State of the Climate Report, Suriname. Summary for Policy Makers

Climate Change Division

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State of the Climate Report Suriname

Summary for Policy Makers

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Foreword

Juan Pablo Bonilla

Manager Climate Change and
Sustainable Development Sector
Interamerican Development Bank

Suriname is one of South America's best-preserved treasures. With 93% forest cover, the country houses vast ecosystems and rich biodiversity like nowhere else. The country is also a unique cultural melting pot, where the concurrence of people from different heritages and ethnicities makes Suriname a unique land with diverse gastronomies, architecture, and languages.

Despite these wonders, Suriname faces undeniable challenges that threaten its peculiarity. As a low-lying coastal state, it is prone to natural disasters and climate change. Estimations suggest that a 1-meter rise in sea level would affect over 6.4 percent of Suriname's GDP, 7 percent of its population, and 5.6 percent of agricultural land. Indigenous and Maroon communities are at risk because of their economic situation and location in remote areas where extreme droughts and floods have been recorded in the past. Neglecting this reality could result in severe human and economic casualties.

Fortunately, the government of Suriname has been proactive in understanding climate change variability and its potential impacts on its population and economic assets. In doing so, the Inter-American Development Bank (IDB) has been a close ally to Suriname in its effort to enhance its resilience to climate change. This collaboration has produced initiatives like the update to the Nationally Determined Contributions (NDC) and the Technical Cooperation "Mainstreaming Climate Change into Decision-Making tools." In the context of the latter and considering climate change as a fundamental pillar of its 2025 Vision Strategy to guide the region towards a sustainable recovery, the IDB has supported the elaboration of the State of the Climate (SOC) Report.

The SOC Report is an in-depth technical assessment of potential changes in climate in Suriname. The report provides crucial insights into the potential risks of important sectors of the economy, such as water, agriculture, forestry, and infrastructure by assessing climate trends and projections. The gathering and processing of information by specialists represent a multi-sectoral effort in which many stakeholders from Suriname have taken part, and the efforts to raise awareness by the IDB and government officials reflect the outstanding commitment of all to make this report a reality. Today, Surinamese can feel proud they are once more at the forefront of environmental and climate action in the region.

This summary for policymakers highlights the main findings of the full State of the Climate Report. We hope this first glimpse provides you with the information you require for your purposes and encourages you to dig deeper and explore the full report. We are sure the report could serve as the primary source to guide decision-making and climate policy planning in Suriname.

The COVID-19 pandemic has highlighted the importance of preparing for events of global influence. Enhancing the resilience of our societies and economies should be at the top of our agendas. This process should be guided by science-based evidence and informed decision-making. The SOC report shows that more sustainable pathways ensure the livelihood of the less favored and the country as a whole.

We invite you to review the State of the Climate Report Suriname and learn a bit more about this fantastic country, the challenges it faces, and the ways we can help overcome them together.

Silvano Tjong-Ahin

Minister of Spatial Planning and Environment, The Government of the Republic of Suriname.

The state of the climate report comes at a remarkable point in history where the world is being challenged by forces of nature to reinvent its thinking about the environment. Our irresponsible interference in nature produced a deadly uncontrollable virus, that currently dominates our life and threatens our existence. COVID-19 cannot be seen separately from the challenges of climate change. We have come to know that it has its origin in human behavior and we have also seen the reverse reaction that the pandemic forced us to temporary halt our industrial activities which has proven to reduce global carbon emission, albeit temporarily.

Climate change is our universal concern and responsibility. We have reached a point where it is no longer a phenomenon of the future. We are in the middle of it; it can be felt everywhere and the consequences are unpredictable. It is also present in Suriname where a general perception exists that we are blessed by nature with an abundance of pristine forest, clean water resources and thus not significantly vulnerable to climate change. This report proves this perception wrong.

With our new Ministry of Spatial Planning and Environment (ROM), the policy regarding climate change will be fundamentally revised. Improved monitoring of carefully selected indicators; maximum participation of all relevant parties and evidence-based policy will be fundamental to our policies to reinvent our relationship with nature.

In that regard, this report is timely and we are grateful that the IDB anticipated to this new orientation. It provides a deep analysis of our climate patterns, past and in the future, and it will contribute significantly to the quantitative framework of environmental indicators that the Ministry of ROM intends to establish and use as the main driving tool for environmental policy.

Acknowledgments

The State of the Climate Report was elaborated as part of the Technical Cooperation "Mainstreaming Climate Change into Decision Making Tools" implemented by the Climate Change and Sustainability Division of the Inter-America Development Bank and the Ministry of Spatial Planning and Environment of Suriname. The elaboration of the Report was led and supervised by Gerard Alleng (Senior Specialist at the Climate Change Division) and Adrián Flores Aguilar (Consultant at the Climate Change Division).

The State of the Climate Report was developed by the consultancy firm Factor between April 2020 and May 2021. The team was led by Kepa Solaun and consisted of Chiquita Resomardono, Victor Homar, Helena Antich, Carlos Alonso, Craig Menzies, Katharina Hess, Florence Sitaram, Lydia Ori, Priscilla Miranda, Antonio Castaño, Alejandro Buil, Julia de Juan, Sukarni Mitro, Ria Jarap, and Madhawi Ramdin. We are thankful for your excellent technical work.

The authors thank numerous colleagues from other divisions at the IDB and multiple institutions from the Government of Suriname. The team also appreciates the comments received from all the participants during the consultation and awareness-raising in March 2021.

The Report was edited by Zachary Zane. Graphic design by Evi Jurado. Publishing support by Andrea García and Catalina Aguiar from IDB's Climate Change and Sustainability Division.

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Abbreviations

ADEKUS	Anton de Kom University
CELOS	The Foundation Center for Agricultural Research in Suriname
CMIP6	Coupled Model Intercomparison Project Phase 6
GCM	General Circulation Models
IDB	Inter-American Development Bank
IPCC	Intergovernmental Panel on Climate Change
LVV	Ministry of Agriculture, Animal Husbandry and Fisheries
MUMA	Multiple Use Management Area
NCCPSAP	National Climate Change Policy, Strategy and Action Plan
NTFP	Non-Timber Forest Products
OP	Suriname's National Development Plan
RCP	Representative Concentration Pathway
REDD+	Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks
SoC	State of the Climate
SSP	Shared Socioeconomic Pathways
UNFCCC	United Nations Framework Convention on Climate Change

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.

In order 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, which makes evidence-based decision-making difficult. Therefore, the Inter-American Development Bank (IADB) and Government of Suriname decided to collaborate on the project "Mainstreaming Climate Change in Sustainable Decision-Making tools", as discussed in Chapter 1, and includes the State of the Climate (SOC) Report. The SOC Report is an excellent resource to complement other efforts such as Suriname's Nationally Determined Contribution (NDC) of the Paris Agreement on climate change and the National Communications to the United Nations Framework Convention on Climate Change (UNFCCC). By providing science-based evidence, the SOC should serve as a resource for prioritization amongst policy planners. Chapter 2 provides details on the data and methodologies used to obtain the results of the climate and risk analyses contained in this report.

The SOC Report analyzes Suriname's historical climate (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 two scenarios show similar trends throughout the timeframes at different levels. These findings are presented at a subnational level, though both scenarios show Suriname to become hotter and drier, with the average, minimum, and maximum temperatures all expected to raise significantly by the end of the century. Consequently, the number of hot days is expected to increase to 295 per year and nights to 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 more intense and rarer. Maximum wind speed is expected to increase moderately in all scenarios.

The SOC analyzes climate risk for the country's ten districts by examining the factors which increase their exposure and vulnerability on the four most important sectors affected by climate change: infrastructure, agriculture, water, and forestry, as well as examining the effects across the sectors. These were then combined with the historical and projected data and climate hazards to produce impact chains. The impact chains help calculate the climate risk index for each district and for each timeframe, provided in Chapter 5. The analysis shows that.

Paramaribo, Sipaliwini and Wanica are the districts most at risk, and Coronie and Nickerie those least at risk. Sipaliwini and Brokopondo are the most vulnerable districts due to their vulnerable agriculture and infrastructure sectors, while Coronie is the least vulnerable district. Also assessed are the strengths and weaknesses for each sector, as well as existing opportunities and threats to be addressed.

It is essential for Suriname to have updated climate change policies and targets in place, as well as robust institutional arrangements to ensure their implementation. These policies and all other recommendations, and the conclusions drawn are expressed in Chapter 6 and enable an adequate mainstreaming of climate change adaptation and resilience enhancement into day-to-day operations. The references for the SOC Report can be found in Chapter 7.

The SOC report helps solidify climate change as a national agenda instead of solely a concern of the environmental authorities. Local capacities should also be strengthened to address the most urgent challenges established by the SOC, and should accompany the introduction of state-of-the-art technology to support institutions such as the Meteorological Service Suriname and the National Institute for Environment & Development (NIMOS).

Suriname continues to step in the right direction in addressing climate change. Science-based decision-making is key to face the challenges Suriname faces. The SOC report will surely help the country plan and pursue a climate-resilient future and ensure the wellbeing of its citizens.

Introduction

Suriname's contribution to global climate change is relatively small. 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: It depends on fossil fuels, has forests liable to decay, fragile ecosystems, and a low-lying coastal area where about 87 % of the population and most of the country's economic activities are concentrated. Key sectors such as infrastructure, agriculture, water, and forestry are at great risk of suffering loss and damage incurred by gradual changes as well as extreme weather events related to changes in sea level, temperature, precipitation, humidity, and winds. Today, climate change impacts the Surinamese people in the form of extensive coastal erosion, prolonged dry seasons, and flooding.

Suriname has fully committed itself 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 2005 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. However, 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.

Therefore, the Inter-American Development Bank (IDB) and the Government of Suriname have decided to collaborate on the project "Mainstreaming Climate Change in Sustainable Decision-Making Tools". The project's objective is to support the mainstreaming of climate change into Suriname's OP and to enable evidenced-based decision-making that is inclusive, transparent, considers the impacts of climate variability in multiple sectors. One of the project's products is the State of the Climate (SoC) report.

The overall objective of the State of the Climate Report is two-fold: First, it comprehensively analyzes the likely impacts of climate change on several geographic areas as well as for key sectors of agriculture, water, forestry, and infrastructure through historic climatic trends. Second it provides projections that include sub-country level details. The Non-Technical Summary provides the analyses, results, and recommendations of the SoC in a non-technical language.

The Report consists of seven chapters including an introduction, a conclusion, and references. Chapter two describes the methods used to model the climate using different General Circulation Models (GCMs), emission scenarios and statistical means to regionalize the projections. Chapter three provides a historical summary and future projections of the climate at the regional and local level. Chapter four describes the risk and impact chain analysis. The results are presented for individual sectors and for all sectors in total. The Report closes with a chapter of recommendations.

Overall, Suriname's State of the Climate Report provides a comprehensive analysis of the climate risks the country faces and how it can ameliorate these. The Non-Technical Summary provides stakeholders, policymakers, various communities, and the public with a version of the SoC in non-technical language that supports development planning and 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.

1. Climate modeling

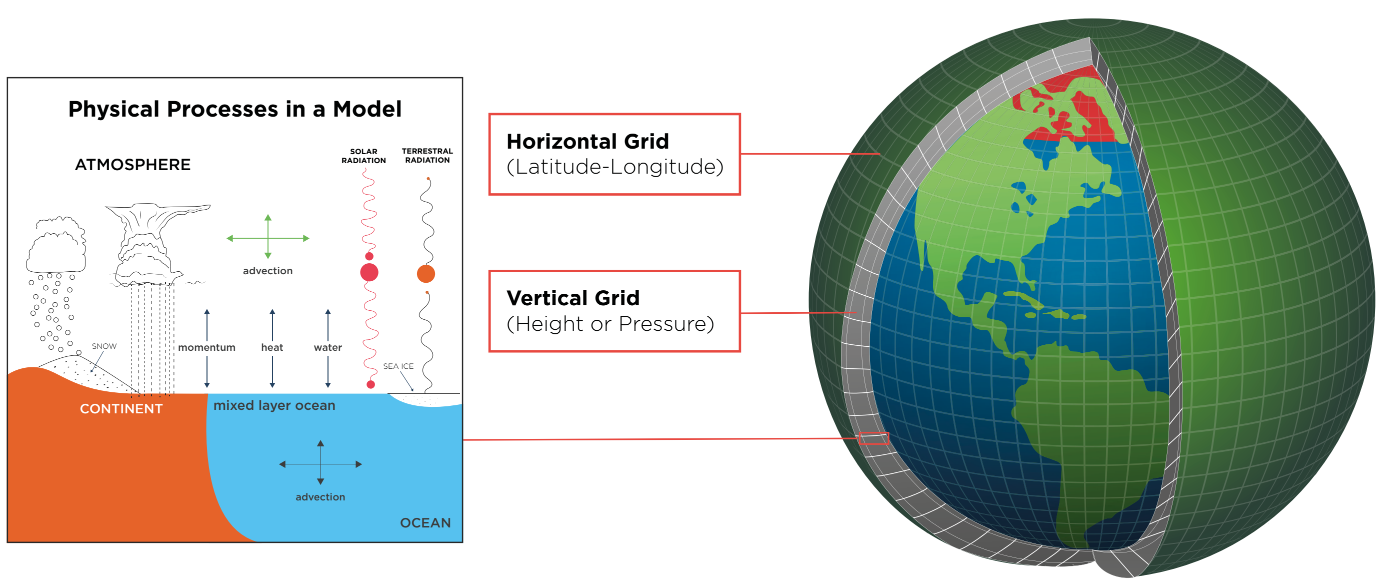
“

Climate modeling allows scientists and decision-makers to deal with future climate uncertainty by proposing different development scenarios based on the CO_2 emissions pathways.

1.1. Global Circulation Models

The main tools used in this study are three GCMs from the Coupled Model Intercomparison Project Phase 6 (CMIP6), considered state-of-the-art complex computer programs among climate modeling projects. These models have several components, of which the most important are the atmosphere, the hydrosphere, and the land surface (figure 1). They allow us to understand variations in climate and its evolution over years and decades, and use them to explore different possible futures. The use of different models is also an advantage, since not all of them respond in the same way to changing radiative forcing scenarios. Radiative forcing is defined as the difference between solar irradiance (sunlight) absorbed by the Earth and energy radiated back to space. That is, the stronger the radiative forcing, the warmer the earth will be.

Figure 1 General schematics of the parts of a general circulation model, with a description of the physical processes that take place in each grid-cell

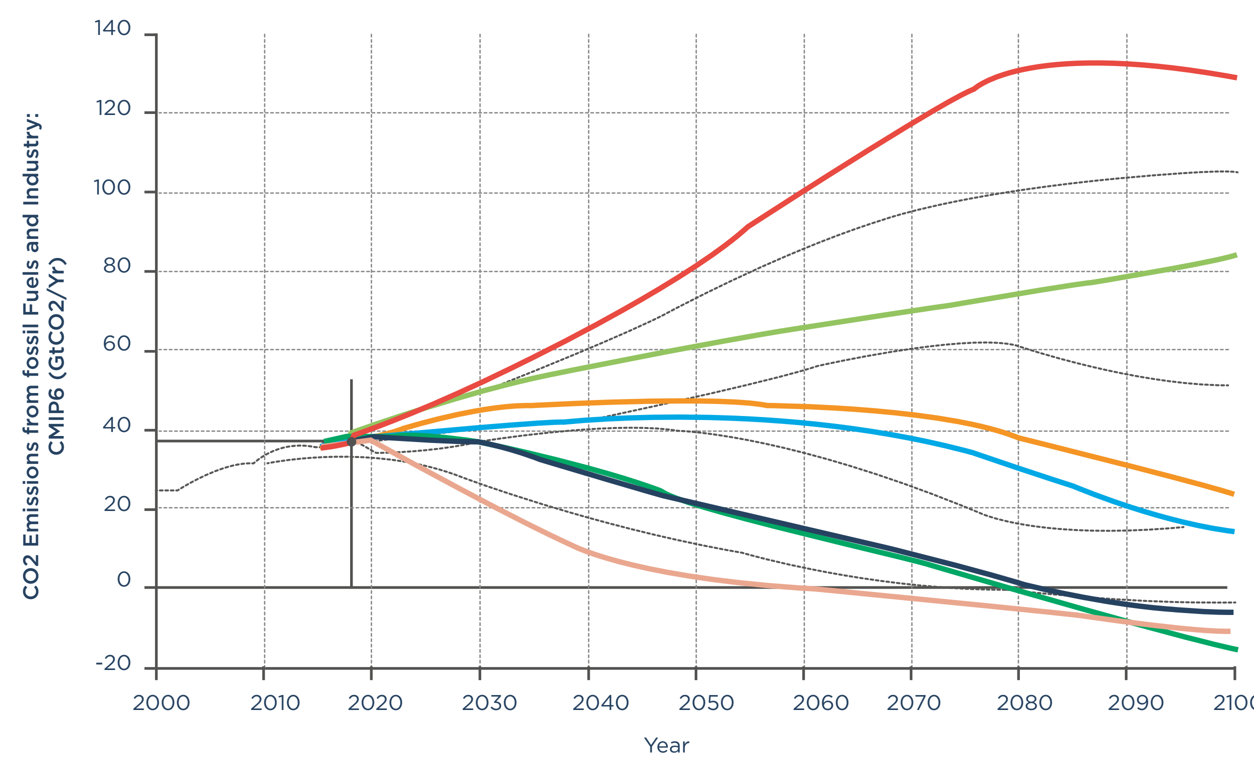


Source: Wikimedia Commons.

1.2. Emission scenarios

Climate scientists deal with the future climate uncertainty by proposing different development scenarios based on the CO_2 emissions from the burning of fossil fuels, and characterized by the radiative forcing estimated to be reached by 2100. These scenarios are enriched by speculations on the paths global societies might take, including a continuation of the present global order, a general transition to more equal and less resource-intensive societies, and an increased overall use of natural resources. In this work two different Shared Socioeconomic Pathways (SSP) or scenarios are considered: SSP2-4.5 (CIMP6 – RCP4.5 in figure 2) which represents a "middle of the way" scenario, in which society uses slightly more resources than the present and there is a moderate increase in radiative forcing by the year 2100. The second scenario, SSP5-8.5, deals with a resource-intensive society which drives emissions up very quickly (CMIP6 – RCP8.5 in figure 2).

Figure 2 Emissions paths established for the CMIP6 experiments



» **Note:** Our work uses the Representative Concentration Pathway (RCP) 4.5, a difficult-to-achieve but likely emissions reductions path, and the RCP8.5, the business-as-usual path, in which no reduction on the rate of emissions is taken.

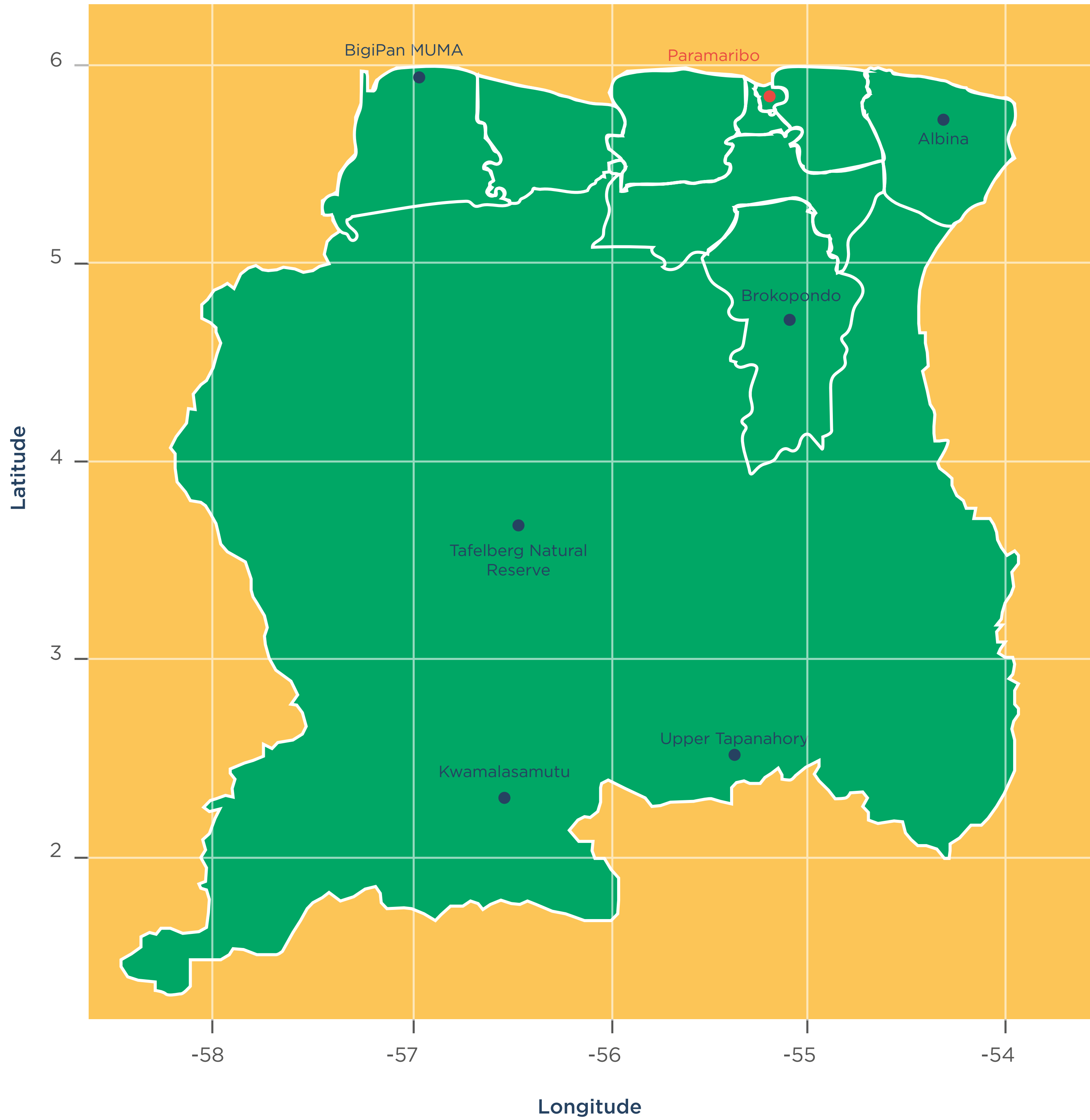
Source: Carbon Brief.

1.3. Downscaling global models to the local level

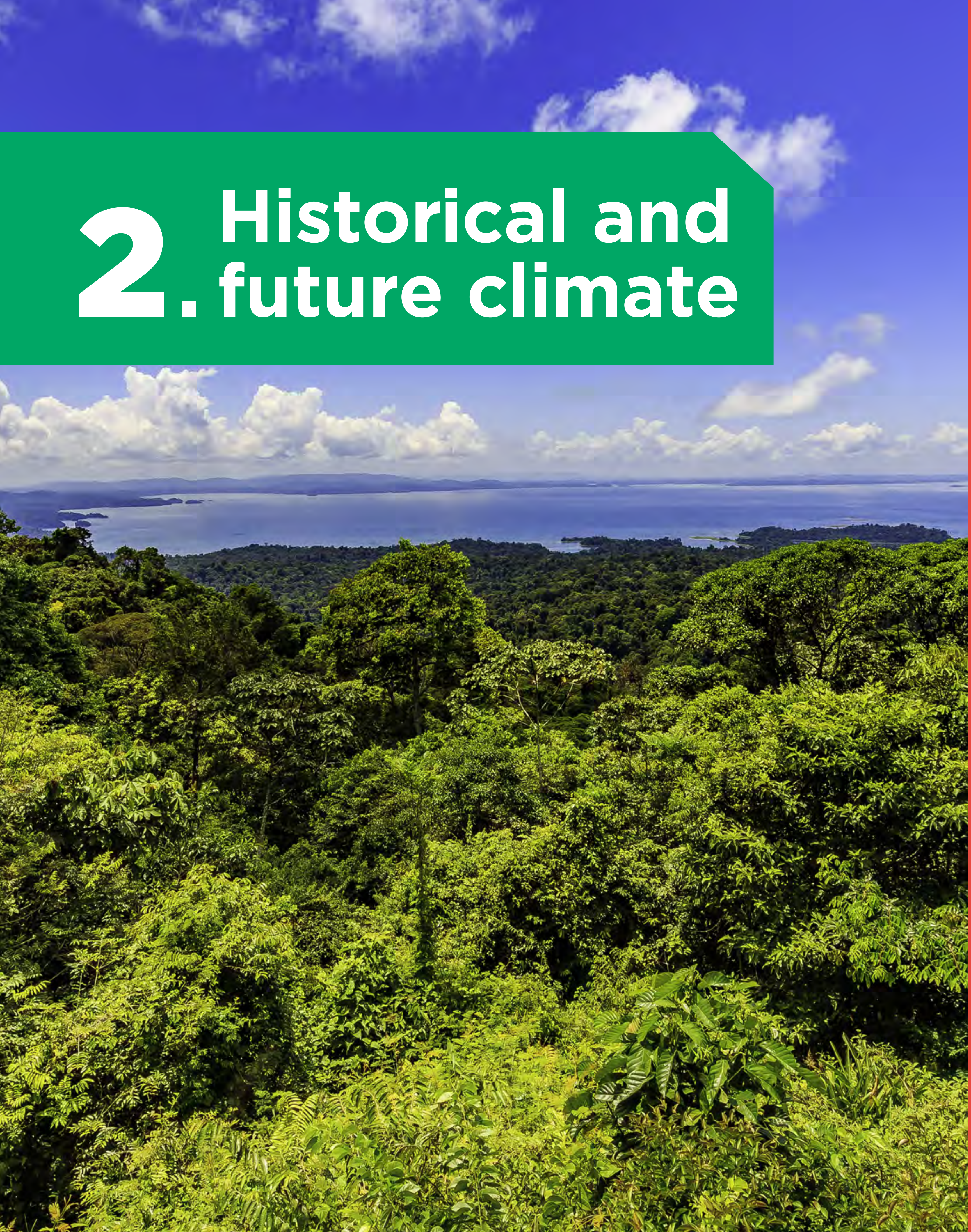
Spatial resolution also varies among models. In this study grid cells range between 100km to 250km of horizontal resolution. This is enough to capture the general evolution of the climate, but it does not allow resolution of phenomena at smaller scales, which leaves out meteorological phenomena of interest from a public policy point of view. To be able to study these events, statistical downscaling techniques have been applied to the results of the models.

Model data is evaluated by comparing it against observed data. Historical daily data from 1990 to 2019 has been obtained from the Suriname Meteorological Service records. These come from a dense array of 35 stations which, together with global data, have allowed us to use 16 atmospheric variables to establish an observed climatology. The analysis of the present climate and future projections in Suriname has been carried out for both the complete domain of the country, for which the mean fields for each variable and scenario have been computed, and for seven points of interest (figure 3). At these locations, distributed throughout the country from the Caribbean coast to the hilly interior, the seasonal cycle of the variables and yearly occurrence of extreme events were computed.

Figure 3 Points of interest of the study



Source: SOC Report team elaboration



2. Historical and future climate

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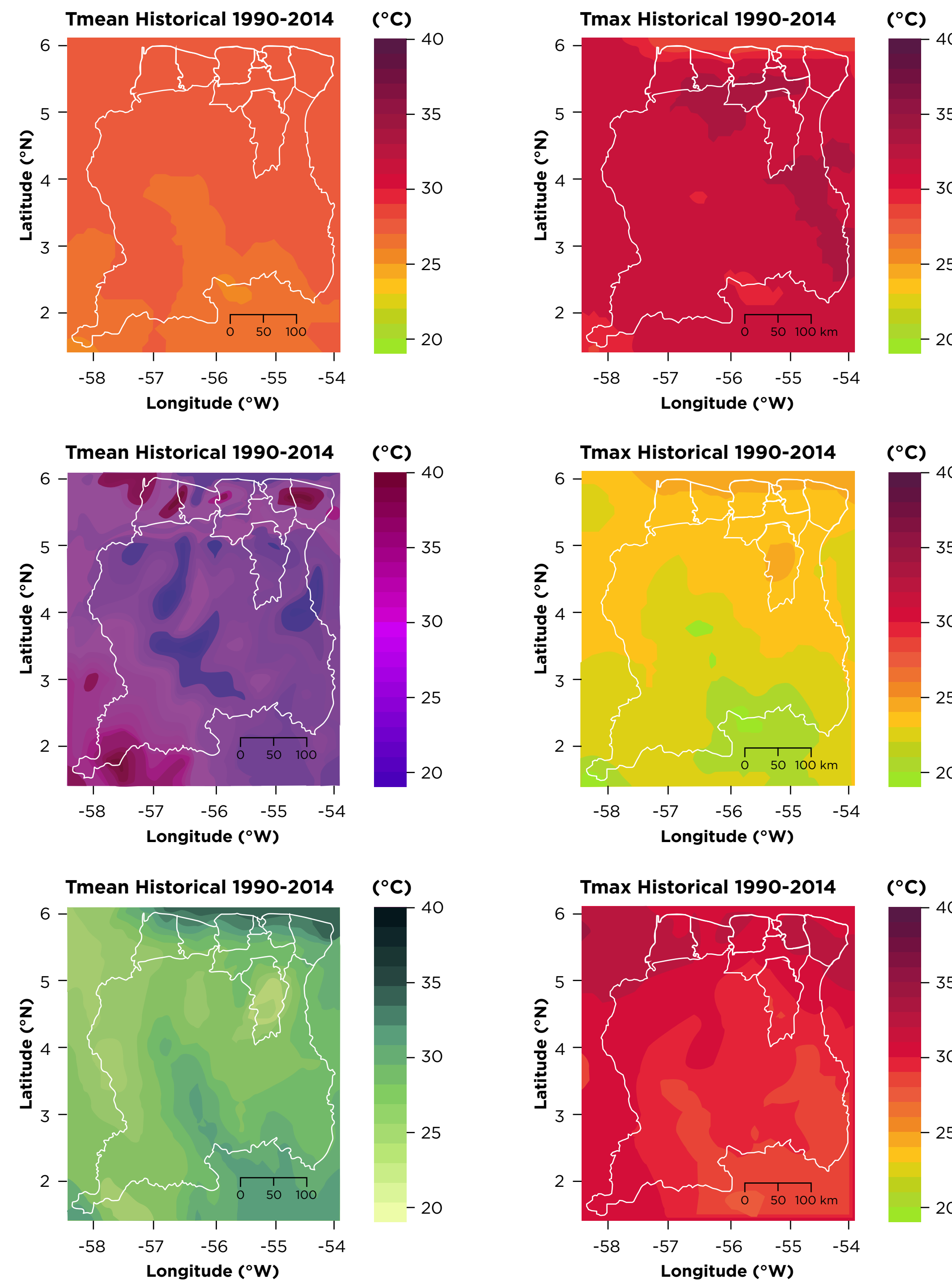
The historical climate analysis in Suriname shows an increasing trend in precipitation, a decreasing wind speed, and rising temperatures, while the future climate analysis shows projected increases for the daily temperature and the decrease of accumulated precipitation.

2.1. Historical climate: regional analysis

The SoC provides an analysis at a regional scale, presented in maps that cover the entire country at a resolution of 10 km. The baseline climatology data used for the regional analyses is for the period 1990-2019. The variables are temperature, precipitation, wind, and relative humidity. The average temperature for the country is around 27°C, and the daily maximum temperature varies between 32°C-33°C. The daily minimum temperature in Suriname varies between 21°C-25°C and the coastal areas record higher temperatures than the south of the country. The annual precipitation totals vary between 1500mm-3000mm across the country, with maximum totals around 3000 mm/year for the south. The maximum daily winds vary from 35kph-40kph in the corridor of the north to the southeast of the country, and for the rest of the country it varies between 25kph-32kph. Relative humidity is high for all of Suriname (80% or more) (Figure 4).

Figure 4 Maps of the average values in the period 1990-2014 of mean temperature (top left), maximum (top right), minimum (center right), annual accumulated precipitation (center left), maximum wind (bottom left) and relative humidity (bottom right).



Source: SOC Report team elaboration

2.2. Historical climate: local analysis

This section presents the climatological behavior of the seven points of interest. The variables chosen for this study are temperature, precipitation, and daily wind speeds. These variables were chosen because they best characterize the local climate.

Paramaribo has two distinct wet seasons (April to July and a shorter season in December and January) and two distinct dry seasons (a short season in February and March, and from August to November). Maximum and minimum temperatures show the same behavior, with a strong maximum in October and minimum temperatures in each wet season show a smoother yet similar cycle.

This climate regime is shared by Albina, Bigi Pan MUMA, and to a lesser extent Brokopondo. Further inland, the precipitation is more evenly distributed. Kwamalasamutu and Tafelberg have a wet season from April to August, and in Upper Tapanahony from January to June. The dry season for all of Suriname lasts from September to December. Minimum temperatures are lowest in February for Tafelberg and Upper Tapanahony, the highest in altitude, and July in Kwamalasamutu. Maximum temperatures for the entire county occur in October during the dry season.

The main driver of the differences in climate regimes is the annual cycle of the Intertropical Convergence Zone (ITCZ), a belt of very intense precipitation that surrounds the globe. This belt reaches its southernmost position for Suriname's region in March. During this month, the ITCZ effects are felt in the south of the country, but not in the north. It then moves north until September, where it is beyond any point in Suriname, creating the dry season throughout the country, lasting longer in the north.

The climate analysis of the seven points of interest in Suriname shows an increasing trend in precipitation, a decreasing maximum wind speed, and rising minimum temperatures. The analysis points to a climate that has overall become more humid, and while coastal areas have become warmer, the south has turned a bit cooler.

2.3. Future climate: regional analysis

Future climate conditions were produced for three future time periods of 25 years: near (2020-2044), mid-term (2045-2069), and long-term (2070-2094). In this work two different scenarios are considered: First is SSP2-4.5, which represents a "middle of the way" scenario, in which society uses slightly more resources than the present. Second is SSP5-8.5, which deals with a "business as usual" resource-intensive society, driving emissions up very quickly. The variables for the regional analyses regarding the future climate conditions are temperature, precipitation, wind, and relative humidity. The projected sea-level anomaly is also presented and discussed.

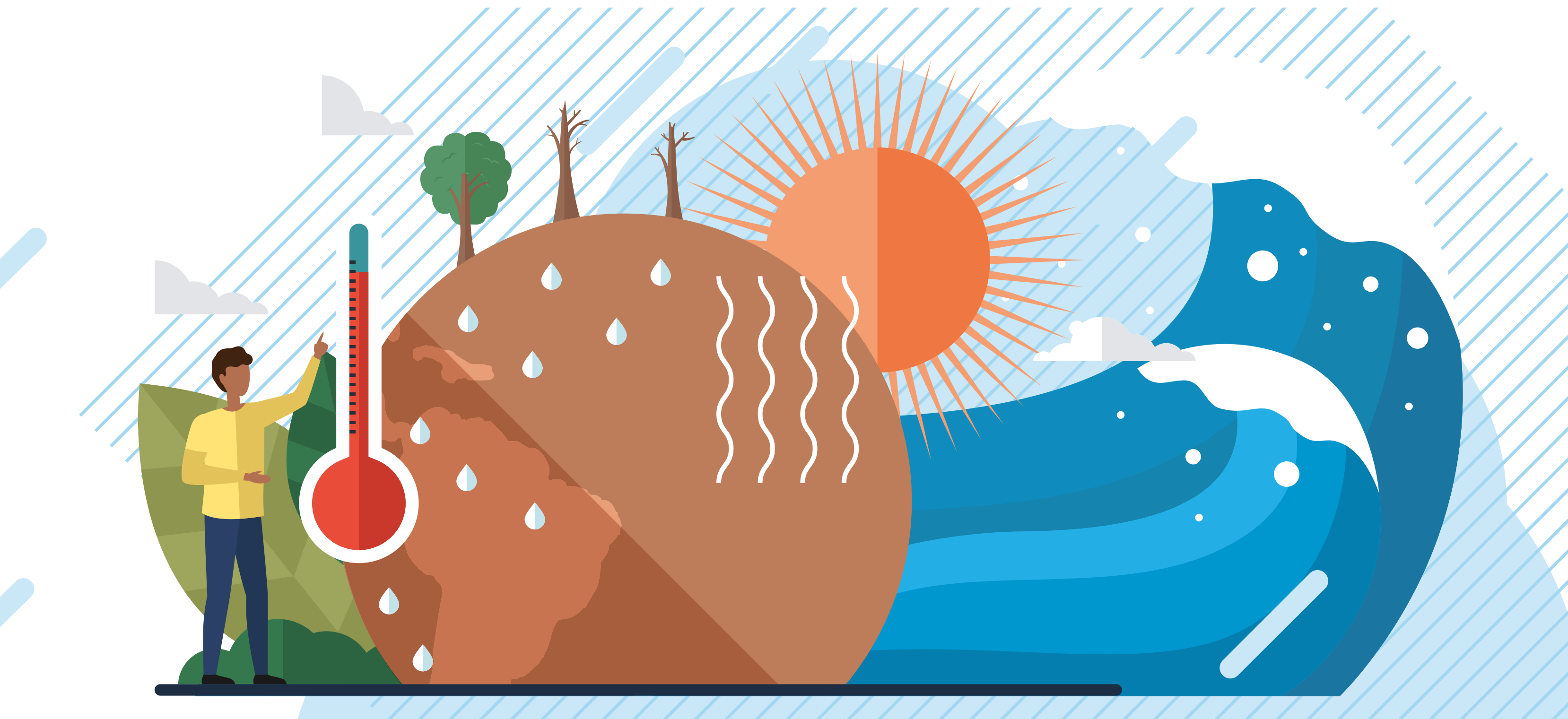
The analyses show projected increases for the daily temperature over the entire country for all periods, lesser in the coastal areas and more in the southwestern region of Suriname. Considering the scenarios, the results are the following for temperature:

- The mean temperature is projected to change by the end of the century from around 27°C to 32°C (SSP2-4.5) or 33°C (SSP5-8.5). Maximum temperature for most of the country will increase from 32°C to 37°C (SSP2-4.5) or 39°C (SSP5-8.5). Minimum temperature, which is reached in the southeast of the country (20°C), is expected to increase to 24°C (SSP2-4.5) or 26°C (SSP5-8.5),

- The range of mean temperature on the coast is projected to increase 0.5°C in the short term for the SSP2-4.5 scenario, and more than 3°C at the end of the century for the SSP5-8.5 scenario.
- The mean minimum temperature in the central region of the country is projected to increase between 1.5°C in the short-term SSP2-4.5 scenario, and 5°C in the long-term SSP5-8.5 scenario.

Accumulated precipitation in Suriname is expected to decrease strongly as the mean position of the ITCZ shifts northwards. Considering the different scenarios, the results are the following:

- The maximum precipitation per year reached in the southwest could reduce by 500mm by the end of the century in the SSP2-4.5 scenario, reaching values of just over 3,000mm/year. The projected decrease in yearly precipitation is also strong in the coastal region, especially in the SSP5-8.5 scenario, which points to a decreasing trend from around 2,500mm to just over 2,000mm. In general, the decrease in precipitation for the country could surpass 20% of the historical climatological accumulated precipitation.
- Considering wind, no remarkable trends are projected in any of the scenarios considered.
- The analysis shows a decrease of relative humidity in the short term for both the SSP2-4.5 and SSP5-8.5 scenarios, particularly in the southwest of the country. The long-term scenario shows a country-wide recovery, which would put the new average relative humidity at about 80% in the coastal region and between 65%-70% in the south of Suriname.
- The scenarios were also studied for sea-level rise for Suriname. However, relative sea level is a complex issue with many additional factors to those calculated in this study. Such an analysis would require a much more detailed study that is out the scope of this Report. Sea-level anomaly increases with a rise in temperatures and can be expected to surpass 0.25 meters in the long term if emissions are not curbed.



2.4. Future climate: local analysis

There are two major climate regimes in Suriname. Historical studies show two wet and two dry seasons in the coastal areas of Paramaribo, Albina, and Bigi Pan MUMA, and one wet and one dry season in the southern part of the country (Kwamalasamutu and Upper Tapanahony, mainly). Considering the scenarios, the overall results are the following:

1. Temperatures are expected to increase in both scenarios, especially in SSP5-8.5, throughout the 21st century.
2. For the northernmost locations (Paramaribo, Albina, Brokopondo and Bigi Pan MUMA) total precipitation is expected to decrease, especially during the short dry season. Both the wet and dry seasons are expected to intensify in both scenarios and all timeframes. However, in some cases, such as Tafelberg and Upper Tapanahony, the beginning of the wet season from January to April is expected to become very dry.
3. There is almost no change at all in the wind regime for Brokopondo, Paramaribo, Albina, Kwamalasamutu and Bigi Pan MUMA
4. The two-season regime in the south will change to four seasons, similar to what is now seen on the northern coast. It is expected that the effect of the ITCZ is to be much more focused and only last a few months.

3. Climate risk

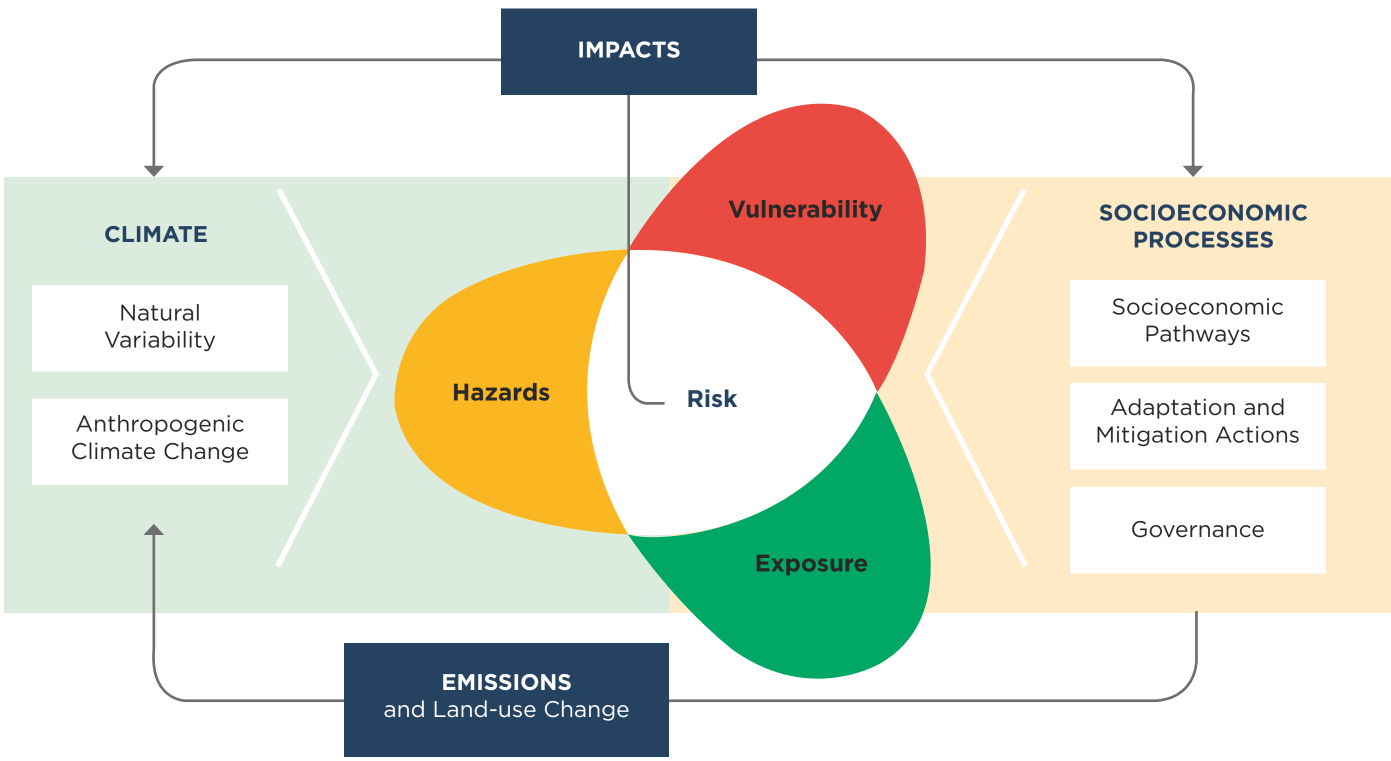
"Changing climate conditions will increase hazards such as sea-level rise and flooding, which will pose serious pressure on infrastructure and natural assets in Suriname. Therefore, decision-makers should adopt mitigation measures to protect these assets and the vulnerable population.

3.1. Methodology

The aim of this section is to analyze the impacts of socio-economic processes of each sector and climate conditions to provide a comprehensive overview of the climate risk in Suriname and its most important sectors. Climate risk is the product of exposure, vulnerability, and hazards. Impact chains were developed to provide an insight into which factors determine climate risk in each sector. An impact chain has been developed for the four sectors of Water, Agriculture, Forestry, and Infrastructure, and provides an interpretation of its five elements: hazards, intermediate impacts, risks, exposure, and vulnerability (Figure 5).

Based on the impact chains, indicators were selected to construct the risk index, which was complemented by the hazard indicators.

Figure 5 Climate risk is the product of exposure, vulnerability, and climate hazards.



Source: IPCC (2014b).

3.2. Water

Hazards

The water sector is affected by changes in precipitation and temperatures, higher winds, and sea-level rise. Much of the coastal area of Suriname is very low-lying and susceptible to sea-level rise.

Intermediate impacts

- An increase in precipitation as well as waves can cause flooding in coastal and inland regions.
- Floods and intense precipitation events, as well as salinization caused by sea-level rise and waves, negatively impact freshwater sources through their treatment, storage, and distribution.
- Infrastructure of water works can get damaged from flooding, neglect, waves, and sea-level rise.

- Higher intensity of precipitation events decreases aquifer recharge due to a low runoff infiltration rate, and affects the efficiency of natural purification processes from increased groundwater levels.
- Reduced water quality increases the risk of infectious diseases and intensifies drinking water treatment, which result in an increase in the price of drinking water.
- Droughts affect water quality and availability, due to rivers carrying less water in their catchment areas and their reduced discharges.

Risks

The impact of the hazards results in two main risks: health deterioration, and low accessibility and availability of drinking water. The higher cost of drinking water, the decrease in general availability, and the higher probability of infectious disease are all exacerbated by an increase in high-intensity precipitation events but a lower annual precipitation.

Exposure

The risk of health deterioration is most pronounced for:

- People 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 prevalent for:

- People already affected by an inadequate water access and availability
- People dependent on aquifers in low-lying coastal areas and confined aquifers without recharge, as droughts and floods result in less freshwater availability and poorer quality, respectively

Vulnerability

Several factors contribute to vulnerability in the Water sector:

- Unconfined aquifers in low lying coastal areas
- Protective infrastructure of freshwater sources, treatment, storage, and distribution works
- Septic tanks in coastal areas
- Institutional arrangements for water management
- Number of aquifers receiving rainfall recharge
- Unsustainable water consumption
- Water storage capacity
- Efficient use and leakage management
- Desalinization and rainwater
- Natural and artificial drainage

3.3. Agriculture

Hazards

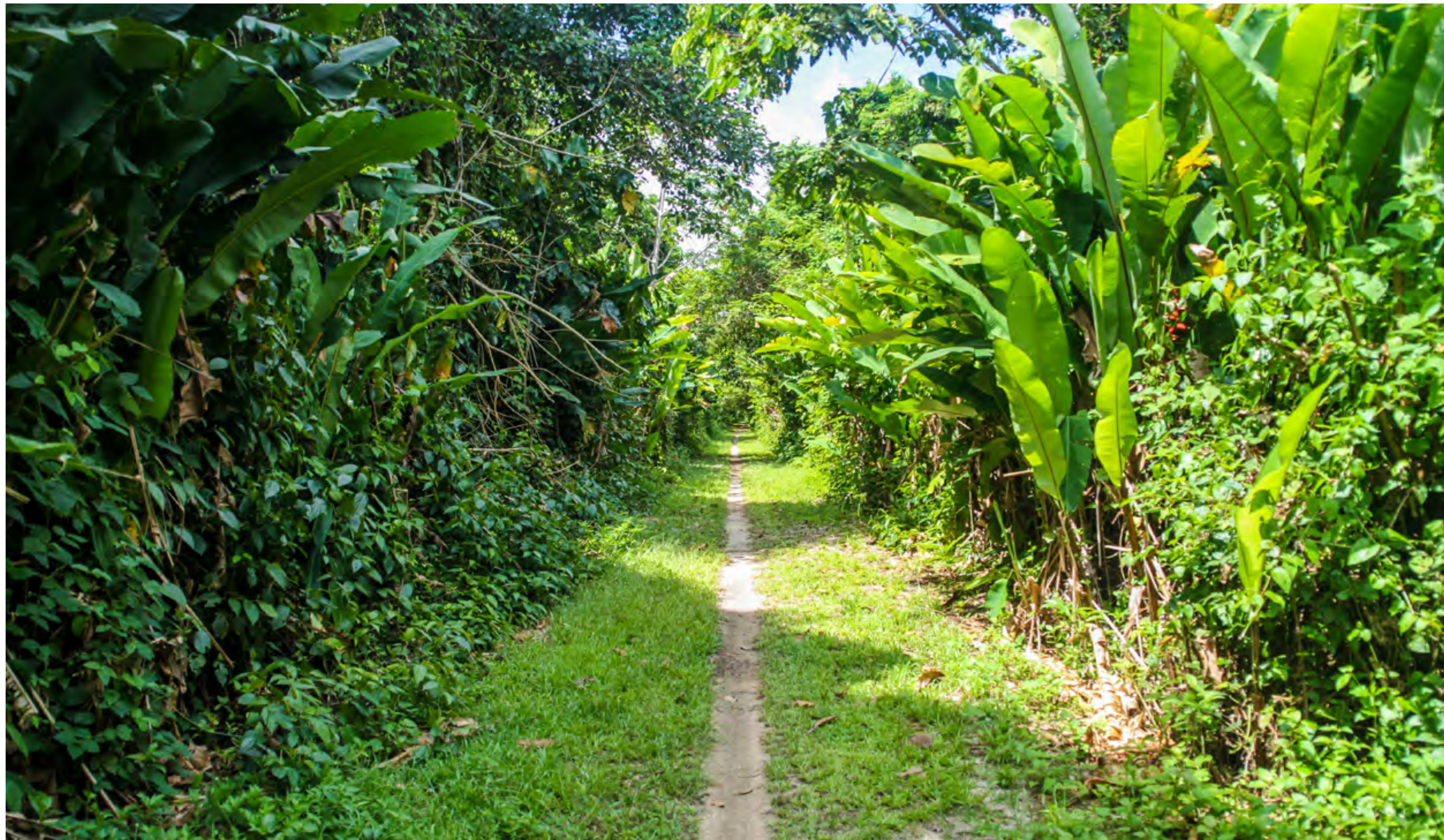
The agriculture sector is affected by changes in precipitation, higher winds, sea-level rise, and higher temperatures including heat waves.

The four subsectors are not affected equally:

- Fisheries are most affected by increases in precipitation, high winds, and temperature.
- Crop production is most affected by increases in precipitation, high wind activity which particularly affects bananas, and sea-level rise which affects irrigation and therefore rice production.
- Plants (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.

Intermediate impacts

- In the case of plants, fish and livestock, all intermediate impacts may lead to higher production costs and food prices, and lower competitiveness.



- Plant production suffers from three high-level intermediate impacts that ultimately lead to plant yield losses and damage and higher production costs if the current level and quality of productivity is to be sustained:
    - Floods provoked by increases in precipitation, sea-level rise, and waves can directly cause plant yield losses and damage. Additional intermediate impacts from floods like the increase in plant disease, erosion of agricultural land, and the removal of soil nutrients and agricultural products like fertilizers and pesticides.
    - Sea-water intrusion caused by waves and sea-level rise 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. Higher production costs and lower yields.
    - Droughts caused by decreases in precipitation and increases in temperature can directly cause plant yield losses, and cause additional 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. Drought in areas where riverine transport is the main mode of transportation can exacerbate conditions, such as rendering rivers unnavigable.
- With regards to livestock, the sector suffers mostly from increases in temperature and heat waves, directly resulting in less livestock productivity.

The fishery sector suffers from increases in precipitation and temperature, which affect the water quality of rivers and lead to oxygen depletion. Oxygen depletion and high water temperatures cause the death of fish.

Risks

The different hazards and intermediate impacts cause decreases in plant and animal production, which increases production and transportation costs, all leading to higher food prices. Increases in food prices lead to a higher risk of food insecurity and affects 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.

Exposure

In general, exposure will be highest in the districts where households dedicate themselves to agriculture. Agricultural land and livestock are potentially affected by climate change.

The risk of food insecurity is discernible 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.

The risk of food insecurity is high for low-income people and for people who are already food insecure.

Additionally, the risk of food insecurity concerns people employed on farms, as farms may decrease their workers' wages or reduce the number of workers due to decreases in production 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.

Vulnerability

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

- Protective infrastructure
- Natural and artificial drainage
- Nutrients, fertilizers, and pesticides
- Drought, flood, and salt-resistance of plants
- Financial capacity of farmers and fishers
- Education of farmers and fishers
- Gender
- Price of agrochemicals
- Freshwater availability
- Irrigation infrastructure
- Heat-resistant kinds and breeds of livestock and production conditions.

3.4. Forestry

Hazards

The forestry sector is affected by changes in precipitation, high winds, sea-level rise, more irregular freshwater, sediment discharge from the Guyana current, and higher temperatures. High winds combined with sea-level rise can increase the intensity of waves which affect the sector in the coastal regions.

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.

Intermediate impacts

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

- Irregular erosion caused by waves and irregular freshwater degrade the coastal mangrove forests, and accretion and sedimentation from the Guyana Current leads to the degradation of ecosystems.
- Seawater intrusion is caused by sea-level rise and more waves.

- Droughts caused by decreases in precipitation and increases in temperature can contribute to forest fires which result in coastal and terrestrial forest degradation.
- Floods are provoked by increases in precipitation and waves.

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

Risks

The different intermediate impacts of fewer ecosystem services and fewer benefits from forest utilization raise the risk of livelihood insecurity. 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 (i.e., breeding ground for species), which also contributes to the risk of food insecurity. The risk of loss of natural coastal protection ultimately results in a risk of infrastructure loss. Ultimately, climate change poses two risks for the forestry sector: risk of loss of infrastructure, and risk of food insecurity.

Exposure factors

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

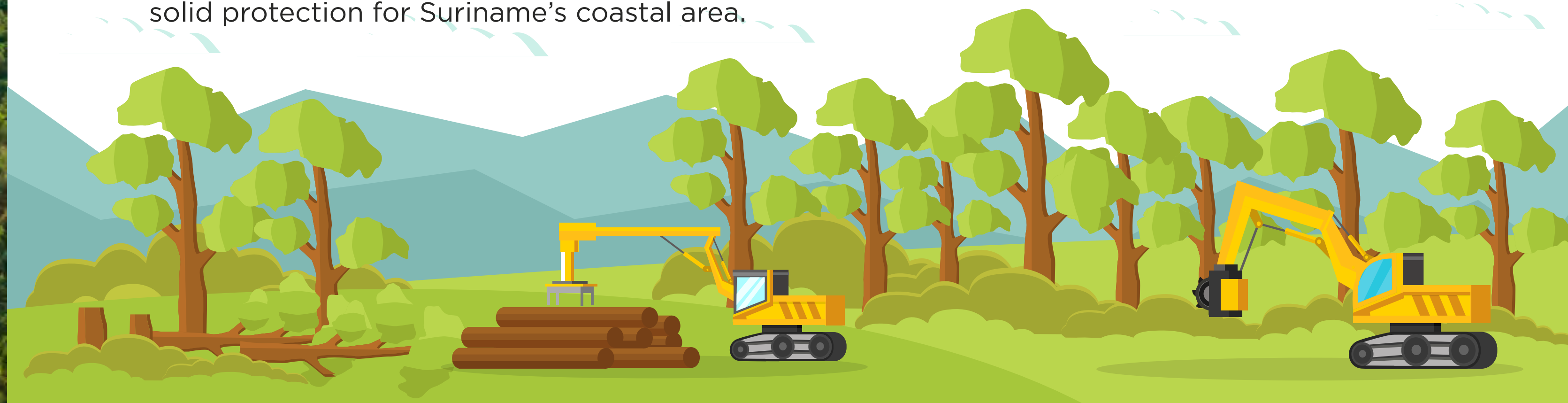
The areas most at risk of loss of nursery function are:

- Coastal forests such as mangroves which fulfill an especially important nursery function for terrestrial and marine species
- Districts and resorts with high forest cover are proportionally more exposed
- Protected forests with high biodiversity and cultural value
- Savanna forests and peat swamp areas which are particularly exposed to forest fires

Vulnerability factors

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

- Protective infrastructure
- Spatial planning and adequate land tenure
- Unsustainable land-use practices
- Ecosystem management
- Deforestation
- Natural and artificial drainage
- Wet resistant roads and harvesting techniques
- Existing degradation



3.5. Infrastructure

Hazards

Increases in precipitation, high winds, and sea-level rise are the most important hazards for Suriname's infrastructure sector. In the case of energy, this subsector is particularly affected by irregular water levels, given the large capacity of the Afobaka hydropower plant.

Intermediate impacts

With regards to energy, two factors are important for the sector's health and affect prices:

- Water availability is reduced from the combination of higher temperatures, decreases in precipitation, and more droughts, affecting hydroelectric energy production and thermal cooling.
  - » Extended periods of intense drought result in severe water availability reduction for the Afobaka hydropower plant. 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 lead to blackouts and need for more maintenance.
  - » Increases in ambient air and water temperatures can reduce the thermal efficiency of thermoelectric power plants, resulting in reduced power output and additional fuel consumption.

- Increases in precipitation can lead to more downstream sedimentation. This leads to algal blooms in hydroelectric dams and the congestion through the blockage of turbines of hydroelectric plants. Ultimately, both lead to interruptions in energy supply and demand more maintenance of the dam and power plant.

With regards to transport, one path in the impact chain is important for the sector's services:

- Increases in precipitation, sea-level rise, higher winds, and waves lead to an increase in floods. Floods erode riverbanks and the coastline. Erosion and flooding result in transport interruptions that also affects the distribution of fuels.

With regards to energy, transport, buildings, and telecommunications, different hazards all result in the loss and damage of land and assets.

When high water levels of the tidal Suriname river combine with runoff from impermeable areas floods appear that affect assets in the building and telecommunication sectors. Extreme winds and waves can cause flooding of the coastal transportation infrastructure, leading to infrastructure failures and road obstructions.

In Paramaribo, pluvial flooding tends to form locally with rainwater ponding in low lying areas, with poor drainage across the city. Flooding in combination with insufficient drainage may affect construction stability of substations and pole foundations.

Risks

For the energy sector, supply interruptions and higher energy prices lead to a risk of energy insecurity.

Regarding 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 depend 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.

Exposure

The risk of loss of lives and of financial losses is most prevalent for people and infrastructure in the coast, and areas prone to high winds and flooding:

- The population density in the coastal zone is almost five times higher than that of non-coastal areas. People continue to concentrate in low-lying areas on the coast where high wind speeds are recorded, which quickly inundate (such as the north of Paramaribo) and where coastal flooding due to sea-level rise and increases in precipitation are important issues. Here, the risk of loss of lives is high.
- Severe flooding and risk of loss of lives also concerns the interior.
- Critical buildings like hospitals and schools, and infrastructure systems such as power plants telecommunication stations located on higher grounds are less prone to flooding and water damage.

The risk of energy insecurity is most observable for people and factories whose energy security depends on fuels brought by water and power plants already close to their output and efficiency limits. As a changing climate will either lead to supply limitations, interruptions or price increases, there may be no margin for at-risk power plant operators to compensate for the electricity and financial losses that arise with 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.

Vulnerability

Several factors contribute to the vulnerability of people and factories whose energy security depends on power plants already close to their output and efficiency limits, as well as people and infrastructure in coastal, flood and high wind-prone areas:

- Old and scarce equipment and installations and their poor maintenance which leads to higher maintenance costs and less efficient energy production, especially in rural districts
    - » Evident in the high System Average Interruption Duration Index (SAIDI) of the EPAR system
- Natural and artificial drainage
- Protective infrastructure
- Income and education of the population
- Weather-resistant building

3.6. Risk index

This chapter provides the results of the risk index, which was constructed according to the impact chain analysis and based on indicators for hazards, exposure, and vulnerability. Those results are presented across the ten districts.

Hazards

Considering the hazard subindex of scenario SSPS2-4.5, Paramaribo has the highest hazard subindex, followed by Wanica. Nickerie has the lowest hazard subindex. Para is the district which changes the least. The Sipaliwini hazard subindex will increase and overtake Wanica in the short-term, and eventually Paramaribo in the long-term, thus becoming the district with the highest hazard subindex by the end of the century.

Considering the hazard subindex of scenario SSPS5-8.5, Paramaribo and Nickerie remain the highest and lowest, respectively. However, Nickerie's hazard subindex does increase over time. Sipaliwini also projects high increases, particularly in the long-term, where it surpasses Wanica. Para is the district where the hazard subindex changes the least.

Exposure

The result of the exposure subindex is that Commewijne demonstrates high exposure values in agriculture, water, and forestry, while Paramaribo has the highest exposure value in infrastructure, Brokopondo scores exceptionally low for agriculture and infrastructure, with elevated and medium exposure values in water and forestry.

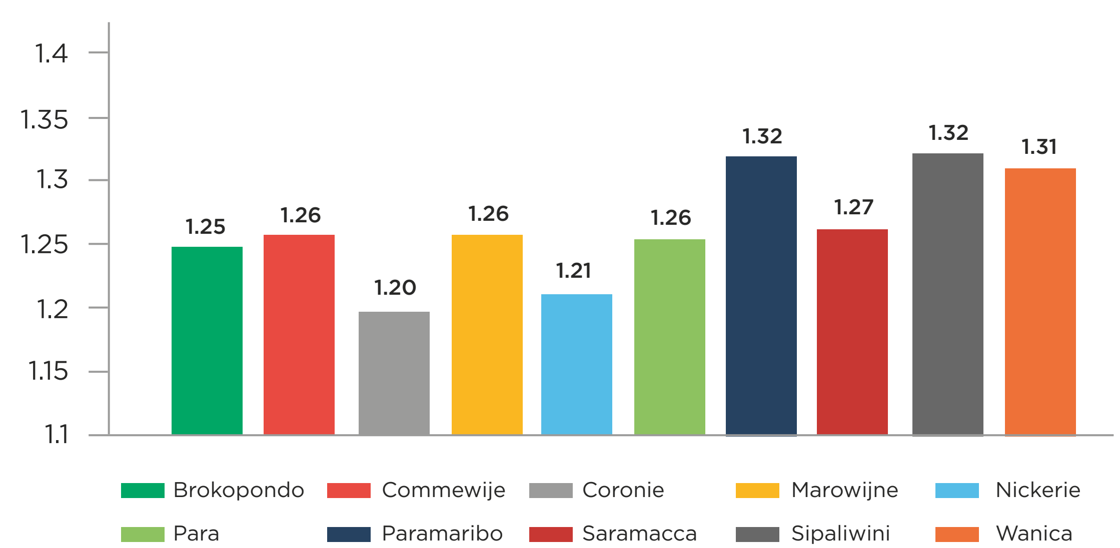
Vulnerability

The result of the vulnerability subindex is that Brokopondo is the most vulnerable district in agriculture, the second most vulnerable district in infrastructure, and the third most vulnerable district in forestry. 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 for forestry and infrastructure. Unlike the other sectors, the districts' vulnerability subindex values lie close together in the forestry sector.

Risk

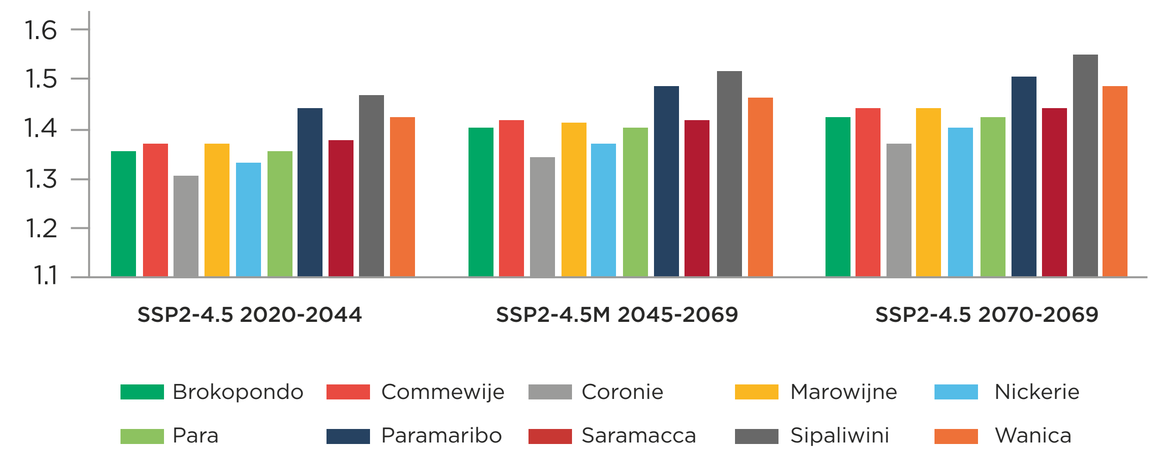
The following shows the results of the risk index for the historic period, and for the future through scenarios SSPS2-4.5 and SSPS5-8.5, across the ten districts (Figures 6-8). At present, Sipaliwini, Paramaribo and Wanica have the highest risk indices. This is due to Sipaliwini's high vulnerability, Paramaribo's high hazard and exposure subindices, and Wanica's high hazard subindex. Coronie and Nickerie show the lowest risk index. Coronie is the least vulnerable of all, and Nickerie has the lowest hazard subindex. Throughout the timeframes of SPSS5-8.5, Sipaliwini, Paramaribo and Wanica remain the three districts most at risk, while Coronie and Nickerie remain the districts with the least climate risk.

Figure 6 Historic climate risk index for the ten districts.



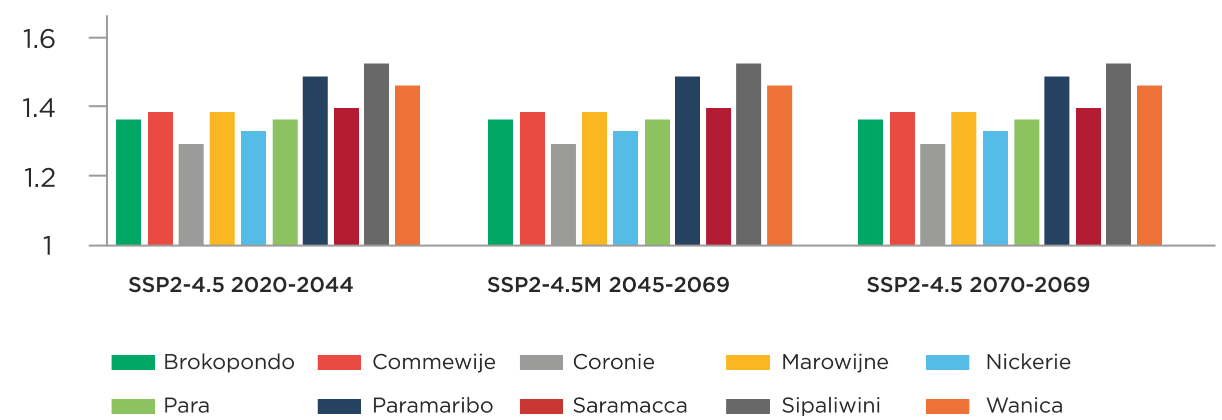
Source: SOC Report team elaboration

Figure 7 Climate risk index for the SSP2-4.5 scenario and future time frames in the ten districts.



Source: SOC Report team elaboration

Figure 8 Climate risk index for the SSP5-8.5 scenario and future time frames in the ten districts.



Source: SOC Report team elaboration

Importantly, risk is always the product of hazards, exposure, and vulnerability. Moreover, perceptions of climate risk may be different from what the data tells us. Although the risk index can be taken as it is to inform policymaking, it should be periodically updated and improved, always considering the best indicators and data available.

Recommendations

Water

Data gathering and availability on water resources should be upgraded. Additionally, the institutions within the water sector should be evaluated and strengthened. It is recommended that the implemented SWRIS be continued and upgraded as well, thereby increasing awareness and providing up-to-date data on water resources and the accompanying climate risks on the sector.

Forestry

It is highly recommended that Suriname continues to implement its REDD+ strategy. This offers a holistic approach to address the most important factors that can decrease the sector's climate risk, namely financing sustainable forest management, offering alternative livelihoods, increasing non-timber forest product (NTFP) supply, strengthening forest governance, land use planning, research, and education on forestry.

Infrastructure

Investments to protective infrastructure in order to enhance resilience against the impacts of climate change is recommended. Appropriate policies and regulations considering climate change in the Infrastructure sector (energy, buildings, transport, and telecommunication) should be developed. An emphasis on strategic and sustainable future land use and planning is also recommended. Furthermore, the study suggests developing a disaster-risk financing and insurance framework for the infrastructure sector to manage economic and fiscal shocks caused by major disasters.

Agriculture

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 in the agricultural sector. Specific recommendations include:

- Determine the impact of climate change on Suriname's most important crops, livestock, and fishery sector.
- Foster efficient cultivation methods that reduce the risk of diseases and pests.
- Solve irrigation problems for the rainy and dry season.
- Implement and promote the participation The National Mangrove Strategy, and launch pilots in high-risk coastal areas.
- Introduce more R&D activities with other national institutions, including Anton de Kom University (ADEKUS), Ministry of Agriculture, Animal Husbandry and Fisheries (LVV), The Foundation Center for Agricultural Research in Suriname (CELOS), among others.

Inter-American
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