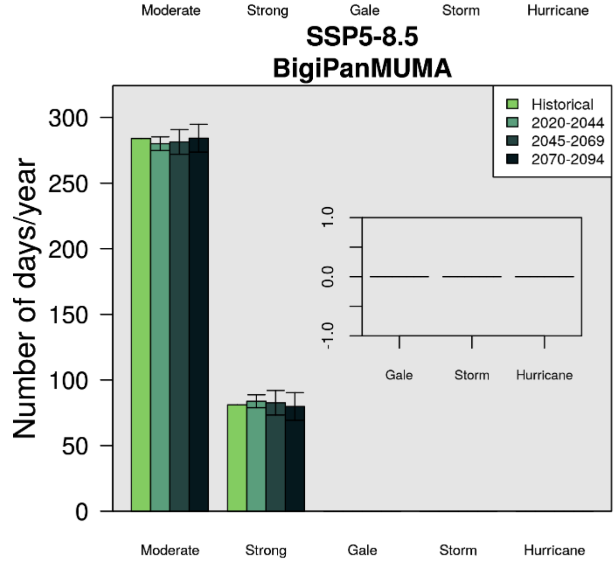
***Figure 45**- Wind regimes for each scenario and period in the seven locations*

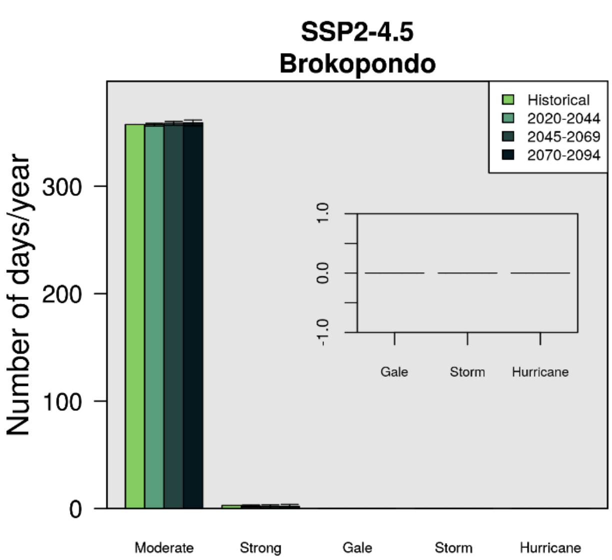


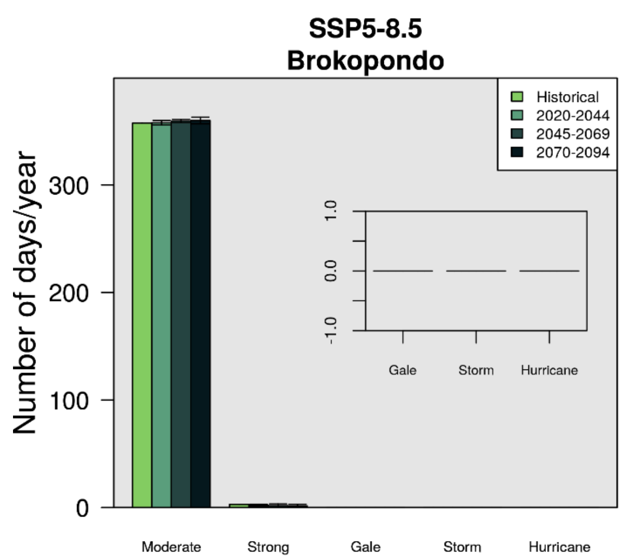

SSP2-4.5
Albina
Number of days/year
0
50
100
150
200
250
300
Historical
2020-2044
2045-2069
2070-2094
1.0
0.0
-1.0
Gale
Storm
Hurricane
Moderate
Strong
Gale
Storm
Hurricane

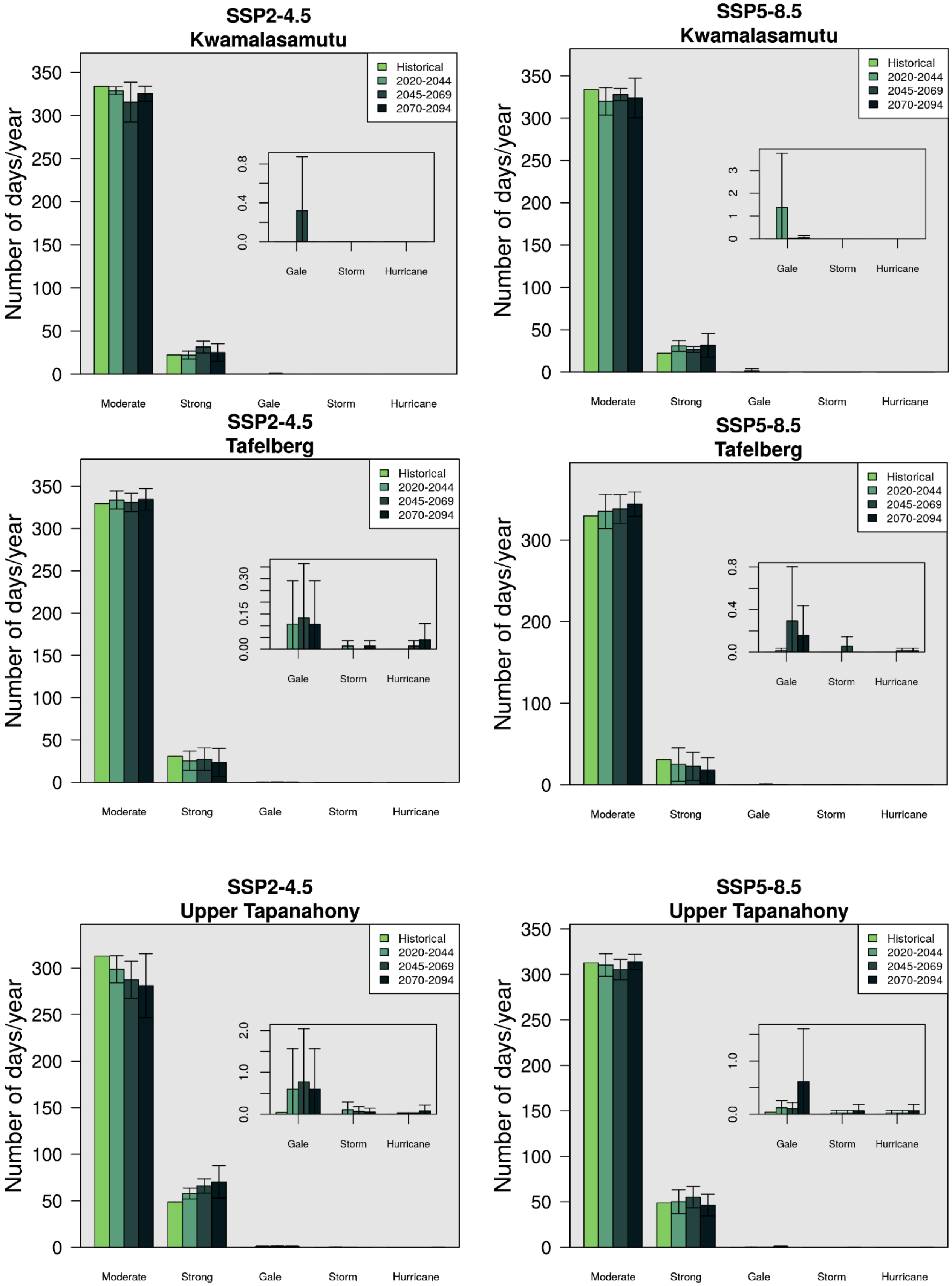

SSP5-8.5
Albina
Number of days/year
0
50
100
150
200
250
300
Historical
2020-2044
2045-2069
2070-2094
1.0
0.0
-1.0
Gale
Storm
Hurricane
Moderate
Strong
Gale
Storm
Hurricane


SSP2-4.5
BigiPanMUMA
Number of days/year
0
50
100
150
200
250
300
Historical
2020-2044
2045-2069
2070-2094
1.0
0.0
-1.0
Gale
Storm
Hurricane
Moderate
Strong
Gale
Storm
Hurricane


SSP5-8.5
BigiPanMUMA
Number of days/year
0
50
100
150
200
250
300
Historical
2020-2044
2045-2069
2070-2094
1.0
0.0
-1.0
Gale
Storm
Hurricane
Moderate
Strong
Gale
Storm
Hurricane


SSP2-4.5
Brokopondo
Number of days/year
0
100
200
300
Historical
2020-2044
2045-2069
2070-2094
1.0
0.0
-1.0
Gale
Storm
Hurricane
Moderate
Strong
Gale
Storm
Hurricane


SSP5-8.5
Brokopondo
Number of days/year
0
100
200
300
Historical
2020-2044
2045-2069
2070-2094
1.0
0.0
-1.0
Gale
Storm
Hurricane
Moderate
Strong
Gale
Storm
Hurricane



Source: SOC Report team elaboration

4.3.2. Wind extremes

The number of days per year in which strong winds occur and number of days per year in which gale winds occur show very little change, as days with gale force winds are zero or close to zero for all locations and periods (Tables 31-32). Only Kwamalasamutu shows a significant increase in days with strong winds, and Tafelberg a certain decrease.

Sibibusi, the name given in Suriname to extreme events of rain and wind, are common at the end of the rainy season, in August. Changes in timing of seasons might also affect their frequency and intensity, but there is no available information regarding this extreme as of now.

Table 31- *Average number of strong wind days per year and variations projected for the indicated periods, obtained from the regionalized daily series at the seven locations*

Location	1990-2014	2020-2044		2045-2069		2070-2094	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Paramaribo	82.4	84.6	82.4	84.8	85.5	85.0	84.3
Albina	61.5	63.7	63.0	63.4	63.0	63.2	64
Bigi Pan MUMA	81	83	84	83	83	83	80
Brokopondo	2.92	2.3	2.1	2.1	1.8	2	1.6
Kwamalasamutu	22.4	22.2	31	31.5	27	25.2	31.5
Tafelberg	31	25.3	24.8	27.3	22.7	23.5	17.7
Tapanahony	49	58	50.1	66	55.1	70.3	46.4

Source: SOC Report team elaboration

Table 32- *Average number of gale wind days per year and variations projected for the indicated periods, obtained from the regionalized daily series at the seven locations*

Location	1990-2014	2020-2044		2045-2069		2070-2094	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Paramaribo	0	0	0	0	0	0	0
Albina	0	0	0	0	0	0	0
Bigi Pan MUMA	0	0	0	0	0	0	0
Brokopondo	0	0	0	0	0	0	0
Kwamalasamutu	0	0	1.4	0.32	0	0	0.1
Tafelberg	0	0.1	0	01	0.3	0.1	0.2
Tapanahony	37	108	137	169.7	245.3	220.7	321.3

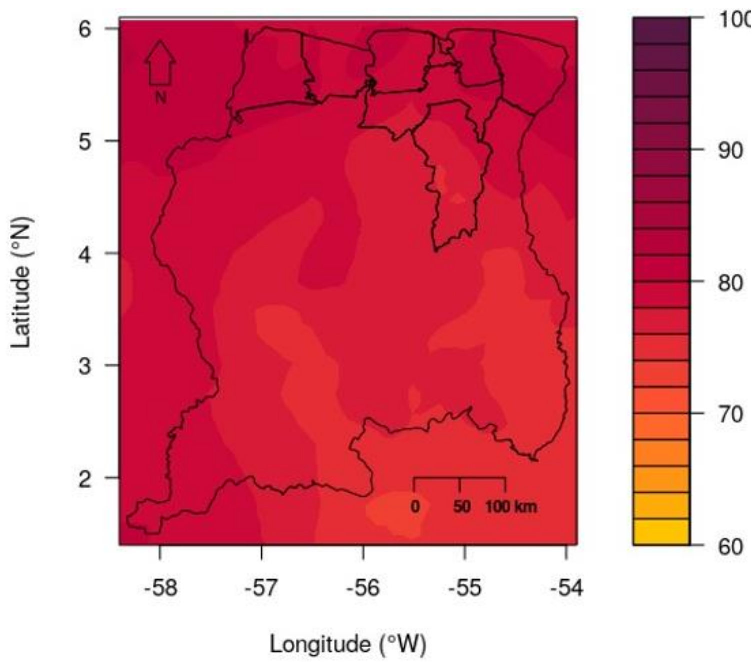
Source: SOC Report team elaboration

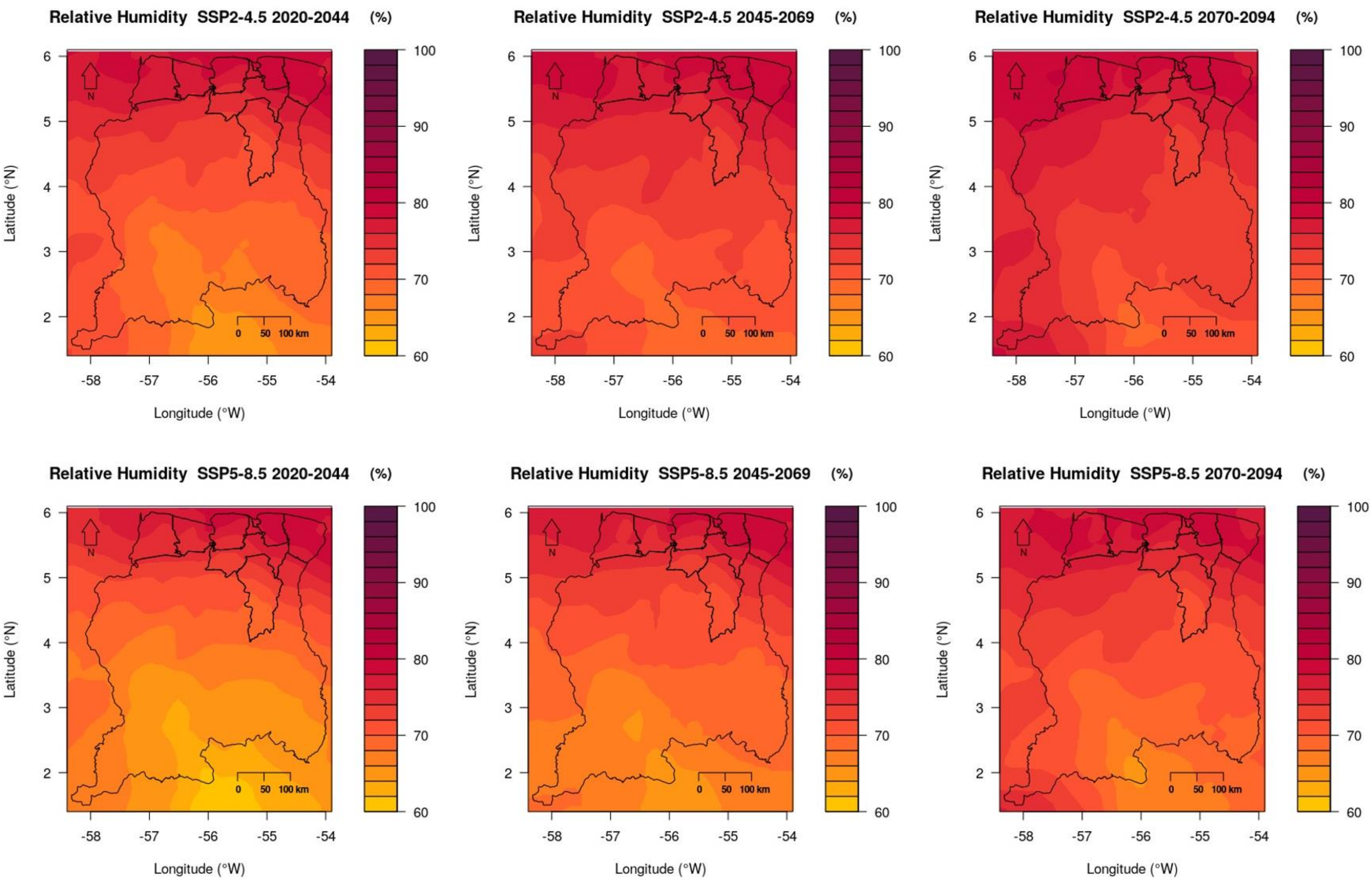
4.4. Relative humidity

4.4.1. Relative humidity climatology

The climate in Suriname is expected to become drier, particularly in the SSP5-8.5 (Figures 45-46). Relative humidity is very high throughout the country in the observed climatology and decreases in the first decades in both scenarios, in the southwest of the country by up to 14% for the SSP5-8.5 scenario. However, the long-term scenario shows a recovery of the humidity for most of the country, which would put the new average relative humidity at about 80% in the coastal region and between 65% and 70% in the south of Suriname.

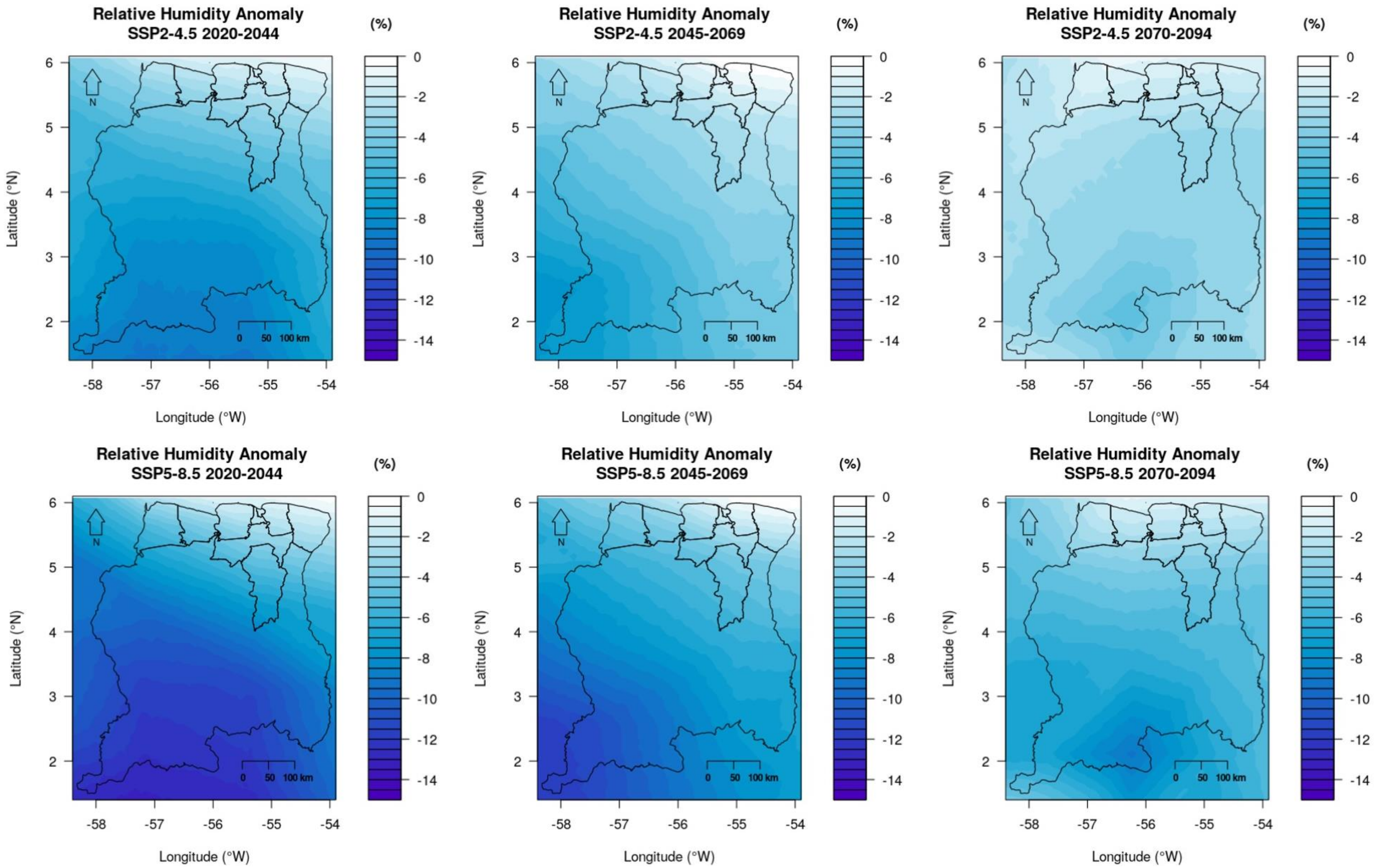
Figure 46- *Average relative humidity for each scenario and period in the seven locations*





Source: SOC Report team elaboration

Figure 47- Average relative humidity anomalies for climate projection of the average mean temperature for each scenario and period in the seven locations



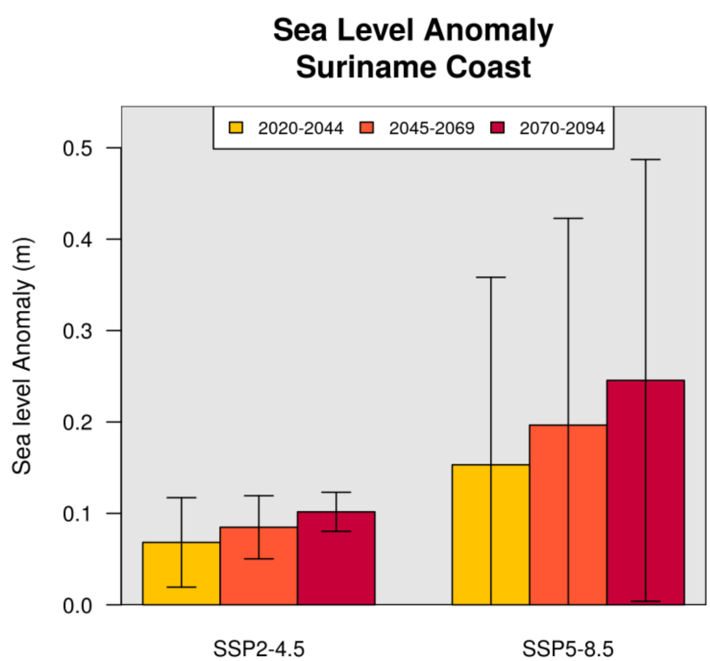
Source: SOC Report team elaboration

4.5. Sea level rise

Two of the variables provided by all three climate models are the sea surface height above the geoid and the global average of thermosteric contribution to sea level. Given the importance of sea-level rise for Suriname, the outputs of the models were also studied for these variables. The combination of these two variables provides a result for sea level rise that does not include possible variations of the geoid nor of the land surface. Therefore, this calculation does not include possible variations in the morphology of the coast and the sea floor, and it does not include variations in the sea surface caused by geoid variations. Relative sea level is a complex issue with additional factors to those calculated in this study. Given the importance of coastal expansion and regression in Suriname, such an analysis would require a much more detailed study that is out the scope of this report.

Sea level anomaly will increase with a temperature increase and can be expected to surpass 0.25 meters in the long-term future if GEI emissions are not curbed (Figure 47). However, future sea level provided by coupled models are subjected to even greater uncertainty than other variables, therefore these results should be taken cautiously (Yin, 2012).

Figure 48- *Sea level anomaly at the Surinamese coast, for the projected periods and scenarios, where error bars represent the standard deviation*



Source: SOC Report team elaboration

CLIMATE RISK

The aim of this chapter is to analyze Suriname's risk to suffer impacts from climate change in its ten districts and four most important sectors agriculture, water, forestry, and infrastructure. For each one of the sectors, this chapter first provides an introductory description, then illustrates how climate risk unfolds in the sector and presents the results of the risk index, and finally closes off with a SWOT (strengths, weaknesses, opportunities, threats) analysis of the sector based on the results. The chapter also contains a subchapter on cross-sectoral aspects and results.

5.1. Introduction

Suriname has about 590,100 inhabitants (ABS, 2020), of which 80% live at the coast. The population density is largest in the capital Paramaribo (NIMOS, 2005), where about 52% of the total population lives (ABS, 2014a). Suriname's area sums about 16.4 million hectares and is divided into ten administrative districts (Figure 48): Marowijne, Commewijne, Wanica, Paramaribo, Para, Brokopondo, Sipaliwini, Saramacca, Coronie and Nickerie. The country's main rivers are the Marowijne River, Commewijne River, Suriname River, Saramacca River, Coppename River, Nickerie River, and Corantijn River.

Figure 49- *Administrative map of Suriname*

Source: Gonini (2020)

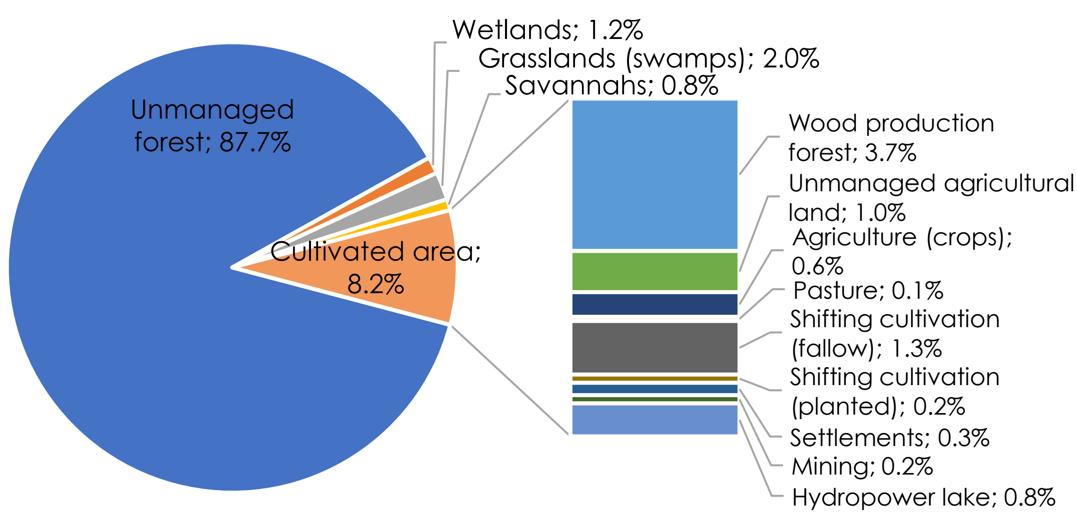
5.2. Agriculture

5.2.1. Context

5.2.1.1. Agriculture in the geographical context

Suriname is largely forest, covering 93% of total land, equivalent to 15.2 million hectares (Matai, 2020). Of that, 82% is considered tropical rainforest that is not used or only marginally used by locals for non-timber forest products (NTFP) (Figure 49). Only 8% of the total land area is cultivated. The remaining 4% of total land area consists of other non-forested natural areas like savannahs, swamps, and wetlands. The cultivated area is used for forestry (3.7% of total land area), agriculture (3.2%) and settlements, mining, and hydropower lakes (1.3%) (Berrenstein & Gompers-Small, 2016). Although only 3.2% of total land area is utilized for agriculture, mostly in the coastal plain, around 9% (1.5 million ha) of the total land area is regarded suitable for this aim, 27% (400,000 ha) of which are attributed to the interior. However, these are currently not exploited because national policies and strategies on the matter are not integrated and harmonized.

Figure 50- Land use in percentage of total land area of Suriname



Source: Berrenstein & Gompers-Small (2016)

Agricultural activities are mostly carried out in the young and old coastal areas. The young coastal plain is the most fertile zone in Suriname and where large-scale agricultural activities are established for the production and export of fruits and vegetables. The soils of the old coastal plain offer opportunities for agricultural activities such as horticulture. Here, agricultural activities are mostly carried out by small-scale farmers. In the hilly and mountainous interior agriculture is mostly limited to shifting cultivation practices, which is a sustainable system in Suriname where the pressure on the forest is minimal.

The aging population, the migration of village people, and limited market opportunities mean that only a small part of the forest is being cleared for agriculture and that the cleared piece of land is given sufficient time to recover for a second phase of agriculture which ranges from 7-20 years. The production system is primarily focused on self-sufficiency with surplus being sold on the market. About 30% of the production is sold within the village and 7% is sold in Paramaribo. In general, women practice most of the shifting cultivation, but men are also involved, especially in selecting and clearing new agricultural land. The usual crops cultivated in shifting agriculture in Suriname are dryland rice, banana, and cassava. Important cash crops are ginger, pomtayer, cassava, Chinese tayer, plantain, banana, sweet potatoes, and napi (Tropenbos International Suriname, 2017).

5.2.1.2. Food security

Suriname still faces considerable challenges in all four areas of food security, namely availability, access, use, and stability (FAO, 2015a). Of the country's population, 8% are malnourished, 24% of women have iron deficiency, and 25% of the population are overweight. High food prices as well as the world economic and financial crises have affected Suriname like all Caribbean Community (CARICOM) member states, as Suriname depends largely on imports for its food supply. In 2010 CARICOM adopted the Regional Food and Nutrition Security Policy and Action Plan. Its objective is to provide safe, nutritious, and affordable food for the region's inhabitants through improved food production, processing, and distribution. Currently, the FAO is supporting the Ministry of Agriculture in the implementation of the Policy's agenda in Suriname.

Food availability

Regarding food availability, i.e. crop production, the challenges facing Suriname are fluctuations in the volume of vegetable production throughout the year caused by climatic factors such as drought and floods, and low-quality products. Product quality refers to consistency in the product's appearance, taste, shelf life, packaging, and safety.

The inferior quality of Surinamese products is a consequence of physical damage and is partly due to inadequate treatment at certain stages of the agricultural value chain:

- Farmers do not harvest at the right time and in the right way.
- The products are not adequately stored immediately after harvesting.
- Exporters transport and store their products insufficiently cooled.
- Exporters do not sort the products.
- The quality of the packaging is poor and does not meet international requirements.
- Competition instead of cooperation between actors along the value chain and their lack of trust affects the final product.

Moreover, Malgie (2018) report that not all small-scale farmers are producing according to Good Agricultural Practices (GAP) which ensure that fruits and vegetables are produced, packed, handled, and stored as safely as possible to minimize risks of microbial food safety hazards.

Food access

The physical accessibility of food in Suriname is favorable, especially in the coastal area. There are several large supermarkets and hundreds of small supermarkets and vegetable markets selling a variety of canned and fresh products. In most communities small supermarkets are within a 5km radius of the consumer. However, some socioeconomic factors regarding food access remain.

The high price of food products, and the fluctuations of price due to sensitivity to the effects of climate change. Small-scale farmers are dependent on seasonal precipitation, have poor irrigation and drainage infrastructure, and are more affected by drought and heavy rainfall, all affecting food prices. Poverty related to the lack of access to resources like land and financial capital and high unemployment rates affect the population's ability to purchase sufficient food. This is combined the lack of basic services and ineffective safety net programs and coupled with inadequate monitoring and evaluation of the programs.

Food use

Regarding food use, the challenges Suriname face are:

1. Food quality
2. Food choices
3. Childcare
4. Lifestyle

Inadequate food use has been linked to Suriname's relatively high prevalence of morbidity and mortality due to chronic non-communicable diseases such as heart disease, stroke, diabetes, cancer, and obesity, which have been steadily increasing over recent years

Food stability

Food stability refers to the stability of food availability, access, and use. These dimensions must be stable and should not be adversely affected by natural, social, economic, or political factors. An important indicator for measuring food stability is the percentage of irrigated agricultural land of total agricultural land.

5.2.1.3. Importance of the sector to the country's economy

Agriculture is an historically important sector in Suriname. The contribution of the agricultural sector to the gross national product (GNP) over the last five years has been about 7%, although there has been a downward trend over the past decade and the current area of land under production is only about 20% of its historical maximum. One of the main causes is the aging of agriculture workers due to migration of young people to urban areas. Other causes include small profit margins due to inaccessibility of financial credits, a lack of rice seeds for sowing, chemicals and synthetic fertilizers, machines, good irrigation water, and infrastructure.

In 2013 Suriname entered a severe recession due to the falling prices of gold, oil, and aluminum. Government revenue from mining fell from around 10% of the gross domestic product (GDP) in 2013 to just 3% of the GDP in 2015; the currency devalued by half; and government debt as a percentage of GDP tripled between 2012 and 2016. In 2016 and 2017, Suriname's economy was so unstable that its inflation rate ranged from 22% to 55% (Central Bank Suriname, 2015). The country's recession and unstable economy resulted in a decrease in farmers' purchasing power and a contraction of the agriculture sector. Nowadays, both production and exports have the potential to increase, especially those of high-value fruit, vegetable, and meat products.

The sector can be divided into four subsectors:

1. Fishery (including aquaculture)
2. Crop production (rice, bananas, and vegetables)
3. Livestock (cattle, sheep and goat, poultry and pigs, ruminants)
4. Flowers, ornamentals, and fruits (other than banana)

Within the agricultural sector, rice, shrimp, and fish are the main commodities, followed by vegetables and fruits.

Fishery

The fishery sector in Suriname is divided into deep sea, coastal, brackish water, and freshwater fishery. Aquaculture and fisheries employed an estimated 4,876 people in 2017. The fishery sector also ensures the local population has a reasonable animal protein supply (approximately 17.7 kg in 2013). In 2017, the export of fish and fish products was around 29,391 tonnes (ABS, 2018). Aquaculture, especially small-scale freshwater aquaculture and rice-fish culture is seen to have a good potential for improving livelihoods of low-income rural households.

Crop production

Suriname's rice production capacity is about 300,000 tonnes per year on about 59,000 hectares of land (ABS, 2018). Rice cultivation is most prevalent in Nickerie. However, currently less than 30,000 hectares are used for rice production as a result of inadequate infrastructure in the rainy season, a shortage of good irrigation water, and insufficient rice seeds. The production system is highly mechanized and utilizes agricultural aircrafts, tractors, and harvesting machines. Rice cultivation can be regarded as intensive, with two harvests a year taking place. Overall, the rice sector makes a significant economic contribution to Suriname through significant employment and rice valued at USD 6 to 8 million is exported annually (ABS, 2018).

With regards to bananas, Suriname has approximately 2,000 hectares of commercial banana plantations. The government of Suriname is currently deliberating with a team of experts about the possibilities to revive the country's banana industry despite the *moko* disease that affected a quarter of the plantations' area. Closing the banana companies will result in the loss of nearly 2,500 jobs.

The districts of Wanica and Saramacca, among others, play an important role in vegetable production and Suriname's food security, as they have many smallholder family farms. Every day, fresh crops are brought to Suriname's biggest market, the Central Market of Paramaribo. The income these farmers generate from agriculture is relatively low and in addition to that of their daily profession. Cabbage, tomatoes, cucumber, eggplant, pepper, and yard-long beans are some of the most important vegetables they plant.

Livestock

The livestock sector is predominated by smallholders with some medium and large-size poultry and cattle farms. The pig industry is dominated by a few companies that produce about 60% of the entire output. In terms of numbers, there are about an equal number of cattle as of pigs (Table 33).

Table 33- *Number of livestock in 2014-2017*

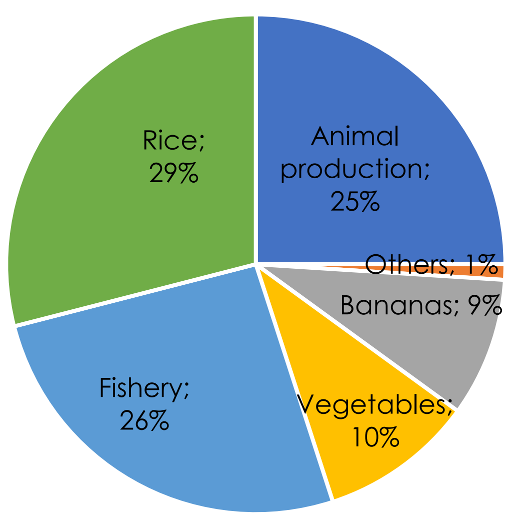
District	2014	2015	2016	2017
Cattle	36,138	37,620	35,763	35,995
Goats and sheep	9,831	10,706	10,234	9,463
Chicken and other poultry (x 1,000)	5,098	5,439	4,697	5,567
Pigs	36,422	36,716	35,395	37,754

Source: ABS (2018)

Employment

The sector employs 12% of the economically active workforce (Milton, 2009), where half of which engage in animal production and fishery, while the other half work in crop production (Figure 50). In addition to both private and publicly owned commercial agribusiness operations, there are about 10,000 smallholder farmers. The agricultural sector of Suriname is characterized in small, medium, and large-scale agriculture with commercial farming concentrated in the coastal area and traditional farming practices in the interior, mainly for household food security. A variety of crops, livestock, and fishery commodities are produced, the majority for local consumption. The Fifth Agricultural Census recorded 10,234 holdings, of which 6,886 were in the coastal area and 3,348 in the interior (Ministry of Agriculture, Husbandry and Fisheries, n.d.).

Figure 51- *Labor involved in the agriculture sector in 2010*



Source: Tjien Fooh (2011)

Exports

Many agricultural products are exported. Suriname has preferential market access to the Caribbean due to its CARICOM membership, and to Europe due to its historical export connections to the Netherlands. Rice exported to Jamaica, bananas exported to France and the Netherlands, while fish and fish products are the most important exports, with annual exports amounting to USD 10 million, accounting for 6% of all exports (World Bank, 2019). However, in recent years a sharp decrease in the export volume of bananas and other fruit was observed (Table 34). This decline is a result of different socioeconomic and environmental factors such as inadequate infrastructure, lack of investments, innovation, strong winds, droughts, and varying rain intensities.

***Table 34**- Export volumes (MT) of agricultural products in 2013-2017*

Export product	2013	2014	2015	2016	2017
Rice	77,101	103,755	99,663	121,609	78,430
Banana	76,585	75,261	66,178	56,099	54,993
Fish and fish products	25,568	28,991	29,270	24,433	29,381
Fruit (excl. banana)	579	431	272	192	304
Vegetables, fruits, and plant parts	648	409	266	1,260	2,212
Floriculture	54	49	46	57	102
Shellfish	4,053	2,778	2,136	3,611	4,175
Root crops	2,806	2,717	2,363	2,405	2,575

Source: ABS (2018)

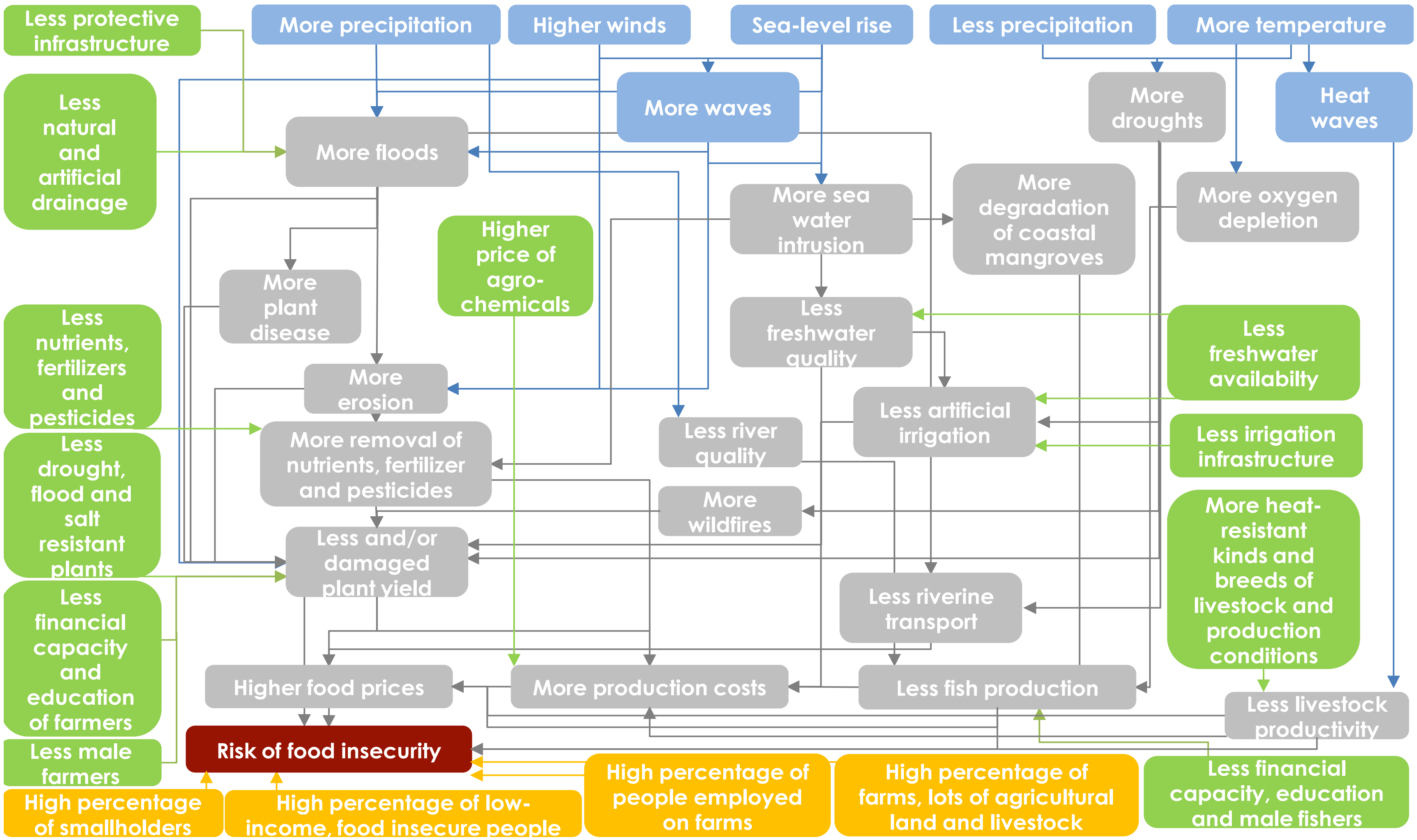
5.2.2. Climate impacts and risk

5.2.2.1. Historical impact of climate change on the agriculture sector

Historically, the agriculture sector has been especially affected by floods such as in 2006 and 2008 (ABS, 2018). In both cases, flooding severely affected the coastal region where the majority of Suriname's agricultural activity is concentrated. The most cultivated districts are Nickerie (rice), Saramacca (bananas and plantains), and Wanica (vegetables and fruits) (ABS, 2018). An assessment of the socio-economic impact of the 2006 flood carried out by Simpson et al. (2012) indicates that agriculture was the second most affected sector, concentrating 39% of the total monetary damage.

Apart from increases in precipitation and floods, the agriculture sector is also affected by sea-level rise, high winds, and decreases in precipitation which lead to droughts. Figure 51 provides an overview of the impact chain for the agriculture sector, with the most important hazards in blue, the intermediate impacts in grey, and final risks in red. The impact chain is shown as a product of exposure, shown in yellow, and green vulnerability factors. The subsequent section provides an interpretation of each risk component.

Figure 52- Impact chain for the Agriculture sector



Source: SOC Report team elaboration

5.2.2.2. Hazards

The agriculture sector is affected by four main hazards: changes in precipitation, higher winds, sea-level rise, and higher temperatures including heat waves. With regards to precipitation, high winds, and temperature, their frequency, intensity, distribution, and seasonality must be considered. Moreover, high winds in combination with sea-level rise can lead to waves which affect the sector in the coastal regions.

The four subsectors are not affected equally by the hazards. Fishery is most affected by increases in precipitation, high winds, and temperature. Crop production is most affected by increases in precipitation, high wind activity particularly affects bananas production, and sea-level rise affects rice production which relies on irrigation. Flowers, ornamentals, and other fruits are most affected by changes in precipitation, sea-level rise, and temperature increases. Livestock are most affected by changes in precipitation, sea-level rise, and increases in temperature which affects grazing, and increases in temperature which directly affects the livestock.

Table 35 provides an overview of the relevance of the projected changes in climate hazards for the sector.

Table 35- *Relevance of projected changes in climate hazards for the agriculture sector*

Hazard indicator	Relevance	
Average daily temperature **Maximum daily temperature** **Minimum daily temperature** **Frequency of hot days** **Frequency of hot nights**	High	Crop, livestock, and fish production are directly related to optimum temperatures. High temperatures can lead to losses and reduced reproduction rates, as organisms are pushed out of their comfort zone. Plant tissue can get damaged, livestock can die, and fish production decrease as the oxygen content of water drops. High temperatures increase the demand for water. This is an issue in areas where there is a water shortage or no irrigation infrastructure, all of which affect food stability and the health of agricultural workers.
Frequency of cold days **Frequency of cold nights**	Low	As there is no frost in Suriname, crop, livestock, and fish production are not affected.
Accumulated yearly precipitation **Number of rainy days per year**	High	Crop and livestock production are heavily affected by a decrease in accumulated yearly precipitation and the number of rainy days, as both crop production and the production of fodder and water for animal consumption depend on water.
Maximum precipitation in five days **Maximum precipitation in one day**	High	Strong rainfall and downstream events such as the floods pose an important hazard to crop and livestock production.
Short dry season	Medium	Short dry season precipitation is of medium

Hazard indicator	Relevance	
precipitation		importance for agriculture and livestock production in terms of fodder availability.
Dry season precipitation	High	The dry season precipitation is of high importance for agriculture and livestock production in terms of fodder availability.
Short rainy season precipitation	Medium	Short dry season precipitation is of medium importance for agriculture and livestock production in terms of fodder availability.
Rainy season precipitation	High	Rainy season precipitation is of high importance for agriculture livestock production in terms of fodder availability, particularly in the interior where slash-and-burn agriculture is rainfed and excess rainfall may have negative effects.
Maximum daily winds	High	This affects crop production like bananas, as plants get damaged from high winds.
Gale wind days	Low	Their occurrence is very rare and projected to change little.
Strong wind days	High	This affects crop production, as plants get damaged from strong winds.
Relative humidity	High	Lower humidity may decrease plant production.
Sea-level rise	High	Floods, saltwater intrusion, and salinization affect all coastal districts, which rely on freshwater irrigation and are in proximity to the sea.

Source: SOC Report team elaboration

5.2.2.3. Intermediate impacts

In the case crops, flowers and ornamentals, fish, and livestock, all intermediate impacts may lead to higher food prices and lower competitiveness.

With regards to plant production, the sector suffers from three high-level intermediate impacts that ultimately lead to plant yield losses, damage, and higher production costs if the current level and quality of productivity are to be sustained. Higher production costs in combination with lower production rates result in higher food prices.

1) **Floods** caused by increases in precipitation, sea level-rise, and waves can directly cause plant yield losses and damage and subsequent intermediate impacts such as an increase in plant disease, erosion of agricultural land, and the removal of soil nutrients and agricultural products like fertilizers and pesticides. These effects drive up production costs if current production levels are to be sustained. These are aggravated in areas where riverine transport is the main mode of transportation, and where floods can render rivers unnavigable, and alternative modes of transportation are more expensive.

2) **Sea-water intrusion** caused by sea-level rise and waves reduces the quality of freshwater, which leads to plant yield losses as salinity has negative effects on plant physiology. Salinization also reduces opportunities for artificial irrigation, which is particularly important for rice. Rice production costs increase when more costly means for providing freshwater are required. The washing out of nutrients, fertilizers, and pesticides by seawater intrusion may also result in higher production costs.

3) **Droughts** caused by decreases in precipitation and high temperatures can directly cause plant yield losses. In the case of rice, for example, droughts can inhibit photosynthesis and reduce biomass production, and temperatures outside the cultivation range can lead to its sterility (Korres et al., 2016). Additionally, droughts can contribute to plant yield losses via supplemental intermediate impacts such as an increase in wildfires and less artificial irrigation. If production is to be sustained, this involves employing new means of protecting plants from wildfires and providing artificial irrigation, which increases the production costs. These are aggravated in areas where riverine transport is the main mode of transportation, and where droughts can render rivers unnavigable.

With regards to fishery, the sector suffers from increases in precipitation and temperature, which negatively affect the water quality of rivers and lead to oxygen depletion. Oxygen depletion and high water temperatures in brackish-water lagoons, freshwater swamps, and rainforest creeks causes the death of catfish, snook, tilapia, mullet, and tarpon. Sea-water intrusion leads to the degradation of coastal mangroves, which are havens of biodiversity and productivity. All three hazards therefore have a negative impact on fish production.

With regards to livestock, the sector suffers mostly from increases in temperature and heat waves. These directly result in less livestock productivity.

5.2.2.4. Risks

The different intermediate impacts that cause decreases in plant and animal production all cause cost increases in production and transportation, which lead to higher food prices due. Floods, seawater intrusion, and droughts affect all four agriculture subsectors. Increases in food prices lead to a higher risk of food insecurity and reduced competitiveness on the international scale. A higher risk of food insecurity is also triggered by decreases in plant and animal production in the case of subsistence farmers.

5.2.2.5. Exposure

In general, exposure will be highest in the districts where many households dedicate themselves to agriculture. There is a lot of agricultural land and livestock potentially affected by climate change.

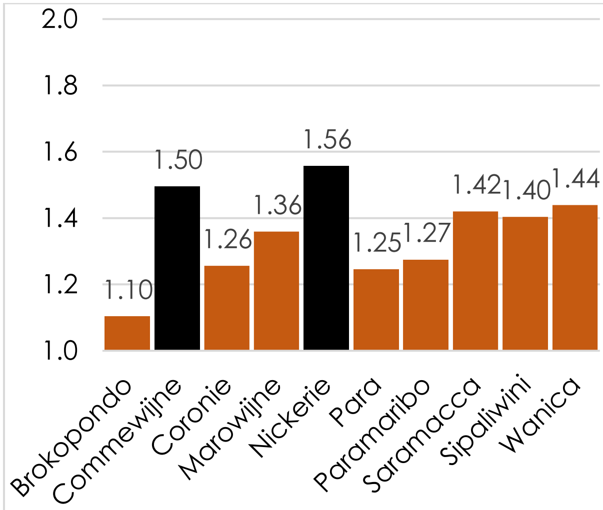
The risk of food insecurity is most prominent for smallholders of plants, livestock, and aquaculture who rely on their own production for nutrition. They also suffer the economic consequences of production losses and higher production costs. As the capacity of smallholders to mitigate such production and economic losses or prevent them by adapting their production systems is limited, the quantity and quality of food they are able to generate and purchase is likely to be negatively affected, resulting in their exposure to the risk of food insecurity.

The risk of food insecurity is also pronounced for low-income people with little financial capacity to pay higher food prices, and for people who are already food insecure and are not able to reach food security if food prices increase.

Food insecurity also concerns people employed on farms, as farms may decrease their workers' wages or reduce the number of workers they employ due to decreases in production that result in less workload or less financial means to pay for hired workers. People previously employed on farms may lack the financial resources to buy food in adequate quantity and quality, especially if food prices rise.

The following figure presents the results of the exposure subindex for the agriculture sector:

Figure 53- Exposure of the agriculture sector in the ten districts



Source: SOC Report team elaboration

Figures 53-60 provide an overview of the indicators used to construct the exposure subindex.

Figure 54- Number of family farms as a percentage of the total number of households

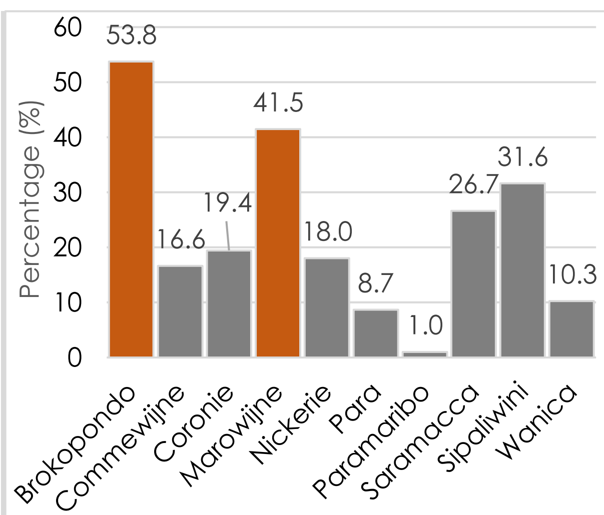


Figure 55- Number of animals (cattle, sheep, goats, pigs) per farm on average

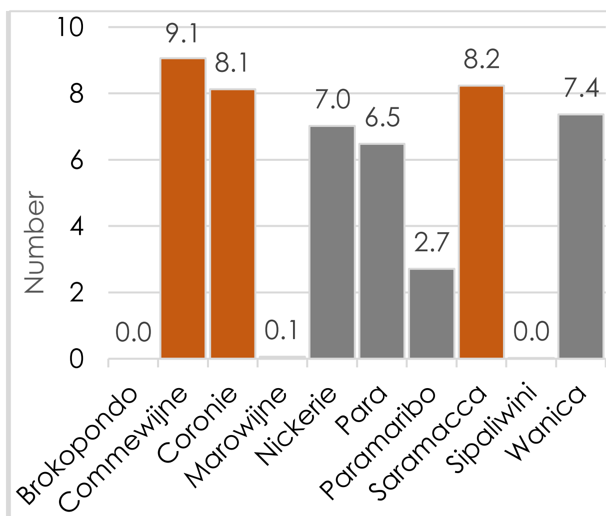


***Figure 56**- Agricultural land as a percentage of the total area of the district*

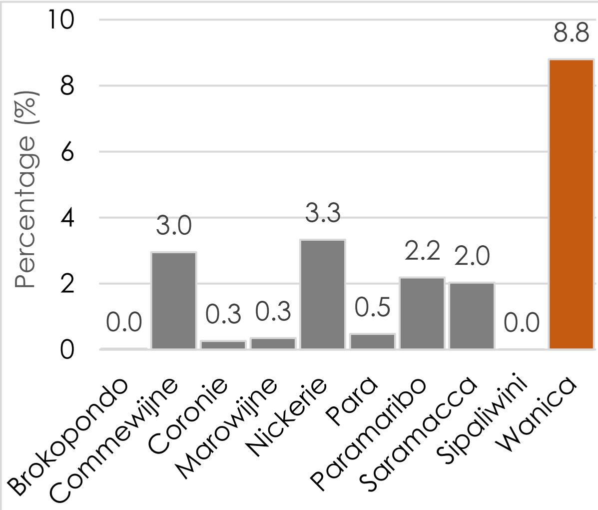


***Figure 57**- Number of hired workers as a percentage of the total population*

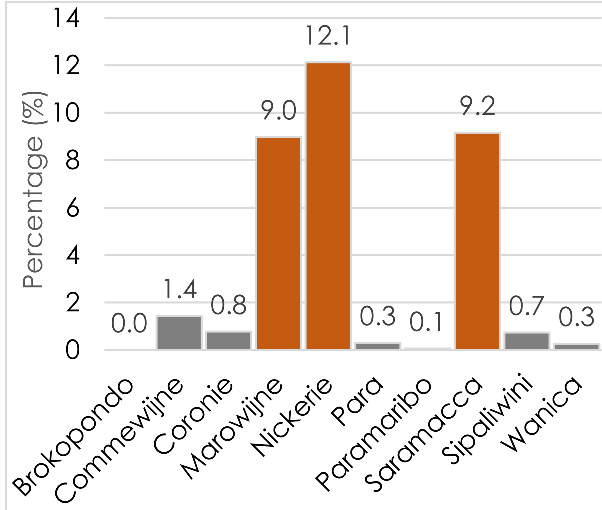


***Figure 58**- Number of farms with less than 2 ha of agricultural land as a percentage of all farms*

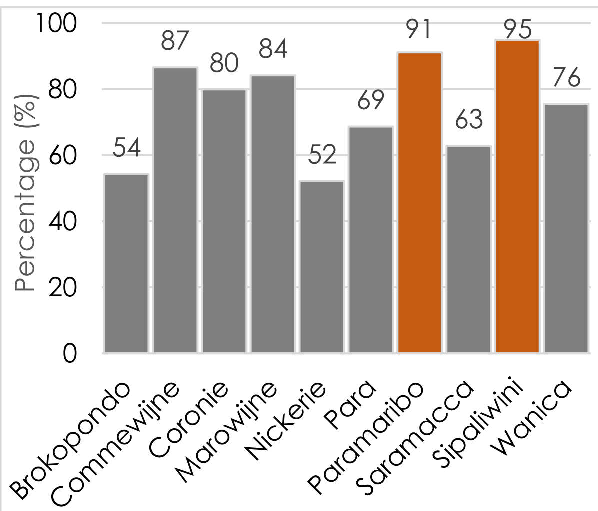


***Figure 59**- Percentage of the population whose income is less than half the GNI per capita of the district*

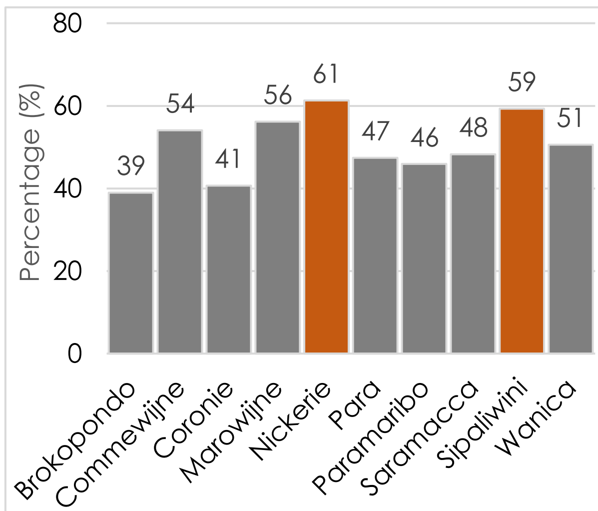


Figure 60- Percentage of children under the age of five that are stunted (-2 SD)

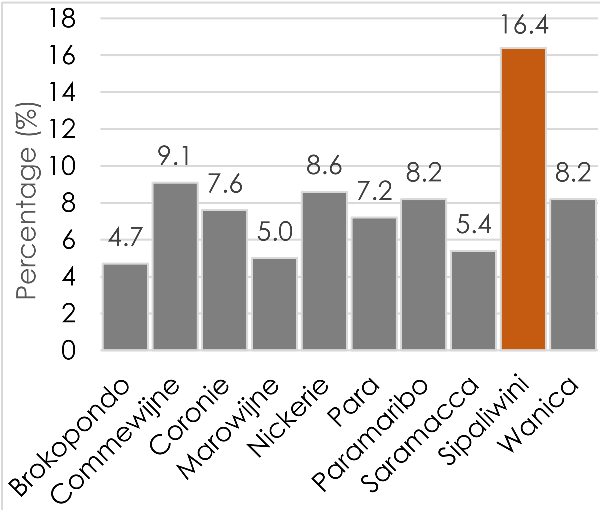
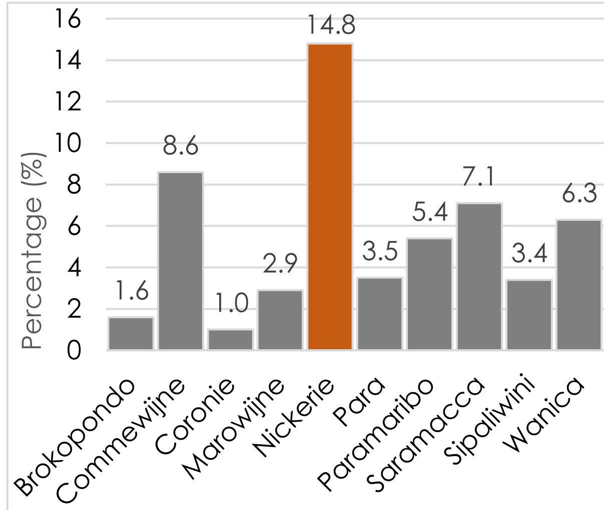


Figure 61- Percentage of children under the age of five that are wasted (-2 SD)



Source: SOC Report team elaboration

Nickerie is the most exposed district (Figure 52). It has the highest number of hired workers in agriculture as a percentage of the total population (Figure 56), the biggest relative population with a low income (Figure 58), and the highest percentage of wasted children (figure 60) out of all districts.

The second most exposed district is Commewijne (Figure 52). It has the highest number of animals per farm on average out of all districts (Figure 54) and has a comparatively very high percentage of agricultural land (Figure 55), smallholders (Figure 57), low income population (figure 58), and stunted and wasted children (Figures 59-60).

Both Nickerie and Commewijne are located at the coast. Due to their location, which is not measured by any of the indicators, they will suffer from additional exposure to sea-level rise, saltwater intrusion, and salinization, which particularly affects rice production.

Brokopondo is the least exposed district (Figure 52). Although it has the highest number of households which are family farms (Figure 53), it scores lowest on almost all the other indicators.

The second least exposed district is Para. In contrast to Brokopondo, only 8.7% of its households are family farms (Figure 53), however, the district performs less well on other indicators such as the number of animals per farm (Figure 54).

5.2.2.6. Vulnerability

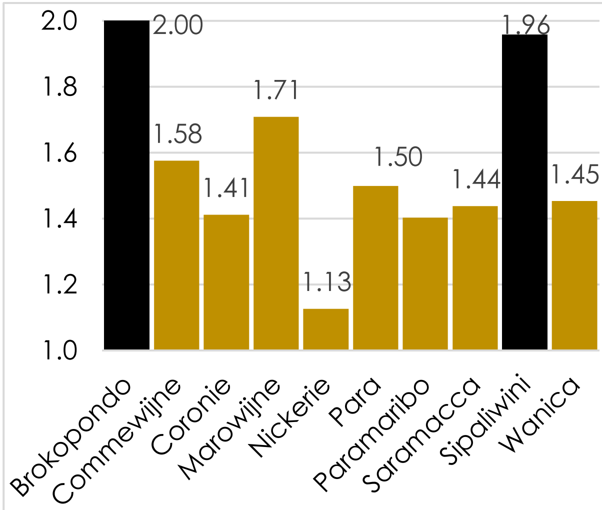
Several factors contribute to the vulnerability of low-income and food insecure people, smallholders, and people employed on farms:

- Protective infrastructure (see impact chain on infrastructure)
- Natural and artificial drainage (see impact chain on infrastructure)

- **The availability of nutrients in soils**, the means to add nutrients to the soil in the form of chemical fertilizers, and to protect plants from disease with pesticides all positively contribute to productivity and thus compensate decreased productivity due to climate hazards.
- **Intensive rice cultivation** with two harvests a year increases the pressure on the soil and results in a decline in soil fertility, according to Wildschut and Noordam (1999), Bliek and Noordam (1985), and more recently by Diran (2018). Their studies demonstrate that the availability of nutrients (e.g. nitrogen, potassium, kalium) in the soil decreases over time. The continuous mitigation of these shortages through the application of inorganic fertilizers implies additional production costs.
- **Plants whose physiology favors their resilience** to drought, flood, and salinization under the new circumstances imposed by climate change will be productive despite adverse conditions.
- **Farmers and fishers with a greater economic capacity** are in a better position to adapt their production systems to changing conditions through the ability to put flood protections in place, buy fertilizers and pesticides, improve seeds and livestock breeds, and to install artificial drainage and irrigation systems. Fishers are able to buy better equipment, travel longer distances to more populated fishing sites, and can improve their aquaculture system.
- **More educated famers and fishers** are in a better position to adapt their production systems to changing conditions by employing innovative approaches regarding conservation, and the rebuilding of fishery stocks.
- **Gender** can be a vulnerability. In 2009 the United Nations Development Program (UNDP) examined the impacts of climate change on agriculture and housing in two indigenous communities after the 2006 flooding (UNDP, 2009a). The study shows that women were more vulnerable than men to the negative impacts of the flood. This is due to women less frequently receiving payments for their work than men and women having less opportunities to earn an income. Suriname's Fifth Agricultural Census indicates that there are more and younger women farmers in the interior per district than in the coastal area (LVV, n.d.).
- **The cost of agrochemicals** like fertilizers and pesticides directly impacts on the production cost. If they are cheaply available, farmers can compensate decreases in productivity due to climate change more easily.
- **Freshwater availability** (see impact chain on water)
- **Farmers without irrigation infrastructure** are heavily impacted by droughts or changes in the seasonality of rainfall.
- **Heat-resistant livestock** favors their resilience under the new circumstances imposed by climate change, particularly heat waves. The livestock production conditions can be adapted to provide cooler climates, too, and this prevent negative impacts derived from increased temperatures.

Figure 61 presents the results of the vulnerability subindex for the agriculture sector:

***Figure 62**- Vulnerability of the agriculture sector in the ten districts*



Source: SOC Report team elaboration

Although Brokopondo is the least exposed district, it is the most vulnerable (Figure 61). This inverse relationship between exposure and vulnerability can also be found in Nickerie. Nickerie is the most exposed district but the least vulnerable.

Figures 62-63 provide an overview of the indicators used to construct the vulnerability subindex.

***Figure 63**- Number of family farms with the farmer having received no formal education as a percentage of all family farms*

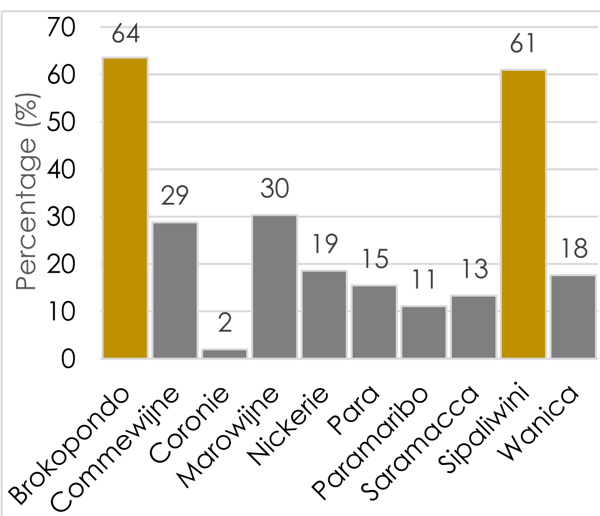
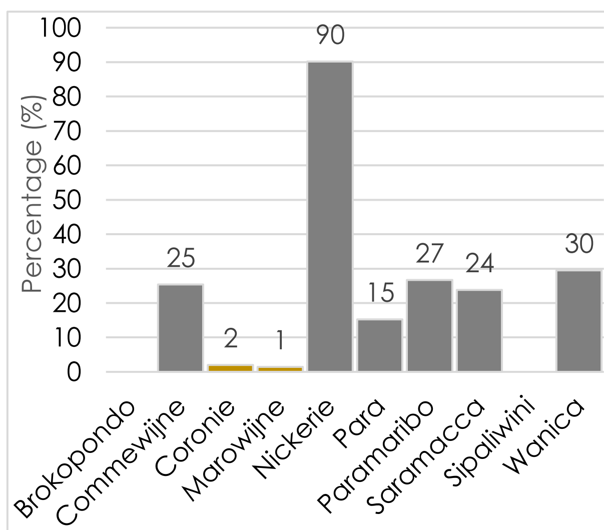


***Figure 64**- Number of farms with irrigation infrastructure as a percentage of the total number of farms*



Source: SOC Report team elaboration

Brokopondo and Sipaliwini are the most vulnerable districts because their farmers are the least educated, as 64% and 61% of them received no formal education (Figure 62). In comparison, only 2.0% of farmers in Coronie have no formal education.

Nickerie is the least vulnerable district, as its farmers are fairly educated (Figure 62) and the highest percentage of farms out of all districts (90.2%) to have irrigation infrastructure, whereas most other districts score between 15-30% (Figure 63).

5.2.3. Needs and responses

The following strengths, weaknesses, opportunities, and threats were identified for the agriculture sector.

5.2.3.1. Strengths

- In February 2019, several locals set up the agricultural cooperative Hatti Wai in Pikin Slee. with the support of Tropenbos Suriname, some ministries, students from ADEKUS, Cooperative Godo Bank, a marketing consultant, and Wi! Uma Fu Sranan. The main goal of the cooperative is to improve the agricultural system for farmers.
- There is a project in the pipeline to increase food supply, security, and safety through home-gardening and demonstration plots. The project is led by the LVV, the ministry of education, RO, Polytechnic College Suriname, and the Institute for Natural Resources and Engineering Studies.
- The Suriname Agricultural Market Access Project (SAMAP) was formulated. This program is aimed at enhancing sustainable agriculture development for inclusive growth and employment. One of the expected outcomes is that at least 30% of 1,000 small-scale farmers will be able to achieve increased horticultural production and sustainable market access upon completion of the project. This program also supports at least 15 agribusinesses with obtaining a basis bank loan.
- The LVV in collaboration with the IDB is currently planning the implementation of a project titled *Sustainable agricultural productivity program*. Its objective is to increase agricultural productivity in Suriname through investments in infrastructure and the management of irrigation and drainage systems in the main production areas. Moreover, the program aims at improving the quality of agriculture statistics for decision and policymaking. Expected results will include improved production and management and better operation of water boards which contribute to the statistics information systems.
- The Ministry of Social Affairs and Public Housing provides financial support to vulnerable farmers.
- In 2019 the ADEKUS formulated the National Mangrove Strategy (NMS) based on prior experiences from the project *Enhancing resilience of the coastline removing stress, rehabilitation and mangrove planting* from 2010. Mangroves are an important habitat for fish and their resilience is important to reduce the impact of climate change on the sector.
- In 2019, the FAO and ADEKUS carried out the study *Evaluation of raised beds as an alternative agricultural practice for eggplant and cabbage on an agricultural field with water intrusion at the Weg Naar Zee Area*. The objective of the study was to determine if raised beds could enhance plant performance and increase resilience of farmers in this vulnerable area.

- In 2018 CELOS conducted a multidisciplinary assessment in Pikin Slee, a village along the Upper Suriname River, addressing landscape, vegetation, soil, and agriculture.
- ADRON has a rice breeding program that is focusing on high producing varieties that are resistant to diseases, insects, and droughts that may increase as an impact of climate change. In addition, ADEKUS is conducting rice research in collaboration with ADRON and international organizations.
- There are several institutions working on climate-smart agricultural technologies including ADEKUS, Department of Agricultural Production, Department of SMNR, and the Department of MERSD, LVV, FAO, and UNDP.
- The Inter-American Institute for Cooperation on Agriculture (IICA) and the UNDP through the GCCA+ have carried out an agricultural project in August 2018 named *Reducing risks against the negative effects of climate change*, together with farmers at Weg naar Zee.
- The GEF, FAO, and the Caribbean Trawl Fisheries offer financial assistance and tools to fisher organizations in various resorts (Gallibi, Boskamp, Coronie, Nickerie). This decreases their vulnerability to the impacts of climate change.
- The UNDP, LVV, and IICA are engaged in a project called *Reducing farmer vulnerability to climate change impacts through the promotion of climate-smart agricultural technologies in Suriname*.
- ADRON, ADEKUS, and the LVV extensively collaborate with international organizations for technical assistance.
- The LVV is providing training and education to small-scale farmers and fishers on good practices. This increases their production and reduces their vulnerability to climate change.
- The FAO signed a collaboration agreement with international agencies on the integration of climate change information into the fishery management decision-making process.
- Gender issues are taken into consideration in the implementation of projects by the LVV and international organizations. Women are particularly vulnerable, and these considerations will foster resilience among female farmers and fishers.
- Women's groups, NGOs, and civil society organizations have empowered and given rural women farmers a voice and recognition.
- Even though imported agrochemicals are expensive, they are used in agricultural activities in Suriname to ensure food security, enhance production, and reduce the exposed population.
- Suriname is rich in freshwater resources needed for irrigation. This fosters resilience against droughts.

5.2.3.2. Weaknesses

- The farmer population is aging. This means traditional knowledge, important for adapting to climate change, is not passed on to younger generations.
- There is little knowledge on adding value to fruit and vegetables, which could increase the income from agriculture and reduce farmers' vulnerability.
- There is no information on whether the NMS has been implemented or not.
- The livestock sector produces only for local markets and is dependent on import. This limits the income that can be derived from livestock activities and the resilience of farmers.
- There are no drought resistant rice varieties yet developed in Suriname that would decrease the vulnerability of the sector.

- There has been no evaluation of the existing rice breeding program.
- Despite several programs, farmers still have few skills on climate-smart technologies and little awareness of the effects of climate change on their production systems.
- The capacities of farmers concerning the management and protection of agricultural production systems, rainwater collection, identification of pests and diseases are low.
- Women's productivity is severely constrained by the fragmentation of their time, their role in society, and their lack of access to essential inputs and knowledge.
- There is little public awareness on the need for freshwater conservation, which also impacts agriculture as it is dependent on irrigation.
- The existing irrigation infrastructure is not adequately managed, and rice crops are not optimally irrigated during the dry season, leading to production losses and a higher vulnerability of the sector.
- There is a lack of legislation to protect water resources for irrigation, and a lack of appropriate irrigation infrastructure.
- Little research is done on the impact of climate change on freshwater availability for agriculture, the replenishing and salinization of aquifers.
- Communication services in remote areas are weak, limiting farmers’ access to information.

5.2.3.3. Opportunities

- The conditions for growth in the livestock sector are favorable and there are agro-industrial companies that are processing primary products, which can increase the income from livestock and reduce the vulnerability of the sector.
- Food processing machines can add value and increase income from agriculture.
- There is a high demand for fish and shrimp on the national, regional, and international market. This can increase the income from fishery and reduce the vulnerability of the sector.
- ADEKUS in collaboration with UNDP and FAO has submitted grant applications to donors for sustainable mangrove management projects.
- Suriname has enough land and water to increase grassland for animal husbandry.
- There are innovation opportunities in the poultry sector.
- Implementation of the Coastal Management Plan can increase the efficiency of irrigation.

5.2.3.4. Threats

- Mangrove degradation threatens fish production.
- Due to the bad socioeconomic conditions in Suriname, agrochemical importers will focus more on the price of an agrochemical, rather than if it is environmentally friendly.

5.3. Water

5.3.1. Context

5.3.1.1 Freshwater sources in the geographical context

The World Water Council recognizes Suriname as one of the most freshwater-rich countries, ranking sixth among the countries that have superfluous water resources (UNDP, 2016). The abundance of water results from a combination of three main factors: topography, soil, and land cover (defined by its very high biomass per area) (Simpson et al., 2012). In 2006, the total water withdrawal was near 616 million m^3, accounting for 0.6% of all renewable water resources. Of all fresh water that was withdrawn in 2006, around 8% was provided by groundwater and 92% by surface water (FAO, 2015b). Rainfall is the most important source of fresh water in Suriname. The many rivers originating in the hinterland, groundwater aquifers, and swamps found in the coastal area are all fed by rainfall, with annual averages varying from 1,750 mm/year in the north to about 3,000 mm/year in the center of the country (Berrenstein & Gompers-Small, 2016).

Groundwater

With regards to groundwater, Suriname has two distinct provinces. The interior Precambrian shield of crystalline rocks comprises 80% of the country's surface, and the coastal plain basin comprises the remaining 20%. Groundwater conditions of the Precambrian shield are generally unfavorable because such geological formations have little or no primary permeability (Waterforum, 2019). People in the interior rely mainly on surface water for drinking and other purposes. The coastal basin on the other hand has good quality groundwater in abundance. The thickest and most extensive coastal aquifers are found in the west of Suriname. In the east only one major aquifer is found.

Surface water

Surface water sources include rivers, swamps, wetlands, man-made lakes and canals, lakes that were formed in sites of bauxite excavation, and urban and rural drainage systems. Currently, there is only one drinking water treatment plant in Moengo (Marowijne district) abstracting water from the Cottica river. In Commewijne, where people currently rely on rainwater and creek water, another drinking water treatment plant which will abstract water from the Suriname River is under development (De Ware Tijd, 2020).

Rivers and creeks

There are seven main rivers originating in the interior that discharge about 4,800 m^3 of freshwater into the Atlantic Ocean per second, which is 30% of the annual rainfall (table 36).

Table 36- Suriname's seven main rivers, their basin area and discharge

River	Basin area (km^2)	Discharge (m^3/s)	Specific discharge ($L/s/km^2$)
Marowijne	68,700	1,780	25.9
Commewijne	6,600	120	18.2
Suriname	16,500	426	25.8
Saramacca	9,000	225	25.0
Coppename	21,700	500	23.0
Nickerie	10,100	178	17.6
Corantijn	67,600	1,570	23.2
Total		4,799	

Source: Berrenstein & Gompers-Small (2016).

Freshwater swamps and wetlands

Numerous freshwater swamps and wetlands are found in the coastal zone. They cover a total area of 1.2 million hectares, one-third of which is permanently inundated, and the remaining are inundated during the rainy season (Berrenstein & Gompers-Small, 2016).

From east to west the four major freshwater swamps are the Surnau Swamp, Coesewijne Swamp, Coronie Swamp, and Nani Swamp. The swamps all function as potential large freshwater reservoirs. These swamps are poorly drained through small rivers and creeks. However, evapotranspiration significantly contributes to their depletion. The northern portion of these swamps is dammed by the east-west road or by dams along irrigation and drainage canals. These dams also function as dikes against high water levels in the swamps during periods of heavy rainfall. Their poor construction and maintenance often result in dam breaches and inundations of adjacent agricultural lands and urban areas (Amatali & Naipal, 1999; Berrenstein & Gompers-Small, 2016).

Man-made lakes

The Van Blommenstein reservoir, officially named Professor Doctor Ingenieur W. J. van Blommenstein Meer, covers an area of about 160,000 hectares. The reservoir was built from 1961 to 1964 by constructing a dam across the Suriname River. Originally, the main purpose of the lake was to serve a hydropower plant that generates electricity for the aluminum smelter at Paranam. Since the closure of the aluminum smelter in 1996, the electricity is mainly consumed by Paramaribo. The water level in the lake depends on rainfall and alternating water levels have led to inconsistencies in hydropower output. The lake's water is discharged via the Suriname River into the sea (ATM, 2015).

5.3.1.2. Freshwater uses

Groundwater resources are used for public supply and to a lesser extent industry. On the other hand, surface water is used for irrigation, hydropower, transportation, domestic use, and as drinking water, mostly in the interior but also in some coastal communities. Of the total freshwater withdrawal in 2016, 70% was used for agricultural purposes, 8% for municipal, and 22% for industrial purposes (Table 37).

Table 37- Water withdrawal according to its use in 2006

Use	Water withdrawal (m^3) in 2006
Agriculture	431 million
Municipalities	49 million
Industry	136 million
Total water use for agriculture, municipalities, and industry, per inhabitant	1,220

Source: FAO (2015b)

Drinking water

Overall, 98.2% of the population has access to improved sources[3] of drinking water, with 99% in urban areas, 98% in rural coastal regions and 91% in rural interior regions (Ministry of Social Affairs and Public Housing, 2019) (Table 38). Coronie is the district with the highest percentage of households using improved drinking water sources with 100%. Sipaliwini is the district with the lowest percentage, with 84.5% of households using improved drinking water sources 84.5. The main source of drinking water varies by district. In Paramaribo, 89.1% of the households have access to piped drinking water. In Nickerie 81.9% of households have access to the same service. Households with the least access are in Brokopondo with 34.3%, Commewijne with 27.8%, and Sipaliwini has only 6.4%. Here, rainwater is more important and used by 61.3%, 48.2%, and 72.9% of households, respectively. Rainwater is the second most important source of drinking water, followed by bottled water which is used by 29.8% of households in Coronie. Surface water such as rivers and ponds is also used as drinking water, for instance in 14.1% of households in Sipaliwini. However, surface water is considered an unsafe source of drinking water due to contamination with pathogens (Ministry of Social Affairs and Public Housing, 2019).

[3] Improved sources of drinking water are the following: piped water whether into the dwelling, compound, yard or plot, and to neighbors, or by public tap or standpipe, as well as tube wells and boreholes, protected dug wells, protected springs, rainwater collection, and packaged or delivered water.

Table 38- Percentage of households by main source of drinking water in 2018

		Improved sources										Unimproved sources							
		Piped water				Non-piped water													
		Into dwelling	Into yard/ plot	To neighborhood	Public tap/ standpipe	Tube well/ borehole	Protected well	Protected spring	Rainwater collection	Tanker truck	Bottled water	Sachet water	Unprotected well	Unprotected spring	Surface water	Other	Missing	Total	Percentage using improved sources
	Total	**58.9**	**10.5**	**1.0**	**0.5**	**0.3**	**0.7**	**0.7**	**16.8**	**0.2**	**8.2**	**0.4**	**0.2**	**0.1**	**0.9**	**0.6**	**0.0**	**100**	**98.2**
Area	Urban	70.2	8.5	0.9	0.5	0.2	0.6	0.5	8.7	0.2	8.5	0.4	0.0	0.1	0.0	0.7	0.0	100	99.2
	Rural coastal	38.1	18.2	1.3	0.8	0.6	1.1	0.9	25.0	0.1	11.0	0.6	0.7	0.2	1.0	0.5	0.2	100	97.5
	Rural interior	7.9	11.6	0.6	0.3	0.3	0.4	2.2	67.1	0.0	0.4	0.3	0.3	0.5	7.7	0.6	0.0	100	91.0
District	Paramaribo	78.1	9.9	0.8	0.3	0.0	0.4	0.1	2.4	0.1	7.4	0.0	0.0	0.0	0.0	0.4	0.0	100	99.6
	Wanica	63.9	8.2	1.2	0.9	0.3	1.0	0.7	12.9	0.1	8.5	1.0	0.0	0.1	0.0	1.1	0.0	100	98.7
	Nickerie	77.5	3.9	0.4	0.1	0.0	0.0	0.5	3.3	0.0	13.5	0.2	0.0	0.0	0.2	0.5	0.0	100	99.3
	Coronie	59.3	6.8	0.7	0.0	0.0	0.0	0.0	3.2	0.2	29.8	0.0	0.0	0.0	0.0	0.0	0.0	100	100
	Saramacca	34.3	11.7	0.3	0.0	1.5	0.8	0.4	34.9	0.2	13.9	0.0	0.1	0.0	0.0	1.9	0.1	100	97.9
	Commewijne	23.1	4.1	0.2	0.4	1.2	0.9	1.6	48.2	1.1	16.9	0.4	0.9	0.3	0.1	0.3	0.4	100	97.9
	Marowijne	32.8	22.9	0.9	1.4	0.1	2.2	0.3	28.7	0.0	5.8	0.8	0.8	0.6	2.9	0.0	0.0	100	95.7
	Para	37.6	33.9	3.8	1.3	0.4	1.4	1.8	12.7	0.0	3.5	0.9	1.1	0.3	1.3	0.1	0.0	100	97.3
	Brokopondo	13.5	19.4	0.8	0.6	0.0	0.0	1.4	61.3	0.0	0.4	0.0	0.6	0.0	1.2	0.7	0.0	100	97.4
	Sipaliwini	2.2	3.8	0.4	0.0	0.6	0.8	2.9	72.9	0.0	0.3	0.5	0.0	0.9	14.1	0.5	0.0	100	84.5

Source: Ministry of Social Affairs and Public Housing (2019).

The Suriname Water Company (SWM) is the sole drinking water production company in the country and responsible for five main supply areas, namely Paramaribo, Wanica, Para, Nickerie and Marowijne (Berrenstein & Gompers-Small, 2016). In 2016, parts of Commewijne, Saramacca, and Coronie were connected to the distribution network. The districts that are not serviced by SWM, mostly those in the interior, are provided with drinking water by the Ministry of Natural Resources' (NH) Water Supply Service (DWV) division, the Foundation Funding Development Interior (FOB) which is a technical arm of the Ministry of Regional Development (RD), or private companies (ABS, 2018). Drinking water supply in the hinterland is poor and DWV water standards are below those of the SWM (Berrenstein & Gompers-Small, 2016).

In 2017 the SWM produced 46 million m^3 of drinking water, which is approximately 8% of annual freshwater withdrawal. There are five SWM water tariff categories: 1) yard cranes and house connections, 2) house connections with pool, 3) commercial connections, 4) public connections including schools and government buildings, and 5) construction cranes.

While most of Paramaribo's population has access to water, approximately 40% of the distribution network consists of asbestos and needs replacing (Simpson et al., 2012). Moreover, the distribution network is poorly maintained and compromised by water theft, leakages, pump breakdowns and low pressure leading to intermittent supplies, and a high potential for contamination. The non-revenue water (NRW) within greater Paramaribo is between 40-50% of total water supply, mostly as a result of leakage (Waterforum, 2019).

5.3.1.3. Disposal and treatment of wastewater

Suriname

In general, there are no wastewater treatment plants. However, there are some private companies that have wastewater treatment facilities, places such as the Fernandes Soft drinks bottling plant, Berg en Dal ecotourism resort, and Staatsolie, but still many companies discharge their untreated wastewaters into rivers and creeks.

In Paramaribo, Wanica, and parts of Para, up to 90% of the households have a septic tank for treatment of water from the toilets, but due to bad design, installation, and usage, most of these tanks do not work properly, resulting in pollution of water resources.

In the interior, there are almost no septic tanks and wastewater is discharged directly into rivers and creeks, as is all other household water. In addition, about 25% of the interior population defecates in the rivers, which are also used for water supply, as approximately 44% of the rural population has no access to sanitary facilities (USACE, 2001).

City of Paramaribo

Different types of wastewaters from Paramaribo include rainwater run-off, domestic, industrial, hospital, and mortuary wastewaters. The Ministry of Public Works (OW) is responsible for the collection and discharge of household wastewater as well as the discharge of stormwater. Both types of wastewater run through a combined system of open canals and pipes, with public health depending on their operation and maintenance.

The Building State order for Paramaribo requires a part of domestic sewage to be treated in septic tanks and a filter bed, the standards of which are provided by the OW. The effluent of the septic tanks is collected in the street sewers. However, due to lack of supervision and control, septic tanks are sometimes constructed without a bottom and without a filter bed. During heavy rain water may back up leading to contamination. Septic tank sludge is removed using vacuum trucks and discharged into canals and rivers untreated, leading to surface water contamination, although this is generally not allowed. The other part of domestic sewage is from personal washing, laundry, and the kitchen, all of which enters the storm and street drains untreated.

Wastewater from the city of Paramaribo is mostly discharged into the Suriname River via the Saramacca canal to which the sewer network connects. The Saramacca canal is also used as a water transport route. Part of northern Paramaribo's wastewater is discharged directly into the Atlantic Ocean through sluices. The area of Greater Paramaribo is served by 25 sluices and pumping stations.

5.3.2. Climate impacts and risk

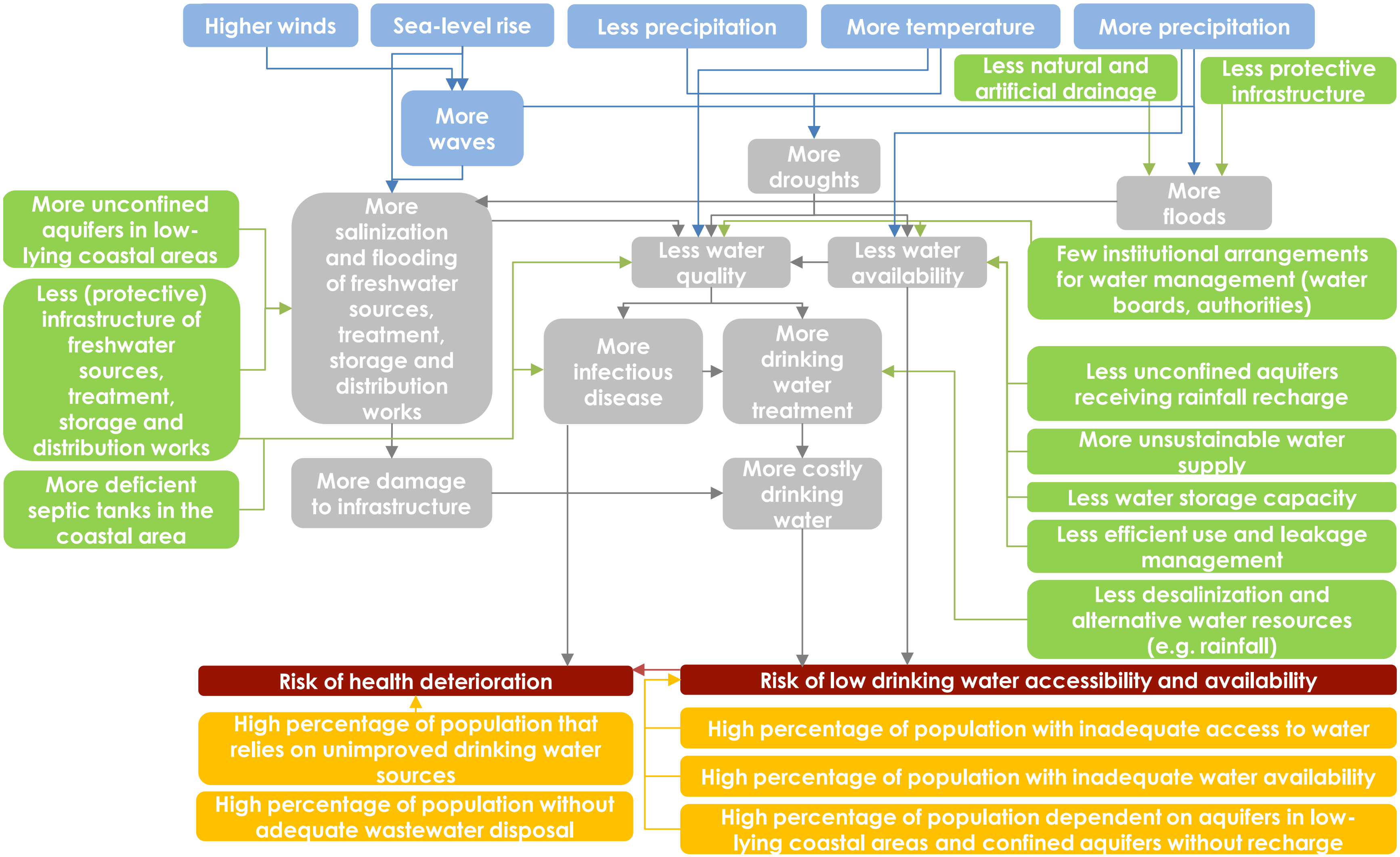
5.3.2.1. Historical impact of climate change on the water sector

A decrease in rainfall and numerous drought events have already affected the Prof. Dr. Ir. van Blommenstein reservoir between 1987-1988, in 1999, 2001, and 2005 (Simpson et al., 2012). During the 2005 drought the reservoir's low water-levels led to a four to five-day power failure. During a drought in 2009 river levels in a Maroon village in the Boven Suriname resort declined to the extent that boat transportation was not possible anymore (Simpson et al., 2012).

Equally, excessive rainfall has posed a problem in the past. In 2006 excessive rainfall caused two weeks of sustained flooding of the Tapanahony, Saramacca, and Suriname Rivers in the interior of Suriname. In some areas, the water levels remained high for three to six days (Simpson et al., 2012).

Figure 64 provides an overview of the impact chain for the water sector, with the most important hazards in blue, the intermediate impacts in grey, and final risks in red. They produce the risk factors exposure in yellow, and vulnerability in green. The subsequent section provides an interpretation of each risk component.

Figure 65- Impact chain for the Water sector



Source: SOC Report team elaboration

5.3.2.2. Hazards

The water sector is affected by four main hazards: changes in precipitation, higher temperatures, higher winds, and sea-level rise. Changes in precipitation are unlikely to greatly impact water resource availability (UNDP, 2009b). However, much of the coastal area of Suriname is very low lying and susceptible to sea-level rise. Table 39 provides an overview of the relevance of the projected changes in climate hazards for the sector.

Table 39- Relevance of projected changes in climate hazards for the water sector

Hazard indicator	Relevance	Explanation
Average, maximum, and minimum daily temperature	High	Higher temperatures negatively impact water quality and availability. They also increase the demand for water.
Frequency of hot days and nights		
Frequency of cold days and night	Low	These indicators do not affect the water sector.
Accumulated yearly precipitation	High	Decreased precipitation can negatively impact water availability in surface and groundwater sources. This in turn affects water quality. All districts, both those that rely on groundwater and those that use alternative drinking water sources such as rainwater, will be negatively affected by these changes.
Number of rainy days per year		
Maximum precipitation in five days	High	Intense precipitation events can cause damage to water infrastructure. In addition, it may decrease aquifer recharge and water availability, and contaminate surface water and groundwater sources. On the contrary, those households with rainwater collection can harvest this precipitation and will be less affected by the negative impacts mentioned above.
Maximum precipitation in one day		
Short dry season precipitation	High	Drier seasons affect water availability for rainwater, surface, and groundwater, and the quality of surface and groundwater.
Dry season precipitation		
Short rainy season precipitation		
Rainy season precipitation	Medium	Precipitation decreases at the coast. The effects are the same as those described for "accumulated yearly precipitation" and "number of rainy days per year".

Hazard indicator	Relevance	Explanation
		Precipitation increases in the interior. The effects will be beneficial, as more rainwater can be collected.
Maximum daily winds	Low	These indicators do not affect the water sector greatly.
Gale wind days		
Strong wind days		
Relative humidity	Low	This indicator does not affect the water sector greatly. It may increase the demand for water for irrigation in agriculture (see agriculture sector for more detail).
Sea-level rise	High	Sea-level rise leads to flooding, saltwater intrusion, and salinization of freshwater sources, specifically on the coast. Floods may also damage water works' infrastructure.

Source: SOC Report team elaboration

5.3.2.3. Intermediate impacts

An increase in precipitation and waves can cause flooding in coastal as well as inland regions. Floods and intense precipitation events, as well as salinization caused by sea-level rise and waves, all negatively impact on freshwater sources like rivers, wetlands, and particularly unconfined coastal aquifers, their treatment, storage, and distribution works. Water infrastructure can get damaged intense precipitation events, while a decrease in aquifer recharge and water availability occurs, as the infiltration rate of run-off is low. Moreover, floods increase groundwater levels, which decreases the efficiency of natural purification processes.

Flooding and intense precipitation events also lead to the erosion of topsoil, while animal waste, feces, pesticides, fertilizers, sewage, and garbage then contaminate surface and groundwater sources as well as marine areas (Caribsave, 2012). Overall, this results in a reduced water quality, which can cause an increase in infectious disease or a need for enhanced drinking water treatment. Both infrastructure damage as well as a reduced water quality result in an increase in the price of drinking water as some of these costs are internalized in the good's value. Other costs will have to be compensated for by regular taxes.

Another important intermediate impact is drought, a product of less precipitation and higher temperature. Droughts affect water quality and availability. With regards to water quality, higher temperatures favor cyanobacterial blooms, the accumulation of cyanotoxins and natural organic matter in water sources. Higher temperatures and reduced water flows can also reduce the level of dissolved oxygen in water. Poorly oxygenated water releases more benthic nutrients which promotes elevated phytoplankton activity and the release of metals from sediments into the water body (WHO, 2017). Decreases in water quality during drier conditions are also of concern for groundwater sources, particularly those of already low quality. For water quality, the impact chain leads to the same intermediate impacts as in the case of floods, intense precipitation events, and salinization. Reduced water availability may result from rivers carrying less water due to decreases in precipitation in their catchment areas, their reduced discharge in freshwater sources such as wetlands, and a lower percolation and recharge of aquifers. Reduced water availability in the different freshwater sources also leads to saltwater intrusion and salinization.

5.3.2.4. Risks

Taking the hazards into consideration, the risk arises of health deterioration and the risk of low drinking water accessibility and availability. The risk of health deterioration stems from more infectious diseases, while the risk of low drinking water accessibility and availability stems from more costly drinking water and less water availability.

5.3.2.5. Exposure

The risk of health deterioration is most discernible for:

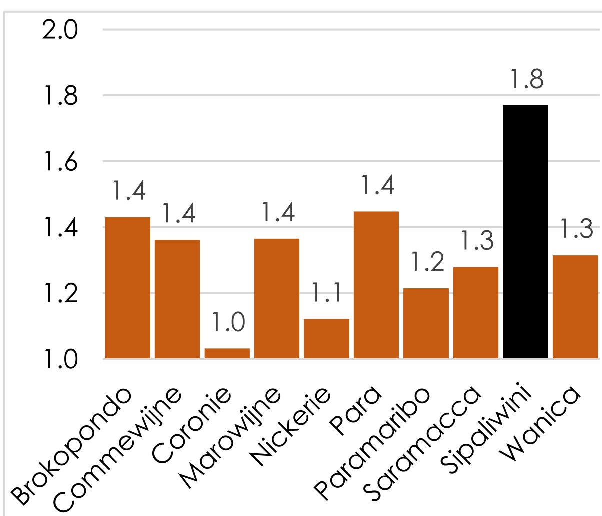
- People already relying on unimproved drinking water sources, as a further reduction in their quality will have strong negative impacts on their health
- People without adequate wastewater disposal, as this is likely to result in a contamination of their freshwater sources

The risk of low drinking water accessibility and availability is most eminent for:

- People already affected by an inadequate access to water and inadequate water availability, as these will be most affected by further reductions in water accessibility and availability
- People dependent on aquifers in low-lying coastal areas and confined aquifers without recharge, as these will be most affected by droughts and floods resulting in less freshwater availability and quality

Figure 65 presents the results of the exposure subindex for the water sector:

Figure 66- *Exposure of the water sector*



Source: SOC Report team elaboration

Figures 66-68 provide an overview of the indicators used to construct the exposure subindex.

Figure 67- *Number of households not using improved drinking water sources as a percentage of the total number of households*

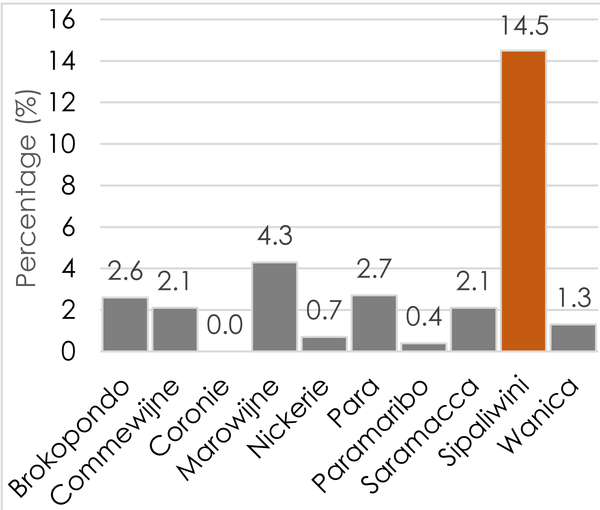


Figure 68- *Number of households without drinking water available in sufficient quantities as a percentage of the total number of households*

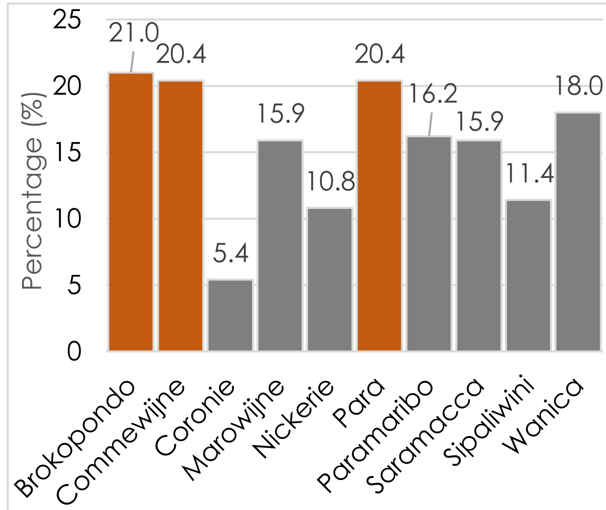
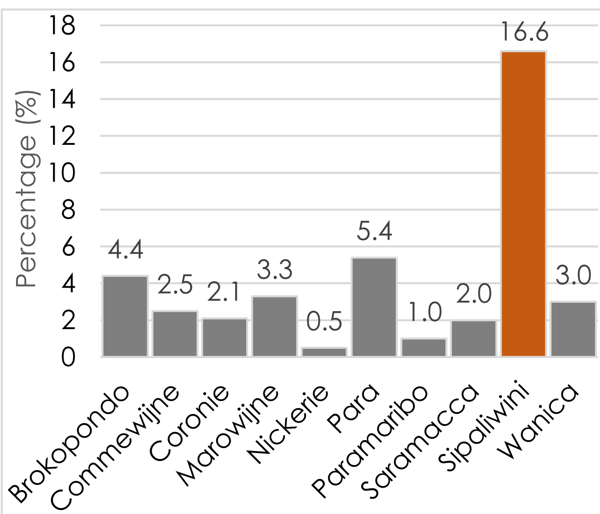


Figure 69- *Number of household members without access to drinking water on premises as a percentage of the total number of household members*



Source: SOC Report team elaboration

Sipaliwini is the most exposed district (Figure 65). It has the highest percentage of households not using improved drinking water sources (Figure 66), and the without access to drinking water on the premises (Figure 68).

Coronie is the least exposed district (Figure 65). It has the lowest percentage of households not using improved drinking water sources, with zero (Figure 66), and the least suffering from low drinking water availability (Figure 67) out of all districts. The district also scores well for access to drinking water on the premises, as only 2.1% of households fall short on such a supply (Figure 68).

The second least exposed district is Nickerie (Figure 65), which performs well on the three indicators and particularly on access to drinking water on the premises, which over 99% of the households have (Figure 68). This is more than in any other district.

5.3.2.6. Vulnerability

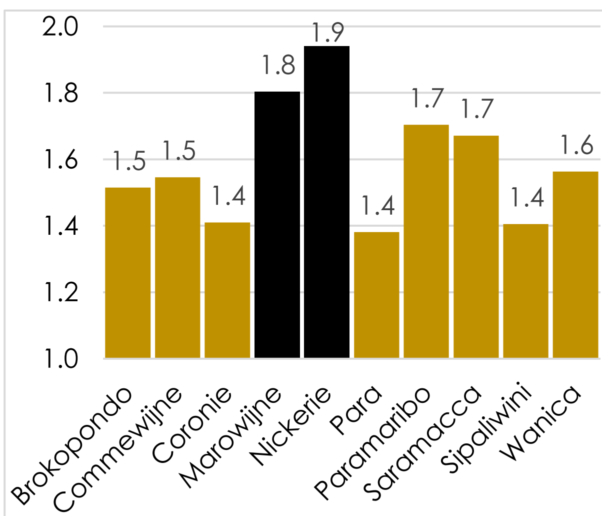
Several factors contribute to the vulnerability of the exposed elements:

- **Unconfined aquifers in low lying coastal areas** are expected to be unaffected by sea-level rise, whereas unconfined aquifers may suffer from saltwater intrusion. In this case, the volume of freshwater an aquifer can store is reduced as its water table cannot rise freely and is limited by the saltwater. This occurs where land surfaces are low-lying and where groundwater discharges into streams (Jiménez Cisneros et al. 2014). Moreover, saltwater intrusion leads to salinization of the aquifer. Salt-levels exceeding the WHO guideline value of 250 mg/L have already been observed in areas such as Nickerie, the north of Paramaribo, and in Commewijne (Waterforum, 2019).
- **Protective infrastructure of freshwater sources**, and the treatment, storage, and distribution can easily be overwhelmed by storm waters and floods. In principle, pathogens, nutrients, and hazardous chemicals are diluted by higher flows (WHO, 2017). In practice, however, overwhelmed water systems usually have higher concentrations of pathogens and hazardous chemicals during high flow periods, particularly the first flush. Specific protection measures include the sealing of wells with a protective cap of concrete or clay that extends several meters below the surface and acts as a barrier against contamination from the surface (Elliot, Armstrong, Lobuglio & Bartram, 2011). Catchment and storage works may also be protected from non-climatic hazards that can introduce pathogens and reduce water quality, like recreation and grazing in their direct proximity.
- **Septic tanks in the coastal area** with poor design, installation, and employment, and lack of enforcement and monitoring of related laws may result in the pollution of water resources, especially unconfined aquifers. Surface water entering septic tanks after flooding events leads to effluent overflow into streams, rivers, and unconfined aquifers.
- **Strong institutions concerned with water resource management** and close cooperation between them, including those specializing on climate change adaptation, contribute to water quality and quantity.
- Of the three **aquifers from which groundwater is abstracted** only the Zanderij aquifer recharges from rainfall percolation in the savanna belt (UNDP, 2016). Due to reductions in precipitation, increases in overland flow during the more frequent rainstorms, and increases in evapotranspiration, recharge of this aquifer and water availability will drastically decline.
- **Unsustainable water consumption** from population growth will severely affect the availability of water. An increase in water consumption not only affects water availability but also quality as excessive extraction results in increased saltwater intrusion (ATM, 2013). Over abstraction of groundwater is particularly harmful during the dry seasons when recharge rates are low.

- **Structures for water storage** include reservoirs, the damming of natural water bodies, ground excavations in low-lying plains fed either by rainwater or diverted rivers, among others. In areas that are increasingly dry, infrastructure may be needed to increase surface water storage and to enhance natural groundwater recharge (DFID, 2009).
- **Efficient leakage management** can be achieved through improved infrastructure, capacity building, and awareness raising. In urban areas, more leakage management and leakage detection technology can prevent and reduce leakage volume and speed up the repair by water utilities. This concerns small leaks which are often neglected, as large breaks only account for about 1% of water losses (Elliot et al. 2011).
- **Technological improvements** such as desalinization, and the use of alternative freshwater resources can reduce pressure on conventional freshwater sources, increase the supply of fresh water, and promote climate change adaptation, primarily through diversification of water sources and resilience to water quality degradation, as desalination technologies can produce drinking water even from highly contaminated water.
- Protective infrastructure. (see impact chain on infrastructure)
- Natural and artificial drainage. (see impact chain on infrastructure)

Figure 69 presents the results of the vulnerability subindex for the water sector:

***Figure 70**- Vulnerability of the water sector in the ten districts*



Source: SOC Report team elaboration

Figures 70-72 provide an overview of the indicators used to construct the vulnerability subindex.

Figure 71- SWM and DWV water production (m3/day) per capita[6]

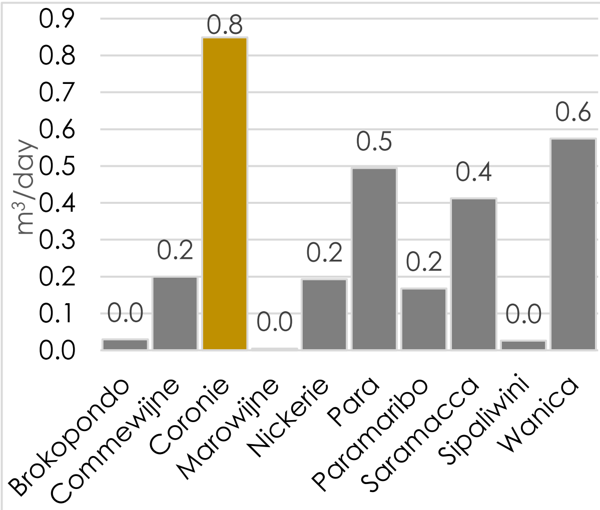


Figure 72- Storage capacity (m3/day) per capita[7]

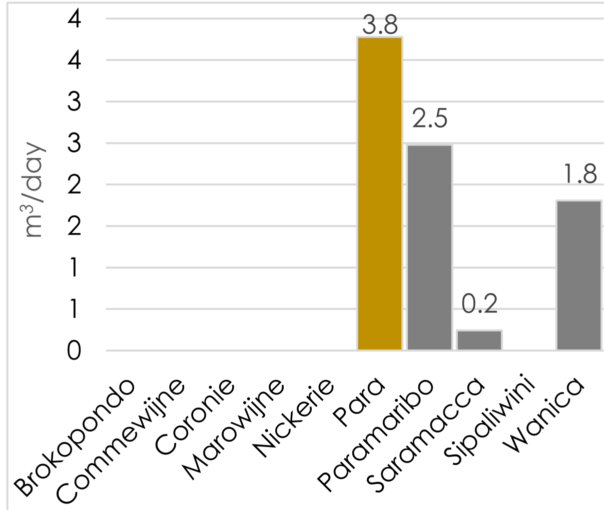
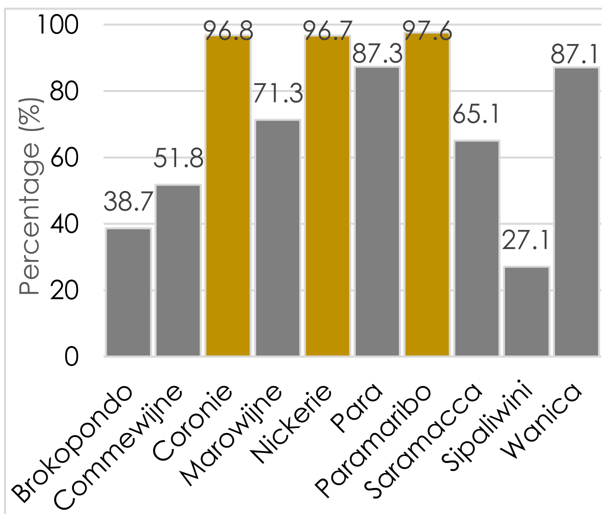


Figure 73- Number of households which main source of drinking water is not rainwater collection as a percentage of the total number of households



Source: SOC Report team elaboration

Nickerie is the most vulnerable district (Figure 69). It scores low on water production (figure 70) and only 3.3% of households have alternative sources of drinking water, mainly through rainwater collection (Figure 72).

The second most vulnerable district is Marowijne (Figure 69). It has the lowest water production

[6] Water production was considered beneficial. Therefore, the indicator was inverted upon including it in the vulnerability subindex. A high value in this figure corresponds to a smaller degree of vulnerability, and a small value corresponds to a higher degree of vulnerability.

[7] Only four of the ten districts had numbers for this figure. Storage capacity was considered beneficial. Therefore, the indicator was inverted upon including it in the vulnerability subindex, meaning a high value in this figure corresponds to a smaller degree of vulnerability, and a small value corresponds to a higher degree of vulnerability.

(Figure 70), however, almost 29% of households have alternative drinking water sources (Figure 72).

The least vulnerable districts are Para, Sipaliwini, and Coronie (Figure 69). Para has the highest water storage capacity out of all districts (Figure 71). Para also performs third best on water production (Figure 70), but fourth worst on alternative sources of drinking water with only 12.7% of households collecting rainwater (Figure 72). Sipaliwini has the second lowest water production (Figure 70), but it performs best on alternative sources of drinking water with nearly two thirds of households collecting rainwater (Figure 72). Coronie has the highest water production out of all districts (Figure 70), though few households collect rainwater (Figure 72).

5.3.3. Needs and responses

The following strengths, weaknesses, opportunities, and threats were identified for the water sector.

5.3.3.1. Strengths

- In 2016 the Government identified the need to develop a roadmap for integrated water resources management (IWRM), which is currently being developed under the lead of the NH.
- In April 2020, the implementation of the second phase of the GCCA+ project began, its parties reaffirming their joint efforts to increase resilience against climate change impacts. The overall objective of this phase is to build climate change resilience through IWRM, the sustainable use of mangroves, and management of coastal ecosystems.
- Within the French Development Cooperation project *Water Supply System Improvement*, one of the project components includes the upgrading and replacement of the surface water treatment plant in Moengo. The production capacity will be restored to 200 m^3 per hour. The new plant will also supply water to the surrounding villages Ricanaumofo and Abadoekondre.
- In February 2020, the construction of a second surface water treatment plant in La Liberté in Commewijne started. The plant will produce 500 m^3 per hour. The plant will also use desalinization techniques including a combination of UV and active carbon to reduce the high salinity of water from the Suriname River. This is the first drinking water treatment plant with state-of-the-art technologies and a role model for future treatment plants.
- The OW is aiming at involving the private sector and civil society in improving water drainage and infrastructure in Greater Paramaribo (United News, 2020).
- In March 2020, a USD 25 million project aimed at improving the efficiency and quality of the services provided by the SWC to over 3,700 households were approved and then financed by the IDB. The project will take six years to be completed. One of the components focuses on reducing the levels on non-revenue water by adopting smart water technologies that will replace outdated meters to reduce losses throughout the network in Greater Paramaribo (IDAB, 2020).
- Generally, there is a strong political will to foster IWRM, sustainability, and adaptation to climate change in the sector.
- Paramaribo and Wanica, the most populated districts, have an advanced wastewater drainage system.

- There are guidelines for constructing septic tanks to avoid groundwater contamination.
- The Suriname Water Resources Information System (SWRIS) is a web-based scientific framework with water-related information on Suriname, or water portal. It is open to the public. Its main goal is to promote and foster human resources development, knowledge, and techniques on IWRM in Suriname focused on the sustainable use of water resources. In addition to the online information system there are awareness programs about water resources for primary and secondary schools, training, and academic courses.
- The field equipment of the Hydraulic Research Division (WLA) was upgraded in 2019 when it received a second boat for data collection on water level rise, velocity, and increased quality at its measuring stations. Digital telemetric recorders and standalone data loggers for water level recording were successfully introduced as part of the planned modernization of WLA.
- After disastrous flooding in 2006 and 2008, an Early Warning System was developed in 2009 by the ADEKUS in cooperation with the NCCR to predict the occurrence of flooding of the Upper-Suriname River and the Tapanahony river. Since 2010 the network expanded with water-level measuring stations in Pikin Rio and the Gran Rio, the Coronie swamp, and the Nani swamp. Staff from NCCR, ADEKUS, and other institutions are trained in the use of this system and interpretation of the data.
- In 2016 the Interdepartmental Water Workgroup (IWW) was founded, but the working group fell apart in 2016 and 2017 due to a lack of political commitment and mandate.
- The Water Forum Suriname has organized workshops and public debates to promote IWRM for attaining water sustainability, as well as fostering regional and international partnerships with stakeholders sharing a common objective of sustainability. It has organized public debates and has published articles in newspapers like the World Water Day. Additionally, it actively participates in water-related workshops, and annually awards the best water student in Suriname.
- In 2018 Water Forum Suriname started a project to develop capacities for IWRM as part of the GCCA+ project by UNDP. This resulted in a report called the *Comprehensive Report for the Implementation of Integrated Water Resources Management* comprising a situation analysis and an action plan for implementing IWRM in Suriname).

5.3.3.2. Weaknesses

- The regulations on wastewater disposal, inter-institutional collaboration on wastewater disposal, and awareness of its importance are poor.
- Wastewater drainage systems are poorly maintained.
- A lack of enforcement of the Building State Order results in the poor design, installation, and employment of septic tanks. The institutions involved do not sufficiently collaborate to improve the enforcement of the order.
- The application of the guidelines for the construction of septic tanks is not controlled.
- SWRIS lacks effective coordination and promotion. Although the SWRIS website is a good platform for data sharing, it is not used in an optimal way by the stakeholders involved in the water sector. This has several reasons: stakeholders are not familiar with the website; part of the information on the website is outdated; data-sharing is not open and must be obtained by filling in a form; it is not clear what data can be requested; there is no clear

ownership of the website, who updates it and promotes contributing and retrieving data to and from it.

- There is only a limited number of WLA measuring and monitoring stations in operation. Previously the WLA had a hydrometric basic network consisting of around 140 measuring stations in operation until 1986. From these stations water levels, water discharges and water quality data were collected. At present, only 18 stations in the coastal area are in operation, and 2 stations are not in operation temporarily.
- Overall, the sector institutions suffer from poor data availability. Most of the available data is not in digital format. Some institutions have an open data policy, others request options with fees. There are no consistent data and information sharing arrangements. Some institutions like BOG, WLA, Meteorological Service, SWM, and DWV provide data to the ABS for the Environmental Statistics Report. Data availability for water resources is constrained by a lack of financial, technical, and human capital, and political will.
- Aquifers are not regarded as separate management units yet, and there is a lack of cooperation on their sustainable management. SWM is the only stakeholder with the information and tools to manage aquifers. SWM monitors changes of water quality and quantity in the aquifers, but only at the sites of their activities. The SWM also conducts research on the aquifers in cooperation with NH. However, no management instruments are in place to promote multi-level cooperation and address potential conflicts among users, stakeholders, and levels of government for an IWRM.
- NRW within greater Paramaribo is between 40-50% of total water supply. Revenue losses occur due to insufficient data collection and management.
- There is a shortage of academic staff at MDS and WLA. Staff qualifications and service has declined at MDS over the past fifteen years. Most of the employees only have a high-school background. The head of the service is the only employee that has a tertiary education academic background. There is currently only one staffing member trained to undertake meteorological modelling work.
- There is a poor cooperation between ministries and knowledge institutes such as the ADEKUS. Cooperation is mostly project-based and limited to sharing data and knowledge.
- Drinking water is being used for purposes other than human consumption like flushing toilets washing cars. For these purposes, other water sources of less quality could be used.
- There is limited public awareness on the efficient use of water.
- There is little research on the impact of climate change on water storage capacity.

5.3.3.3. Opportunities

- In 2009, ADEKUS started a project called *Management of Water Resources in North West Suriname under Climate-Change Conditions* (2009-2011/2013) in cooperation with Waternet-Nederlands. This project aims at developing water resource management strategies for a sufficient drinking water supply in urban and rural areas, and irrigation water supply in the agricultural areas in the district of Nickerie by 2050. All the necessary data have been collected and the next step is to analyze and prepare modelling strategies.
- There have been informal discussions on merging WLA and MDS, where data exchange takes place already. The possibility of transforming both existing institutions into privatized institutions and eventually falling under a Ministry, similar to the NIMOS institutional structure, could make investments in equipment and staff more feasible and cost-efficient.

- There are a number of promising international cooperation projects: the GCCA+ project on water boards funded by the European Union and UNDP, and the WLA, ADEKUS and BUZA work on defining the boundary of the Marowijne river (funded by the French Development Agency).
- The construction of the surface water treatment plant in Commewijne using desalinization technology is a new experience. If successful it can be used as blueprint for other areas.
- Some companies have wastewater disposal plants that comply with international standards. These can increase knowledge on wastewater disposal in the public sector.

5.3.3.4. Threats

- Water sources are drying out.
- Illegal mining, the inefficient use of pesticides, and illegal landfills contaminate freshwater.

5.4. Forestry

5.4.1. Context

5.4.1.1. Forestry in the geographical context

The total land area of Suriname encompasses 16.4 million hectares, of which about 93% are forested, resulting in a 15.2 million hectares of total forest cover (Table 40) (FAO, 2020). Suriname is committed to maintaining this forest cover and remaining a high forest cover and low deforestation (HFLD) country. Most forest cover, around 98% is undisturbed (FAO, 2020). Sipaliwini, Para, and Marowijne are the districts with the highest relative forest cover, which ranges between 78-98%. Sipaliwini, Brokopondo, and Para have the highest absolute forest cover. Paramaribo and Wanica have the lowest relative and absolute forest cover.

***Table 40**- Relative and absolute forest cover per district in 2015*

District	Relative forest cover (%)	District area (ha)	Absolute forest cover (ha)
Paramaribo	3	18,200	546
Wanica	15	44,300	6,645
Coronie	57	390,200	222,414
Nickerie	66	535,300	353,298
Commewijne	69	235,300	162,357
Saramacca	71	363,600	258,156
Brokopondo	72	736,400	530,208
Marowijne	78	462,700	360,906
Para	87	539,300	469,191
Sipaliwini	98	13,056,700	12,795,566
Total	**93**	**16,382,000**	**15,159,287**

Source: SBB (2017)

Suriname's forests can be categorized into three ecosystems: Open savannas, swamps, and dryland forests. About 80% of all forests are dryland forests and around 10% are march forests or swamps.

Open savanna

Open savannas can be considered remnants of the extensive Pleistocene climate savanna that once covered Suriname. Savanna ecosystems only survived where they were frequently burned. In the absence of fire, savannah vegetation eventually develops into forests (Berrenstein & Gompers-Small, 2016). Savannah forests, known as xerophytic forests, grow on excessively drained, permeable soils that rest on impermeable subsoils, hardpans, and rock. As a result, the soil contains little water during the dry season. These ecosystems can also be found in the hilly or mountainous areas of the interior, especially where lateritic caps, conglomerates, dolerite, and granite rocks and sandstones are covered with a thin layer of soil. There, they are known as mountain savannah forests (Berrenstein & Gompers-Small, 2016).

Open swamp

Open swamp can be split into five different ecosystems (Berrenstein & Gompers-Small, 2016):

- *Ecosystems of brackish water* are found in the estuarine zone at the coast. They are influenced by coastal changes and tidal action. Examples of such ecosystems include mangrove forests, locally interrupted by salty to brackish lagoons, low succulent salt-plant cover, and brackish herbaceous swamps.
- *Freshwater swamp forests/wetlands* are found slightly inland. They dominate the young coastal plain and part of the old coastal plain. Wetlands play an important role in supplying freshwater to the estuarine zone, contributing to the maintenance of the brackish condition of these waters. The swampy areas are inundated throughout most of the year, allowing a peat layer to accumulate on top of the mineral soil.
- *Low swamp forests/swamp wood* includes palm swamp forests. Low swamp forests become high swamp forests if no forest fires occur.
- *High swamp forests and creek forests* are found in the shallow freshwater swamps of the coastal plain, where strong fluctuations in surface water levels occur. This ecosystem comprises the climax vegetation in the ecological succession of wet areas. Similar forests known as creek forests are found along creeks. Typically, these are enriched by numerous species from the surrounding high dryland forest.
- *High marsh forests*/*seasonal swamp forests* are found on poorly drained soils. During the rainy season, the soil may be totally inundated. In dry seasons the soil does not desiccate. Species diversity is intermediate, falling between that of high swamp forests and high dryland forests. Marsh forests are usually abundant in palms.

The marine, near-shore ecosystems of the continental shelf of Suriname are strongly influenced by the east-west directed Guyana Current. The Guyana Current is an extension of the north equatorial current off Brazil that carries outflow of fresh, sediment-laden water from the Amazon plume, a 5-

10 m thick layer of water of low salinity separated from underlying oceanic water of high salinity by a shallow mixed layer. In effect, the Amazon plume creates high-suspended sediment, low-salinity, estuarine conditions in the shallow, near-shore waters of Suriname. Each year approximately 162 tonnes of Amazonian sediments are transported in suspension with the Guyana Current and about 108 tonnes move along the coast of the Guyanas in the form of mud banks (UNDP, 2016).

High dryland forest

The largest part of Suriname's undisturbed forest, and about 80% of Suriname's total surface, is high dryland forest. These ecosystems are found from sea level up to elevations of 400-600 m. General characteristics of these ecosystems include the presence of a high, dense canopy at 25-45 m, with emergent trees of up to 50-60 m. The number of species of trees is anywhere between 100-300 per hectare, providing an important habitat for large mammals and over 500 bird species (Berrenstein & Gompers-Small, 2016).

At elevations above 600 m, the high dryland forests of the highlands are found. These ecosystems are frequently covered in clouds, limiting the average number of sunshine hours. Furthermore, temperatures are lower, and the average humidity is higher than in the high dryland forests of the lowlands. Mosses, ferns, orchids, and bromeliads are abundant both in numbers and species. The flora and fauna of these montane forests are quite different from those of lowland forests (Berrenstein & Gompers-Small, 2016).

5.4.1.2. Deforestation

Table 41 provides an overview of deforestation rates since the year 2000.

Table 41*- Deforestation rates and absolute deforested area in the years 2000-2017*

Period	Deforestation rate (% of total forest cover)	Absolute deforested area (ha)
2000-2009	0.02	24,784
2009-2013	0.05	30,833
2013-2014	0.01	17,222
2014-2015	0.06	12,308
2015-2016	0.07	10,990
2016-2017	0.05	8,683
2000-2017		104,820

Source: SBB (2017), FAO (2020), ABS (2018)

Geographical distribution of deforestation

Deforestation between 2000 and 2015 is concentrated in the following districts (SBB, 2017):

- Paramaribo (29.8% of the forested area)
- Wanica (11.6% of the forested area)
- Brokopondo (4.9% of the forested area)
- Sipaliwini (0.3% of the forested area, but overall is larger than Brokopondo's deforested area)

Deforestation drivers

Deforestation of 72.9% (62,102 ha) of the total deforested area (85,146 ha) has been attributed to mining activities, particularly gold mining. As gold prices increased from 2009 to 2012, with the price of gold peaking to almost USD 1,600 per troy ounce, so did deforestation increase in Suriname, with a two-year delay. Equally, with gold prices plummeting from 2012 onwards, deforestation also decreased as seen in the rate for 2015. The other main drivers of deforestation are infrastructure and urban development, accounting for 15.2% (12,964 ha) and 4.0% (3,424 ha) of the total deforested area (SBB, 2017).

Some drivers are more important for some districts than others:

- In Wanica and Paramaribo, urban development accounts for 36% of total deforested area, agriculture for 28% of total deforested area, and conversion to pasture with 25% are the main drivers of deforestation (SBB, 2017).
- In Brokopondo and Sipaliwini the main drivers of deforestation are mining and infrastructure, with mining accounting for 87% and 81% of the districts' total deforested area. These districts form part of the Green Stone Belt which is a gold-rich geological deposit that stretches through the eastern part of Suriname. (SBB, 2017).

5.4.1.3. Protected areas

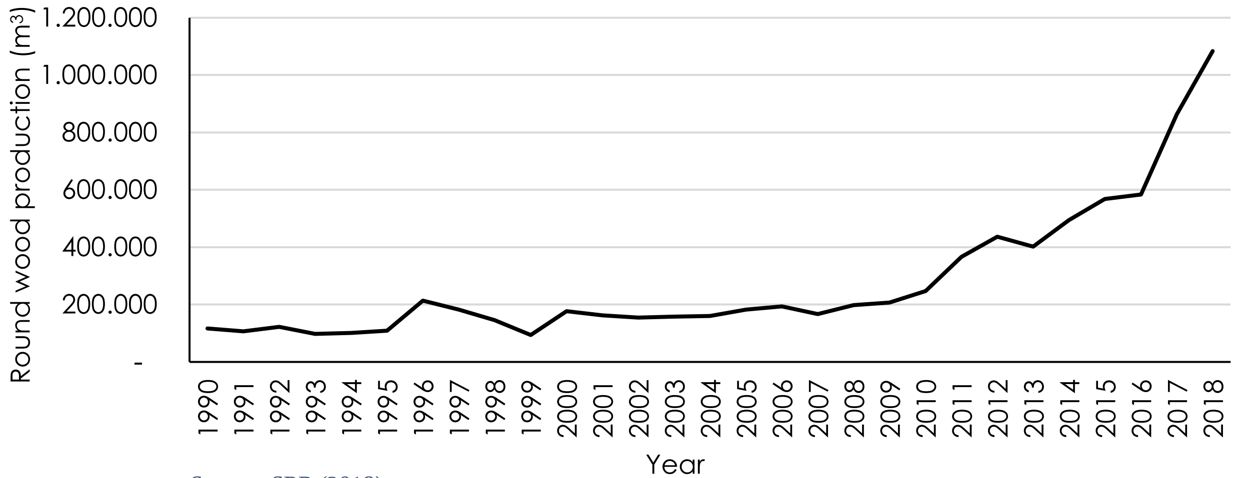
Suriname has 16 designated protected areas which cover 14% of the country's surface (2.3 million ha) (FAO, 2020). Four additional protected areas are currently proposed: Nani Nature Reserve (54,000 ha), Kaburi Nature Reserve (68,000 ha), Mac Clemen Special Protected Forest (6,000 ha) and Snake Creek Special Protected Forest (4,000 ha). Most of the designated protected areas are terrestrial or marine-terrestrial and are important to the sector due to the opportunities for eco-tourism they offer.

5.4.1.4. Importance of the sector to the country's economy

On a macro-economic level, forests are particularly important for both the forestry and the tourism sector. In 2017, the forestry and tourism sectors contributed 2.5% and 3.5% to Suriname's GDP, (Knoema, 2020). In total, 6,650 people are employed in the forestry sector which is 3.5% of the economically active population (FAO, 2020; Berrenstein & Gompers-Small, 2016).

Most of the forestry contribution to the country's GDP is based on timber production and wood export. Timber is produced in a 4 million hectare forest belt authorized for sustainable forestry by the Center for Agricultural Research Suriname (CELOS) management system. A gradual expansion of timber production took place over recent years, with a total amount of 176,516 m^3 of round wood produced in 2000 and a total of 1,083,758 m^3 of round wood produced in 2018, mostly in the district of Sipaliwini (SBB, 2018) (Figure 73).

Figure 74- *Round wood production (m3) 1990-2018*

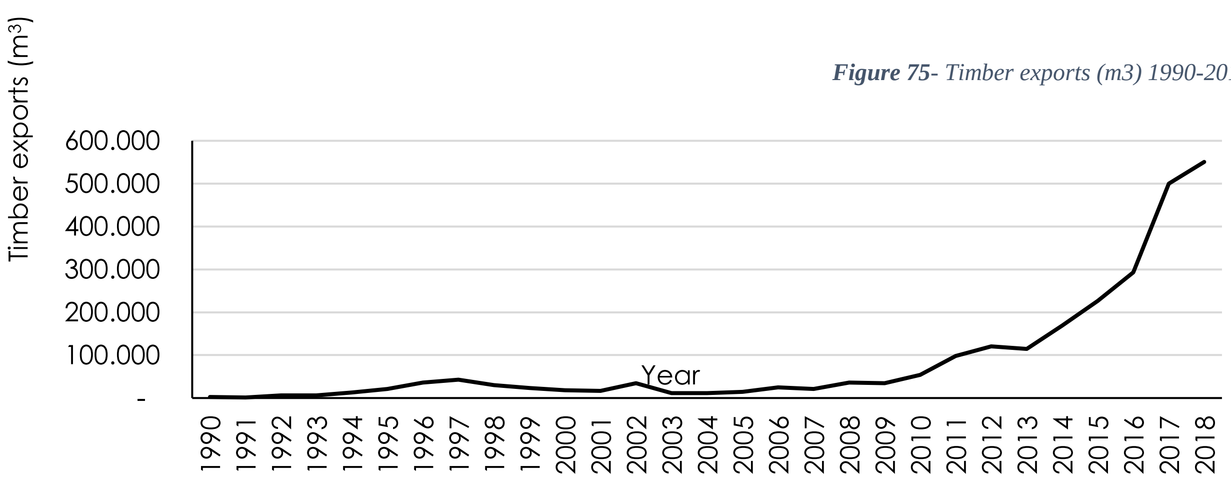


Source: SBB (2018)

In view of roundwood production, the years 2000-2017 can be divided as follows:

- 2000-2007: Round wood production was stable (on average about 170,000 m^3 per year).
- 2008-2012: Production increased steadily at 23% per year on average.
- 2013: Production decreased by 8% in 2013 compared to 2012. In April 2013, the EU-FLEGT scheme entered into force. This regulation allows only legally produced wood and wood products on the European market.
- 2014-2017: Production increased steadily at 22% per year on average. This growth is partly due to the high demand for raw materials, including round wood, on the Asian market.

Figure 75- *Timber exports (m3) 1990-2018*



Source: SBB (2018)

In view of timber exports (Figure 74), which mimic round wood production to some extent, the years 2000 to 2017 can be divided as follows:

- 2000-2007: Timber exports were stable, on average about 19,000 m^3 per year.
- 2008-2012: Exports increased steadily at 39% per year on average.
- 2013: Exports decreased by 5% compared to 2012, while the realized export value in 2013 increased by 4% compared to 2012, because in 2013 more processed wood was exported.
- 2014-2017: Exports increased steadily at an average of 45% per year. Compared to 2016, exports increased by 70% in 2017. In 2017, timber exports were 4.4% of Suriname's total national exports of USD 1.4 million.

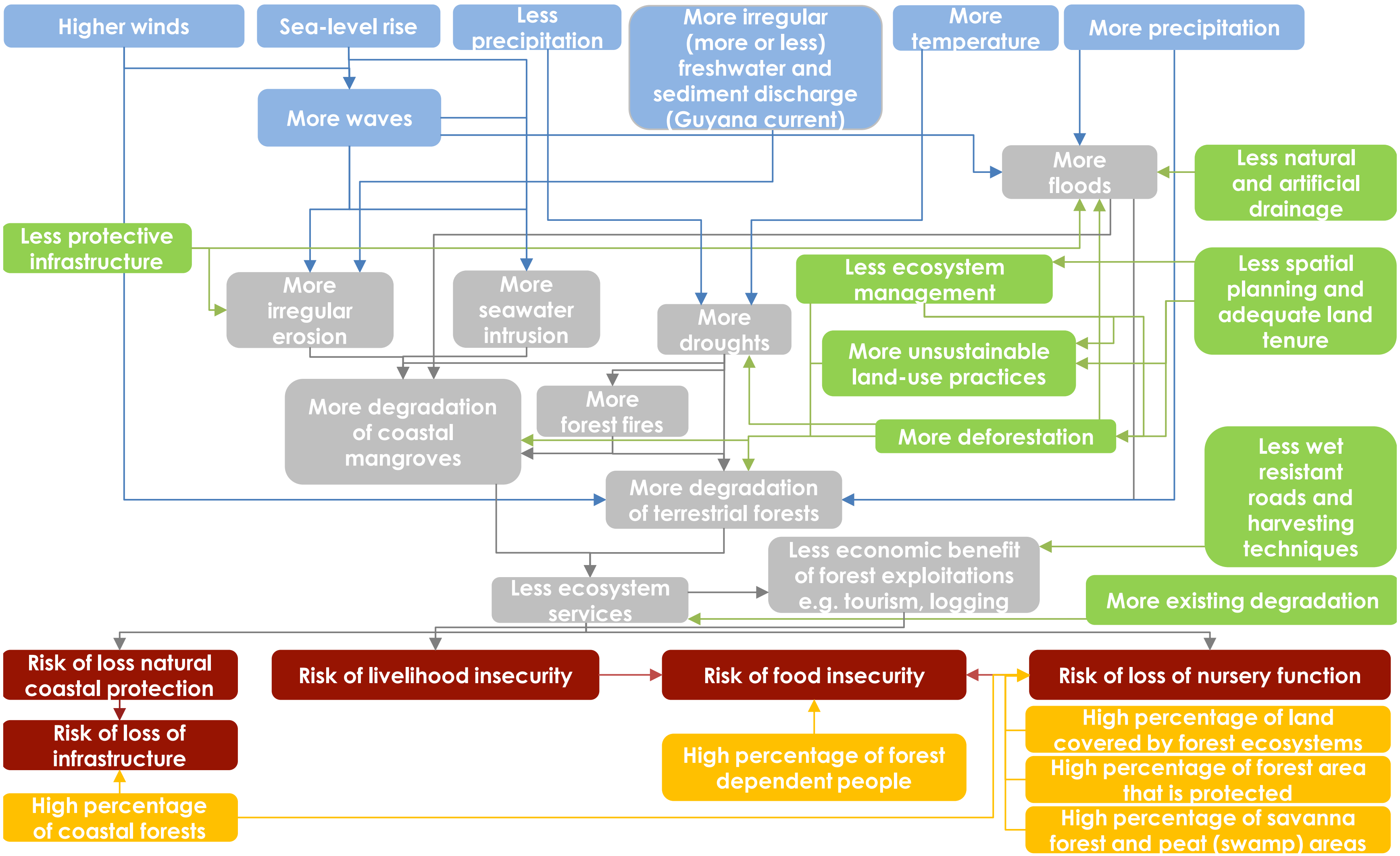
5.4.2. Climate impacts and risk

5.4.2.1. Historical impact of climate change on the forestry sector

The impacts of extreme climate events and gradual changes in climate have been rarely recorded for Suriname's forestry sector. Most of Suriname's forest ecosystems are unmanaged and unused. Due to the comparatively long lifetime of arboreous forest species and their physical persistence in the environment after the end of their lifetime, the effects of climate change on species' populations become evident long after the initial impact. However, the 2006 floods did have an economic impact on the use the forests for tourism, with total losses of SRD 4.4 million (Buitelaar, Kambon, Hendrickson & Blommestein, 2007). Ramnath (2012) also reported on the impacts of droughts in 2009 and 2012 on coastal forestry ecosystems in Bigi Pan, one of the most used multiple-use management areas on the west coast of Suriname. The author reported that the drought caused low water levels, an increase in the frequency of forest fires, and biodiversity losses in the area.

Increases in temperature and decreases in precipitation can lead to droughts, but the forestry sector is also affected by climate hazards like sea level rise, high winds, increases in precipitation, and the irregularity of the freshwater and sediment discharge from the Guyana Current. Figure 75 provides an overview of the impact chain for the forestry sector, including the most important hazards in blue, the intermediate impacts in grey, and final risks in red. They are the product of the factors of exposure in yellow, and vulnerability in green. The subsequent section provides an interpretation of each risk component.

Figure 76- Impact chain for the Forestry sector



Source: SOC Report team elaboration

5.4.2.2. Hazards

The forestry sector is affected by five main hazards: changes in precipitation, high winds, sea level rise, more irregular freshwater, and sediment discharge from the Guyana Current, and higher temperatures. High winds in combination with sea-level rise can lead to waves which affect the sector in the coastal regions.

The hazards impact the forestry sector differently according to geographic location. Sea level rise, changes in the Guyana Current, high winds, and waves mainly impact coastal forests, while higher temperatures and changes in precipitation impact both coastal and interior forests. With respect to the duration of the hazards, increases in precipitation, floods, high winds, and waves are relatively short-lived hazards for the forestry sector. On the other hand, increases in temperature and decreases in precipitation and the droughts they cause, as well as sea level rise, affect forestry ecosystems for longer periods of time and may have greater impacts.

Table 42 provides an overview of the relevance of the projected changes in climate hazards for the sector.

***Table 42**- Relevance of projected changes in climate hazards for the forestry sector*

Hazard indicator	Relevance	Explanation
Average, maximum, minimum daily temperature **Frequency of hot days and night, cold days and nights** **Accumulated yearly precipitation** **Number of rainy days per year**	High	Higher temperatures and less precipitation contribute to droughts and forest fires. These affect savannas and swamps wherever they occur throughout the country.
Maximum precipitation in five days **Maximum precipitation in one day**	High	The rise in intense precipitation events can lead to the flooding of forests by overflowing rivers.
Short dry season precipitation **Dry season precipitation** **Short rainy season precipitation**	Medium	The seasonality of rainfall is not crucial for the forestry sector. However, a drier climate contributes to droughts and forest fires and the effect is the same as for the indicators on temperature (see above).
Rainy season precipitation	Medium	At the coast, a drier climate contributes to droughts and forest fires and the effect is the same as for the indicators on temperature (see above). In the interior, a wetter rainy season can lead to an overflooding of forests and the effect is the same as for the indicators for intense precipitation events.
Maximum daily winds	Low	These indicators do not affect the forestry sector

Hazard indicator	Relevance	Explanation
Gale wind days Strong wind days		much.
Relative humidity	High	Reduced relative humidity contributes to droughts and forest fires. This affects savannas and swamps wherever they occur throughout the country.
Sea-level rise	High	Sea level rise causes erosion and saltwater intrusion which affects coastal mangroves.

Source: SOC Report team elaboration

5.4.2.3. Intermediate impacts

The sector suffers from four high-level intermediate impacts that lead to forest degradation:

1. **Irregular erosion** caused by more waves and more irregular freshwater and sediment discharge from the Guyana current degrades the coastal mangrove forests. Erosion and accretion/sedimentation are natural processes that normally exist in a steady state in healthy ecosystems, while the imbalance of these processes leads to the degradation of ecosystems.
2. **Seawater intrusion** caused by sea level rise and more waves changes the overall water salinity of mangrove ecosystems, which leads to their degradation (Maulud, Mohd, Wan, Jaafar & Benson, 2018).
3. **Droughts** caused by decreases in precipitation and temperature increases cause degradation of coastal mangroves as well as terrestrial forests (FAO, 2013). Moreover, droughts can contribute to forest fires which result in coastal and terrestrial forest degradation.
4. **Floods** caused by increases in precipitation and waves directly impact growth and productivity of terrestrial forests causing forest degradation (Parolin & Wittman, 2010).

The degradation of the coastal mangrove and terrestrial forests reduces the ecosystem's capacity to provide services, resulting in less economic benefit of forest exploitations such as tourism and logging.

5.4.2.4. Risks

The different intermediate impacts of fewer ecosystem services and the economic benefits of forest exploitations converge in the risk of livelihood insecurity. Livelihood can be defined as the method and means of making a living, consisting of capabilities, assets, and activities that are required for living. Livelihood insecurity increases the risk of food insecurity. The intermediate impact of fewer ecosystem services also leads to the risk of loss of natural coastal protection and the risk of loss of the forests' nursery function, which also contributes to the risk of food insecurity. The risk of loss of natural coastal protection results in risk of loss of infrastructure.

Therefore, climate change poses two risks for the forestry sector: risk of loss of infrastructure, and risk of food insecurity.

5.4.2.5. Exposure

The risk of food insecurity is most discernible for forest-dependent people (FAO & CIFOR, 2019):

- People who live in and natural forests or on the forest frontier, often as hunter-gatherers or shifting cultivators, are heavily dependent on forest resources for their livelihoods, primarily, but not always, on a subsistence basis. In Suriname, this applies to ITP living in the interior.
- People who live in the proximity of forests are usually involved in economic practices either within or near the forests, and regularly use forest products like timber, fuelwood, bush foods, and medicinal plants, partly for their own subsistence purposes and partly for income generation. In Suriname, this definition often applies to the people living in the rural areas.
- People rely on forests for commercial activities such as tourism.

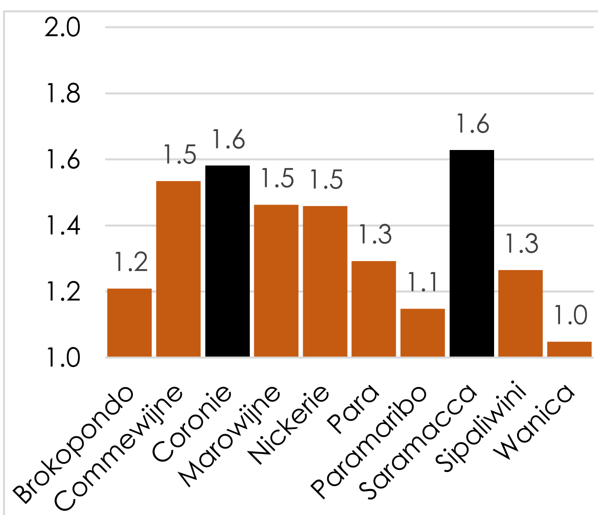
The risk of loss of natural coastal protection and loss of infrastructure is most eminent for coastal forests, as coastal mangrove forests currently provide a solid coastal protection for Suriname's coastal area.

As for the risk of loss of nursery function, the areas most at risks are:

- Coastal forests such as mangroves which fulfill a very important nursery function for terrestrial and marine species
- Districts and resorts that have a high forest cover and are therefore proportionally more exposed than those that have a low forest cover
- Protected forests have a high biodiversity and cultural value and are thus more likely to suffer losses
- Savanna forests and peat swamp areas which are particularly exposed to forest fires

Figure 76 presents the results of the exposure subindex for the forestry sector:

Figure 77- *Exposure of the forestry sector in the ten districts*



Source: SOC Report team elaboration

Figures 77-79 provide an overview of the indicators used to construct the exposure subindex.

***Figure 78**- Area of mangroves as a percentage of the total area of the district*

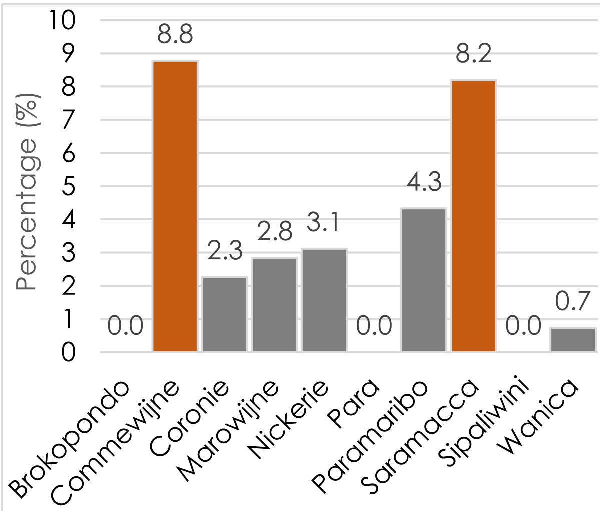


***Figure 79**- rea of open savanna and swamp as a percentage of the total area of the district*

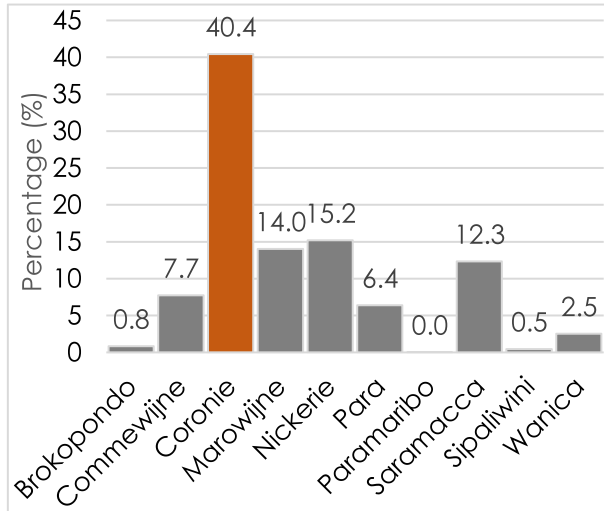
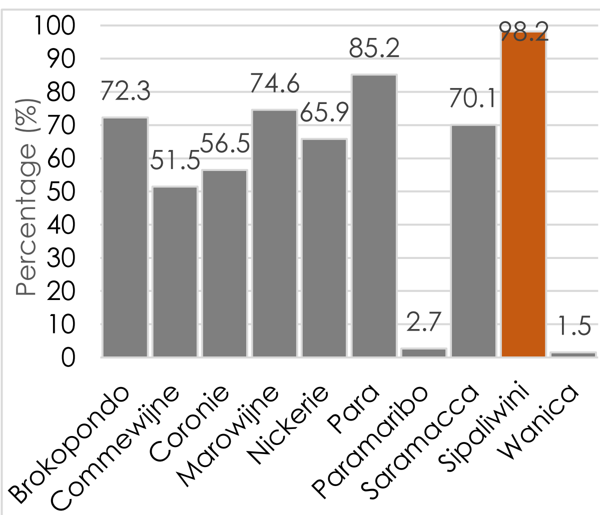


***Figure 80**- Area of forest as a percentage of the total area of the district*



Source: SOC Report team elaboration

Saramacca is the most exposed district (Figure 76). It has 8.2% mangrove cover, the second highest after Commewijne with 8.8%, and 2-3.5 times that of those other districts which have mangroves, but excluding Brokopondo, Para, and Sipaliwini which do not lie at the coast (Figure 77). Saramacca also has 12.3% savanna and swamp cover, comparable to that of Marowijne and

Nickerie (Figure 78). This is the indicator where Coronie, the second most exposed district, scores highest with 40.4% due to the Coronie swamp (Figure 78). Both Saramacca and Coronie score fairly on other forest cover (56.5% and 70.1%, respectively) (Figure 79). This is where Sipaliwini scores highest (98.2%), followed by Para (85.2%), Marowijne (74.6%) and Brokopondo (72.3%) (Figure 79).

Wanica is the least exposed district, as it consistently scores between lowest and fourth lowest on all indicators (Figures 77-79). The second and third least exposed districts are Paramaribo and Brokopondo, despite Paramaribo scoring higher on mangrove cover (Figure 77) and Brokopondo scoring higher on other forest cover (Figure 79).

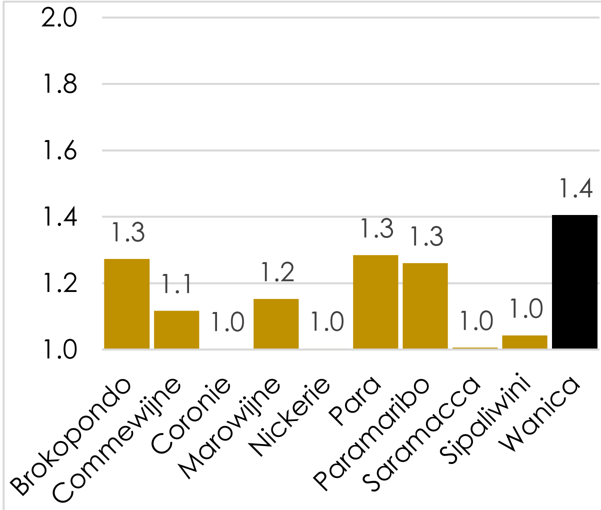
5.4.2.6. Vulnerability

Several factors contribute to the vulnerability of forest dependent people and forests:

- **Protective infrastructure** (see impact chain on infrastructure)
- **The lack of spatial planning and adequate land tenure** of forested areas contributes to unsustainable land-use practices and deforestation due to land-use conflicts. Spatial planning and adequate land tenure are also necessary for an effective ecosystem management.
- **Unsustainable land-use practices** such as artisanal mining degrade forests due to contamination with harmful chemicals.
- **Ecosystem management** through understanding the dynamics of ecosystems and human interactions with them, as well as defining protected areas or species, helps prevent unsustainable land-use practices, deforestation, and forest degradation.
- **Deforestation** and the removal of vegetative cover reduces the permeability of soils and their capacity to retain water and increases evapotranspiration and erosion. This amplifies floods and droughts, which affect forests. Deforestation itself also reduces the forest cover and affects forests' biodiversity due to fragmentation, thus leading to forest degradation.
- **Natural and artificial drainage** (see impact chain on infrastructure)
- In the logging sector, harvesting under wet conditions is more difficult. **Wet resistant roads and harvesting techniques** can minimize intermediate impacts and risks spurred by floods and increases in rainfall as they guarantee the economic benefit of logging activities.
- **Existing degradation** affects the forests' biodiversity and predisposes them to forest fires, droughts, floods, and erosion, which results in fewer ecosystem services.

Figure 80 presents the results of the vulnerability subindex for the forestry sector:

Figure 81- *Vulnerability of the forestry sector in the ten districts*



Source: SOC Report team elaboration

Figures 81-83 provide an overview of the indicators used to construct the vulnerability subindex.

Figure 82- *Deforested area between 2000 and 2015 as a percentage of the total forested area*

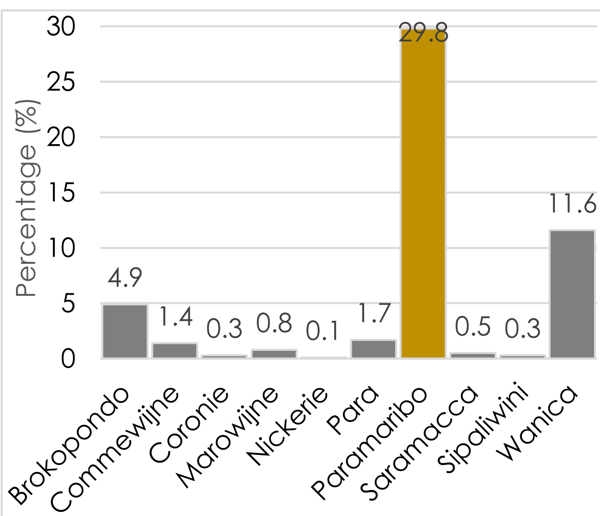


Figure 83- *Number of Amerindian and Maroon settlements per 10 km2 forest area*

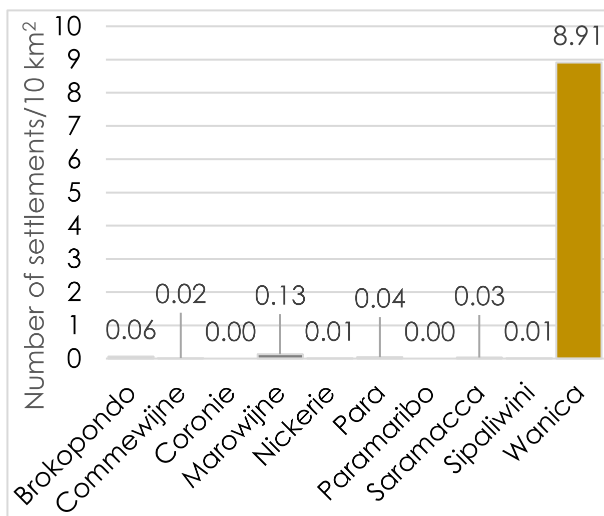
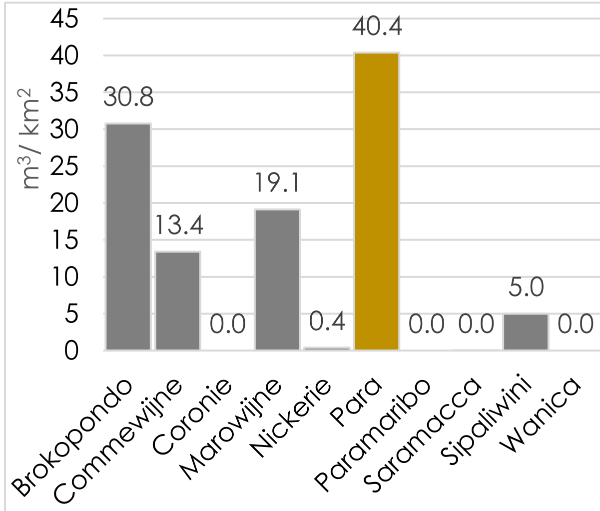


Figure 84*- Volume (m3) of roundwood produced per km2 forest*



Source: SOC Report team elaboration

Wanica is the most vulnerable district (Figure 80). It has the second highest deforestation rate with 11.6%, only Paramaribo scoring higher with 29.8%, whereas most other districts score below 2% (Figure 81). These numbers reflect that Paramaribo and Wanica are the smallest districts with the least forested area (Figure 79). Therefore, deforestation is noted very easily. Moreover, Wanica has the by far highest density of Amerindian and Maroon settlements, followed by Marowijne (Figure 82) Wanica also has no considerable roundwood production (Figure 83).

The second, third, and fourth most vulnerable districts are Para, Brokopondo, and Paramaribo, (Figure 80). Para has a fairly high deforestation rate (Figure 81), settlement density (Figure 82), and the highest roundwood production per km^2 forest with 40.4 m^3 (Figure 83), as Sipaliwini is the biggest roundwood producer but has a high forest area. Brokopondo has the third highest deforestation rate with 4.9% (Figure 81) and second highest roundwood production per km^2 forest with 30.8 m^3 (Figure 83). Paramaribo has the highest deforestation rate (Figure 81).

Although Coronie is the second most exposed district, it is the least vulnerable district. The second least vulnerable district is Nickerie. They perform consistently low on all indicators (Figure 81-83).

5.4.3. Needs and responses

The following strengths, weaknesses, opportunities, and threats were identified for the forestry sector.

5.4.3.1. Strengths

- There is a common interest in the development of alternative livelihoods in the interior. This can reduce the vulnerability of forest-dependent people.

- Efforts have been made in the logging subsector over the past years to increase the sustainable development and utilization of the community forest of indigenous and tribal communities. This would decrease the vulnerability of these forest-dependent people.
- There are some initiatives and pilots to market NTFP's internationally. Marketing NTFPs would reduce the vulnerability of forest-dependent people.
- A draft of a law considering nature conservation has been developed which benefits sustainable forest management and climate change resilience of forests.
- A draft Coastal Protection Act has been developed and submitted to parliament. This will benefit mangrove conservation.
- With the draft on ITP land rights submitted to parliament, there is momentum for parties to finalize the process and create more clarity on land tenure of forested areas. This will reduce land conflict and unsustainable forest management as well as the vulnerability of forest-dependent people.
- With the change of government, intentions to address spatial planning have been materialized by creating a new ROM.
- Suriname is making an effort to become a participating country in the Extractive's Industry Transparency Initiative (EITI). Mining is Suriname's main driver of deforestation. The EITI will reduce forest degradation and thus increase the resilience of forests to climate change.
- Suriname is engaging in the REDD+ mechanism and currently finalizing the Readiness phase. A REDD+ strategy has been developed. In addition to the efforts to build institutional capacities for better use and management practices, Suriname also leverages its forests for financial compensation.
- Efforts have been made in promoting a sustainable exploitation policy for wood processing. Sustainable wood processing will reduce the vulnerability of forests to climate change.
- The government adopted the Environmental Framework Act. According to this Act, the planning of developments in the forestry sector is subject to a strategic environmental impact assessment which evaluates the effect the project, sector policy, plan or program has on the environment. The Act also addresses land tenure and land rights of indigenous and tribal people by ensuring the enforcement of consultation and free prior informed consent.
- The country has a low population density and thus human pressure on forests is comparatively low. Therefore, the vast majority of Suriname's forests are still intact and thus resilient to climate change impacts.
- The population has a profound traditional knowledge of forests, their sustainable use and management, an important asset for adapting to climate change.
- There are 16 legally established protected areas which cover 14% of the country's surface and many different types of forest ecosystems, including mangroves and savannas. Their legal status provides an important basis for ensuring their adequate management and use, including in the context of climate change.
- The country has a good policy basis for the enforcement and monitoring of logging controls and forest conservation. These are important to reduce the pressure on forests, which are already facing important climate hazards.
- There is a lot of data available on forests (e.g. on the Gonini Geoportal). The National Forest Monitoring System monitors deforestation. The Sustainable Forestry Information System Suriname tracks logging activities. This data can be used to design adequate adaptation strategies for forests.

- With regards to mining activities, the country has ratified the Minamata Convention to prevent mercury pollution from gold mining.

5.4.3.2. Weaknesses

- There are few opportunities for the development of alternative livelihoods in the interior due to less access to education, energy, and communication compared to the coast. Thus, the population depends on forests and their resources. If forests are negatively impacted by climate change, so are the livelihoods of those peoples.
- Protected area management is not a priority on the political agenda, and there is a lack of technical capacity to harvest the economic potential of protected areas. However, leveraging the environmental, economic, and cultural value of protected areas can provide additional benefits to the country and reduce the socioeconomic vulnerability of its population.
- The predominant export of roundwood production limits its benefits (employment, income, technological development) to forest-dependent people. If more value were added to roundwood before export, this would improve the socioeconomic development of the population and reduce its vulnerability to the impacts of climate change.
- There are policy gaps in spatial planning and land use. The existing laws are not fully implemented, raising the likeliness of unsustainable use of forests, making them prone to degradation and the effects of climate change.
- Land tenure of Suriname's forested area remains unclear, as it relates to land rights of indigenous and tribal people. Land conflicts encourage degradation which increases the vulnerability of forests to climate change. Land conflicts also result in more vulnerable livelihoods of forest-dependent people.
- Weak institutional capacities limit the monitoring of mining activities and enforcement of regulations. This results in the unsustainable use of forests, making them prone to degradation and the effects of climate change.
- There is a lack of capacity for SFM related to logging, which would enhance the resilience of forests to climate change.
- Currently the concession issuing policy results in the underutilization of concessions. Underutilization of residual wood and waste is also a problem. More concessions are needed to harvest the same economic benefit. This encourages deforestation and results in a greater vulnerability of the forestry sector.

5.4.3.3. Opportunities

- The global demand for wood is developing in favor of Suriname and there are potential international markets for NTFP. Such economic development can boost the region and reduce the socioeconomic vulnerability of forest-dependent people.
- The payment for ecosystem services could provide important economic incentives to forest-dependent people and reduce their vulnerability.
- There is great support from civil society organizations and NGOs to support the government in planning and implementing ecosystem management which can reduce the vulnerability of forests.

- External funding to compensate for carbon sequestration and other forest-related ecosystem services are available (e.g. the REDD+ mechanism). This encourages the conservation of forests and results in their enhanced resilience.
- There are sustainability-related certification schemes for logging and wood processing companies that allow them to access a broader market and increased revenues.
- There are direct foreign investments in sustainable forestry and wood processing.
- Leveraging the environmental, economic, and cultural value of protected areas can provide additional benefits to the country and reduce the socioeconomic vulnerability of its population.

5.4.3.4. Threats

- There is an information gap, as the logging industry of the forestry sector is negatively perceived by society, which overall does not value SFM options and related development potentials.

5.5. Infrastructure

5.5.1. Context

For this report, infrastructure is defined as structures and facilities that underpin energy systems, transport, telecommunications, and buildings, especially in the urban context, and that are intended to deliver services in support of human quality of life.

The World Economic Forum Global Competitiveness Report (2013) ranked Suriname 79th out of 148 countries regarding the quality of its infrastructure overall. The quality of its roads was ranked 71st, that of its port infrastructure 43rd, its electricity ranked 91st, and the mobile telephone subscriptions 7th (Hanouz, Geiger & Doherty, 2014). Currently, infrastructure developments focus mainly on the pavement of roads, rehabilitation of dams, and building of public housing. Infrastructure activities have mostly been centered in the capital Paramaribo where the country's main economic activities take place. It is estimated that 75% of Suriname's GDP originates in Paramaribo (IDB, 2016), where 69% of the country's population lives (World Bank, 2019a).

5.1.1.1. Energy

The following section is on the energy carriers and consumers, producers and providers, and transmission and distribution.

Carriers and consumers

The main energy carriers in Suriname are fuel (oil, gasoline, kerosene, diesel), electricity, liquified petroleum gas (LPG), and biomass (wood).

- Fuel is mostly consumed by the transport sector to produce kinetic energy, as well as for industry and electricity generation.
- Electricity is mostly used by households and industry. Over 85% of the population have access to electricity, where 79% are connected to the national grid and 6% rely on generators. Electricity demand increased by 2.7% between 2013 and 2017 (ABS, 2018).
- LPG is mostly used by coastal households for cooking. In the coastal districts of Paramaribo and Wanica 91% of households use LPG to cook, and only 7% of households use wood or charcoal (ABS, 2018).
- Biomass is mostly used by households in the interior for cooking and by small businesses to produce thermal energy. In total 130.675 m^3 of wood per year are used for energy purposes. Households, mostly in Sipaliwini where LPG is scarce, consume the most wood, mainly for cooking (57,200 m^3 of wood per year) (Matai, Jagessar & Egerton, 2015). Entrepreneurs or agencies use wood for operating their activities such as drying and smoking fish, producing cassava bread, baking activities, and cremation.
  In 2017, local sawmills processed 307,500 m^3 of round wood, of which 40% resulted in processed products and 60% in waste and scrap. Waste and scrap are destroyed by, among other things, incineration. In the case of three companies, this supplies the entire energy for the wood drying process.

Producers and providers

The main energy producers are Staatsolie, the Energy Company of Suriname (NV EBS), and the NH, precisely the Department of Rural Energy (DEV).

The state-owned company Staatsolie produces 15,000 barrels of oil per day and exports crude oil, diesel oil, fuel oil, and bitumen (Staatsolie, 2020). Two of the company's main production sites are the Tambaredjo oilfield and the Calcutta oilfield in Saramacca. From there, the crude oil is transported via a 55 km long pipeline to storage and distribution facilities at the refinery near Paramaribo. Staatsolie also runs a thermal power plant with a capacity of 96 MW, whose electricity is transferred to NV EBS (on average 35-45 MW) for distribution. NV EBS also purchases diesel from Staatsolie.

Since 2020 the Afobaka hydropower plant, which was run by the Suriname Aluminum Company (Suralco) for 75 years, is owned and operated by Staatsolie (precisely, the Staatsolie Power Company Suriname (SPSC), an independent power producer and subsidiary of Staatsolie). It has a capacity of 189 MW. The power generated at Afobaka is transferred to NV EBS for distribution. Most of Suriname's electricity, is generated by the Afobaka Hydropower Plant (IEA, 2018), and is the supply for almost half of the electricity consumption of Paramaribo and its surroundings. Other hydro-systems are a 40kW micro-hydropower plant at Poeketie and 405 kW mini-hydropower plant at Gran Olo in Sipaliwini.

The NV EBS provides most of Suriname's electricity, and has two centralized large-scale electricity generation systems: Electricity Paramaribo (EPAR), and Electricity Nickerie (ENIC). EPAR and ENIC generate electricity with thermal fuel oil and diesel power plants in Paramaribo and at Clara Polder.

EPAR generates electricity for greater Paramaribo and parts of the districts Commewijne, Wanica, Para, and Saramacca. It has a capacity of 168 MW (to which the outputs of the Staatsolie thermal power plant (96 MW) and Afobaka hydropower plant (189 MW) are added) and had 143,485 customers in 2017, of which 88% are residents, 10% businesses and 0.3% industrial (Castalia, 2018).

ENIC has a capacity of 25 MW. ENIC supplies electricity to the city of Nieuw Nickerie and the rice plantations in the area around the city.

The DEV is in charge of rural electrification of the sparsely inhabited interior. The DEV owns and operates diesel generators in 130 villages with a total capacity of about 4.5 MW, serving about 37,000 people (ABS, 2014b). DEV delivers diesel monthly to provide electricity for 4-6 hours per day. However, high diesel prices and transportation costs (with many villages being only accessible by plane or boat) raise the price of electricity and limit effective access to electricity. In total 6% of Suriname's population, namely those who live in the interior, rely on electricity from diesel generators (Raghoebarsing & Reinders, 2019).

A part of rural electrification in Coronie, Marowijne, and Nickerie as well as the villages Apura, Washabo, and Section in Sipaliwini is also provided by NV EBS. Here, isolated small-scale electricity generation systems have been installed for households that are not connected to the national grid.

Table 43 provides an overview of the most important electricity producers, electricity generation plants and their installed capacities.

Table 43*- Suriname's major electricity producers, electricity generation plants and their installed capacities (MW)*

Producer	Plant	Capacity (MW)
Staatsolie	Thermal power plant	96
	Afobaka Hydropower Plant	189
NV EBS	EPAR thermal power plant	168
	ENIC thermal power plant	25
DEV	Diesel generators in approximately 130 villages	4.5

Source: SOC Report team elaboration

Electricity transmission and distribution

Electricity in Suriname is transmitted over long distances by high voltage transmission lines of 161 kV, while the distribution of electricity takes place over 33 kV, 12.6 kV, and 6.3 kV transmission lines. The operating frequency is 60 Hz and the voltage supplied is 127 V or 220 V. Distribution categorizes costumers into five types: residential, social, small commercial, and large and industrial commercials.

5.1.1.2. Transport

The transport sector is divided into three subsectors, namely road transport, air transport, and water transport.

Road Transport

The road transport in Suriname is made up of primary, secondary, and tertiary roads where a primary road is defined as a road of national importance both socially and economically according to the Roads Authority Act. The total length of the road system in Suriname is 4,305 km and comprises asphalt, paved, sand-shell, and laterite roads. 1,105 km of the road system are in Paramaribo and 1,126 km in Wanica, equal to 52% of the entire road system. Over 78% of the total road system in Paramaribo is made of asphalt or paved (Table 44).

The hinterland consists of an extensive network of rivers and airfields, but a poorly developed road system. Water transport is mostly used by indigenous and maroon tribes (Berrenstein & Gompers-Small, 2016). In Marowijne, Para, Brokopondo, and Sipaliwini laterite roads of a total of 473 km serve the transport of timber, granite, and other natural resources, and to connect various villages situated along primary, secondary, and tertiary roads, and rivers.

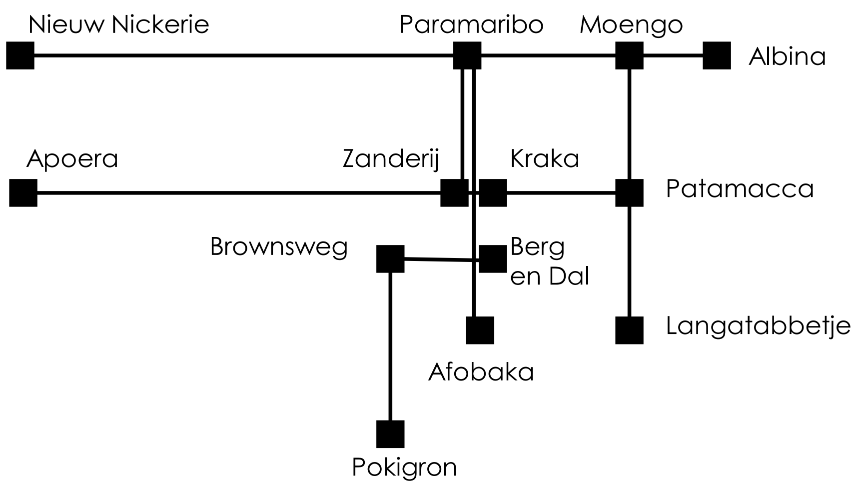
Table 44- *Roads (in km) of different materials per district in 2019*

District	Asphalt	Paved	Sand-shell	Laterite	Total in Km
Paramaribo	706	152	247	0	1,105
Wanica	409	96	621	0	1,126
Saramacca	147	2	167	0	316
Coronie	85	0	5	0	90
Nickerie	258	37	26	0	321
Commewijne	125	12	123	0	260
Marowijne	143	5	0	50	198
Para	201	7	95	24	327
Brokopondo	138	0	16	32	186
Sipaliwini	10	0	0	367	377
Total	2,223	311	1,299	471	4,305

Source: Personal communication with the OW (2020)

Suriname's primary road system has three axes (Figure 84).

Figure 85- Suriname's primary road system



Source: Blupfand (2006)

The three axes that the primary road system connects are:

- East and west (north) from Nieuw Nickerie to Albina serves many functions and a great part of Suriname's population, connecting districts, cities, resorts, and villages. The primary road is of asphalt and complemented by secondary and tertiary asphalt, paved, or sand-shell roads.
- East and west (south) from Apura to Patamacca runs through the forest belt and has an important productive function. The road is made of laterite and crosses 18 bridges of wood and steel.
- North and south from Paramaribo to Pokigron is an asphalt road that connects the hinterland and the capital (COSIPLAN, 2002).

All regions and the capital Paramaribo are connected via the primary road system. In the regions the primary roads often end at rivers where transportation continues by water at:

- Pokigron (Sipaliwini)
- Berg en Dal and Afobaka (Brokopondo)
- Apura and Nieuw Nickerie
- Albina (Marowijne)

Air transport

Air transport in Suriname is divided into international travel and local travel. The Johan Adolf Pengel Airport is an international airport and located in Para. With an annual capacity of 300,000 passengers, it is the country's largest airport. Another international airport is the de Zorg & Hoop Airport located in Paramaribo. The majority of its flights, however, are domestic (Ricover, 2015).

In addition, there are local and small airports are spread all over Suriname, especially the interior. These airstrips provide transportation to mostly isolated indigenous and maroon village for the purpose of communication, education, and health services, as well as the supply of goods such as food, medicine, and fuel. These airstrips also provide services for the tourism industry by operating flights for tourists to visit the nature resorts of the interior.

Water transport

There are 17 certified harbors in Suriname, most of which are in Paramaribo and Wanica (ABS, 2018). Suriname has two main ports, the Port of Paramaribo (Dr. Jules Sedney Port) and the Port of Nieuw Nickerie. Both ports are currently administered by the autonomous, state-owned, limited liability company NV Havenbeheer Suriname. The Dr. Jules Sedney Port is located on the Suriname River about 34 km from the estuary of the Suriname River in the Atlantic Ocean. As the main cargo gateway, the port handles approximately 90% of Suriname's total seaborne trade, excluding oil. With respect to the Port of Nieuw Nickerie, its importance has declined over recent years (Berrenstein & Gompers-Small, 2016) and the port is currently under-utilized. NV Havenbeheer Suriname is working toward upgrading facilities to increase freight flows through this port.

5.1.1.3. Buildings

Almost 90% of Suriname's population lives along the 384 km long coastal plain, with 44% coming from Paramaribo and 22% from Wanica (ABS, 2014b). Suriname's urbanization rate is around 1% (2010-2015) and 70% of the Surinamese live in urban areas. Current population projections estimate an increase in the total population to 2.5 million people by the end of the century. Three quarters of this increase are projected to occur in Paramaribo and Wanica (Government of Suriname, 2019).

In 2019 an average of 3% of the households in Paramaribo and Wanica (98,477 total households) indicated that their dwelling was in very good condition, 44% of the households indicated that their dwelling was in a good state, 39% in reasonable state, 13% in bad state and 1% indicated that their house was in very bad condition (ABS, 2020, p.15, table 1.4a). The most used building construction materials are block only, followed by wood and block, and wood only (Table 45).

Table 45*- Percentage of household in Paramaribo and Wanica by the most important materials of the outer walls of the dwelling in 2016*

Construction material	Percentage of households (2016)
Wood	18
Block	58
Wood and block	22
Other	1

Source: ABS (2018)

5.1.1.4. Telecommunications

In 2019, 14% of inhabitants had a fixed broadband subscription (World Bank., 2019b), 58% of urban, 42% of rural coastal, and 22% of rural interior households had access to internet at home (Ministry of Social Affairs and Public Housing, 2019). Broadband connections are reliable in the more populated coastal region, though poor in the interior, where the deployment of telecommunication infrastructure is affected by the terrain, population, and vegetation density. These conditions prompt private operators to prioritize investments in coastal areas, making access to mobile telecommunication services scarcer in interior regions (Cabrera & Gabarró, 2017).

5.5.2. Climate impacts and risk

5.5.2.1. Historical impact of climate change on infrastructure

The floods in May 2006 caused losses and damage of approximately USD 40 million across the energy, transport, housing, communications, health, education, agriculture, tourism, commerce, and trade sectors (Falconi, Melandri, Thomas and Edward, 2016). Moreover, three people were killed during the floods and 25,000 people affected (Table 46).

All disasters in Table 46 (floods, heavy winds, storms) affect energy infrastructure (snapped light poles), transport infrastructure (toppled trees on roads, damaged roads), buildings (torn roofs) and telecommunication infrastructure (damage of poles, lines, etc.).

Table 46- *Climate-related disasters in Suriname, and the number of people injured or killed, and homes affected for the period 1969-2017*

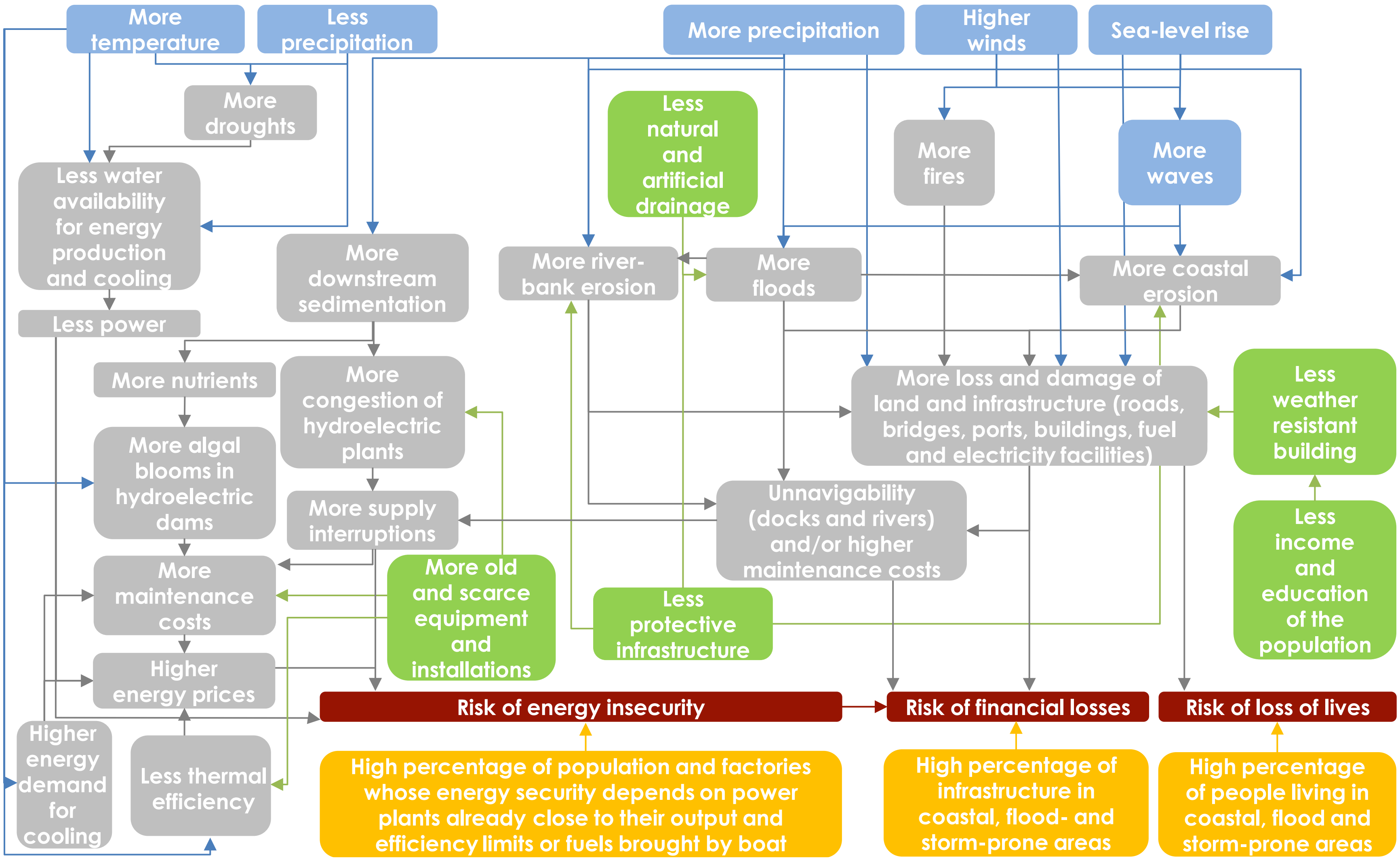
Event	Month and year	Number of people killed/ injured	Number of people/ homes affected
Flood	1969	-	4,600 people
Flood	**2006**	**3 deaths**	**25,000 people**
Flood	2008	2 deaths	6,548 people
Flood	May 2013	-	-
Strom/ Flood	June 2013	-	300 homes
Flood	2013	-	-
Hailstorm	January 2014	-	150+ homes
Heavy storm	July 2014	4 injured	150 homes (including a school and hospital)
Heavy storm	June 2015	1 injured	35 homes
Heavy storm	June 2015	1 death	183 homes
Heavy storm	July 2015	2 injured	562 homes
Heavy storm	December 2015	-	10 homes
Heavy winds	May 2016	-	36 homes
Floods and storm with heavy winds	June 2016	2 injured	-
Heavy winds	May 2017	-	69 homes
Heavy winds	August 2017	-	10+ homes

Event	Month and year	Number of people killed/ injured	Number of people/ homes affected
Tail of heavy tropical storm	September 2017	-	30 homes

Source: NCCR (2017) adopted from ABS (2018)

Apart from increases in precipitation causing floods, storms, and waves, the infrastructure sector is also affected by climate hazards such as sea level rise, increases in temperature, and decreases in precipitation. This applies to Suriname as a whole and especially the capital, Paramaribo. Figure 85 provides an overview of the impact chain for the infrastructure sector, including the most important hazards in blue, the intermediate impacts in grey, and final risks in red. They produce the factors exposure, in yellow, and vulnerability in green. The subsequent section provides an interpretation of each risk component. While the figure focuses on existing infrastructure, some developments are to be expected in other sectors such as energy in order to meet national development targets. For instance, by increasing the installed capacity of other sources of electricity generation, additional risks may arise.

Figure 86- Impact chain for the Infrastructure sector



Source: SOC Report team elaboration

5.5.2.2. Hazards

Of the five main hazards, increases in precipitation, high winds, and sea level rise are the most important concerning Suriname's infrastructure sector.

In the case of energy, this subsector suffers particularly from irregular water levels, given the large capacity of the Afobaka hydropower plant which depends on water.

Table 47 provides an overview of the relevance of the projected changes in climate hazards for the sector.

Table 47- Relevance of projected changes in climate hazards for the infrastructure sector

Hazard indicator	Relevance	Explanation
Average, maximum, and minimum daily temperature **Frequency of hot days and nights, cold days and nights**	High	With increasing temperatures come fewer cold days and nights that allow for some cooling off, which means energy demand for cooling increases, water for hydropower becomes less available, and the thermal efficiency of thermoelectric power plants decreases. These effects can lead to energy insecurity for both on and off-grid areas. Off grid areas have to adapt to an increased demand for electricity by providing more fuel or fuel-powered electricity generators, or alternative means of energy generation such as PV panels.
Accumulated yearly precipitation **Number of rainy days per year**	High	Decreases in accumulated yearly precipitation and the number of rainy days have limited effects on buildings and telecommunications. However, the whole country is affected through different impacts. Less precipitation has negative effects on the navigability of rivers, a prominent mode of transport in the interior, and on hydropower generation at Afobaka, supplying electricity to the coast.
Maximum precipitation in five days **Maximum precipitation in one day**	High	Both indicators show an increase and intensification of precipitation events. These intense precipitation events can result in floods which lead to losses and damage of infrastructure assets and the unnavigability of rivers and roads.
Short dry season precipitation **Dry season precipitation** **Short rainy season precipitation**	High	As precipitation decreases throughout the country in these seasons, the effect is the same as for "accumulated yearly precipitation".

Hazard indicator	Relevance	Explanation
Rainy season precipitation	High	At the coast precipitation decreases and the effect is the same as for "accumulated yearly precipitation". In the interior the rainy season becomes wetter. Rivers can become unnavigable and roads non-transitable.
Maximum daily winds	Medium	These occur mostly at the coast and can damage housing, electricity, transport, and telecommunication infrastructure. At the seaside they can cause higher waves, which may also damage the assets mentioned above. However, their frequency is low, and the indicators are projected to vary very little in the future.
Gale wind days		
Strong wind days		
Relative humidity	Low	These indicators do not affect the infrastructure sector to an observable degree.
Sea-level rise	High	Sea level rise leads to coastal and riverbank erosion, flooding, and associated losses and damage of infrastructure assets.

Source: SOC Report team elaboration

5.5.2.3. Intermediate impacts

With regards to energy, two paths in the impact chain are important for the sector's goods and services:

1. **Higher temperatures, decreases in precipitation, and more droughts reduce water availability** for energy production through hydroelectric power and cooling through thermal electric power plants. They also increase the electricity demand for cooling. Extended periods of intense drought result in severe water availability reduction for the Afobaka hydropower plant. Hydroelectric power potential depends on stream flow, which depends directly on precipitation, temperature levels, and potential evapotranspiration. Precipitation directly impacts runoff levels and stream flows which then determine the amount of water available for hydroelectric generation.

    a) As a result, thermal plants increase their generation to make up for lost generation from hydropower plants and increased electricity demands for cooling. The combination of both phenomena can cause the occurrence of blackouts, causing higher maintenance costs and energy end prices (Contreras-Lisperguer & de Cuba, 2008).
    b) Thermal energy generation processes are based on the use of steam cycles, where the difference between ambient and combustion temperature has an impact on the overall efficiency of the boiler or turbine. Increases in ambient air and water temperatures can reduce the thermal efficiency of thermoelectric power plants.

Reduced thermal efficiencies can result in reduced power output and additional fuel consumption, resulting in higher energy prices.

2. **Increases in precipitation can lead to more downstream sedimentation**. This in turn will lead to algal blooms in hydroelectric dams and congestion (blockage of turbines) of hydroelectric plants. Both lead to interruptions in energy supply, demand the maintenance of the dam and power plant, and increase energy prices.

With regards to transport, one important path in the impact chain is that increases in precipitation, sea-level rise, higher winds, and waves lead to an increase in floods. Floods erode riverbanks and the coastline. Such erosion, as well as flooding itself, results in docks and rivers becoming unnavigable, and the increased need for maintenance activities (Noordam, 2007). Importantly, transport interruptions can also lead to energy interruptions regarding the distribution of fuels.

With regards to all infrastructure sectors (energy, transport, buildings, telecommunications), different hazards all result in the loss and damage of land and assets such as electricity poles, transmission and distribution lines, sub-stations, pylons, roads, bridges, buildings, and transmission lines, either directly or indirectly via floods, fires, and coastal and riverbank erosion (Noordam, 2007).

Floods in Suriname's coastal regions are a product of intense rainfall, extreme winds, and sea level rise, particularly during spring tide and tropical storms in the form of storm surges. When high water levels of the tidal Suriname River combine with runoff from impermeable areas floods appear that affect assets from the building and telecommunication subsectors. Extreme winds and waves can cause flooding of the coastal transportation infrastructure, leading to infrastructure failures and road obstructions from fallen power lines and trees, among others.

In Paramaribo, pluvial flooding tends to form locally with rainwater ponding in low lying areas with poor drainage across the city. This means that flooding is unlikely to be deep or fast flowing, but could be widespread and damaging, and in low lying areas could be slow to clear (World Bank, 2017). Flooding in combination with insufficient drainage may affect the construction stability of substations and pole foundations.

5.5.2.4. Risks

For the energy sector, supply interruptions and higher energy prices lead to a risk of energy insecurity, meaning the risk of not having reliable, affordable access to fuel and energy sources (IEA, 2020).

For the transport sector, the unnavigability of docks and rivers leads to a risk of financial losses both for transport enterprises and individuals whose economic productivity and subsistence depends on marine and riverine transport.

For all infrastructure sectors, loss and damage of land and assets leads to a risk of financial losses and a risk of losses of human lives.

5.5.2.5. Exposure

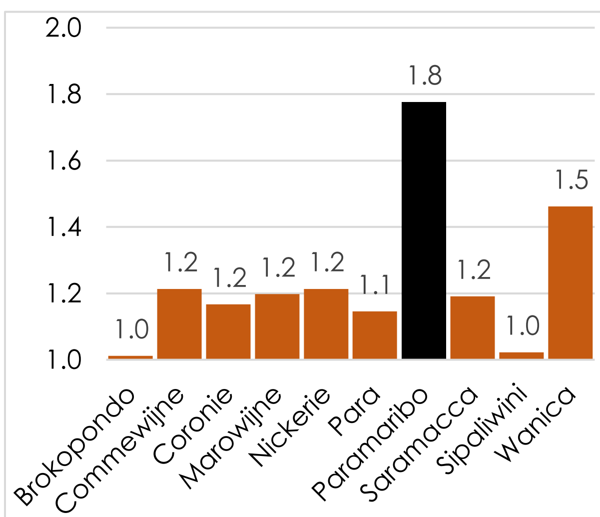
The risk of loss of lives and of financial losses is most pronounced for people and infrastructure in coastal, flood and high wind-prone areas:

- The population density in the coastal zone is nearly five times higher than that in non-coastal areas. The capital city of Paramaribo and the surrounding urban areas contain the highest population densities and greatest concentrations of economic activities in the country. People continue to concentrate in low-lying areas at the coast, such as the north of Paramaribo, where high wind speeds are recorded, which quickly inundate and where coastal flooding is an important issue. Here, the risk of loss of lives is high.
- Severe flooding and risk of loss of lives also concerns the interior, as in the events of 2006 and 2008 (NCCR, 2017).
- Critical buildings like hospitals and schools and infrastructure systems like power plants and telecommunication stations that are located on higher grounds are less prone to flooding and water damage.

The risk of energy insecurity is most prevalent for people and factories whose energy security depends on power plants already close to their output and efficiency limits or fuels brought by water. As a changing climate will either lead to supply limitations, interruptions, or price increases, the population dependent on power plants already close to their limits will suffer the highest risk of energy insecurity, as there may be no margin for at-risk power plant operators to compensate for the electricity and financial losses that arise from climate change. Moreover, the population dependent on fuels brought by boat will suffer from a reduced or more costly fuel supply due to the unnavigability of rivers.

Figure 86 presents the results of the exposure subindex for the infrastructure sector:

Figure 87- *Exposure of the infrastructure sectors in the ten districts*



Source: SOC Report team elaboration

Figures 87-92 provide an overview of the indicators used to construct the exposure subindex.

Figure 88- Km of road per km2 area

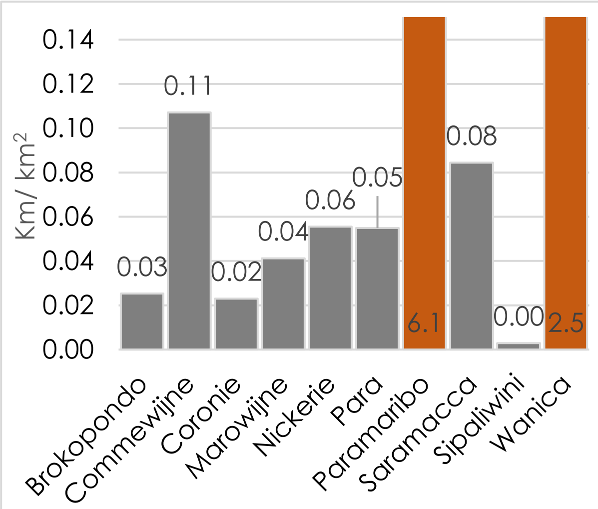


Figure 89- Number of certified harbors per capita (x 100,000)

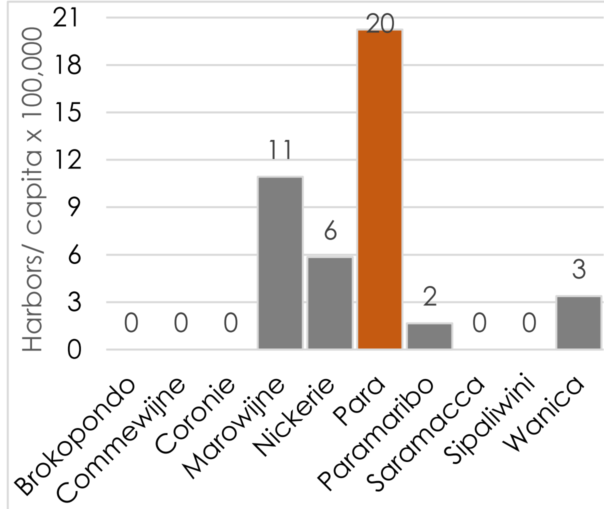


Figure 90- Number of electricity connections as a percentage of the total number of people

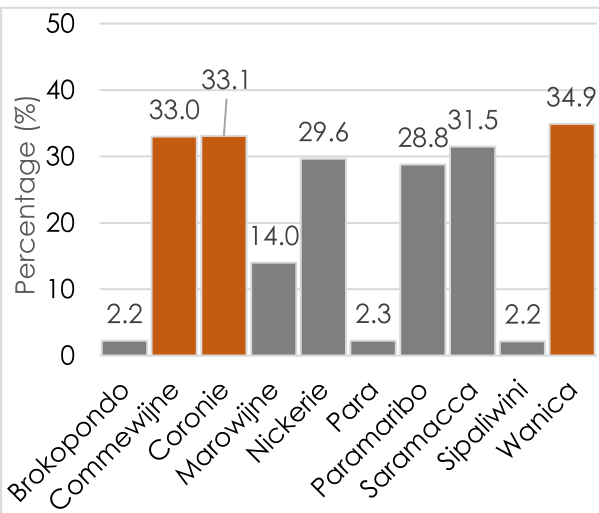


Figure 91- Coastline (km) per area (km2) x 1,000

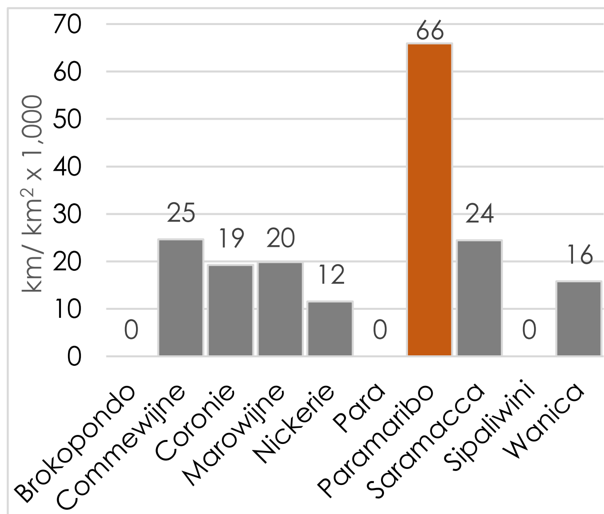


Figure 92- Number of people as a percentage of the total population of Suriname

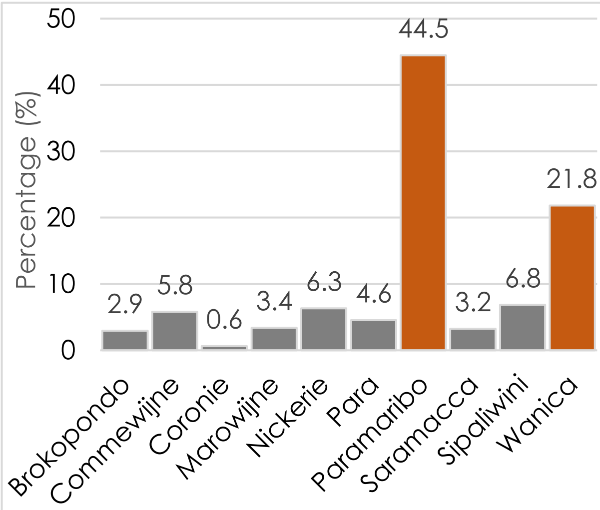
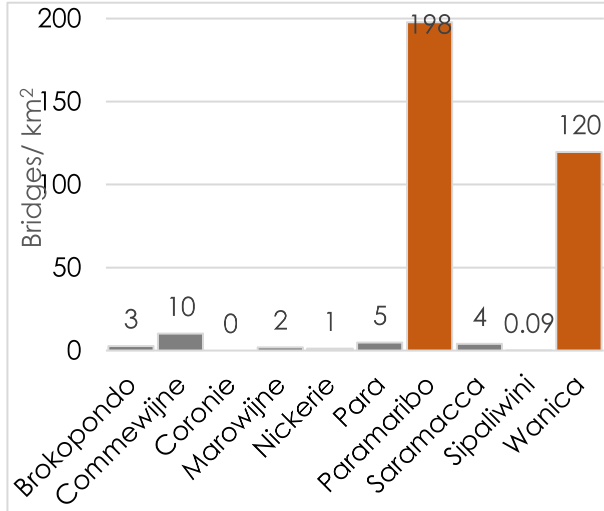


Figure 93- Number of bridges per km2 area



Source: SOC Report team elaboration

Paramaribo is by far the most exposed district (Figure 86). It scores highest for several indicators: the highest road density (6.1 km of road per km^2, whereas most other districts score below 0.1 km of road per km^2, with only Wanica having a comparable road density of 2.5 km of road per km^2) (Figure 87), the longest coastline per area (66 km per km^2 area, around 2.5-5 times that of other districts with a coastline) (Figure 90), the highest percentage of the country's population (44.5%, with only Wanica having a comparable population of 21.8% of the total) (Figure 91), and the highest density of bridges (198 per km^2 area, whereas most other districts have below 10 bridges per km^2 area, with only Wanica having a comparable density of 120 bridges per km^2 area) (Figure 91). Accordingly, Wanica is the second most exposed district.

Brokopondo and Sipaliwini are the least exposed districts (Figure 86). They have little transport infrastructure, little penetration of household electricity connections (Figure 89), a low share of the population, and no coastline.

5.5.2.6. Vulnerability

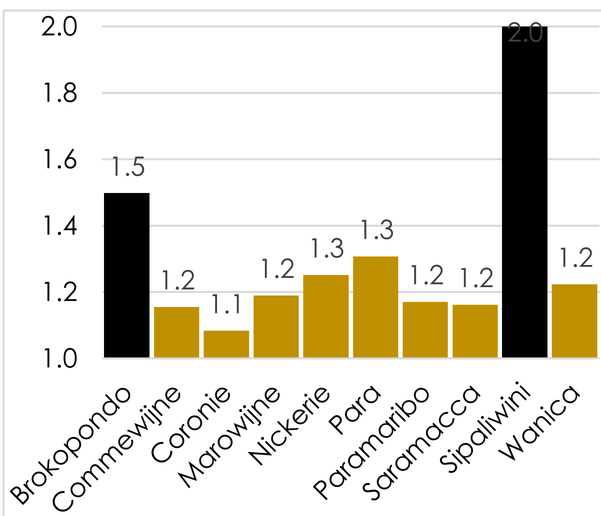
Old and scarce equipment and installations are the major factors that contribute to the vulnerability of people and factories whose energy security depends on power plants already close to their output and efficiency limits. Electricity systems consist of various components such as power plants, substations, and transmission and distribution lines. Outdated equipment and materials and their poor maintenance lead to higher maintenance costs and less efficient energy production. This is evident e.g. in the high System Average Interruption Duration Index (SAIDI) of the EPAR system. Rural districts are supplied by older infrastructure that lacks robustness to cover power failures.

Several factors contribute to the vulnerability of people and infrastructure in coastal and other flood and high wind-prone areas:

- **Natural and artificial drainage** systems in Paramaribo and surroundings are outdated. Moreover, a lack of building and civil regulations and finance results in poor maintenance of the existing canal network which includes waste deposition, outlet structures like sluices and pumping stations, and uncontrolled developments in retention areas intended to support drainage. In addition, uncontrolled migration of population from rural areas to urban areas results in the drainage infrastructure being undersized (OW, 2001).
- In some places along the Suriname coast, **protective infrastructure** and defense structures have been built. These range from small-scale ad hoc constructions consisting of waste material, car wrecks, and tires such as at Weg naar Zee, to engineered dikes such as at the Corantijn River mouth and Coronie.
- **Income and education of the population** refers to the low-income segments of the population that are disproportionately affected by flooding, other climate-related hazards, and intermediate impacts, mainly because they have no other choice but to live in cheap, low-quality housing in exposed areas. Less educated people may reside in low-quality housing in exposed areas.
- **Weather-resistant building**
    - High humidity levels impose considerable constraints on building materials like wood which rots quickly under humid conditions and is vulnerable to termites and fungi (IDB, 2017).
    - High levels of salinity from seawater intrusion into watercourses, sea level rise, or seawater flooding all damage and reduce the life of infrastructure such as roads and buildings.
    - Storms and heavy winds can destroy lightweight wooden houses and tear roofs.
    - High temperatures and draughts can cause heat stress in buildings and lead to damage of equipment and building materials.

Figure 93 presents the results of the vulnerability subindex for the infrastructure sector:

***Figure 94**- Vulnerability of the infrastructure sectors in the ten districts*



Source: SOC Report team elaboration

Figures 94-98 provide an overview of the indicators used to construct the vulnerability subindex.

Figure 95*- Length of non-novel roads as a percentage of all roads*

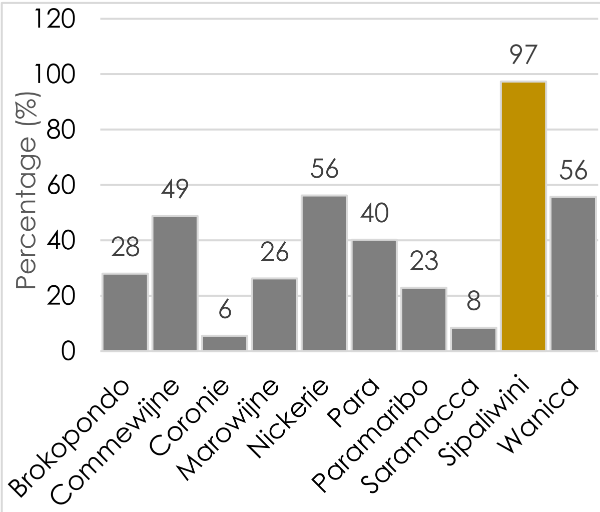


Figure 96*- Number of non-novel bridges as a percentage of all bridges*

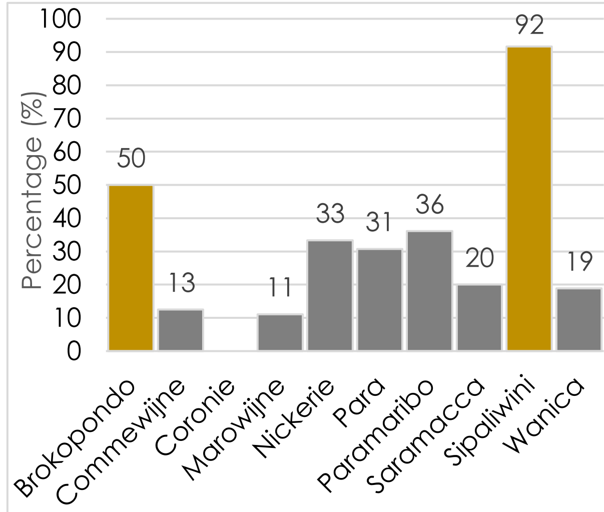


Figure 97*- Percentage of dwellings without a finished roof*

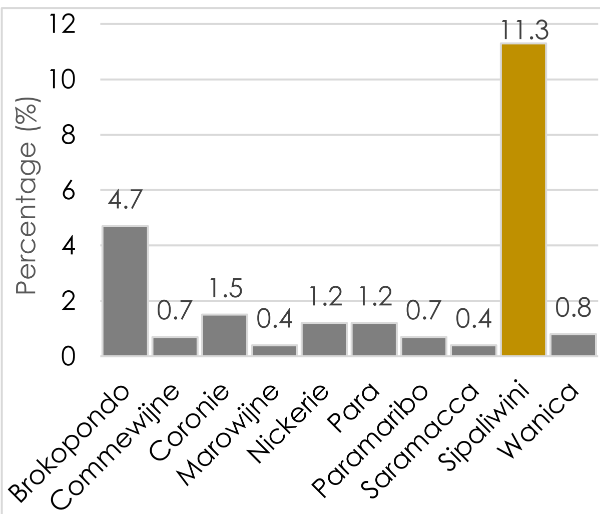


Figure 98*- Percentage of dwellings without finished walls*

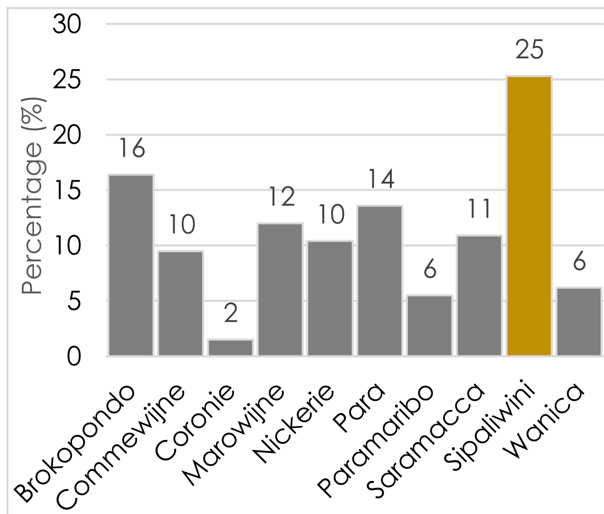
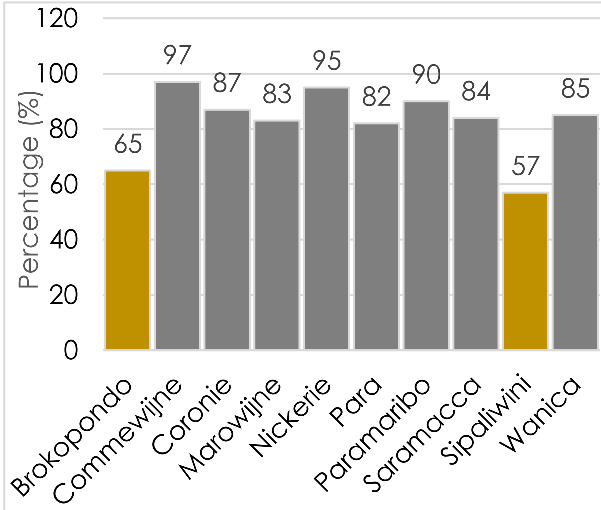


Figure 99- Primary completion rate[8]



Source: SOC Report team elaboration

Although Sipaliwini and Brokopondo are the least exposed districts, they are also the most vulnerable districts (Figure 93). Sipaliwini scores highest for all indicators. It has the highest percentage of non-novel roads with 97%, with the next highest score being 56% in Nickerie and Wanica, and as low as 6% in Coronie (Figure 94), non-novel bridges with 92% (Figure 95), dwellings without a finished roof with 11.3%, whereas most other districts score below 1.5% (Figure 96), dwellings without finished walls with 25%, at least double the percentage of most other districts (Figure 97), and the lowest primary completion rate with 57%, whereas all other districts score above 80%, with the exception of Brokopondo with 65% (Figure 98).

Coronie is the least vulnerable district (Figure 93). Notably, it has the smallest proportion of non-novel roads (Figure 94) and dwellings without finished walls (Figure 97).

5.5.3. Needs and responses

The following strengths, weaknesses, and opportunities were identified for the infrastructure sector. The only threats facing the sector will be addressed in the cross-sector chapter that follows.

5.5.3.1. Strengths

- The updated building code is pending finalization and emphasizes the strengthening of roof structures against climate hazards.

[8] The primary completion rate was considered beneficial. Therefore, the indicator was inverted upon including it in the vulnerability subindex. Thus, a high value in this figure corresponds to a smaller degree of vulnerability, and a small value corresponds to a higher degree of vulnerability.

- Improved institutional capacity has resulted from various training workshops, for example on the use and development of hydrological models. Communication between stakeholders has intensified through various workshops and meetings.
- Developing a disaster risk financing and insurance framework, which may include instruments such as the Caribbean Catastrophic Risk Insurance Facility (CCRIF), is underway.
- A new ring dike and ring canal has been proposed for Weg naar Zee coast to reduce flooding.
- The newly established ROM has plans to update polices on spatial planning and zoning, important for urban development in Paramaribo and Wanica.
- The IDB-GEF project *Development of Renewable Energy, Energy Efficiency and Electrification of Suriname* strengthens energy efficiency policy and regulation.
- Currently there are initiatives to deploy market-based incentives to transform the energy sector.
- The OW is committed to updating the building code.
- Concrete as a building material is highly preferred by society because of its solidity and image, increasing resilience against climate hazards.
- The academic society (e.g. Department of Infrastructure within the Faculty of Technological Sciences at the ADEKUS) is aware of the threat climate change poses on the built environment.
- The NMS promotes green-grey protective infrastructure against sea level rise at the coast.
- The Saramacca canal is the most important drainage system for the central and western areas of Paramaribo. The *Saramacca Canal System Rehabilitation Project*, funded by the World Bank and currently in its kick-off phase, aims at upgrading the Saramacca canal as well other secondary and tertiary drainage systems, improving overall maintenance and navigation of the canal, reducing the inundation time for properties and businesses, developing a flood forecasting service and implementing an emergency response in the event of a disaster.
- The EBS has staff with strong technical capacities.
- The EBS is in the process of modernizing its generation and transmission capacity, including electrification in rural and hinterland areas.
- The government shows a serious interest in addressing the burden of electricity subsidies by increasing electricity tariffs. Thereby, consumers use electricity more efficiently and generation capacity does not reach its limits or need to be enhanced.
- With the 2015 Electricity Law, and 2019 established EAS, EBS is institutionally strengthened to increase its performance.
- Several NGOs and CSOs have taken up programs to inform and educate the population on the effects of climate change. For instance, Tropenbos Suriname with a project on urban heat island effects in Paramaribo, and UNDP Suriname with the GCCA+ project creating awareness among the population regarding protective infrastructure.
- At the Weg naar Zee resort sediment traps collect soil that results in a medium to long-term land gain. Mangroves are being planted as well to protect the coastline.

5.5.3.2. Weaknesses

- Vulnerable people in the coastal areas are not aware of the hazards they are exposed to.

- There is no content in the current education curriculum to assist people to make informed decisions on how to adapt to climate change.
- There is no financial support for people whose livelihoods are destroyed by disasters.
- There is a lack of practical application of knowledge in policymaking and management decisions to increase the resilience of the built environment. Research findings and new insights are not used in decision making and planning.
- The infrastructure sector suffers from understaffing and a lock of operational means.
- The OW, in charge of all building and construction permits in the country, has limited capacities to technically review plans, provide guidance, and technical studies on the design of building and construction plans.
- There is little awareness of the use of appropriate building materials for tropical climates and for improving resilience against climate hazards.
- Inadequately constructed zinc sheet roofs increase the risk of torn roofs in the event of severe storms and heavy winds.
- The OW is responsible for the collection and discharge of household waste as well as the discharge of rain and storm water in the city of Paramaribo. Financial and management constraints, like a lack of adequate investment levels and limited institutional capacities, regarding drainage systems have led to the deterioration of the drainage system of Paramaribo.
- Limited institutional capacities and inter-institutional coordination between the Meteorological Service and the WLA have led to inconsistent and inefficient efforts because systems, resources, and data are not shared and integrated.
- The lack of an urban spatial planning policy has led to the establishment of unplanned and informal urban settlements.
- Many ministries (OW, NH, TCT, Regional Planning) are responsible for regulation and management of the infrastructure sector. However, they do not act in a concerted manner due to conflicting operational goals, affecting the quality of public services.
- Adaptation initiatives to protect mangrove (green protective infrastructure) are dependent upon external, donor-funded interventions (e.g. UNDP).
- There is no effective early warning system for disasters. There are no disaster risk reduction training opportunities.
- Market-based electricity tariffs have not fully been explored and implemented.

5.5.3.4. Opportunities

- In 2017, the World Bank elaborated a *Flood Risk Assessment* report, which provided valuable results for flood risk management. The report highlighted that the NCCR's role in disaster risk management (DRM) should be consolidated, and the roles and responsibilities of other actors involved in DRM clearly delineated.
- There are private green building initiatives (e.g. Kirpalani Super Store Leadership in Energy and Environmental Design (LEED) standards building, Assuria high-rise building) that act as ambassadors for promoting energy efficiency in buildings.
- The NAP considers climate-smart policies to influence private sector activity (Strategic Objective 6.2) such as stricter land use administration to guide development away from vulnerable floodplain lands and positive incentives to promote green infrastructure among building and infrastructure developers.

- The 2018 CARICOM *Regional Energy Efficiency Building Code* (CREEBC), covering both commercial and residential construction, is available for Suriname as a CARICOM member.

5.6. Across sectors

5.6.1. Legal and institutional framework

In recent years, Suriname has made international commitments and developed a sound set of national policies and legislative pieces that regard environmental management and climate change in different sectors. The following section provides an overview of Suriname's commitments, policies, and legislation related to environmental management and climate change.

5.6.1.1. International commitments

United Nations Framework on Climate Change (UNFCCC) and the *Nationally Determined Contributions (NDC) (2020)*

The NDC outlines a cost-effective pathway for the decarbonization and sustainability of Suriname's economic development. The NDC is fully aligned with national development priorities and contains a comprehensive package of sectoral projects, policies, measures, and targets. The NDC includes mitigation actions in four out of six emitting sectors: forests, electricity, agriculture, and transport. Together they cover an estimated 70% of the country's emissions.

Considering the agriculture sector, land-use planning, research, and the development of climate-smart farming are central to the NDC. Some of the main needs prioritized in NDC include the strengthening of climate change work, especially on mainstreaming climate change into sectoral policies, processes, and practices, and relevant capacity development aimed at the broader objective of food security and nutrition.

No specific provisions were made for the water sector. The only reference to the water sector was on the impacts of climate change on the agriculture sector. In this context, Suriname is focusing on the development of climate-smart farming which also includes water resource management.

Regarding the forestry sector, Suriname stated in the NDC the commitment to maintaining its forest cover by employing Payment for Ecosystem Services (PES) via reducing emissions from deforestation and forest degradation, promoting forest conservation, the sustainable management of forests, and enhancing forest carbon stocks (REDD+). The country's final NDC reiterates this commitment, recognizing the global importance of its forests to both biodiversity and as a carbon sink. However, the country also highlights that significant international financial support is needed in order to reach its aim.

With regards to the energy sector the NDC describes the expansion of the gird-connected and off-grid capacity, efficiency programs, and mini-grids. An estimation of share of electricity from renewable sources above 35% by 2030 is proposed, and the adoption of a Renewable Energy Act to provide the legal, economic, and institutional basis for the promotion of the use of renewable energy resources, including as part of rural electrification and the connection of off-grid systems to the national grid, and in the form of solar PV systems, mini-grids, and micro- and small-scale hydropower plants. In this regard, promotion of fiscal sustainability measures for energy efficiency is recommended.

Investment in the infrastructure sector is focused on projects such as road improvements, drainage including sea defense infrastructure for Paramaribo, and upgrading canals. Infrastructure investment projects are presented in the NDC as part of the transport sector. The total investment in upgrading the drainage system and flood protection is estimated to reach USD 500 million. Reference is made to the Transport Master Plan (ISTS 2011) that contains a proposal for a transport network based on long term plans and growth rates, integrated with a spatial planning model for Paramaribo. Suriname commits to introduce by 2027 vehicle emissions controls and tighten imports to vehicles less than five years old, in order to reduce emissions under the NDC.

Second National Communication (SNC) (2016)

The SNC provides a greenhouse gas inventory which demonstrates that Suriname's contribution to global emissions is relatively low due to Suriname's small industrial sector. Despite that, sea-level rise may lead to inundations of large parts of the coastal zone with detrimental effects.

The SNC highlights that although the government's development policy is based on an integrated approach towards economic, social, and environmental sustainability, a cross-cutting climate change policy and cooperation among stakeholders is still missing.

To mitigate and adapt to the adverse effects of climate change, the SNC makes the following recommendations:

- Incorporate climate change adaptations in long-term planning and development programs.
- Improve the institutional framework by establishing a coordinating body.
- Raise consciousness of climate change issues within the government and with other key stakeholders through awareness and capacity building campaigns.
- Set up a strategic awareness raising program to avoid the need of ad hoc awareness campaigns.
- Conduct a technology-needs assessment which will provide information on the technology needs of the country to effectively mitigate greenhouse gas emissions and adapt to climate change impacts.
- Allocate more funds to research and development of technology to tackle climate change.
- Improve the Meteorological Services Suriname in its organization and equipment.

Considering the agriculture sector the SNC identified the decrease of productive land as one of the country's six biggest issues to be considered for adaptation. It proposes specific adaptation measures for the development and implementation of appropriate research programs, capacity building, and training required for animal husbandry, enhancing crops in the form of the introduction of new varieties including salt tolerant rice and upland rice varieties, integrated pest management, and improving the competitiveness of fisheries.

The SNC also includes a vulnerability assessment regarding the water sector, focusing on climate change impacts on water resources. Water resources in the coastal area and in the hinterland are classified as vulnerable to highly vulnerable to climate change. Coastal urban areas are susceptible to flooding from the cumulative impacts of abundant rainfall, poor drainage, and rising sea and river water levels. With regards to the hinterland, this region is vulnerable to excessive rainfall. The SNC also highlights impacts such as increasing pressure on freshwater resources, saltwater intrusion in rivers, riverbank erosion, wetland fires, and aquifer salinization. Additionally, it proposes specific adaptation measures regarding legislation to protect water resources in general, water quality standards, and wastewater discharge to promote its sustainable use.

The SNC identifies important mitigation options for the forestry sector based on the REDD+ Programme. With regards to adaptation the SNC identifies essential measures for ecosystems such as the development of a full coastal plain strategy that includes the protection of all mangroves, Multiple Use Management Areas (MUMA), the cessation of permit issuance for building and other developments within vulnerable areas, the preservation of unused and abandoned lands on the coastal plain, the provision of incentives for the protection of remaining mangrove forests, and the implementation of a monitoring system for ecological resources.

The SNC highlights the role of the energy sector with focus on the energy demand in Suriname's future socioeconomic profile. This is projected to increase by 5%, the long-run historical mean.

The SNC identified the breaching of dams and dikes and damage to water defense infrastructure, and a decrease of draining potential of urban areas as two of the country's six biggest issues to be considered for adaptation. It proposes adaptation measures on infrastructure such as proper maintenance, frequent inspections of coastal stretches with dikes and dams, and development of feasible insurance schemes.

REDD+ Strategy 2018-2027 (2019)

In 2012 Suriname started its REDD+ Readiness Preparation with the aim of later participating in the REDD+ mechanism that economically compensates its efforts to reduce emissions from deforestation, forest degradation, conservation, the sustainable management of forests, and enhancement of carbon stocks. As part of its preparations Suriname developed its REDD+ Strategy, a five-year plan that should result in participation in the REDD+ mechanism. The Strategy has four strategic lines:

1) Continue to be a HFLD country and receive compensation to invest in economic transition, while maintaining Suriname's high forest cover, biodiversity, and environment. It has two policy lines:
    a) Multilateral and bilateral negotiations aiming at receiving financial support for the preservation of Suriname's forest cover
    b) Support existing, alternative, and additional sustainable livelihoods and diversification of the economy
2) Forest governance is about increasing the forests' contribution to development by promoting sustainable forest management via participatory forest governance structures that involve Indigenous and Tribal Peoples (ITPs) and the private sector. It has three policy lines:
    a) Advance participation of different stakeholders
    b) Enforcement, control, and monitoring
    c) Forest and environmental laws and regulations
3) Land-use planning is considered developing, implementing, and maintaining land-use planning, zoning, sustainable practices, and tools that result in the optimal use of Suriname's

forest and natural resources across sectors (mining, forestry, infrastructure, and agriculture), actors, times, and scales, as well as taking into account the development and rights of forest communities. It has four policy lines:

a) Land tenure

b) Land--use planning

c) Promotion of sustainable practices in land use sectors other than forest

d) Participatory community development

4) Conservation of forests and reforestation as well as research and education to support sustainable is important in developing, implementing, and maintaining land-use planning, zoning, sustainable practices, and tools that result in the optimal use of Suriname's forest and natural resources across sectors (mining, forestry, infrastructure, and agriculture), actors, times, and scales, as well as taking into account the development and rights of forest communities. It has three policy lines:

a) Protected areas

b) Rehabilitation and reforestation of degraded and deforested areas

c) Scientific research and education on forest management

5.6.1.2. Main national policies and legislation

National Climate Change Policy, Strategy and Action Plan for Suriname 2014-2021 (NCCPSAP) (2015)

The NCCPSAP provides a national climate change policy and strategy that is consistent with Suriname's National Development Plan (OP). It contains a roadmap, as well as information on different sectors, capacity building, green technology, financing, and monitoring. Finally, a national climate change action plan is presented.

The climate change policy within the NCCPSAP highlights the importance of generating climate data and information, reducing vulnerability, pursuing low-emission development, climate awareness campaigns, access to climate finance, and climate-smart development.

In the NCCPSAP action plan aligns with the 13 national planning themes. For each planning theme there are objectives and programs (Table 48).

Table 48- NCCPSAP themes and objectives

NCCPSAP theme	Objectives
Infrastructure	Infrastructure should be designed, built, and operated to be climate resilient and produce minimal emissions. Infrastructure development increases the adaptive capacity of Suriname's population through increased access to markets and social services.
Energy	Energy generation, transmission, and distribution systems should be designed, built, and operated to be climate resilient. Diversification of energy generation sources toward renewables increases access, reliability, and affordability of electricity, while reducing Suriname's emissions.
Drinking water	There should be sustainable and secure water supplies available across the country despite a variable and changing climate.
Housing	Existing and new buildings should be retrofitted, designed, and built to be climate resilient and take advantage of potential green growth opportunities such as feed-in tariffs.
Agriculture, animal husbandry and fisheries	Food security, safety, and export in agriculture, animal husbandry, and fisheries should be maintained and expanded in the context of a variable and changing climate. More efficient production systems should be implemented and reducing energy consumption and reusing exploited or abandoned fields should be considered. Opportunities to produce renewable energy in the agricultural sector should be seized and attract climate finance.
Education	The focus in the education sector should be on climate-smart education. Early childhood, primary, secondary, tertiary, and vocational education institutions should provide the information needed for the current and next generations to respond to climate change.
Disaster risk management	Disaster risk management services should collaborate with institutions responsible for climate change management to ensure improved knowledge and management of climate impacts across Suriname.
Spatial planning	For spatial planning and sustainable land management, the impacts of a changing climate and the need for low carbon development should be taken into account.
Environment	Environmental protection measures should consider the impacts of a variable and changing climate and low carbon growth opportunities.
Sustainable forest management	Sustainable forest management (SFM) should consider the impacts of a changing climate and the need for low carbon development.

Source: ATM (2015)

Suriname National Adaptation Plan (NAP) 2019-2029 (2019)

The objective of the NAP is to support medium and long-term climate change adaptation planning. It builds on the country's existing adaptation activities and mainstreams climate change into national decision making, development planning, policies, and programs. The NAP has two goals, impact reduction through adaptation and resiliency building, and coherent integration and mainstreaming of climate change into new and existing policies, programs, activities, development planning processes, and strategies, across multiple sectors and levels. The NAP covers adaptation needs at the strategic national level and economic sectoral level.

National Development Plan (OP) 2017-2021 (2017)

The OP highlights four pillars for Suriname's development:

1. Strengthening development capacity
2. Economic growth and diversification
3. Social progress
4. Utilization and protection of the environment

Environmental wellbeing and climate action are an integral part of all pillars, and particularly the fourth pillar, which elaborates on sea level rise and its dangers to development, long-term investments, and strategies. Moreover, the OP makes suggestions on how to minimize impacts derived from sea level rise and other hazards like mercury and cyanide, pesticide, and herbicide pollution. Another focus of the fourth pillar is the sustainable use of forests as a source of income in accordance with the Environmental Framework Act.

5.6.1.3. Environmental management structure

Environmental Framework Act and National Environmental Authority (2020)

In March 2020, the Environmental Framework Act was passed unanimously after two decades of negotiation. With the 2020 Environmental Framework Act the Environmental Coordination Unit was merged with NIMOS, creating the National Environmental Authority (NMA). The NMA is an independent administrative body with legal personality and has the task and power to implement all of Suriname's environmental management, policy, and strategy rules and the Environmental Framework Act. Moreover, the NMA is the authority to conduct investigations, to prosecute, and to bring criminal offenses regarding the environment to justice. Thus, the NMA is the only competent entity on environmental matters. This authority replaces the previous environment management structures.

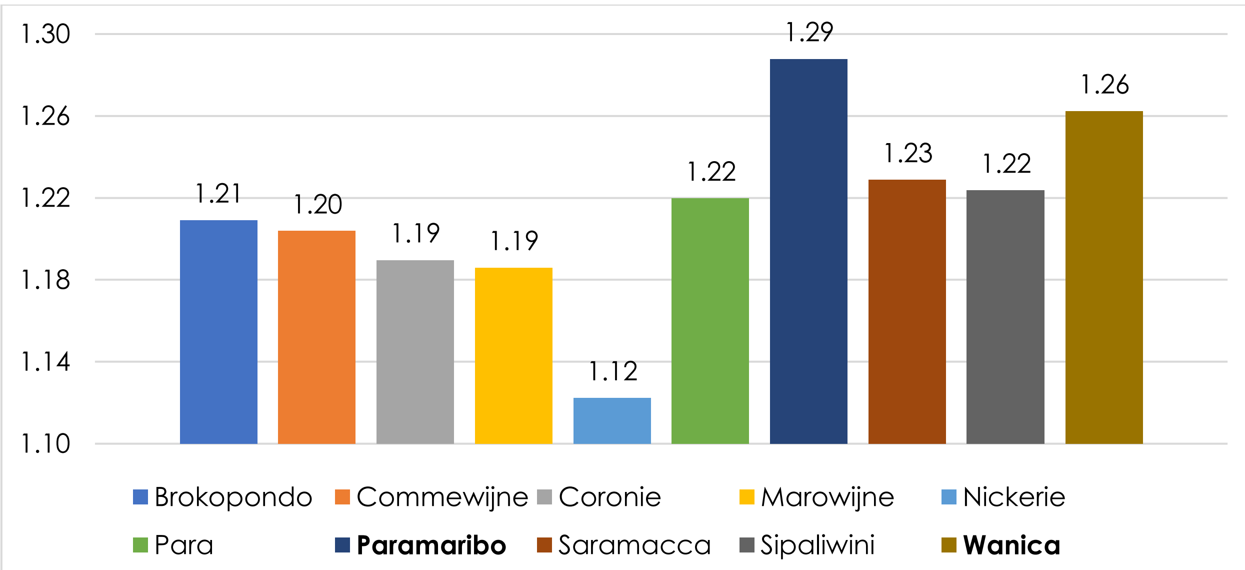
5.6.2. Climate impacts and risk

5.6.2.1. Hazards

The following figures present the results of the risk subindex on hazards, constructed based on 19 climate indicators for the historical period (Figure 99), scenario SSP2-4.5 (Figure 100), and scenario SSP5-8.5 (Figure101).

Tables 49 and 50 accompany Figures 100 and 101 and show the change in the hazard subindex between the historical, near, medium, and long-term future for each district.

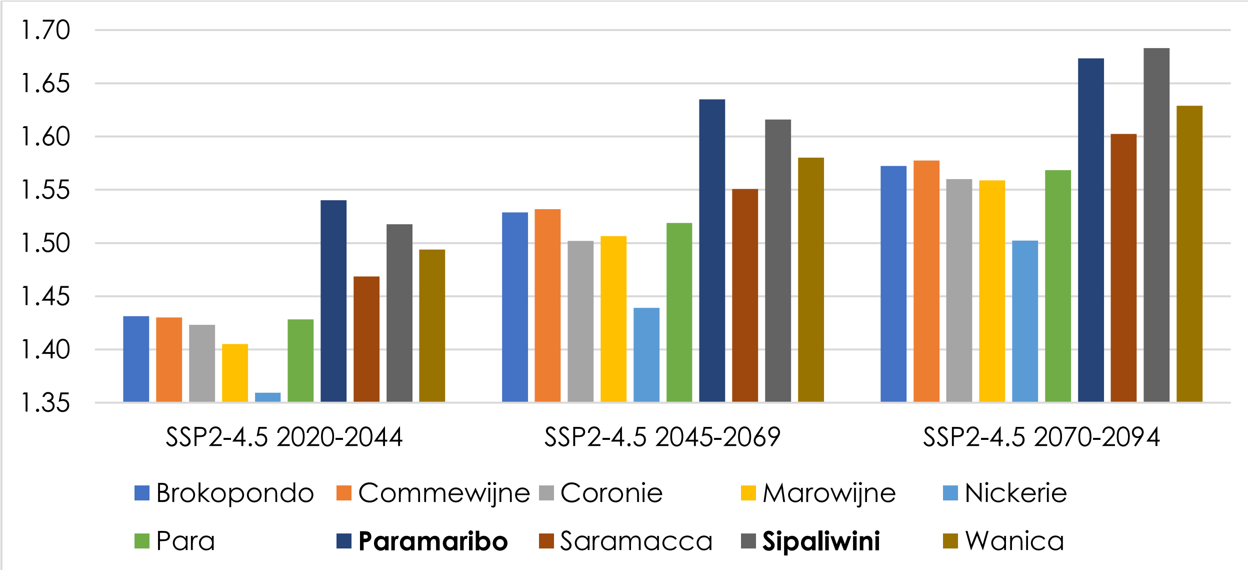
Figure 100- Hazard subindex for the historical period in the ten districts



Source: SOC Report team elaboration

Paramaribo has the highest hazard subindex, followed by Wanica. Nickerie has the lowest hazard subindex.

Figure 101- Hazard subindex for the scenario SSP2-4.5 and the near-, mid- and long-term future in the ten districts



Source: SOC Report team elaboration

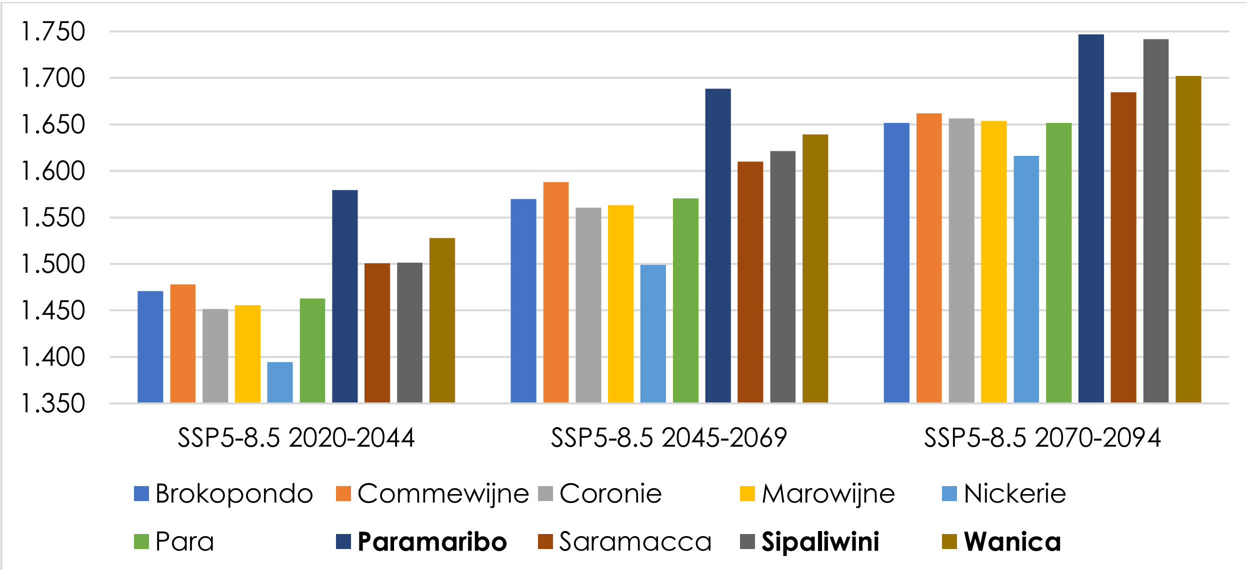
Table 49- Percentage increase of the hazard subindex between the historical value and three time periods of scenario SSP2-4.5

	Hazard subindex under SSP2-4.5 vs historical period		
	2020-2044	2045-2069	2070-2094
Brokopondo	+ 18.4%	+ 26.4%	+ 30.0%
Commewijne	+ 18.8%	+ 27.2%	+ 31.1%
Coronie	+ 19.6%	+ 26.2%	+ 31.1%
Marowijne	+ 18.5%	+ 27.0%	+ 31.4%
Nickerie	**+ 21.1%**	**+ 28.2%**	**+ 33.8%**
Para	+ 17.1%	+ 24.5%	+ 28.6%
Paramaribo	+ 19.6%	+ 27.0%	+ 29.9%
Saramacca	+ 19.5%	+ 26.2%	+ 30.4%
Sipaliwini	**+ 24.0%**	**+ 32.1%**	**+ 37.6%**
Wanica	+ 18.3%	+ 25.2%	+ 29.0%

Source: SOC Report team elaboration

In the SSP2-4.5 scenario, all districts' subindices increase by at least 17.1% (Table 49). Paramaribo remains the district with the highest hazard subindex in the short and medium term (Figure 100). Nickerie remains the district with the lowest hazard subindex throughout all timeframes. However, Nickerie's hazard subindex increases from 21.1% to 33.8% over time. This increase is only topped by Sipaliwini, whose hazard subindex increases from 24% to 37.6%. Accordingly, Sipaliwini shoots to the top of the hazard subindex ranking, overtaking Wanica in the short term, and eventually Paramaribo in the long term, becoming the district with the highest hazard subindex toward the end of the century. The district whose hazard subindex changes the least is Para, facing an increase from 17.1% to 28.6% (Table 49).

Figure 102- Hazard subindex for the scenario SSP5-8.5 and the near, mid, and long-term future in the ten districts



Source: SOC Report team elaboration

Table 50- Percentage positive increase of the hazard subindex between the historical value and three time periods of scenario SSP5-8.5

	Hazard subindex under SSP5-8.5 vs historical period		
	2020-2044	**2045-2069**	**2070-2094**
Brokopondo	+ 21.6%	+ 29.8%	+ 36.6%
Commewijne	+ 22.8%	+ 31.9%	+ 38.1%
Coronie	+ 22.0%	+ 31.2%	+ 39.2%
Marowijne	+ 22.7%	+ 31.8%	+ 39.4%
Nickerie	**+ 24.2%**	**+ 33.6%**	**+ 44.0%**
Para	+ 19.9%	+ 28.8%	+ 35.4%
Paramaribo	+ 22.6%	+ 31.1%	+ 35.6%
Saramacca	+ 22.1%	+ 31.0%	+ 37.1%
Sipaliwini	**+ 22.7%**	**+ 32.5%**	**+ 42.3%**
Wanica	+ 21.0%	+ 29.8%	+ 34.8%

Source: SOC Report team elaboration

In the SSP5-8.5 scenario, all districts' hazard subindices increase by at least 19.9% (Table 50). Paramaribo remains the district with the highest hazard subindex, and Nickerie remains the lowest throughout all timeframes (Figure 101). However, Nickerie's hazard subindex increases from 24.2 to 44.0% over time. This increase is not topped by any other district. It is also substantially higher than the increase witnessed in the SSP2-4.5 scenario (Table 49). Sipaliwini also witnesses high increases in its hazard subindex, particularly in the long-term, where Sipaliwini overtakes Wanica (Figure 101). The district whose hazard subindex changes the least is again Para, facing increases from 19.9 to 35.4, still considerably higher than in the SSP2-4.5 scenario (17.1-28.6%), particularly as time progresses (Table 50).

Tables 51-53 demonstrate the percent change in the hazard indicators between the historical, near, medium, and long-term future and the two scenarios for each district[4].

Table 51- *Percentage change (+/-%) of the normalized and inverted values of the indicators on temperature between the historical value and different scenarios and periods across the ten districts*

Variables and changes of particular interest are highlighted in grey.

Indicator	Time period and scenario		Brokopondo	Commewijne	Coronie	Marowijne	Nickerie	Para	Paramaribo	Saramacca	Sipaliwini	Wanica
Frequency of cold days (inverted)	SSP2-4.5	2020-2044	71	78	79	71	77	73	85	81	63	80
		2045-2069	86	92	91	87	89	87	98	92	79	92
		2070-2094	93	96	95	93	95	93	99	96	87	96
	SSP5-8.5	2020-2044	76	81	83	75	81	78	88	84	68	84
		2045-2069	91	95	94	91	94	92	98	95	86	95
		2070-2094	98	99	99	98	98	98	100	99	96	99
Frequency of cold nights (inverted)	SSP2-4.5	2020-2044	89	78	77	71	74	68	98	85	67	85
		2045-2069	95	87	86	83	84	81	99	92	83	92
		2070-2094	97	90	90	88	88	86	99	94	89	94
	SSP5-8.5	2020-2044	91	80	79	73	77	71	98	87	71	87
		2045-2069	97	90	90	87	88	85	99	94	90	94
		2070-2094	99	95	94	93	94	92	99	97	95	96
Frequency of hot days	SSP2-4.5	2020-2044	22	30	27	23	30	23	36	28	27	26
		2045-2069	44	57	52	46	57	46	64	54	48	53
		2070-2094	63	73	71	63	75	64	81	72	65	70
	SSP5-8.5	2020-2044	30	37	35	29	39	31	43	35	35	32
		2045-2069	62	71	71	62	76	63	79	71	69	68
		2070-2094	94	96	97	92	98	92	100	97	92	97
Frequency of hot nights	SSP2-4.5	2020-2044	87	77	79	70	74	74	89	84	58	87
		2045-2069	96	92	95	87	93	91	99	96	80	97
		2070-2094	98	94	97	91	96	94	99	97	88	99
	SSP5-8.5	2020-2044	90	80	84	74	79	78	92	87	64	90
		2045-2069	98	94	97	91	96	94	99	97	89	99
		2070-2094	99	96	99	94	99	97	100	98	95	99
Maximum temperatu re	SSP2-4.5	2020-2044	15	13	13	12	14	14	13	14	17	12
		2045-2069	27	22	22	21	23	23	25	23	29	21
		2070-2094	34	30	30	28	32	30	32	30	39	28
	SSP5-8.5	2020-2044	20	14	16	15	17	16	16	16	22	15
		2045-2069	34	28	30	27	32	30	30	30	41	28

4 Positive percentage changes in inverted indicators (whose higher values reduce climate risk and have a positive impact on the sectors) means their absolute values decrease.

Positive percentage changes in non-inverted indicators (whose higher values increase climate risk and have a negative impact on the sectors) means their absolute values increase.

Negative percentage changes in inverted indicators (whose higher values reduce climate risk and have a positive impact on the sectors) means their absolute values increase.

Negative percentage changes in non-inverted indicators (whose higher values increase climate risk and have a negative impact on the sectors) means their absolute values decrease.

Indicator	Time period and scenario		Brokopondo	Commewijne	Coronie	Marowijne	Nickerie	Para	Paramaribo	Saramacca	Sipaliwini	Wanica
		2070-2094	59	48	49	46	54	49	52	50	66	46
Average temperature	SSP2-4.5	2020-2044	20	17	18	17	19	18	18	16	26	16
		2045-2069	36	30	33	30	31	32	31	29	44	27
		2070-2094	47	40	42	39	44	43	41	40	58	38
	SSP5-8.5	2020-2044	25	21	22	20	22	21	20	20	32	18
		2045-2069	47	40	42	39	44	43	41	40	62	38
		2070-2094	80	66	71	67	74	71	69	67	100	63
Minimum temperature	SSP2-4.5	2020-2044	16	14	16	15	16	17	13	14	23	14
		2045-2069	29	24	26	27	28	29	22	25	39	24
		2070-2094	38	32	35	35	36	39	29	33	52	33
	SSP5-8.5	2020-2044	19	16	18	17	18	19	15	16	27	16
		2045-2069	38	32	35	35	38	37	29	33	54	33
		2070-2094	65	54	58	58	61	64	48	55	89	56

Source: SOC Report team elaboration

All hazard indicators on temperature increase over time and with more severe climate scenarios. The indicators which most lead to the hazard subindex increasing are the frequency of cold days (increases between 71-100% across districts), cold nights (67-100%), and the frequency of hot nights (70-100%) (Table 51). The indicator on the frequency of hot days also contributes substantially to the hazard subindex in the SSP5-8.5 scenario and in the long term increases between 92-100%.

Sipaliwini's hazard subindex increase is owed more to sharp increases in the indicators on maximum, average, and minimum temperature, where the district scores the highest increases throughout all scenarios and timeframes in all districts.

Table 52*- Percentage change of the normalized values of the indicators on precipitation between the historical value and different scenarios and periods across the ten districts*

Variables and changes of particular interest are highlighted in grey.

Indicator	Time period and scenario		Brokopondo	Commewijne	Coronie	Marowijne	Nickerie	Para	Paramaribo	Saramacca	Sipaliwini	Wanica
Maximum precipitation in five days	SSP2-4.5	2020-2044	64	67	76	73	85	65	56	70	74	64
		2045-2069	75	72	81	77	88	73	60	75	81	69
		2070-2094	77	75	83	81	90	75	63	78	80	72
	SSP5-8.5	2020-2044	69	67	73	73	81	66	54	68	76	63
		2045-2069	77	82	84	88	88	79	68	81	78	76
		2070-2094	79	75	89	81	98	77	60	79	86	71
Maximum precipitation in one day	SSP2-4.5	2020-2044	-3	-17	-1	-15	12	-7	-15	-5	4	-15
		2045-2069	30	1	12	3	23	17	-5	9	16	0
		2070-2094	43	17	29	20	37	33	2	25	23	16
	SSP5-8.5	2020-2044	16	-8	-5	-5	6	3	-14	-4	5	-11
		2045-2069	51	32	31	32	26	44	21	35	18	30

Indicator	Time period and scenario		Brokopondo	Commewijne	Coronie	Marowijne	Nickerie	Para	Paramaribo	Saramacca	Sipaliwini	Wanica
		2070-2094	49	16	33	23	47	41	3	23	35	9
Accumulated precipitation (inverted)	SSP2-4.5	2020-2044	7	15	11	17	12	10	9	12	8	11
		2045-2069	11	25	18	28	22	15	15	19	12	18
		2070-2094	13	27	21	31	27	17	16	21	14	20
	SSP5-8.5	2020-2044	12	25	21	28	26	16	15	21	13	19
		2045-2069	13	25	23	28	32	17	16	22	19	19
		2070-2094	18	39	32	44	46	24	24	30	25	28
Number of rainy days (inverted)	SSP2-4.5	2020-2044	21	28	32	32	45	16	33	27	16	25
		2045-2069	27	48	39	50	52	20	63	35	19	37
		2070-2094	29	51	47	53	60	22	70	40	20	38
	SSP5-8.5	2020-2044	19	38	30	42	43	13	53	26	14	26
		2045-2069	30	54	48	58	62	24	71	42	20	42
		2070-2094	33	61	56	67	73	27	78	47	22	44
Precipitation short dry season (inverted)	SSP2-4.5	2020-2044	60	25	34	29	37	43	21	29	77	19
		2045-2069	80	46	52	55	58	61	36	45	92	34
		2070-2094	73	39	44	48	49	54	31	38	87	29
	SSP5-8.5	2020-2044	72	35	43	42	47	53	27	36	80	26
		2045-2069	75	40	47	48	54	56	31	40	90	30
		2070-2094	86	54	57	64	65	67	41	50	98	40
Precipitation dry season (inverted)	SSP2-4.5	2020-2044	-6	12	-8	13	-7	-7	3	-1	5	11
		2045-2069	-12	-2	-22	-3	-24	-17	-5	-13	1	-1
		2070-2094	-11	1	-18	1	-17	-14	-3	-10	4	2
	SSP5-8.5	2020-2044	-8	9	-11	9	-9	-10	1	-4	6	8
		2045-2069	-9	5	-16	4	-15	-12	-1	-8	6	5
		2070-2094	-15	-4	-19	-8	-14	-20	-5	-14	2	-2
Precipitation short rainy season (inverted)	SSP2-4.5	2020-2044	2	-8	0	-12	3	-2	3	-4	7	-10
		2045-2069	4	0	8	-5	12	3	9	4	8	-4
		2070-2094	14	15	19	13	26	14	19	15	12	7
	SSP5-8.5	2020-2044	9	3	12	0	16	7	12	7	11	-1
		2045-2069	17	15	25	13	32	18	19	19	14	8
		2070-2094	26	32	35	33	45	29	31	30	19	20
Precipitation rainy season (inverted, but not for Sipaliwini)	SSP2-4.5	2020-2044	-6	13	7	15	3	5	5	11	23	12
		2045-2069	-3	25	15	27	13	10	11	19	20	21
		2070-2094	-4	21	17	23	17	10	10	19	17	19
	SSP5-8.5	2020-2044	-3	23	19	24	18	11	11	21	17	20
		2045-2069	-6	15	14	15	18	5	7	15	10	14
		2070-2094	0	30	24	34	31	14	15	25	2	25
Number of rainy days (inverted)	SSP2-4.5	2020-2044	21	28	32	32	45	16	33	27	16	25
		2045-2069	27	48	39	50	52	20	63	35	19	37
		2070-2094	29	51	47	53	60	22	70	40	20	38
	SSP5-8.5	2020-2044	19	38	30	42	43	13	53	26	14	26
		2045-2069	30	54	48	58	62	24	71	42	20	42
		2070-2094	33	61	56	67	73	27	78	47	22	44

Source: SOC Report team elaboration

Most hazard indicators on precipitation increase over time and with more severe climate scenarios, at the forefront being the indicator on maximum precipitation in five days (Table 52). The only exception is dry season precipitation. Dry season precipitation increases for all districts apart from Sipaliwini, where an increase is considered beneficial, and therefore negative percentage changes can be observed. Improvements in the indicators on maximum precipitation in one day and precipitation of the short rainy season can also be observed in the short-term SSP2-4.5 scenario for most districts, but the indicator switches signs in the rest of the timeframes and scenarios. Sipaliwini also scores particularly high in the indicator on short dry season and dry season precipitation.

Table 53*- Percentage change of the normalized values of the indicators on wind and humidity between the historical value and different scenarios and time periods across the ten districts*

Variables and changes of particular interest are highlighted in grey.

Indicator	Time period and scenario		Brokopondo	Commewijne	Coronie	Marowijne	Nickerie	Para	Paramaribo	Saramacca	Sipaliwini	Wanica
Gale wind	SSP2-4.5	2020-2044	0	0	0	0	0	0	0	0	75	0
		2045-2069	0	0	0	0	0	0	0	0	75	0
		2070-2094	0	0	0	0	0	0	0	0	100	0
	SSP5-8.5	2020-2044	0	0	0	0	0	0	0	0	25	0
		2045-2069	0	0	0	0	0	0	0	0	25	0
		2070-2094	0	0	0	0	0	0	0	0	75	0
Maximum wind speed	SSP2-4.5	2020-2044	5	2	3	2	5	4	2	3	4	3
		2045-2069	6	4	6	3	9	5	3	5	8	4
		2070-2094	8	4	7	4	10	6	4	6	9	5
	SSP5-8.5	2020-2044	6	3	4	3	7	5	3	4	7	4
		2045-2069	6	4	7	3	10	5	3	6	9	4
		2070-2094	11	7	13	6	18	10	7	10	12	8
Number of days with strong wind	SSP2-4.5	2020-2044	0	1	2	1	2	0	1	2	6	1
		2045-2069	-1	0	5	2	5	0	2	2	10	1
		2070-2094	-2	0	5	1	4	-1	2	2	12	1
	SSP5-8.5	2020-2044	-1	1	4	2	4	0	2	2	1	1
		2045-2069	-2	0	5	1	4	-2	1	2	0	0
		2070-2094	-4	-1	8	2	8	-3	0	3	-4	-1
Relative humidity	SSP2-4.5	2020-2044	-19	-7	-11	-7	-13	-13	-6	-9	-30	-8
		2045-2069	-12	-3	-9	-4	-11	-9	-2	-7	-20	-4
		2070-2094	-13	-7	-6	-7	-6	-10	-5	-7	-15	-7
	SSP5-8.5	2020-2044	-26	-8	-15	-9	-19	-17	-7	-11	-43	-9
		2045-2069	-22	-6	-15	-7	-18	-16	-5	-11	-33	-8
		2070-2094	-19	-8	-8	-10	-10	-13	-6	-9	-26	-8

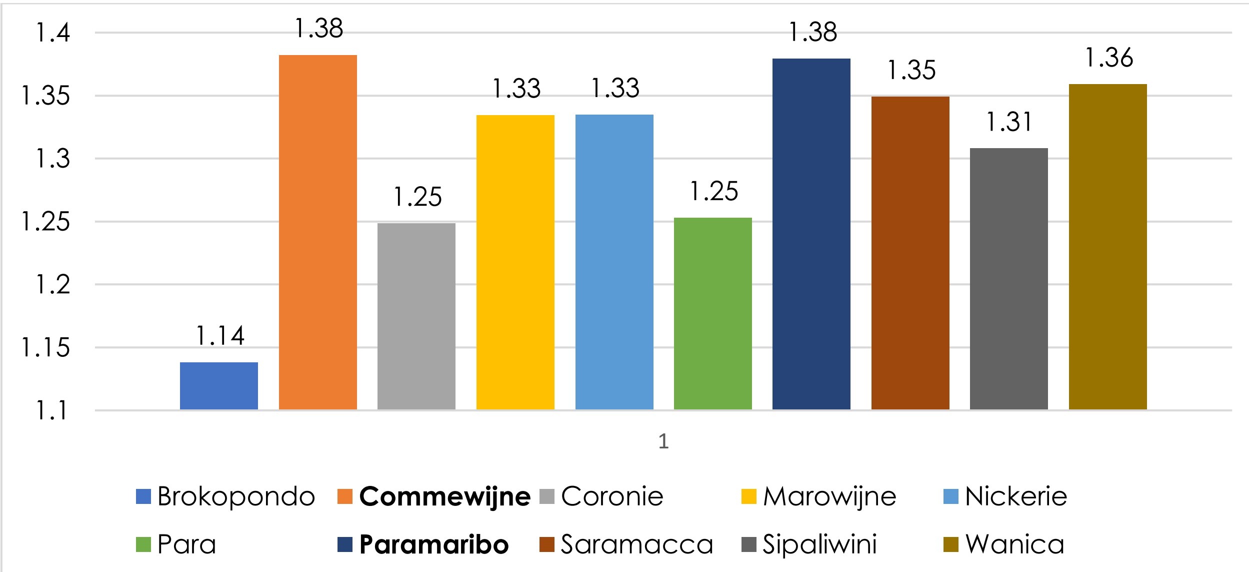
Source: SOC Report team elaboration

The hazard indicator on gale wind does not change for any district but Sipaliwini (Table 53). Maximum wind speed increases slightly, and the number of days with strong wind increases or decreases slightly, depending on the district. Relative humidity decreases across timeframes and scenarios, where an increase is considered beneficial, therefore negative percentage changes can be observed. This is particularly true for Sipaliwini and Brokopondo.

5.6.2.2. Exposure

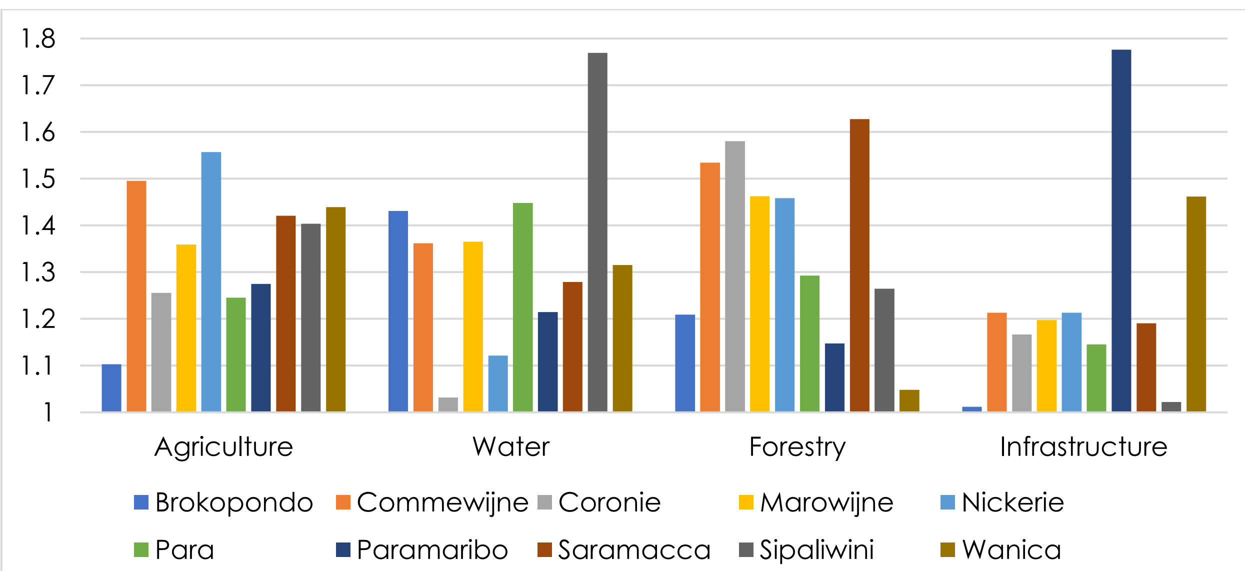
Figure 102 presents the results of the risk subindex on exposure for the ten districts across sectors constructed based on a total of 20 indicators. Figure 103 shows the exposure values of the four sectors and ten districts.

Figure 103*- Exposure subindex across sectors for the ten districts*



Source: SOC Report team elaboration

Figure 104*- Exposure subindex values for the four sectors across the ten districts*



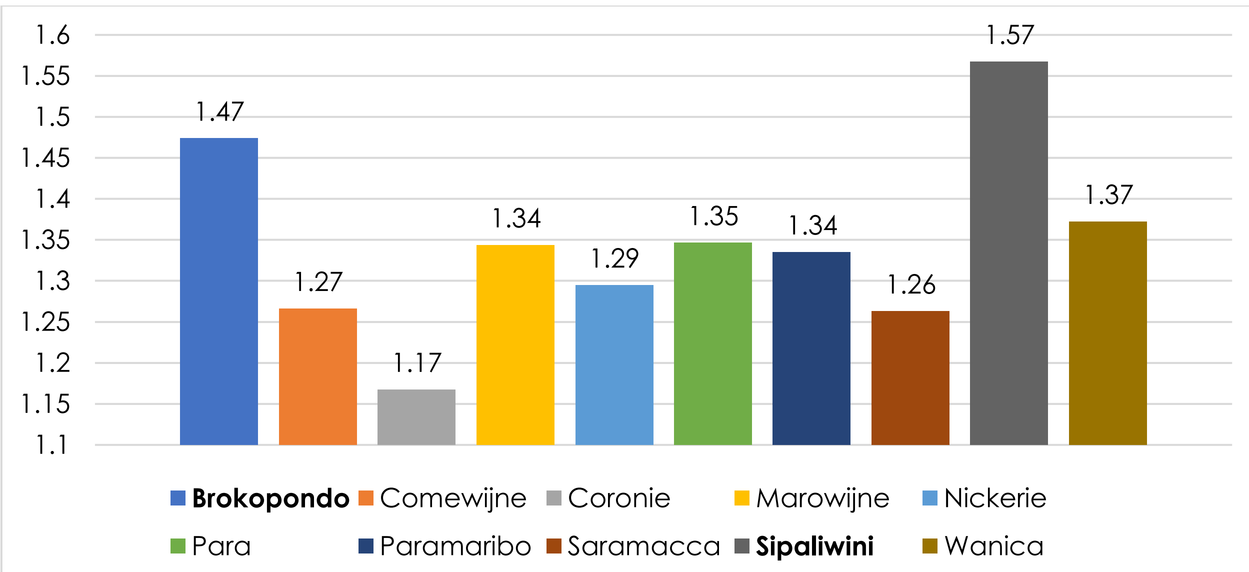
Source: SOC Report team elaboration

Commewijne and Paramaribo are the most exposed districts, and Brokopondo is the least exposed district (Figure 102). Commewijne demonstrates high exposure values in agriculture, water, and forestry, while Paramaribo has the highest exposure value in infrastructure (Figure 103). Brokopondo scores very low for agriculture and infrastructure, with elevated and medium exposure values in water and forestry.

5.6.2.3. Vulnerability

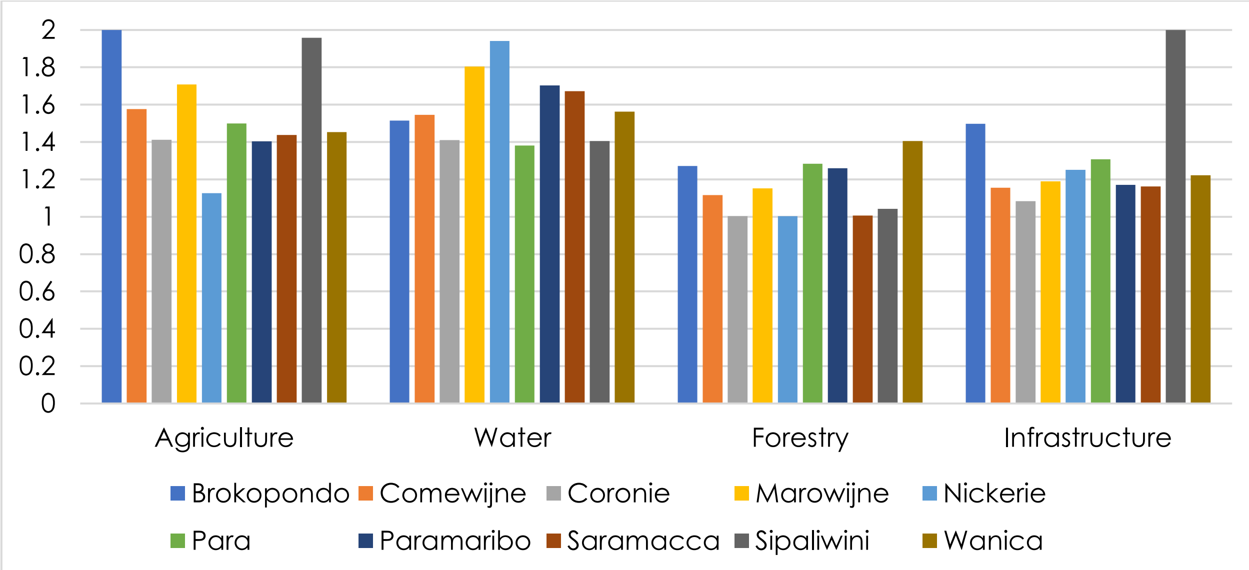
Figure 104 presents the results of the risk subindex on exposure for the ten districts across sectors constructed based on 13 indicators. Figure 105 shows the exposure values of the four sectors and ten districts.

Figure 105- Vulnerability subindex across sectors for the ten districts



Source: SOC Report team elaboration

Figure 106- Vulnerability subindex values for the four sectors across the ten districts



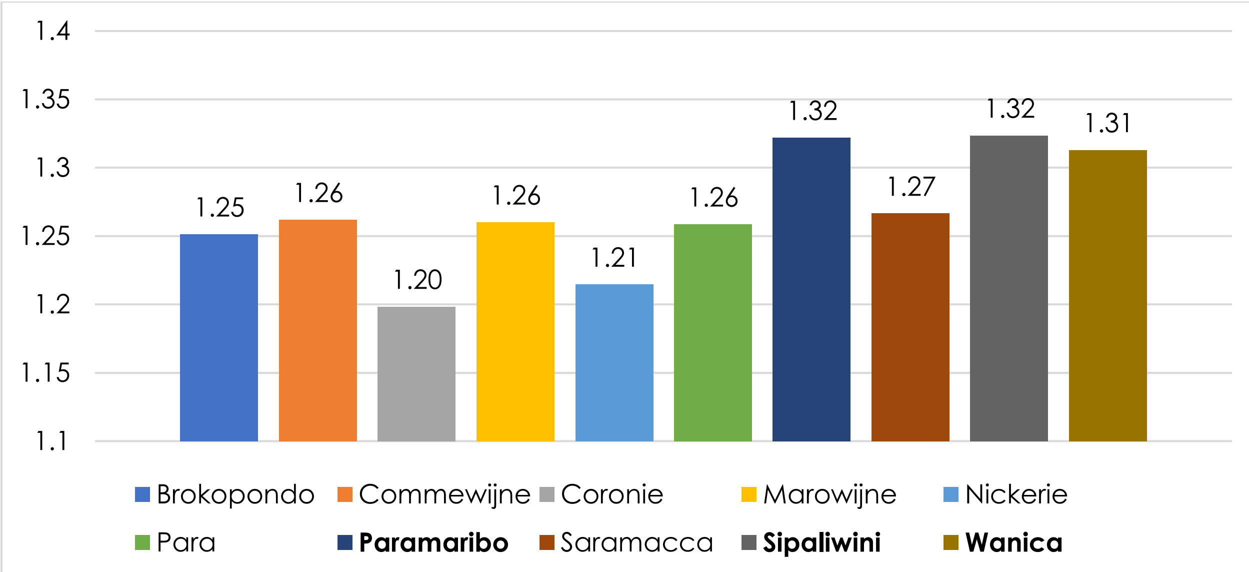
Source: SOC Report team elaboration

Although Brokopondo is the least exposed district, it is the second most vulnerable district after Sipaliwini (Figure 104). Brokopondo is the most vulnerable district in agriculture, the second most vulnerable district in infrastructure, and the third most vulnerable district in forestry (Figure 105). Sipaliwini is the most vulnerable district in infrastructure and the second most vulnerable district in agriculture. The least vulnerable district is Coronie, which has the lowest vulnerability of all for forestry and infrastructure. The districts' vulnerability subindex values lie close together only in the forestry sector, with values ranging from 1.0-1.4.

5.6.2.4. Risk

The following figures present the results of the risk index, constructed based on 19 hazard indicators, 20 exposure indicators, 13 vulnerability indicators for the historical period (Figure 106), the scenario SSP2-4.5 (Figure 107) and the scenario SSP5-8.5 (Figure 108), across the ten districts.

Figure 107- Historical risk index for the ten districts

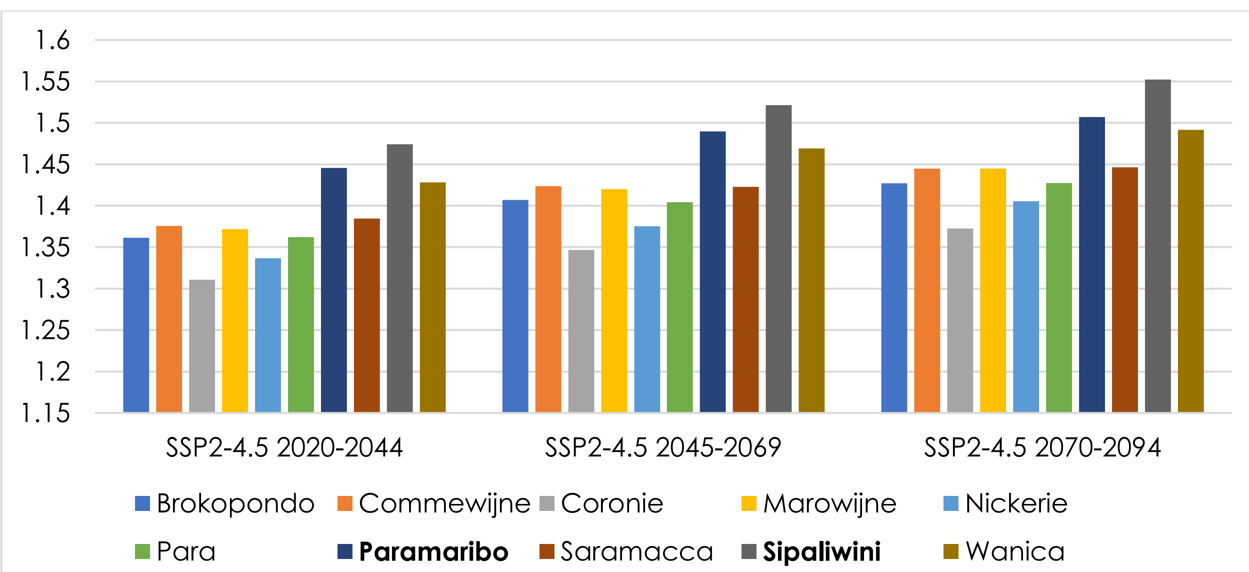


Source: SOC Report team elaboration

At present, Sipaliwini, Paramaribo and Wanica face the highest climate risk (Figure 106). This is due to Sipaliwini's high vulnerability, Paramaribo's high hazard subindex and exposure, and Wanica's high hazard subindex.

Coronie and Nickerie face the least climate risk. Coronie is the least vulnerable of all, and Nickerie has the lowest hazard subindex.

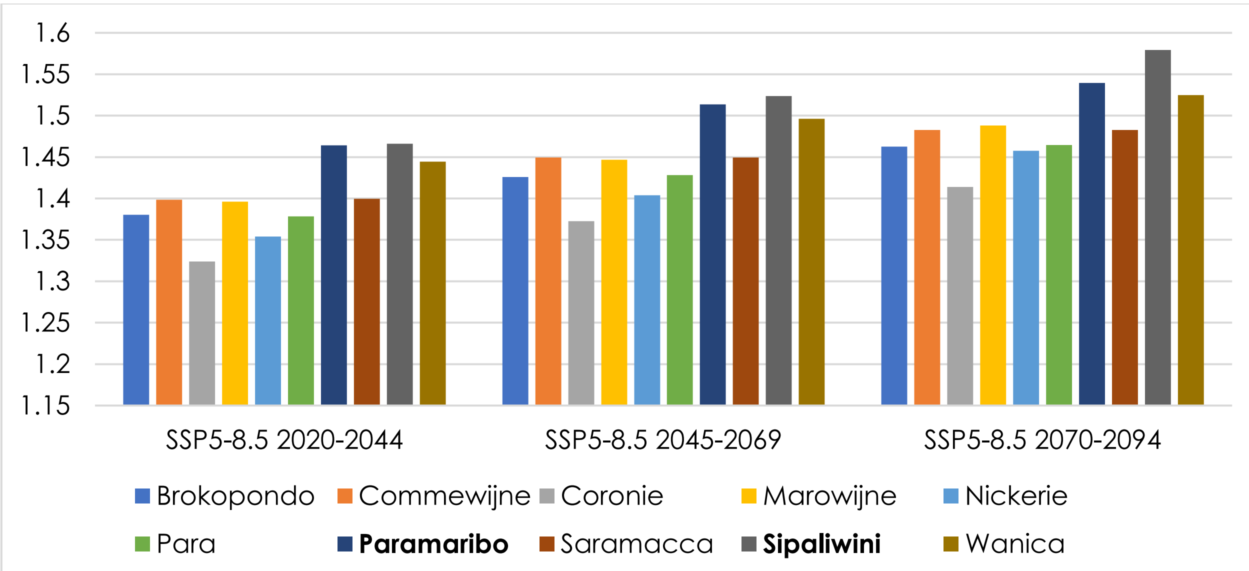
Figure 108- Risk index for the scenario SSP2-4.5 and three time periods



Source: SOC Report team elaboration

Throughout the timeframes of SSP2-4.5, Sipaliwini, Paramaribo and Wanica remain the three districts most at risk (Figure 107). Coronie and Nickerie also remain those with the least climate risk. The difference between the districts most and least at risk increases by 44% between the historical period and the long term.

***Figure 109**- Risk index for the scenario SSP5-8.5 and three timeframes*



Source: SOC Report team elaboration

Throughout the timeframes of SSP5-8.5, Sipaliwini, Paramaribo and Wanica remain the three districts most at risk (Figure 108). Coronie and Nickerie also remain those districts with the least climate risk.

The difference between the districts most and least at risk increases by 32% between the historical period and the long term, and thus is less pronounced than in the SSP2-4.5 scenario (Figure 107).

5.6.3. Needs and responses

The following strengths, weaknesses, opportunities, and threats were identified across sectors.

5.6.3.1. Strengths

- In 2020 Suriname passed the Environmental Framework Law. This is the government's major cross-sectoral response to enhance its strengths, take advantage of opportunities, and to reduce its weaknesses and threats.
    - The law is formulated based on the principles of publicity and participation, among others. These principles aim at involving citizens in decision making on environmental matters. Public access to environmental data is regarded as an

essential condition for effective public participation. This will raise awareness among the public.

   - With the law, the Environmental Coordination Unit and NIMOS were merged, creating the NMA. The NMA is an independent administrative body with legal personality and has the task and power to implement all of Suriname's environmental management, policy, and strategy. The NMA is the authority to conduct investigations, to prosecute, and to bring criminal offenses regarding the environment to justice. This will increase the efficiency of the implementation of the NAP.
- In 2020 the ROM was founded. Its purpose is to focus on environmental policy and spatial planning. The ministry also plays an important role for climate change:
   - The ROM is charged with preserving and enlarging Suriname's forest cover, which is central to the country's mitigation and adaptation efforts and closely linked to the REDD+ Programme and other results-based payments. This decision was made in February 2019 (see "Krutu of Paramaribo Joint Declaration" between HFLD countries).
   - The ministry will update climate policies, implement the NDCs, coordinate climate finance, and set up a data bank for a greenhouse gas inventory.
- The Meteorological Service of Suriname is the country's voice for weather and climate, and is included in national policies and legislation, and all relevant international commitments. The Meteorological Service has an up-to-date weather and climate data base with digital and hard copy information. Also, Suriname is a member of the WMO.
- Suriname collaborates with international organizations on climate change.
- In 2018 the Metrological Services, with support from the UNDP and the Global Climate Change Alliance Plus Initiative (GCCA+), digitalized 75 years of climatological data, reaching back to the colonial period.
- Potential climate change impacts on different sectors are efficiently mapped through reporting efforts like 2NC, NAP, National Communication on Climate Services, among others,
- ADEKUS has highly qualified technical staff which elaborates important studies on climate risk.
- The *VLIR-OI Capacity Building Project*, a collaboration between ADEKUS and the Flemish universities of Flanders (Belgium), developed a 2-year Master of Science program in Sustainable Management of Natural Resources (SMNR).
   - The project strengthened research capacities at ADEKUS in the fields of sustainable land and water management, renewable energy resources, mineral resources, biodiversity, sustainable forestry, sustainable agriculture, and natural products.
   - Within the SMNR, three courses regarding climate change are provided. These courses are "Water resources management", "Climatology and hydrology" and "Geohydrology and modeling" (Berrenstein & Gompers-Small, 2016). The research of students and faculty members that form part of the SMNR contributes to the national knowledge base on environment and climate change.
- The bachelor's degree course in Environmental Sciences contributes to increased academic environmental knowledge at the national level and prepares the students for follow-up courses. The degree grants access to the SMNR and a Master in Education Research and Sustainable Development (MERSD)at ADEKUS.

- Although there are no specific environmental programs at the secondary level, there are specializations that link to nature sciences like NATIN Agriculture and Tourism. This enhances youth capacities and develops professionals focusing on the environment and climate change.
- At the primary education level there is one subject related to the environment, namely "nature sciences". Also, when the school children visit the mediatheek (multimedia library), they receive information on natural sciences thanks to various interventions, such as the World Wildlife Fund for Nature (WWF) Guyana groene leskisten (green education boxes) and the Junior Chamber International (JCI) Suriname environment booklet and board game.
- There are initiatives to strengthen the environmental knowledge base through the Global Environment Facility (GEF) project on Climate Change Awareness Education for the Youth, and Green Ambassadors, a project on community-based adaptation to climate change and biodiversity conservation within the Johanna Margaretha Plantation (Commewijne).
- Government institutions, international organizations, and NGOs usually take advantage of the annual celebration of international environment events such the World Environment Day, World International Day of Forests, Earth Day, World Water Day, and World Ocean Day to raise public awareness of climate change. They organize presentations, video screenings, produce posters, pamphlets, and flyers for the benefit of the community and youth.
- In recent years there was also a television channel dedicated to environmental awareness (94 Green TV).
- Local green NGOs also produce communication materials (videos, flyers etc.) and organize events to raise awareness of environmental issues and climate change.
- Suriname's third national communication preparation will assist the country in deepening the integration and mainstreaming of climate change into national development goals, coordinating efforts among different actors and sectors to address climate change. The project will enable Suriname to respond to international environmental obligations by strengthening the institutional and technical capacity of government agencies, NGOs, and the private sector.

5.6.3.2. Weaknesses

- Policies, laws, and regulations are insufficient and outdated, not enforced, not monitored, evaluated, or revised.
- There is a lack of human, financial, and technological capacity in the ministries and their agencies to consistently implement policies, laws, and regulations.
- The Meteorological Service has stations that are not in operation. Rainfall data is collected mostly with rain gauges for which Suriname has 70 stations spread across the country. There are currently six automatic stations (there used to be seven, but one is not working), four synoptic stations (there used to be five, but one is not working) and 6 climate stations (there used to be eleven but five are not working).
- There is a lack of information availability, accessibility (as it is often in hard copy), and consistency across institutions.

- There is a lack of research, climate experts, research opportunities (e.g. grants, institutions), instruments, collaboration between research institutions, and research findings are not integrated into decision-making at the political level.
- There are poor facilities, equipment, and instruments for climate measurements. Moreover, society is not aware that data collection is an expensive operation and vandalism of observation instruments occurs.
- There is a lack of public and political awareness and will on climate change and its impacts on Suriname.
- There is a lack of interinstitutional cooperation and coordination.
- Cooperation projects on climate change are often not sustainable as they lack ownership due to the insufficient engagement of stakeholders.

5.6.3.3. Opportunities

- International and regional networks and organizations offer trainings, scholarships, and support for implementing the climate change agenda.
- There is funding available from international organizations to conserve Suriname's status as the most forest-rich country in the world.

5.6.3.4. Threats

- There is a high technical staff turnover with each electoral cycle. Ministries and institutions are also changing and being dissolved or newly created. In combination with poor knowledge management, this undermines the progress of institutions.
- With the recent elections in 2020, already developed plans like the NAP 2019-2029 may not be implemented or their implementation may be delayed.
- A lot of highly qualified technical staff is retiring. Additionally, Suriname loses human capital as graduates leave the country for more promising opportunities elsewhere.
- Instruments are deteriorating due to a lack of finance for maintenance.
- The unstable exchange rates and current price of developments will push society to make environmentally unfriendly but cheaper choices.
- Suriname's economy depends on extractive industries like oil and mining, which are environmentally unfriendly.

CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

6.1.1. Climate analysis

In the short-term future (2020-2044) mean, maximum, and minimum temperatures show a slight increase, which is stronger in the south of the country. This pattern is enhanced in the SSP5-8.5 scenario. Temperatures increase constantly over time, reaching a warming of up to 6°C in the southern region for the long-term future (2060-2094). Increases are particularly strong during the dry season when the maximum temperatures are reached.

As a consequence of warming temperatures, extreme indices which depend on these variables are projected to change considerably. The number of cold days and nights is expected to plummet in the medium-term for the SSP2-4.5 scenario, and in the short-term for the SSP5-8.5 path. By the end of the century there is very little chance of there being any cold nights or days in Suriname. As could be expected, the data point to an inversely proportional increase of hot days and nights. By mid-century, some points of Suriname might have hot nights more than 90% of the time.

Accumulated precipitation is expected to decrease, more strongly in the southwest and the coastal region than in the center of the country. The effects are gradual (the decrease is under 300 mm/year for the short-term and reaches 600 mm/year in the long-term for SSP2-4.5), and much faster under SSP5-8.5. The decrease in overall precipitation is less relevant than the changes in temporal distribution, where the dry season is expected to become wetter on the coast, while the rainy season gets drier. In the interior, the short dry season might get much drier, with this effect being clear in both RCPs in the short-term, while the rainy season becomes considerably wetter in the short-term, and only slightly wetter in the long-term in SSP5-8.5. This change in the seasonality of rain might be related to the changes in the ITCZ seasonal cycle, which spends less time over Suriname. The most obvious consequence is that the precipitation distribution in southern Suriname will become less smooth, with rain concentrated in fewer months.

This shift towards a more binary precipitation regime is also visible in the extreme indices. The number of rainy days decreases strongly, more so on the coast, while episodes of extreme precipitation (maximum precipitation accumulated in one or five days) strongly increase overall, in some locations almost tripling in the long-term for SSP5-8.5.

Relative humidity is not expected to change much in the short-term, although it could decrease significantly by the end of the century in the SSP5-8.5 scenario.

Wind, both in its mean fields and in the extreme indices, shows very little change for the whole country, less than a 5% increase in the most extreme cases, the SSP5-8.5 in the long term.

Sea-level is also expected to gradually rise by about 1 cm per decade for the SSP2-4.5, reaching almost one meter in the long term. According to the SSP5-8.5 scenario, the rate of sea-level rise would be 2.5 times that, reaching 25 cm per decade in the far future. However, the uncertainty that surrounds this variable is great so while the general trend is robust, the concrete sea-level anomaly that will be reached is not so clear. Sea level rise and coastal risk warrant deeper analysis.

There is no consensus about how the frequency and intensity of ENSO are going to change due to global warming. Climate change is expected to impact on the frequency of extreme ENSO events, both El Niño and La Niña (IPCC, 2019). Therefore, the drought associated to positive (El Niño) ENSO episodes in Suriname can be expected to intensify, while the excessive precipitation and flooding due to La Niña might be more frequent as the climate warms. The grade of this increased frequency is dependent on the emissions path. Extreme ENSO events are more likely to happen in SSP5-8.5 and near the end of 21st century, than earlier on and in SSP2-4.5.

The climate in Surinam's capital Paramaribo is expected to become hotter. Average temperature, historically 27.3°C, is expected to increase to 28.9°C by mid-century according to scenario SSP2-4.5, and to 29.4°C by the end of the century. Minimum and maximum temperatures are expected to reach 26.4°C and 32.4°C, respectively, in the long-term, from historically 24.4°C and 30.2°C. Consequently, hot days and nights are expected to increase to 295 and 364 per year, respectively, by the end of the century. Cold days and nights disappear altogether. Rain is expected to decrease for all seasons in the SSP2-4.5 scenario, with episodes of precipitation becoming more intense and rarer. In the SSP5-8.5 scenario the trends are similar, but more intense. Mean, maximum, and minimum temperatures would be 30.7°C, 27.7°C and 33.8°C, respectively, in the long term, and the effects of climate change in these variables would be felt already in the near future, with mean temperatures rising 0.9°C with respect to the historical period. Maximum wind speed is expected to increase moderately in all scenarios.

The changes in Albina's climate for the XXI century are very similar to those in Paramaribo. The average temperature is expected to increase from 27.5°C to 28.5°C in the near future, and to 29.7°C in the long-term according to SSP2-4.5, and to 28.6°C and 31.2°C according to SSP5-8.5. Cold nights and days are expected to disappear in all cases, becoming very rare in both scenarios as soon as the near term. Hot days and nights will increase accordingly. Precipitation is expected to decrease and become more intense in the fewer days it falls, with a 10% increase in maximum daily precipitation by the end of the century in all scenarios.

Bigi Pan MUMA mimics Paramaribo and Albina. Less rain falls during all seasons, with stronger episodes of precipitation and higher average temperature (28.2°C in the close-term SSP2-4.5 scenario, 30.7°C in the long-term SSP5-8.5 scenario), maximum (31.2°C and 33.8°C), and minimum (25.2°C and 27.7°C) temperatures are recorded.

Brokopondo shows a decrease in total accumulated rain, but more importantly a shift in its seasonal regime. Accumulated precipitation during the rainy season decreases slightly in all scenarios and periods, but it increases in the dry season, and falls abruptly in the short dry season. The average temperature rises from 27.6°C historically to 28.7°C in the near future (SSP2-4.5), and increases steadily, reaching 31.9°C, in SSP5-8.5 by the end of the century. Maximum wind speeds double in the near term in both scenarios (from 14.6 km/h to 30 km/h) and stay that way until the end of the century. Rainy days decrease from 190 per year to around 170 per year in all periods and scenarios, while daily and five-day maximum precipitation increases by 82.3 mm and 185.1 mm in the long-term future.

In the center and the south of the country, in places such as Kwamalasamutu, the shift in seasonal rain is very marked, as the regime changes to only two seasons. One rainy and one dry season. Total precipitation decreases and focuses on the rainy season, while the other three seasons receive much less precipitation. This is valid for all scenarios and periods. The maximum temperature is expected to increase by 6.2°C in the SSP5-8.5 scenario by the end of the century, with a strong change already happening in the near term (1.9°C). Minimum and average temperature are also projected to increase, albeit more slowly. More than 90% of the days and nights are expected to be hot in 2070-2094 in this scenario, although less in the SSP2-4.5 scenario, with just 254 hot days and 308 hot nights a year. Rainy days are expected to decrease slightly from 196 days a year in the historical period to around 190 by mid-century in both scenarios.

Tafelberg also experiences the same shift in seasonal rain and a decrease of yearly accumulated precipitation of more than 50 mm per decade in the SSP5-8.5 scenario, which leads to a 21% decrease by the end of the century from 1852 mm/year to 1458 mm/year. By the end of the century more than 90% of the days are hot in the SSP5-8.5 scenario, and 68% in the SSP2-4.5 scenario, while precipitation is less frequent but more intense.

Upper Tapanahony mimics the results for Tafelberg. The mean temperature rises from 26.7°C historically to 28.6°C and 29.6°C in the medium-term (SSP2-4.5 and SSP5-8.5, respectively), maximum temperatures increase by 3.3°C by the end of the century in the SSP2-4.5 scenario and by 5.7°C in the SSP5-8.5 scenario. Minimum temperatures increase constantly at the same rhythm that mean and maximum temperatures rise in both scenarios. Precipitation shifts to a two-season regime and becomes less frequent and more intense.

6.1.2. Risk analysis

Paramaribo, Sipaliwini, and Wanica are the districts most at risk, and Coronie and Nickerie those least at risk. In the past, Paramaribo and Wanica faced the most climate hazards, and Nickerie the least. In the future, Nickerie remains the district with the least hazards. Sipaliwini's hazards increase, and it becomes one of the districts with the most hazards. Commewijne and Paramaribo are the most exposed districts due to their agriculture, water, and forestry sectors (Commewijne) as well as infrastructure sector (Paramaribo). Brokopondo is the least exposed district due to its extensive agriculture and undeveloped infrastructure sector. Sipaliwini and Brokopondo are the most vulnerable districts due to undeveloped infrastructure sector. Coronie is the least vulnerable district due to its forestry and infrastructure sector.

Therefore, in Paramaribo and Wanica, infrastructure assets such as roads and bridges, and the population, should be protected from climate hazards, particularly sea-level rise, intense precipitation events, and flooding. In Sipaliwini and Brokopondo the infrastructure should be improved for the government to offer more goods and services like education, roads, and bridges to its citizens. This way, they can access alternative livelihoods, generate a higher income, and improve their living standard. In Commewijne agricultural land and livestock, and those people whose livelihoods depend on them, should be protected from the negative impacts of climate change. Water shortage is an issue to be addressed in this district. The district's high mangrove cover demands attention in light of sea-level rise and increased erosion.

6.2. Recommendations

6.2.1. Climate analysis

The following best practices on data storage and dissemination should be followed to facilitate future climate analyses:

- The use of a consistent file format is highly recommended. Furthermore, open formats such as .txt or .csv should be preferred to private formats.
- Whenever possible, the International System of Units should be used for all variables.
- Observed data should be preferred to averaged or calculated data, whenever possible.
- Consistency in station identifiers across all documents is needed and the use of reference codes should be preferred to station names.
- Consistency in date formats is needed and ISO format should be preferred.
- Formatted text, such as underlined values, should not be used to convey information. It is difficult to identify such information in algorithms and it is not compatible with open file formats.

6.2.2. Climate risk in the Agriculture sector

6.2.2.1. At the coast

- Farmers should start to engage in steady cultivation and not cultivate for market demand.
- More information on the need for vegetables should be gathered to meet food needs. This would also ensure farmers can market their products at a reasonable price and there is no surplus on the market.
- Efficient cultivation methods that reduce the risk of diseases and pests should be fostered.
- Solutions to irrigation problems in the rainy and dry season should be found.
- Awareness of efficiency and mechanization in crop production should be improved.
- Responsibilities of ensuring food security should be clarified.
- Access to land should be improved.
- Agricultural information should be stepped up. There is a lack of effective agricultural information. The LVV's agricultural extension workers should be more qualified.
- Cooperation between farmers should be encouraged.

6.2.2.2. In the interior

- Crops with a higher economic potential should be introduced.
- Agriculture should become more economically viable by introducing subsidies for agricultural inputs and planting materials.

6.2.2.3. Good practices

- More adequate information on good practices should be made available and accessible by trained communication staff.
- Participatory approaches and pilots in different regions should be conducted.
- Climate-smart agriculture policies and practices need to be put in place so that tested interventions to mitigate the negative effects of climate change can be introduced.

6.2.2.4. Research and development

- There should be more R&D activities with other national institutions, including ADEKUS, LVV, CELOS, ADRON and international institutions (e.g. UNDP, FAO).

- There should be more R&D on climate-smart agriculture, irrigation, integrated pest management, the value chain of rice and rice waste, value-added products related to rice (e.g. milk, paper, paper cups, straws), climate control systems in livestock farming, the behavior of fodder and pasture lands to a changing climate, and local livestock feed.
- Agricultural experts from the government and other organizations should work on providing information on techniques to improve agricultural production under climate change and introducing climate resistant crops in the villages.
- The impact of climate change on Suriname's the most important crops, livestock, and fishery sector should be determined.

6.2.2.5. Rice production

- Rice producers and processors should increase cooperation to produce more efficiently.
- Districts should set up water boards and a rice commodity board.
- The LVV should provide the necessary finance to increase irrigation capacity.

6.2.2.6. Mangroves

- The NMS should be implemented, and the government should promote participation in the NMS and launch pilots in high-risk coastal areas.
- The government should establish administrative capacity and a legal policy framework for mangrove ecosystem management. Mangroves should be effectively protected and rehabilitated. More donors should be attracted for mangrove conservation.
- Education on the importance of mangroves should be provided.

6.2.2.7. Fishery

- The legislation in the fishery sector should be updated.

6.2.2.8. Livestock

- The livestock sector needs to witness a transformation from being a small-scale self-sufficiency-oriented industry to becoming several potentially collaborative groups of enterprises that are competitive in the regional market. Herewith, the government should set up a program with multiple livestock enterprises that use modern production systems and technological innovation.

6.2.3. Climate risk in the Water sector

The following recommendations can reduce climate risk in the water sector.

6.2.3.1. Collaboration and coordination

- The coordination between ministries and government institutions should be improved by building on existing cooperation mechanisms which are project-based. Within cooperation projects specific arrangements should be made to focus on capacity building and improvement of cooperation between ministries/departments/institutes even after project closure.
- Cooperation between ministries and university and other education institutes should be improved by agreements giving students the opportunity for internships or research projects at the ministries or institutes. As such, both parties can benefit, the student receiving practical experience, and the institutions and ministries receiving additional insights and techniques.
- The implementation of the NAP will require the collaboration of ministries, government agencies and other actors. Thus, the coordination between government organizations, water boards, authorities, NGOs, and the private sector should be improved. The government can design cross-sectoral systems on climate observation, integrated water resource, and risk and disaster management.

6.2.3.2. Research and information

- Data gathering by the WLA and the Meteorological Service should be optimized with the aim of improving data availability. Both institutions should be strengthened in terms of measuring equipment and stations.
- More research on topics such as water storage, wastewater, septic tanks in coastal areas, and the impacts of climate change on water resources should be conducted. Research papers or at least a summary should be uploaded on the SWRIS website for knowledge management.
- The SWRIS is a good initiative and should be nurtured and maintained. It is a good platform to promote the sustainable use of water resources. An institution should be formally appointed or given the responsibility to maintain and regularly update its information. The ABS has a solid experience with data gathering and their support of the SWRIS should be encouraged.
- Human resources required for field measurements and data analysis should be improved, specifically at WLA and MDS, but also at other water-related government institutions. Vocational training for example is highly relevant because technicians are charged with the operation, repair, and maintenance of the equipment. Besides education and training issues, it is essential to deal with employment issues. Adequate salaries as well as professional and financial incentives need to be provided. Water charges paid by the customers, either through direct payments or taxes, are the single most important and promising sources of revenue to cover employment costs (UNESCO, n.d.). In view of the political and social sensitivity of water charges in many countries, public awareness campaigns can be initiated explaining the cost and cost recovery mechanisms of water treatment and supply.

6.2.3.3. Other

- Initiatives to improve water-use efficiency, such as the reduction of leakage, and water-saving by introducing volumetric tariffs, should be implemented within specific management efficiency programs. As water shortages are expected to become more serious, the formulation of data-based medium to long-term plans for water resources development and management and the development of monitoring systems for hydrological data are highly recommended.

- The new laws on water are currently in the concept phase and policies and acts for water management in boundary rivers are lacking.
- The wastewater disposal guidelines and standards should be improved.

6.2.4. Climate risk in the Forestry sector

Overall, the forestry sector benefits the most from the implementing of Suriname's REDD+ strategy. The implementation builds upon responses taken so far and is focused on four strategic lines which cover the previously highlighted issues and threats in an integrated way.

The following recommendations can reduce climate risk in the forestry sector.

6.2.4.1. Continue being a HFLD and receive compensation for economic transition

The first focus area is about receiving financial compensation for the country's high value forest and investing this in the transition to a more diversified and resilient economy. Suriname committed to maintaining 93% of its forest cover, a good basis for multilateral and bilateral negotiations to receive financial support. Also, a communication and branding plan of Suriname's forests should be developed, both at the national and international level. For the use of the financial support to drive the transition to a diversified economy, a benefit sharing mechanism should be explored.

This first focus area also aims at supporting existing, alternative, and additional sustainable livelihoods by analyzing market potentials of local communities and by promoting NTFP, ecotourism, medicinal plants and agroforestry practices, and creating training and education opportunities for forest-based communities.

6.2.4.2. Forest governance

The second focus area is about forest governance and stakeholder participation in the strategy's planning and implementation process. Precisely, this component aims at strengthening the capacity of ITP and encouraging participation of private sector and other forest-related actors.

Another aspect is related to increasing the ability of the government to manage, control, and monitor its resources. This includes capacity building of institutions and forest-based communities in forest monitoring, control, and protection, as well as the implementation of the NFMS.

Further aspects include updating forest and environmental laws and regulations, such as updating the Forest Management Act, legalizing the Code of Practice guidelines for sustainable timber harvesting, implementing the Environmental Framework Act, and revising the Nature Conservation Law.

Finally, attention should be paid to the promotion of SFM. This is done by increasing the proportion and size of the area that is under control by forest management (SFM, including Reduced Impact Logging) by increasing the efficiency of the forest sector through appropriate taxation by reviewing timber charges, and by increasing the added value of wood production by reducing the proportion of roundwood exports in favor of processed products.

6.2.4.3. Land use planning

The third focus area is about developing, implementing, and maintaining land use planning, zoning, and sustainable land use practices and tools that result in optimal use of the forest and natural resources. This includes clarifying land tenure by supporting the process toward legal recognition of land right for ITP, by strengthening capacities of judiciary and government officers on the rights of ITP, and by making information on traditional land ownership publicly available in the central registry.

A component related to land use planning is also included, by streamlining concession policies (mining and logging) and geographic information, system information, mapping and publicizing areas designated for small-scale mining, formulating new land use planning legislation, and improving the location and size of community forest concessions.

Another aspect is related to the promotion of sustainable practices in land use sectors other than forest, by adopting and implementing the Environmental Framework Act, reviewing the Mining Decree from 1986 and improving mining regulations, and further supporting Suriname's participation in EITI.

Finally, the focus area deals with empowering participatory community development, specifically by supporting alternative livelihoods and diversifying the economy in the interior. This is done by promoting a democratic management of community forests and the equitable allocation of benefits, and by promoting planning at the community level.

6.2.4.4. Conservation of forests and reforestation as well as research and education support sustainable development

The final strategic line focusses on forest conservation, aiming to continue and expand current efforts for the conservation and rehabilitation of the forest, its biodiversity, and ecological functions, while exploring extractive and non-extractive uses that result in community development and wellbeing as well as in economic diversification.

This includes actions on protected areas, increasing the coverage of protected areas in relation to the draft Nature Conservation Act, the rehabilitation and reforestation of degraded and deforested areas, mangroves, and abandoned mining sites, and scientific research and education on forest management.

6.2.5. Climate risk in the Infrastructure sector

The following recommendations can reduce climate risk in the infrastructure sector.

6.2.5.1. Climate-resilient building and infrastructure

- The Master Plan of Greater Paramaribo should be updated to integrate climate change considerations.
- Climate-resilient building materials suitable for tropical climates should be increasingly promoted among the population and research and education institutions.
- Capacities should be built not only in the OW, but also in the private sector (construction companies, architectural bureaus).
- The awareness of vulnerable communities along the coast toward climate hazards should be raised. Their activity there should be gradually reduced or moved to areas less at risk, and the development of new activities in at-risk areas should be forbidden (Government of Suriname, 2019).
- There should be explicit design criteria for assets in flood risk areas (Government of Suriname, 2019).
- Laws, policies, and regulations considering climate change in the planning of public investments should be developed.
- The land tenure systems should be geared towards the long-term, as this will favor adaptation by landowners, tenants, and other users (Government of Suriname, 2019).
- The government should strengthen the resilience of key infrastructure that is of strategic importance to the country.

6.2.5.2. Natural and artificial drainage

- Here, the emphasis should be on the strategic and sustainable future land use as urbanization and associated land use changes (e.g. paved surfaces) lead to a greater flood risk as a result of reduced infiltration (Sumaqua, 2019).

6.2.5.3. Protective infrastructure

- An effective early warning system should be introduced.
- Buffer zones and dikes should be developed along the coastline and rivers.
- Regular maintenance and frequent inspections of infrastructure should be conducted and areas which require investment for improvements should be identified.

6.2.5.4. Energy

- Energy conservation and efficiency for domestic and commercial uses should be promoted.
- The development of renewable off-grid electricity should be fostered.
- An energy building code for housing and infrastructure should be developed.

6.2.6. Climate risk across sectors

The following recommendations can reduce climate risk across all sectors.

- The Environmental Framework Act should be fully enforced.
- The Environmental Framework Act provides a great basis from which to take climate action. However, sectoral legislative pieces should also be updated and complemented.
- A participatory approach should be fostered throughout the country to find integral solutions, i.e. activities should include tribal and local organizations, the private sector, NGOs.
- Community-based adaptation, pilots and other participatory approaches should be fostered. These should explicitly consider traditional knowledge.
- Institutions should strengthen their knowledge management so that no knowledge gets lost between electoral cycles due to staff turnover.
- There should be cooperation agreements between government institutions, between government institutions and research institutes, and between research institutes, including on the sharing of information and research informing political decision-making.
- International cooperation projects should include a component on capacity building to foster the continuity of interinstitutional cooperation mechanisms after the end of a project.
- Roles and responsibilities between cooperating actors should be clear. The NMA should assure that various actors execute their functions in a concerted manner.
- There should be more finance for research and development, including studying the impact of climate change. Finance also needs to be available to retain human capital in academic and government institutions.
- Research on climate change impacts such as water shortages on extractive industries (oil, mining), the main drivers of the Surinamese economy, is highly recommended.
- The change in position of the ITCZ and in ENSO, their impacts on precipitation and temperature regimes, and consequently the availability of water demands further investigation.
- A study on the economics of climate change in Suriname would be helpful to ascertain the specific sectoral impacts from an economic standpoint, as well as to provide the basis for the development of a cost-benefit analysis of adaptation options.
- The risk index should be updated whenever new indicators or data are available.
- A detailed study on coastal risk to sea level rise, including more precise data on sea level rise and the geomorphology of the coast, shoreline change rates (erosion and accretion), the coastal slope, wave height, and tidal range is also recommended.
- Human, financial, and technological capacity should be strengthened across the board.
- There should be more education and awareness raising activities for the public.
- The government should increasingly collaborate with the private sector, which can offer technological solutions and decrease climate change impacts by protecting its assets.
- As an HFLD country, Suriname should make use of the carbon market.
- More climatological observation stations should be installed to have a continuous data collection in space and time. There should be a transition from conventional instruments to automatic recording instruments, especially for the remote areas of Suriname.
- The government should improve the institutional framework of DRM and develop a disaster risk financing and insurance strategy.
- The synergies between adaptation and mitigation should be fully taken advantage of (forests offer many opportunities), and trade-offs should be addressed.

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