Preparation of the "State of the Environment" Report for Suriname

State of the Environment Report

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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
CAHFSA	CARICOM Agricultural Health and Food Safety Agency
CARICOM	Caribbean Community
CBD	United Nations Convention on Biological Diversity
CBvS	*Centrale Bank van Suriname* Suriname Central Bank
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	Couples 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
EAS	Energy Authority Suriname
ECMWF	European Centre for Medium-Range Weather Forecasts
ECMWF IFS	Integrated Forecasting System
EIA	Environmental Impact Assessment
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

FSC	Forest Stewardship Council
GAP	Good Agricultural Practices
GB	*Ministerie van Grondbeleid en Bosbeheer*
	Ministry of Land Policy and Forest Management
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
IADB	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
ITTO	International Tropical Timber Organization
IWW	Interdepartmental Water Workgroup
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
NAHFSA	National Agricultural Health and Food Safety Agency
NAP	National Adaptation Plan
NASA	National Aeronautics and Space Administration
NBSAP	National Biodiversity Strategy and Action Plan
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
NMR	*Nationaal Milieu Raad*
	National Council for the Environment
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
RAS	Road Authority Suriname
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
RGB	*Ministerie van Ruimtelijke Planning, Grond- en Bosbeheer* Ministry of Physical Planning, Land and Forest Management
ROM	*Ministerie van Ruimtelijke Ordening en Milieu* Ministry of Spatial Planning and Environment
RoS	Republic of Suriname
SAMAP	Suriname Agricultural Market Access Project
SBB	*Stichting voor Bosbeheer en Bostoezicht* Foundation for Forest Management and Production Control
ScenarioMIP	Scenario Model Intercomparison Project
SIDS	Small Island Developing State
SFM	Sustainable Forest Management
SMNR	Sustainable Agricultural Management of Natural Resources
SNC	Second National Communication
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
TAS	Telecommunication Authority Suriname
TCT	Ministry of Transport, Communication and Tourism
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
WTO	World Trade Organisation

WWF World Wide Fund for Nature

1. Introduction

Suriname's contribution to 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 is a Small Island Developing State (SIDS), has forests liable to decay and a low-lying coastal area where about 87 % of the population and most of the country's economic activities are concentrated. Thus, most sectors including infrastructure, agriculture, water and forestry are at great risk of suffering loss and damage provoked by gradual changes as well as extreme weather events related to changes in sea-level, temperature, precipitation, humidity and winds. Already today the Surinamese people experience extensive coastal erosion, prolonged dry seasons and flooding that are all examples of climate change impacts.

In this context Suriname has fully commitment 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 20016 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 policy-makers that are making increasing efforts to consider the objective of the Convention in their development strategies. However, the Communications also highlighted the need for more research and capacity building to be done on climate models, projections and impact assessments in order to validate and complement existing assumptions on the effects of climate change and support decision-making in favor of a sustainable development. Equally, 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 support such decision-making along this line. 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 (IADB) and 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 and takes the impacts of climate variability in multiple sectors into consideration. One of the project's products is this report on the State of the Environment. Other products include sharing it with stakeholders to gather their feedback and engage them in the Report's development, the presentation of the Report to policy-makers to raise their awareness and build their capacities, as well as the implementation of a capacity building program and the development of training material for local technical experts on the production of near to long-term climate projections and the deduction of possible impacts based on their results.

The overall objective of the **State of the Environment Report** is to comprehensively analyze the likely impacts of climate change on key sectors (agriculture, water, forestry, infrastructure) and geographic areas based on the analysis of historic climatic trends and the production of projections that provide up to sub-country level details. The Report consist of seven chapters in addition to this introduction:

The second chapter provides **background** information on the country's geography and climate. Moreover, it characterizes the four sectors and provides an overview of the sectoral policies and laws that are most relevant to climate action, as well as presents the country's environmental management structure and sectors' institutional framework. Herefore, an extensive review of previous works and analyses on climate change in Suriname has been conducted, including those by the IPCC, the Climate Studies Group, Suriname's National Communications to the UNFCCC, the country's nationally determined contribution (NDC), OP for 2017- 2021, NCCPSAP and REDD+ Strategy 2019.

The third chapter analyses **climatic trends** in Suriname. In this context historic climatic data was analyzed to produce three near- and long-term future projections for 19 key climate parameters such as temperature, rainfall, wind and humidity. The results of these projections with reference to the historic period were interpreted for seven points of interest and on country-wide scale.

The fourth chapter complements the results of the third chapter to produce an **impact analysis**. First, each sector's elements that are most exposed to the climate hazards analyzed in chapter three, and the non-climatic factors that increase or reduce their vulnerability in this context, are mapped. Then, indicators are selected for the hazards, exposure and vulnerability factors, and a risk index is constructed and interpreted for different geographic areas and the four sectors for different future time periods and scenarios.

The fifth chapter is on **capacity building**. This chapter is based on an analysis of each sector's institutions' and strategies' strengths, weaknesses, opportunities and threats (SWOT), taking into consideration the exposure and vulnerability factors highlighted in chapter three.

The sixth chapter elaborates on the **responses taken by Suriname** to close the gaps that are evident from the SWOT analysis in chapter five.

The seventh chapter closes the report with **recommendations** on how Suriname can improve its current performance regarding climate action.

The eight chapter summarizes the results of chapters two to seven and offers some final **conclusions**.

Overall, Suriname's State of the Environment Report provides a comprehensive analysis of the climate risks the country faces and how it can ameliorate these. The Report not only serves stakeholders and policy-makers 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 thereby 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.

2. Background of Suriname

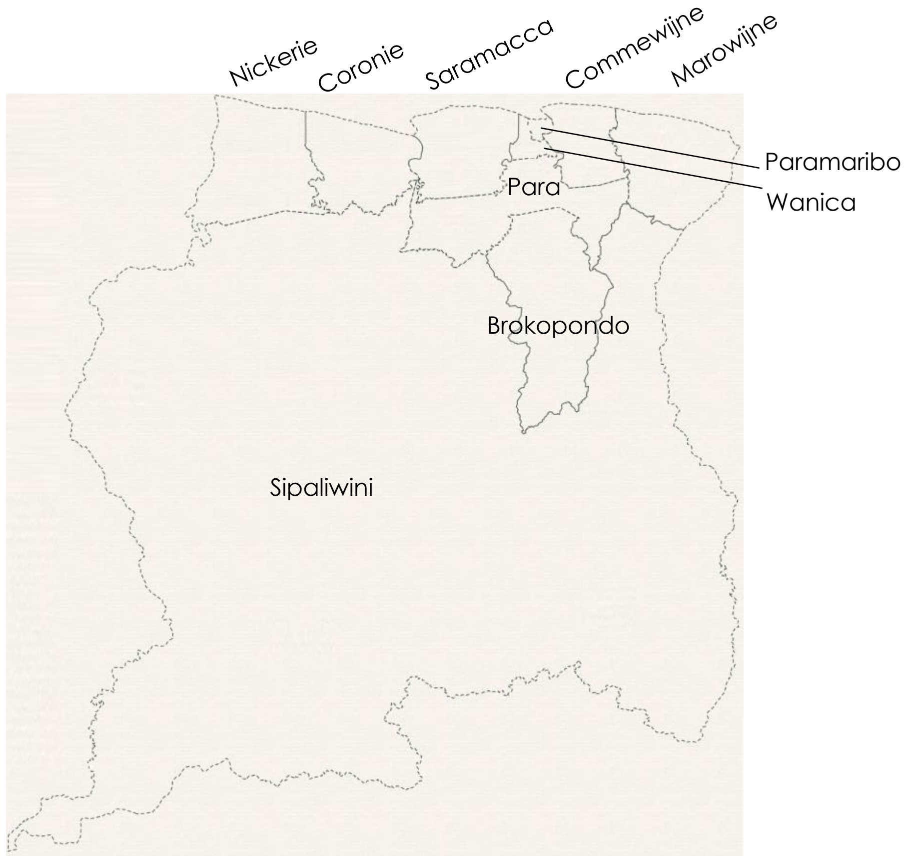
The aim of this chapter is to set the scene for the risk index in chapter four. This chapter provides an overview of cross-sectoral aspects, such as the geography and climate, of Suriname (chapter 2.1.). Moreover, it provides a brief review of each of the four sectors this report focuses on: Agriculture, water, forestry and infrastructure (energy, transport, buildings, communications). Specifically, this chapter provides an analysis of each sector in the geographic context, its main constituents and the importance of the sectors to the country's economy (chapter 2.2.). The second last part (chapter 2.3.) describes the national policy and legal framework. Again, this chapter analyses cross-sectoral aspects as well as each one of the four sectors in detail. At the end (chapter 2.4.), the environmental management structure is presented, i.e. cross-sectoral institutions and bodies as well as those particularly related to one of the four sectors.

2.1. Geography and climate

2.1.1. Geography

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. It is bordered by the Atlantic Ocean to the north, by French Guyana to the east, by Brazil to the south and by Guyana to the west. Paramaribo is the country's capital, largest urban area and located at the coast. Suriname has an area of about 16.4 million ha and is divided into ten administrative districts: Marowijne, Commewijne, Wanica, Paramaribo, Para, Brokopondo, Sipaliwini, Saramacca, Coronie and Nickerie (figure 1). The country's main rivers are the Marowijne River, Commewijne River, Suriname River, Saramacca River, Coppename River, Nickerie River and Corantijn River.

Figure 1: Administrative map of Suriname.
Source: Gonini (2020).

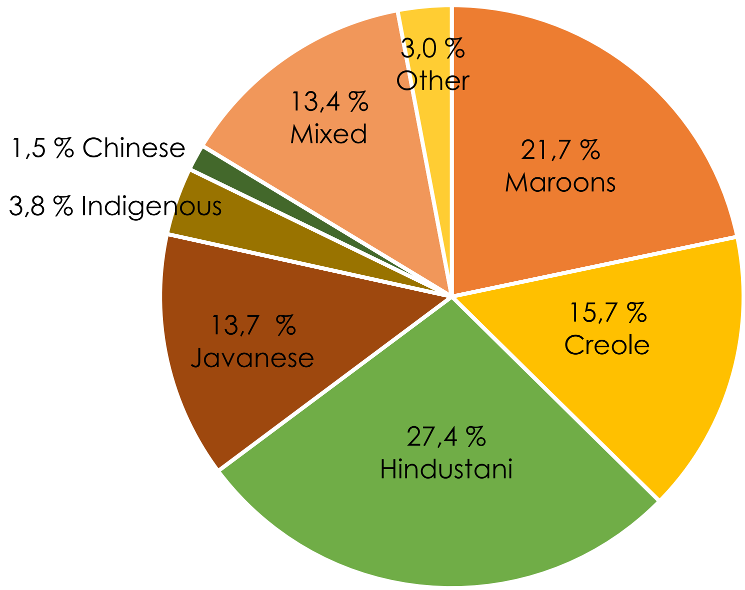


The topography of the northern half of the country is composed of a flat coastal plain and low hills further inland. The overall pattern of the hinterland, the southern half of the country, is composed of the central highlands, with a few locations rising to slightly over 1000 m above sea-level (Boedhram & Baldew, 1988), e.g. Tafelberg (1026 m above sea-level) and Suriname's highest mountain Juliana Top (1230 m above sea-level) (Boedhoe, 2004).

The country has about 590,100 inhabitants (ABS, 2020), 80 % of which live at the coast. The population density is largest in the capital Paramaribo (NIMOS, 2005), where about 52 % of the total population live (ABS, 2014a). Moreover, Suriname has a diverse population, with eight major ethnicities (figure 2).

Figure 2: Population of Suriname.

Source: ABS (2014a).



2.1.2. Climate

Overall Suriname has a wet tropical climate. Rainfall varies substantially during the year, while temperature is relatively stable (table 1).

Table 1: The average weather conditions for Suriname.

Source: Own elaboration.

Element	Average Value (1971-2008)	Variation (minimum, maximum)
Temperature	27.1 ^{0}C	17.2 ^{0}C - 35.0 ^{0}C
Wind velocity	3 m/s	0 m/s – 15m/s
Wind Direction	north northeast	northeast southeast
Rainfall	2060 mm	1900 mm – 3000 mm
Humidity	70 %	40-100 %

2.1.2.1. Inter-Tropical Convergence Zone (ITCZ)

The ITCZ is an area near the equator, between the northern and southern hemisphere. In this area, the northeast and the southeast trade winds meet. The ITCZ I seasonal and moves between 40^0 and 45^0 latitude north and south of the equator according to the sun. The air in the ITCZ heats up due to the intense sun and warm water of the equator, creating a humid climate. The seasonal shifts in 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, spatial and temporal rainfall variability (figure 3) (Nurmohamed, Naipal & Becker, 2006). The ITCZ is pushed back and forth by the northeast and southeast tradewinds that have an average speed of 3 m/s, but may range from 0-15 m/s (Meteorologische Dienst, 1998). Therefore, most of the climatological elements, such as temperature, humidity and rainfall, manifest a strong semi-annual oscillation, e.g. there are two wet seasons and two dry seasons (Emanuels, 1968):

- The short dry season starts at the beginning of February and lasts until mid-April (two and a half months). During this season, the ITCZ moves further towards the south. The area with low atmospheric pressure, the ITCZ, is in its southernmost position during these months. Sometims the short wet season does not occur (Boedhram & Baldew, 1988).
- The long wet season starts mid-April and lasts until mid-August (four months). During this season, the ITCZ moves back up north across Suriname. In most areas monthly rainfall amounts to at least 200 mm (figure 4). 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 starts mid-August and ends at the beginning of December (three and a half months). 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 even less than 50 mm. The long dry season records the highest temperatures (figure 5) and lowest relative humidity values in Suriname (Meteorologische Dienst, 1998; Emanuels, 1968).

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

Figure 3: Movement of the ITCZ above Suriname.

Source: SPS/OAS (1988).

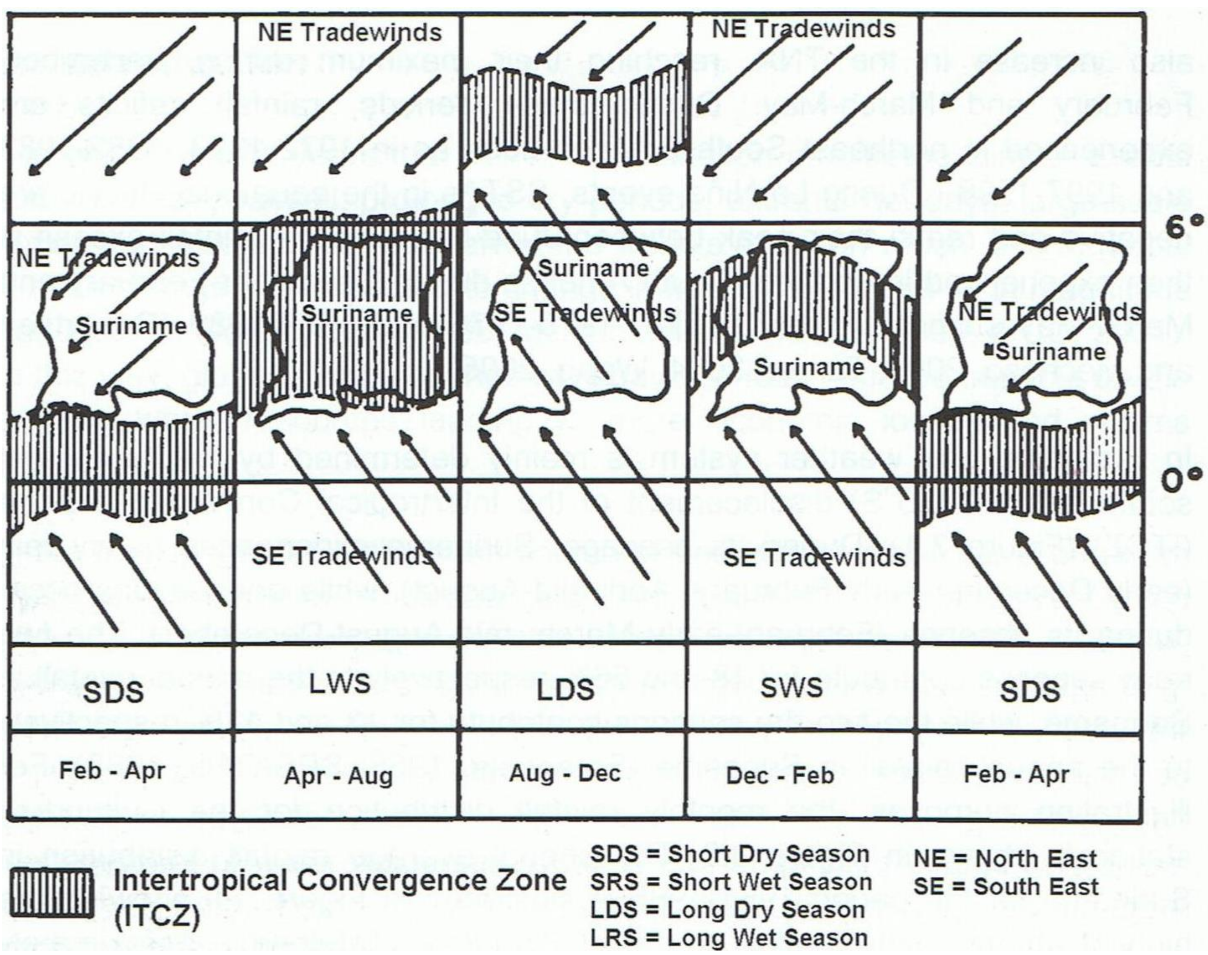


Figure 4: Annual average rainfall (mm) for Suriname.

Source: Own elaboration.

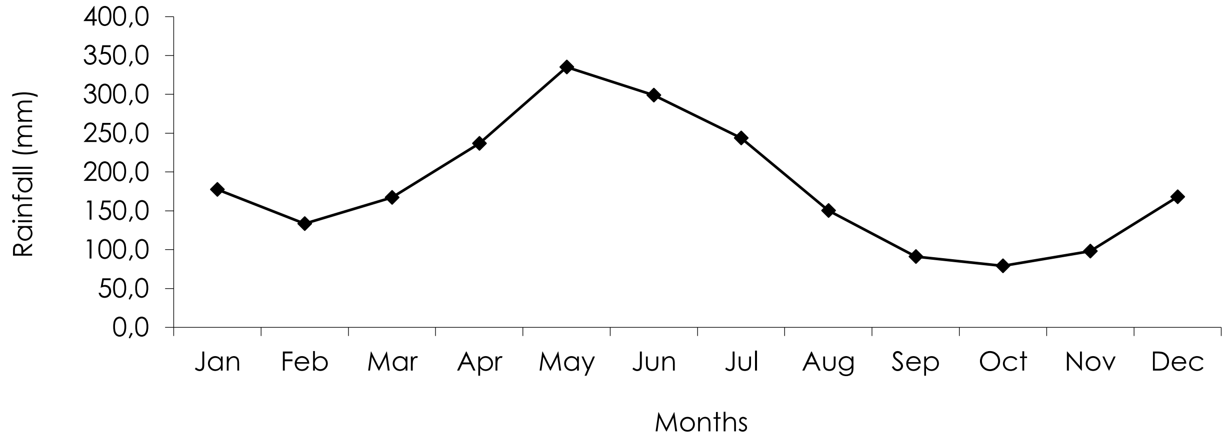
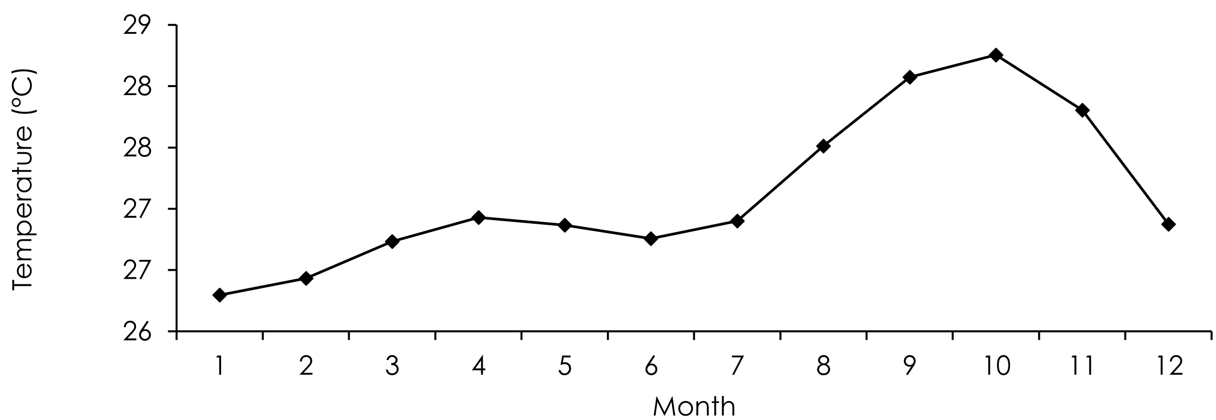


Figure 5: Average annual temperature (°C) pattern for Suriname.

Source: Own elaboration.



2.1.2.2. El Niño Southern Oscillation (ENSO)

ENSO is a recurring climate pattern based on changing temperatures of the tropical central and eastern Pacific Ocean. It occurs about every three 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. The third phase is neutral.

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 the opposite of El Niño and 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, El Niño/ La Niña may cause increases or decreases in precipitation, during the seasons, leading to more rainfall variability during the seasons.

2.2. Socio-economy

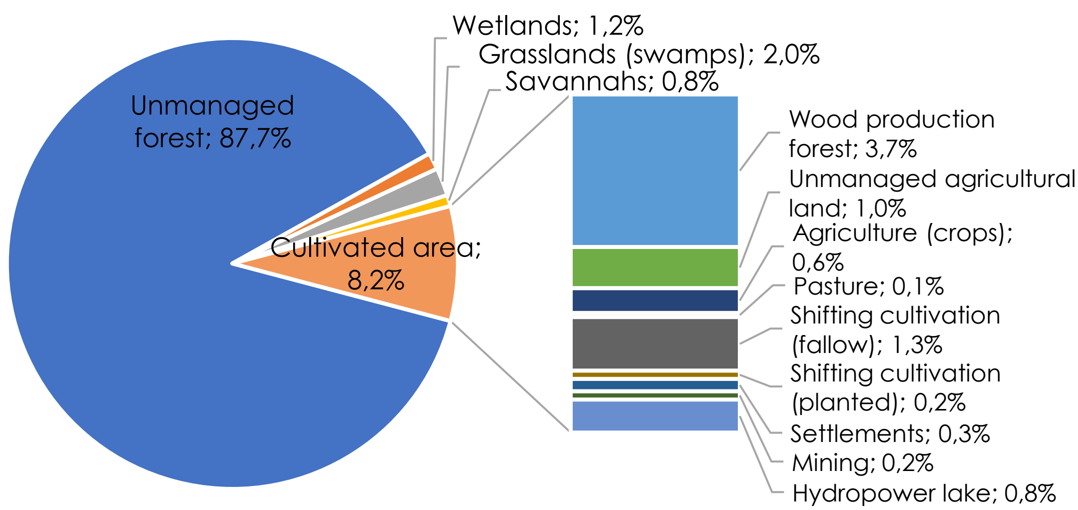
2.2.1. Agriculture

2.2.1.1. Agriculture in the geographical context

Suriname constitutes an area of 16.4 million ha of land. The largest part of Suriname is covered with forest (93 % equivalent to 15.2 million ha), (Matai, 2020), almost all of which (82 %) is tropical rainforest that is not or only marginally used by local people for non-timber forest products (NTFP) (figure 6). Only 8 % of the total land area is cultivated. The remaining 4 % of total land area consist of other non-forested natural areas (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 are utilized for agriculture purposes, mostly in the coastal plain, around 9 % (1.5 million ha) of the total land area are regarded suitable for this aim, 27 % (400,000 ha) of which are attributed to the interior. However, these are currently not exploited because there is no political will herefore and national policies and strategies on the matter are not integrated and harmonized.

Figure 6: 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 where the most fertile zone in Suriname is located and large-scale agricultural activities are established for the production and export of fruit and vegetable. The soils of the old coastal plain offer good 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 mainly limited to shifting cultivation practices. Shifting cultivation is a sustainable system in Suriname, due to the fact that the pressure on the forest is minimal. The aging population, the migration of village people and the limited market opportunities mean that only a small part of the forest is being cleared for agriculture and the cleared piece of land is given sufficient time to recover for a second phase of agriculture (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 (mainly within the village) and a very small part (7 %) is sold in Paramaribo. In general, women are the ones who 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).

2.2.1.2. Food security

Suriname still faces considerable challenges in all four areas of food security, namely food availability, access, use and stability (FAO, 2015a). 8 % of the population are malnourished, 24 % of women have iron deficiency while 25 % of the population are overweight. High food prices as well as the world economic/ financial crisis have affected Suriname as all other Caribbean Community (CARICOM) Member States, as Suriname depends to a large extent 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.

<u>Food availability</u>

Regarding food availability, i.e. crop production, the challenges Suriname faces are:

1. Fluctuations in the volume of vegetable production throughout the year caused by climatic factors such as drought and floods.
2. 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, e.g.:
    - 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.

    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.
3. Competition instead of cooperation between actors along the value chain and a lack of trust.

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 almost all communities, small supermarkets are within a radius of 5 km of the consumer. However, some challenges regarding food access remain. These are conditioned by a number of socioeconomic factors:

1. The high price of food products.

   Malgie (2018) reported that one problem of small-scale farming is its dependence on the seasons due to poor irrigation and drainage infrastructure, and thus its sensitivity to drought and heavy rainfall, ultimately resulting in price fluctuations.

2. Poverty related to:

   - Lack of access to resources, including land and financial capital.
   - High unemployment rates, especially among women and young people.
   - Ineffective safety net programs coupled with their inadequate monitoring and evaluation.

3. Lack of basic services.

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, morbidity and mortality due to chronic non-communicable diseases (e.g. heart disease, stroke, diabetes, cancer, 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.

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

Agriculture is a 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 historic maximum. One of the main causes is the ageing of agriculture 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 prices of gold, oil and aluminum falling. 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; 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.

<u>Fishery (including aquaculture)</u>

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 assures 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 t (ABS, 2018). Aquaculture, especially small-scale freshwater aquaculture and rice-fish culture, is seen to have a good potential for improving livelihoods of poor rural households.

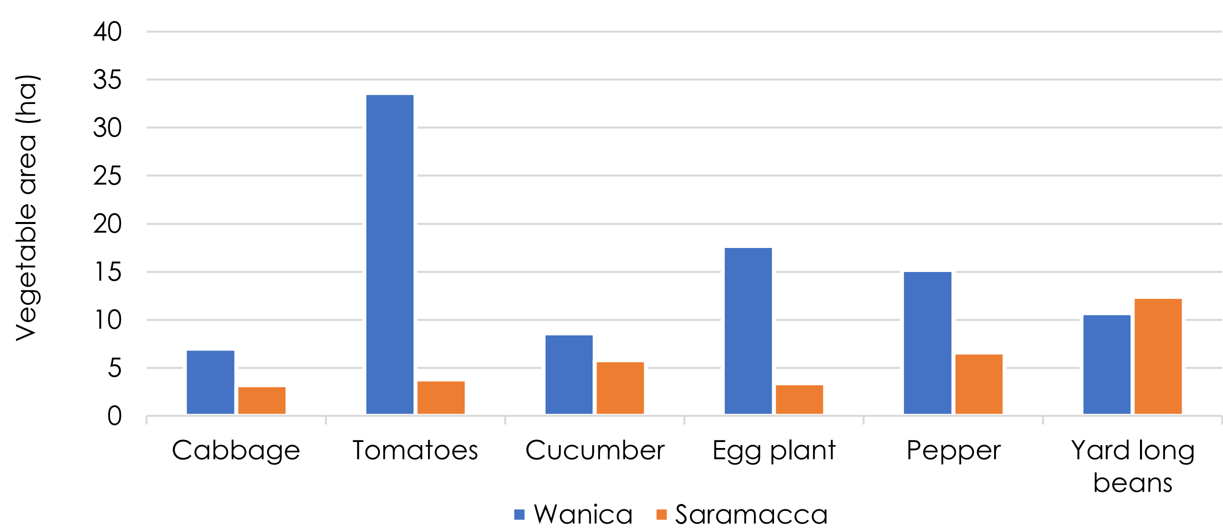
<u>Crop production (rice, bananas and vegetables)</u>

Suriname's rice production capacity is about 300,000 t per year on about 59,000 ha of land (ABS, 2018). Rice cultivation is most prevalent in Nickerie. However, currently less than 30,000 ha are used for rice production as a result of inadequate infrastructure in the rainy and wet season, a shortage of good irrigation water and insufficient rice seeds. The production system is highly mechanized and agricultural aircrafts, tractors and harvesting machines (combines) are being employed. 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: In addition to employment, annually rice for the value of USD 6 to 8 million is exported (ABS, 2018).

With regards to bananas, Suriname has approximately 2,000 ha of commercial banana plantations. The government of Suriname is currently deliberating with a team of experts about possibilities to revive the country's banana industry despite the "moko" disease that affected nearly a quarter of the plantations' area. Closing down 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, many fresh crops are brought from there to Suriname's biggest market, the Central Market of Paramaribo. The income the poor farmers generate from agriculture is relatively low and additional to that of their daily profession. Cabbage, tomatoes, cucumber, eggplant, pepper and yard long beans are some of the most important vegetables they plant (figure 7). However, some of the farmers face problems with extreme weather, flooding, increases in pests and diseases and a lack of information on which varieties to plant and which environmentally friendly pesticides to use.

Figure 7: Cultivated vegetable area (ha) in Wanica and Saramacca in 2013.
Source: LVV (n.d.).



Livestock (cattle, sheep and goat, poultry and pigs)

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 2).

Table 2: Number of livestock in 2014-2017.
Source: ABS (2018).

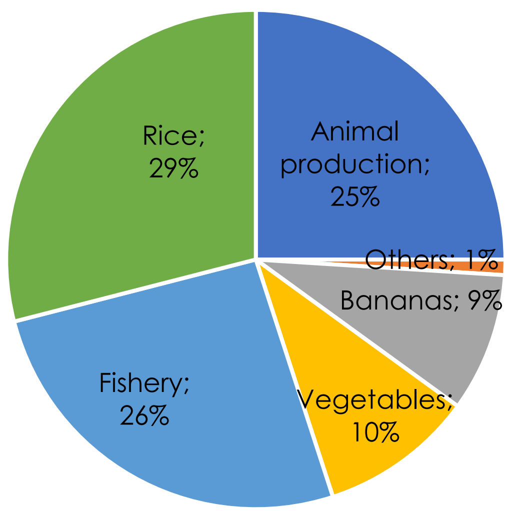
District	2014	2015	2016	2017
Cattle	36,138	37,620	35,763	35,995
Goats and sheep	9,831	10,706	10,234	9,463
Chicken and other poultry (x 1,000)	5,098	5,439	4,697	5,567
Pigs	36,422	36,716	35,395	37,754

Employment

The sector employs 12 % of the economically active workforce (Milton, 2009), approximately half of which engage in animal production and fishery, while the other half mainly in crop production (figure 8). 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 mainly found 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 8: 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 Europe due to its historic export connections to the Netherlands. Rice (being exported to Jamaica), bananas (being exported to France and the Netherlands), fish and fish products are the most important export products and their annual exports amount to around USD 10 million (6 % of all exports) (World Bank, 2019). However, in recent years a sharp decrease in the export volume of bananas and other fruit could be observed (table 3). This decline is a result of different socio-economic and environmental factors such as an inadequate infrastructure, lack of investments, innovation, strong winds, droughts and varying rain intensities.

Table 3: Export volumes (million tons) of agricultural products in 2013-2017.
Source: ABS (2018).

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

Fertilizers

For the production of rice, vegetables, root crops and fruit nutrients (nitrogen, phosphate and potassium) are added to the soil in the form of fertilizers to maintain soil fertility and to produce quality products. The main sources of nutrients are synthetic fertilizers and animal manure. Between 2013 and 2017 the import of nitrogen, phosphate and potassium increased by up to 116 % (in the case of nitrogen) (table 4).

Table 4: Import of fertilizer (in million tons) in 2013-2017.
Source: ABS (2018).

District	2013	2014	2015	2016	2017
Nitrogen	12,975	19,254	24,648	29,930	28,031
Phosphate	298	305	65	268	348
Potassium	125	42	70	267	239
Other	10,424	9,471	7,637	5,282	8,135

Pesticides

In Suriname, pesticides are often used to avoid harvest losses due to crop damage by insects (insecticides), weeds (herbicides), animals (molluscides and rodenticides), fungi (fungicides) and bacteria. As in the case of fertilizers, the improper use of pesticides comes at an environmental cost and may also affect human health. Between 2013 and 2017 the total import of pesticides increased by on average 80 %, up to 708 % in the case of molluscides and 195 % in the case of insecticides (table 5). Only the import of fungicides decreased by 22.6 %.

Table 5: Import of pesticides (kg/liter) in 2013-2017.
Source: ABS (2018).

Type of pesticide	2013	2014	2015	2016	2017
Fungicides	447,391	415,911	744,182	89,864	346,279
Herbicides	277,234	716,039	795,093	810,156	749,789
Insecticides	73,145	24,966	249,530	221,142	215,685
Molluscides	5,196	20,250	19,600	18,000	42,004
Rodenticides	3,512	13,020	14,038	4,244	4,875

2.2.2. Water

2.2.2.1 Freshwater sources in the geographical context

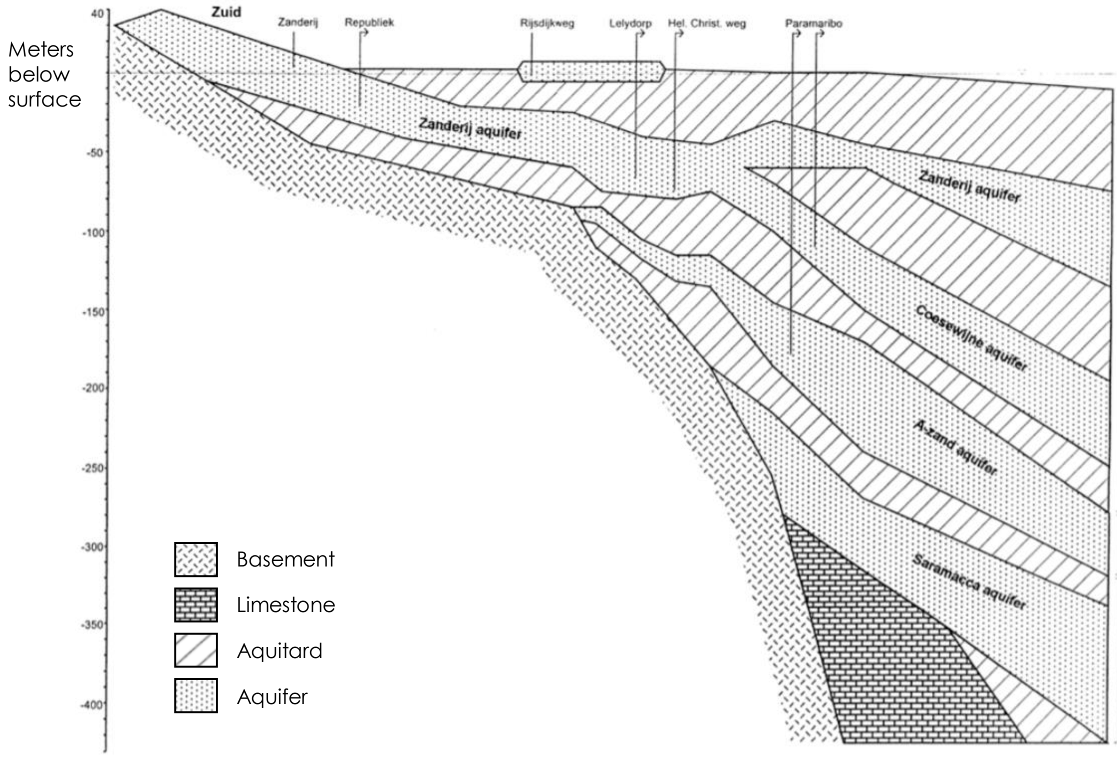
The World Water Council recognizes Suriname as one of the most freshwater rich countries, ranking sixth among the countries that have superfluous water resources (UNDP, 2016). The abundance of water results from a combination of three main factors: Topography, soil and land cover (defined by its very high biomass per area) (Simpson et al., 2012). In 2006, the total water withdrawal was approximately 616 million m^3 (0.6 % of all renewable water resources). Of all freshwater that was withdrawn in 2006, 8 % were provided by groundwater and 92 % by surface water (FAO, 2015b). Rainfall is the most important source of freshwater 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 centre of the country (Berrenstein & Gompers-Small, 2016).

<u>Groundwater</u>

With regards to groundwater, Suriname has distinct provinces: The interior Precambrian shield of crystalline rocks comprising 80 % of the country's surface and the coastal plain basin comprising 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 therefore mainly rely on surface water for drinking water and other purposes. The coastal basin on the other hand has good quality groundwater in abundance. Precisely, the thickest and most extensive coastal aquifers are found in the west of Suriname. In the east only one major aquifer is found. The most important aquifers (in order of increasing depth) are the Zanderij aquifer (15-60 m below surface), followed by the Coesewijne aquifer (70-110 m below surface), the A-zand aquifer (130-190 m below surface). The Saramacca aquifer is less important (figure 9). Of the first three aquifers previously mentioned only the Zanderij aquifer recharges from rainfall percolation in the savanna belt (UNDP, 2016). According to a study done by the US Army of Corps of Engineers (USACE) (2001), the intensive use of the deeper aquifers A-zand and Coesewijne has resulted in an annual water-level decrease of about 0.5 m.

Figure 9: Overview of aquifers in the coastal basin.

Source: SWRIS (2020).



<u>Surface water</u>

Surface water sources include rivers, swamps, wetlands, man-made lakes and other lakes that were formed in sites of bauxite excavation, man-made canals 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 the district Commwijne, 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 (approximately 30 % of the annual rainfall) into the Atlantic Ocean per second (table 6). The Marowijne and the Corantijn Rivers alone contribute 70 % of the total discharge. With the exception of the Suriname River, which is regulated by the Afobaka hydropower dam, the seven main rivers and their numerous tributaries discharge excessive rainfall from the mainland directly into the Atlantic Ocean (Berrenstein & Gompers-Small, 2016).

Table 6: Suriname's seven main rivers, their basin area and discharge.
Source: Berrenstein & Gompers-Small (2016).

River	Basin area (km²)	Discharge (m³/s)	Specific discharge (L/s/km²)
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	

The rivers in the interior have clear and always fresh water which is poor in nutrients but rich in oxygen, plant and animal life. The smaller creeks have less flora and fauna compared to the main rivers. In the Cover Landscape, the rivers and creeks have fresh and clear water, but are very acidic and poor in oxygen. In the young and old coastal plains, the creeks and especially the rivers have less transparent water which can be brackish (depending on tides and seasons), the water is oxygen poor, but rich in nutrients, aquatic plants and animals. The lower river courses are frequented by a number of marine animals, such as dolphins (UNDP, 2016).

- *Freshwater swamps/ wetlands*
  Numerous freshwater swamps and wetlands are found in the coastal zone. They cover a total area of approximately 1.2 million ha, one-third of which is permanently inundated and two-thirds of which 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, the Nani swamp currently being the most important one in the northwest of Suriname. This swamp supplies irrigation water for about 18,000 ha of agricultural land where mostly rice is cultivated. Furthermore, the Overliggend Waterschap Multi-Purpose Corantijn Project in the Nickerie district is responsible for supplying irrigation water to 31 waterboards, their polder population and rice crop production (two harvests a year) from the Nani swamp.
  Generally, these swamps are poorly drained by only 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 dykes against high water-levels in the swamps during periods of heavy rainfall. Their poor construction and maintenance often result in dam breaches and inundation 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 Blommestein Meer, covers an area of about 160,000 ha. The reservoir was created by constructing a dam across the Suriname River between 1961 and 1964. Originally, the main

purpose of the lake was to serve a hydropower plant that generates electricity for the aluminium 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).

Protected areas cover approximately 14 % of Suriname's surface. These make an important contribution to the conservation of freshwater resources. Particularly with the establishment of the Central Suriname Nature Reserve (making up 70 % of all protected areas), a complete rainforest and freshwater river system that is home to a large number of species (including endangered species) has been protected.

2.2.2.2. Freshwater uses

Groundwater resources are used for public supply and to a lesser extent industry. On the other hand, surface water is mainly used for irrigation (e.g. for rice and banana cultivation), 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 (irrigation and livestock), 8 % for municipal and 22 % for industrial purposes (table 7) (FAO, 2015b). Some companies also abstract water for export purposes. Between 2013-2017 the volume of water exports has increased four- to five-fold (table 8) (ABS, 2018).

Table 7: Water withdrawal according to its use in 2006.

Source: FAO (2015b).

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

Table 8: Export of drinking water 2013-2017.

Source: ABS (2018).

Year	Value (USD)	Volume (kg)
2013	65,867	207,869
2014	54,135	143,458
2015	220,859	666,383
2016	270,686	714,614
2017	307,513	923,633

Drinking water

Overall, 98.2 % of the population have access to improved sources[1] of drinking water (99 % in urban areas, 98 % in rural coastal regions and 91 % in rural interior regions (Ministry of Social Affairs and Public Housing, 2019)) (table 9). Coronie is the district with the highest percentage of households using improved drinking water sources (100 %). Sipaliwani is the district with the lowest percentage 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 in the districts of Brokopondo (34.3 %), Commewijne (27.8 %) and Sipaliwini (6.4 %) have the lowest access to piped drinking water. 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 e.g. 29.8 % of households in Coronie. Surface water (rivers and ponds) is also used as drinking water, e.g. by 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).

[1] Improved sources of drinking water are the following: Piped water (into the dwelling, compound, yard or plot, to neighbours, by public tap/ standpipe), tube wells/ boreholes, protected dug wells, protected springs, rainwater collection, and packaged or delivered water.

Table 9: Percentage of households by main source of drinking water in 2018.
Source: Ministry of Social Affairs and Public Housing (2019).

		Improved sources										**Unimproved sources**							
		Piped water				Non-piped water													
		into dwelling	into yard/ plot	to neighbourhood	public tap/ stand pipe	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

The Suriname Watersupply Company (SWM) is the sole drinking water production company in the country and responsible for five main supply areas, namely the districts Paramaribo, Wanica, Para, Nickerie and Marowijne (Berrenstein & Gompers-Small, 2016). In 2016, also parts of the districts Commewijne, Saramacca and Coronie were connected to the distribution network. The districts that are not addressed by SWM, mostly those in the interior, are provided with drinking water by the Ministry of Natural Resources' (NH) Water Supply Service (DWV) division or the Foundation Funding Development Interior (FOB) which is a technical arm of the Ministry of Regional Development (RD) or private companies (ABS, 2018). However, generally speaking 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 approximate 46 million m^3 of drinking water (approximately 8 % of annual freshwater withdrawal). There are five SWM's 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.

Despite most of Paramaribo's population having 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 and 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).

2.2.2.3. Disposal and treatment of wastewater

<u>Entire Suriname</u>

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

In the districts of Paramaribo, Wanica and a part 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 are not working 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).

<u>City of Paramaribo</u>

Different types of wastewaters from Paramaribo include e.g. 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 the same (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 (faeces and urine) 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. Also, during heavy rain, the water may back up leading to contamination. Septic tanks' 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 resulting from personal washing, laundry and the kitchens enters the storm and street drains untreated, too.

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/ or pumping stations.

2.2.3. Forestry

2.2.3.1. Forestry in the geographical context

The total land area of Suriname encompasses 16.4 million ha of which about 93 % are forested, resulting in a 15.2 million ha large total forest cover (table 10) (FAO, 2020). Suriname is committed to maintaining this forest cover and thus remaining a high forest cover and low deforestation (HFLD) country. Almost the entire forest cover (98 %) is undisturbed (FAO, 2020). Sipaliwini, Para and Marowijne are the districts with the highest relative forest cover, which ranges between 98-78 %. Sipaliwini, Brokopondo and Para are also the districts with the highest absolute forest cover. Paramaribo and Wanica are the districts with the lowest relative and absolute forest cover.

Table 10: Relative and absolute forest cover per district in 2015.

Source: SBB (2017).

District	Relative forest cover (%)	District área (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**

About 80 % of all forests are high dryland forests, and around 10 % are march forests (table 11).

Table 11: Forest cover (ha and percentage of total) per forest type in 2010.

Source: ABS (2018).

	Forest types	Forest cover (ha)	Percentage of total cover
Wet vegetation types	Mangrove forest	29,584	0,2
	Swamp forest	241,560	1,6
	Marsh forest	1,628,966	10,5
	Creek forest	391,434	2,5
Dry vegetation types	Savanna forest	161,237	1,0
	Woodland savanna	150,191	1,0
	Bush savanna	110,735	0,7
	High dryland forest	12,464,427	80,4
	Mountain Forest	280,242	1,8
Secondary forest		36,672	0,2
	Total	15,495,048	

Suriname's forests can be categorized into three ecosystems: Open savannas, swamps and dryland forests.

<u>Open savanna</u>

Open savannas can be considered remnants of the extensive Pleistocene climate savanna that once covered nearly all of 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 (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).

<u>Open swamp</u>

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

- *Ecosystems of brackish water*
  These ecosystems are found in the estuarine zone at the coast where there is brackish water. 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*
  These ecosystems 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, thus 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*
  These ecosystems include palm swamp forests. Low swamp forests become high swamp forests if no forest fires occur.

- *High swamp forests and creek forests*
  High swamp 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 a large number of species from the surrounding high dryland forest.

- *High marsh forests* **/** *seasonal swamp forests*
  These ecosystems 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 river (the so-called 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 t of Amazonian sediments are transported in suspension with the Guyana current and about 108 t move along the coast of the Guyanas in the form of mud banks (UNDP, 2016).

<u>High dryland forest</u>

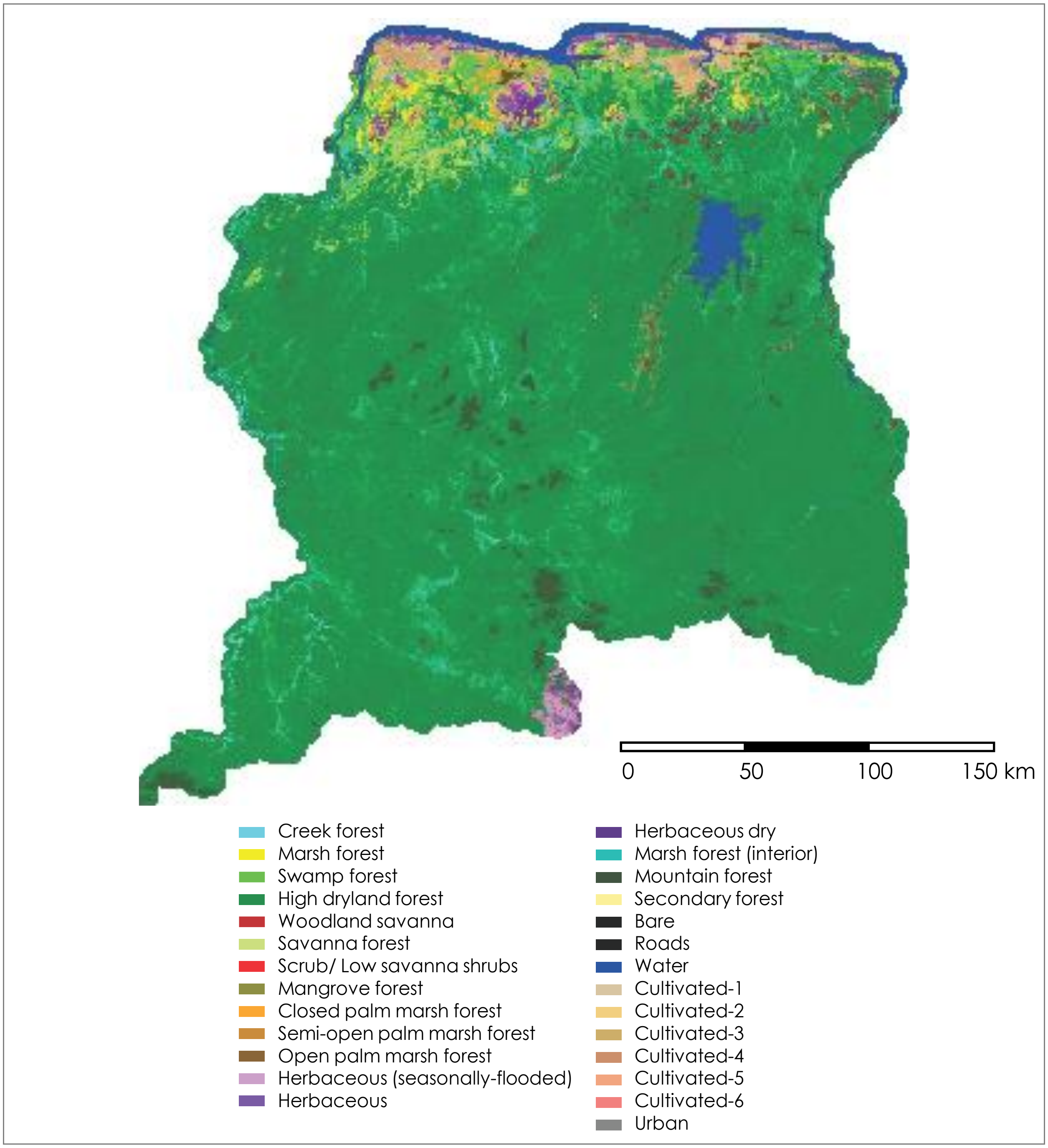
The largest part of Suriname's undisturbed forest, and the largest part of Suriname's surface (about 80 %), is covered by high dryland forest. These ecosystems are found from sea-level up to elevations of 400-600 m. General characteristics of these ecosystems include the presence of a high, dense canopy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

At higher 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. Epiphytes (such as 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).

Figure 10 provides an overview of the geographical location of the different ecosystems.

Figure 10: Geographical location of Suriname's ecosystems, including savannahs, swamps and high dryland forests in the year 2000.

Source: Gonini (2020).



2.2.3.2. Deforestation

Table 12 provides an overview of deforestation rates since the year 2000.

Table 12: Deforestation rates and absolute deforested area in the years 2000-2017.
Source: SBB (2017), FAO (2020), ABS (2018).

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

<u>Geographical distribution of deforestation</u>

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

- Paramaribo (29.8 % of the district's forested area)
- Wanica (11.6 % of the district's forested area)
- Brokopondo (4.9 % of the district's forested area)
- Sipaliwini (0.3 % of the district's forested area; Nevertheless, in terms of absolute area, this figure is larger than Brokopondo's deforested area)

<u>Deforestation drivers</u>

Deforestation of 72.9 % (62,102 ha) of the total deforested area (85,146 ha) has been attributed to mining activities, particularly gold mining. Mining also explains the increase in deforestation rates since 2009. Here, deforestation has been linked to the price of gold. 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 in Suriname (albeit 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, respectively (SBB, 2017).

Some drivers are more important for some districts than others:

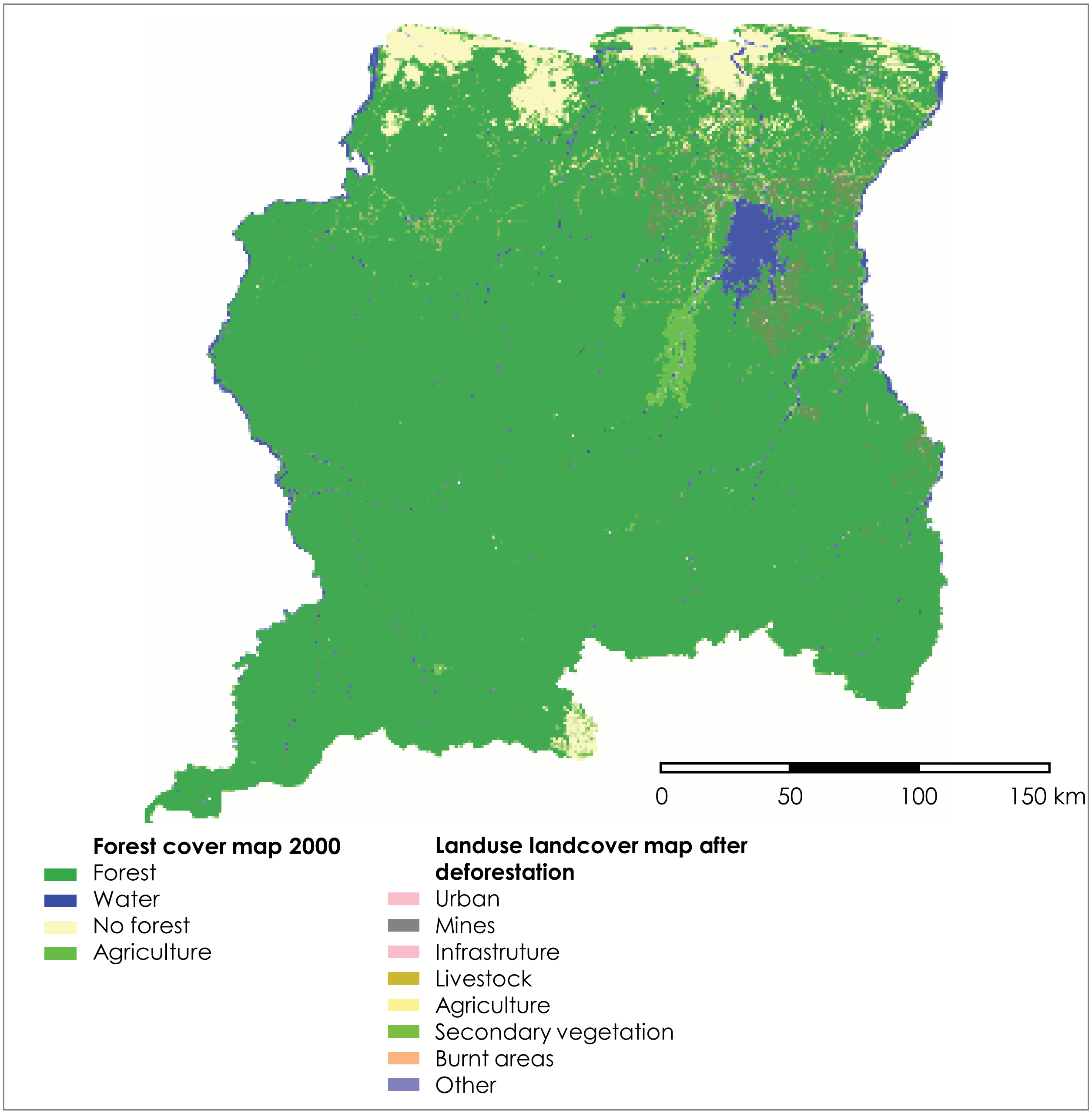
- In Wanica and Paramaribo, urban development (36 % of total deforested area in Wanica and Paramaribo), agriculture (28 % of of total deforested area in Wanica and Paramaribo) and conversion to pasture (25 % of total deforested area in Wanica and Paramaribo) are the main drivers of deforestation (SBB, 2017).

- In Brokopondo and Sipaliwini the main drivers of deforestation are mining (87 % and 81 % of the districts' total deforested area, respectively), as these districts form part of the Green Stone Belt which is a gold-rich geological deposit that stretches through the eastern part of Suriname, and infrastructure (10 % and 15 % of the districts' total deforested area, respectively) (SBB, 2017).

Figure 11 provides an overview of the geographical location of the deforested area according to the different drivers for 2000-2017.

Figure 11: Geographical location of deforested areas according to different drivers for 2000-2017.

Source: SBB (2017).



2.2.3.3. Protected areas

Suriname has 16 designated protected areas which in total 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 and terrestrial (table 13) and are important to the sector due to the opportunities for eco-tourism they offer.

Table 13: Suriname's designated protected areas in 2020.

Source: Own elaboration based on SBB (2017).

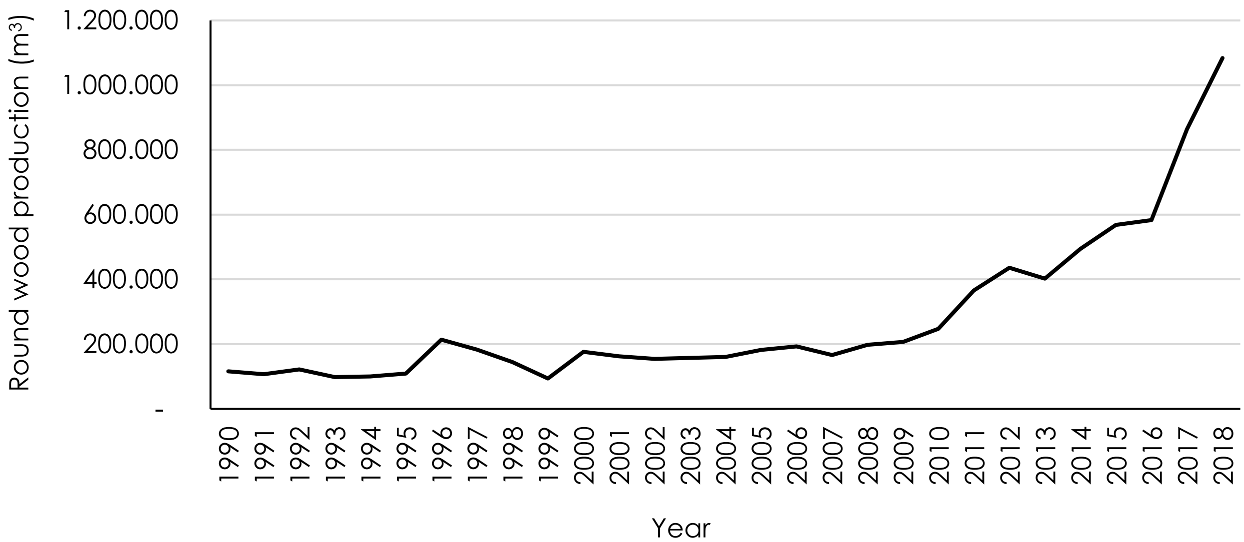
Protected area		Established	Area (ha)	District	Marine/ terrestrial
Nature reserve	Boven – Coesewijne	1986	27,000	Saramacca and Para	Terrestrial
	Brinckheuvel	1966	6,000	Brokopondo	
	Centraal Suriname	1998	1,592,000	Sipaliwini	
	Coppename Monding	1966	12,000	Saramacca	Marine and terrestrial
	Galibi	1969	4,000	Marowijne	
	Hertenrits	1972	100	Nickerie	Terrestrial
	Copi	1986	28,000	Para	
	Peruvia	1986	31,000	Coronie	
	Sipaliwini	1972	100,000	Sipaliwini	
	Wane kreek	1986	45,000	Marowijne	
	Wia Wia	1966	36,000	Marowijne	Marine and terrestrial
Nature park	Brownsberg	1970	12,200	Brokopondo	Terrestrial
Multiple Use Management Area	Bigi Pan	1987	67,900	Nickerie and Coronie	Marina and terrestrial
	Noord – Coronie	2001	27,200	Coronie	
	Noord – Saramacca	2001	88,400	Saramacca	
	Noord Commewijne – Marowijne	2002	61,500	Commewijne and Marowijne	
		Total	**2,138,300**		

2.2.3.4. 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 sector contributed 2.5 % and 3.5 % to Suriname's GDP, respectively (Knoema, 2020; SBB, 2019). 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 sectoral contribution to the country's GDP is based on timber production and wood export. Timber is produced in a 4 million ha 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 12).

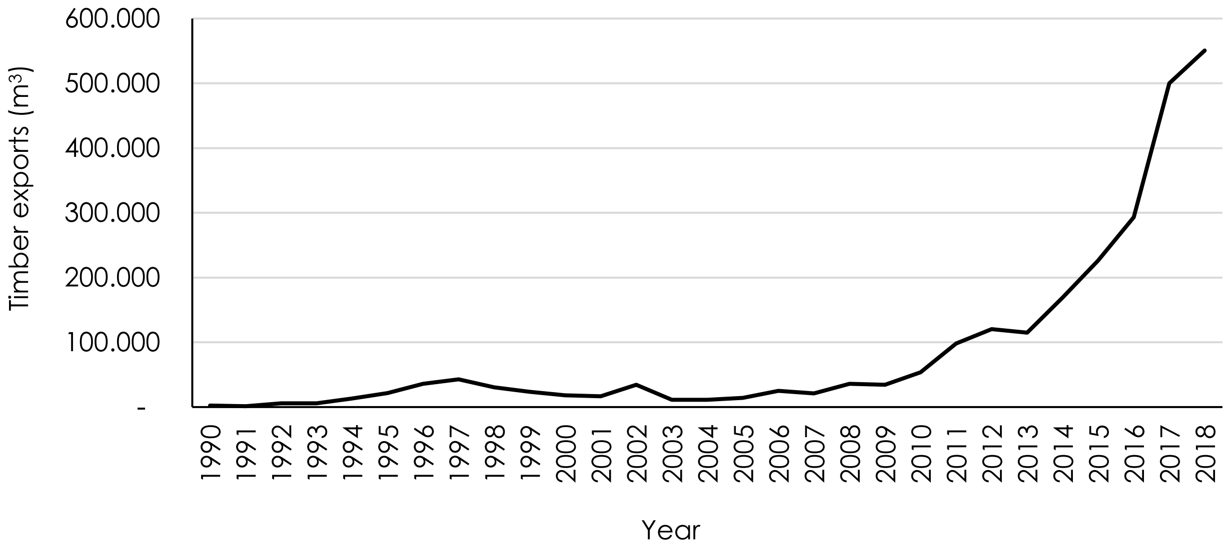
Figure 12: Round wood production (m³) 1990-2018.
Source: SBB (2018).



In view of the realized roundwood production, the years 2000 to 2017 can be divided as follows (SBB, 2019):

- 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 enormous demand for raw materials, including round wood, on the Asian market.

Figure 13: Timber exports (m^3) 1990-2018.
Source: SBB (2018).



In view of the realized timber exports (figure 13), which mimic round wood production to some extent, the years 2000 to 2017 can be divided as follows (SBB, 2019):

- 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. This is due to the fact that 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, Suriname's total national exports amounted to USD 1.4 million. The contribution of timber exports to this was approximately 4.4 %.

2.2.4. Infrastructure (energy, transport, buildings, telecommunications)

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 railroad infrastructure was ranked 108th and the quality of its electricity supply was ranked 91st (Hanouz, Geiger & Doherty, 2014). Nowadays, 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 approximately 75 % of Suriname's GDP originates in Paramaribo (IADB, 2016), where 69 % of the country's population live (Worldbank, 2019a).

2.2.4.1. Energy

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

<u>Carriers and consumers</u>

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, of which 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 Sipaliwani 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/ smoking fish, producing cassava bread, baking activities or cremation.
  Moreover, 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 is 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). This activity is of great economic importance to Suriname and Staatsolie registered a USD 500 million gross revenue in 2019 based on the sales of 2,838 Kbbls of fuel oil and crude, 1,884 Kbbls of premium diesel, 607 Kbbls of premium gasoline, 49 Kbbls of bitumen and 204 Kbbls of other oil products. Most of the fuel oil is exported to several Caribbean countries. Two of the company's main production sites are the Tambaredjo oilfield and the Calcutta oilfield in the district of Saramacca. From there, the crude oil is transported via a 55 km long pipeline to storage and distribution facilities at the refinery near Paramaribo. In addition, in 2020 new reserves with oil equivalent resources of almost 1.4 billion barrels were discovered (OilNOW, 2020). Staatsolie also runs a thermal power plant with a capacity of 96 MW, which electricity is transferred to NV EBS (on average 35-45 MW) for distribution.

In 1958 the Suriname Aluminum Company (Suralco) LLC entered into a 75-year agreement (the Brokopondo agreement) with the Government of Suriname on the development and utilization of a hydroelectric dam and works at Afobaka in combination with an aluminum producing facility. However, as in 2017 the refinery and bauxite mines were permanently closed, Suriname and Suralco LLC terminated the agreement in 2019. Since 2020 the Afobaka hydropower plant 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. The majority of Suriname's electricity, and almost half of the electricity consumption of Paramaribo and its surroundings, is generated by the Afobakka Hydropower Plant (IEA, 2018). Other hydrosystems are a 40kW micro-hydropower plant at Poeketie and 405 kW mini-hydropower plant at Gran Olo in the district Sipaliwini.

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

- EPAR generates electricity for greater Paramaribo and parts of the districts Commewijne, Wanica, Para and Saramacca. It has a capacity of approximately 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 approximately 130 villages with a total capacity of about 4.5 MW. With this energy it covers over 200 villages (ranging from 7 to over 3,500 people per village) with a total population of approximately 37,000 people (ABS, 2014b). Herefore, DEV delivers diesel on a monthly basis 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 minor part of rural electrification in the coastal districts Coronie, Marowijne and Nickerie as well as the towns Apura, Washabo and Section in the district of Sipaliwani 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.

Renewable energy (RE)

Suriname has a high RE potential in the form of hydro and solar power. With respect to wind, several tests have been carried out, but wind energy is not considered a feasible energy source for Suriname due to too many fluctuations in wind speed.

The largest stand-alone photovoltaic (PV) facility is the 5 MWp grid-connected system owned by Rosebel Goldmine Company which is used within the facilities of the company in the district Brokopondo. The second largest PV facility is the NV EBS Pokigron Hybrid Power Plant in the district Sipaliwini with an installed capacity of approximately 500 kWp working in hybrid mode with a 700 kW diesel generator. Other PV systems are the 27kWp grid-connected PV system at the headquarters of Staatsolie in Paramaribo. Other smaller PC systems installed in the Hinterland (Sipaliwani district) are:

- 3 kWp PV system at a school in Botopasi village (Boven resort).
- 20 kWp PV system in Pelelutepu (Tepu) village.
- 4 kWp rooftop PV system at an elementary school in Gujaba village

There are also standalone PV systems and solar boilers used by several companies and households that are not registered. Also, in the interior, telecommunication companies use PV systems to power their telecommunication towers and the health care service relies on PV systems for cooling medicines and vaccines.

Table 14 provides an overview of the most important electricity producers, electricity generation plants and their installed capacities.

Table 14: Suriname's major electricity producers, electricity generation plants and their installed capacities (MW).

Source: Own elaboration.

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

Electricity transmission and distribution

Electricity in Suriname is transmitted by high voltage transmission lines of 161 kV over long distances 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 and small commercial as well as large and industrial commercials. The price per kWh is according to customer type and consumption (table 15).

Table 15: Electricity distribution by type of costumer, consumption and price (SRD per kWh). Source: NV EBS (2020).

Customer Type	Consumption in kWh	Price (SRD per kWh)
Residential	< and equal to 150 kWh	0.15
	0 – 150 kWh	0.27
	151 – 300 kWh	0.30
	301 – 450 kWh	0.33
	451 – 600 kWh	0.50
	601 – 800 kWh	0.74
	> 800kWh	1.31
Social	Any	0.35
Small commercial (Companies with a connection < 24 KVA)	Any	0.50
Large commercial (Companies with a connection > 24 KVA)	KWh-LT kWh-HT	0.45 0.54
Industrial commercial (Companies with a high-voltage connection)	KVA	10.90

2.2.4.2. Transport infrastructure

The transport sector is divided into three sub-sectors, 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 the 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 the district Paramaribo and 1,126 km in the district Wanica, equal to 52 % of the entire road system. Over 78 % of the total road system in the district of Paramaribo is made of asphalt or paved (table 16).

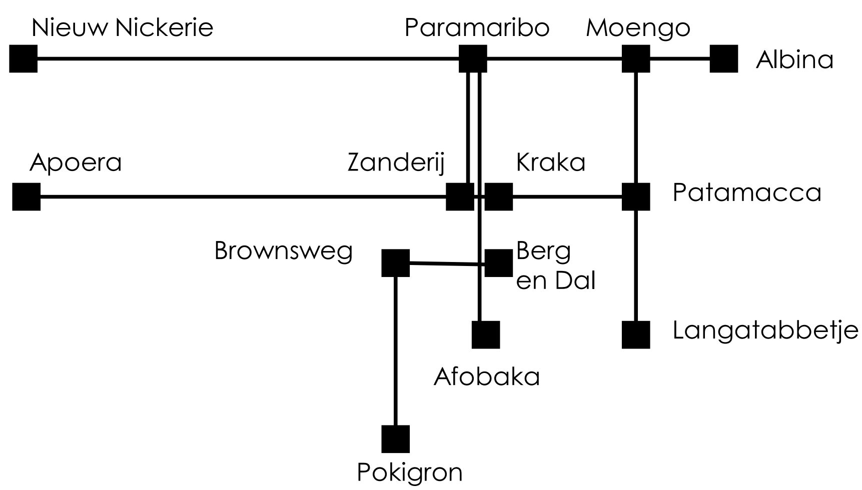
The hinterland consists of an extensive network of rivers and airfields, but a poorly developed road system. Water transport is mostly used by indigenous and maroon tribes (Berrenstein & Gompers-Small, 2016). In the districts Marowijne, Para, Brokopondo and Sipaliwini a primary laterite roads of a total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

Table 16: Roads (in km) of different materials per district in 2019.
Source: Personal communication with the OW (2020).

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

Suriname's primary road system has three axes (figure 14).

Figure 14: Suriname's primary road system.
Source: Blupfand (2006)



The three axes that the primary road system connects, mostly to develop forestry and mining activities, are:

- East and west (in the north) (Nieuw Nickerie - Albina): This connection 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 (in the south) (Apura - Patamakka): This connection 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 (Paramaribo – Pokigron): This asphalt road connects the hinterland and the capital (COSIPLAN, 2002).

Moreover, 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:

- Pokigron (district Sipaliwini): This village is situated along the Suriname river and has a small harbor named Atjoni where boats connect to villages along the upper Suriname River.
- Berg en Dal (district Brokopondo): Now a resort, this used to be an old plantation along the Suriname river. The secondary roads starting from Berg en Dal lead to villages' harbors where boats connect to villages along the Suriname River and eventually the van Blommenstein hydropower lake.
- Afobakka (district Brokopondo): This is where the van Blommenstein hydropower lake starts. Here boats can be taken to travel to islands on the lake.
- Apura (district Nickerie): This village is situated along the Corantijn river from where small small and mostly private boat transport is available.
- Nieuw Nickerie (district Nickerie): This city is situated on the Corantijn river where boats can be taken to travel to Guyana or other villages along the Corantijn river.
- Albina (Marowijne district): This city is situated on the Marowijne river where boats can be taken to travel to French Guyana or other villages along the Marowijne river. Along the Marowijne river small and mostly private boat transport is available.

The good connection to the capital has resulted in considerable migration from rural to urban areas. Despite people and businesses nowadays settling outside Paramaribo due to the high cost of living in the center of the city, overcrowding persists and in combination with various factors such as the following results in inefficient transportation, congestion and parking problems (EuropeAid, 2011; Lachman, 2018; Prosur N.V., 2012):

- The lack of zoning, urban and regional planning (which causes mixed land-use).
- An unstructured road network outside the city center.
- A lack of facilities for non-motorized transportation.
- Encroachment on public areas.
- Uneven walkways for pedestrians.
- The lack of different road infrastructures for public, taxi and private transportation (including heavy vehicles such as container, sand and wood logging trucks).
- The lack of an official functional hierarchy of roads.
- Drastic change in traditional residential areas to commercial-residential areas.
- The unreliability of public transport, not well-maintained bus stops, long walking distances to and from the stops, and more affordable private car ownership. According to the 2012 census, almost 60 % of the population used their own means of transportation to school or work (ABS, 2014b), while only about 15 % used public transportation despite being the

cheapest transportation option. Moreover, car ownership has doubled between 1992 and 2013 (De Koe & Van't Loo, 2017).

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 the district of Para. With a 3.5 km runway and annual capacity of 300,000 passengers, it is the country's largest airport. Annually nearly 230,000 commercial passengers depart and arrive from here.

Another international airport is the de Zorg & Hoop Airport located in Paramaribo. The majority of its flights, however, are domestic (Ricover, 2015). This airport has a 550 m runway.

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 located 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. The Port covers a total area of approximately 55 ha, with a quay of about 600 m in length that can accommodate about four ships of 100 m each. Moreover, there are about 119 reefer points but there are no facilities for cruise ships (Havenbeheer Suriname NV, 2017). As the main cargo gateway, the port handles approximately 90 % of Suriname's total seaborne trade (excluding oil). Cargo handling at the port is the responsibility of two private companies, VSH United and DP World Paramaribo. The project "Capital and Maintenance Dredging Suriname River", launched in March 2020, will dredge an additional 68 km of the Suriname River to provide a deeper fairway and make the port more accessible to large container ships.

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 towards upgrading facilities to increase freight flows through this port. In 2016 the port handled about 32,000 t of cargo.

Moreover, there are four privately run harbors at the following locations:

- Moengo (district Marowijne): This harbor functions as a multipurpose cargo quay handling lumber, fuel, sand and gravel.
- La Vigilantia (district Wanica): This harbor is dedicated to handling cargos for the mining, oil and forestry sectors as well as cement cargos.
- Paranam (district Para): This harbor at Paranam formerly served the now closed Suralco aluminum plant.

- Kuldipsingh (district Wanica): This harbor handles the export of building materials including cement, rock and river sand and the import of steel for the construction sector.

2.2.4.3. Building infrastructure

Almost 90 % of Suriname's population lives in the 384 km long coastal plain, 44 % in Paramaribo and 22 % in Wanica (ABS, 2014b). Suriname's urbanization rate is approximately 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 2016 an average of 4 % of the households in Paramaribo and Wanica (95,369 households) indicated that their dwelling was in a very good condition, 36 % of the households indicated that their dwelling was in a good state, and 2 % indicated that their house was in very bad conditions (ABS, 2018). The most used building construction materials are block only, followed by wood and block, and wood only (table 17).

Table 17: Percentage of household in Paramaribo and Wanica by the most important materials of the outer walls of the dwelling in 2016.

Source: ABS (2018).

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

Paramaribo's historic center (48 ha and 100 ha of buffer zones) was designated a World Heritage Site by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 2002. The historic core zone hosts mostly public buildings (70 %), some for commercial purposes (18 %) and some for residential purposes, or they remain empty (12 %). In general, the historic buildings of the core zone do not receive enough maintenance (IADB, 2000). Moreover, the historic center is highly vulnerable to flooding due to sea-level rise and intense and frequent precipitation coupled with undersized and poorly maintained drainage systems (IADB, 2017).

The building sector can be seen as an essential sector, directly and indirectly, for the country's economy. Directly, because it creates employment and indirectly, because sustainable and affordable housing in many ways contributes to economic, social and cultural development according to the National Development Plan. According to a study by the Islamic Development Bank (Cleophas Pierre, J. & Schalkwijk, J., 2018), the construction sector is expected to grow 4-5 % annually on average from 2019 onwards. The study also mentioned that in 2004 around 21,130 people were employed in the construction sector.

2.2.4.4. Telecommunications infrastructure

Telecommunications in the geographical context

The telecommunication sector in Suriname is partly deregulated. Telecommunication infrastructure and fixed-line services are state-owned, but mobile telecom is deregulated. The mobile market supports only two players: Telesur (trading as TeleG), and Digicel (part of the Digicel Group, a significant operator across the Caribbean region). Telesur is the state-owned telecom company and has exclusivity of fixed-line services. However, the mobile telecom market has grown significantly in recent years and nowadays is much greater than the landline market.

In 2019 14 % of inhabitants had a fixed broadband subscription (Worldbank., 2019b) and 58 %, 42 % and 22 % of urban, rural coastal and rural interior households had access to internet at home, respectively (Ministry of Social Affairs and Public Housing, 2019). Broadband connections are reasonably 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).

One can state that every sector is dependent on telecommunications. Telecommunication facilitates the functioning and connectivity of the country. Damage and disruption of telecommunication infrastructure (or electricity infrastructure that powers telecommunication) can be detrimental to a government, the private sector and citizens. Examples of these effects are ineffective e-Government and poor online education development and decreased basic information and communication technology skills among the population (ICT Associatie Suriname, 2015).

2.3. National policy and legal framework

2.3.1. Cross-sectoral

In recent years, Suriname has made international commitments as well as 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 on them:

2.3.1.1. International commitments

United Nations Framework on Climate Change (UNFCCC)

- *Nationally Determined Contributions (NDC) (2020)*
  The NDC outline a cost-effective pathway for the decarbonization and sustainability of Suriname's economic development. The NDC are fully aligned with national development priorities and contain a comprehensive package of sectoral projects, policies, measures and targets.

  The entire project portfolio is worth around USD 696 million, however, it does not encompass the full scope of Suriname's contribution. Instead, it is intended to serve as a tool for investors and development partners wishing to support Suriname in the implementation of its NDC. Projects worth USD 2.7 million are on agriculture, projects worth USD 49 million on transport, projects worth USD 209 million on forestry and USD 435.5 million on energy.

  The NDC include 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.

  The NDC also refer to adaptation, however, the 2019 National Adaptation Plan (NAP) describes how the NDC commitments to adaptation are to be achieved.

- *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. On the other hand, 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 prevent adhoc awareness campaigns.
- Conduct a technology-needs assessment which will e.g. 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 entire organization and equipment.

- *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 being a HFLD country and receive compensation to invest in economic transition

This strategic line is about maintaining Suriname's high forest cover, biodiversity and environment. It has two policy lines:

- Multilateral and bilateral negotiations aiming at receiving financial support for the preservation of Suriname's forest cover.
- Support existing, alternative and additional sustainable livelihoods and diversification of the economy.

2. Forest governance

This strategic line is about increasing the forests' contribution to development by promoting sustainable forest management, e.g. via participatory forest governance structures that involve Indigenous and Tribal Peoples (ITPs) and the private sector. It has three policy lines:

- Advance participation of different stakeholders.
- Enforcement, control and monitoring.
- Forest and environmental laws and regulations.

3. Land use planning

This strategic line is about 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 (e.g. 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:

- Land Tenure.
- Land use planning.
- Promotion of sustainable practices in land use sectors other than forest.
- Participatory community development.

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

This strategic line is about continuing and expanding conservation and rehabilitation of forest, their biodiversity and ecological functions, while exploring extractive and non-extractive uses that result in community development, well-being and economic diversification. It has three policy lines:

- Protected areas.
- Rehabilitation and reforestation of degraded and deforested areas.
- Scientific research and education on forest management.

2.3.1.2. 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, 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 18).

Table 18: NCCPSAP themes and objectives.

Source: ATM (2015).

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 towards renewables increases access to, 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/ or built to be climate resilient and take advantage of potential future green growth opportunities such as feed-in tariffs.
Mining	The mining sector should adjust its infrastructure so that its operations are climate resilient and produce minimal emission.

NCCPSAP theme	Objectives
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, reducing energy consumption and reusing exploited or abandoned fields. Opportunities to produce renewable energy in the agricultural sector should be seized and attract climate finance.
Tourism	Tourist infrastructure, attractions and suppliers should be protected from negative climate impacts to ensure a strong, reliable service to visitors. Benefits from low carbon branding and carbon taxes should be exploited.
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.
Health	Health services and infrastructure should be equipped to provide support to those impacted by a variable and changing climate and its effects on health (e.g. changes in vector-borne diseases).
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 take into account the impacts of a variable and changing climate and low carbon growth opportunities.
Sustainable forest management	Sustainable forest management (SFM) should take into account the impacts of a changing climate and the need for low carbon development.

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:

1. Impact reduction through adaptation and resiliency building.
2. 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 is based on eight policy principles:

1. Manage risk, build resilience and explore opportunities.
2. Legislate.
3. Equitable participation.
4. Educate and train.
5. Inform and report.
6. Commit resources to goals.
7. Partner with the private sector and prioritize technology.
8. Science and research-based decision making.

The NAP covers adaptation needs at two levels:

1. The strategic national level that will strengthen efforts across the board, now and in the future. The priorities are:
   - Institutional arrangements, policies and capacities able to lead and coordinate national and sub-national climate change adaptation.
   - Data and information collection systems to fully support national and sub-national climate change impacts, vulnerability and adaptation decision-making.
   - The integration and institutionalization of climate change adaptation in broader Surinamese economic development policies, plans and programs.
   - National technical capacity that is fully trained and skilled at leading and implementing Suriname's climate change adaptation actions.
   - Climate change adaptation that respects Surinamese society and culture and reduces gender and social inequities.
   - Identify and access financing and investment especially for innovation driven climate change adaptation technologies.
2. The economic sectoral level that prioritized sectors according to climate risk and vulnerability levels. The priorities are:
   - Water resources.
   - Sustainable forestry.
   - Agriculture, livestock and fisheries.
   - Energy.

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 well-being and climate action are an integral part of all pillars, and particularly the fourth pillar. The latter elaborates on sea-level rise and its dangers to development, long-term investments and strategies. Moreover, the OP makes suggestions on how to minimize possible impacts derived from sea-level rise and other hazards (e.g. 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.

Environmental Framework Act (2020)

In March 2020 the Environmental Framework Act was passed unanimously after two decades of negotiation. Although a major milestone for environmental protection in Suriname, to date the law is not yet fully enforced, as it lacks implementing decrees that must first be approved by the government.

In the context of Suriname's sustainable development, it was necessary to develop a national environmental strategy and plan that creates a well-adjusted balance between economic growth and environmental protection in order to meet the aspirations of the Surinamese people. This was done with the Environmental Framework Act.

The Act also establishes the National Environmental Authority's (NMA) (see chapter 2.4. on Suriname's environmental management structure). The establishment and responsibilities of the NMA is fully described in the Environmental Framework Act.

The Act is based on the following five principles:

- Publicity, participation and legal protection.
- Precautionary principle.
- "The polluter pays" principle.
- Environment and planning principle.
- Environmental impact analysis principle.

Planning Regulation Act (1973)

This Act serves good land-use planning. It states that the natural resources of the territory must serve the material, social and cultural needs of the population to generate prosperity and well-being, while their original character should be sustained to the extent possible. The Act is also on the creation and maintenance of healthy living environments, e.g. by safeguarding nature reserves and recreation areas, as well as keeping the soil, water and air clean. Furthermore, the Act indicates that the OP should include a map with the areas that correspond to production (e.g. forestry, agriculture, mining, industry), residential (by means of urban development regulations and building regulations' laws) and special management areas.

2.3.2. Agriculture

2.3.2.1. International commitments

United Nations Framework on Climate Change (UNFCCC)

- *Nationally Determined Contributions (NDC) (2020)*
  The agriculture sector is both a source of emission as well as strongly impacted by the effects of climate change. 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, the support of adaptation/ mitigation planning processes, the implementation of mitigation and adaptation practices, and relevant capacity development with aimed at the broader objective of food security and nutrition.

  Table 19 summarizes the conditional and unconditional contributions Suriname has committed itself to for agriculture.

Table 19: Conditional and unconditional contributions of Suriname for agriculture.

Source: Cabinet of the President of the Republic of Suriname (2019).

Unconditional	Conditional
o Rehabilitation and enhancement of infrastructure such as dikes and river defenses (precondition). o Improvements to water resources management. o Promotion of sustainable land management. o Applying innovative technologies in the use of land.	o Introduction of a national land use planning system, to make the embedding of climate change in (agricultural) development plans possible. This will allow assessment of the potential emissions impact of proposed agricultural land development, with a view to limiting emissions from agricultural land clearing. o Clustering of agricultural development, thus ensuring an efficient protection against sea-level rise. o National research, development and innovation program on agriculture. Identification, trial and introduction of more permanent agricultural systems to replace traditional shifting cultivation methods.

- *Second National Communication (SNC) (2016)*
  The SNC identified the decrease of productive land as one of the country's six biggest issues to be considered for adaptation. Moreover, it proposes the following specific adaptation measures:

  - Development and implementation of appropriate research programs, capacity building, and training required for animal husbandry (e.g. water buffaloes), crops (the introduction of new varieties including salt tolerant rice and upland rice varieties, integrated pest management) and fisheries (enhancement of competitiveness).
  - Rice: The construction of dikes in the areas which lay in the lower parts of the land.
  - Rice: Increase in the availability of freshwater for rice irrigation through establishment of necessary infrastructures.

- o Rice: Agro-ecological research programs focussed on integrated pest management and disease control.
- o Rice: Establishment of an insurance fund to compensate farmers who suffer from the effects of unexpected weather influences on crop production.
- o Rice: Research focussed on crop rotation. During the dry season crops that are drought tolerant can be grown in areas where availability of irrigation water is a constraint during the long dry season.

- o Banana: Planting of hedgerows of trees to protect against strong winds.

- o Fruits and vegetables: Change farming systems (greenhouses and hydroponics) to cope with alternating climate change conditions.
- o Fruits and vegetables: Improve drainage systems to guarantee efficient production and quality products.
- o Fruits and vegetables: Crop diversification to guarantee food security under alternating climate conditions.

- o Livestock (poultry, dairy production, sheep, goats and pigs): Rehabilitation of abandoned farms to guarantee food security (shift of cattle from vulnerable coastal areas to higher grounds).
- o Livestock: Measures to prevent further decline in the number of productive animals (ban on the slaughtering of female animals and import of beef cattle for a certain period).

- o Aquaculture and fisheries: Measures to enhance sustainable aquaculture and fisheries management.
- o Aquaculture and fisheries: Protection of fishing breeding grounds (salt pans, mangrove vegetation, coastal wetlands).
- o Aquaculture and fisheries: Establish funds for fishermen to promote aquaculture.

2.3.2.2. Main national policies and legislation on agriculture

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

Table 20 summarizes agriculture, animal husbandry and fisheries' programmes and their related outcomes:

Table 20: NCCPSAP programmes and their outcomes for agriculture, animal husbandry and fisheries.

Source: ATM (2015).

Programme	Outcome
• Comprehensive national research programme on social, environmental and economic baselines, climate science, vulnerability, impacts and risk management. • Integration of climate resilience into agricultural extension services (raising awareness of farmers, pastoralists and fisherfolk on the impacts of climate change, and building capacity on how to manage impacts).	Improved knowledge of how climate change will impact on Suriname's agriculture, livestock and fisheries sectors and development of climate resilient products/techniques.
• Develop and implement law, policy and regulation to incorporate climate resilience into agriculture, livestock and fisheries management. • Infrastructure development to conserve water, provide irrigation and protect agriculture from saltwater intrusion. • Financial support to farmers, pastoralists and fisherfolk to build climate resilience.	Agricultural crops, livestock and fisheries are protected from water shortages, flooding and saltwater intrusion.
• Technological transfer programme on sustainable and environmentally friendly agricultural practices.	Decreased GHG emissions from agriculture.

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

The NAP strategic objectives for agriculture, livestock and fisheries include the following:

1. Comprehensive national research program on climate resilient crops, agricultural practices, animal husbandry and fisheries.
2. Integration of climate resilience into agricultural extension services.
3. Develop and implement Sustainable Agriculture Policy including relevant climate resilience mechanisms in existing and new regulations.
4. Financial support to farmers, pastoralist and fisherfolk to build up climate resilience.

The sector has the following strategic objectives and adaptive measures (table 21):

Table 21: Strategic objectives and adaptive measures for agriculture, livestock and fisheries.

Source: Government of Suriname (2019).

Strategic objectives	Adaptive measures
Comprehensive national research program on climate resilient crops, agricultural practices, animal husbandry and fisheries.	• Develop a comprehensive national research program on climate resilient crops, adaptive agricultural practices, animal husbandry and fisheries. • Conduct analysis on past and future climate impacts on Suriname's agriculture, livestock and fisheries sector and responses. • Strengthen participation in agricultural activities particularly among women and vulnerable groups.

Strategic objectives	Adaptive measures
Integration of climate resilience into agricultural extension services.	• Increase the capacity and effectiveness of the agriculture extension services. • Focus on community specific and loca lspecific awareness and training. • Provide training and guidance in climate smart crop production. • Climate-control systems on livestock farms and modification of livestock feed, in both the coastal area and the interior.
Develop and implement Sustainable Agriculture Policy including relevant climate resilience mechanisms in existing and new regulations.	• Implement the Water Boards Act as the most relevant legislation for water management in the agricultural sector and strengthen the governance in water management for agriculture.
Financial support to farmers, pastoralist and fisherfolk to build up climate resilience.	• Develop and provide a financial incentives scheme for farmers, based on research results appropriate to each region and ecotype, to implement climate resilient farming techniques/actions. • Develop and provide a financial incentives scheme to promote aquaculture.

<u>National Development Plan (OP) 2017-2021 (2017)</u>

The Ministry of Agriculture, Animal Husbandry and Fisheries' (LVV) policy area is divided into three subsectors and 14 product clusters:

A. Crop cultivation

1. Grains, in particular rice, corn.
2. Vegetables and legumes, tuber and root crops (in particular cassava).
3. Banana and cooking banana.
4. Other fruit, in particular citrus.
5. Edible oils, in particular, oil palm and coconut.
6. Stimulants, and in particular cocoa and herbs.
7. Non-food crops: Bio-energy, ornamental plant cultivation and fiber crops.

B. Animal husbandry

8. Poultry: Meat and eggs.
9. Cattle: Milk/ meat and small ruminants.
10. Pig husbandry.

C. Fisheries and Aquaculture

11. Population fishing
12. Sea fisheries
13. Aquaculture

The OP sets out three priorities for the sector:

1. Investing in research in the agricultural and agroindustry sectors.
2. Improving infrastructure, services and technology in order to increase production and exports.

   The OP aims at increasing the responsibility of stakeholders that are directly involved in the various stages of the production cycle. In practice, individual family businesses, self-employed workers, collaborative groups or cooperatives, women's organizations and organized young people should manage their services independently. The government provides the necessary production areas and infrastructure such as access roads.
3. Ensuring food safety and security for the Surinamese population.

   The OP also advocates the local consumption of fresh products, the development of tourism in the sector and increasing exports to neighbouring countries and the region. The government provides the necessary production storage, processing and preservation facilities. Industrial centers with small processing units are to be set up for the reception of surpluses.

Law on the Sale and Storage of Pesticides

This law still has to be passed and proclaimed. It will allow the LVV to certify farmers on local GAP (van Dijk, 2016) that comply with standards set by the Surinamese Standaarden Bureau (Manusami, 2016). Compliance of the farmers' agricultural practices will be evaluated by audits that measure their farms' compliance with standard criteria.

Furthermore, the LVV will have the authorization to control the sales and storage of pesticides and eventually confiscate illegally sold and stored pesticides. At this moment the Department of Economic Control Services of the Ministry of Trade and Industry is the competent power to confiscate illegally sold and stored pesticides (van Dijk, 2016).

2.3.2.3. Other national policies and legislation related to agriculture

- Crops Protection Act (1965, last amended 1980)
  These are rules preventing the introduction and spread and promoting the control of pests in plants, plant products and other regulated goods. This legislation assists in reducing diseases and pests in plants so that food safety is guaranteed.
- Pesticides Act (1972)
  This Act defines a pesticide as any substance and mixture of substances, as well as micro-organisms and viruses, intended to be used in the control or repelling of animals which may cause damage to plants and parts of plants. Under this Act it is forbidden to sell, stock or use a pesticide which is not permitted. A pesticide shall be authorized only if:
  - The content of the active substance and the composition, color, shape, finish, packaging and indications on, to or near packaging comply with general rules.
  - The product is sound for the purpose for which it is intended, the correct use of the product is in accordance herewith, and its intended purpose will not cause harm.

- Fish Tides Act (1961, last amended 1981)
  This Act states that it is forbidden to fish within Suriname other than with the rod or with the handline, unless with a written permit. The minister may, in the interest of protection of fish stocks, specify the number and species of fish that can be caught, and when they can be caught.

- Slaughterhouse and Meat Inspection Act (1961, last amended 1986)
  This Act is about the inspection before and after slaughter of live animals. The Act applies to establishments for slaughter, processing, packaging, repackaging, storing, selling, transporting and distributing meat and other products of animal origin intended for human or animal consumption.

- Fish Inspection Act (2000)
  This Act states that the LVV is responsible for establishing the quality standards for fishery products, for producing fishery products and for verifying compliance with those standards.

- Sea Fishing Act (1980, last amended 2001)
  This Act states that sea fishing must be licensed and that the documentation masters of fishing vessels must have on board.

2.3.3. Water

2.3.3.1. International commitments

United Nations Framework Convention on Climate Change (UNFCCC)

- *Nationally Determined Contributions (NDC) (2020)*
  In December 2019, Suriname submitted its second NDC, which focused on four key areas; Forests, electricity, agriculture and transport. No specific provision was 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 resources management.

- *Second National Communication (SNC) (2016)*
  The SNC includes a vulnerability assessment focusing on climate change impacts on water resources, amongst others. Water resources in the coastal area as well as in the hinterland are classified as vulnerable to highly vulnerable to climate change. Coastal urban areas are susceptible to flooding as a result of 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, aquifer salinization. Moreover, it proposes the following specific adaptation measures:

  - Formulation of necessary legislation to protect water resources in general and to promote its sustainable use.
  - Formulation of necessary legislation on water quality standards and wastewater discharge.
  - Establishment of necessary institutional organization for the enhancement of water management, among others (water boards and authority).
  - Establishment of physical infrastructure such as wastewater treatment plants.
  - Performing in-depth studies, including water balance studies, and the establishment of a required observation network and monitoring system.
  - Implementation of the Integrated Coastal Zone Management plan.
  - Increase of the efficiency in drinking water supply and in water use in general. For the rural areas, increase in efficiency regarding irrigation practices through technical improvements of infrastructure, capacity building, training and awareness rising.
  - Decrease in the demand and increase of the capacity of available freshwater resources through technological improvements.
  - Encourage use of alternative freshwater resources such as the utilization of rainwater and surface water.
  - Carry out monitoring and in-depth studies to enhance water management and sustainable use of water resources.
  - Upgrade of infrastructures for water supply, irrigation, drainage and flood protection.

- *REDD+ Strategy 2018-2027 (2019)*
  The national REDD+ Strategy (2019) is a sustainable development tool that aims at reducing greenhouse gas emissions from deforestation and forest degradation. The strategy also creates conditions for sustainable economic development (e.g. in the form of ecotourism)

and ecosystem services such as water regulation. Although ecotourism promotes the socioeconomic development of forest dependent communities, it also implies trade-offs such as an increased demand for drinking water and wastewater management in areas difficult to access.

2.3.3.2. Main national policies and legislation on water

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

Table 22 summarizes drinking water's programmes and their related outcomes (table 22):

Table 22: NCCPSAP programmes and their outcomes for drinking water.
Source: ATM (2015).

Programme	Outcome
• Comprehensive national research programme on social, environmental and economic baselines, climate science, vulnerability, impacts and risk management.	Improved knowledge of climate impacts on water resources and how to manage climate impacts.
• Develop and implement law, policy and regulation to ensure sustainable exploitation and use of drinking water resources. • Water management programme to ensure resilience of water supply.	Water resources and supply have greater resilience to climate change.
• Climate-resilient infrastructure development to ensure availability of drinking water. • Awareness raising programme on avoiding contaminated water post-disaster.	Clean, safe and affordable drinking water is available to households at all times.

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

The NAP provides overarching guidance for Suriname's efforts to adapt to climate change. Water, especially water resources, were identified as a key productive sector that is vulnerable to climate change and suffering high impacts already in the short-term. The NAP further recognizes the importance of technology transfer. As such, a technology needs assessment was performed in 2019 and is to be concluded by 2020. Water management (water modeling, water resource mapping, water storage and harvesting) was identified as one of three priorities to be considered within the assessment. The sector has the following strategic objectives and adaptive measures (table 23):

Table 23: Strategic objectives and adaptive measures for water resources.

Source: Government of Suriname (2019).

Strategic objectives	Adaptive measures
Comprehensive national research programme on social, environmental and economic baselines, climate science, vulnerability, impacts and risk management.	• Undertake in-depth studies and establish an observation network and monitoring system,in order to enhance water management and sustainable use of water resources.
Develop and implement law, policy and regulation to ensure sustainable exploitation and use of drinking water resources and waste water management.	• Addition of the climate change aspect including the law on meteorological services after formal approval of the water law; And development of surface water law. • Assess options for the establishment of an institutional organization for the enhancement of water management. • Develop robust land management and waste management policies. • Develop policy, regulations, standards and best practice guidance to support national waterresource management that is adaptive to climate change.
Water management programme to increase resilience of water supply.	• Consider current integrated water resource management approaches and future proposals with an intent of mainstreaming climate change adaptation processes into these frameworks. • Identify and implement wastewater recycling schemes, including mining and forestry sector.
Climate-resilient infrastructure development to ensure availability of drinking water and other uses of water.	• Develop and upgrade infrastructure for water supply, irrigation. • Develop and upgrade infrastructure to cope with the effects of climate change and sea level rise e.g. drainage and flood protection.

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

The OP recognizes the availability of safe drinking water as indispensable for the socio-economic development of the country and preventive health care. Furthermore, the OP sets out a number of policy priorities to be implemented in the water sector, such as:

- The establishment of new and the rehabilitation of existing drinking water facilities to increase the production capacity of the coastal plain from 5,800 m^3/h to 11,000 m^3/h.
- The approval of four draft water laws (*water wetten*) (see below).
- The development of a “National Water and Export Marketing Strategy” and an “Integrated Water Resources Management System for Suriname”. These two should provide an overarching national integrated water policy to set direction in the sector.
  So far, there is no strategic vision or (draft) law regarding integrated water resource management and protection (Del Prado, 2013). Existing water related legislation is out of

date and does not comply with current social requirements. Some shortcomings in the current legislation are the lack of rights and obligations of water users, lack of control mechanisms, clear division of responsibilities and powers (no integration of functions), lack of water quality standards, surface water, etc. Adjustment or renewal is therefore an urgent necessity (Waterforum, 2019).

- The incorporation of laws and regulations regarding the existing and future use and extraction of water into new planning legislation, thereby protecting the quality of both soil and water.
- Addressing the water storage and drainage of areas in regional and zoning plans.

2.3.3.3. Protection of water resources in general

Drilling Act (1952)

Currently, this Act does not protect groundwater, but it contains provisions to protect the soil and prevent the mixing of soil layers by regulating the treatment of drill holes. This act is very outdated and not being enforced by the Geological Mining Service (GMD). It is expected that this Act will be reviewed and amended (Del Prado, 2013), since boreholes can lead to groundwater contamination.

Act on Pesticides (1974)

This Act prohibits the removal or destruction of empty containers of undiluted pesticides in a way that this leads to the contamination of areas used for the extraction of water or surface waters.

Nature Conservation Act (1954, last amended 1992)

This Act stipulates that the president may designate land and waters belonging to domain land as a nature reserve. This act is outdated and focuses more on nature conservation rather than pollution control.

Water Board Act (2005)

This Act regulates the establishment and management of waterboards, as well as the authorization of the board, the obligations of the stakeholders, the possibility of administrative coercion, the supervision of the waterboards and the possibilities of appeal against decisions taken by the board.

Guidelines for land issuance in the estuarine management areas (2005)

This regulation addresses the issuance and use of domain land in estuarine management areas in order to protect their ecosystem services such as coastal and shore protection, soil and water management, the provision of breeding and feeding ground for fish, shrimp and birds. Precisely, issuing domain land in the estuarine management areas has to comply with three important conditions:

1. A strip of 500 m on both sides of rivers (and of 200 m on both sides of creeks) is reserved for forest protection.
2. The withdrawal of water from estuarine swamps is prohibited.
3. The discharge of wastewater containing chemicals and pesticides is prohibited.

2.3.3.4. Protection of drinking water resources

Water Supply Act (1938)

This Act obliges owners of buildings and houses (but not water companies) to make use of the public water supply system. It prohibits the ownership or possession of wells, pits or similar to extract water, as well as of bins, barrels, tanks or similar objects to collect and/ or store water in the areas where the law is applicable.

Concession Act (1907, last amended 1944)

This Act includes rules concerning the exploitation of public utilities. Accordingly, the President can grant concessions for the use of domain land for the construction and operation of works of public utility. The SWM operates as a concessionaire under this law. However, its concession expired in 1982. The request for an extension and expansion of the concession is pending.

The Price-fixing and Price-control Act (1957)

This Act is on the competence to intervene in the fixation of water tariffs. The responsibility for tariff approvals lies with the government. According to the Act, the government can establishing an independent advisory office to review and comment on tariff issues (Del Prado, 2013).

Draft Act concerning the extraction of groundwater (Concept Grondwaterwet)

This Act concerns the extraction of groundwater, which must be licensed by the Minister of Natural Resources. The Act also establishes a water management commission to advise the Minister in granting licenses for water extraction and in the permission procedure. The Act also contains technical specifications for drilling. The implementation regulation of the Act provides the technical specifications that water companies and their staff must follow to drill and close wells.

Draft Act concerning the protection of groundwater extraction areas (Concept Wet Grondwaterbeschermingsgebieden)

This Act protects catchment areas and ensures that no bacteria-contaminated water, hydrocarbons or other toxic substances reach the wells within a period of 60 days before their natural degradation.

Draft Act on supervision of drinking water quality (Concept wet Toezicht Drinkwaterkwaliteit)

This Act sets standards for drinking water quality and apllies to all companies that supply potable water to the public.

Draft Act on Suriname's Water Authority (Concept wet Surinaamse Waterautoriteit)

This Act establishes the Suriname Water Authority (SWA). The SWA is responsible for the supervision, monitoring and advising of the water sector. The establishment of the SWA enhances the coordination of water management.

3.5 Wastewater management

Harbor Decree (1981)

The Decree prohibits the discharge of waste, oil, oil-contaminated water and condemned goods into public waters. It is also prohibited to pump oil, oil-containing ballast and bilged water into public waters.

Building State Order (1956, last amended 2002)

The Order sets specific drainage and sewage requirements for the construction of buildings. Some important provisions and licensing requirements to be taken into account when building are:

- Each toilet must be connected to a septic tank or a designated sewage.
- Each building, in whole or in part, intended to house must have a well-established adequate drainage to drain rainwater and household water in a sewer to be designated by the Director of Public Works.
- The stool of a private household may be transferred only by air- and watertight stones, metal or cement pipes into the septic tank.

Nuisance Act (1930, last amended 2011)

The Act states that the District Commissioner must issue a license for certain types of enterprises to operate. A license may be refused if the enterprise harms or damages property, business or the environment, e.g. by discharging untreated wastewater.

2.3.4. Forestry

2.3.4.1. International commitments

United Nations Framework on Climate Change (UNFCCC)

- *Nationally Determined Contributions (NDC) (2020)*
  Suriname's efforts to protect its forests form a key part of the country's NDC. In Suriname's intended NDC, the country committed 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 reiterate 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.

  Table 24 summarizes the conditional and unconditional contributions Suriname has committed itself to for forestry.

Table 24: Conditional and unconditional contributions of Suriname for forestry.

Source: Cabinet of the President of the Republic of Suriname (2019).

Unconditional	Conditional
○ To increase the percentage of forests and wetlands under protection from 14% to at least 17% of the terrestrial area by 2030. ○ To increase efforts at sustainable forest and ecosystem management and stabilizing and minimizing deforestation and forest degradation unconditionally. ○ To maintain the share of electricity from renewable sources above 35% by 2030.	○ To maintain its HFLD status while, side by side with other HFLD nations, pledging to raise international recognition of the significant contribution that HFLD developing countries provide to the global response to climate change by enabling their forests to serve as vital carbon sinks. ○ To implement the REDD+ Investment Strategy with a 10-year timeframe.

- *Second National Communication (SNC) (2016)*
  The Agriculture, Forestry and Land Use (AFOLU) sector forms the only sink of greenhouse gases in the 2008 inventory. The Communication identifies important mitigation options for the sector based on the REDD+ programme. With regards to adaptation the Communication identifies the following adaptation measures for ecosystems:

  - 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, 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 incorporation of forest-fire measures into the national disaster plan.
  - The implementation of conservation strategies for protecting marine turtles.

- *REDD+ Strategy (2019)*
  Suriname's vision for the forestry sector as outlined in its national REDD+ Strategy from 2019 is that "Suriname's tropical forest continues and improves its contribution to the welfare and wellbeing of current and future generations, while continuing to offer a substantial contribution to the global environment, enabling the conditions for an adequate compensation for this global service". The Strategy has four strategic lines:
  - Remaining a HFLD country and receiving financial compensation.
  - Forest governance.
  - Land-use planning.
  - Conservation of forests and reforestation.

  Currently, Suriname is still in its REDD+ Readiness phase, waiting to start with the implementation of its strategy. To enable results-based REDD+ payments, baseline Forest Reference Emission Levels (FREL) were produced based on the historic period of 2000-2015. The FREL was submitted and reviewed by to the UNFCCC in 2018, after which it was finalized. FREL are updated every five years.

United Nations Convention on Biological Diversity (CBD)

Suriname has been part of the CBD since its signing in Rio de Janeiro, Brazil, in 1992. The CBD strives for the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits from its genetic resources. Its second objective is related to the sustainable use of biodiversity, including sustainable forestry, comprehending both the logging and harvesting of plant and NTFP (Berrenstein & Gompers-Small, 2016). As a consequence of being party to the CBD, Suriname develops its National Biodiversity Strategy and Action Plans (NBSAPs) to report on the measures taken to implement the objectives of the CBD. The sixth and most recent Report dates back to 2019.

International Tropical Timber Agreement (ITTA)

The International Tropical Timber Organization (ITTO) is an intergovernmental organization promoting the sustainable management and conservation of tropical forests and the expansion and diversification of international trade of tropical timber from sustainably managed and legally harvested forests. In 2006 Suriname signed the ITTA which is the legal basis of the ITTO. The agreement supports Suriname's forestry sector by offering both financial and technical opportunities to gain more economic benefits from its forests in a sustainable way.

2.3.4.2. Main national policies and legislation on forestry

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

Table 25 summarizes SFM programmes and their related outcomes:

Table 25: NCCPSAP programmes and their outcomes for SFM.

Source: ATM (2015).

Programme	Outcome
• Comprehensive national research programme on social, environmental and economic baselines, climate science, vulnerability, impacts and risk management. • Awareness raising and capacity building programme on SFM, carbon accounting and carbon monitoring.	Improve knowledge across Suriname of how climate change will impact forests and forest management practices.
• Develop and implement law, policy and regulation to incorporate climate resilience and mitigation in forestry. • Increase access to climate finance for sustainable forest management. • Implement forest resources management programme.	Sustainable management of forest resources taking into account climate impacts and increased carbon sequestration.

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

The forestry sector is ranked second in priority for climate action. The NAP highlights that the lack of legislation on land-use planning jeopardizes Suriname's ability to retain its high forest cover. Climate hazards such as increased temperatures and droughts, and downward intermediate impacts such as forest fires, increase the forests' risk to degradation. The sector has the following strategic objectives and adaptive measures (table 26):

Table 26: Strategic objectives and adaptive measures for SFM.

Source: Government of Suriname (2019).

Strategic objectives	Adaptive measures
Comprehensive national research program on social, environmental and economic baselines, climate science, vulnerability, impacts and risk management.	• Continued analysis on past climate impacts on forests and SFM with emphasis on mangroves. • Identification, analysis and implementation of sustainable forestry options in Suriname including, but not limited to, soil nourishment, reforestation, irrigation, protected areas, agroforestry, buffer zones, participatory management, among others.
Awareness raising and capacity building programme on sustainable forest management, forest carbon	• Awareness activities regarding the role of forest conservation, restoration and sustainable use of forests in climate change.

accounting and forest carbon monitoring.	
Develop and implement a governance and finance regime to incorporate climate resilience and mitigation in forestry.	• Assessment of options to access climate finance through e.g. UNFCCC mechanisms to finance carbon sequestration by forests and sustainable forest management, climate resilience and mitigation action. • Review and update of the Forest Management Act to include climate change considerations. • Strengthening of the National Forest Management System (NFMS).
Management of mangrove and coastal forest resources.	• Inclusion of mangrove conservation and afforestation in REDD+ strategy and identification of REDD+ readiness actions needed for mangrove carbon sequestration including through mangrove planting, effective management and rehabilitation.

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

The OP's last pillar on the "use and protection of the environment" makes direct reference to climate change and tapping the economic value of forests. Specifically, the OP suggests designating Suriname and the Guianas as a large nature reserve. The OP also states that the country will pursue attracting investments for reducing its greenhouse gases emissions, e.g. in the energy sector, and minimizing the loss of biodiversity and damage to ecosystems.

For the production cluster forestry and related industry, the policy will be aimed at:

- Increasing the national timber production.
- Increasing the contribution of the production of NTFP to the national economy.
- Increasing the income from ecosystem services.

With the outcomes:

- The compensation for the presentation of Suriname's pristine tropical forest is part of the international climate change action program, including REDD+ and contributes to the national growth and development by means of a program-based approach of the conservation and where necessary restoration of the Surinamese rainforest.
- The increased (production) capacity of village communities, competitive small-, medium-sized and large companies increases the sustainable production of roundwood, decreases the share of exported roundwood by diversifying wood resources, and allows for a better use of residual wood, waste and NTFP.

Forest Management Act (1992)

The Forest Management Act was passed in 1992 and is the main law on forestry in the country. The norm addresses forest management, forest exploitation and primary wood processing. It sets the provisions for the national authority to grant permits and concessions for harvesting forest products (including timber). It also defines different types of licenses for harvesting timber and other forest products according to categories of concessions and the use of community forests.

National Forest Policy (NFP) (2005)

The NFP was developed in a participatory process and adopted in 2005. The NFP is one of the key policies guiding the functioning of the forestry sector in Suriname. It sets key objectives and principles, its main objective being "enhancing the contribution of the forests to the national economy and the welfare of the current and future generations, taking into account the preservation of the biodiversity".

Based on the NFP, an Interim Strategic Action Plan for the Forest Sector in Suriname spanning the years 2009-2013 was adopted in 2008. Currently, there is no plan in force. The plan from 2008 prioritizes four of the seven strategic goals of the NFP, namely:

- Increasing the contribution of commercial forestry and the forest industry to the national economy by increasing sustainable timber production, industrial added value and exports.
- Increasing the contribution of multiple-use community forestry to the national economy by increasing the production of timber and NTFP by communal forests.
- Increasing the contribution of NTFP to the national economy.
- Increasing the physical and financial contribution of ecological functions to the national economy by realizing their monetary value.
- Preserving biodiversity and essential environmental functions by expansion and sustainable management of the protected areas network.

These goals reflect a shift in profile of the forestry sector from traditional forestry towards a more integral sector providing additional source of additional income.

2.3.4.3. Other national policies and legislation related to forestry

- Nature Conservation Act (1954) and Game Act (1954)
  Both of these Acts date back to colonial times. They set up protected areas and group them into four different categories:

  i. Nature reserves (in which specific species or ecosystems are protected and human activities are limited).
  ii. MUMAs (covering almost the entire coastal area of the country, where economic activities are allowed provided that specific protection goals are not threatened).
  iii. Nature parks (in which e.g. recreational activities with minimal impact are allowed).
  iv. Specially Protected Forests (which have a special value due to their location, flora and/or fauna with specific aesthetic, educational, cultural, scientific or recreational value).

  Another possible category of forest protection could be applied to forests that have a relevant stabilizing influence on the natural environment, considering soil and hydrological features, as provided in the Forest Management Act. Although it has not yet been used, this category could be relevant for the protection of mangroves and forests located on mountain slopes.

As a result, over 2 million ha of forests and forests ecosystems are comprised in 16 protected areas in Suriname.

- National Biodiversity Strategy and Action Plan (NBSAP) (2019)
  The sixth National Report to the CBD reports on actions, policies, strategies and legislations implemented over the period 2015-2018. Under the CBD's sub-objective 2.2 on sustainable forestry (regarding timber and NTFP) the Report identified the following actions:
  - The evaluation of the sustainability and productivity of exploitations of timber and NTFP.
  - The adjustment of laws and regulations that promote the sustainable and productive utilization of forests.
  - The enforcement of laws on forest exploitation and conversion.
  - The certification of forestry companies.
  - The restoration of damaged areas.

  Specific activities identified are:
  - The implementation and review of the Forest Management Act and Interim Strategic Action Plan related to the development of the REDD+ Strategy.
  - The adjustment of legislation on retribution, concession rights, retribution fees and inspection tariffs.
  - To support the Forest Stewardship Council (FSC) certification.
  - The development of a Roadmap for a National Forest Monitoring System (NFMS).
  - Investments in capacity building of SBB (RoS, 2019).

- Mining Decree (1986)
  Mining is one of the most relevant economic activities in the country. The activity is mainly regulated under the MD from 1986. The law governs the exploration and exploitation of mineral resources in the country. It provides for granting different categories of mining rights and other licenses for different mineral groups, as well as for inspection and monitoring. The MD generally recognizes the need to consider the environmental impacts of mining activities, as they must consider "norms for the protection of ecological systems" (article 8.1). Moreover, upon termination of a mining right, "the right holder shall, to the approval of the Minister, execute all necessary measures in the interest of public safety [...] and protection of the environment" (article 16.1). A plan should be submitted describing the activities that will be done to rehabilitate the mined-out area to a useful state (article 30.i).

- Land-use planning and management
  Land-use planning and management are of critical importance to ensure a balanced approach towards conserving forest ecosystems, while supporting the wellbeing of society at the local and national level.

  However, confusion about, and overlap of, responsibilities related to land-use planning hamper its efficient implementation: The Planning Act is implemented by the National Planning Office, the Urban Planning Act is implemented by the OW and the Act on Regional Bodies is implemented by the RD.

  The same applies to land-use management: The Forest Management Act is implemented by the Ministry of Physical Planning, Land and Forest management (RGB) and the Mining Act is implemented by the NH.

Moreover, with regards to concessions, the Geological and Mining Department is responsible for mining concessions, the Foundation for Forest Management and Production is responsible for forestry concessions, and the District Commissions are responsible for the development of the interior. Often the concessions they grant are conflicting and result in deforestation and forest degradation (WWF, 2015).

- Land tenure
  The national legal framework on land tenure states that "all land to which the right of ownership cannot be proven by other parties, is property of the State" (L-Decrees of 1982, (article 1.1)). Therefore, 97 % of forested lands are state-owned according to national legislation (NIMOS, SBB & UNIQUE, 2017). Most forests in Suriname are in the interior, in the southern part of the country, where indigenous and tribal peoples live. These, however, have traditional customary systems regarding land tenure and do not usually enforce their rights relying on the national legal framework. These communities depend on forests for many reasons, including for productive activities, such as subsistence agriculture, hunting, fishing, timber harvest and small-scale gold mining. Up until some decades ago, the coastal area and the interior of Suriname developed virtually independently from one another. This situation changed in the 1960s when access to the interior increased for economic development purposes such as the construction of the van Blommenstein hydropower dam. This resulted in a growing number of land related conflicts between the indigenous and tribal peoples on one hand and the Surinamese Government and other individuals on the other hand. Conflicting land uses result in challenges to forest management and use. Other examples include the issuance of concessions in living areas of indigenous and tribal people (ITP) without their prior consultation, which has profound implications for them as they are highly dependent on the forests under concession. However, a draft law on the collective land rights of ITP has been submitted to parliament in April 2020. The law acknowledges the ITP's right to use and live on their land, and the necessity to have their free prior and informed consent when issuing concessions.

2.3.5. Infrastructure

2.3.5.1. International commitments

United Nations Framework on Climate Change (UNFCCC)

- *Nationally Determined Contributions (NDC) (2020)*
  Table 27 summarizes the conditional and unconditional contributions Suriname has committed itself to for energy and transport.

Table 27: Conditional and unconditional contributions of Suriname for energy and transport.

Source: Cabinet of the President of the Republic of Suriname (2019).

	Unconditional	Conditional
Energy	• Expansion of grid-connected and off-grid capacity. • Efficiency programs. • Mini-grids.	• Share of electricity from renewable sources is above 35 % by 2030. • 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. • Fiscal sustainability measures to promote energy efficiency.
Transport	• Infrastructure investment projects improving road and drainage infrastructure, including sea defense infrastructure (grey and green) for Paramaribo and the upgrading of roads and canals. The total investment in upgrading the drainage system and flood protection is estimated to reach up to more than 500 million USD.	• Update the Transport Master Plan (ISTS 2011). The plan contained 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 import to vehicles less than five years old, in order to reduce emissions under this NDC.

- *Second National Communication (SNC) (2016)*
  The SNC highlights the role of energy demand in Suriname's future socio-economic profile. This is projected to increase by 5 % (the long run historical mean). Moreover, the SNC

identified the breaching of dams and dikes/ damage to water defense infrastructure, as well as a decrease of draining potential of urban areas as two of the country's six biggest issues to be considered for adaptation. Moreover, it proposes the following specific adaptation measures on infrastructure:

- Proper maintenance and frequent inspections of coastal stretches with dikes and dams.
- Determination of minimum set of conditions that reduce the vulnerability of key assets to flooding associated with sea level rise, for instance mangrove protection or prohibition of coastal sand and shell ridge removal.
- Realization of land use planning in the coastal zone.
- Realization of spatial planning and zoning by a central authority to encourage appropriate urban growth.
- Development of feasible insurance schemes that provide protection to both business and personal property and encourage adherence to minimum standards and building codes, through exclusion if the building or residence is not climate resistance
- Formulation of building codes that incorporate new appropriate and affordable technologies to improve resilience of physical infrastructure to climate change as well as encouraging mitigation through improved energy efficiency.
- Realignment and or relocation of the transport infrastructure located in the vulnerable coastal zone. Transport policy needs to consider future climate change scenarios in design.
- Construction of appropriate and hydrological correct transport routes in the coastal zone. Present transportation routes are currently built along sand dunes and shell ridges in the coastal area; This may hamper the hydrological process essential for the preservation of the natural systems such as mangrove swamps along the coastline.
- Incorporation of the Interior transportation into national transport planning.
- Adaptation of boat transportation, particularly during the extreme and prolonged dry periods.
- Advancing of necessary investments in research regarding alternative and improved transport solutions for the Interior, given the projected difficulties in future river navigation.
- Incorporation of the Interior into the national energy policy rather than being seen as a special side issue.
- Application of appropriate technologies that take advantage of local natural resources and that provide sustainable energy solutions.
- Implementation of renewable energy projects such as mini- and micro-hydropower stations and solar energy accommodations where these are possible and feasible.

2.3.5.2. Main national policies and legislation on infrastructure

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

Table 28 summarizes the programmes and their related outcomes for infrastructure, energy and housing:

Table 28: NCCPSAP programmes and their outcomes for infrastructure, energy and housing. Source: ATM (2015).

Theme	Programmes	Outcomes
Infra-structure	• Comprehensive national research programme on social, environmental and economic baselines, climate science, vulnerability, impacts and risk management. • Awareness raising programme on how to integrate climate change resilience into the infrastructure programme and project cycle.	Improved knowledge across Suriname about the risks of climate change to infrastructure and how to manage climate impacts.
	• Develop and implement law, policies and regulations to integrate climate change resilience into infrastructure planning and development. • Infrastructure development to improve drainage, storm surge and flood management and prevent saltwater intrusion in "at risk" areas. • Incorporate climate resilience into road development and maintenance.	Infrastructure has greater resilience to direct and indirect impacts of climate change.
	• Incorporate measures to reduce greenhouse gas emissions into road infrastructure.	Incorporate measures to reduce GHG emissions into road infrastructure.
	• Develop and implement law, policy and regulation to minimise waste. • Waste management incentivisation. • Awareness programme for minimising waste.	Decreased GHG emissions from waste.
Energy	• Comprehensive national research programme on social, environmental and economic baselines, climate science, vulnerability, impacts and risk management. • Awareness raising and capacity building programme to encourage energy conservation, energy efficiency and the use of renewable energy.	Improved knowledge about how climate change will impact energy generation, transmission, and distribution, and development of options to increase energy security and decrease emissions.
	• Develop and implement law, policies and regulations to encourage energy efficiency and the use of renewables. • Financial incentives to influence energy use and decrease emissions.	Energy generation, transmission and distribution systems are climate resilient and low-emitting, contributing to energy security and accessible, reliable

Theme	Programmes	Outcomes
	• Infrastructure improvements of existing (and new) hydropower facilities. • Increase access to climate finance.	and affordable electricity.
Housing	• Comprehensive national research programme on social, environmental and economic baselines, climate science, vulnerability, impacts and risk management.	Improved knowledge of climate change impacts on housing provides evidence base for informed decision making.
	• Develop and implement law, policies and regulations for climate resilient housing development planning.	Increased resilience and energy efficiency of new housing from effective zoning and development control.
	• Develop and implement law, policies and regulations for climate resilient building design. • Financial incentives to build climate resilient homes.	Increased resilience and energy efficiency from new building design.

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

The sector has the following strategic objectives and adaptive measures (table 29):

Table 29: Strategic objectives and adaptive measures for energy, infrastructure and housing.

Source: Government of Suriname (2019).

Sector	Strategic objectives	Adaptive measures
Energy	Comprehensive national research programme including the analysis and collection of data on past climate impacts.	• Implement an energy sector focused national research programme to address: links between climate change and climate impacts; Gaps in understanding about the sector and climate change; Translation of data analysis to useable and well communicated policy options.
	Awareness and capacity building programme to encourage training of new professionals in energy research and development.	• Facilitate technical and university education that focuses on the use of new technologies and research into alternative technologies. • Strengthen government institutions or establish new institutions to facilitate the newly trained professionals in research and development.
	Financial incentives to influence energy use and decrease emissions.	• Deploy market-based incentives to transform the energy sector.
	Conduct assessments and baseline studies for the development of the	• Develop national energy policy, strategy and regulatory framework. • Amend the Act on Import Duty 1996.

Sector	Strategic objectives	Adaptive measures
	national energy strategy.	• Develop and deploy new financing mechanisms for communities, entrepreneurs and small business owners.
Infra-structure and housing	Enhance comprehensive infrastructure and housing information and data for decisive decision-making.	• A comprehensive national research programme on social, environmental and economic baselines, climate science, vulnerability, impacts and risk management. • Expand climate data monitoring network (number of stations and climate variables collected).
	Design and implement infrastructure and housing regulations, standards and guidelines.	• Develop specific infrastructure guidance on the appraisal, design and operation of assets under conditions of a changing climate. • Develop and implement law, policy and regulation to integrate climate change resilience into infrastructure planning and development. • Design and implement measures to protect existing assets located in flood risk areas.
	Build infrastructure and housing sector skills, training and expertise; Manage and keep human capital.	• Promote infrastructure development to improve drainage, storm surge and flood management and prevent saltwater intrusion in "at risk areas. • Conduct regular maintenance and frequent inspection of infrastructure and identify areas which require investment for improvements. Incorporate climate change considerations into road development and maintenance.
	Co-ordinate infrastructure and housing efforts in transportation and capital projects.	• Assess and adjust the coordination of the main transport infrastructure, currently located in the vulnerable coastal zone. • Develop roads that are climate-proof (i.e. resilient to heavy rainfall) and hydrologically sensitive (that do not disrupt the hydrological processes essential to preserve ecosystems).

<u>National Development Plan (OP) 2017-2021 (2017)</u>
The OP directly addresses energy, physical infrastructure and transport.
With regards to energy, the OP aims at the following:

1. Energy access for everyone in the country.
2. Promoting energy efficiency.
3. Stimulating the use of renewable energy.

The longer-term goal is that the electricity sector functions within the legal framework as set and in line with the national electricity strategy and national generation sources identified therein, supplies sustainable electricity to families, companies and other buyers at the lowest possible prices.

With regards to physical Infrastructure, the OP aims at for good roads, bridges and well-functioning structural works. It also addresses coastal and riverbank protection, the goal being the sustainable repair and maintenance of riverbanks along the coast and the rivers against the effects of sea-level rise, and protecting the coastal area by putting in place a proper drainage system. With regards to irrigation and drainage the OP aims to improve these for developing and production areas, residential and other special management areas via adequate facilities and physical infrastructure, adjusted laws and regulations and efficient administrative, managerial and financing systems.

With regards to transport, the OP aims at transportation on the road of people and goods being safer and increased and that it facilitates local and foreign tourism, thus increasing the mobility of the population and promoting the trade, especially the transit trade. The OP considers transport infrastructure key for the development of other sectors. Transport infrastructure also makes an important contribution to regional integration. The longer-term goal for the transport sector is that transport activities, the organizational and physical infrastructure will contribute in an efficient, safe and effective manner to increasing the economic growth and social development, and intensify the contact and the trade between Suriname, the region and the rest of the world.

On the matter of air transport the OP states that it can contribute substantially to the country's economic development and seizing of trade opportunities. The goal of the AP is to Increase the volume and safety of air traffic and related activities to facilitate tourism, public travelling and trade. To stimulate the water transport, the OP recognizes that better facilities, a more navigable Suriname River and higher capacity of the ports of Paramaribo and Paranam are needed.

Environmental Framework Act

The Act's relevance to infrastructure is related to the development and/ or rehabilitation of areas where the energy sector and infrastructure play a crucial role. The Act states that environmental impact assessments (EIA) are mandatory for the construction of photovoltaic solar parks.

National Energy Policy

The government's vision on energy for 2013-2033 is as follows: "A modern, efficient energy sector, providing all citizens with access to reliable and affordable energy supplies and long-term energy security towards enhancing the quality of life of all Surinamese, advancing international competitiveness and environmental sustainability".

Further, the policy consists of five goals aligned with the OP to achieve this vision:

1. All citizens have access to reliable and affordable energy supplies and Suriname is able to meet its energy demands for households and industry, improving the quality of life of all.
2. Suriname has modern energy infrastructure that enhances energy generation capacity and ensures that energy is transported safely, reliably, and affordably to homes, communities throughout the country and the productive sectors on a sustainable basis.
3. Suriname continuously engages in research and development (R&D) to facilitate the wide-scale development and deployment and use of renewable energy, towards enhancing

international competitiveness and energy security supporting long-term economic and social development and environmental sustainability.

4. Suriname has a well-defined and established governance, institutional, legal and regulatory framework supporting the future developments in the energy sector underpinned by high levels of consultation and citizen participation, including indigenous peoples.
5. Surinamese are well aware of the importance of energy conservation, use energy wisely and continuously pursue opportunities for improving their use of energy.

The National Energy Policy enables Suriname to develop a green and sustainable economy through wide-scale renewable energy penetration. The Policy also details the strategies that need to be implemented to ensure effective promotion of conservation and efficiency in the use of energy resources amongst all sectors of the society, thereby creating a more sustainable Suriname. In addition, full implementation of the National Energy Policy would ensure that, by 2033, all citizens have access to energy and there is energy security advancing the economy of the country, contributing to international competiveness and a marked reduction in poverty.

So far, the country has made progress in implementing the Policy especially by installing small scale off-grid solar panel systems in the interior.

Electricity Act

This Act from 2016 aims at improving the availability of electricity, ensuring the affordability of supply and increasing the environmental quality of electricity generation. The Act also promotes renewable energies by giving customers the opportunity to generate electricity for their own consumption, for example using solar panels, and feed the excess power into the grid managed by NV EBS.

The Act also mandates the creation of an Electricity Sector Plan (ESP) that integrates a 20-year Strategic Plan with 5-year (2019-2023) Technical Plans and a Regulatory Plan. The ESP establishes a long-term strategic development plan for the sector and provides guidance for taking investment decisions, defining performance targets, and setting electricity tariffs. Energy efficiency measures and guidelines are also included in the ESP. The OP also refers to the ESP by stating that the ESP will draft the legal framework for the electricity sector.

2.3.5.3. Other national policies and legislation related to infrastructure

- Building Act

  This Act oversees licenses for new construction and residential areas in Suriname. It also controls the architectural compatibility of new developments with the existing built environment of the World Heritage Sites. The Building Committee within the OW evaluates building plans according to the 1956 and 2002 building codes.

- Building State Order

  This Order consists of codes which provide the rules for new construction and require construction to be done in accordance with land-use plans. The Codes define criteria (architecture, scale, height, color etc.) for new houses within and outside Paramaribo's inner city.

  The interdepartmental committee for updating the Buildings Act submitted a new draft version at the beginning of 2020 to the Minister. In this concept, the emphasis was placed mainly on roof structures and the effects of gusts of wind. Separate guidelines have been drawn up on this subject, which can already be declared applicable by the director. However, the draft is not yet finalized.

- State Order on Building Construction (1956, revised in 2010)

  This Order initially provided rules for the construction of buildings in Paramaribo. Construction permits are issued based on an approved construction plan. Since 2010 this act is applicable to all of Suriname, unless there are conflicting customary laws of tribal communities. The Order does not detail technical requirements for disaster prevention. The need for such technical standards has been discussed publicly, but legislation to this end has not yet been initiated (NCCR, 2017).

- Roads Authority Act (1995)

  This Act establishes the requirements for managing roads and bridges and gives the Road Authority Suriname the responsibility of providing guidance for construction, rehabilitation and maintenance of primary roads and bridges (as determined by the State Order on Primary Roads of 2001).

- State Order on Primary Roads (2001)

  This Order gives the Ministry Public Works the responsibility of carrying out major rehabilitation of roads legally determined to be primary roads (that are of great social and economic national value). Rehabilitation of these roads are often not planned or designed considering climate impacts and are often designed under the assumption that these effects will be rare and insignificant. This results in shortening the service life and/ or poor accessibility. Solutions to prepare for climate adaptation and rehabilitation of roads are for example developing models that predicts the impacts on the road infrastructural network, revise designs to consider climate change impacts and use of climate resilient materials.

2.4. Environmental management structure

2.4.1. Cross-sectoral

Presidential Cabinet

Environmental management in Suriname started in 1997 with the establishment of the National Council for the Environment (NMR) by Presidential Decree as the competent institution on environmental matters (Staatsblad van de Republiek Suriname, 2020). The Presidential Decree also specified that the NMR would carry out its tasks via a technical arm. The National Institute for Environment and Development in Suriname (NIMOS) was established in 1998 and is the NMR's technical arm and implementing body (Staatsblad van de Republiek Suriname, 2020). Its mission the development of a national legal and institutional framework for environmental policy and management compatible with sustainable development. After the establishment of the Ministry of Labor, Technological Development and Environment (ATM), the NMR and NIMOS continued to exist: From then on, the NMR advised the ATM instead of the Presidential Cabinet, and the NIMOS was the technical-arm and implementing body of the Ministry instead of the NMR.

National Climate Change Steering Committee

In 2004 the National Climate Change Steering Committee was established to coordinate, monitor and evaluate climate change-related activities and to formulate an effective and balanced climate policy. This Committee, led by the ATM consisted of representatives, mostly from ministries, of all relevant sectors such as energy, industry, agriculture, forestry and economy, the Meteorological Services and the Anton de Kom University of Suriname (ADEKUS). At present, the Committee is inactive, as its mandate has expired (Berrenstein & Gompers-Small, 2016).

Ministry of Labor, Technological Development and Environment (ATM)

The ATM, established in 2002, operated until 2015.

In 2011 the government established the *Climate Compatible Development Agency*, which was incorporated into the ATM in 2012. Its goal was to assist the Ministry to look for climate change funding opportunities and to provide support for the development of climate change policies.

In 2011, a *Directorate on Environment* was established in the Ministry, which was in charge of preparing and coordinating the environmental policy, coordinating and monitoring Suriname's commitments under all major environmental conventions of the United Nations.

In 2015 the Directorate on Environment moved from the ATM to the Presidential Cabinet and changed its name to *Environmental Coordination Unit* (Berrenstein & Gompers-Small, 2016). As part of the Presidential Cabinet, the unit had the necessary mandate to formulate policies regarding the environment and climate change that would be binding for the sectoral ministries (Berrenstein & Gompers-Small, 2016).

Ministry of Spatial Planning and Environment (ROM)

In 2020, when the ROM was established, the Environmental Coordination Unit was absorbed by the new Ministry's Directorate on Environment. With the 2020 Environmental Framework Act the Environmental Coordination Unit was merged with NIMOS, creating the National Environmental Authority (NMA). NMR seized to exist.

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.

National Coordination Center for Disaster Management (NCCR)

The NCCR contributes to the development of a resilient, self-aware, and therefore safer society, in which everyone takes responsibility. NCCR fulfills a guiding role in disaster management, to prevent crises and disasters and control them where necessary using policy development, coordination, and management.

NCCR core tasks are to manage and coordinate crisis and disaster and to develop and establish integrated policy framework to prevent crises and disasters where possible. Furthermore, they monitor and analyze social development to identify potential disasters. They are the operational body during disasters in collaboration with the District Commissioners, the Disaster Committee, formed by Law Enforcement, National Army and the Fire Brigade (NCCR, 2020).

Since 2014, the NCCR forms part of the Presidential Cabinet. Before that, it formed part of the Ministry of Defense. However, the draft Disaster Management Legislation and the law providing NCCR with a legal base have not yet been approved. NCCR works closely with the Ministries which closely contribute to disaster risk management (Government of Suriname, 2019) and institutions responsible for climate change management to ensure an improved knowledge and management of climate impacts across Suriname (ATM, 2015).

2.4.2. Sectoral

Most ministries have an environment-related task within their mandate. The sector ministries with important functions for environmental management and climate change are:

Ministry of Agriculture, Animal Husbandry, and Fisheries (LVV)

This Ministry controls and monitors agricultural issues such as crop production and the proper use of agriculture lands and water. Its mission and vision are to guarantee food security and safety for society. It promotes and facilitates the sustainable development of the agricultural sector. Furthermore, the Ministry is in charge of preventing and controlling animal and plant diseases and pests, assuring quality standards of agricultural products, improving the productivity of the sector, and effectively manageing national fishing resources.

In 2003, the ministry established a GAP program in response to pesticide residue exceedances and the presence of insects in Surinamese export vegetable and fruit. The GAP´s task was to maintain Surinamese vegetable exports (Goeptar, 2012). GAP consists of a series of measures and activities that are applied during cultivation, harvesting and the packaging of crops. The focus of the GAP program is on farmers, exporters, processors, and harvesting, and packaging of the crops.

To comply with the World Trade Organisation's (WTO) sanitary and phytosanitary measures, the CARICOM Agricultural Health and Food Safety Agency (CAHFSA) was established by the CARICOM in 2010. The regional agency coordinates and organizes the establishment of an effective and efficient regional sanitary and phytosanitary regime, and executes regional sanitary and phytosanitary activities on behalf of Member States. In this context, Suriname has its own National Agricultural Health and Food Safety Agency (NAHFSA), too. The unit is responsible for the coordination, monitoring, administration and reporting of LVV's activities regarding animal and plant health and food safety.

The Ministry of Natural Resources (NH)

This Ministry is responsible for the management and development of energy, mining and water resources. The NH's goal is to generate as many revenues for the country in the field of the mining sector. Furthermore, society should have access to sufficient water and electricity for its socio-economic development. With regards to water, the Ministry delegated its responsibilities to the SWM which assures water supply in the densely populated urban areas at the coast and in some rural areas. However, the Ministry remains responsible for the inventory, exploration, optimal use and management of water. With regards to energy, the Ministry is responsible for energy policy-making and supervision of the energy sector, legislation, issuance of permits, budget allocation and inter-ministerial coordination**.** The DEV is responsible for the electricity supply to the interior

Ministry of Public Health

The Bureau of Public Health (BOG) which resides under the Ministry of Public Health is responsible for the promotion of preventative health care and monitoring of public health at the national level. Within BOG, the division on Environmental Inspection is responsible for the monitoring of water pollution at the micro and meso level and monitoring of drinking water quality.

Ministry of Public Works (OW)

This Ministry is responsible for planning and implementing civil technical and infrastructure works, water management and drainage, hydrological and meteorological services, waste management, public green spaces, the planning, building and construction of road and walkway infrastructure (primary roads in Suriname and secondary and tertiary roads in Paramaribo), parking, bridges, sea walls, dikes and public transportation.

Its Meteorological Service is the preeminent authority responsible for climate data gathering and analysis related to weather, climate and the supply of water as part of the hydrological cycle. This service provides important weather and climate information necessary to manage spring waters.

The Hydraulic Division has a very important function in terms of research and data collection for the formulation of integrated water policies. More specifically, they promote optimal utilization, management and protection of water resources. It is the principal agency in the country that collects and publishes hydrologic, hydraulic and water quality data and information and conducts investigation and research.

The ministry's Drainage Works Service is responsible for maintaining drainage infrastructure and areas.

The Ministry of Land Policy and Forest Management (GB)

This ministry makes, regulates, implements and monitors policies on land-use planning, sustainable forest use and nature conservation. Its tasks are:

- Land allocation.
- The management of nature, nature parks and conservation.
- Hunting custodians.
- Zoning.
- Spatial planning.
- Topography and mapping.
- Land registration.
- Monitoring the lawful and efficient use of land.
- Monitoring the compliance of geodesy rules and regulations.
- The inventory of the resources of flora and fauna.
- Monitoring and managing of timber activities.

Up until its creation in 2020, many of this ministry's functions were fulfilled by RGB. In 2020, the ROGB dissolved, forming the GB and the ROM.

The Ministry of Finance and Planning

The mission and vision of the Ministry are to be the treasury guardian of the country and responsible for the management and monitoring of the country's finances. The Ministry monitors the income and expenditure of the State and consists of two directorates, the Directorate of Finance and the

Directorate of Taxation.

- *Planning Office*
  The Planning Office designs the OP. The Office has a Department on Environment and Spatial Planning which keeps an inventory of land and soil, natural resources, existing infrastructures and land allocations. The structural characteristics of urban and rural areas, geographic data, ecosystems, and also socio-demographic and physical indicators are collected and mapped in this subdirectorate.

Ministry of Regional Development (RD)

This Ministry administers Suriname's rural districts (including the interior), coordinates development activities and governance in these areas. The Ministry is also responsible for the maintenance of secondary and tertiary roads.

On the level of Suriname's ten districts, District Commissioners operate under the Ministry of Regional Development (RD) and act as focal points for activities such as general management, economic promotion and development and environment-related topics. The District Commissioners work in close collaboration with the elected District Council (Berenstein & Gompers-Small, 2016) and is responsible for issuing licenses within their designated region, including, but not limited to, shops, parking lots, businesses, cultural centers, and advertisements on public spaces.

Environmental activities should be formulated and implemented together with all relevant non-governmental actors such as civil society, businesses and community organizations. The district's environment plan is aligned with the National Environmental Policy Plan. Each District Commissioner is responsible for drawing up a district environmental program for the activities of the relevant district (Staatsblad van de Republiek Suriname, 2020). Overall, most district plans describe the environmental status, problems and solutions of their districts.

Energy Authority Suriname (EAS)

With the 2016 Electricity Act the EAS was established. It monitors compliance with the national electricity strategy and the electricity sector plan, including that electricity tariffs are reasonable and fair.

Ministry of Transport, Communication and Tourism (TCT)

This Ministry, which used to form a part of the former Ministry of Public Works, Transport, Communication and Tourism was created in 2020. The Ministry of Transport, Communication and Tourism (TCT) is responsible for four areas:

1. The transport sector, including water, air and road transport, as well as public transport and its monitoring.
2. The facilities for water traffic and air traffic, in particular with regards to the safe and efficient handling of persons and goods, the piloting system and the management of all ports.

3. Issuing of air and sea letters.
4. Telecommunications.
5. Tourism.

The Ministry has several parastatal companies under its management such as the Maritime Authority Suriname, Civil Aviation Safety Authority Suriname, Suriname Airways, Telecommunication Authority Suriname, TELESUR and Foundation for Tourism Suriname. One of the tasks of the Ministry regarding the parastatal companies is to create pre-conditions for sustainable national and regional development for parastatals, improving and safeguarding the quality of their products.

Road Authority Suriname (RAS)

The Road Authority Suriname aims to provide road users in Suriname with optimal, passable and safe roads through planning, management and maintenance. The authority enforces the Road Authority Act which establishes the requirements for managing roads and bridges and gives the authority the responsibility of providing guidance for construction, rehabilitation and maintenance of primary roads and bridges (as determined by the State Order on Primary Roads of 2001). The operations of the Road Authority is divided into maintenance of primary roads in and outside Paramaribo as well as maintenance of verges and bridges connected to the primary roads, divers, traffic facilities, road furniture, underground infrastructure and all other activities that fall within the tasks of the law established in 1995.

Ministry of Social Affairs and Public Housing

Through its Department of Housing, this Ministry is responsible for the creation and execution of policies concerning the housing sector and the provision of housing in Suriname. It also manages (new) housing programs and maintains a list of home-seekers for public and private sector developments.

Telecommunication Authority Suriname (TAS)

TAS is the regulatory body for Suriname’s telecommunications industry. It independently supervises the telecommunication industry (carriers and service providers) on the basis of laws and regulations. It stimulates the deregulation and supervises fair competition in the field of services and rates.

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file%3D5065%23%3A~%3Atext%3DThe%2520ICT%2520Vision%25202020%2520envisions%2Cimpact%2520on%2520the%2520Surinamese%2520economy.%26text%3DThe%2520first%2520chapter%2520describes%2520the%2CNational%2520Development%2520Plan%25202012%252D2016.&usg=AOvVaw3Wkm_ViA-4sPUkZJPSkJlh

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3. Climatic trends

The aim of this chapter is to analyze historic and future climate in Suriname for different time horizons (1990-2014, 2020-2039, 2040-2069, 2070-2099), scenarios (SSPS2-4.5 and SSPS5-8.5) and locations (regional and local, i.e. the whole country and discrete points of interest). First, an introduction (chapter 3.1) provides information on the overall climatic conditions of the country as well as the models, scenarios and sources of information used to generate the historic trends as well as future projections. Then, the historic climate (chapter 3.2.) and later the future climate (chapter 3.3.) are each characterized in detail for 16 variables. The last chapter (3.4.) offers final conclusions on the entire analysis.

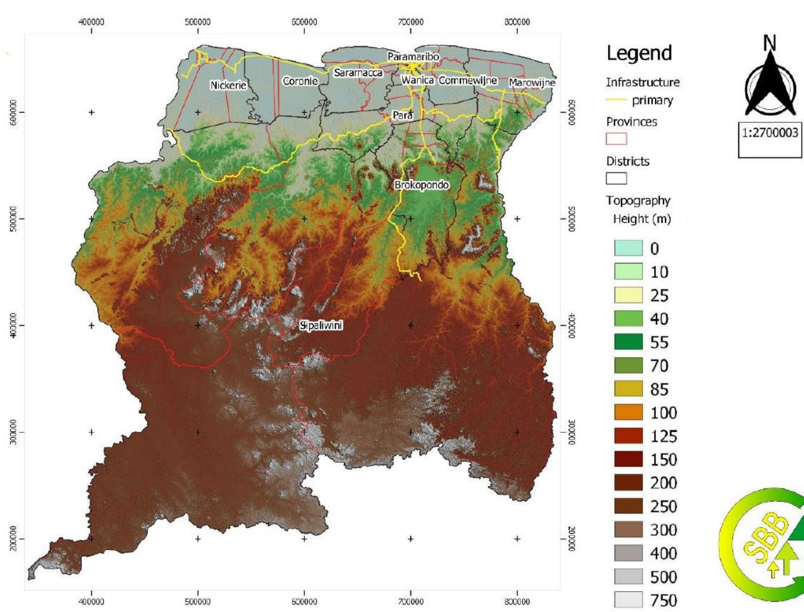
3.1. Introduction

3.1.1. Climate in Suriname (SNC-UNFC and ERA5 reanalysis)

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 15). This difference in altitude leads to diverging coastal and interior climates.

Figure 15: 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). Thus, annual variation of the average temperature is 2-3°C. The interior has relatively 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 (north-western coast) receives 1,796 mm/year; Kwamalasamutu (southern Suriname) 2,392 mm/year and Tafelberg (central Suriname) 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, only one wet and one dry season are distinguished.

Winds in Suriname generally move in a north-easterly 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, generally 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, on 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 air 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 air humidity are between 70-100 % in forested areas and between 50-100 % in open areas.

The El Niño-Southern Oscillation (ENSO), which occurs once every 2-7 years, also has an impact on the climate of Suriname. Studies indicate that El Niño events may cause rainfall below or above normal. In general, during El Niño years, when there is excess rainfall on the west coast of South America, it is dryer in Suriname.

3.1.2. Methods

3.1.2.1. General Circulation Models (GCMs)

GCMs 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 the radiative forcings (i.e., the total net radiation the system receives, which depends, among other factors, on the concentration of greenhouse gases) and scenarios (different reasons for different levels of radiative forcing to occur), and each GCM does so differently because of the way each GCM models 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 Coupled Model Intercomparison Project (CMIP), in which numerous internationally renowned 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 CIMP assures all the information from the GCMs 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 generated in the framework of the CMIP6 were used. As these are still under development, there are only few model outputs available compared to CMIP5 (the previous phase, on which the fifth IPCC assessment report is based). However, the number of available models was still considered to be suitable for a multimodel approach. In addition, CMIP6 projections (based on historical simulations from 1850-2014) have an advantage over CMIP5 projections (based on historical simulations from 1850-2005) because their reference period is longer. This is particularly useful in the context of Suriname, which data record for the purpose of this report starts in 1990.

The multimodel approach of this study was based on the following CMIP6 GCMs (table 30):

Table 30: CMIP6 GCMs used in the multimodel approach.
Source: Own elaboration.

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	Institute Pierre-Simon Laplace (IPSL)

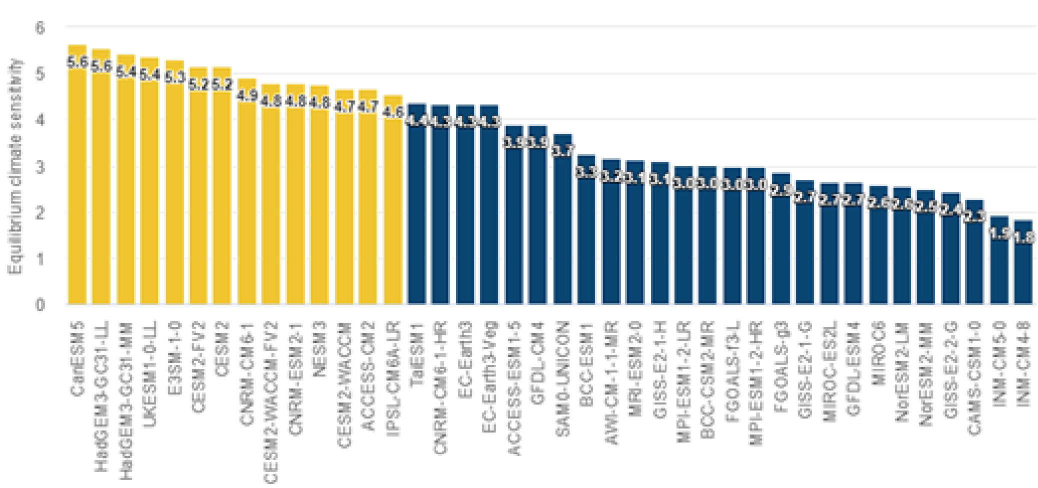
The models were selected based on the following criteria:

- 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. In our study we used 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 (the CMIP6 version of model IPSL-CM5A) was added to the multimodel analysis based on the suggestion of local experts from the ADEKUS. This model was selected, as 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 for double the carbon dioxide concentration. A multimodel approach which covers a wide range of sensitivities thus covers all the statistics for each variable and provides an error calculation that contains all possible climatic variations (table 31, figure 16).

Table 31: Climate sensitivity in CIMP6 models.
Source: Rogelj et al. (2018).

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

Figure 16: Climate sensitivity in CIMP6 models.
Source: Rogelj et al. (2018).



- In addition, the three modes selected have undergone rigorous analysis and validation for the region. All three models have an earlier version (CMIP5) which 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.

3.1.2.2. Scenarios

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

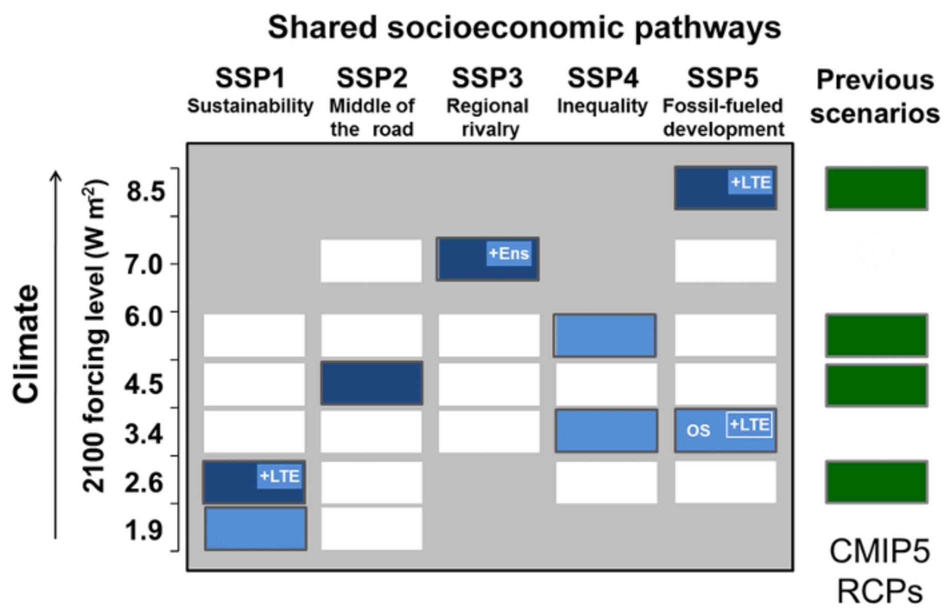
In recent years, a series of new trajectories have been constructed that examine the way in which global society, demography and the economy could change in the next century, including aspects such as population and economic growth, education, urbanization or technological development. These Shared Socioeconomic 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 midway 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 future 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 adaptation and mitigation to climate change (figure 17).

Figure 17: Matrix of SSP-RCP scenarios.

Source: Rogelj et al. (2018).



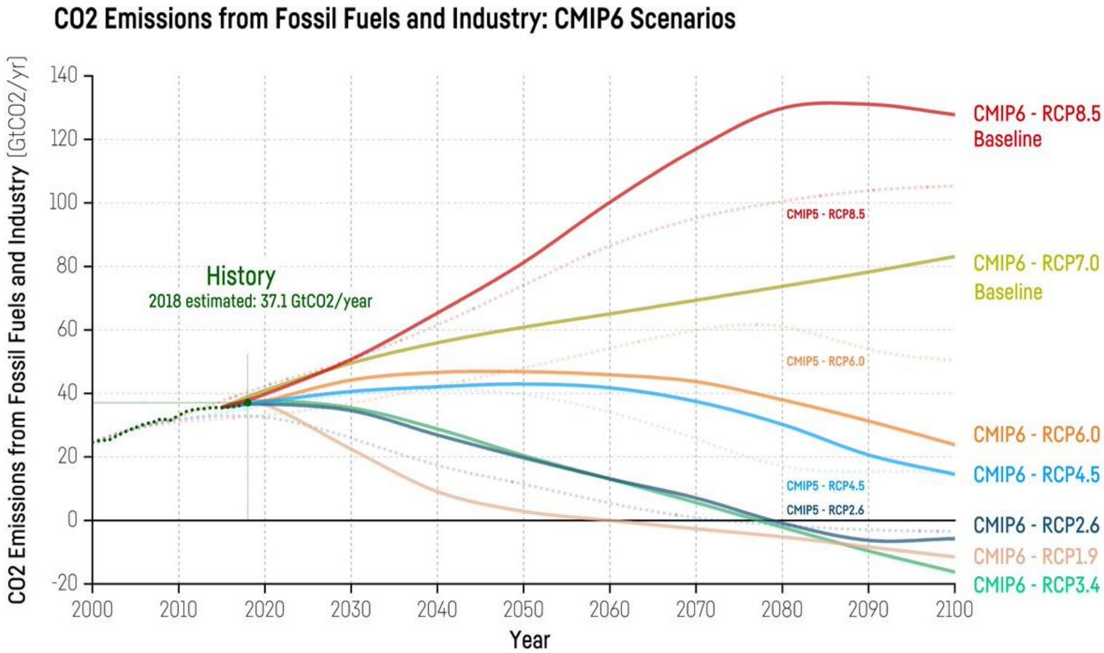
In this study, the scenarios SSP2-4.5 (a combination of RCP4.5 and SSP2) and SSP5-8.5 (a combination of RCP8.5 and SSP5) have been selected:

- SSP2-4.5: Represents the intermediate level in the range of future paths contemplated and updates the RCP-4.5 path (figure 17). 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 future paths. It includes an update of the RCP8.5 trajectory (figure 17) 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 emission trends, which is a significant improvement (figure 18).

Figure 18: Evolution of CO2 emissions from fossil fuels and industry, comparing the scenarios of CMIP5 (dashed line) and CMIP6 (continuous line).

Source: Ritchie (2018).



3.1.2.3. Quantile-Quantile adjustment (Q-Q)

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 thus not simulated accordingly. GCMs also have limitations when simulating feedback mechanisms such as, for example, the greenhouse effect of water vapor, radiation of clouds, ice in ocean circulation or the albedo effect of snow. Therefore, although uncertainties are inherent to the modelling 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 time scales, 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 take into account 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, snow, etc. However, until now only regional forcings are resolved using regional climate models.

There are several procedures for adjusting climate projections, taking into account either regional or local forcings (a process known as downscaling). Two direct corrections consist in

- adding the climatological difference between the future and historical simulations of the RCPs to the observed historical data (the so-called delta method)
- eliminating the bias existent in the future simulations of CGMs applying the difference between the observed and simulated historical datasets (the so-called "unbiasing" method).

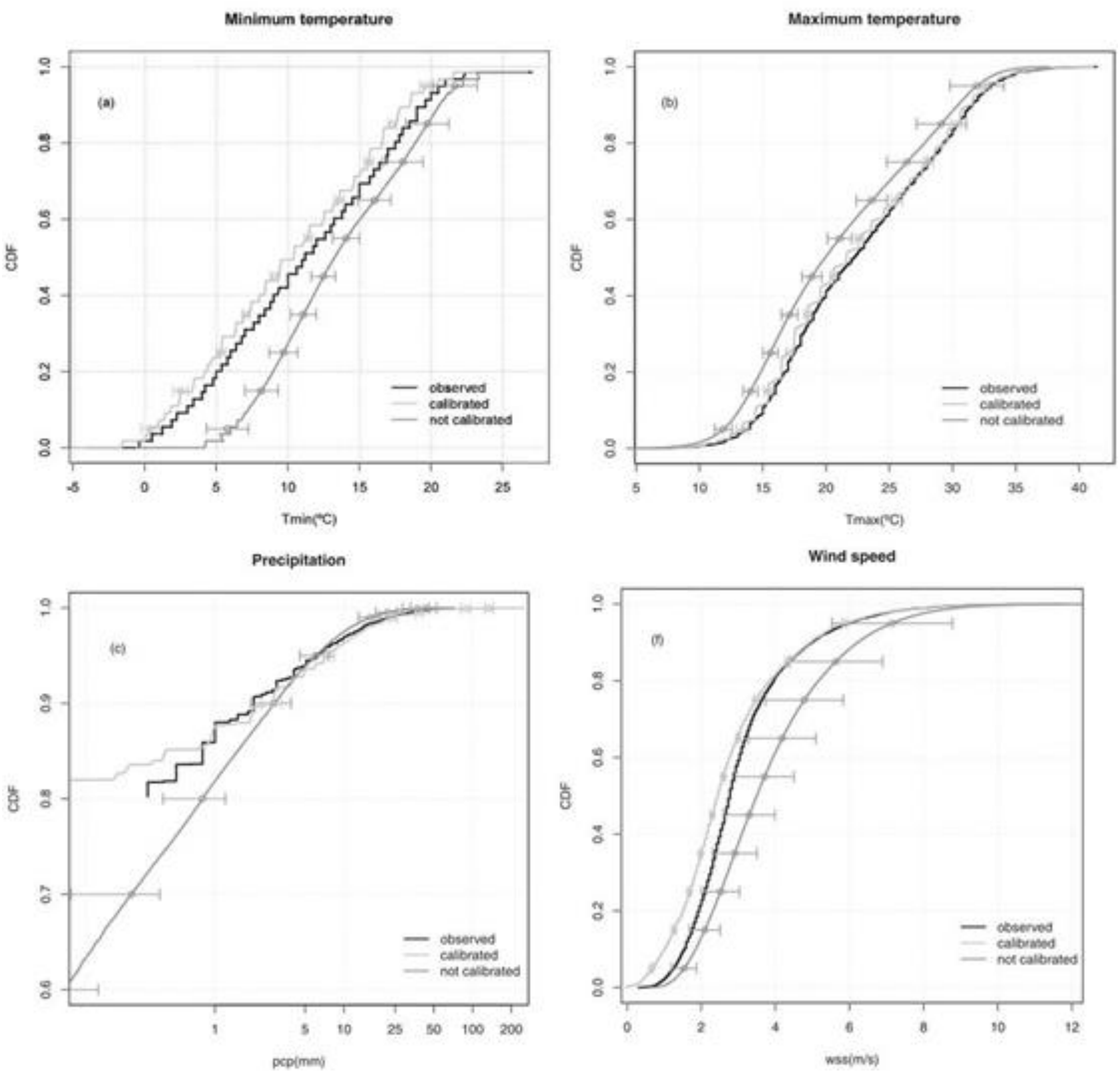
The first correction assumes that the variability of climatic variables in future scenarios remains unchanged, while the second assumes that such variability is identical to that observed, both of which are very restrictive.

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 take into account regional forcings (figure 19). 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, taking into account these differences (light grey line).

Figure 19: Application of the quantile to quantile adjustment: Cumulative distribution function (CDF, i.e. the probability of the variable having a value equal to or smaller than x at each point) of a) minimum and b) maximum temperatures, c) precipitation and d) wind speed in Palma de Mallorca, Spain.

Source: Own elaboration.



This statistical adjustment allows to include local 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.

3.1.2.4. Probability matching

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. In order to apply this technique, first, a probability distribution function was computed for the observed dataset (how many events of any intensity are found in the observed data). From there, the Cumulative distribution function (CDF), ranging from 0 to 1, was computed. This provided the probability of getting events of up to any given intensity. This probability was then applied at the reanalysis dataset, i.e. the probability of the reanalysis data was matched with that of the observed data and the distribution of events was similar in both datasets. For instance, when the observed dataset indicated that events of winds over 100 km/h occur only once a year in Paramaribo, the reanalysis data was forced to have a frequency of such events once every year, too.

3.1.2.5. Reference period and future climatological standard normal

Under the World Meteorological Organization's (WMO) current technical regulations, which recognise the reality of a changing climate, climatological standard normals are defined as averages of climatological data computed for successive 30-year periods. A 30-year time 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, mid-term future, and long-term future, from 2020 onwards, 25-year periods were defined - a good compromise between long time periods to obtain robust results and covering three future time periods.

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

In line herewith, 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 still matches climate models (which reach up to the year 2014), thus allowing for Q-Q adjustments.

3.1.2.6. Sources of observed data for the reference period

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.

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 were only pluviometric.

Of these, some lacked several years of data at the beginning of the period. Coverage varied depending on each variable and location. The most complete variable was mean temperature (meanTT), for which 92.71 % of all possible data (100% being all stations having data for all timepoints during the period of interest) was available. Maximum daily temperature (maxTT) and minimum daily temperature (minTT) each covered 90.11 % and 90.02 % of the total data, respectively. Relative humidity (RH) was available for 92.48 % of all data, while the coverage was significantly less for precipitation, of which 60.7 % of the spatio-temporal data series was available.

It is worth mentioning that the analysis of this dataset has been especially challenging[2]. For this reason, best practices for data storage and dissemination are included in the conclusions at the end of this chapter.

This valuable data set from Suriname was used to calibrate the historical data provided by ERA5, which covers the entire country at a spatial resolution of 0.25° with temporal continuity. The only exception were the ERA5 wind observations, which could not be used as this data was provided as average values on the Beaufort scale, which low resolution made it unsuitable for the purposes of calibrating the historical dataset.

The Copernicus Climate Change Service (C3S) ERA5 dataset is highly accurate and helps to conduct 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 the present back to 1979 of the entire Earth's surface. The dataset comes from a combination of a meteorological models, the ECMWF Integrated Forecasting System (IFS) with 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 a large number of atmospheric, terrestrial, and oceanic climatic variables in hourly time resolution. The data covers the Earth in 30 km grids and divides the atmosphere into 137 levels from the surface to 80 km above ground. ERA5 includes information on uncertainties for all variables with reduced spatial and temporal resolutions.

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 climate indices (summer days, frost days, tropical nights, heatwaves, rain days and moderate to strong wind, or higher). Table 32 details the variables analyzed in this study. 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. This is also one of the lasting results of this work: Creating a multivariable database which can be used as a reliable pseudo-observational reference in future studies of Suriname's climate.

[2] The existing observations were very dense, but the dataseries in many cases lacked integrity and coherence. One of the most time-intensive part of preparing this study was the interpretation and translation of the original data into usable data by various ways of logging precipitation and especially wind data.

Table 32: Variables/ Indices used and their description and unit.
Source: Own elaboration.

Abbreviation	Variable/ index	Description	Units
tmean	Variable	Average daily temperature	°C
tmax	Variable	Maximum daily temperature	°C
tmin	Variable	Minimum daily temperature	°C
TX90	index	Days on which the mean temperature exceeds the mean temperature of 10 % of the hottest days	days/year
TX10	index	Days on which the mean temperature drops below the mean temperature of 10 % of the coldest days	days/year
TN90	index	Nights in which the mean temperature does not reach the mean temperature of 10 % of the hottest nights	days/year
TN10	index	Nights in which the mean temperature drops below the mean temperature of 10 % of the coldest days	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	%

3.1.2.7. Regional and local analysis

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

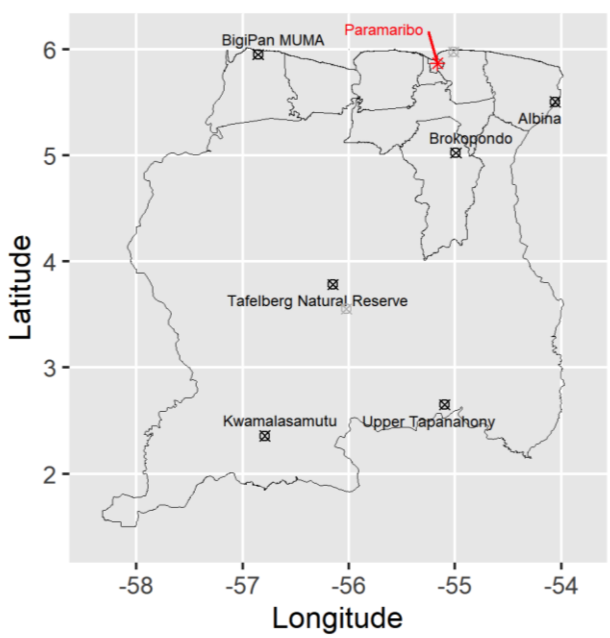
In addition, it also provides an analysis at the local scale, presented in graphs and tables for a seven preselected points of interest:

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

These points of interest of this study are shown in figure 20 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 located in the coastal area (among them, the capital of Suriname, Paramaribo), the rest are located further down south in the interior of the country.

Figure 20: Location of the points of interest used in this study.

Source: Own elaboration.



3.2. Current climate characterization

In order to analyze the future climate, first, the current climate was assessed based on ERA5 reanalysis data calibrated with in-situ observations. This section is structured around the analysis of four variables and the climate indices that are derived from them. The variables are temperature (mean, maximum and minimum), wind (maximum, since it is the only case in which this variable is of any interest in Suriname), precipitation (annual accumulated precipitation) and average relative humidity. From these the frequency of hot and cold days and nights, the frequency of strong and gale wind days and the frequency of rainy days, as well as the maximum daily and five-daily accumulated precipitation were derived.

The information concerning the annual mean of these variables and indices is presented on maps that cover the whole country. The seasonal cycle of each variable in the points of interest is then explored through the use of climographs.

3.2.1. Regional analysis

Average daily temperature is very similar throughout almost all of the country (figure 21). 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 (33°C) and on the eastern border. Minimum temperatures show a slightly different pattern: They are higher in the coastal region (25°C) and decrease constantly going southwards and towards higher ground, reaching 21°C in the highest point of the country.

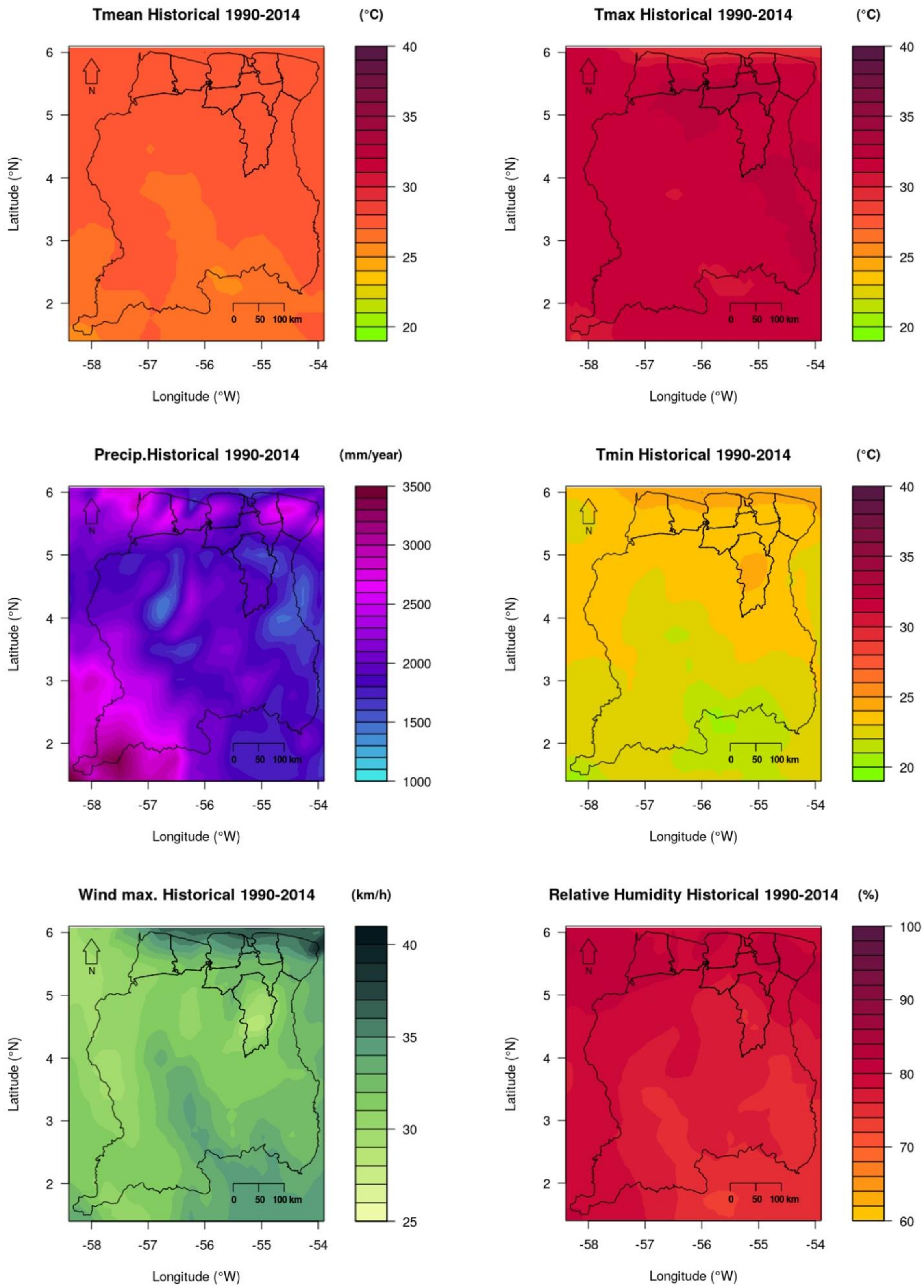
Accumulated yearly precipitation is over 1,500 mm for all the country, with maximums in the southwest (more than 3,000 mm/year) and the coastal region (more than 2,500 mm/year).

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

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

Figure 21: 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: Own elaboration.

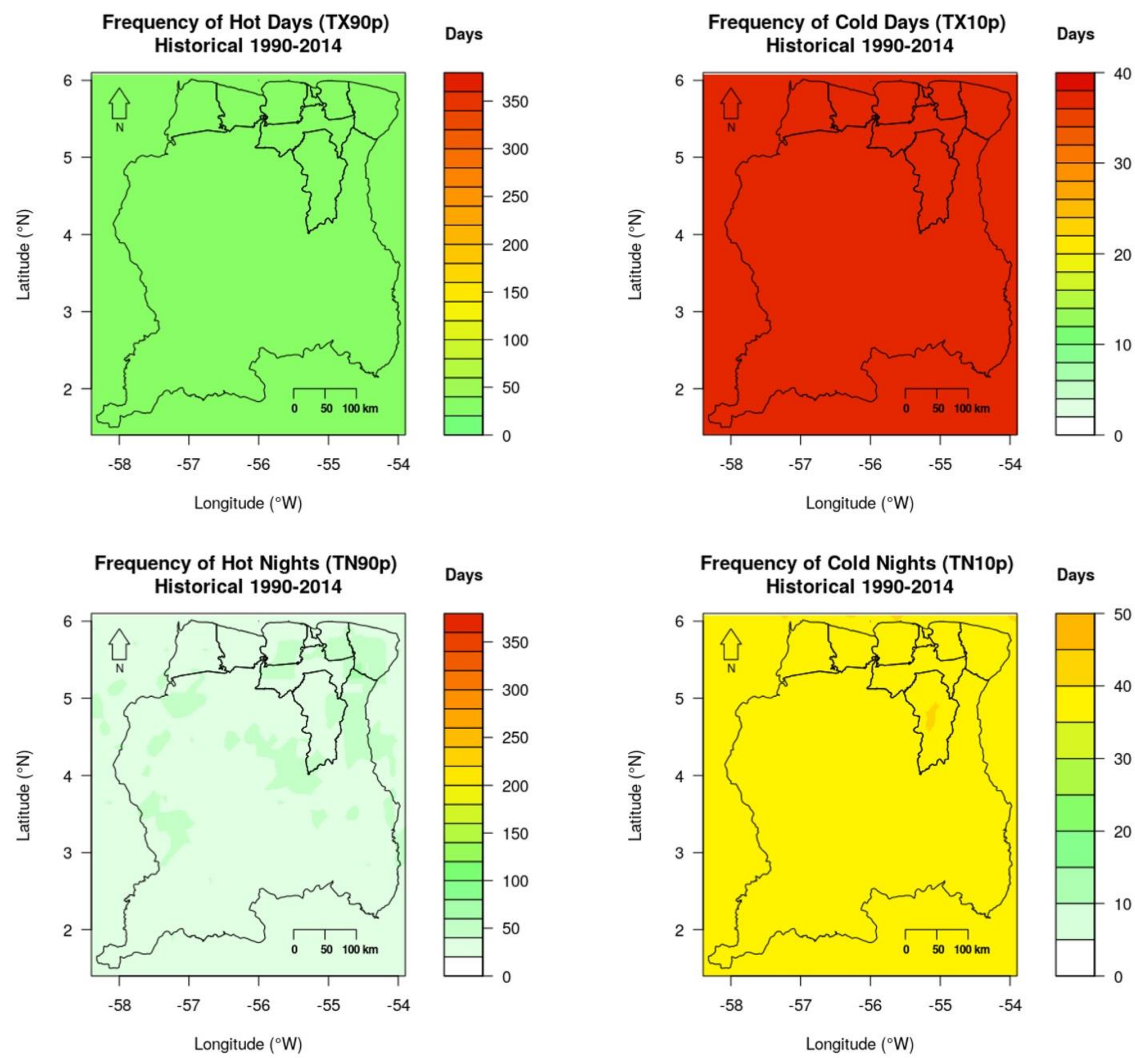


3.2.1.1. Climate indices

This section shows the annual values of the climate indices defined in table 3, for the historical period (1990-2014). These figures work as a baseline for temperature related indices (figure 22), precipitation related indices (figure 23) and wind related indices (figure 24) and allow for a better understanding of how these indices vary in the two scenarios and for all periods (following section). These indices were computed locally, for each grid point.

Figure 22: Maps of the average values in the period 1990-2014 of 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).

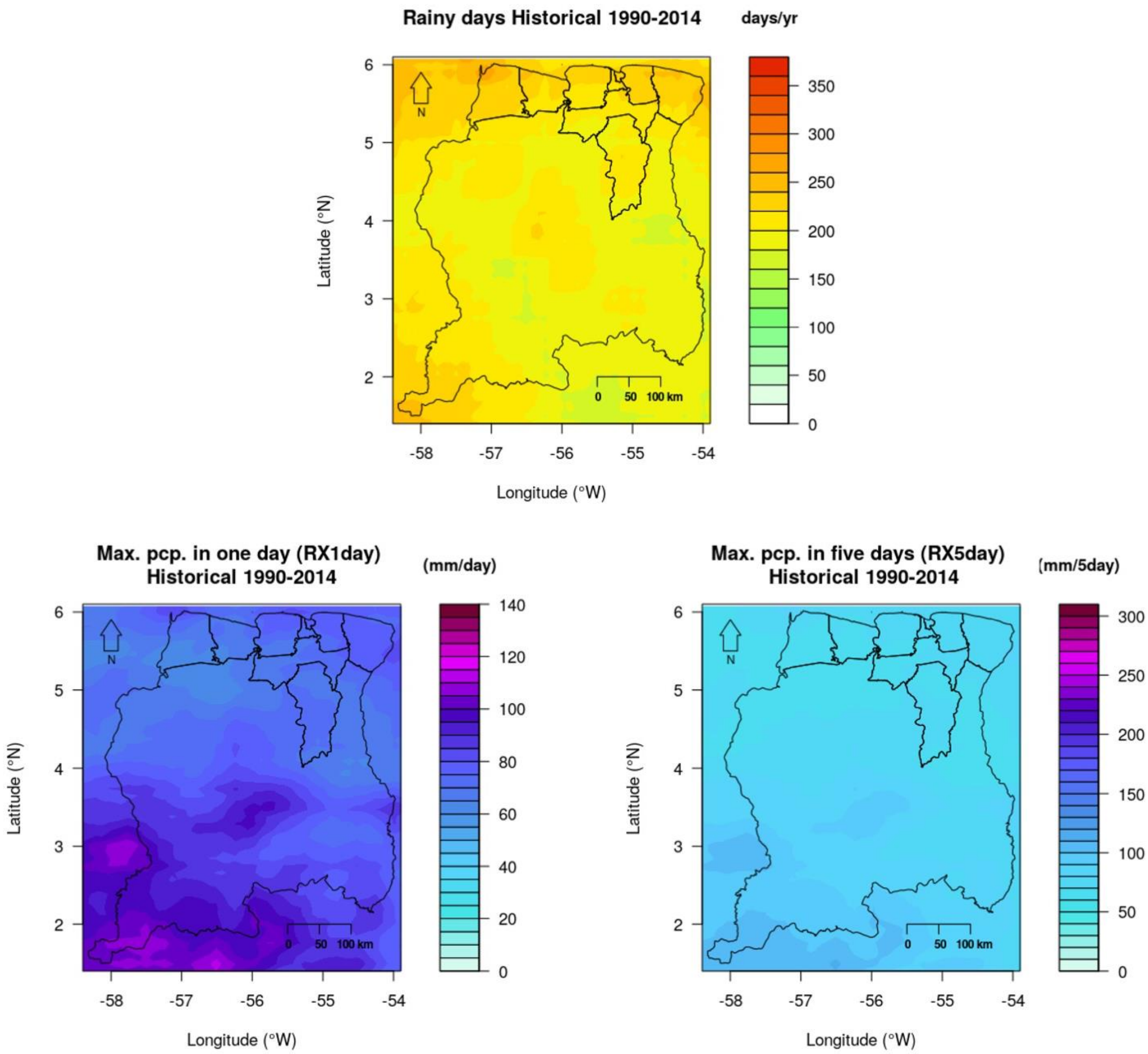
Source: Own elaboration.



Since the definition of hot days (TX90p), cold days (TX10p), hot nights (TN90p) and cold nights (TN10p) is those days/nights in which temperature is above/below the 10% hottest/coldest in the climatology, it is not surprising that the map is very homogeneous for all of them.

Figure 23: Maps of the average values in the period 1990-2014 of number of yearly rainy days (top), maximum daily precipitation (bottom left) and maximum five-daily precipitation (bottom right).

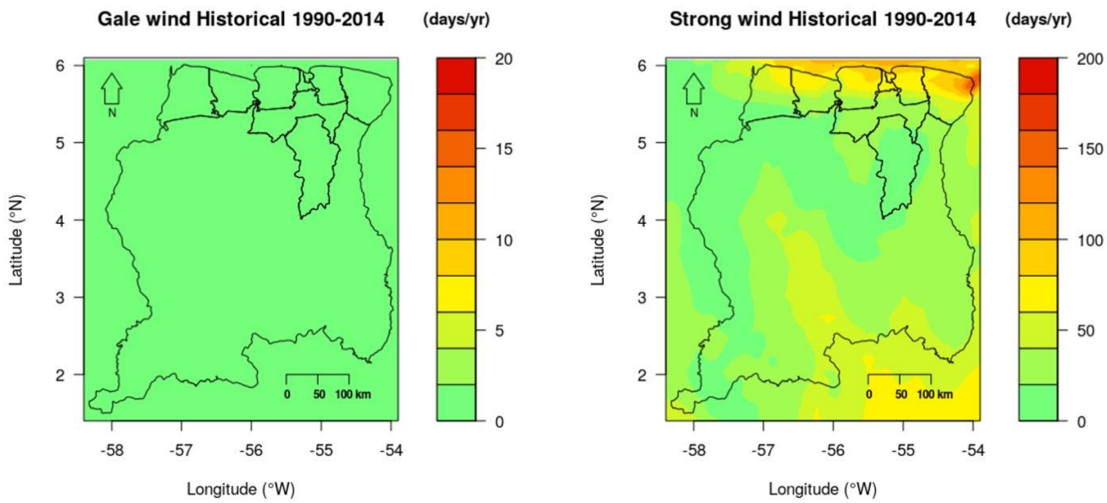
Source: Own elaboration.



Rainy days are more frequent on the coast, the center and southwest of the country, and less so on higher ground towards the southeast. 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 24: Maps of the average values in the period 1990-2014 of frequency of days in which maximum wind speed surpasses 60 km/h (left), days in which maximum wind speed surpasses 40 km/h (right).

Source: Own elaboration.



Gale wind days are very rare in Suriname (less 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.

3.2.2. Local analysis

This section presents the climatological behavior of the seven points of interest. First, climographs assess the seasonal variations of accumulated precipitation and mean temperature, and then the historical trend of mean temperatures, accumulated precipitation and maximum daily wind speed is analyzed. These variables have been chosen because they are those which best characterize local climate. Climographs in particular are especially useful to assess the climate of a point of interest. The climate of all the points of interest is, according to the Koppen classification, tropical humid.

3.2.2.1. Climographs

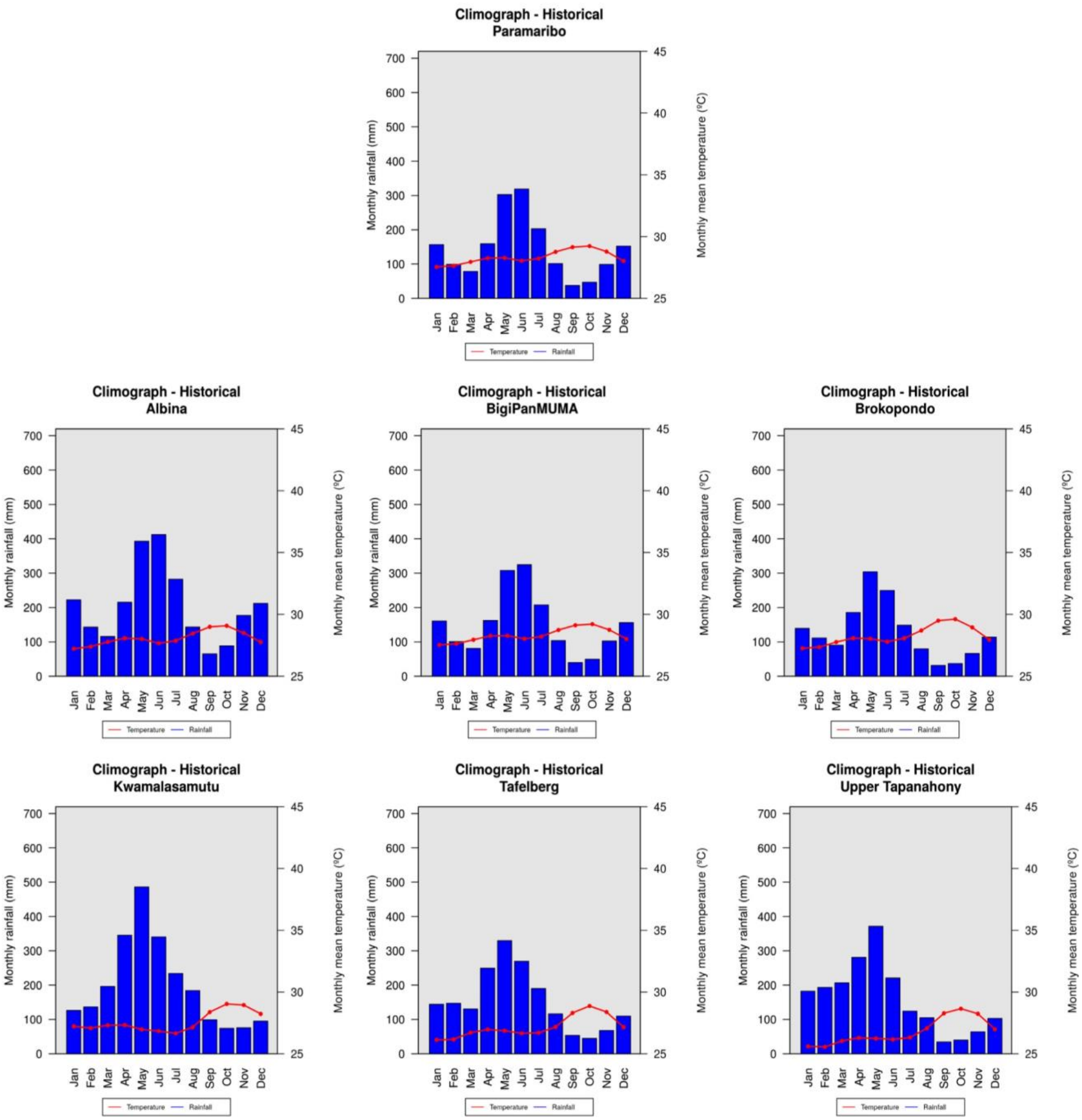
Paramaribo has two distinct wet seasons (a long rainy season between April and July and a short rainy season between December and January) and two distinct dry seasons (a short dry season between February and March and a long dry season between August and November) (figure 24). Temperature is higher during the long dry season, in particular in October, and has two minimums during the wet seasons. Maximum temperatures show the same monthly behavior, with a strong maximum in October. Minimum temperatures show a similar cycle, although smoother.

This regime is shared by the points of interest closer to the coast (Albina, BigiPan MUMA and, to a lesser extent, Brokopondo). The further inland, the more evenly distributed the precipitation is. Kwamalasamutu, Taflberg and Upper Tapanahony show a wet season (in general rainier than up on the cast that goes from April to August in Kwamalasamutu and from January to June at the Uppwe Tapanahony). The dry season lasts from September to December in all cases. Minimum temperatures are lowest in February (Upper Tapanahony, the highest point of interest, and Tafelberg) or July (Kwamalasamutu). Maximum temperatures always occur during the dry season in October.

The main driver of the differences in climate 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 Intertropical Convergence Zone, a belt of very intense precipitation that surrounds the globe. This belt reaches (for the region in which Suriname is located) its southernmost position in March. During this month, its effect is felt in the south of the country, but not in the north. It then moves northwards until September, when it is beyond any point in Suriname, creating the long dry season in the north, and the dry season in the south.

Figure 25: Monthly accumulated precipitation and monthly mean, maximum and minimum temperature for Paramaribo. Values are averaged over the historical period 1990-2014.

Source: Own elaboration.



3.2.2.2. Average annual regimes

The tables accompanying the figures summarize the results obtained for all variables, representing the rate of change per decade, calculated in the period 1990-2014 as well as their probability of occurrence. This concept allows us to estimate whether the observed trend shows a good degree of consistency or if, on the contrary, the recorded trend is weak and inconsistent over time. The probability of occurrence will be determined according to the following table (table 33).

Table 33: Probability of occurrence of a given result.

Source: IPCC (2019).

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%

<u>Paramaribo</u>

Figure 26: Observed annual trends (m) and their probability of occurrence for the average temperature, rainfall and average maximum wind during the period 1990-2014 in Paramaribo.

Source: Own elaboration.

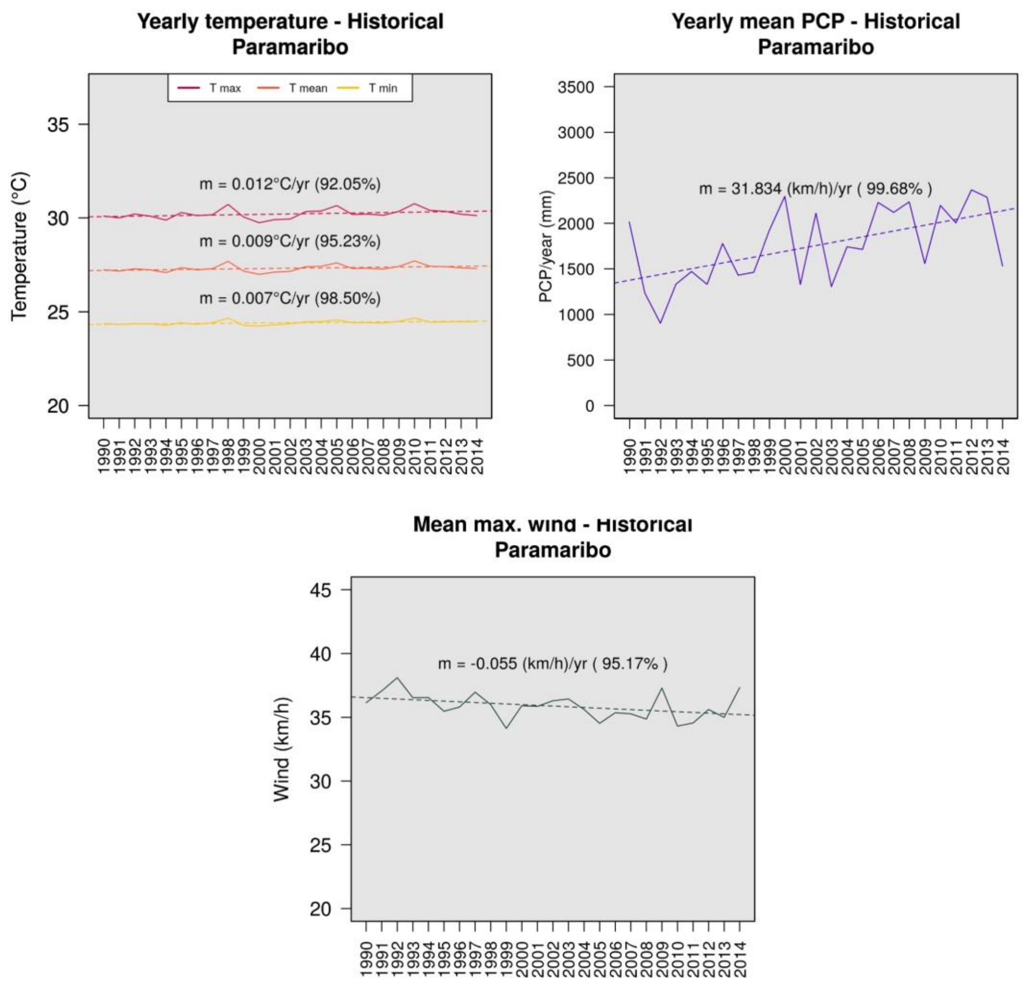


Table 34: Annual average value, decadal rate of change and probability of occurrence in Paramaribo.

Source: Own elaboration.

Variables	Average value	Rate of change per decade	Probability of occurrence
Max. temperature (°C)	30.2	+0.12	Very likely
Mean temperature (°C)	27.3	+0.09	extremely likely
Min. temperature(°C)	24.4	+0.07	Extremely likely
Accumulated precipitation (mm/y)	1756,119	+319.3	extremely likely
Maximum wind (km/h)	35.9	-0.5	more unlikely than likely

Albina

Figure 27: Observed annual trends (m) and their probability of occurrence for the average temperature, rainfall and average maximum wind during the period 1990-2014 in Albina.

Source: Own elaboration.

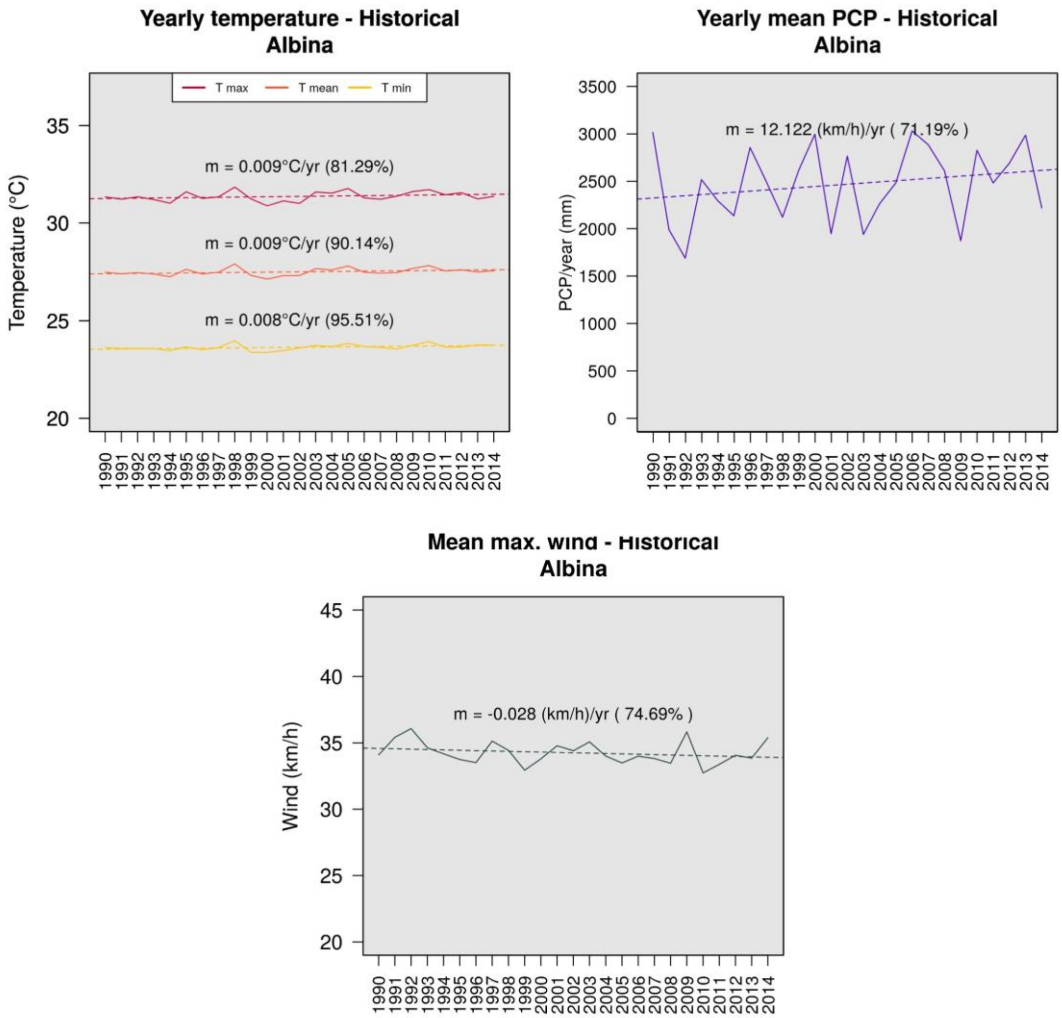


Table 35: Annual average value, decadal rate of change and probability of occurrence in Albina.

Source: Own elaboration.

Variables	Average value	Rate of change per decade	Probability of occurrence
Max. temperature (°C)	31.4	+0.09	likely
Mean temperature (°C)	27.5	+0.09	Very likely
Min. temperature(°C)	23.6	+0.07	Extremely likely
Accumulated precipitation (mm/y)	2,469.4	+121.2	likely
Maximum wind (km/h)	34.25	-0.28	more unlikely than likely

MUMA at Bigi Pan

Figure 28: Observed annual trends (m) and their probability of occurrence for the average temperature, rainfall and average maximum wind during the period 1990-2014 in MUMA at Bigi Pan.

Source: Own elaboration.

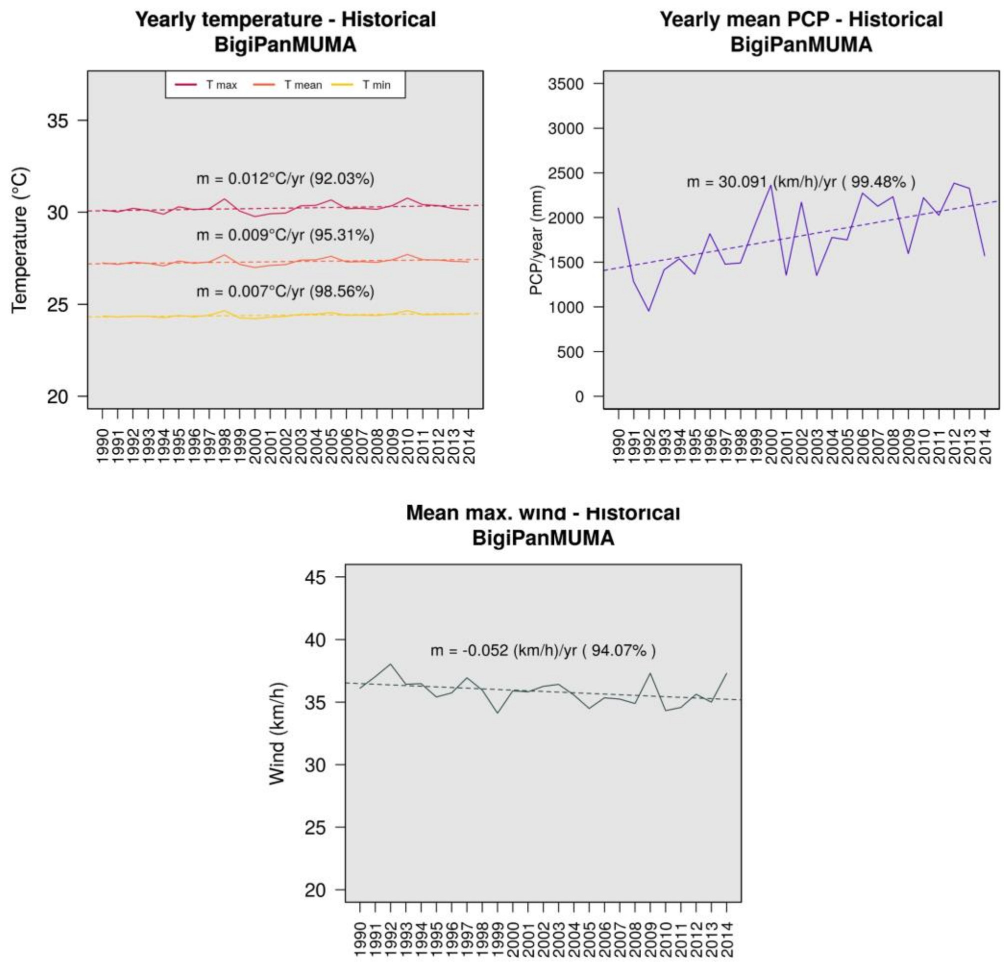


Table 36: Annual average value, decadal rate of change and probability of occurrence in MUMA at Bigi Pan.

Source: Own elaboration.

Variables	Average value	Rate of change per decade	Probability of occurrence
Max. temperature (°C)	30.2	+0.12	Very likely
Mean temperature (°C)	27.3	+0.09	Extremely likely
Min. temperature(°C)	24.1	+0.07	Extremely likely
Accumulated precipitation (mm/y)	1,796.4	+300.9	extremely likely
Maximum wind (km/h)	35.85	-0.52	more unlikely than likely

<u>Brokopondo</u>

Figure 29: Observed annual trends (m) and their probability of occurrence for the average temperature, rainfall and average maximum wind during the period 1990-2014 in Brokopondo.

Source: Own elaboration.

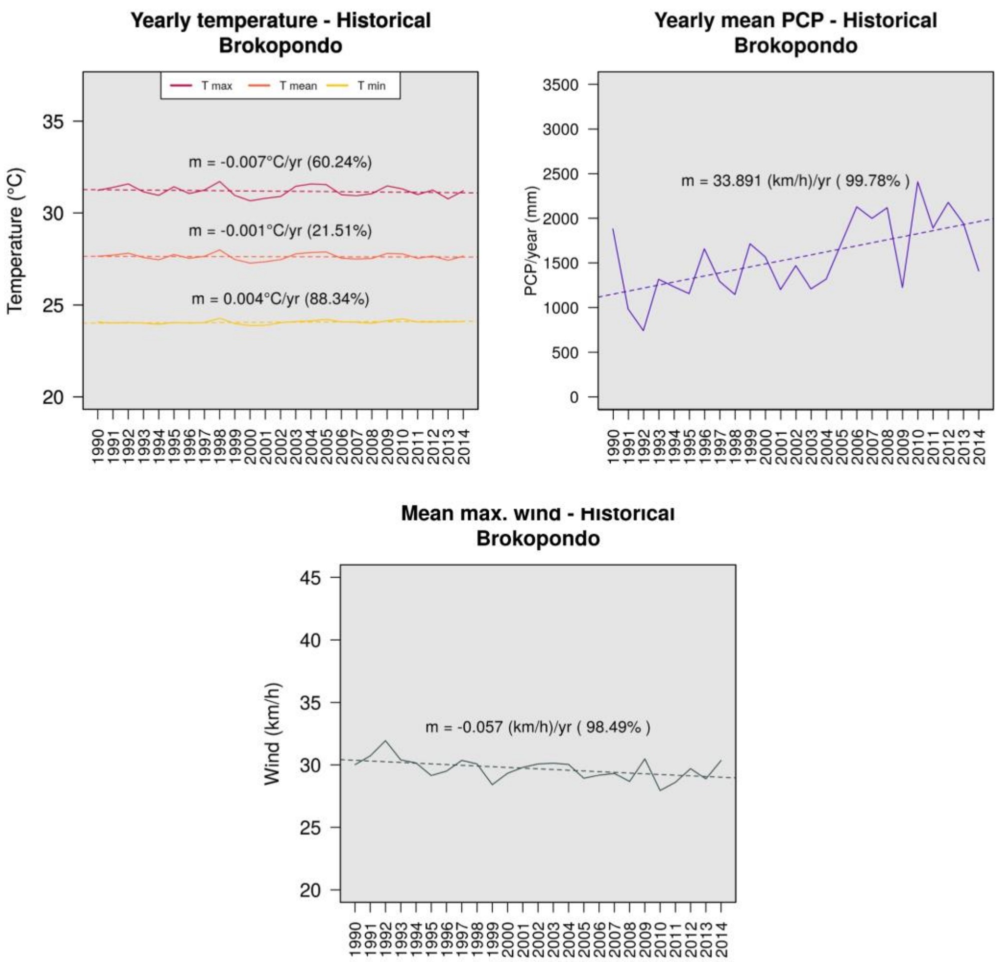


Table 37: Annual average value, decadal rate of change and probability of occurrence in Brokopondo.

Source: Own elaboration.

Variables	**Average value**	**Rate of change per decade**	**Probability of occurrence**
Max. temperature (°C)	31.2	-0.07	More likely than unlikely
Mean temperature (°C)	27.6	-0.01	More unlikely than likely
Min. temperature(°C)	24.1	+0.04	likely
Accumulated precipitation (mm/y)	1,556.4	+318.3	extremely likely
Maximum wind (km/h)	29.69	-0.57	more unlikely than likely

Kwamalasamutu

Figure 30: Observed annual trends (m) and their probability of occurrence for the average temperature, rainfall and average maximum wind during the period 1990-2014 in Kwamalasamutu.

Source: Own elaboration.

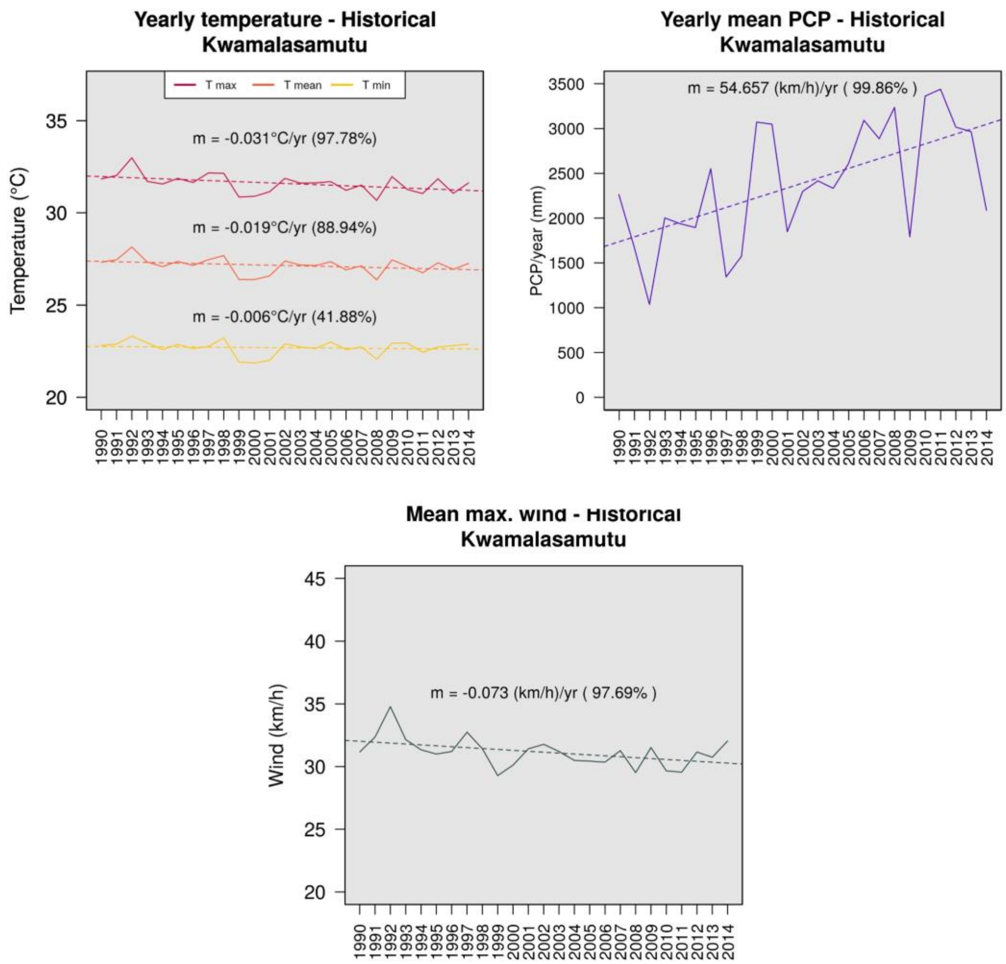


Table 38: Annual average value, decadal rate of change and probability of occurrence in Kwamalasamutu.

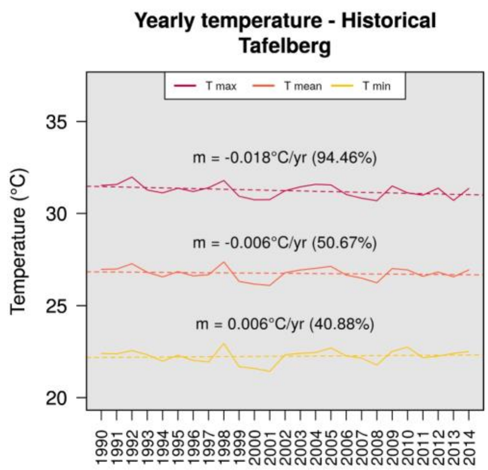
Source: Own elaboration.

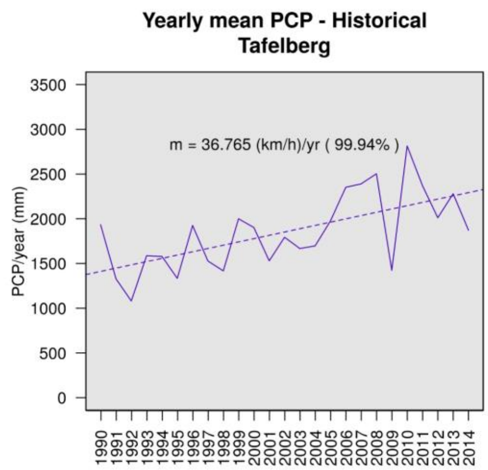
Variables	Average value	Rate of change per decade	Probability of occurrence
Max. temperature (°C)	31.6	-0.31	extremely likely
Mean temperature (°C)	27.1	-0.19	likely
Min. temperature(°C)	22.7	-0.06	more unlikely than likely
Accumulated precipitation (mm/y)	2,391.6	+546.6	Extremely likely
Maximum wind (km/h)	31.15	-0.73	more unlikely than likely

<u>Tafelberg</u>

Figure 31: Observed annual trends (m) and their probability of occurrence for the average temperature, rainfall and average maximum wind during the period 1990-2014 in Tafelberg.

Source: Own elaboration.





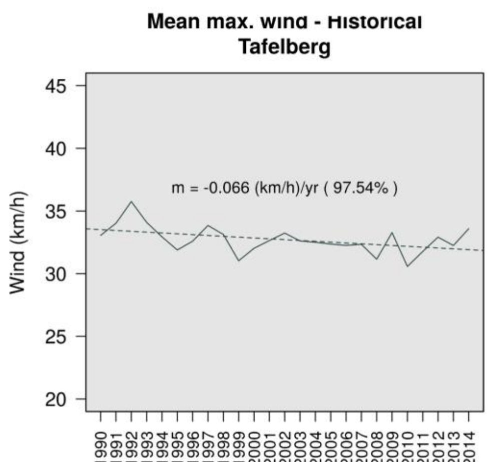


Table 39: Annual average value, decadal rate of change and probability of occurrence in Tafelberg.

Source: Own elaboration.

Variables	Average value	Rate of change per decade	Probability of occurrence
Max. temperature (°C)	31.2	-0.18	Very likely
Mean temperature (°C)	26.8	-0.06	More likely than unlikely
Min. temperature(°C)	22.2	+0.06	more unlikely than likely
Accumulated precipitation (mm/y)	1,851.9	+367.6	extremely likely
Maximum wind (km/h)	32.7	-0.66	more unlikely than likely

<u>Upper Tapanahony</u>

Figure 32: Observed annual trends (m) and their probability of occurrence for the average temperature, rainfall and average maximum wind during the period 1990-2014 in Upper Tapanahony.

Source: Own elaboration.

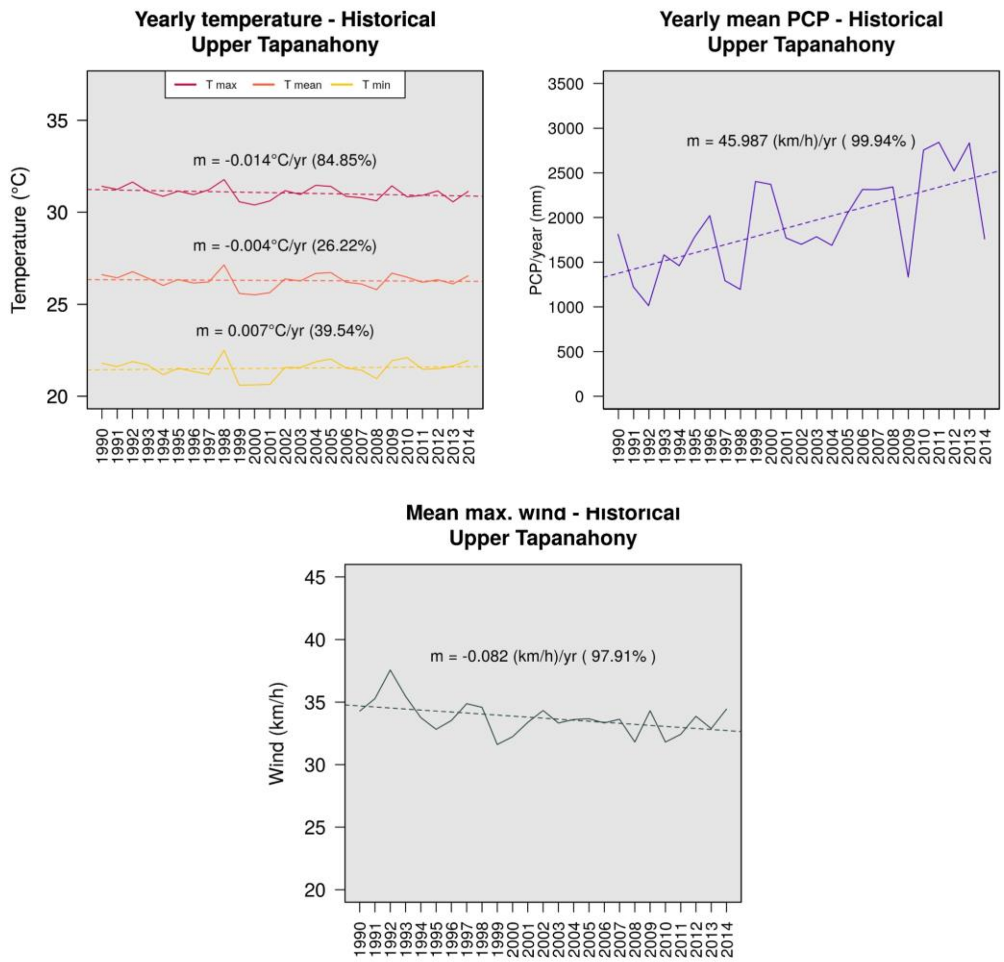


Table 40: Annual average value, decadal rate of change and probability of occurrence in Upper Tapanahony.

Source: Own elaboration.

Variables	Average value	Rate of change per decade	Probability of occurrence
Max. temperature (◦C)	31.1	-0.14	likely
Mean temperature (◦C)	26.3	-0.04	more unlikely than likely
Min. temperature(◦C)	21.5	+0.07	more unlikely than likely
Accumulated precipitation (mm/y)	1,926.3	+459.9	extremely likely
Maximum wind (km/h)	33.7	-0.8	more unlikely than likely

From the analysis of the seven points of interest presented in figures 34-40 and tables 34-40, we conclude that there are two distinct trends in climate regimes in Suriname, one in the coastal north and one in the interior of the country. They have in common that precipitation shows a strong increasing trend (up to 546.6 mm/decade in Kwamalasamutu), maximum wind speed shows a descending trend (ranging from -0.28 km/h per decade in BigiPanMUMA to -0.8 km/h per decade in Upper Tapanahony) and that minimum temperatures are increasing (except for Kwamalasamutu). However, in the north (Paramaribo, Albina, BigiPanMUMA) maximum temperatures are increasing, while in the center and south they show a cooling trend. The two extreme cases are Kwamalasamutu (-0.31°C/decade) and BigiPanMUMA (+0.13°C/decade). Mean temperatures also show two differentiated behaviors in the north (warming) and the south (cooling). The confidence on these results is generally high or very high, with the exception of temperature trends in the southern locations and wind trends on the coast, which are less reliable.

Therefore, the conclusions from this reanalysis point to a climate that has overall become more humid, and while the coast has become warmer, the south has turned a bit cooler.

3.3. Future climate

3.3.1. Regional analysis

For the regional analysis the maps shown below have been obtained from a multi-model analysis (combining the climate models HadGEM3-GC31, IPSL-CM6A and MIROC6), applying the Q-Q statistical adjustment technique, and computing the future projections of all variables for each of the three time horizons and the two scenarios with respect to the current climate. In each subsection, the mean values of each variable are shown, followed by the anomalies which were produced by subtracting the historical climatology from the model results.

At the end of the section, the projected sea level anomaly is presented and discussed for the three future periods and two model scenarios.

3.3.1.1. Temperature

Figure 33: Average mean temperature during the historical period (1990-2014) (top), climate projection of the average mean temperature in the SSP2-4.5 scenario in the short-term future (2020-2039) (center left), medium-term future (2040-2069) (center), and long-term future (2070 - 2099) (center right) and in the SSP5-8.5 scenario in the short-term future (2020-2039) (bottom left), medium-term future (2040-2069) (center bottom), and long-term future (2070 - 2099) (bottom right).

Source: Own elaboration.

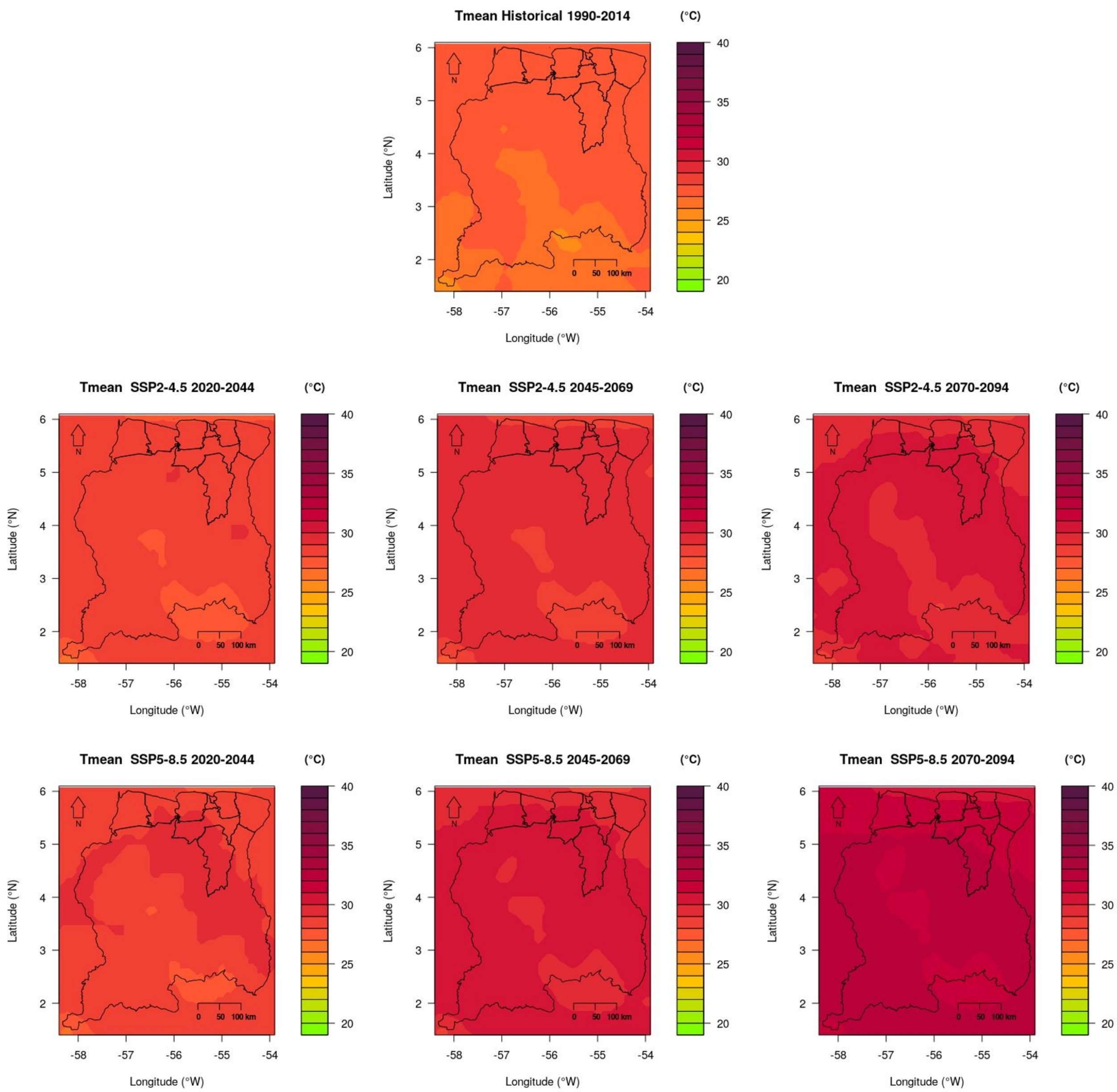


Figure 34: Average mean temperature anomalies (each period minus the historical period (1990-2014)) for climate projection of the average mean temperature in the SSP2-4.5 scenario in the short-term future (2020-2039) (top left), medium-term future (2040-2069) (top center), and long-term future (2070 - 2099) (top right) and in the SSP5-8.5 scenario in the short-term future (2020-2039) (bottom left), medium-term future (2040-2069) (center bottom), and long-term future (2070 - 2099) (bottom right).

Source: Own elaboration.

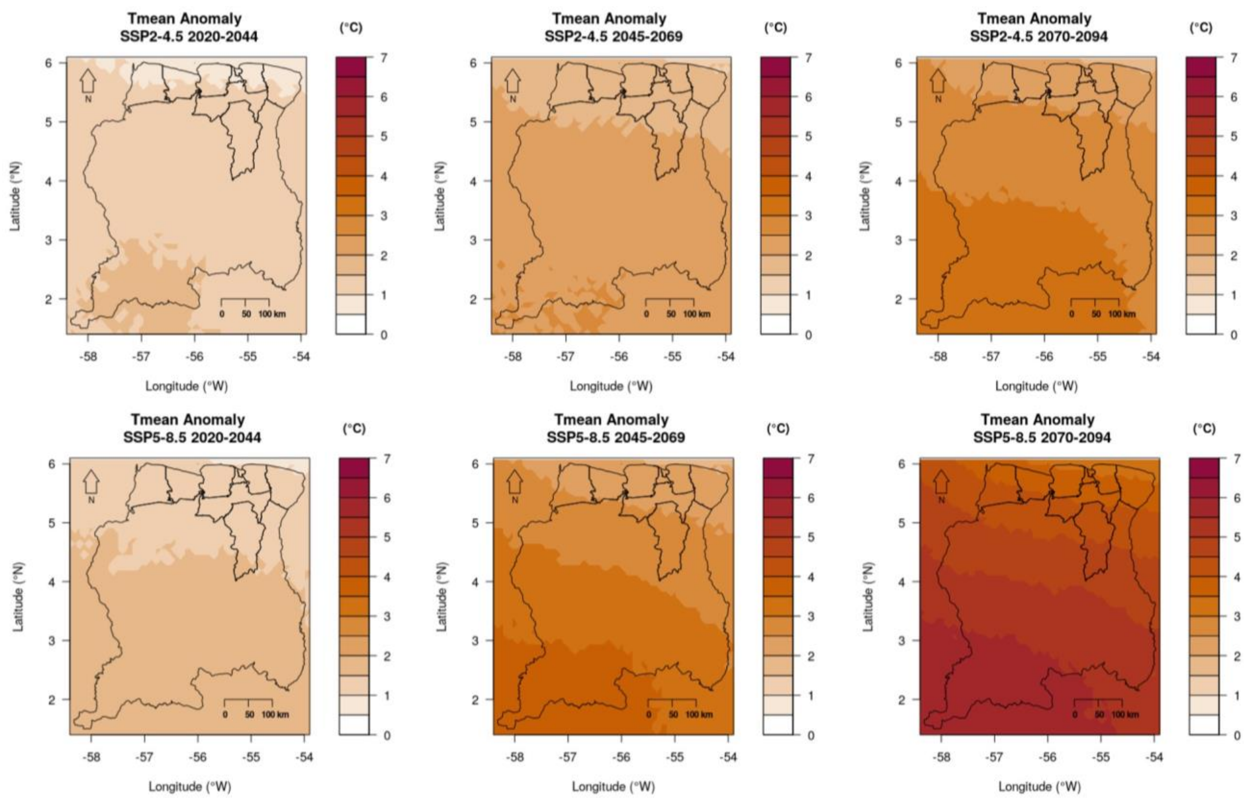


Figure 35: Average maximum temperature during the historical period (1990-2014) (top), climate projection of the average mean temperature in the SSP2-4.5 scenario in the short-term future (2020-2039) (center left), medium-term future (2040-2069) (center), and long-term future (2070 - 2099) (center right) and in the SSP5-8.5 scenario in the short-term future (2020-2039) (bottom left), medium-term future (2040-2069) (center bottom), and long-term future (2070 - 2099) (bottom right).

Source: Own elaboration.

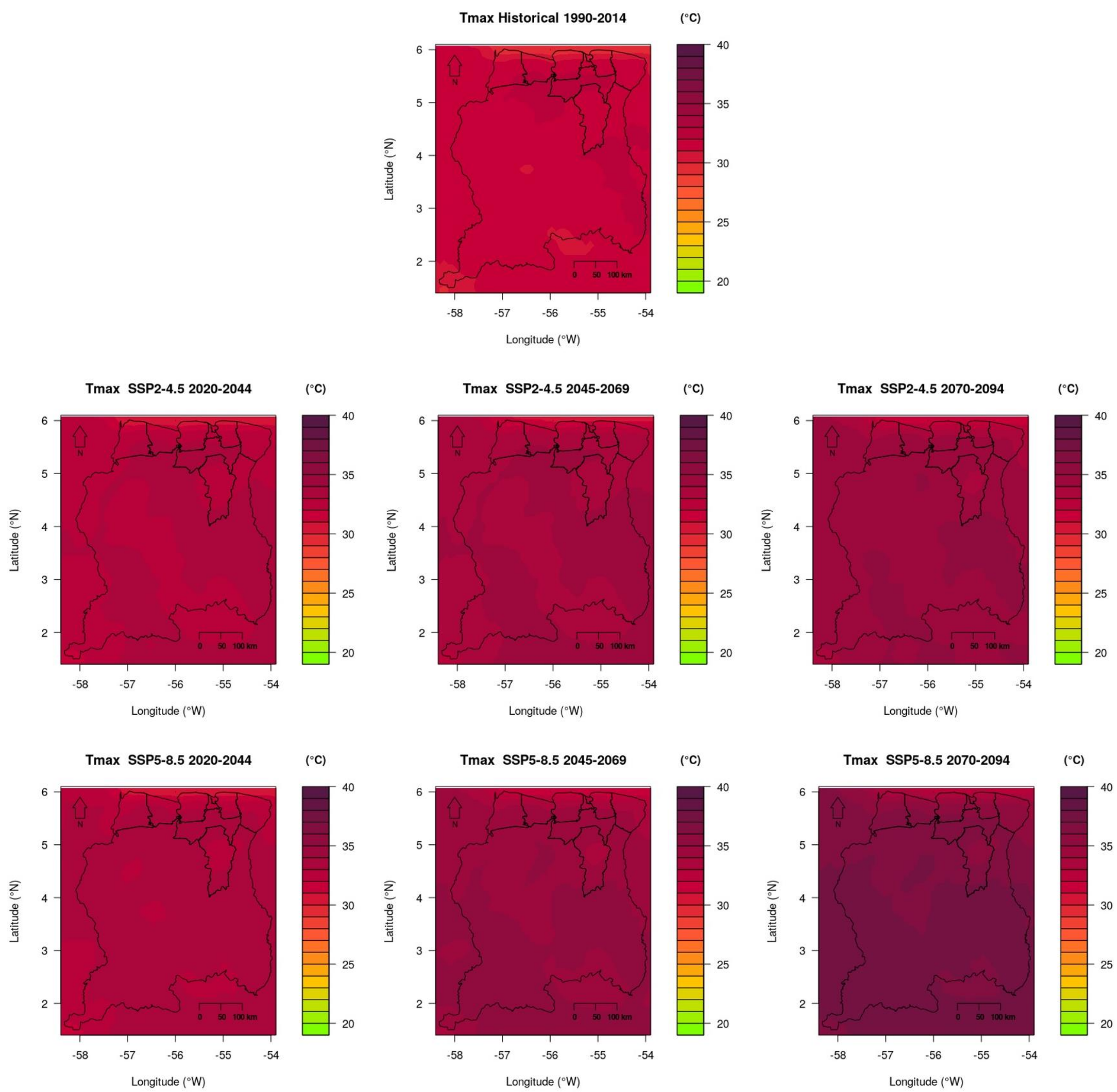


Figure 36: Average maximum temperature anomalies (each period minus the historical period (1990-2014)) for climate projection of the average mean temperature in the SSP2-4.5 scenario in the short-term future (2020-2039) (top left), medium-term future (2040-2069) (top center), and long-term future (2070 - 2099) (top right) and in the SSP5-8.5 scenario in the short-term future (2020-2039) (bottom left), medium-term future (2040-2069) (center bottom), and long-term future (2070 - 2099) (bottom right).

Source: Own elaboration.

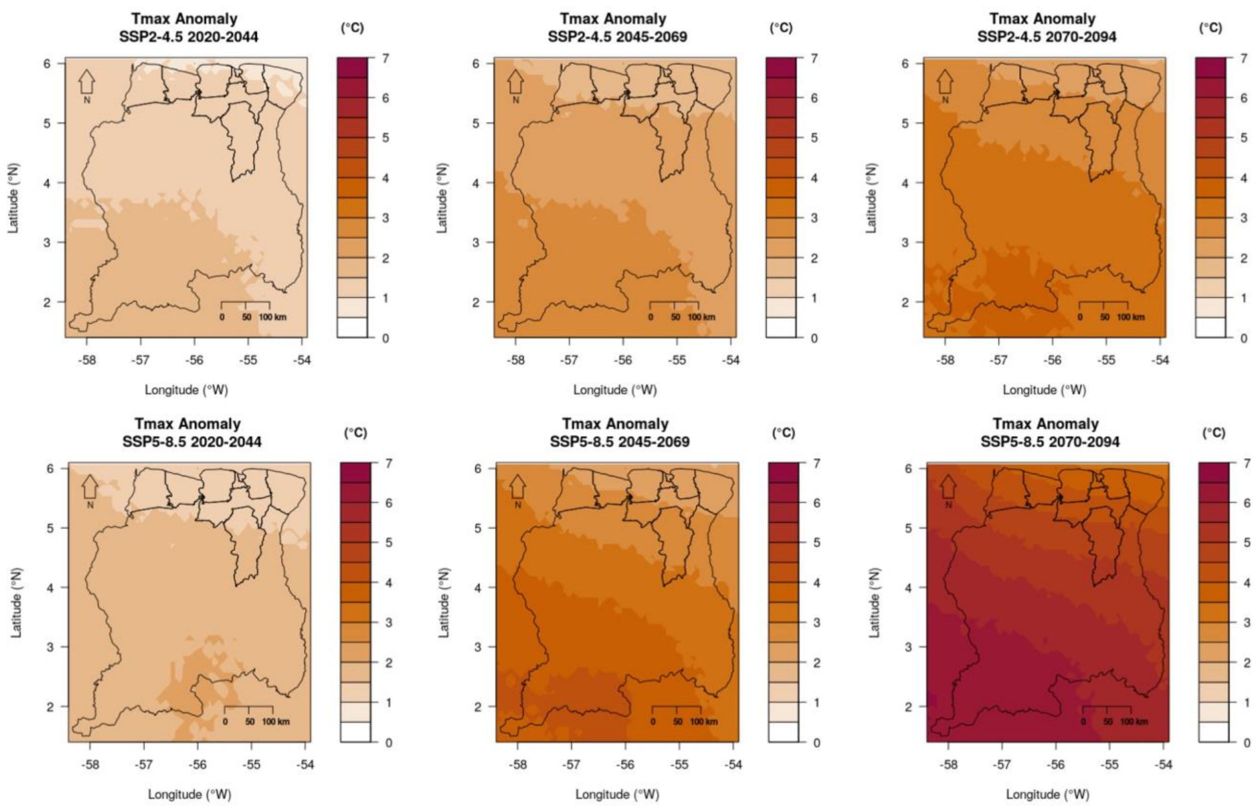


Figure 37: Average minimum temperature during the historical period (1990-2014) (top), climate projection of the average mean temperature in the SSP2-4.5 scenario in the short-term future (2020-2039) (center left), medium-term future (2040-2069) (center), and long-term future (2070 - 2099) (center right) and in the SSP5-8.5 scenario in the short-term future (2020-2039) (bottom left), medium-term future (2040-2069) (center bottom), and long-term future (2070 - 2099) (bottom right).

Source: Own elaboration.

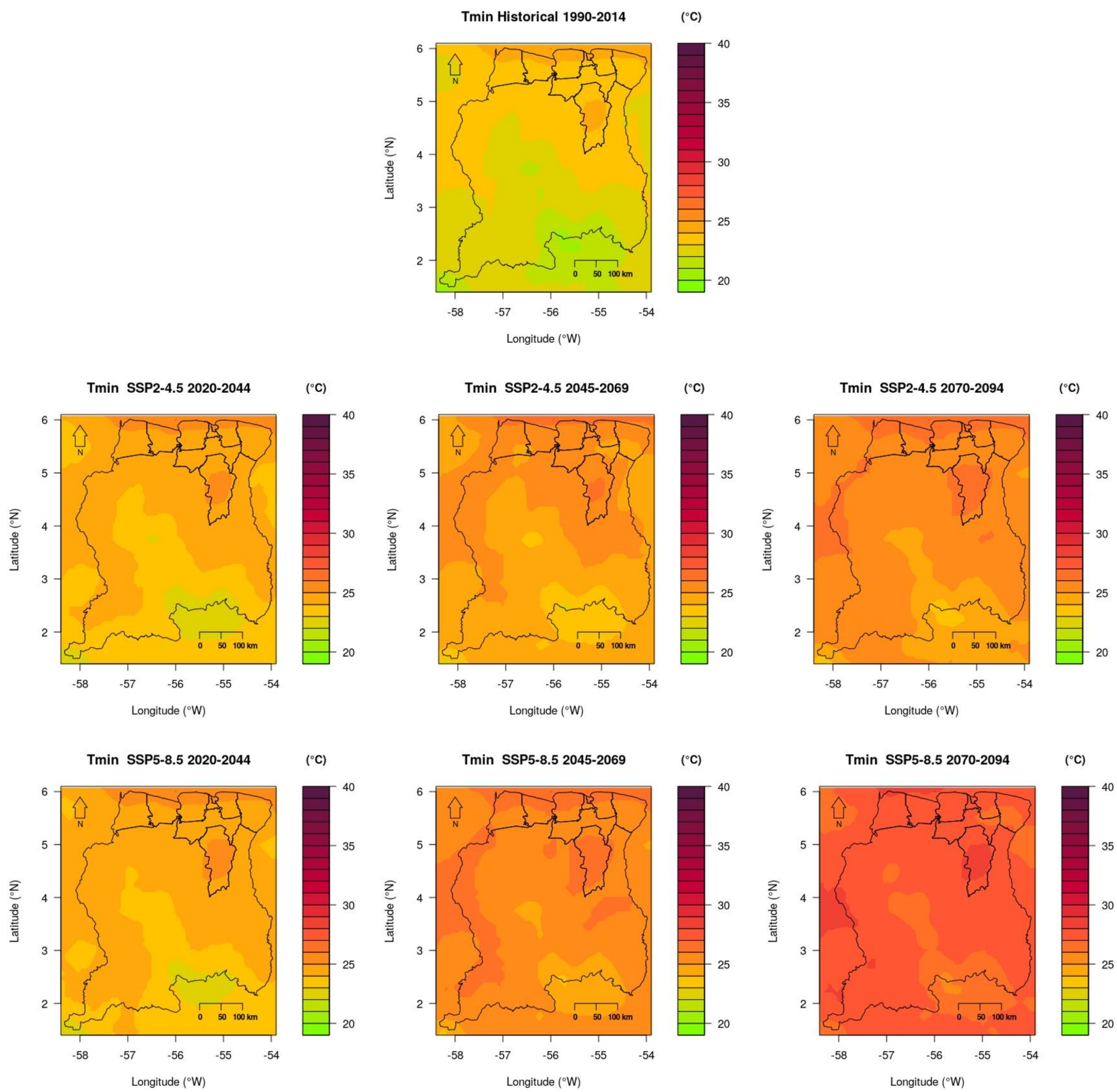
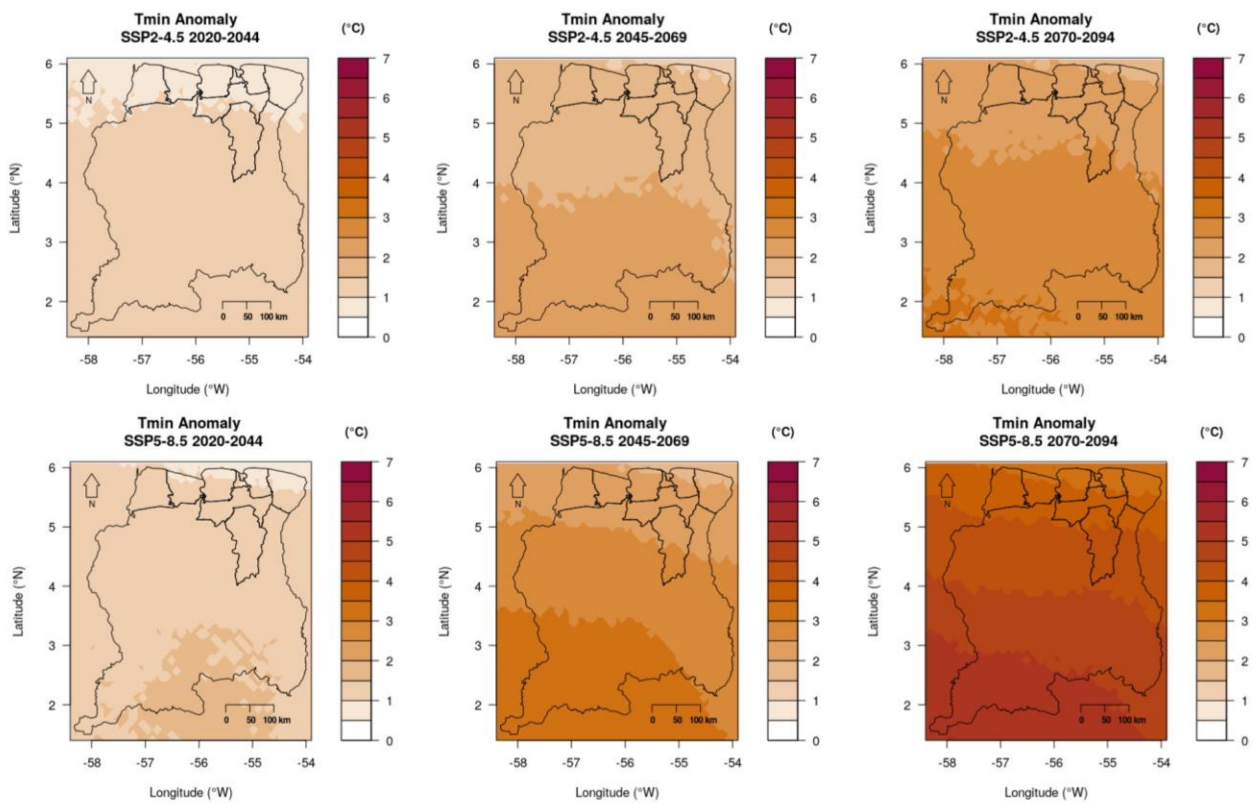


Figure 38: Average minimum temperature anomalies (each period minus the historical period (1990-2014)) for climate projection of the average mean temperature in the SSP2-4.5 scenario in the short-term future (2020-2039) (top left), medium-term future (2040-2069) (top center), and long-term future (2070 - 2099) (top right) and in the SSP5-8.5 scenario in the short-term future (2020-2039) (bottom left), medium-term future (2040-2069) (center bottom), and long-term future (2070 - 2099) (bottom right).

Source: Own elaboration.



Daily mean, minimum and maximum temperatures are projected to increase in both climate scenarios and for all periods over the entire country. The increase in all fields is expected to be less pronounced at the coast and maximum 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 on 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 21Ist century for the SSP5-8.5 scenario. This range is very 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.

3.3.1.2. Precipitation

Figure 39: Average accumulated precipitation during the historical period (1990-2014) (top), climate projection of the average mean temperature in the SSP2-4.5 scenario in the short-term future (2020-2039) (center left), medium-term future (2040-2069) (center), and long-term future (2070 - 2099) (center right) and in the SSP5-8.5 scenario in the short-term future (2020-2039) (bottom left), medium-term future (2040-2069) (center bottom), and long-term future (2070 - 2099) (bottom right).

Source: Own elaboration.

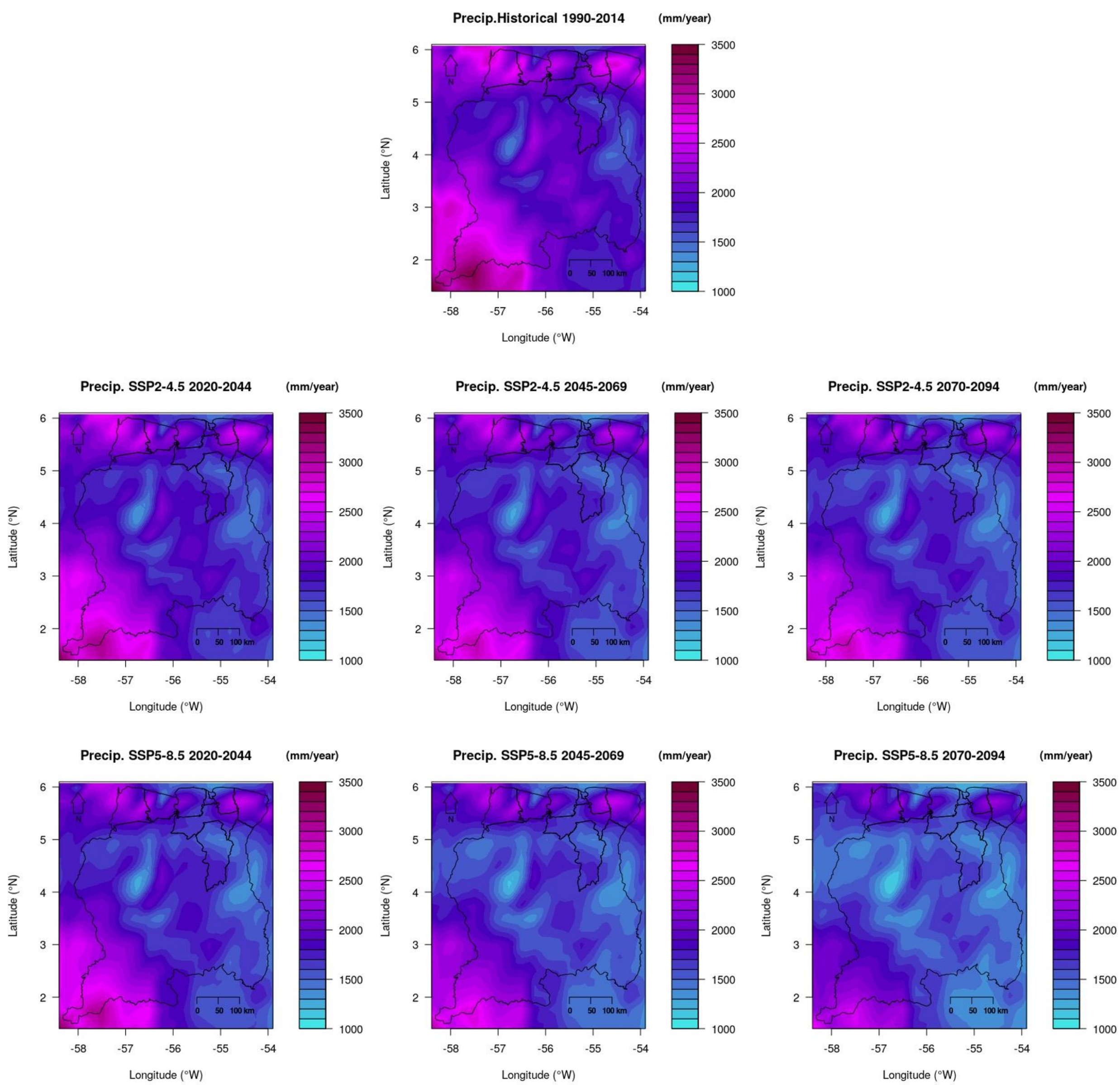
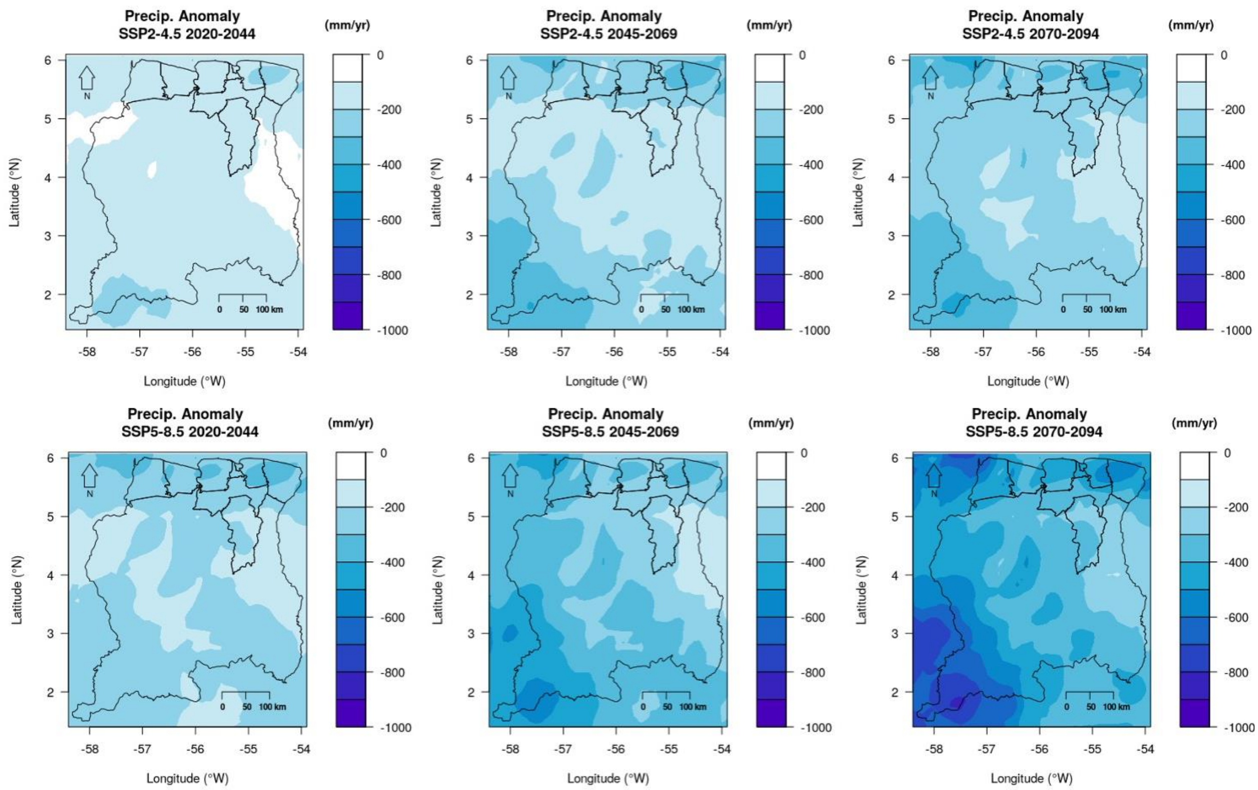


Figure 40: Average accumulated precipitation anomalies (each period minus the historical period (1990-2014)) for climate projection of the average mean temperature in the SSP2-4.5 scenario in the short-term future (2020-2039) (top left), medium-term future (2040-2069) (top center), and long-term future (2070 - 2099) (top right) and in the SSP5-8.5 scenario in the short-term future (2020-2039) (bottom left), medium-term future (2040-2069) (center bottom), and long-term future (2070 - 2099) (bottom right).

Source: Own elaboration.



Accumulated precipitation in Suriname is expected to decrease strongly as the mean position of the intertropical convergence zone shifts northwards. The maximum values of precipitation in the historical record are reached in the southwest (up to 3,500 mm/year), 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.

3.3.1.3. Wind

Figure 41: Average maximum wind during the historical period (1990-2014) (top), climate projection of the average mean temperature in the SSP2-4.5 scenario in the short-term future (2020-2039) (center left), medium-term future (2040-2069) (center), and long-term future (2070 - 2099) (center right) and in the SSP5-8.5 scenario in the short-term future (2020-2039) (bottom left), medium-term future (2040-2069) (center bottom), and long-term future (2070 - 2099) (bottom right).

Source: Own elaboration.

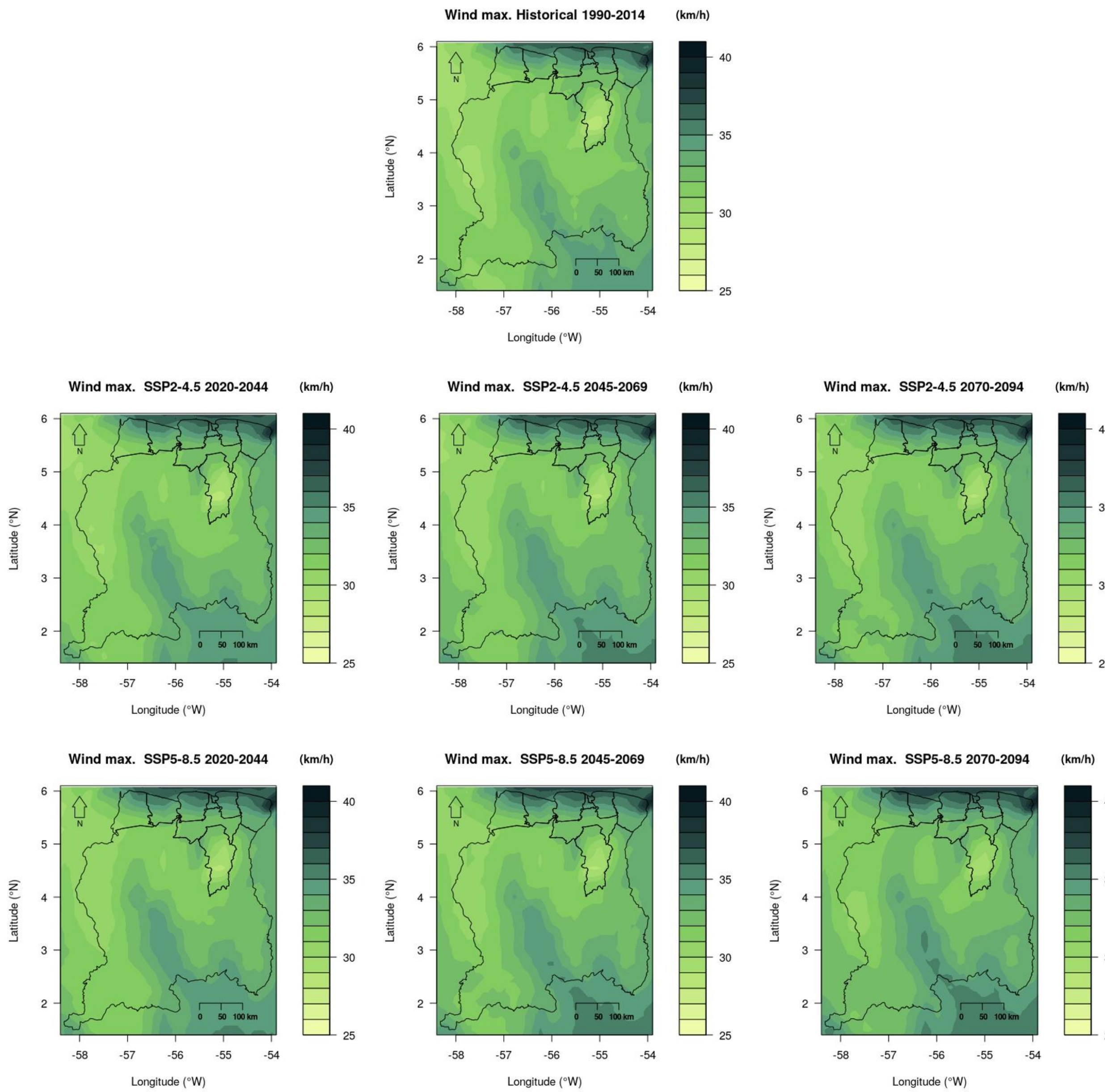
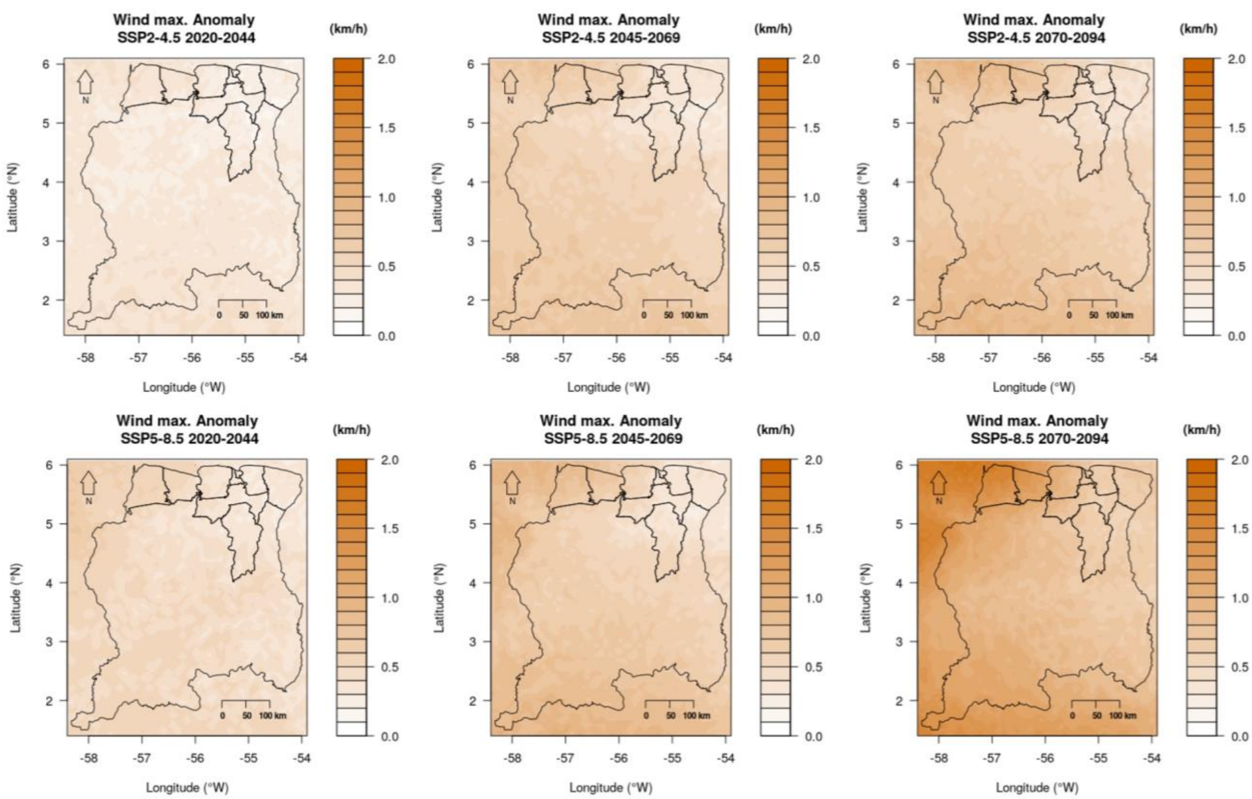


Figure 42: Average maximum wind anomalies (each period minus the historical period (1990-2014)) for climate projection of the average mean temperature in the SSP2-4.5 scenario in the short-term future (2020-2039) (top left), medium-term future (2040-2069) (top center), and long-term future (2070 - 2099) (top right) and in the SSP5-8.5 scenario in the short-term future (2020-2039) (bottom left), medium-term future (2040-2069) (center bottom), and long-term future (2070 - 2099) (bottom right).

Source: Own elaboration.



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

3.3.1.4. Relative humidity

Figure 43: Average relative humidity during the historical period (1990-2014) (top), climate projection of the average mean temperature in the SSP2-4.5 scenario in the short-term future (2020-2039) (center left), medium-term future (2040-2069) (center), and long-term future (2070 - 2099) (center right) and in the SSP5-8.5 scenario in the short-term future (2020-2039) (bottom left), medium-term future (2040-2069) (center bottom), and long-term future (2070 - 2099) (bottom right).

Source: Own elaboration.

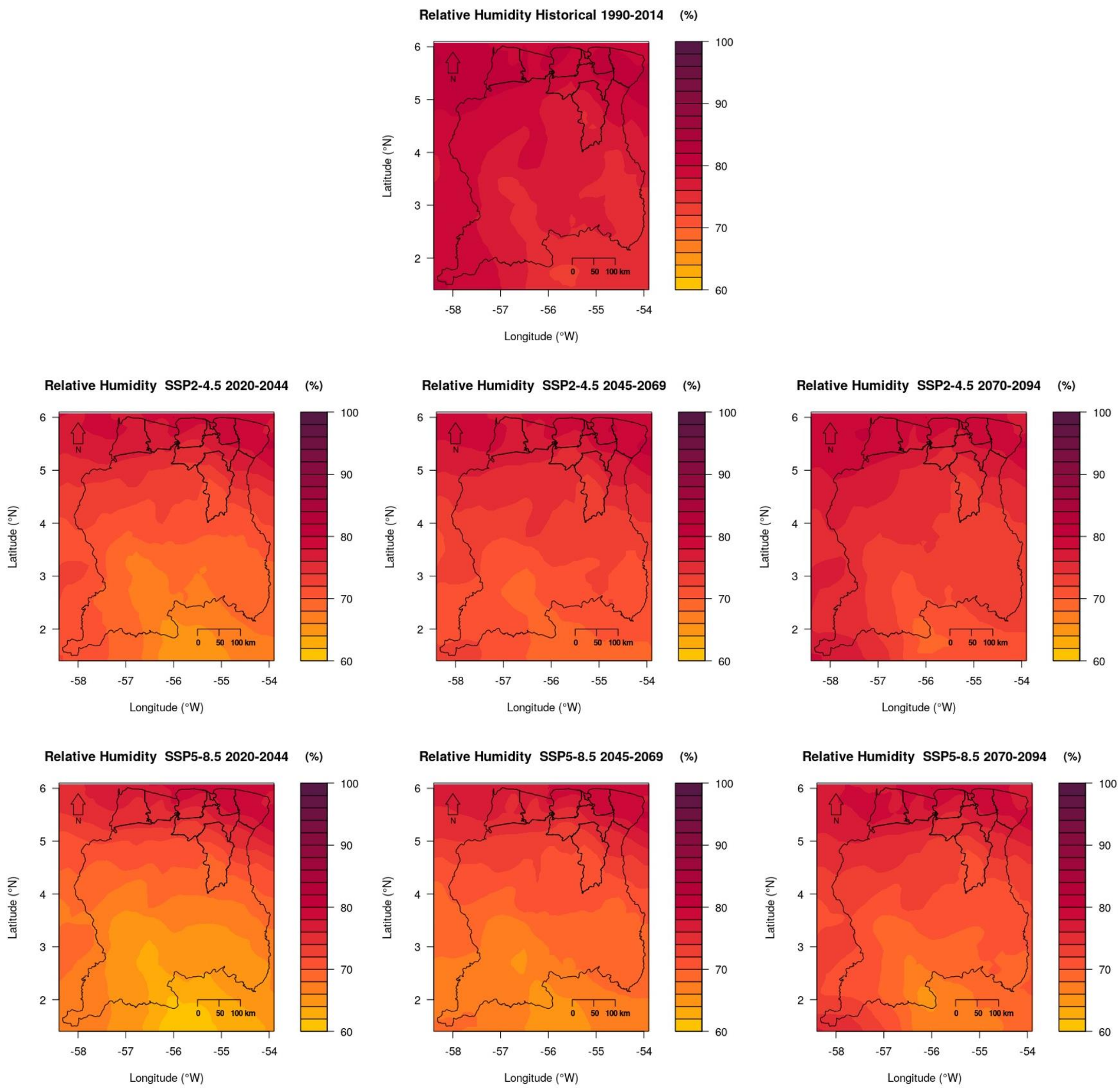
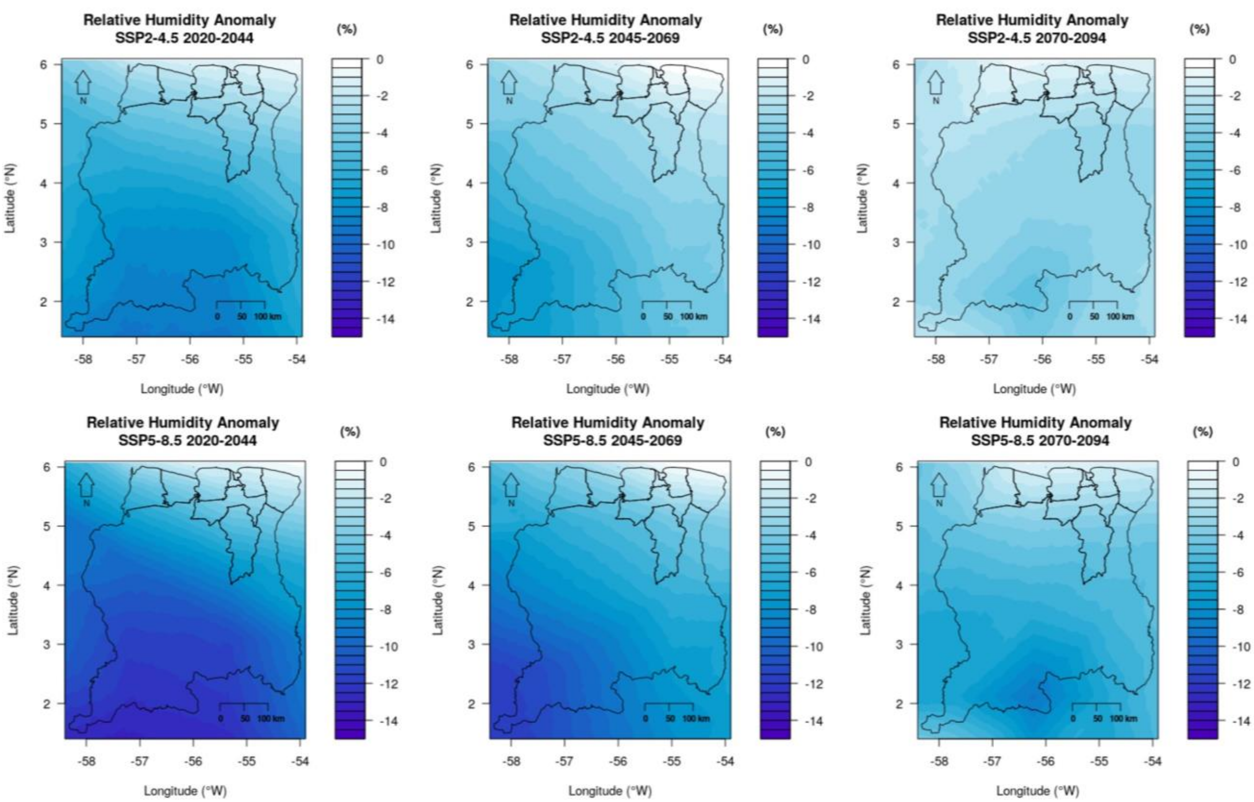


Figure 44: Average relative humidity anomalies (each period mins the historical period (1990-2014)) for climate projection of the average mean temperature in the SSP2-4.5 scenario in the short-term future (2020-2039) (top left), medium-term future (2040-2069) (top center), and long-term future (2070 - 2099) (top right) and in the SSP5-8.5 scenario in the short-term future (2020-2039) (bottom left), medium-term future (2040-2069) (center bottom), and long-term future (2070 - 2099) (bottom right).

Source: Own elaboration.

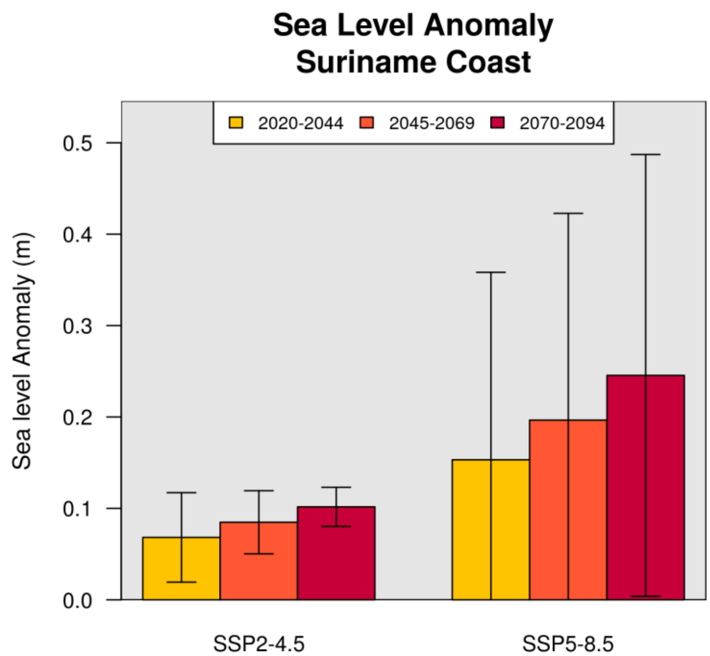


Climate in Suriname is expected to become dryer, in particular in the SSP5-8.5: Relative humidity is very high throughout the country in the observed climatology, and decreases in the first decades in both SSP2-4.5 and SSP5-8.5 scenarios, particularly in the southwest of the country (by up to 14 % in a wide region 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 % to 70 % in the south of Suriname.

3.3.1.5. Sea-level anomaly

Figure 45: Sea level anomaly at the Surinamese coast, for the SSP2-4.5 and SSP5-8.5 scenarios in the short-term (2020-2039), medium-term (2039-2060) and long-term (2070-2094) future. Error bars represent the standard deviation for each scenario and period.

Source: Own elaboration.



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

3.3.2. Local analysis

For the local study, the ERA5 reanalysis data has been used to analyze the current climate for each point of interest. Using the multi-model technique and applying the Q-Q statistical adjustment at the location of each point of interest the future projections of all variables for each time horizon and the two scenarios were computed, in addition to their variation with respect to the current climate.

3.3.2.1. Climographs

Climographs for each point of interest and period (short-term, medium, and long-term futures) were developed, with both scenarios in each panel. These graphs allow to study future changes in monthly precipitation and mean temperature, which are fundamental to classify climate regimes.

Figure 46: Climographs for Paramaribo showing the monthly mean temperature and monthly accumulated precipitation during the historical period (1990-2014) and in the scenarios SSP2-4.5 (light blue bars and orange lines) and SSP5-8.5 (blue bars and red lines) in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099) periods.

Source: Own elaboration.

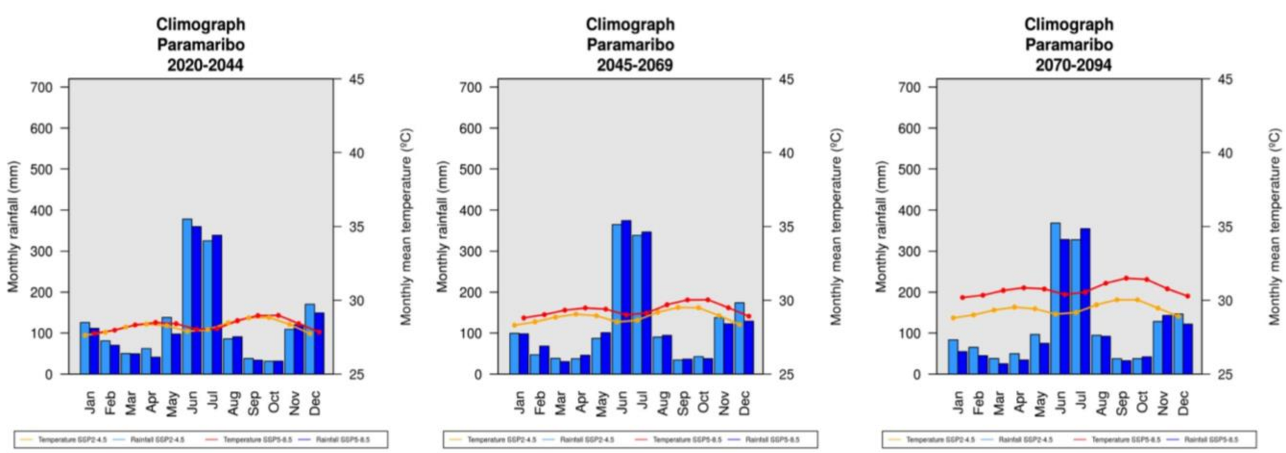


Figure 47: Climographs for Albina, BigiPanMUMA and Brokopondo showing the monthly mean temperature and monthly accumulated precipitation during the historical period (1990-2014) and in the scenarios SSP2-4.5 (light blue bars and orange lines) and SSP5-8.5 (blue bars and red lines) in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099) periods.

Source: Own elaboration.

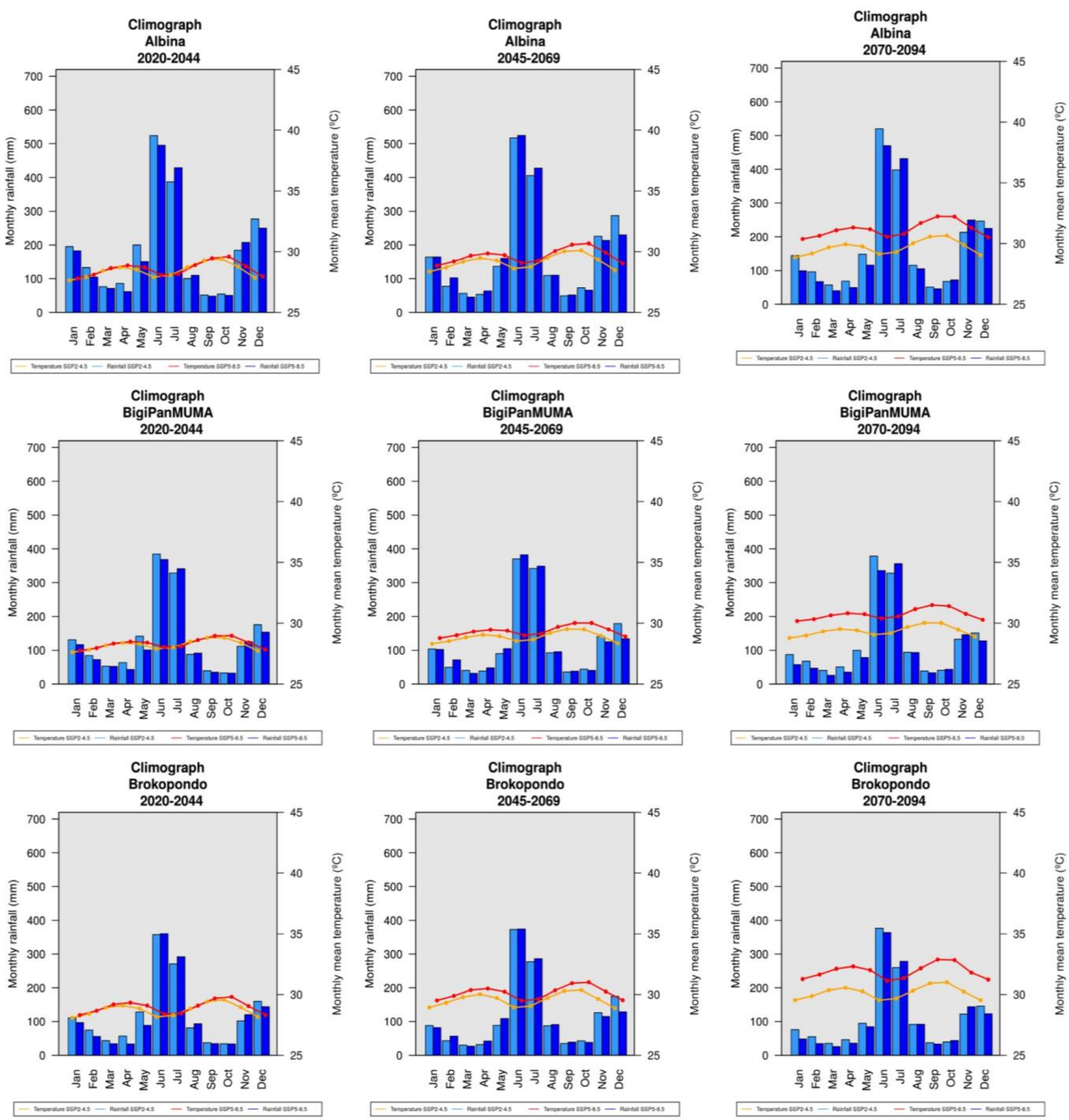
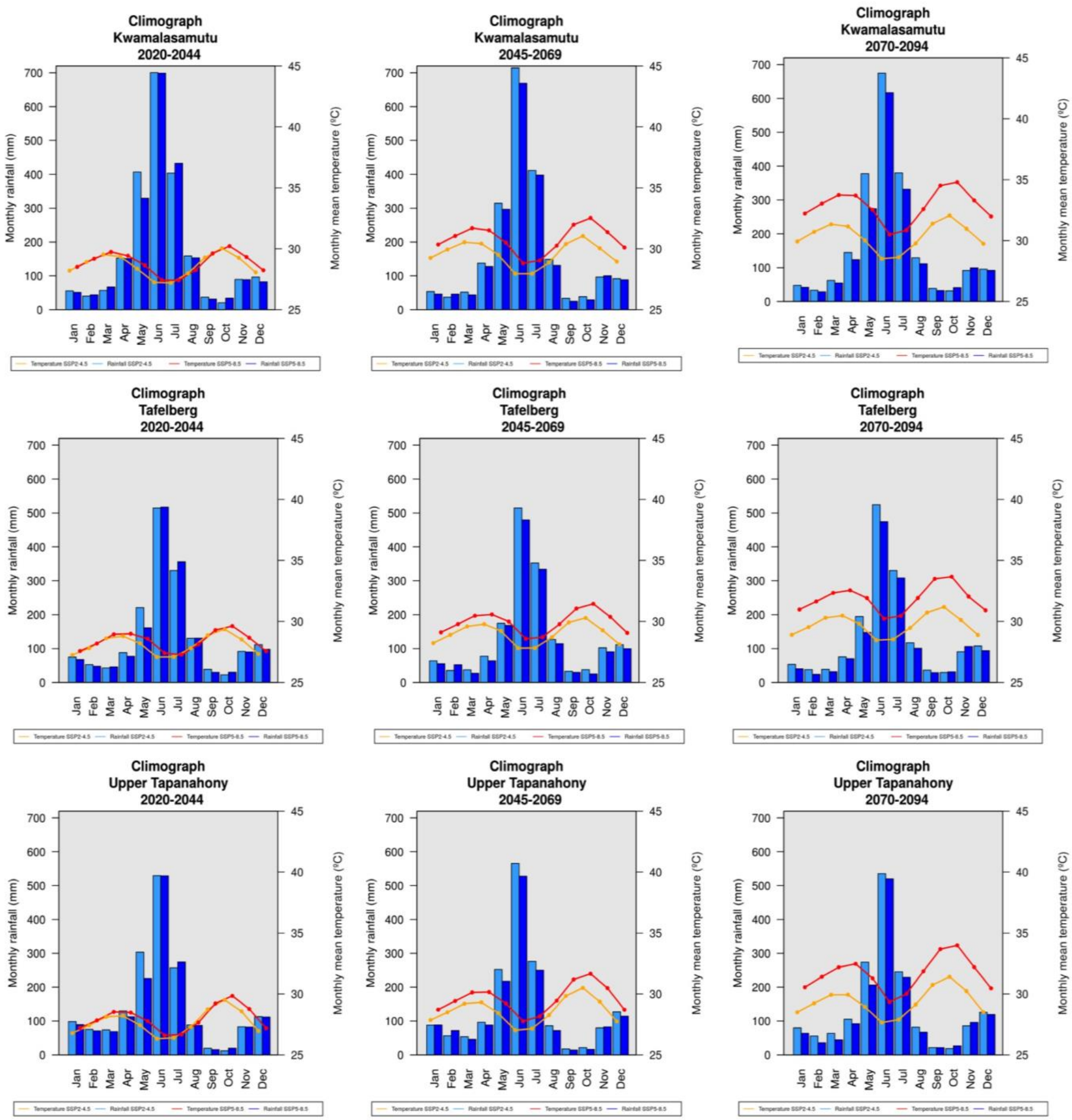


Figure 48: Climographs for Kwamalasamutu, Tafelberg and Upper Tapanahony showing the monthly mean temperature and monthly accumulated precipitation during the historical period (1990-2014) and in the scenarios SSP2-4.5 (light blue bars and orange lines) and SSP5-8.5 (blue bars and red lines) in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099) periods.

Source: Own elaboration.



Figures 46-48 show the climographs for the seven points of interest for the current climate or historical period (1990-2014), the short-term future (2020-2039), the medium-term future (2040-2069) and the long-term future (2070-2099). The mean temperature and precipitation accumulation variables for SSP2-4.5 and SSP5-8.5 are shown in each climograph.

As was pointed out previously, climate regimes in Suriname go from the two wet and two dry seasons of the coastal region (Paramaribo, Albina, BigiPanMUMA) to only two seasons, one rainy and one dry, in the southern part of the country (Kwamalasamutu and Upper Tapanahony, mainly). Climographs show that this regime is expected to persist in most points, and both for the SSP2-4.5 and SSP5-8.5 scenarios. Temperatures are expected to increase in both scenarios (more so in SSP5-8.5) throughout the 21lst century, but the general behaviour (cooler temperatures between December and February, and then between June and July depending on the region, and two temperature maximums between March and April and between September and October) is expected to hold.

However, an important main takeaway from these figures is that the rainy season is expected to get rainier in all scenarios and timeframes, and dry seasons are expected to become drier. In some cases, such as Tafelberg and Upper Tapanahony, the beginning of the wet season (January to April) is expected to become very dry. The two-seasons regime will become a four-season distribution, similar to what is seen now on the northern coast. This is a consequence of the intertropical convergence zone becoming narrower: The effect of the tropical rain belt is expected to be much more focused in a few months.

3.3.2.2. Average annual regimes

In this section, changes in future climate regimes are studied for each point of interest with line plots of mean, maximum and minimum temperature for each period and climate scenario (top row of each figure), distribution of rain episodes (no rain, weak rain, moderate rain, heavy and very heavy rain) in each period and scenario, and distribution of wind speeds (moderate, strong, gale, storm and hurricane) throughout the year in each period and scenario. Gale wind, storms and hurricanes are shown at different scale as they present very small values. Historical values are shown for wind and rain, but not for temperature, for the sake of not including too much information in each panel.

Figure 49: Annual average regimes for precipitation and wind for Paramaribo, for the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099).

Source: Own elaboration.

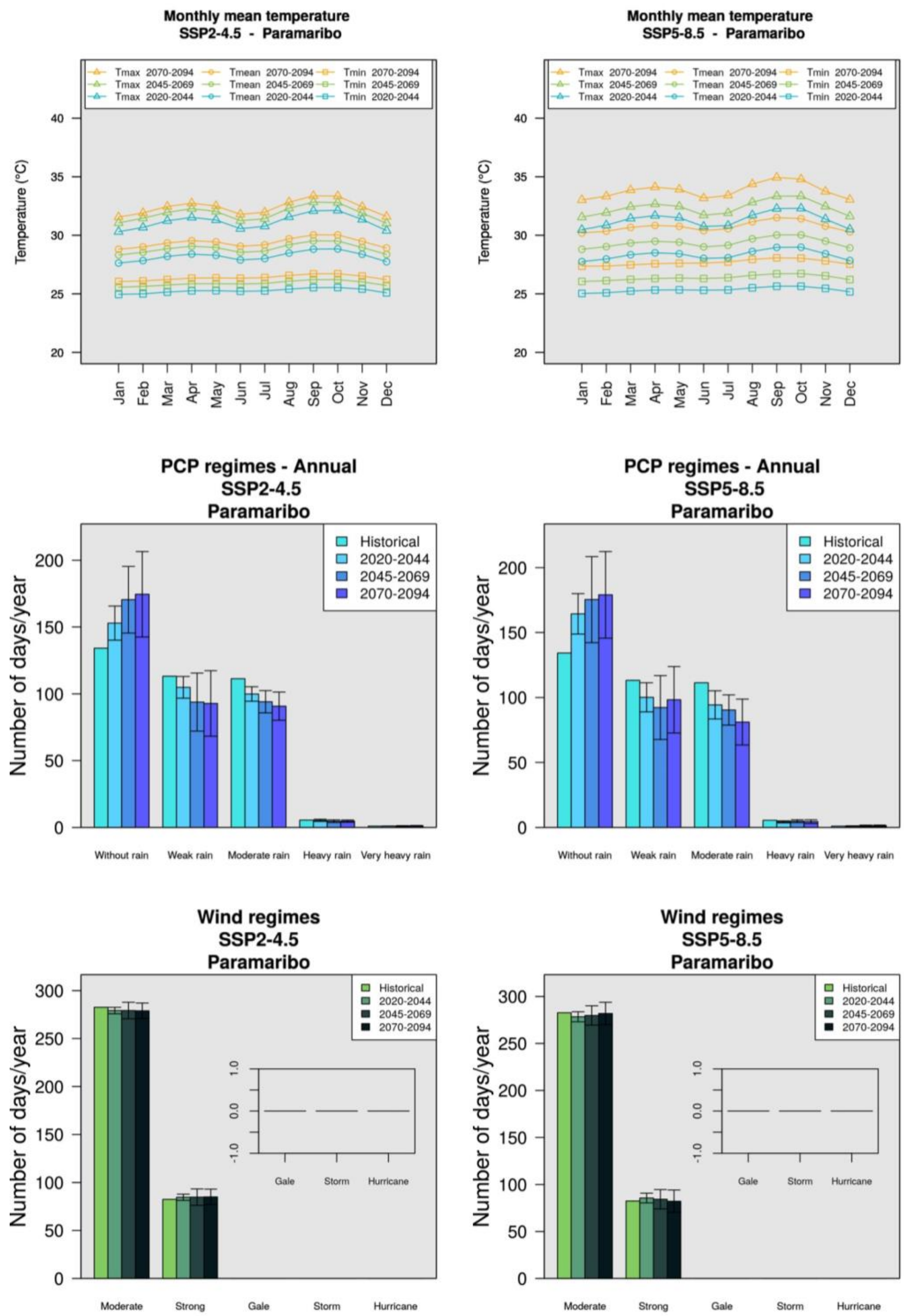


Figure 50: Annual average regimes for precipitation and wind for Albina, for the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099).

Source: Own elaboration.

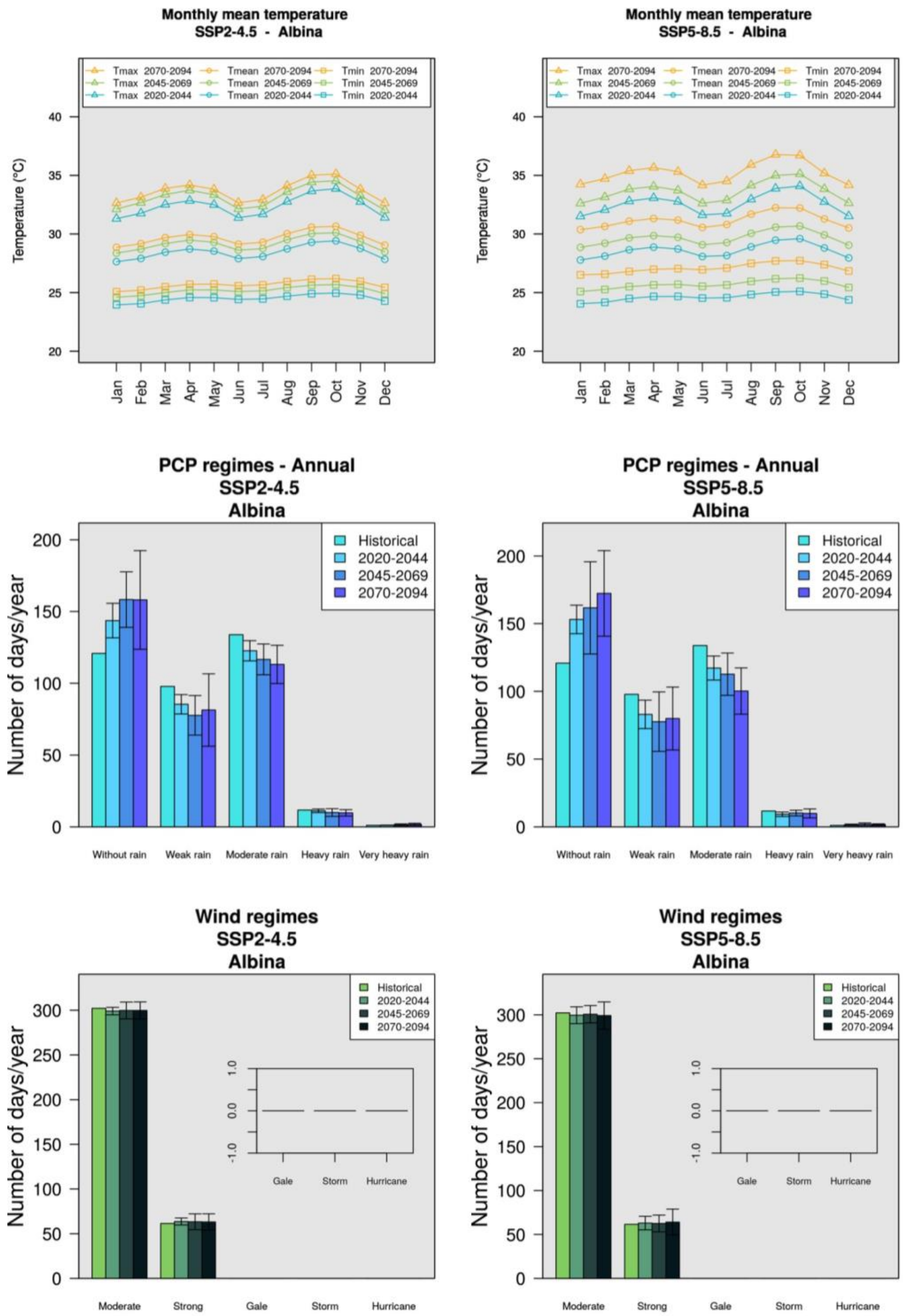


Figure 51: Annual average regimes for precipitation and wind for BigiPanMUMA, for the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099).

Source: Own elaboration.

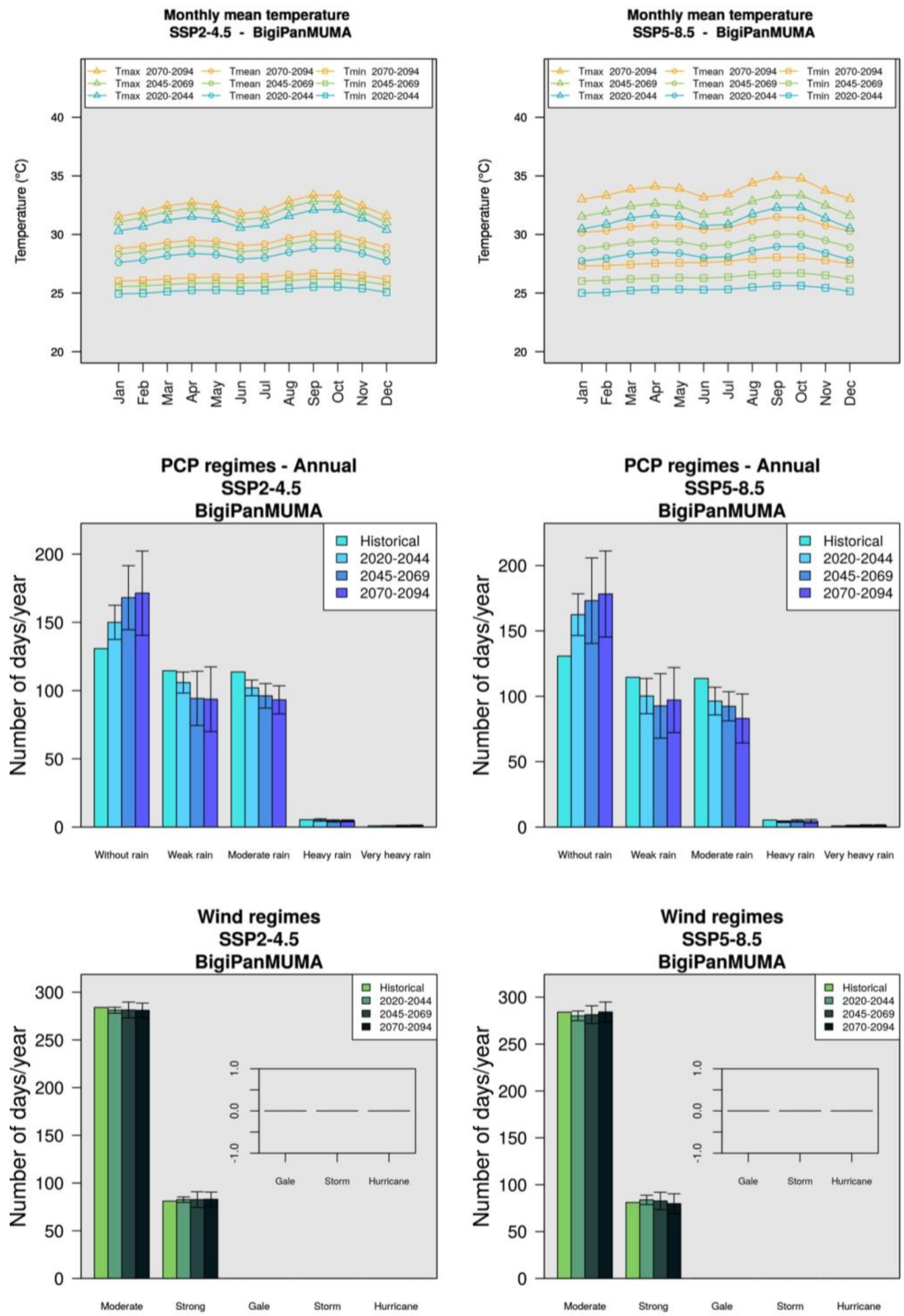


Figure 52: Annual average regimes for precipitation and wind for Brokopondo for the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099).

Source: Own elaboration.

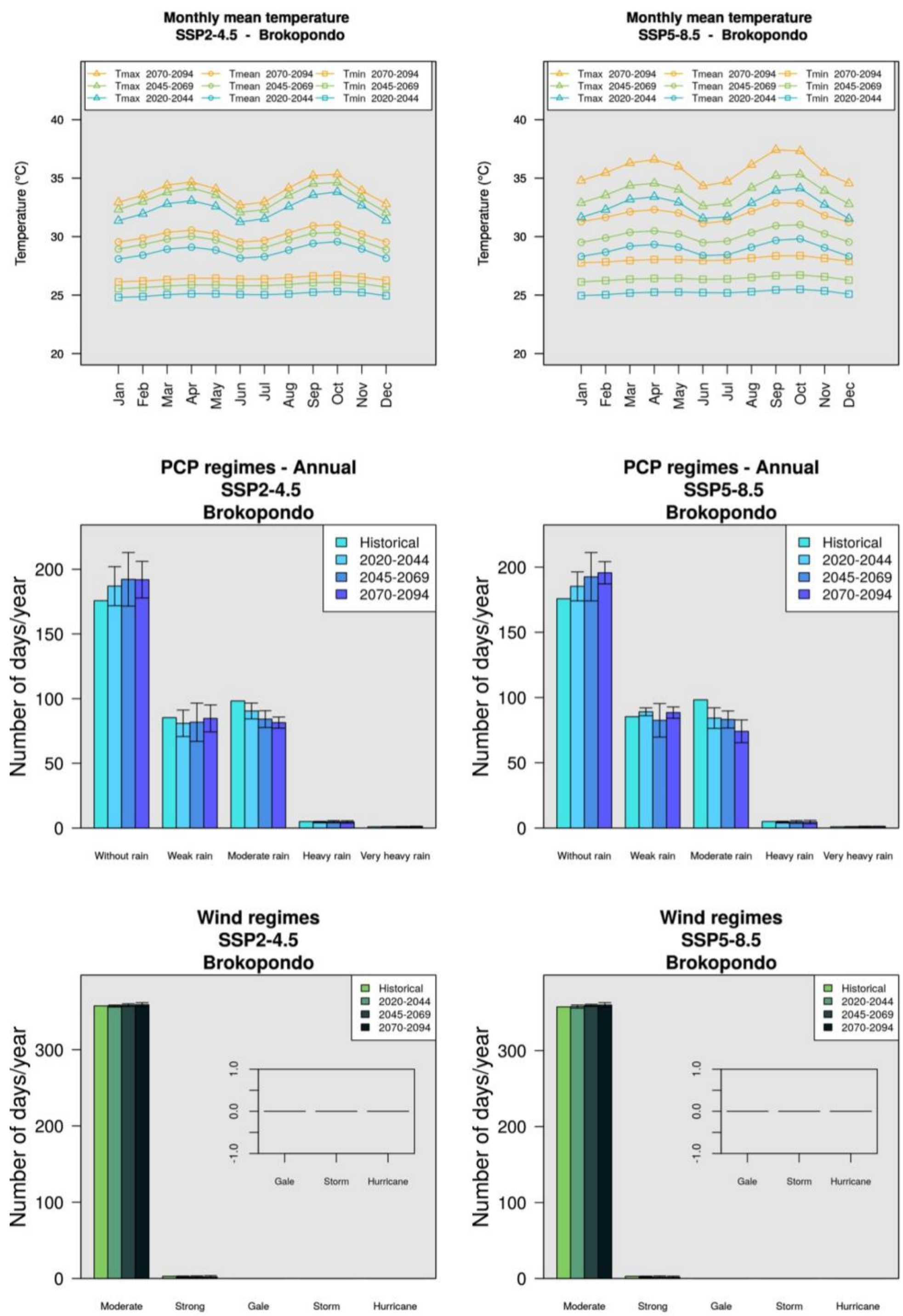


Figure 53: Annual average regimes for precipitation and wind for Kwamalasamutu, for the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099).

Source: Own elaboration.

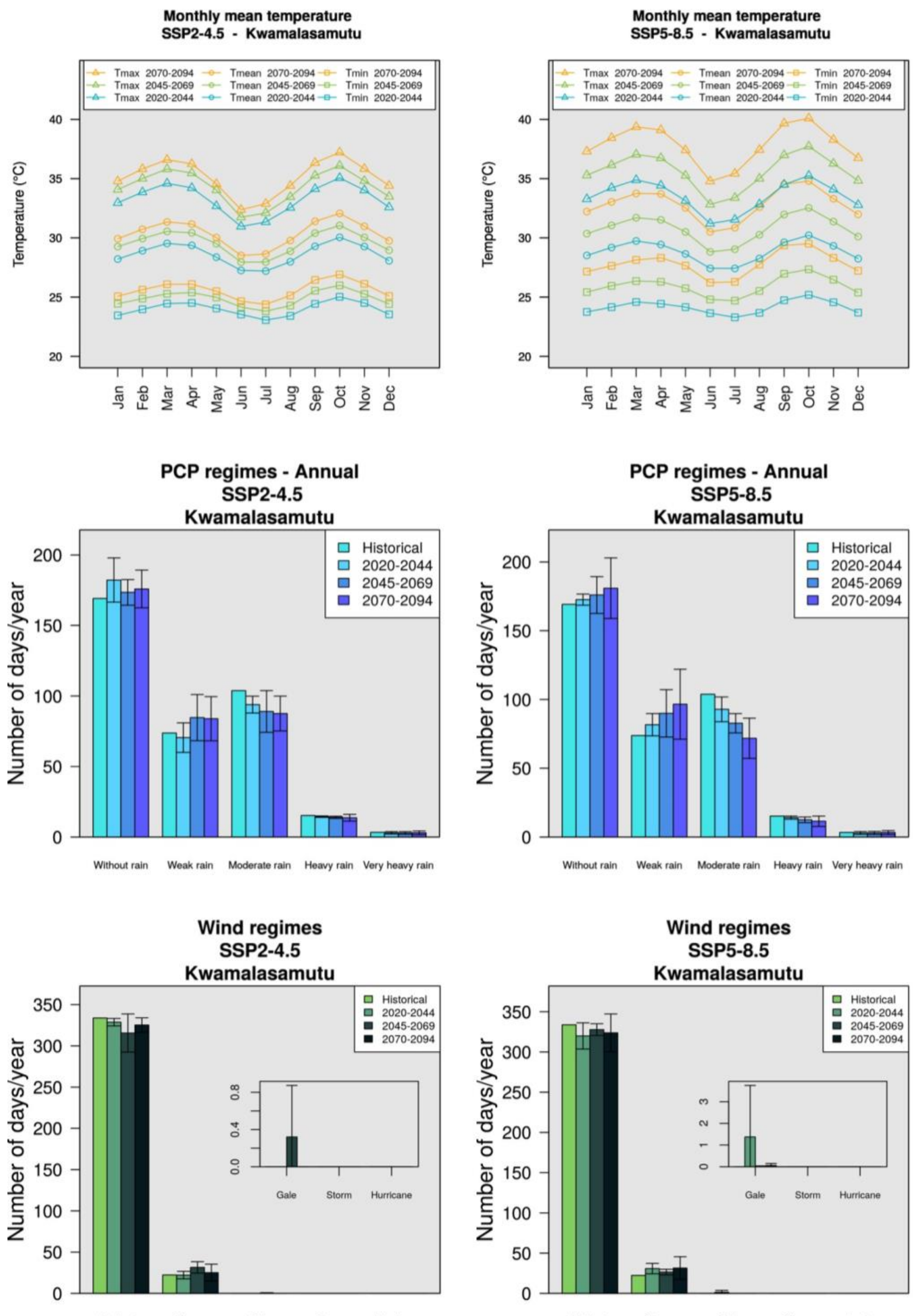


Figure 54: Annual average regimes for precipitation and wind for Tafelberg, for the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099).

Source: Own elaboration.

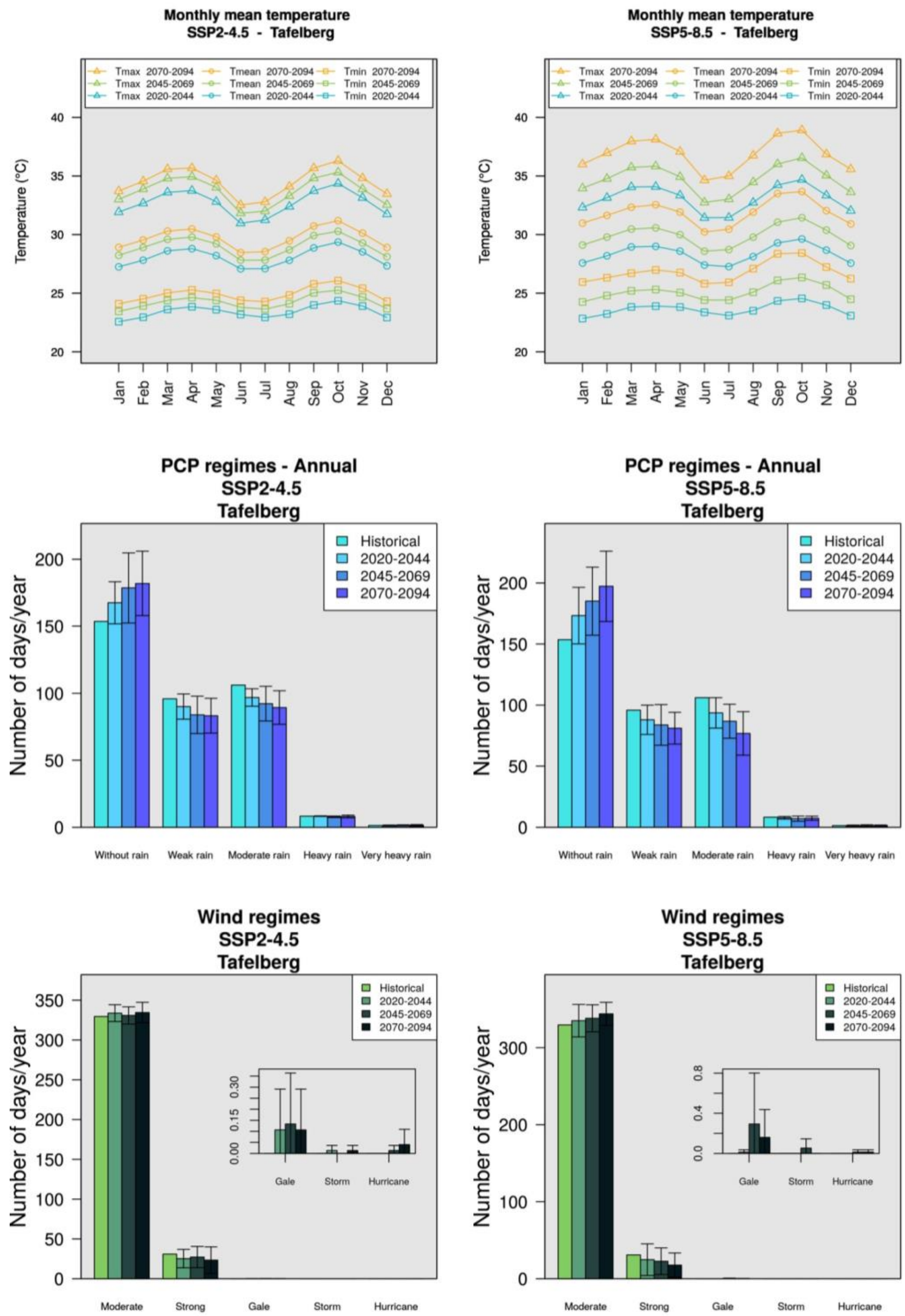


Figure 55: Annual average regimes for precipitation and wind for Upper Tapanahony, for the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099).

Source: Own elaboration.

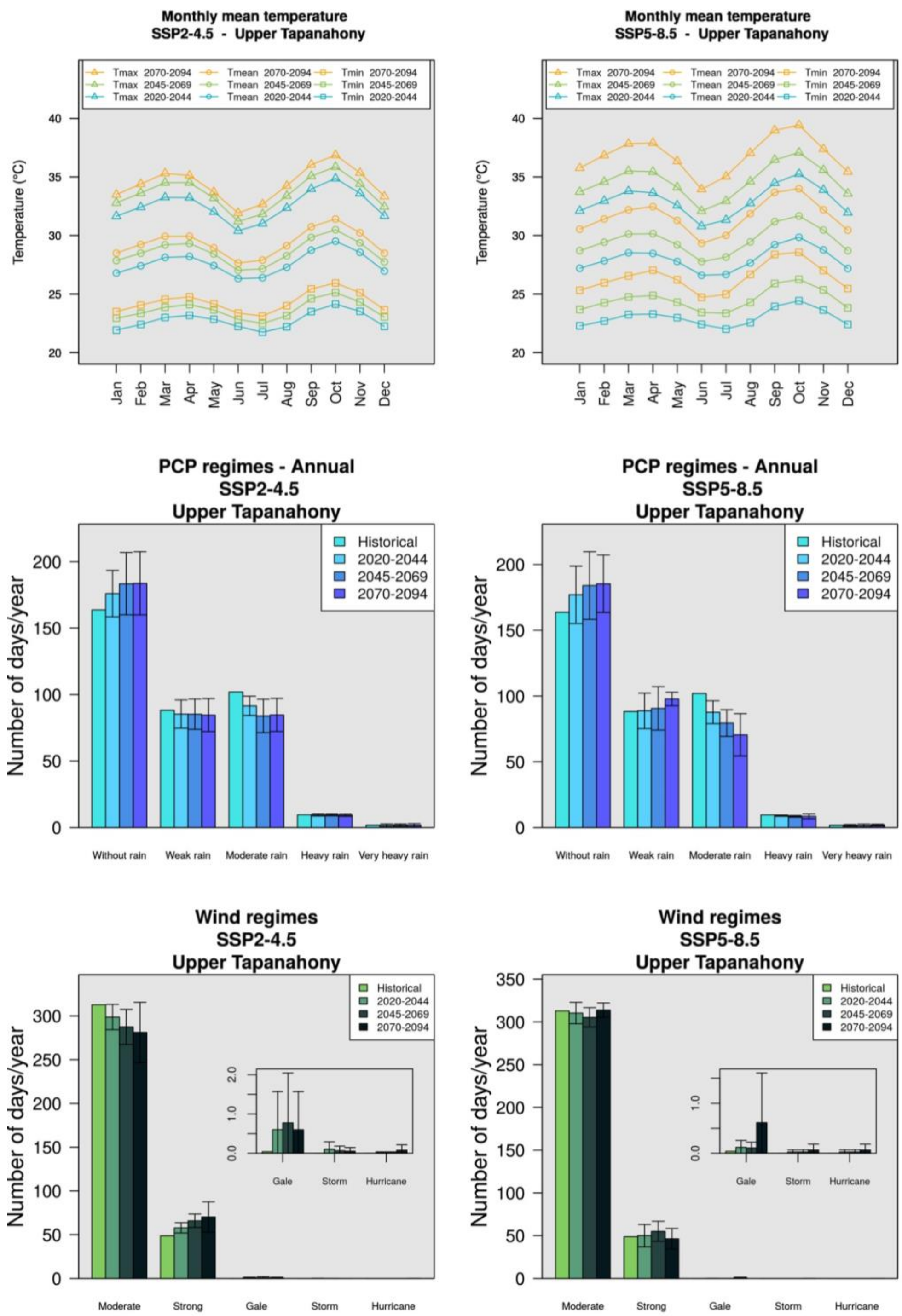


Table 41: Mean values for each variable of interest in each scenario and period in Paramaribo. Source: Own elaboration.

Variables	1990-2014	2020-2039		2040-2069		2070-2099	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Max. temperature (°C)	30.2	31.2	31.3	31.9	32.4	32.4	33.8
Mean temperature (°C)	27.3	28.2	28.3	28.9	29.4	29.4	30.7
Min. temperature(°C)	24.4	25.3	25.3	25.9	26.4	26.4	27.7
Accumulated precipitation (mm/y)	1,756	1,596	1,496	1,493	1,486	1,476	1,350
Maximum wind (km/h)	26.3	36.1	36.2	36.3	36.3	36.4	36.6

Table 42: Mean values for each variable of interest in each scenario and period in Albina. Source: Own elaboration.

Variables	1990-2014	2020-2039		2040-2069		2070-2099	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Max. temperature (°C)	31.4	32.4	32.6	33.1	33.6	33.7	35.2
Mean temperature (°C)	27.5	28.4	28.6	29.2	29.7	29.7	31.2
Min. temperature(°C)	23.6	24.5	24.6	25.2	25.7	25.7	27.1
Accumulated precipitation (mm/y)	2,470	2,270	2,161	2,156	2,160	2,128	1,970
Maximum wind (km/h)	23.2	34.5	34.6	34.6	34.6	34.7	34.9

Table 43: Mean values for each variable of interest in each scenario and period in BigiPanMUMA. Source: Own elaboration.

Variables	1990-2014	2020-2039		2040-2069		2070-2099	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Max. temperature (°C)	30.2	31.2	31.3	31.9	32.3	32.4	33.8
Mean temperature (°C)	27.3	28.2	28.3	28.9	29.3	29.4	30.7
Min. temperature(°C)	24.4	25.2	25.3	25.9	26.4	26.4	27.7
Accumulated precipitation (mm/y)	1,796	1,633	1,531	1,525	1,522	1,510	1,379
Maximum wind (km/h)	26.2	36.1	36.2	36.2	36.2	36.3	36.5

Table 44: Mean values for each variable of interest in each scenario and period in Brokopondo Source: Own elaboration.

Variables	1990-2014	2020-2039		2040-2069		2070-2099	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Max. temperature (°C)	31.2	32.4	32.7	33.3	33.9	33.9	35.8
Mean temperature (°C)	27.6	28.7	28.9	29.6	30.1	30.1	31.9
Min. temperature(°C)	24.1	25.1	25.2	25.8	26.4	26.4	28
Accumulated precipitation (mm/y)	1,556	1,457	1,387	1,397	1,387	1,379	1,306
Maximum wind (km/h)	14.6	29.9	30	30	30	30.1	30.3

Table 45: Mean values for each variable of interest in each scenario and period in Kwamalasamutu.

Source: Own elaboration.

Variables	1990-2014	2020-2039		2040-2069		2070-2099	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Max. temperature (°C)	31.6	33.2	33.5	34.3	35.6	35.1	37.8
Mean temperature (°C)	27.1	28.6	28.8	29.6	30.8	30.4	32.8
Min. temperature(°C)	22.7	24	24.2	24.9	25.9	25.6	27.8
Accumulated precipitation (mm/y)	2,392	2,219	2,166	2,130	2,002	2,108	1,849
Maximum wind (km/h)	17.5	31.5	31.6	31.8	31.9	31.9	32.2

Table 46: Mean values for each variable of interest in each scenario and period in Tafelberg.

Source: Own elaboration.

Variables	1990-2014	2020-2039		2040-2069		2070-2099	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Max. temperature (°C)	31.2	32.7	33.1	33.7	34.7	34.5	36.9
Mean temperature (°C)	26.7	28.1	28.4	29	29.9	29.7	31.8
Min. temperature(°C)	22.2	23.4	23.6	24.2	25.1	24.9	26.8
Accumulated precipitation (mm/y)	1,852	1,718	1,651	1,667	1,541	1,634	1,458
Maximum wind (km/h)	21.5	33	33.2	33.3	33.3	33.3	33.5

Table 47: Mean values for each variable of interest in each scenario and period in Upper Tapanahony.

Source: Own elaboration.

Variables	1990-2014	2020-2039		2040-2069		2070-2099	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
Max. temperature (°C)	31.1	32.5	33	33.6	34.6	34.4	36.8
Mean temperature (°C)	26.7	27.6	28	28.6	29.6	29.3	31.6
Min. temperature(°C)	21.5	22.7	23	23.6	24.5	24.3	26.4
Accumulated precipitation (mm/y)	1,926	1,782	1,686	1,718	1,588	1,692	1,520
Maximum wind (km/h)	22.8	34	34.1	34.3	34.4	34.4	34.5

The previous figures show 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: In the SSP2-4.5 scenario, temperatures are expected to increase by more than 0.3°C per decade in Tafelberg, Upper Tapanahony and Kwamalasamutu. This increase rises to 0.5°C 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.

Annual precipitation regimes throughout Suriname are projected to change similarly in that the days without rain are expected to increase everywhere. Mean accumulated precipitation decreases in all points of interest and by more than a 20 % in the locations in the south of the country for SSP5-8.5 by the end of the century.

Almost for all timeframes, and for both climate scenarios, all locations in Suriname will have more dry days. This is more evident for the far future and for the coastal points of interest, but can also be observed in the interior and for the next decades. Depending on the location, however, episodes of weak and moderate rain are expected to decrease (Paramaribo, Albina, BigiPanMUMA, Brokopondo, Tafelberg) or increase (weak events in Kwamalasamutu). Extreme events might also increase in Kwamalasamutu, Albina or BigiPanMUMA.

Wind regime is expected to change much less: There is almost no change at all in the wind regime for Brokopondo, Paramaribo, Albina, Kwamalasamutu and BigiPanMUMA. Tafelberg shows little change, with the exception of hurricane force winds, which become slightly more likely in this location, and in Uppwe Tapanahony there is an increase in strong winds while moderate winds become slightly rarer. Average mean wind speed, however, shows an increase in all projections and periods, for all locations, but it does not change over time (the increase is very similar for the near-term future than for the long-term future and in both scenarios). This, together with the not very reliable decreasing trend in wind speed shown in the present climate assessment makes a strong case for taking these results with some caution.

3.3.2.3. Seasonal precipitation regimes

The following figures show how accumulated precipitation for each season is expected to change in each scenario (left, SSP2-4.5, right, SSP5-8.5) and period. The distribution of precipitation along the year is as important as the total amount of precipitation received, so a detailed study is required.

Figure 56: Seasonal accumulated precipitation regime for Paramaribo, for the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099).

Source: Own elaboration.

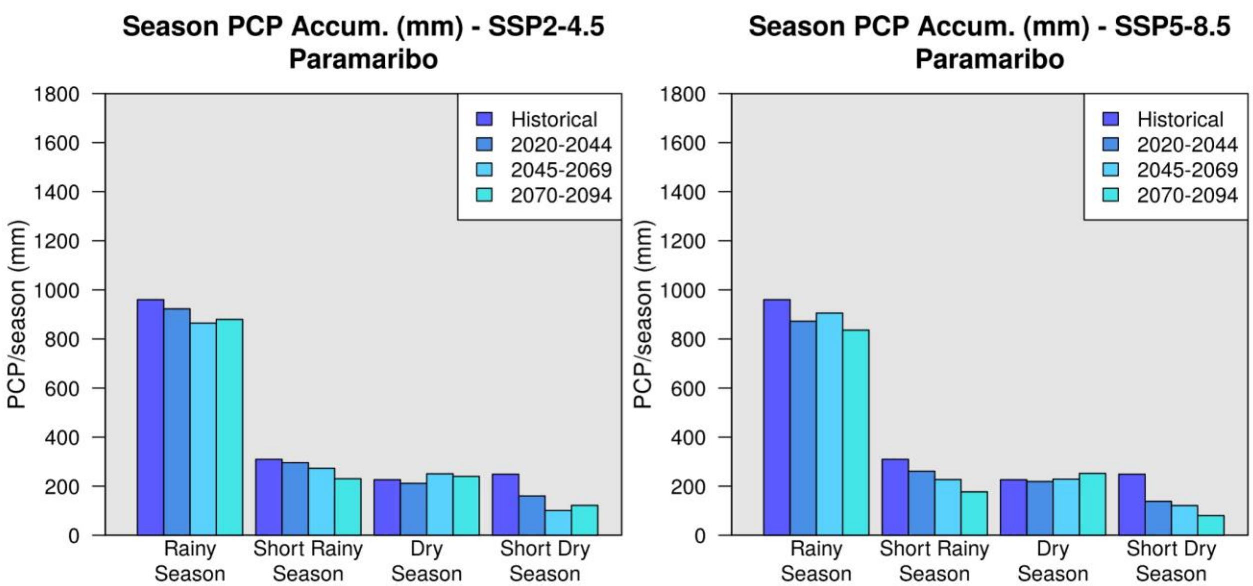


Figure 57: Seasonal accumulated precipitation regime for Albina, for the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099).

Source: Own elaboration.

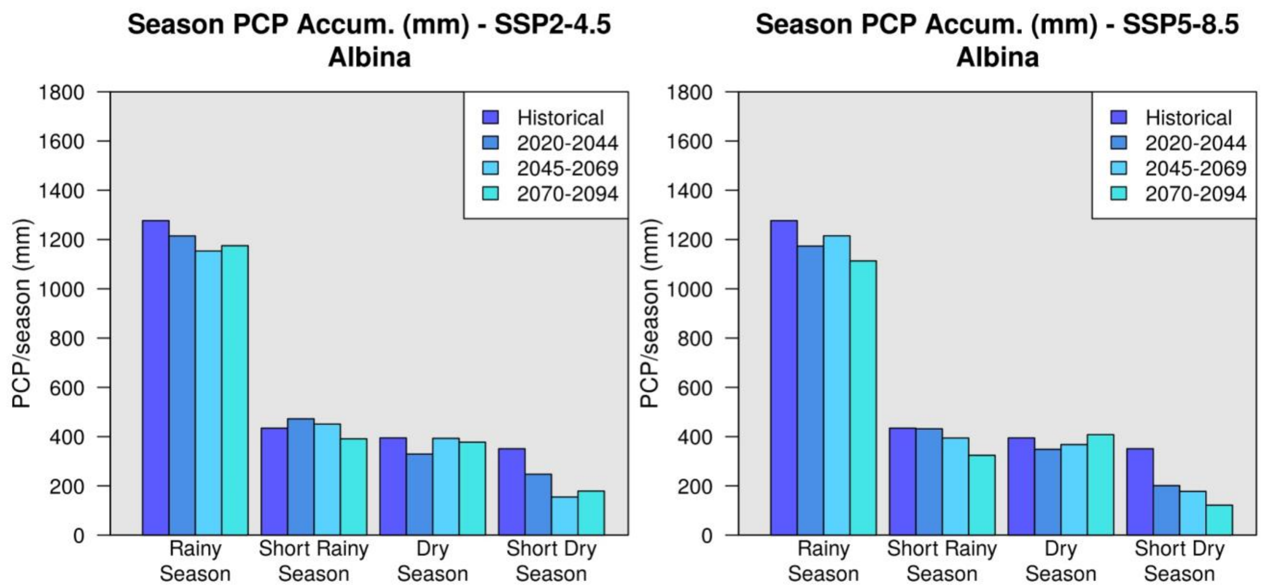


Figure 58: Seasonal accumulated precipitation regime for BigiPanMUMA, for the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099).Source: Own elaboration.

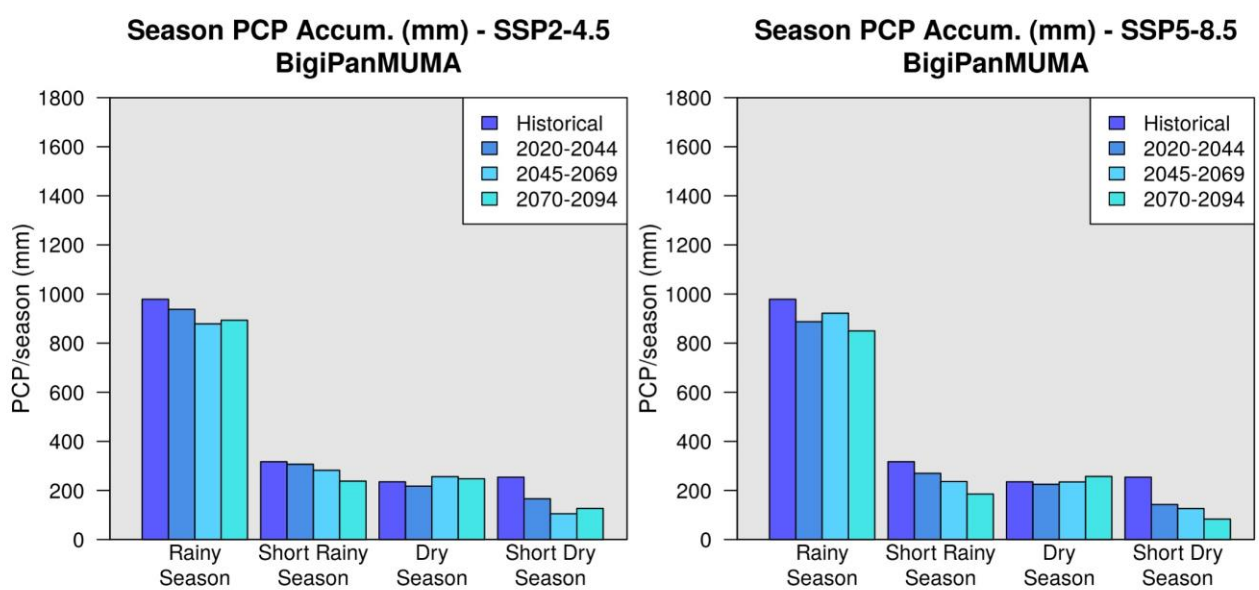


Figure 59: Seasonal accumulated precipitation regime for Brokopondo, for the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099).

Source: Own elaboration.

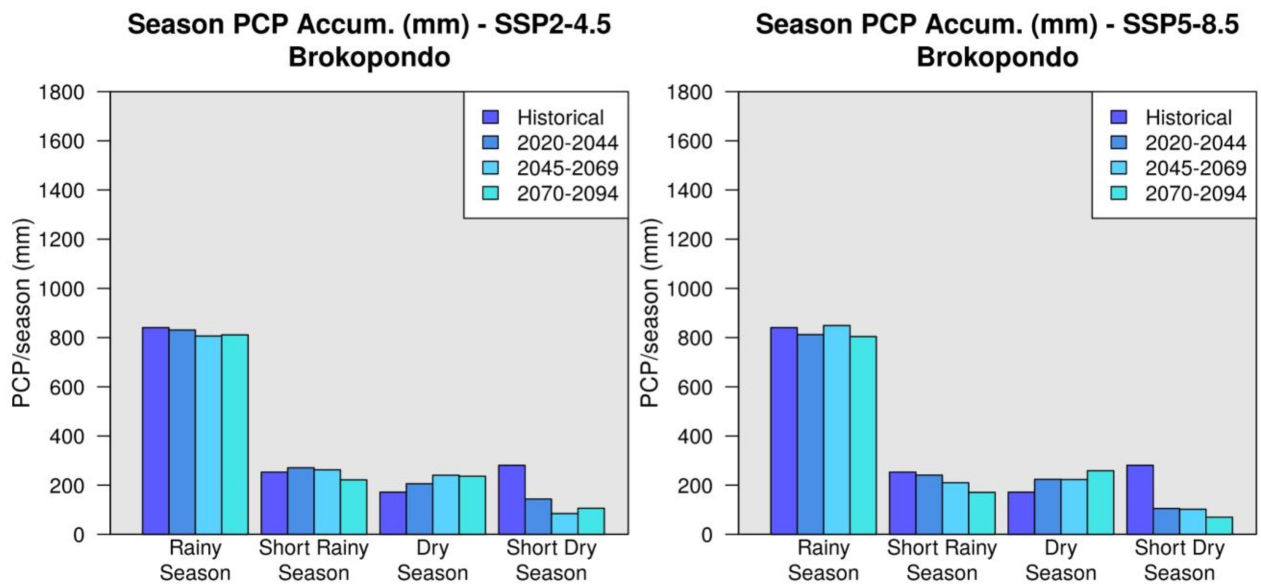


Figure 60: Seasonal accumulated precipitation regime for Kwamalasamutu, for the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099).Source: Own elaboration.

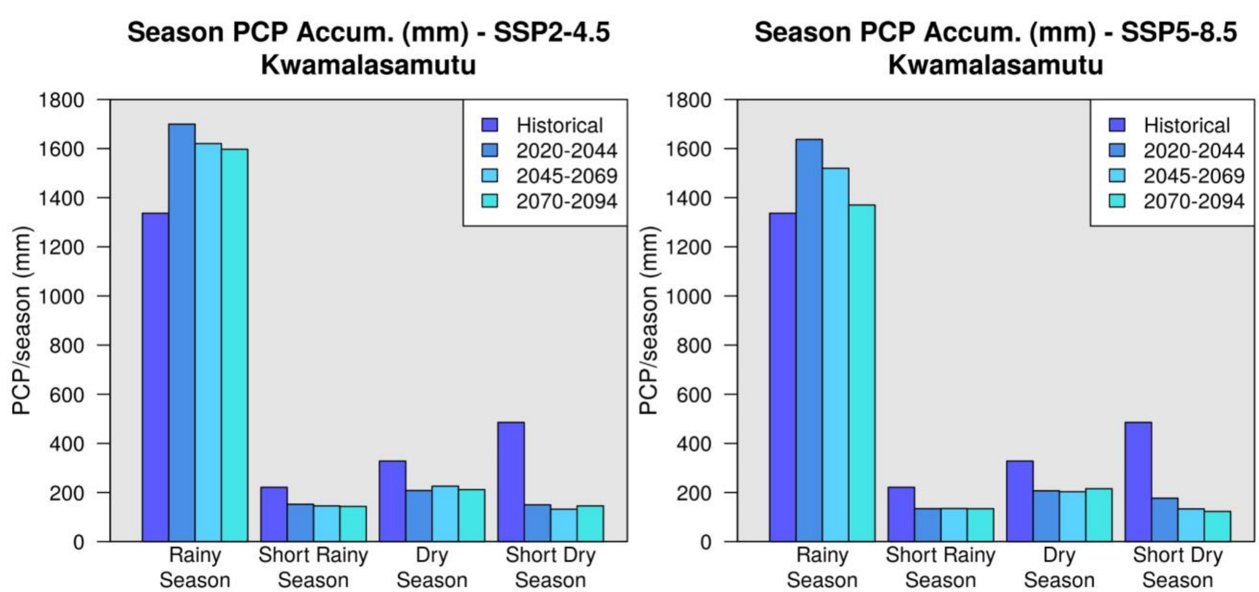


Figure 61: Seasonal accumulated precipitation regime for Tafelberg, for the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099).Source: Own elaboration.

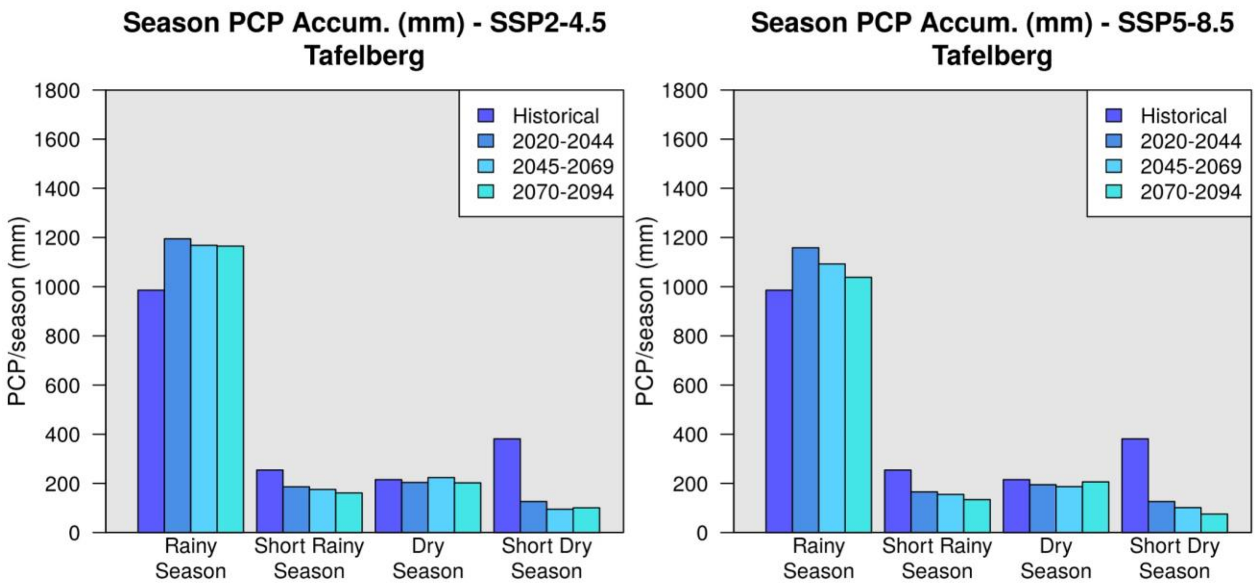
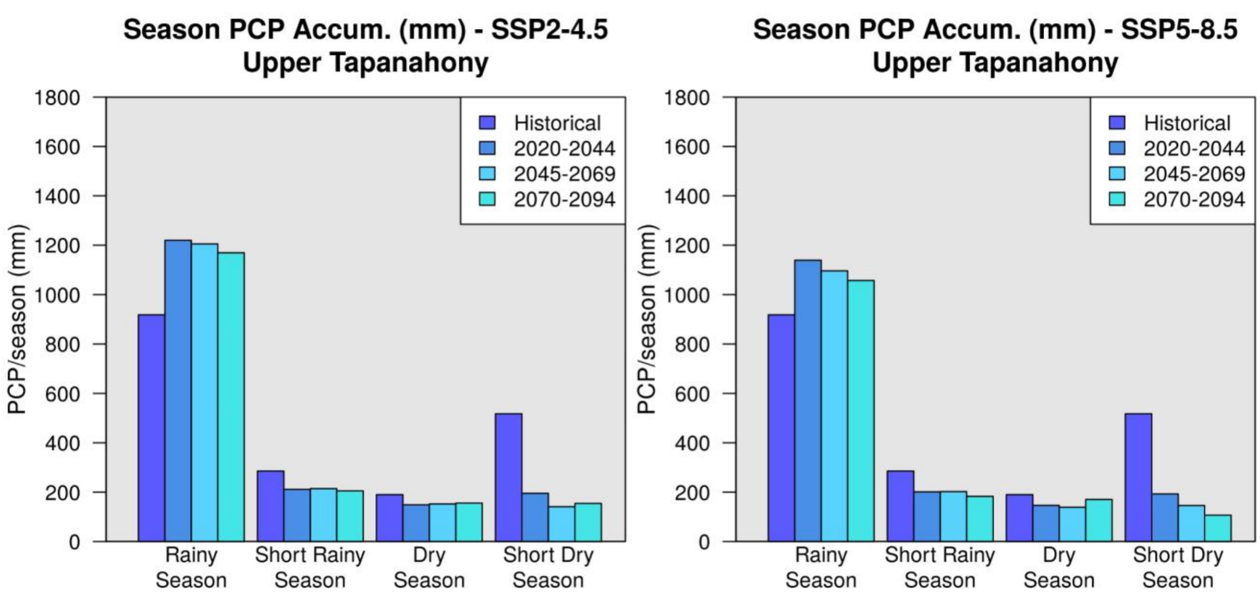


Figure 62: Seasonal accumulated precipitation regime for Upper Tapanahony, for the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the short-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 - 2099).

Source: Own elaboration.



Model projection show more than a few changes in the seasonal distribution of precipitation: For the northermost locations (Paramaribo, Albina, Brokopondo and BigiPanMUMA) total precipitation is expected to decrease, in particular that of the short dry season, and also that of the rainy season. However, the dry season shows a small increase in precipitation for these locations, which points to a displacement of seasons, as was advanced previously in regards to the climographs: the intertropical convergence zone is expected to narrow, which diminishes the length of time it affects 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 short rainy and short dry seasons become much drier in both scenarios and for all timeframes. Meanwhile, the rainy season becomes rainier. The intertropical convergence zone 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 going to shift in time.

3.3.2.4. Climate indices

The climate indices chosen (table 3) are important to assess the probability of extreme events. Here we show indices related to two variables: Temperature and precipitation. Gale winds, storms and hurricanes are not expected to increase in the future, therefore they are not shown.

Climate indices related to temperature are those which show the amount of hot days and nights (days which can be dangerously hot, nights during which sleeping is difficult) and cold days and nights. These last two decrease and almost disappear, and are less important in a tropical climate.

Climate indices related to precipitation are a) yearly rainy days, b) maximum precipitation in 1 day and c) maximum precipitation in 5 days. These two are very important, since torrential rains can cause damage to fields, structures and people.

Figure 63: Future climate indices for Paramaribo. Top row: Hot days and cold days; Center row: cold and hot nights during the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the near-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 -2099). Bottom row: rainy days and maximum precipitation in one and in five days.

Source: Own elaboration.

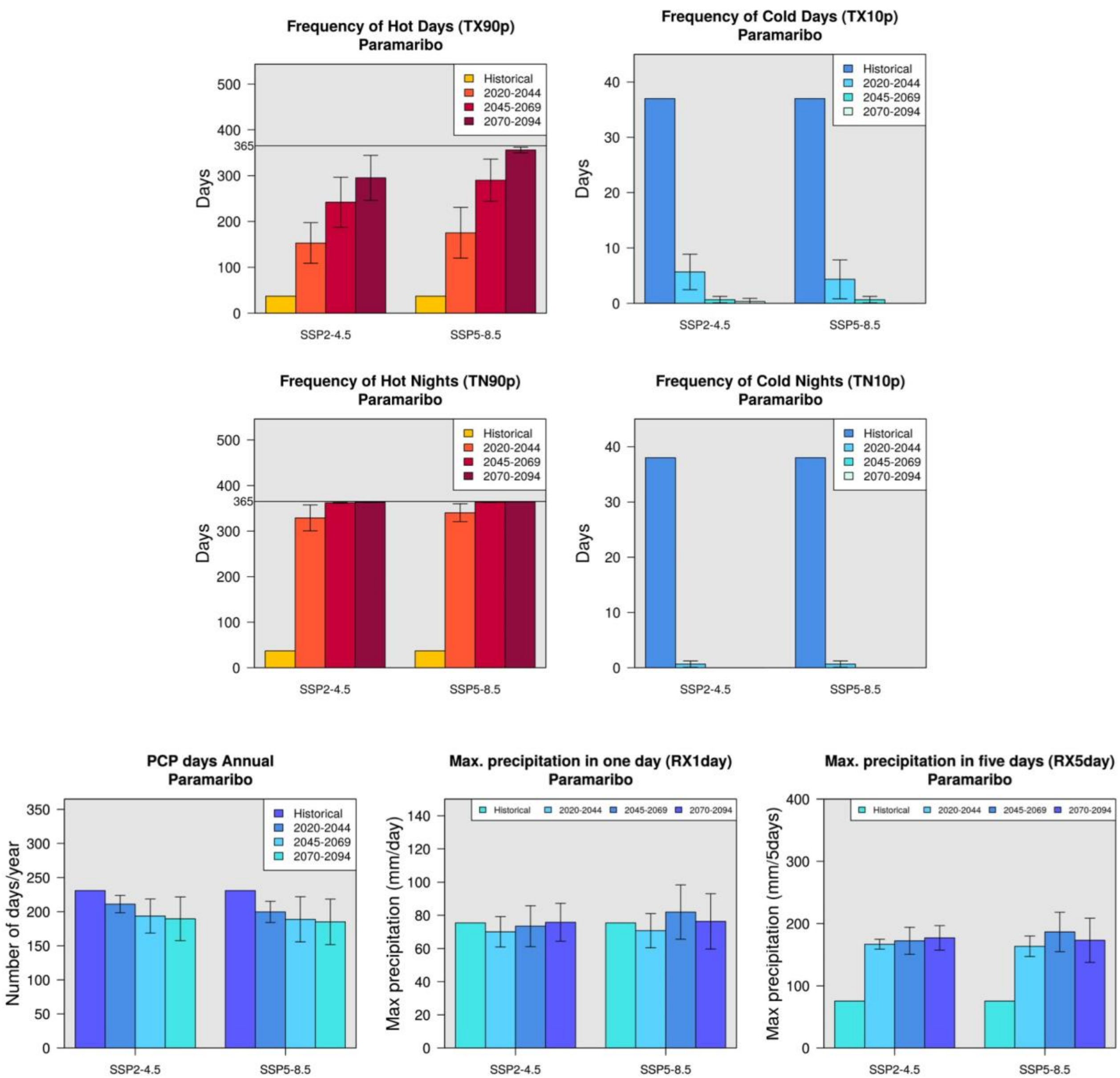


Figure 64: Future climate indices for Albina. Top row: Hot days and cold days; Center row: cold and hot nights during the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the near-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 -2099). Bottom row: rainy days and maximum precipitation in one and in five days.

Source: Own elaboration.

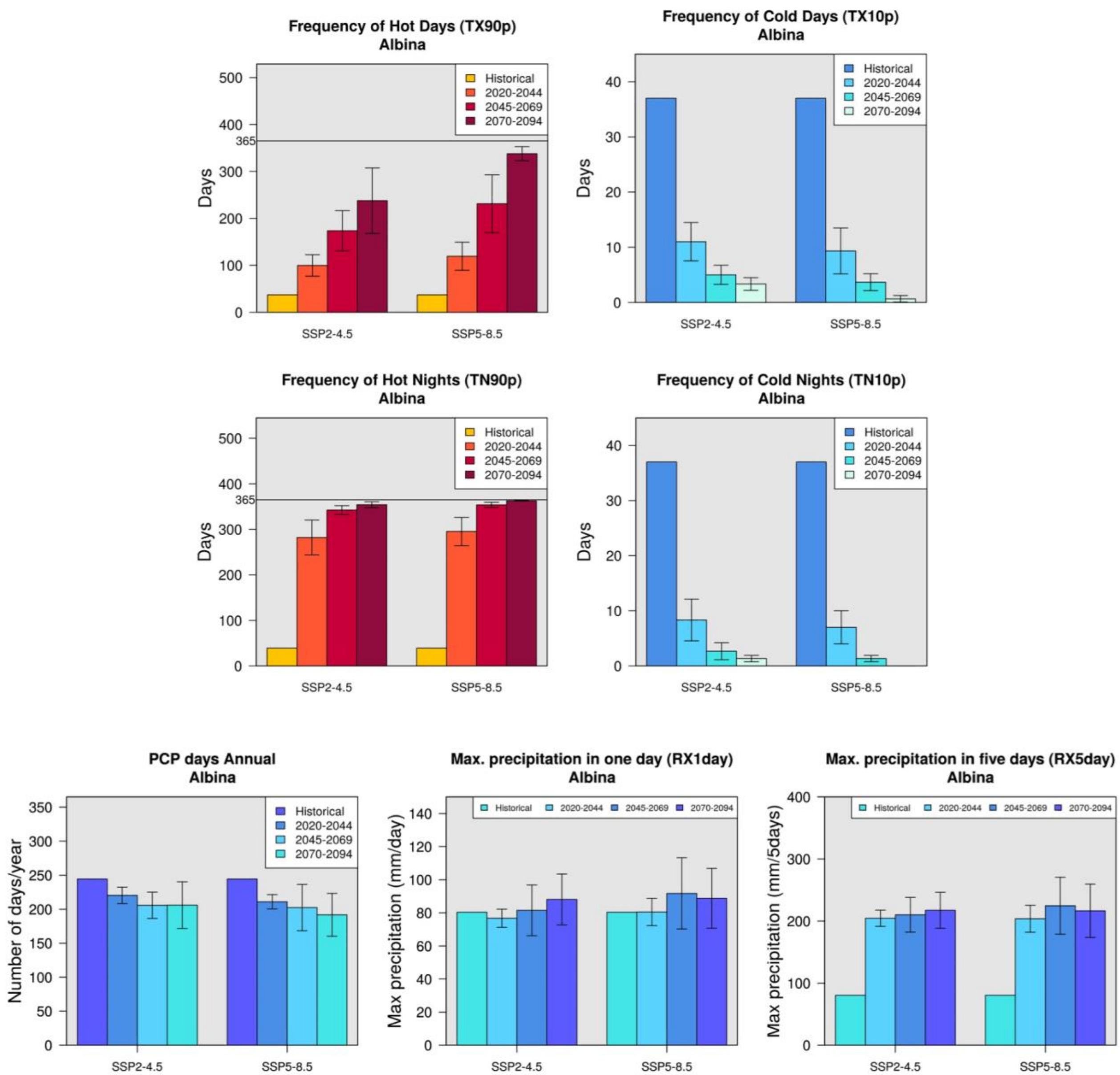


Figure 65: Future climate indices for BigiPanMUMA. Top row: Hot days and cold days; Center row: cold and hot nights during the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the near-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 -2099). Bottom row: rainy days and maximum precipitation in one and in five days.

Source: Own elaboration.

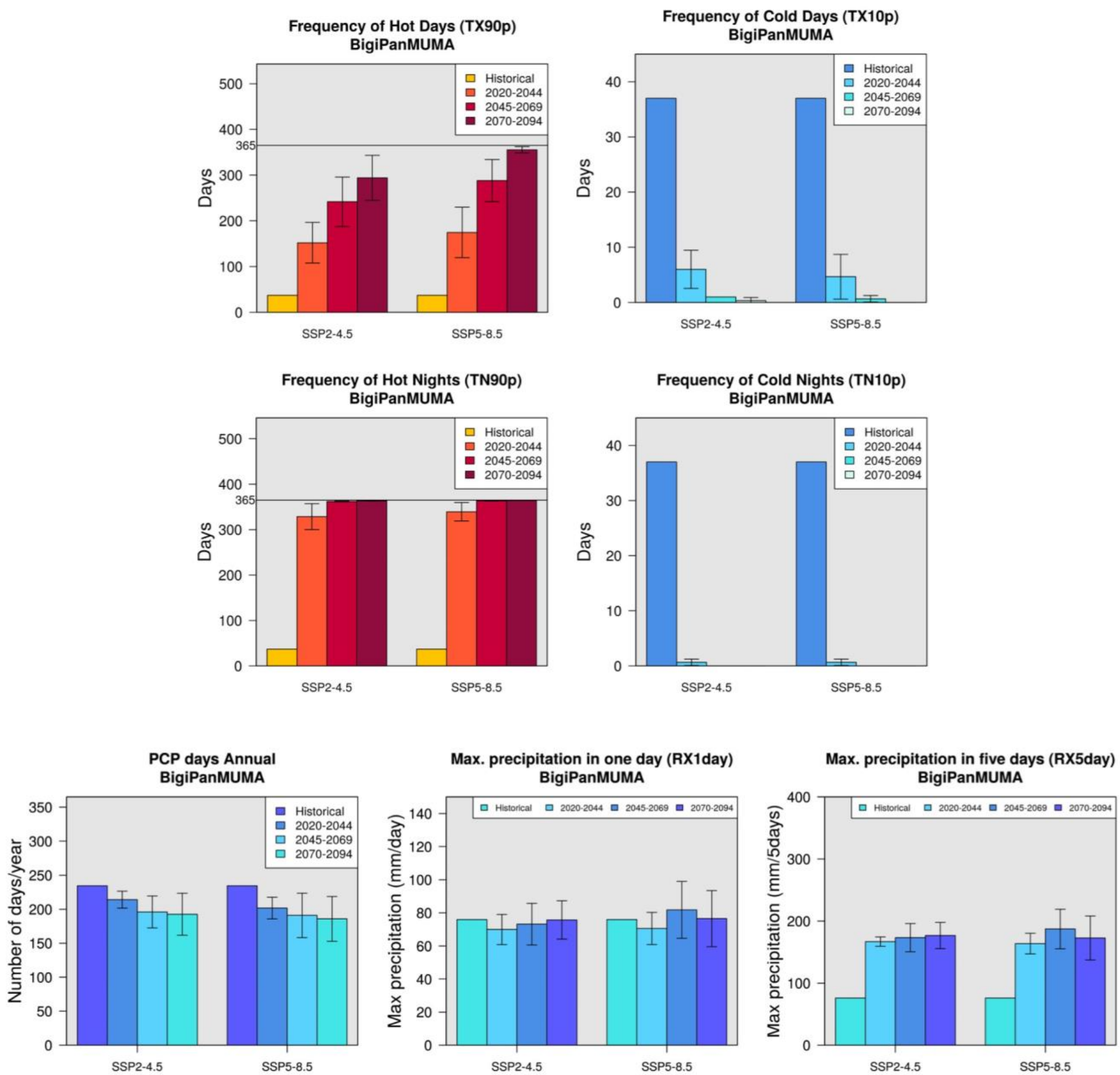


Figure 66: Future climate indices for Brokopondo. Top row: Hot days and cold days; Center row: cold and hot nights during the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the near-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 -2099). Bottom row: rainy days and maximum precipitation in one and in five days.

Source: Own elaboration.

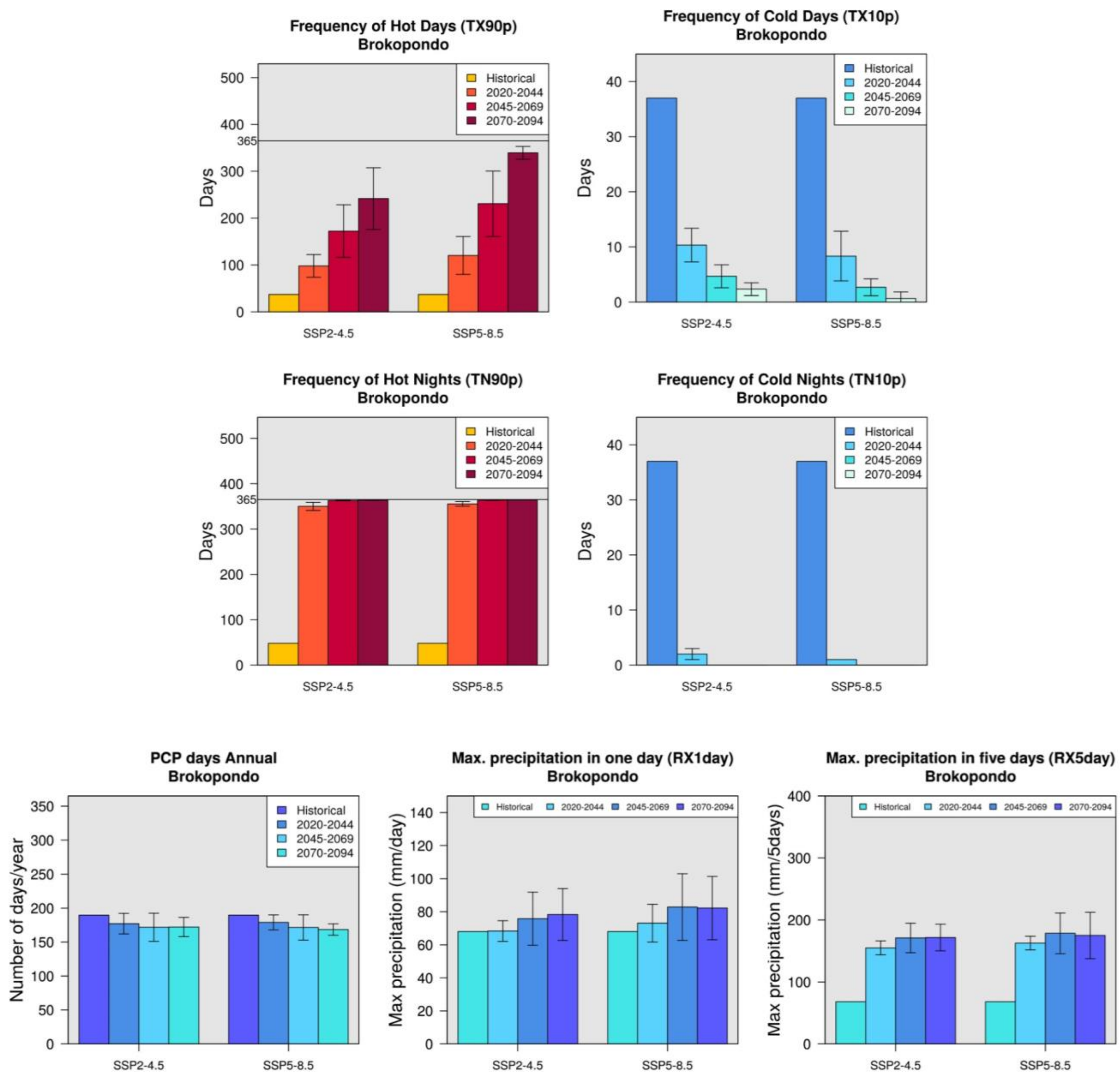


Figure 67: Future climate indices for Kwamalasamutu. Top row: Hot days and cold days; Center row: cold and hot nights during the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the near-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 -2099). Bottom row: rainy days and maximum precipitation in one and in five days.

Source: Own elaboration.

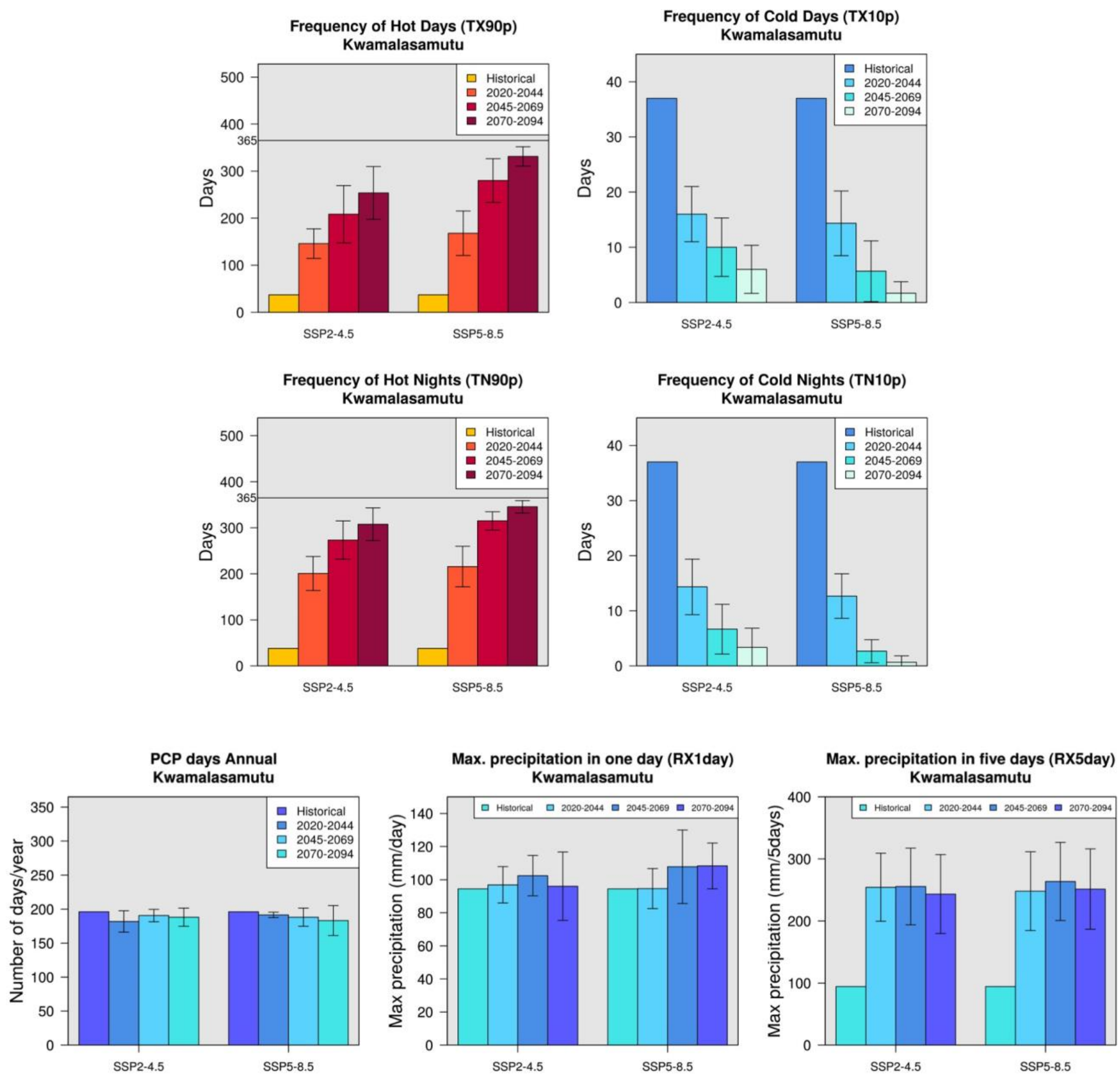


Figure 68: Future climate indices for Tafelberg. Top row: Hot days and cold days; Center row: cold and hot nights during the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the near-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 -2099). Bottom row: rainy days and maximum precipitation in one and in five days.

Source: Own elaboration.

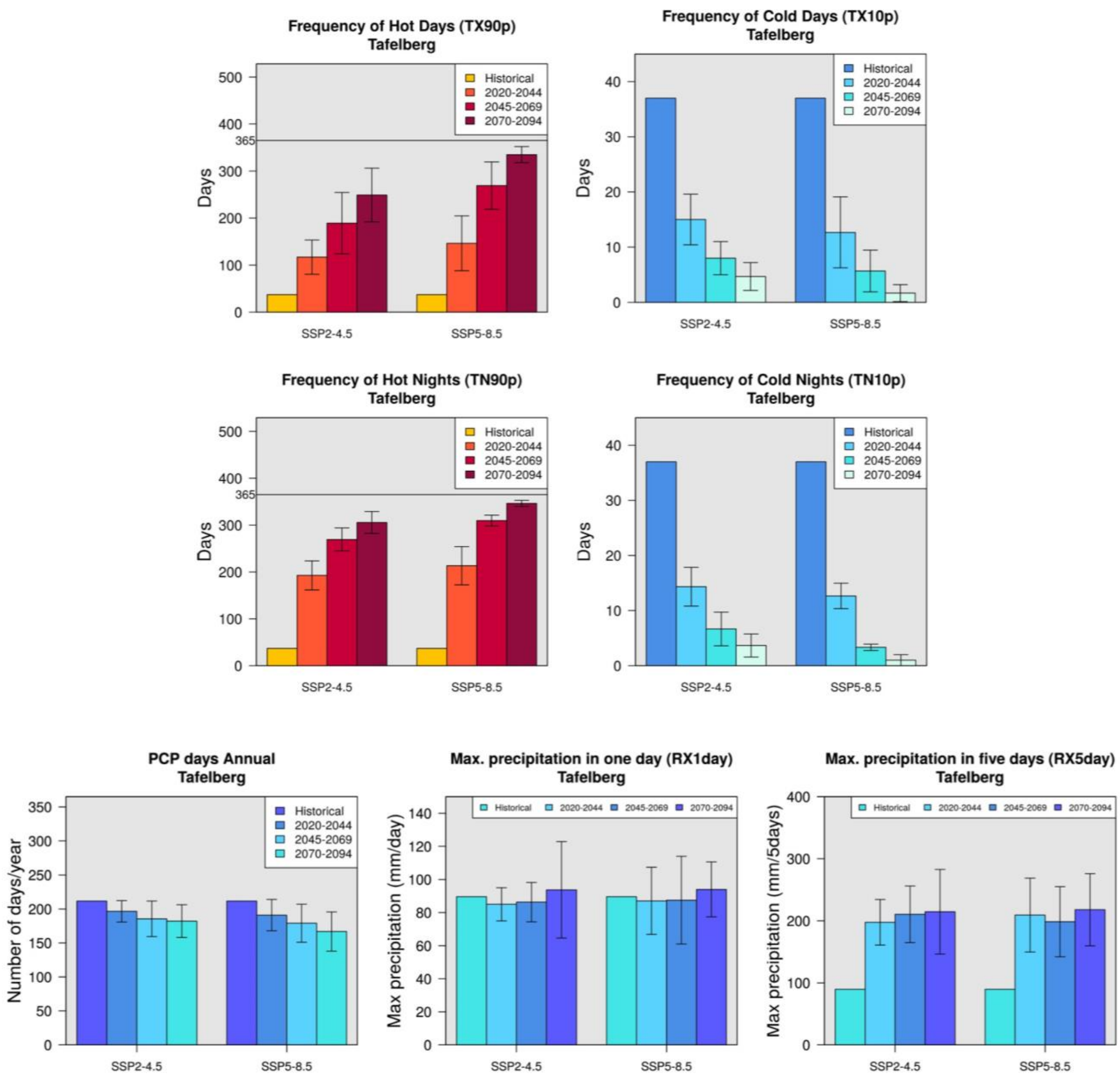
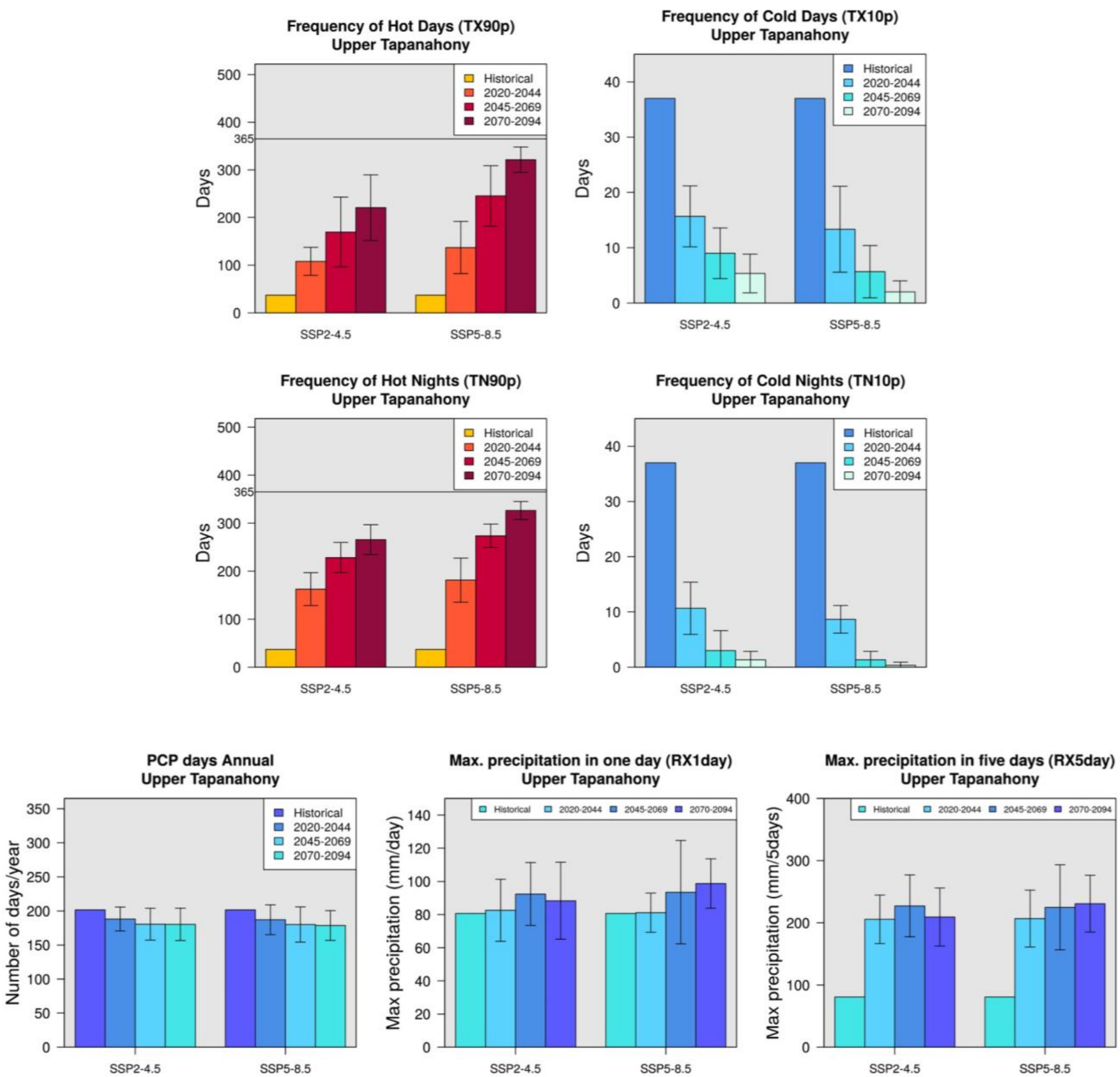


Figure 69: Future climate indices for Upper Tapanahony Top row: Hot days and cold days; Center row: cold and hot nights during the historical period (1990-2014) and climate projection in the SSP2-4.5 and SSP5-8.5 scenarios in the near-term future (2020-2039), medium-term future (2040-2069) and long-term future (2070 -2099). Bottom row: rainy days and maximum precipitation in one and in five days.

Source: Own elaboration.



The results shown in the previous figures are further explored in the following tables, which show the extreme climate indices for each point of interest, period and scenario.

Table 48: Average days of climate indices and variations projected for the indicated periods, obtained from the regionalized daily series at Paramaribo.

Source: Own elaboration.

Indices	1990-2014	2020-2039		2040-2069		2070-2099	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
TX90 (days/year)	37	153	175.3	242	290	295.3	356
TX10 (days/year)	37	5.7	4.3	0.7	0.7	0.3	0
TN90 (days/year)	37	329	340	362	363.3	363.3	364
TN10 (days/year)	38	0.7	0.7	0	0	0	0
Rainy days (days/year)	231	211.1	199.7	193.6	188.7	189.5	185.1
RX1day (mm)	75.4	70.0	70.8	73.5	82.0	75.8	76.3
RX5day (mm)	75.4	166.9	163.6	172.4	186.6	177.0	173.2
Strong wind days (days/year)	82.4	84.6	82.4	84.8	85.5	85.0	84.3
Gale wind days (days/year)	0	0	0	0	0	0	0

Table 49: Average days of climate indices and variations projected for the indicated periods, obtained from the regionalized daily series at Albina.

Source: Own elaboration.

Indices	1990-2014	2020-2039		2040-2069		2070-2099	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
TX90 (days/year)	37	99.7	119.3	173.7	231	237.7	337.7
TX10 (days/year)	37	11	9.3	5	3.7	3.3	0.7
TN90 (days/year)	39	282	295.3	342.3	353.7	354	363.7
TN10 (days/year)	37	8.3	7	2.7	1.3	1.3	0
Rainy days (days/year)	244.4	220.4	211.0	205.7	202.4	206.0	191.7
RX1day (mm)	80.4	76.7	80.5	81.5	91.7	88.1	88.8
RX5day (mm)	80.4	204.5	203.7	210.2	224.8	217.4	216.6
Strong wind days (days/year)	61.5	63.7	63.0	63.4	63.0	63.2	64
Gale wind days (days/year)	0	0	0	0	0	0	0

Table 50: Average days of climate indices and variations projected for the indicated periods, obtained from the regionalized daily series at BigiPanMUMA.

Source: Own elaboration.

Indices	1990-2014	2020-2039		2040-2069		2070-2099	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
TX90 (days/year)	37	152	174.7	241.6	288	294	355.3
TX10 (days/year)	37	6	4.7	1	0.7	0.3	0
TN90 (days/year)	37	328.7	339.3	362	363.3	363.3	364
TN10 (days/year)	37	0.7	0.7	0	0	0	0
Rainy days (days/year)	234.5	214.1	201.1	196	190.9	192.7	185.8
RX1day (mm)	76	70	70.1	73.2	81.8	75.7	76.5
RX5day (mm)	76	167	164	173.4	187.3	176.8	172.8
Strong wind days (days/year)	81	83	84	83	83	83	80
Gale wind days (days/year)	0	0	0	0	0	0	0

Table 51: Average days of climate indices and variations projected for the indicated periods, obtained from the regionalized daily series at Brokopondo.

Source: Own elaboration.

Indices	1990-2014	2020-2039		2040-2069		2070-2099	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
TX90 (days/year)	37	98	120.3	172.3	230.7	241.7	339.3
TX10 (days/year)	37	10.3	8.3	4.7	2.7	2.3	0.7
TN90 (days/year)	37	350	355.3	362.7	363.7	363.7	364
TN10 (days/year)	37	2	1	0	0	0	0
Rainy days (days/year)	190	177.1	179	171.8	171.5	172.1	168.4
RX1day (mm)	68	68.3	73.1	75.8	82.8	78.3	82.3
RX5day (mm)	68	155.1	163	171	178.5	171.7	175.1
Strong wind days (days/year)	2.92	2.3	2.1	2.1	1.8	2	1.6
Gale wind days (days/year)	0	0	0	0	0	0	0

Table 52: Average days of climate indices and variations projected for the indicated periods, obtained from the regionalized daily series at Kwamalasamutu.

Source: Own elaboration.

Indices	1990-2014	2020-2039		2040-2069		2070-2099	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
TX90 (days/year)	37	146	168	208.3	280	253.7	331.3
TX10 (days/year)	37	16	14.3	10	5.7	6	1.7
TN90 (days/year)	38	200.7	215.7	273.3	315	307.7	345.7
TN10 (days/year)	37	14.3	12.7	6.7	2.7	3.3	0.7
Rainy days (days/year)	196.2	181.8	191.5	191	188.1	188.1	183.1
RX1day (mm)	94.4	97	97	102.4	108	96	108.3
RX5day (mm)	94	254	248.1	256	264	243.4	251.4
Strong wind days (days/year)	22.4	22.2	31	31.5	27	25.2	31.5
Gale wind days (days/year)	0	0	1.4	0.32	0	0	0.1

Table 53: Average days of climate indices and variations projected for the indicated periods, obtained from the regionalized daily series at Tafelberg.

Source: Own elaboration.

Indices	1990-2014	2020-2039		2040-2069		2070-2099	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
TX90 (days/year)	37	117	146.3	189	269	249	335
TX10 (days/year)	37	15	12.7	8	5.7	4.7	1.7
TN90 (days/year)	37	192.7	213.3	269.3	309.7	305.7	346.3
TN10 (days/year)	37	14.3	12.7	6.7	3.3	3.7	1
Rainy days (days/year)	211.7	196.5	191	185.5	179	182.1	167
RX1day (mm)	90	85	87	86.3	87.5	93.7	94
RX5day (mm)	90	198	209.3	210.6	199	215	218
Strong wind days (days/year)	31	25.3	24.8	27.3	22.7	23.5	17.7
Gale wind days (days/year)	0	0.1	0	01	0.3	0.1	0.2

Table 54: Average days of climate indices and variations projected for the indicated periods, obtained from the regionalized daily series at Upper Tapanahony.

Source: Own elaboration.

Indices	1990-2014	2020-2039		2040-2069		2070-2099	
		SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
TX90 (days/year)	37	108	137	169.7	245.3	220.7	321.3
TX10 (days/year)	37	15.7	13.3	9	5.7	5.3	2
TN90 (days/year)	37	162.7	181.3	228.3	273.7	265.7	326.3
TN10 (days/year)	37	10.7	8.7	3	1.3	1.3	0.3
Rainy days (days/year)	202	188.1	187.1	181	180	180.3	179
RX1day (mm)	81	83	81.1	92.4	93.5	88.3	99
RX5day (mm)	81	206	207	277.3	225	209.4	231
Strong wind days (days/year)	49	58	50.1	66	55.1	70.3	46.4
Gale wind days (days/year)	37	108	137	169.7	245.3	220.7	321.3

We have obtained the following results in the projections of climate indices:

- **Number of days per year in p90 temperature is exceeded:** This index increases particularly fast in BigiPanMUMA, where it could reach half the days of the year earlier than 2040 in SSP5-8.5, and earlier than 2060 in SSP2-4.5. Everywhere else it also increases, and by the end of the century more than half the days of the year exceed p90 temperature everywhere.

- **Number of days per year in which p10 temperature is not reached:** This index decreases strongly everywhere. The decrease is faster for SSP5-8.5 and in coastal cities and areas (Paramaribo, Albina, Bigi Pan), where it reaches zero by mid-century in both scenarios.

- **Number of nights per year in which p90 temperature is exceeded:** This index increases for all locations. The greatest increase is found in Brokopondo, Paramaribo, Albina and BigiPanMUMA, which might suffer from more than 90 % of nights exceeding p90 temperature by the end of the century in any scenario, and by mid-century in the SSP5-8.5 scenario.

- **Number of nights per year in which p10 temperature is not reached:** As with the number of days below p10 temperature, this decreases strongly for all scenarios and time periods, more so for SSP5-8.5 and in coastal places. It is virtually zero by the end of the century in all cases.

- **Number of rainy days per year:** The number of rainy days decrease on the coast, and does not change significantly 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 this decrease is smaller than 5 %.

- **Maximum precipitation in one day and maximum precipitation in five days:** Both indices increase greatly, in particular maximum precipitation in five days, for all locations. 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.

- **Number of days per year in which strong winds occur and number of days per year in which gale winds occur:** These two indices show very little change (days with gale force winds in particular are zero or close to zero for all locations and periods). Only Kwamalasamutu shows a significant increase in days with strong winds, and Tafelberg a certain decrease.

3.4. Conclusions

3.4.1. General conclusions

This section describes the main climate changes that are expected in Suriname under the emission scenarios RCP 4.5 and RCP 8.5.

In the short-term future (2020-2039) 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 compared against the SSP2-4.5. 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 as soon as 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 than SSP2-4.5. But the decrease in overall precipitation is less relevant than the changes in temporal distribution: On the coast, the dry season is expected to become wetter, 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 and already 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 intertropical convergence zone's 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 in all the country 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 future (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, show very little change for the whole country: less than a 5 % increase in the most extreme cases, the SSP5-8.5 for the long-term future.

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 future. 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 very big so. While the general trend is robust, the concrete sea level anomaly that will be reached is not so clear.

3.4.2. Hurricanes and *sibibusi*

Hurricanes play a very small role in Suriname. The country 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.

Sibibusi, the name given in Suriname to extreme events of rain and wind, are common at the end of the rainy season (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.

3.4.3. ENSO

One of the most relevant drivers of Suriname climate extremes are ENSO cycles. There is no consensus about how their frequency and intensity 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 for the end of 21st century) than earlier on and in SSP2-4.5.

3.4.4. Points of interest

3.4.4.1. Paramaribo. The climate in Surinam's capital 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 future, from historically 24.4°C and 30.2°C, respectively. 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 future, and the effects of climate change in these variables would be felt already in the near-term 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.

3.4.4.2. Albina. 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-term future, and to 29.7°C in the long-term future (according to SSP2-4.5) and to 28.6°C and 31.2°C, respectively (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 future. 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, independently of the scenario chosen).

3.4.4.3. BigiPanMUMA. This point of interest also mimics Paramaribo and Albina: Less rain falls during all seasons, stronger episodes of precipitation and higher average (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 in the respective periods and scenarios) and minimum (25.2°C and 27.7°C in the respective periods and scenarios) temperatures are to be recorded.

3.4.4.4. Brokopondo. This location 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 short-term 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 close-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 descend 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 far-term future for SSP2-4.5 and SSP5-8.5, respectively).

3.4.4.5. Kwamalasamutu. In the center (and also in the south) of the country 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 close-term future (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 2070-2099 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).

3.4.4.6. Tafelberg. This location 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 (68 % in the SSP2-4.5 scenario) and precipitation is less frequent but more intense.

3.4.4.7. Upper Tapanahony. This location 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.

3.4.5. Best practices for data storage and dissemination

The following are the most important best practices for data storage and dissemination:

- 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 averages 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 very difficult to identify such information in algorithms and it is not compatible with open file formats.

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4. Impact analysis

The aim of this chapter is to combine the results of chapter 2 (socio-economy) and chapter 3 (climate) in a risk analysis to provide a comprehensive overview of the climate risk Suriname and its most important sectors are facing. First, the methodology to construct the risk index is outlined (chapter 4.1.). Risk is a product of exposure, vulnerability and hazards. Thus, impact chains were developed. An impact chain provides an insight into which vulnerability and exposure factors determine climate risk in a given sector. Based on these results, indicators were selected to construct that part of the risk index, which was then complemented with the hazard indicators from the previous chapter. In the following, the results are presented, first across sectors for each subindex (hazards, exposure, vulnerability) and later for each sector, going into the detail of each single indicator used in the analysis (chapter 4.2.).

4.1. Methodology

4.1.1. 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:

- <u>Vulnerability</u>
  "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 (…)."
- <u>Exposure</u>
  "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."

Vulnerability and exposure to climate hazards depend on a number of socioeconomic factors, such as income and education, governance and access to public goods and services, and adaptation measures that have been adopted to reduce exposure and vulnerability.

- <u>Hazards</u>
  "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

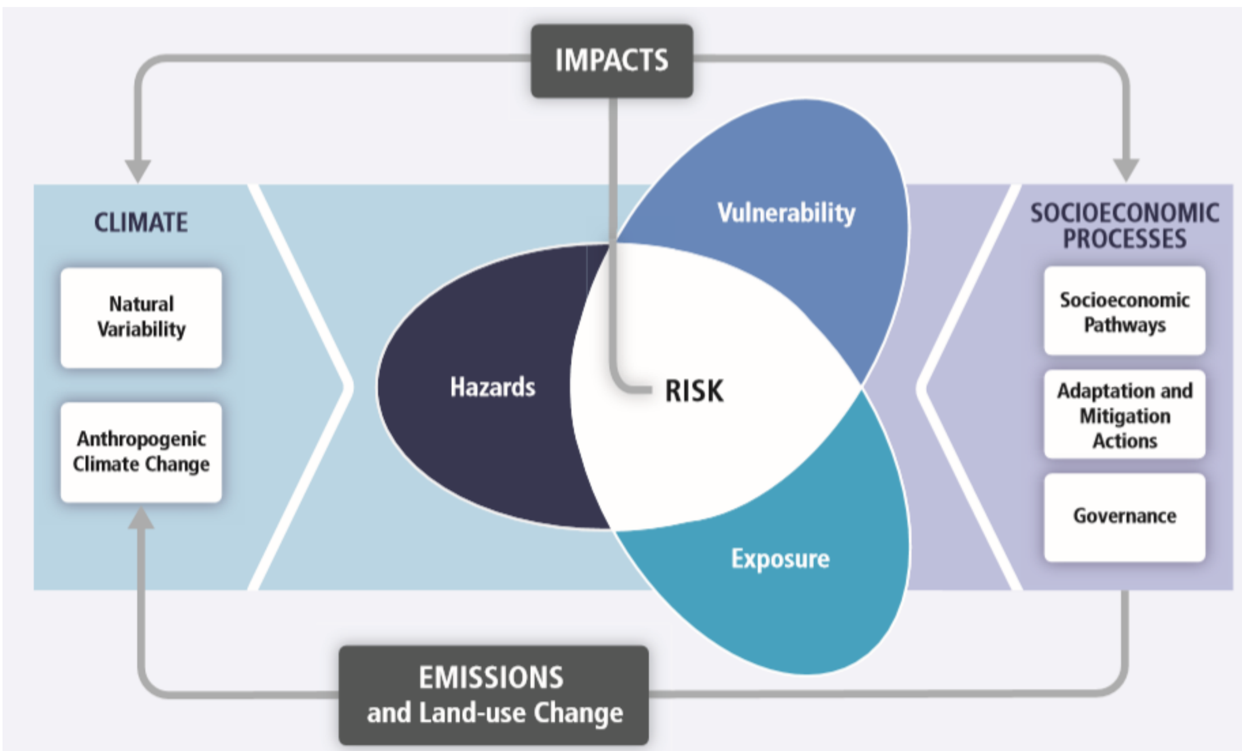
and temperature, as well as extreme events such as floods and droughts. Notably, anthropogenic climate change adds to already existing natural climate variability, and can lead to both a de-/increase in gradual changes and/or extreme events, and thus climate risks.

Importantly, without hazards, there is no exposure, and without exposure, there is no vulnerability.

The materialization of risk results in impacts, which in turn feed back into the climate system and the hazards it produces, as well as the socioeconomic system decisive for vulnerability and exposure (figure 70).

Figure 70: Climate risk is the product of climate hazards, exposure and vulnerability to these.

Source: IPCC (2014b).



4.1.2. Impact chains

An impact chain graphically depicts the different hazards, exposure and vulnerability factors there are for a given subject such as a sector, how these risk components interact to produce intermediate impacts and the risks they result in. The following section provides an impact chain and interpretation of each one of its five elements (hazards, exposure, vulnerability, intermediate impacts, risks) for each one of the four sectors the Report focuses on.

4.1.2.1. Agriculture

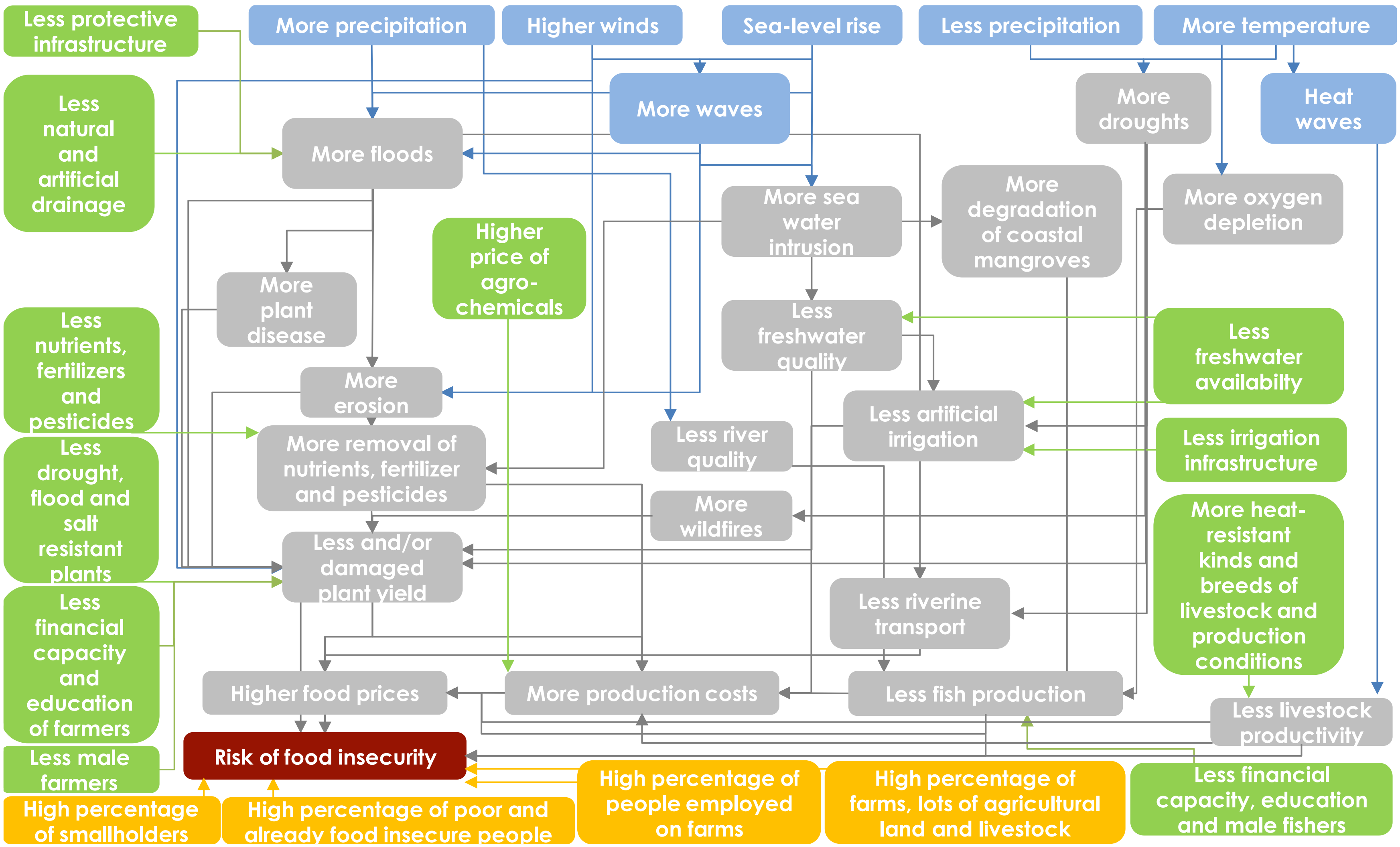
Historic impact of climate change on the agriculture sector

Historically, the agriculture sector has been affected especially by floods such as the two 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 areas are the districts Nickerie (rice), followed by 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 monetary total damage.

Apart from increases in precipitation and floods, the agriculture sector is also affected by the climate hazards sea-level rise, high winds and decreases in precipitation which lead to droughts. Figure 71 provides an overview of the impact chain for the agriculture sector, including the most important hazards (blue), the intermediate impacts (grey) and final risks (red) they produce as a product of exposure (yellow) and vulnerability (green) factors. The subsequent section provides an interpretation of each risk component.

Figure 71: Impact chain for the agriculture sector.

Source: Own elaboration.



Hazards

The agriculture sector is affected by four main hazards: Changes (increases and decreases) in precipitation, higher winds, sea-level rise and higher temperatures (including heat waves). With regards to precipitation, high winds and temperature, both their frequency, intensity and importantly, their 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 aforementioned 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 affecting bananas) and sea-level rise (particularly affecting rice 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 (affecting grazing) and increases in temperature (directly affecting the livestock).

Intermediate impacts

In the case of plants (crops, fruits, vegetables, flowers and ornamentals), fish and livestock, all intermediate impacts may lead to higher food prices and/or lower competitiveness.

With regards to plant production, the sector 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:

1. Floods provoked by increases in precipitation, sea level-rise and waves.

   Floods can directly cause plant yield losses and damage. Moreover, floods can contribute to plant yield losses and damage via additional intermediate impacts such as an increase in plant disease, erosion of agricultural land and the removal of soil nutrients and agricultural products (fertilizers and pesticides), which drive up production costs if current production levels are to be sustained. These higher production costs in combination with lower production rates result in higher food prices. 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 result in more costly products.

2. Sea-water intrusion provoked by sea-level rise and waves.

   Sea-water intrusion reduces the quality of freshwater. This in turn leads to plant yield losses, as salinity has negative affects on plant physiology. Salinization also reduces opportunities for artificial irrigation, which is particularly important for rice. Thus, either productivity decreases as a result of less artificial irrigation, or production costs increase because other more costly means for providing freshwater are required. The washing-out of nutrients, fertilizers and pesticides by sea-water intrusion may also result in higher production costs, if more of the aforementioned products need to be added to obtain the same productivity. Higher production costs and lower yields ultimately increase food prices.

3. Droughts provoked by decreases in precipitation and temperature increases.

Droughts 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). Moreover, droughts can contribute to plant yield losses via additional intermediate impacts such as an increase in wildfires and less artificial irrigation. Again, 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. Higher production costs and lower yields ultimately increase food prices. 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, respectively. 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, resulting in higher food prices.

With regards to livestock, the sector suffers mostly from increases in temperature and heat waves. These directly result in less livestock productivity, higher production costs of production levels are to be sustained, and consequently higher food prices.

Risks

The different intermediate impacts and most importantly decreases in plant and animal production, increases in production and transportation costs lead to higher food prices due to floods, sea-water intrusion and droughts in 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.

Exposure

In general, exposure will be highest in the districts where relatively 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 eminent for smallholders (plants, livestock and aquaculture) who rely on their own production for nutrition. They also suffer the economic consequences of production losses and/or higher production costs. As the capacity of smallholders to compensate 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/ or purchase is likely to be negatively affected, resulting in their exposure to the risk of food insecurity.

The risk of food insecurity is also eminent for poor 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.

Moreover, the risk of food insecurity 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.

Vulnerability

Several factors contribute to the vulnerability of poor 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)
- Nutrients, fertilizers and pesticides. 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 (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.
- Drought, flood and salt resistant plants. Plants which physiology favors their resilience under the new circumstances imposed by climate change will be productive despite adverse conditions.
- Financial capacity of farmers and fishers. Farmers and fishers with a greater economic capacity are in a better position to adapt their production systems to changing conditions, e.g. in the case of farmers by putting flood protections in place, buying fertilizers and pesticides, improved seeds and livestock breeds, installing artificial drainage and irrigation systems, and e.g. in the case of fishers by buying better equipment, travelling longer distances to more populated fishing sites and improving their aquaculture system.
- Education of farmers and fishers. More educated famers and fishers are in a better position to adapt their production systems to changing conditions, e.g. by employing innovative approaches (e.g. regarding conservation and the rebuilding of stocks in the case of fishery).
- Gender. 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 than men.

Suriname's Fifth Agricultural Census indicates that there are more women farmers in the interior per district (2,367 on average, average age 41 years) than in the coastal area (1,167 on average, average age 50 years) (LVV, n.d.).

- Price of agrochemicals. The cost of 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)
- Irrigation infrastructure. Farmers without irrigation infrastructure are heavily impacted by droughts or changes in the seasonality of rainfall.
- Heat-resistant kinds and breeds of livestock and production conditions. Livestock which physiology favors their resilience under the new circumstances imposed by climate change, particularly heat waves, will be productive despite adverse conditions. The livestock production conditions can be adapted to provide cooler climates, too, and this prevent negative impacts derived from increased temperatures.

4.1.2.2. Water

Historic impact of climate change on the water sector

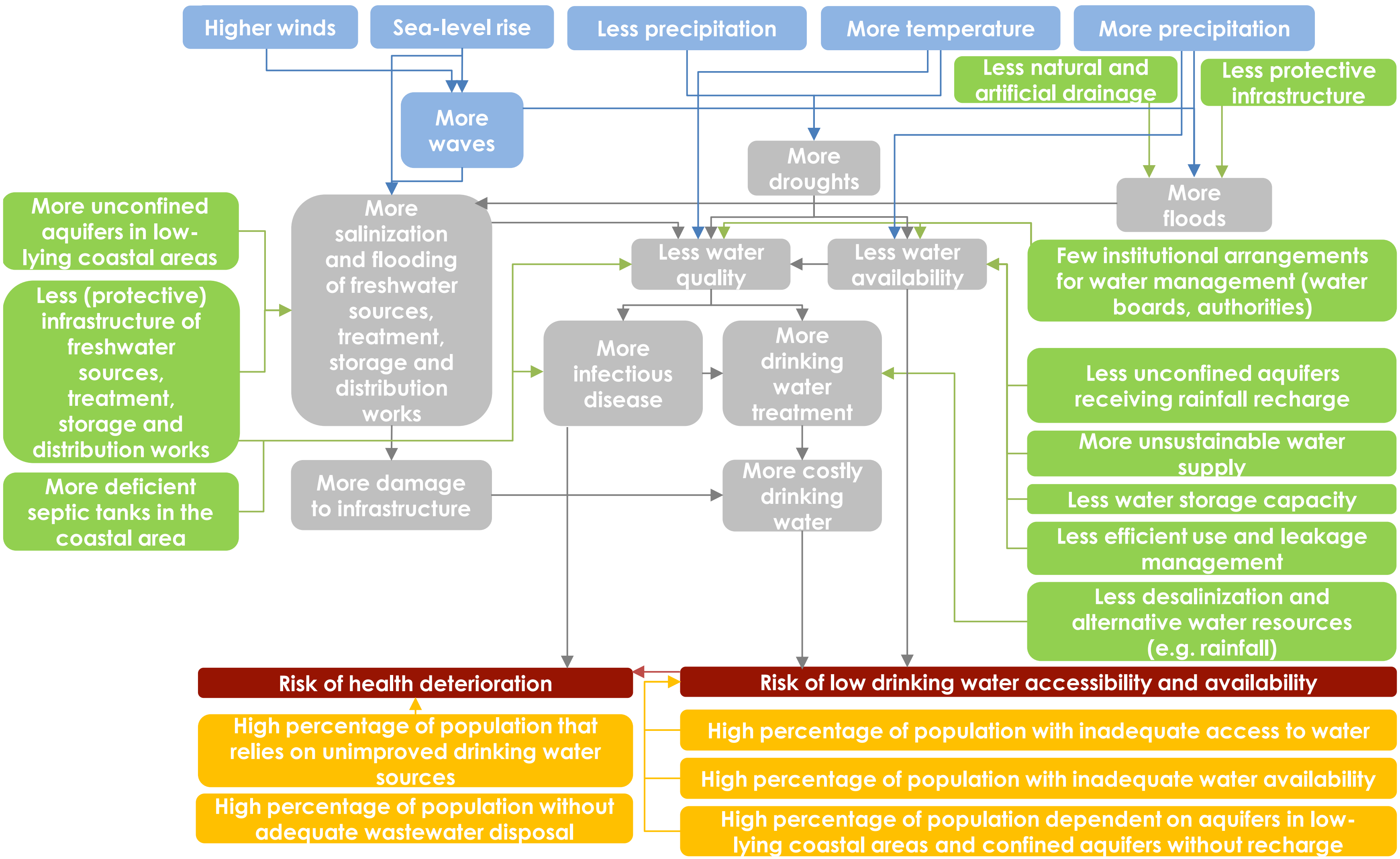
A decrease in rainfall and a number of drought events have already affected the Prof. Dr. Ir. van Blommenstein reservoir during 18 months between 1987-1988, in 1999, 2001 and 2005 (Simpson et al., 2012). During the 2005 drought the reservoir's low water-levels led to a four- to five-day power failure. 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 by the Tapanahony, Saramacca and Suriname rivers in the interior of Suriname (in the districts of Brokopondo and Sipaliwini). In some areas, the rivers' water levels remained high for three to six days (Simpson et al., 2012).

Figure 72 provides an overview of the impact chain for the water sector, including the most important hazards (blue), the intermediate impacts (grey) and final risks (red) they produce as a product of exposure (yellow) and vulnerability (green) factors. The subsequent section provides an interpretation of each risk component.

Figure 72: Impact chain for the water sector.

Source: Own elaboration.



Hazards

The water sector is affected by four main hazards: Changes (increases and decreases) in precipitation, higher temperatures, higher winds and sea-level rise (which lead to more waves). 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.

Intermediate impacts

An increase in precipitation as well as 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, negatively impact on freshwater sources (rivers, wetlands and particularly unconfined coastal aquifers), their treatment, storage and distribution works. On the one hand the actual infrastructure of water works can get damaged. On the other hand, an increase in intense precipitation events decreases aquifer recharge and water availability, 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, animal waste, feces, pesticides, fertilizers, sewage and garbage, which then contaminate surface and groundwater sources as well as marine areas (Caribsave, 2012). Overall, this results in a reduced water quality, which can have two consequences: An increase in infectious disease or an increase in 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 are droughts, a product of less precipitation and more temperature. Droughts affect water quality as well as water 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 (for example phosphorus), which promotes elevated phytoplankton activity and the release of metals (for example iron and manganese) from sediments into the water body (WHO, 2017). Decreases in water quality during dryer 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 precipitations and salinization (see previous paragraph): An increase in infectious disease or an increase in drinking water treatment and cost. 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 (i.e. a decrease in water quality).

Risks

All hazards converge in the risks of health deterioration and the risk of low drinking water accessibility and availability. Low drinking water accessibility also leads to health deterioration.

Apart from that, the risk of health deterioration stems from only one intermediate impact: More infectious diseases. The risk of low drinking water accessibility and availability stems from two intermediate impacts: More costly drinking water and less water availability.

Exposure

The risk of health deterioration is most eminent 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, respectively.

Vulnerability

Several factors contribute to the vulnerability of the exposed elements:

- Unconfined aquifers in low lying coastal areas. Most confined aquifers 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, treatment, storage and distribution works. Poor water and wastewater infrastructure 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 (onset of rain). Specific protection measures include e.g. the sealing of wells with a protective cap (such as 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, e.g. recreation and grazing in their direct proximity.

- Septic tanks in the coastal area. Poor design, installation and employment of septic tanks and lack of enforcement and monitoring of related laws may result in the pollution of water resources, especially unconfined aquifers. Surface water entering into septic tanks after flooding events leads to effluent overflow into streams, rivers and unconfined aquifers.

- Institutional arrangements for water management (water boards, authorities). 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.
- Number of aquifers receiving rainfall recharge. 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. Population growth will severely affect water consumption and the availability of water. An increase in water consumption not only affects water availability but also quality as excessive extraction e.g. results in increased saltwater intrusion (ATM, 2013). Over abstraction of groundwater is particularly harmful during the dry seasons when recharge rates are low.
- Water storage capacity. 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, amongst others. In areas that are increasingly getting drier, infrastructure may be needed to increase surface water storage and to enhance natural groundwater recharge (DFID, 2009).
- Efficient use and leakage management. In rural areas, the efficiency of irrigation practices can be improved through infrastructure, capacity building and awareness raising. In urban areas, more leakage management and leakage detection technology can prevent or reduce leakage volume and speed up 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).
- Desalinization and rainwater. Technological improvements such as desalinization and the use of alternative freshwater resources can reduce pressure on conventional freshwater sources (i.e. aquifers), increase the supply of freshwater 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)

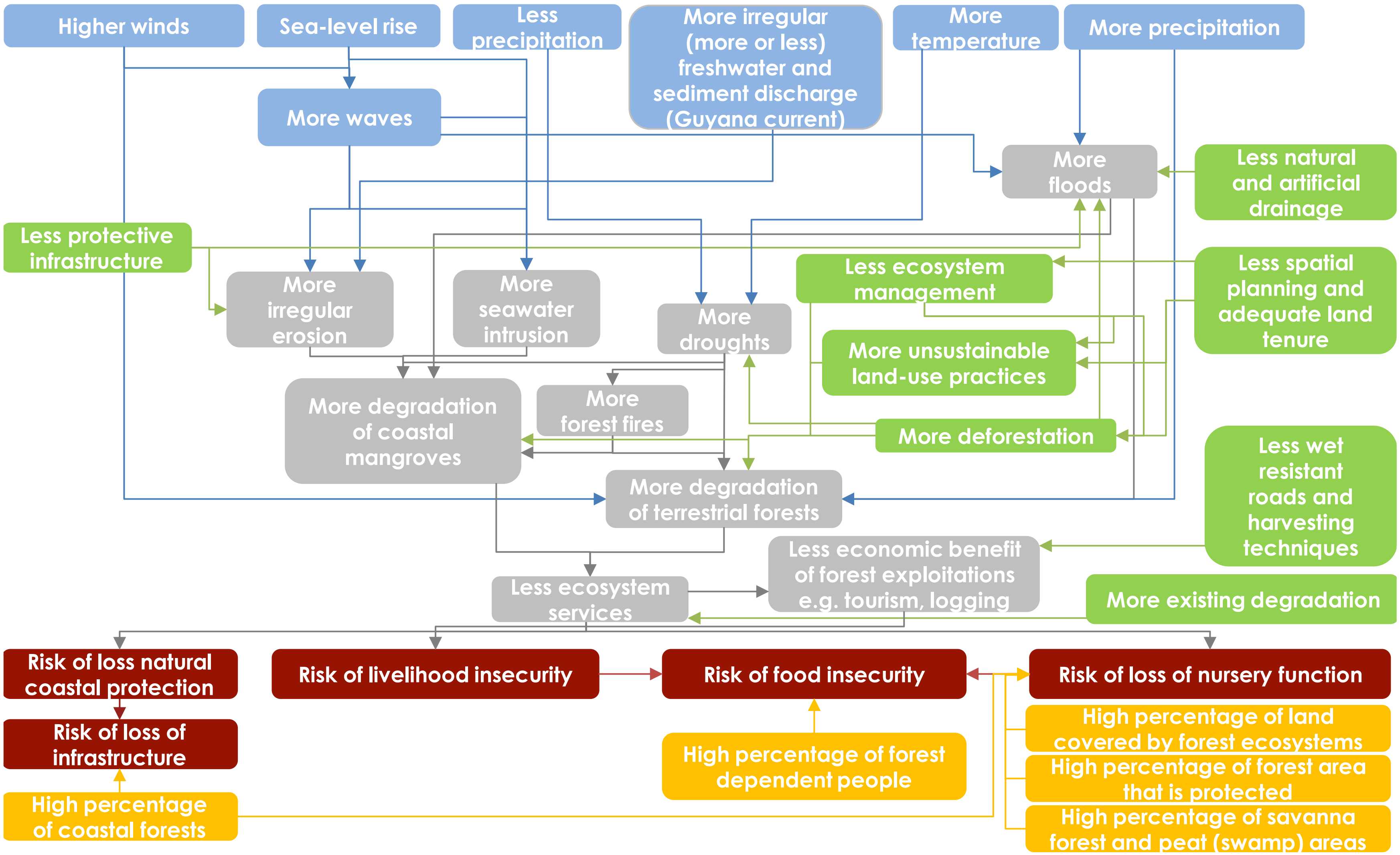
4.1.2.3. Forestry

Historic impact of climate change on the forestry sector

The impacts of very few extreme climate events and gradual changes in climate have been recorded for Suriname's forestry sector. This is partly due to the fact that most of Suriname's forest ecosystems are practically unmanaged and unused. Moreover, given 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 becomes clearly 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 two 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, provoked low water levels and an increase in the frequency of forest fires, caused biodiversity losses in the area.

Apart from increases in temperature and decreases in precipitation leading to droughts, the forestry sector is also affected by the climate hazards sea-level rise, high winds and increases in precipitation leading to floods, and the irregularity of the freshwater and sediment discharge from the Guyana current. Figure 73 provides an overview of the impact chain for the forestry sector, including the most important hazards (blue), the intermediate impacts (grey) and final risks (red) they produce as a product of exposure (yellow) and vulnerability (green) factors. The subsequent section provides an interpretation of each risk component.

Figure 73: Impact chain for the forestry sector.
Source: Own elaboration.



Hazards

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

The five hazards impact differently on the forestry sector according to geographic location. Sea-level rise, changes in the Guyana current, high winds and waves mainly impact on coastal forests, whilst higher temperatures and changes in precipitation impact both coastal and interior forests. In consequence, they are the most important hazards with regards to geographical area. With respect to the duration of the hazards, increases in precipitation and the floods they provoke, 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 provoke as well as sea-level rise affect forestry ecosystems for longer periods of time and may thus have greater impacts.

Intermediate impacts

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

1. Irregular erosion provoked by more waves and more irregular freshwater and sediment discharge from the Guyana current.
   Irregular erosion degrades the coastal mangrove forests. Erosion and accretion/ sedimentation are natural processes that normally exist in a steady state in healthy ecosystems. Therefore, the imbalance of these processes leads to the degradation of ecosystems.

2. Seawater intrusion provoked by sea level-rise and more waves.
   Seawater intrusion changes the overall water salinity of mangrove ecosystems, which leads to their degradation (Maulud, Mohd, Wan, Jaafar & Benson, 2018).

3. Droughts provoked by decreases in precipitation and temperature increases.
   Droughts can directly cause forest 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, too.

4. Floods provoked by increases in precipitation and waves.
   Floods will 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.

Risks

The different intermediate impacts of less ecosystem services and 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, that consist of capabilities, assets and activities that are required for living. Livelihood insecurity increases the risk of food insecurity. The intermediate impact of less 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 risk of loss of infrastructure.

Therefore, 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 is most eminent for forest dependent people (FAO & CIFOR, 2019), i.e.:

- People who live in and around natural forests, or on the forest frontier, often as hunter-gatherers or shifting cultivators, and who 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 outside the forests, and regularly use forest products (timber, fuelwood, bush foods, medicinal plants, etc.), 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 who engage in commercial activities that rely on forests 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 the

- 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 covers.
- Protected forests because they 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.

Vulnerability factors

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

- Protective infrastructure. (see impact chain on infrastructure)

- Spatial planning and adequate land tenure. The lack of spatial planning and clear 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. Unsustainable land-use practices such as artisanal mining degrade forests e.g. due to contamination with harmful chemicals.
- Ecosystem management. Understanding the dynamics of ecosystems and managing human interactions with them, e.g. defining protected areas or species, contributes to preventing unsustainable land-use practices, deforestation and forest degradation.
- Deforestation. 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, e.g. due to fragmentation, thus leading to forest degradation.
- Natural and artificial drainage. (see impact chain on infrastructure)
- Wet resistant roads and harvesting techniques. In the logging sector, harvesting under wet conditions is more difficult. Wet resistant (e.g. paved) 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. Existing degradation affecting the forests' biodiversity predisposes them to forest fires, droughts, floods and erosion, i.e. the provision of less ecosystem services.

4.1.2.4. Infrastructure

Historic impact of climate change on infrastructure

The floods in May 2006 caused loss 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 55).

All disasters in table 30 (floods, heavy winds, storms) affect the energy (e.g. snapped light poles) and transport infrastructure (e.g. toppled trees on roads), buildings (e.g. torn roofs) and telecommunication infrastructure (e.g. damage of poles).

Table 55: Climate-related disasters (floods and storms) in Suriname, people injured or killed and homes affected for the period 1969-2017.

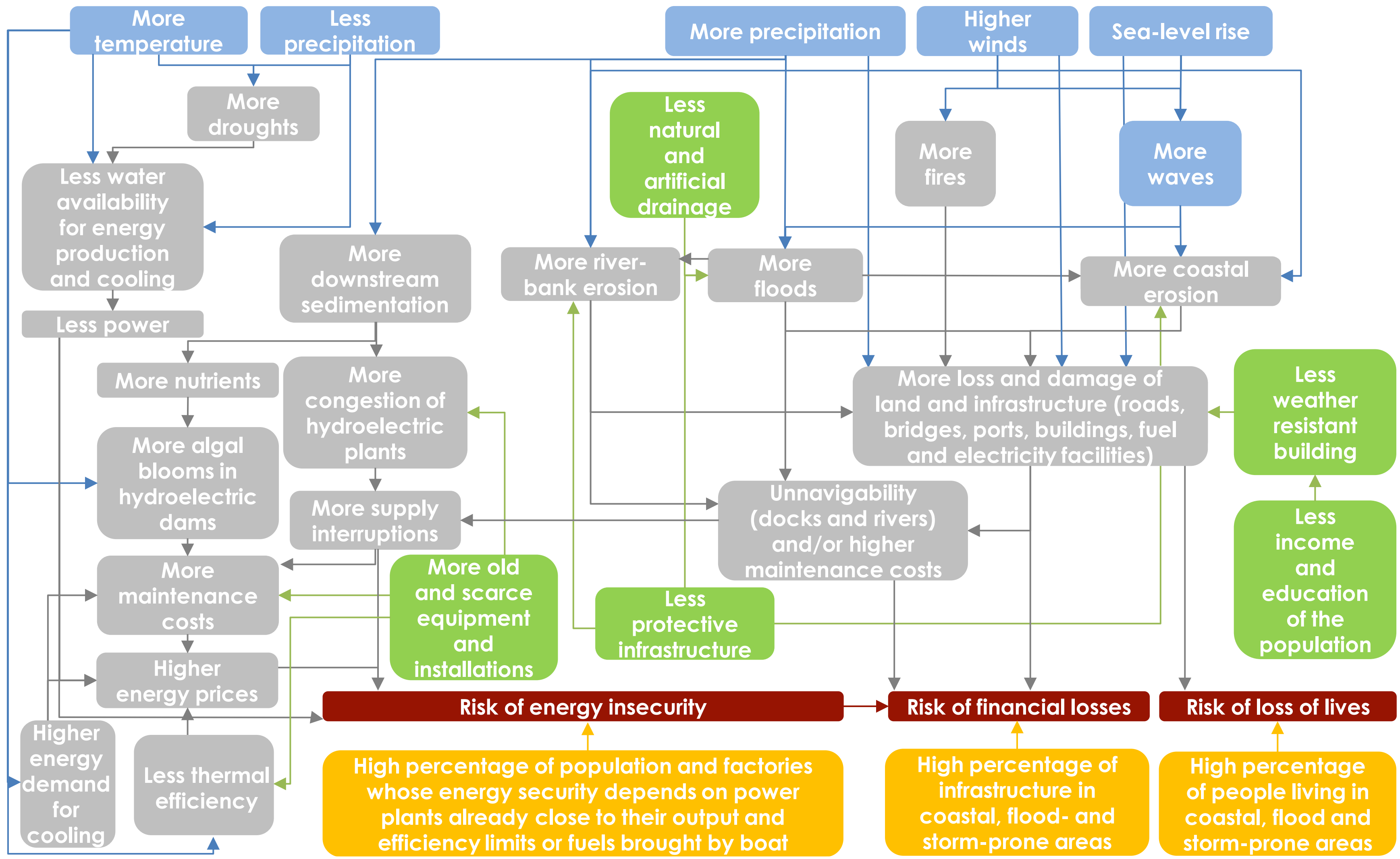
Source: NCCR (2017) adopted from ABS (2018).

Disaster	**Month and year**	**Number of people killed/ injured**	**Number of people/ homes affected**
Flood	1969	-	4,600 people
Flood	**2006**	**3 death**	**25,000 people**
Flood	2008	2 death	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
Tail of heavy tropical storm	September 2017	-	30 homes

Apart from increases in precipitation causing floods, storms (including heavy winds) and waves, the infrastructure sector is also affected by the climate hazards sea-level rise, increases in temperature and decreases in precipitation which lead to droughts. This applies to Suriname as a whole and the capital Paramaribo. Figure 74 provides an overview of the impact chain for the infrastructure sector, including the most important hazards (blue), the intermediate impacts (grey) and final risks (red) they produce as a product of exposure (yellow) and vulnerability (green) factors. The subsequent section provides an interpretation of each risk component. While the figure mainly focuses on existing infrastructure, however the authors acknowledge that some developments are to be expected in some 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 74: Impact chain for the infrastructure sector.

Source: Own elaboration.



Hazards

The infrastructure sector is affected by five main hazards: Changes (increases and decreases) in precipitation, higher winds, sea-level rise and higher temperatures (including heat waves). Moreover, high winds in combination with sea-level rise can lead to waves which affect the sector in the coastal regions.

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 suffers particularly from irregular (higher and or lower) water levels, given the large capacity of the Afobaka hydropower plant which depends on water.

Intermediate impacts

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

1. On the one hand, higher temperatures, decreases in precipitation and more droughts reduce the water availability for energy production (hydroelectric power) and cooling (thermal electric power plants). However, they also increase the electricity demand for cooling (e.g. refrigeration). 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 run-off levels and stream flows which then determine the amount of water available for hydroelectric generation. As a result, thermal plants increase their generation in order 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, provoking higher maintenance costs and energy end-prices (Contreras-Lisperguer & de Cuba, 2008).
   In addition, 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. On the other hand, increases in precipitation can lead to more downstream sedimentation. This in turn will lead to algal blooms in hydroelectric dams and/or the congestion (i.e. blockage of turbines) of hydroelectric plants. Ultimately, both lead to interruptions in energy supply, demand the maintenance of the dam and power plant and thus increase energy prices.

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

1. 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/or increased needs for maintenance activities and costs (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 (sea-level rise, high winds, waves, increases in precipitation) 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, 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 (storm surges). When high water levels of the tidal Suriname river combine with run-off from impermeable areas floods appear that affect assets from the building and telecommunication sectors. Extreme winds and waves can cause flooding of the coastal transportation infrastructure, leading to infrastructure failures and road obstructions from e.g. fallen power lines/ trees.

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 very slow to clear (World Bank, 2017). Flooding in combination with insufficient drainage may affect construction stability of (sub)stations and pole foundations.

Risks

For the energy sector, supply interruptions and higher energy prices lead to a risk of energy insecurity, i.e. the risk of not having reliable, affordable access to all fuels 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/ or subsistence depends on marine and/or 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 eminent for people and infrastructure in coastal, flood and high wind-prone areas:

- The population density in the coastal zone is almost five times higher than that in non-coastal areas. The capital city of Paramaribo and 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 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, as in 2006 and 2008 (NCCR, 2017).
- Critical buildings (e.g. hospitals, schools) and infrastructure systems (e.g. power plants, telecommunication stations) located on higher grounds are less prone to flooding and water damage.

The risk of energy insecurity is most eminent 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 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:

- Old and scarce equipment and installations. Electricity systems consist of various components such as power plants, substations, 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. Especially 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, flood and high wind-prone areas:

- Natural and artificial drainage. The drainage system in Paramaribo and surroundings is outdated. Moreover, a lack of building and civil regulations and finance results in poor maintenance of the existing canal network (including waste deposition), outlet structures (sluices and pumping stations) and uncontrolled developments in retention areas intended to support drainage. In addition, uncontrolled migration of population form rural areas to urban areas results in the drainage infrastructure being under-sized (OW, 2001).
- Protective infrastructure. In some places along the Suriname coast, coastal defense structures have been built. These range from small-scale ad hoc constructions based on e.g. 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. Low-income segments of the population 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 because they are not aware or do not understand the climate hazards they are exposed to.
- Weather-resistant building.
    - High humidity levels impose considerable constrains on building materials such as wood that are being attacked by devouring insects such as termites and fungi. Wood rots more quickly under humid conditions (IADB, 2017).
    - High levels of salinity due to seawater intrusion into rivercourses, sea-level rise or seawater flooding damage and reduce the life of infrastructure such as roads and/or buildings, too.
    - Storms and heavy winds can destroy light-weight wooden houses and tear roofs.
    - High temperatures and draughts can cause heat stress in buildings and lead to damage of equipment and building materials.

4.1.3. Risk indicators and indices

Evidently, climate risk is a complex idea. In order to analyze climate risk, it is therefore convenient to analyze climate hazards, exposure and vulnerability one by one, and later resume their results and interactions in one metric. This is best done using indicators, which can later be comprised in an easy-to-understand risk index. Risk indeces are elaborated using the following six-step procedure (Nardo, Saisana, Saltelli, Tarantolla, Hoffman & Govannini, 2005; Saisana & Tarantola, 2002).

4.1.3.1. Selection of indicators

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

- The theoretical framework, i.e. the definitions of hazard, exposure and vulnerability underlying the indicators.
- The availability of data.
- The quality of the data (see step 4.1.3.2.).

It should be noted that, ultimately, the selection of indicators is subjective and depends on expert opinion.

<u>Hazards</u>

The hazard indicators correspond to the following 19 climate variables:

- 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 (unusually cold) of the average maximum temperatures.
    - Frequency of cold nights: Number of days per year in which the minimum temperature falls below the threshold of the 10th percentile (unusually cold) 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 (unusually warm) 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 (unusually warm) 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 air humidity

- Wind
  - Number of days per year with strong wind (40 km/h<maximum wind<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

Moreover, the variables were projected under/for the following circumstances:

- Time periods: The variables were projected for three future time horizons, the near future (2020-2044), mid-term future (2045-2069) and long-term future (2070-2094). In order to identify important changes in the climate variables, they were be judged against their historic average (1990-2014).
- General Circulation Models (GCM): Multimodel projections using the models HadGEM3-GC31, IPSL-CM6A and MIROC6 were used.
- Scenarios: The two concentration pathways SSP2-4.5 and SSP5-8.5 were considered.

<u>Exposure and vulnerability</u>

The indicators for exposure and vulnerability were selected based on the impact chains and data availability (table 56-59).

Table 56: Indicators for exposure and vulnerability in the agriculture sector.
Source: Own elaboration.

Description	Unit	Source	Year	Explanation
		Exposure		
Farms	Number of family farms as a percentage of the total number of households	LVV (n.d.) ABS (n.d.)	2008-2009	The more households run farms (crops, livestock, aquaculture), and the bigger the farms (more agricultural land and livestock) the more people, land and animals will be negatively affected. 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 (e.g. by 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	
People employed on farms	Number of hired workers on farms (2008) as a percentage of the total population (2012)	LVV (n.d.) ABS (n.d.)	2008 and 2012	The more people are employed on farms, the more people will be negatively affected. Hired employees concern people that do not form part of the household the farm is managed by.
Small-holders	Number of farms with less than 2 ha of agricultural land as a percentage of all farms	LVV (n.d.) Lowder, Sánchez, & Vertini (2019)	2008-2009	The more smallholders (farmers with less than 2 ha agricultural land), the more people will be negatively affected. Smallholders are often subsistence farmers which are more likely to exercise 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.
Poor people	Percentage of population whose income is less than half of GNI per capita of the district (2009)	UNDP (2013)	2009	Poor people are more likely to suffer from food insecurity as they are less able to compensate for higher food prices.

Description	Unit	Source	Year	Explanation
Food insecure people	Percentage of children under the age of 5 that are stunted (-2 SD) (2018) Percentage of children under the age of 5 that are wasted (-2 SD) (2018)	Ministry of Social Affairs and Public Housing (2019) Ministry of Social Affairs and Public Housing (2020)	2018	People who already suffer from food insecurity are more likely to suffer from an increase in food insecurity. Stunting refers to a child who is too short for his or her 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.
		Vulnerability		
Education of farmers	Number of family farms with the farmer having received no formal education as a percentage of all family farms	LVV (n.d.)	2008-2009	The less educated farmers are the lower their adaptive capacity to cope with changing conditions and to find solutions to problems.
Gender of farmers	Number of family farms run by women as a percentage of the total number of family farms	LVV (n.d.)	2008-2009	Female farmers and fishers are likely to have e.g. 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 less male farmers and fishers and more female ones, the higher the sector's risk.
Irrigation infra-structure	Inverted number of farms with irrigation infrastructure as a percentage of the total number of farms	LVV (n.d.)	2008	Coastal agriculture relies on irrigation infrastructure as rainfall is seasonal. Therefore, the less irrigation infrastructure, the more production systems will suffer from water shortage. This indicator only concerns the coastal districts (excluding Sipaliwini and Brokopondo), where

Description	Unit	Source	Year	Explanation
				irrigation infrastructure is important due to less rainfall.

Table 57: Indicators for exposure and vulnerability in the water sector.
Source: Own elaboration.

Description	Unit	Source	Year	Explanation
Exposure				
Population not using improved drinking water sources	Number of households not using improved drinking water sources as a percentage of the total number of households	Ministry of Social Affairs and Public Housing (2019)	2018	The more people already use unimproved drinking water sources, the more people are affected by water quality deterioration. Improved drinking water sources include piped water (into dwelling, compound, yard or plot, to neighbour, public tap/ standpipe), tube well/borehole, protected dug well, protected spring, rainwater collection, and packaged or delivered water.
People without adequate waste-water disposal	Number of households not using improved sanitation facilities as a percentage of the total number of households	Ministry of Social Affairs and Public Housing (2019)	2018	The more people already do not have a proper wastewater disposal system, the more people are affected by water quality deterioration. 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 with in-adequate water availability	Number of households without drinking water available in sufficient quantities as a percentage of the total number of households	Ministry of Social Affairs and Public Housing (2019)	2018	The more people already do not have sufficient drinking water available, the more people are affected by further reductions in drinking water availability.

Description	Unit	Source	Year	Explanation
People with in-adequate access to water	Number of household members as a percentage of the total number of household members without access to drinking water on premises	Ministry of Social Affairs and Public Housing (2019)	2018	The more people already do not have sufficient access to drinking water, the more people are affected by further reductions in drinking water accessibility.
		Vulnerability		
Un-sustainable water supply	Inverted SWM and DWV water production (m3/day) per capita	ABS (2018) ABS (n.d.)	2015 and 2012	The less water per capita, the more likely shortages are to arise due to decreases in drinking water availability.
Storage capacity	Inverted storage capacity (m3/day) per capita	ABS (2018) ABS (n.d.)	2017 and 2012	The less water storage, the less water availability for during drought periods.
Alternative water resources	Number of households which main source of drinking water is not rainwater collection as a percentage of the total number of households	Ministry of Social Affairs and Public Housing (2019)	2018	The less alternative water resources such as rainwater collection, the more people rely on groundwater, most of which is not renewable in Suriname and which availability decreases further over time.

Table 58: Indicators for exposure and vulnerability in the forestry sector.
Source: Own elaboration.

Description	Unit	Source	Year	Explanation
		Exposure		
Coastal forests	Area of mangroves as a percentage of the total area of the district	SBB (2019a) ABS (n.d.)	2018	The more area covered by coastal mangroves, the higher the risk of coastal mangroves being negatively affected.
Savanna forest and peat (swamp) areas	Area of open savanna and swamp as a percentage of the total area of the district	SBB (2019b)	2017	The more area covered by savanna forests and peat (swamp) areas, the higher the risk of savanna forests and peat areas being negatively affected. The complete list of SBB LULUC categories are: Abandoned areas, agriculture, buildings, infrastructure, water bodies, mining, open savanna, open swamp, forest.
Forest cover	Area of forest (excluding savannas and swamps) as a percentage of the total area of the district	SBB (2019b)	2017	The more area covered by forests, the higher the risk of forests being negatively affected. The complete list of SBB LULUC categories are: Abandoned areas, agriculture, buildings, infrastructure, water bodies, mining, open savanna, open swamp, forest.
Forest dependent people	Area of community (HKV) and company concessions as a percentage of the forested area of the district	Internal communication with SBB	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		
Land tenure	Number of Amerindian and Maroon settlements per km^2 district area	SBB (2017) ABS (n.d.)	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.

Description	Unit	Source	Year	Explanation
Ecosystem management and land-use practices	Inverted number of SBB logging checkpoints per km^2 forest	www.gonini.org SBB (2019b)	2020	The smaller the density of logging check points, the more likely illegal logging and forest degradation are.
Deforestation	Deforested area between 2000 and 2015 as a percentage of the total forested area	SBB (2017)	2000	The more deforestation, the more floods and droughts.
Existing degradation	Volume (m^3) of roundwood produced per km^2 forest	SBB (2018) SBB (2019b)	2018 and 2017	Logging causes forest degradation. The higher the roundwood production, the higher the forest degradation.

Table 59: Indicators for exposure and vulnerability in the infrastructure sector.
Source: Own elaboration.

Description	Unit	Source	Year	Explanation
		Exposure		
Infrastructure	Km of road per km² area	ABS (2019)	2018	The more roads, the more likely economic and physical loss and damage.
	Number of bridges per km² area	ABS (2019)	2018	The more bridges, the more economic and physical likely loss and damage
	Number of certified harbors per capita (x 100.000)	ABS (2018)	2017	The more ports, the more likely economic and physical loss and damage are.
	Number of electricity connections as a percentage of the total number of people	ABS (n.d.)	2018 and 2012	The more electricity connections, the more likely economic and physical loss and damage to transmission lines. This indicator concerns EBS electricity connections.
Coastlines	Coastline (km) per area (km2)	ABS (n.d.) Gonini (2020)	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.
People	Number of people as a percentage of the total population in Suriname	ABS (n.d.)	2012	The more people live in a district, the more people can be adversely affected.
		Vulnerability		
Population depending on fuel for electricity	Percentage of household members that rely on fuel for lighting	Ministry of Social Affairs and Public Housing (2019)	2018	The more people rely on fuel for lighting, the less people are connected to the grid, and the more people may suffer from energy insecurity when road or boat transport of fuels is interrupted.
Natural and artificial drainage	Inverted number of water-related data gathering stations per km² area	SWRIS (2020a) SWRIS (2020b)	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	ABS (2018)	2018	

Description	Unit	Source	Year	Explanation
Weather resistant building	finished flooring			Climate hazards affect the durability of especially 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 loss 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	ABS (2019)	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	ABS (2019)	2018	The more non-novel material bridges (wood, steel/wood and fiber bridges), the less long-lived the bridge system. Concrete and/or steel are considered novel materials.
Education	Inverted primary completion rate	Ministry of Social Affairs and Public Housing (2020)	2018	Education can be a powerful tool in enabling effective adaptation to climate change (IPCC, 2014), e.g. by conditioning housing and other infrastructures so they cope with climate stresses. Therefore, the less education, the higher the loss and damage due to climate hazards.

4.1.3.2. Data quality check

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

- <u>Outliers</u>: Data points whose standardized z-value is smaller/ 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 (e.g. shifted comma sign).
    - 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.

- <u>Missing data</u>: Missing data can be distinguished into
    - Data missing at random, which absence does not introduce bias into the analysis.
    - Data missing not at random (e.g. higher incomes not declared by only wealthy households), which absence introduces bias into the analysis. Preferably, only indicators without data missing not at random were used in the analysis.

  The hazard variables were complete for all scenarios, time periods and districts.

  However, 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 on irrigation infrastructure (related to the vulnerability of the agriculture sector) was applied only in the coastal districts (excluding Sipaliwini and Brokopondo), as in the interior of the country shifting cultivation is practiced, and this does not rely on irrigation infrastructure.

  The variable on 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.

  Thus, none of the missing data introduced bias into the analysis and all indicators could be retained in the analysis.

- <u>Correlation</u>

  Correlation between indicators was analyzed 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 60). 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.

In addition, 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, with the exception of rainwater collection, which is inversely related to the rest of variables (table 61). 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 62). 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 a number of variables (table 63): 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 ($p<0.05$). Because of its strong correlation with a number of other variables, and the importance of the indicators on the road network and coastline for estimating infrastructure related loss and damage,

particularly to sea-level rise, the indicator on the number of water-related data gathering stations was excluded from the analysis to avoid redundancy.

The number of electricity connections also correlates significantly with a number of 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 60: P-values of Pearson-correlations 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).

Source: Own elaboration.

	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

Table 61: P-values of Pearson-correlations 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).

Source: Own elaboration.

	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	<u>0,000</u>	0,772	<u>0,000</u>	0,166	<u>0,017</u>
Number of households not using improved sanitation facilities as a percentage of the total number of households		0,969	<u>0,000</u>	0,091	<u>0,005</u>
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	<u>0,027</u>
SWM and DWV water production (m^3/day) per capita					0,078

Table 62: P-values of Pearson-correlations 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).

Source: Own elaboration.

	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

Table 63: P-values of Pearson-correlations 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).

Source: Own elaboration

	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	<u>0,000</u>	0,259	0,187	<u>0,039</u>	0,293	0,074	<u>0,008</u>	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	<u>0,005</u>	0,229	0,651	<u>0,011</u>	0,082	0,159	<u>0,043</u>	<u>0,025</u>
Coastline (km) per area (km²)					0,774	0,322	<u>0,000</u>	0,063	0,748	0,853	0,437	<u>0,012</u>	0,800
Number of people as a percentage of the total population of Suriname						0,229	0,907	<u>0,029</u>	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	<u>0,043</u>	<u>0,030</u>	0,174	0,347
Number of water-related data gathering stations per km² area								0,098	0,726	0,603	0,343	<u>0,013</u>	0,829
Length of non-novel roads as a percentage of all roads									0,701	0,347	0,987	<u>0,043</u>	0,651
Number of non-novel bridges as a percentage of all bridges										0,067	0,061	0,405	<u>0,004</u>
Percentage of dwellings without finished flooring											<u>0,003</u>	0,907	0,128
Percentage of dwellings without finished roof												0,973	0,257
Percentage of dwellings without finished walls													0,803

4.1.3.3. Normalization

In order 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 data set and correlation between indicators. Indicators which have a positive impact (i.e. reduce risk) are inverted at this point, as their higher values correspond to less climate risk.

Chapter 3 on the background of the four sectors provides important insights into whether the projected changes in climate (hazard) indicators are going to have a positive or a negative impact on the sectors, i.e. decrease or increase climate risk. Table 64 provides an overview. Accordingly, the trends and projections of almost all hazard indicators have a negative impact on the country. The only exception is relative humidity: Here, 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 64 also informs on which hazard indicators were inverted upon entering them into the risk index: As 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/ dry/ short rainy/ rainy seasons have a positive impact on the sectors in the context of their expected evolution in future scenarios, these indicators were inverted. The righthand column of the table provides an explanation.

Table 64: Hazard indicators, their historic and future trends/ projections, the positive/ negative impacts these have on the sectors, how the indicator values influence the risk index and underlying reasons herefore.

Source: Own elaboration.

Indicator	Historic trend	Future trend	The trend has a positive/ negative impact	A higher indicator value increases/ decreases the climate risk index	Explanation
Average daily temperature	These indicators are very 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 their effects (such as frost) are not a hazard in Suriname, those locations which have cooler temperatures (mean, minimum, maximum) have an advantage over those locations with higher temperatures, as these are more likely to reach dangerously hot values more quickly.
Maximum daily temperature			Negative	Increases	
Minimum daily temperature			Negative	Increases	
Frequency of hot days	These indices are very homogeneous throughout the country.	Those are days which can be dangerously hot and nights during which sleeping is difficult. 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 hot nights			Negative	Increases	
Frequency of cold days		These two decrease and almost disappear, and are less important in a tropical	Negative	Decreases	Days and nights which can be dangerously cold do not occur in Suriname. As cold days and nights

Indicator	Historic trend	Future trend	The trend has a positive/ negative impact	A higher indicator value increases/ decreases the climate risk index	Explanation
Frequency of cold nights		climate.	Negative	Decreases	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, which is why 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 are the counterweight to intense precipitation events (see indicators on maximum precipitation in one and five days), which can provoke loss and damage, e.g. due to flooding. Thus, they decrease climate risk.
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	Negative	Increases	These indicators represent intense precipitation events, which can provoke loss and damage, e.g. due to flooding. Thus, they

Indicator	Historic trend	Future trend	The trend has a positive/ negative impact	A higher indicator value increases/ decreases the climate risk index	Explanation
Maximum precipitation in one day		rainy days, points to a change of rain regime towards fewer but more intense precipitation events.	Negative	Increases	increase climate risk.
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, also during the rainy season. 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	Coast: Decrease Interior: Increase	
Maximum daily winds	These are highest just off the coast and over the higher ground in the southeast. They show a descending	These indicators are projected to vary very little. The main patterns visible in the historical map	Negative	Increase	Winds can cause damage to infrastructure, housing and crops. Thus, the higher the winds, the higher the climate risk.

Indicator	Historic trend	Future trend	The trend has a positive/ negative impact	A higher indicator value increases/ decreases the climate risk index	Explanation
	trend.	change very little in all scenarios and timeframes.			
Gale wind days	These are very 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 SPS5-8.5 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.

4.1.3.4. 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 risk components (hazards, exposure, vulnerability) (Tonmoy, El-Zein & Hinkel, 2014). In this assignment, we chose to employ equal weights, too. In order to compensate for different numbers of indicators in the sub-indices we apply the following formula:

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

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

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

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

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

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/ percentages.

4.1.3.5. Aggregation

Aggregation of the risk component sub-indices (H, E, V) into the risk index proceeds using the following formula, stressing climate hazards in order 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/ percentages.

4.2. Results

This subchapter provides the results of the risk index, which was constructed according to the previous methodology (subchapter 4.1.), i.e. on the basis of indicators for hazards, exposure and vulnerability. A set of exposure and vulnerability indicators was selected for each one of the four sectors.

The results are presented in a step-by-step manner: First, as part of a cross-sectoral analysis of the risk index, each one of its three components are analyzed (i.e., the subindex on hazards, the subindex on exposure, the subindex on vulnerability) and compared across the ten districts. The combination of the three subindices finally gives rise to the risk index (subchapter 4.2.1.4.).

Second, each sector presents the results of the exposure and vulnerability subindex based on their indicators only. In fact, each indicator is evaluated one by one across the ten districts to provide a detailed picture of risk in Suriname and the four sectors.

4.2.1. Cross-sectoral

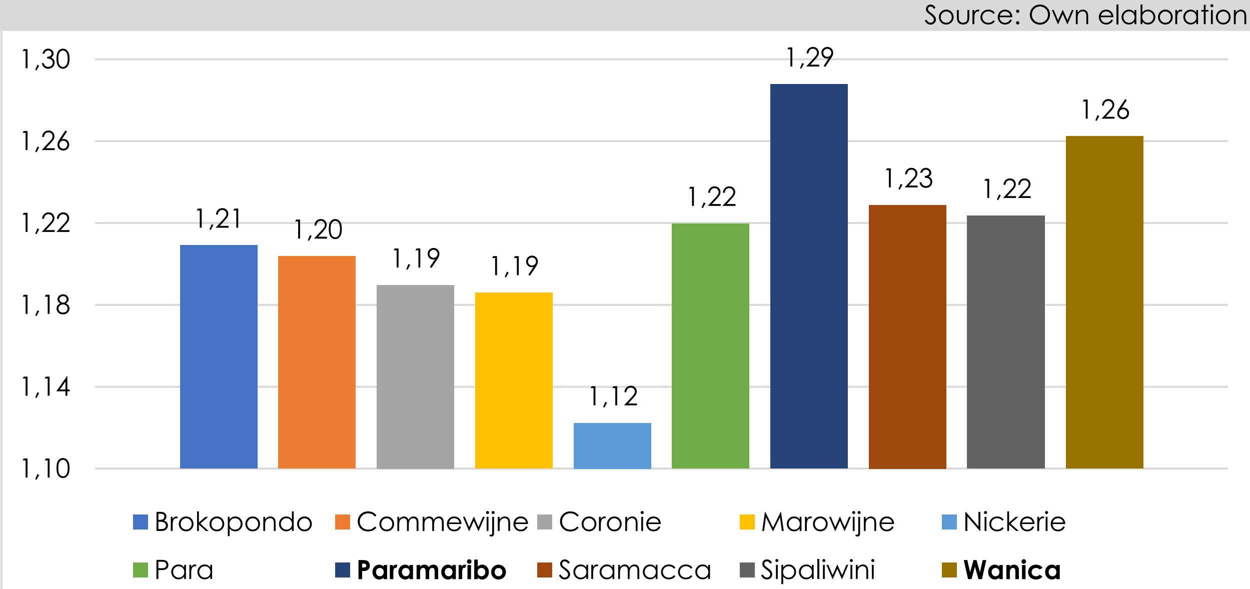
4.2.1.1. Hazards

The following figures present the results of the risk subindex on hazards, constructed based on 19 climate indicators, for the historic period (figure 75), the scenario SSPS2-4.5 (figure 76) and the scenario SSPS5-8.5 (figure 77).

Tables 65 and 66 accompany figures 76 and 77 and show the change in the hazards subindex between the historic, near-, mid- and long-term future for each district.

Figure 75: Hazard subindex for the historic period in the ten districts.

Source: Own elaboration.



Paramaribo has the highest hazard subindex, followed by **Wanica**. **Nickerie** has the lowest hazard subindex (figure 75).

Figure 76: Hazard subindex for the scenario SSPS2-4.5 and the near-, mid- and long-term future in the ten districts.

Source: Own elaboration.

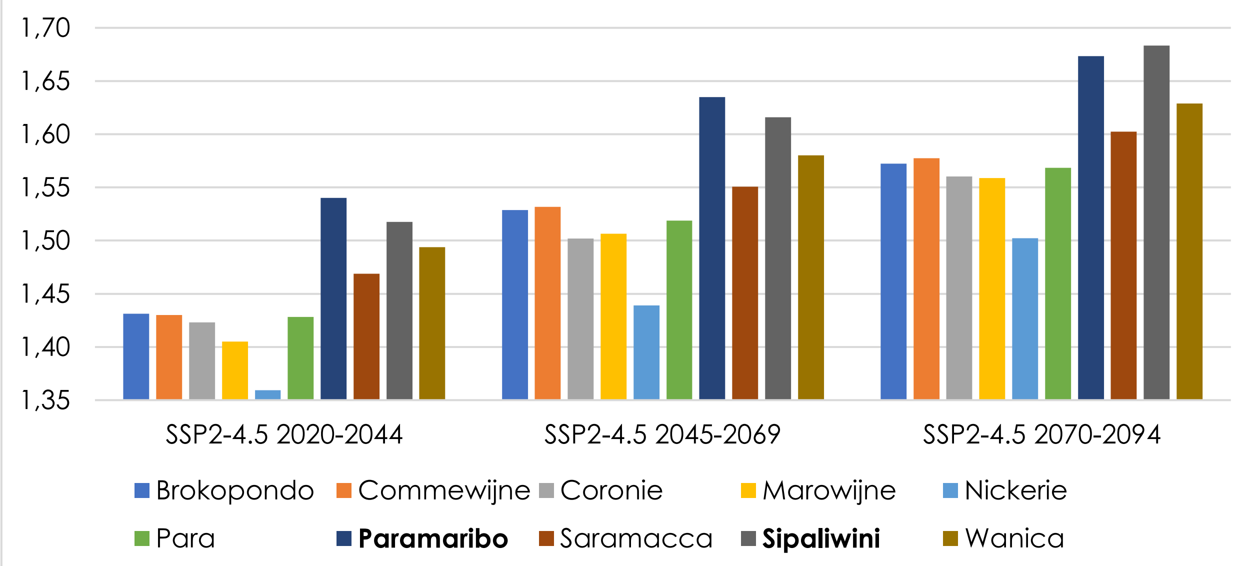


Table 65: Percentage positive increase of the hazard subindex between the historic value and three time periods of scenario SSPS2-4.5.

Source: Own elaboration.

	Hazard subindex under SSPS2-4.5 vs historic 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 %

In the SSPS2-4.5 scenario, all districts' hazard subindices increase by at least 17.1% (table 65). **Paramaribo** remains the district with the highest hazard subindex in the short- and medium-term (figure 76). **Nickerie** remains the district with the lowest hazard subindex throughout all timeframes. However, Nickerie's hazard subindex increases by 21.1-33.8 % over time (table 65). This increase is only topped by **Sipaliwini**, which hazard subindex increases by 24.0-37.6 %. Accordingly, Sipaliwini shoots to the top of the hazard subindex ranking, overtaking **Wanica** already in the short-term, and eventually Paramaribo in the long-term, thus becoming the district with the highest hazard subindex towards the end of the century (figure 76). The district which hazard subindex changes the least is Para, facing increases of only 17.1-28.6 % (table 65).

Figure 77: Hazard subindex for the scenario SSPS5-8.5 and the near-, mid- and long-term future in the ten districts.

Source: Own elaboration.

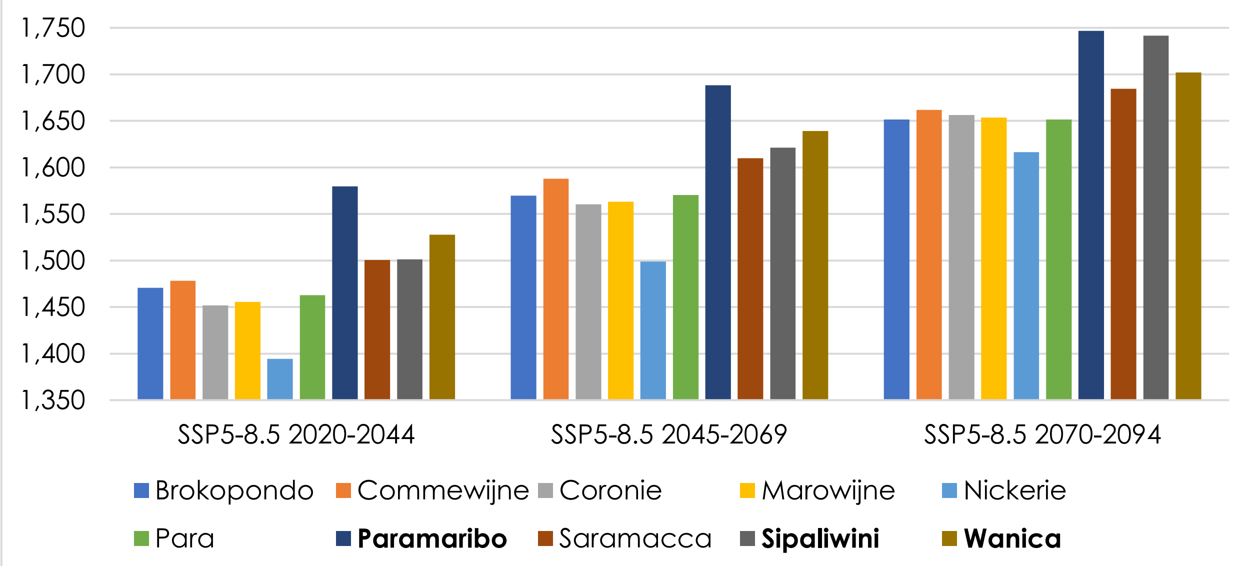


Table 66: Percentage positive increase of the hazard subindex between the historic value and three time periods of scenario SSPS5-8.5.

Source: Own elaboration.

	Hazard subindex under SSPS5-8.5 vs historic 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 %

In the SSPS5-8.5 scenario, all districts' hazard subindices increase by at least 19.9 % (table 66). **Paramaribo** and **Nickerie** remain the districts with the highest and lowest hazard subindices, respectively, throughout all timeframes (figure 77). However, Nickerie's hazard subindex increases by 24.2-44.0 % over time (table 66). This increase is not topped by any other district. It is also substantially higher than the increase witnessed in the SSPS2-4.5 scenario (21.1-33.8 %) (table 65). Again, **Sipaliwini** also witnesses high increases in its hazard subindex (between 22.7-42.3 % compared to 24.0-37.6 % in the SSPS2-4.5 scenario), particularly in the long-term, where Sipaliwini overtakes **Wanica** (figure 77). The district which hazard subindex changes the least is again Para, facing increases of only between 19.9-35.4, which are, however, considerably higher than in the SSPS2-4.5 scenario (17.1-28.6 %), particularly as time progresses (table 66).

Tables 67-69 demonstrate the percentual change in the hazard indicators between the historic, near-, mid- and long-term future and the two scenarios for each district[3].

Table 67: Percentage change (+/- %) of the normalized and inverted values of the indicators on temperature between the historic value and different scenarios and time periods across the ten districts.

Variables and changes of particular interest are highlighted in grey.

Source: Own elaboration.

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

[3] **Positive** percentual changes (increases) in **inverted** indicators (which higher values reduce climate risk and have a positive impact on the sectors) mean their absolute values decrease.

Positive percentual changes (increases) in **non-inverted** indicators (which higher values increase climate risk and have a negative impact on the sectors) mean their absolute values increase.

Negative percentual changes (decreases) in **inverted** indicators (which higher values reduce climate risk and have a positive impact on the sectors) mean their absolute values increase.

Negative percentual changes (decreases) in **non-inverted** indicators (which higher values increase climate risk and have a negative impact on the sectors) mean their absolute values decrease.

Maximum temperature	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
		2070-2094	59	48	49	46	54	49	52	50	66	46
Averag 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 tempera-ture	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

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 67). The indicator on the frequency of hot days also contributes substantially to the hazard subindex in the SSPS5-8.5 scenario and in the long-term (increases between 92-100%).

However, **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 of all districts.

Table 68: Percentage change (+/- %) of the normalized values of the indicators on precipitation between the historic value and different scenarios and time periods across the ten districts.

Variables and changes of particular interest are highlighted in grey.

Source: Own elaboration.

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
		2070-2094	49	16	33	23	47	41	3	23	35	9

Indicator	Time period and scenario		Brokopondo	Commewijne	Coronie	Marowijne	Nickerie	Para	Paramaribo	Saramacca	Sipaliwini	Wanica
Accumula-ted 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

Almost all 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 68). The only exception is dry season precipitation. Dry season precipitation increases for all districts apart from **Sipaliwini** (an increase is considered beneficial, thus negative percentual 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 SSPS2-4.5 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 69: Percentage change (+/- %) of the normalized values of the indicators on wind and humidity between the historic value and different scenarios and time periods across the ten districts.

Variables and changes of particular interest are highlighted in grey.

Source: Own elaboration.

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

The hazard indicator on gale wind does not change for any district but **Sipaliwini** (table 69). 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 (an increase is considered beneficial, thus negative percentual changes can be observed). This is particularly true for **Sipaliwini** and **Brokopondo**.

4.2.1.2. Exposure

Figures 78 presents the results of the risk subindex on exposure for the ten districts across sectors constructed based on a total of 20 indicators. Figures 79 shows the exposure values of the four sectors and ten districts.

Figure 78: Exposure subindex across sectors for the ten districts.
Source: Own elaboration.

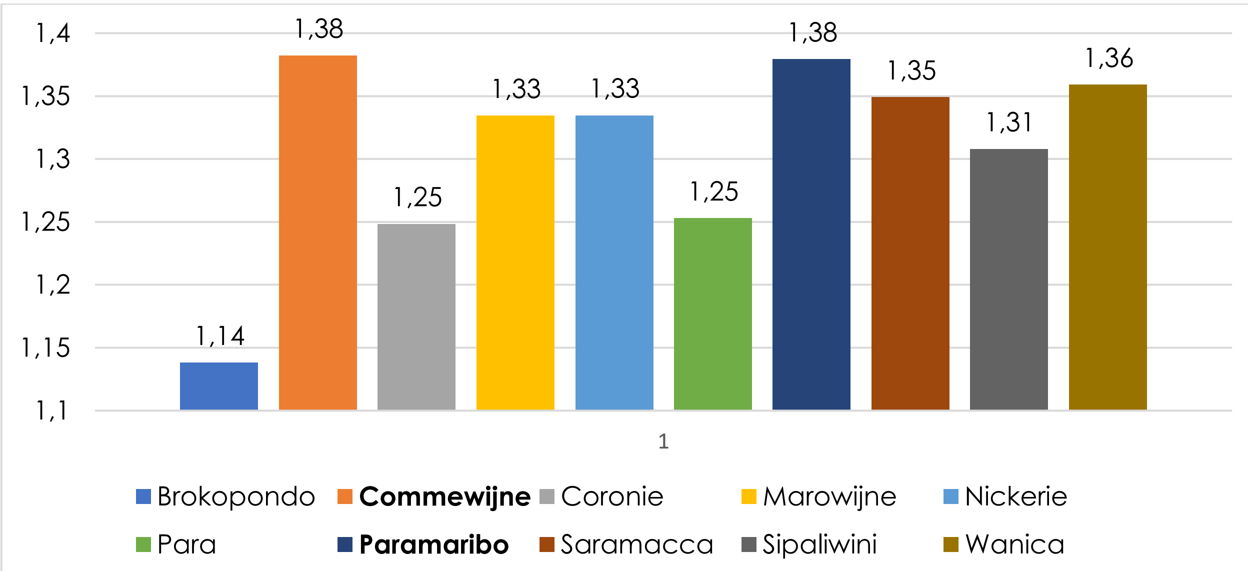
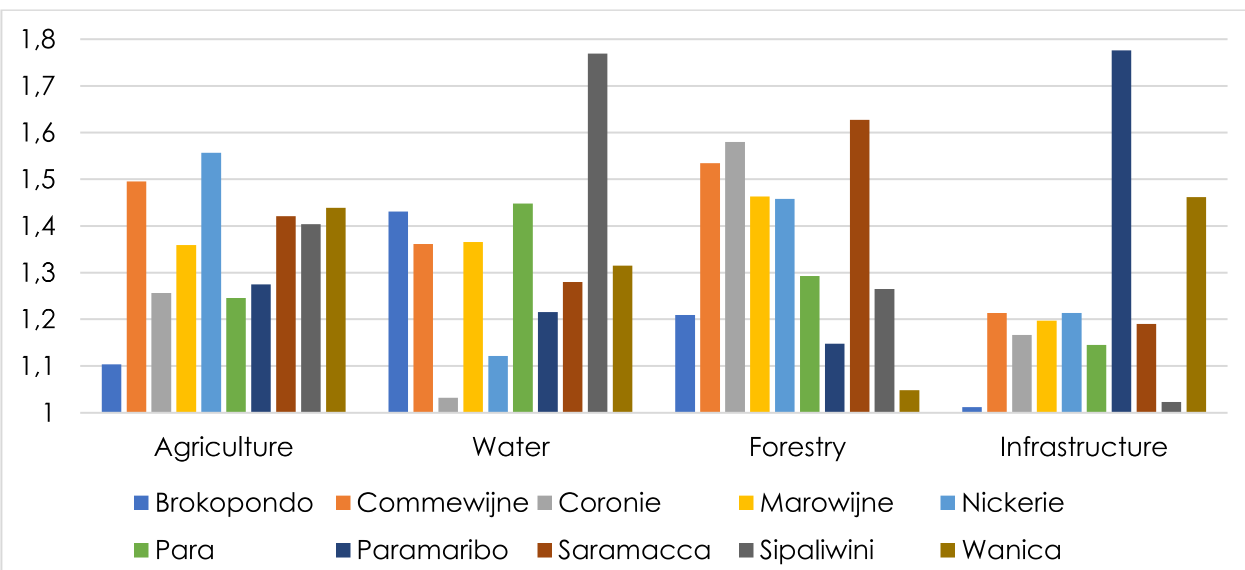


Figure 79: Exposure subindex values for the four sectors across the ten districts.
Source: Own elaboration.



Comewijne and **Paramaribo** are the most exposed districts, and **Brokopondo** is the least exposed district (figure 78). Commewijne demonstrates high exposure values in agriculture, water and forestry; Paramaribo has by far the highest exposure value in infrastructure (figure 79). Brokopondo scores very low for agriculture and infrastructure, with elevated and medium exposure values in water and forestry.

4.2.1.3. Vulnerability

Figures 80 presents the results of the risk subindex on exposure for the ten districts across sectors constructed based on 13 indicators. Figures 81 shows the exposure values of the four sectors and ten districts.

Figure 80: Vulnerability subindex across sectors for the ten districts.

Source: Own elaboration.

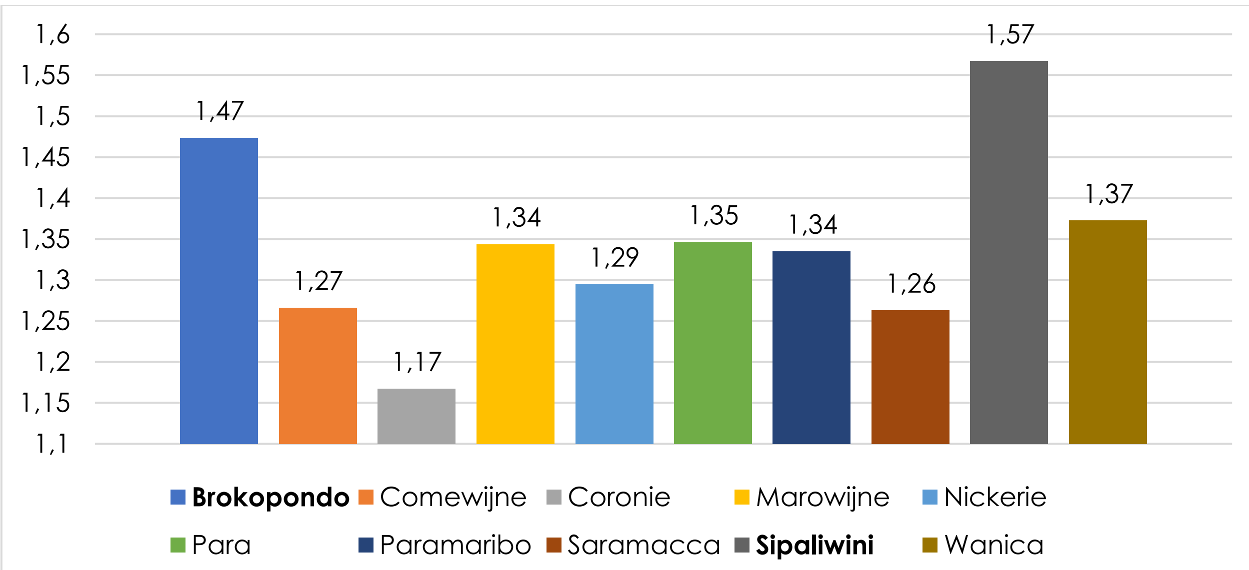
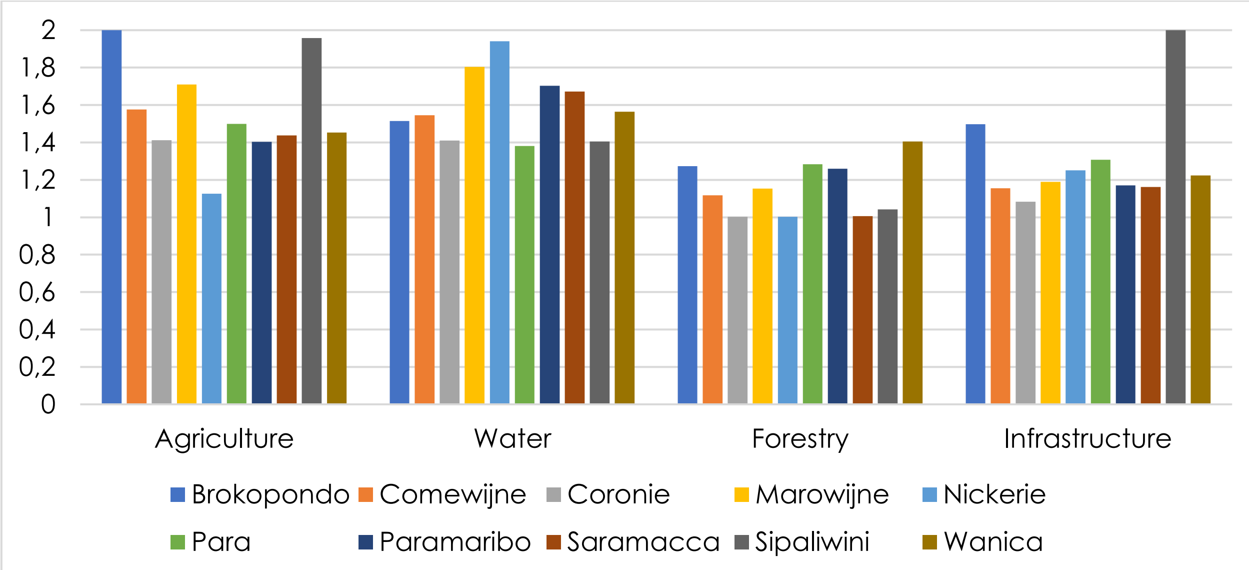


Figure 81: Vulnerability subindex values for the four sectors across the ten districts.
Source: Own elaboration.

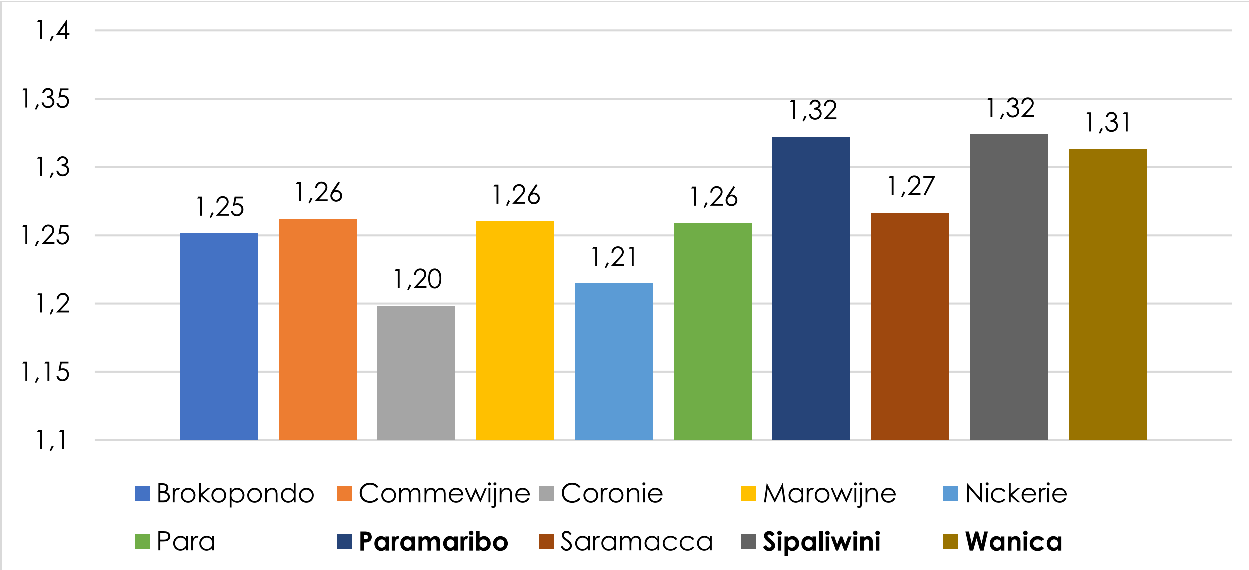


Although **Brokopondo** is the least exposed district, it is the second most vulnerable district after **Sipaliwini** (figure 80). Brokopondo is the most vulnerable district in agriculture, the second most vulnerable district in infrastructure and the third most vulnerable district in forestry (figure 81). 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. Unlike the other sectors, the districts vulnerability subindex values lie close together in the forestry sector, with values ranging from 1.0-1.4.

4.2.1.4. 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 historic period (figure 82), the scenario SSPS2-4.5 (figure 83) and the scenario SSPS5-8.5 (figure 84) across the ten districts.

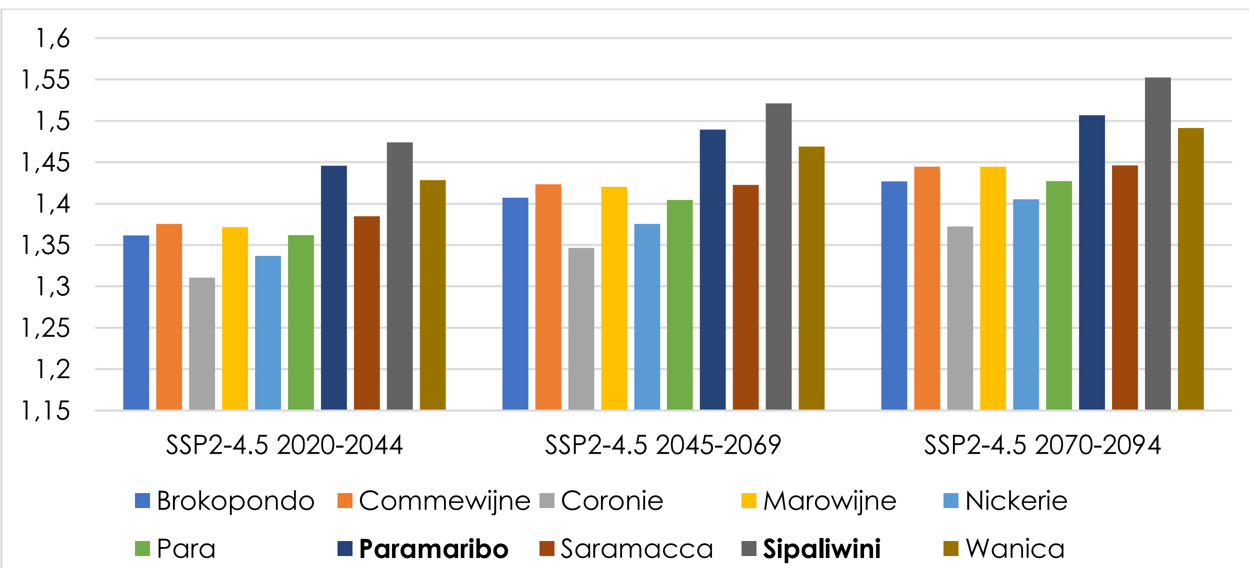
Figure 82: Risk index for the historic period and the ten districts.
Source: Own elaboration.



At present, **Sipaliwini**, **Paramaribo** and **Wanica** face the highest climate risk (figure 82). This is due to Sipaliwini's high vulnerability, Paramaribo's high hazard subindex and exposure, and Wanica's high hazard subindex.

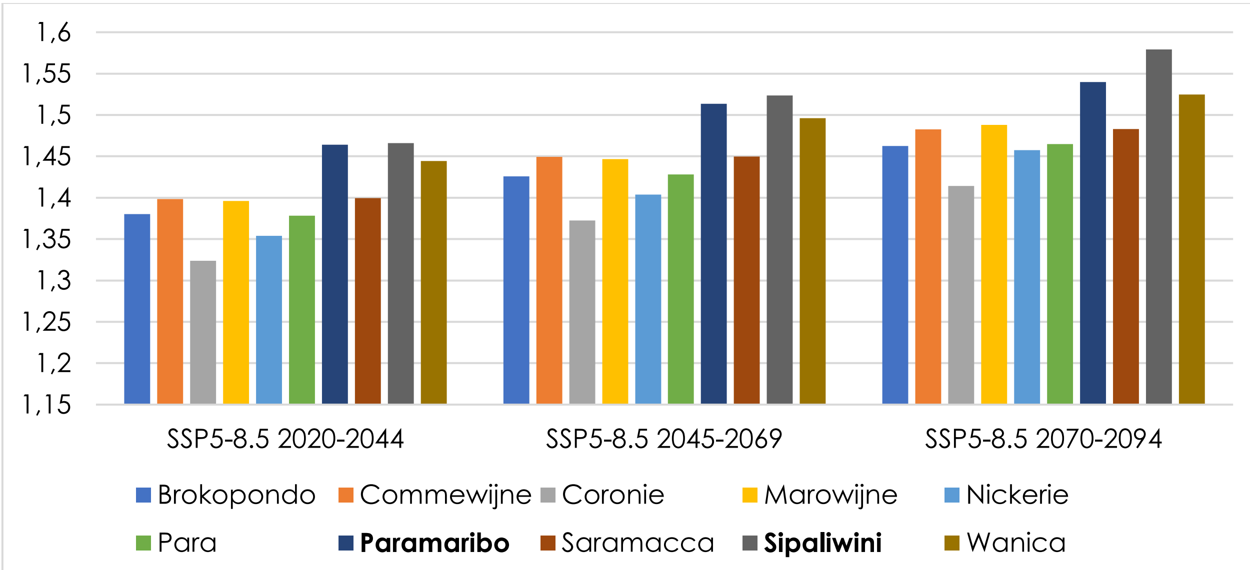
Coronie and **Nickerie** face the least climate risk. Coronie is the least vulnerable of all, and Nickerie has the lowest hazard subindex.

Figure 83: Risk index for the scenario SSPS2-4.5 and three time periods.
Source: Own elaboration.



Throughout the timeframes of SPSS2-4.5 **Sipaliwini**, **Paramaribo** and **Wanica** remain the three districts most at risk in descending order (figure 83). **Coronie** and **Nickerie** also remain those districts with the least climate risk in ascending order. The difference between the districts most and least at risk increases by 44 % between the historic period and the long-term.

Figure 84: Risk index for the scenario SSPS5-8.5 and three time periods.
Source: Own elaboration.



Throughout the timeframes of SPSS5-8.5 **Sipaliwini**, **Paramaribo** and **Wanica** remain the three districts most at risk in descending order (figure 84). **Coronie** and **Nickerie** also remain those districts with the least climate risk in ascending order.

The difference between the districts most and least at risk increases by 32 % between the historic period and the long-term, and thus is less pronounced than in the SSPS2-4.5 scenario (figure 83).

4.2.2. Agriculture

The following figures presents the results of the risk index for the agriculture sector on exposure (figure 85) and vulnerability (figure 86).

Figure 85: Exposure of the agriculture sector in the ten districts.

Source: Own elaboration.

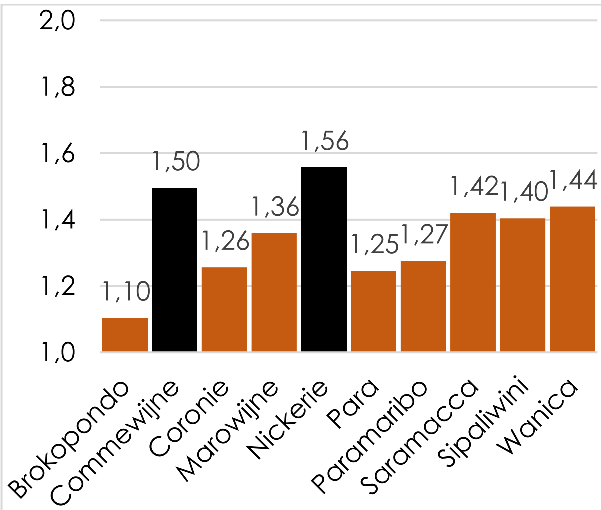
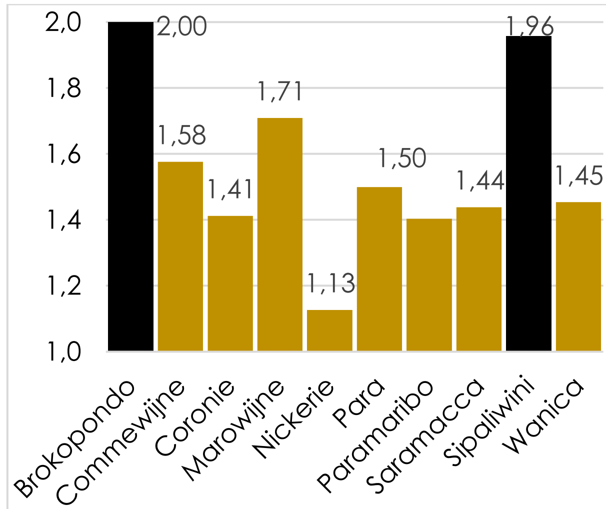


Figure 86: Vulnerability of the agriculture sector in the ten districts.

Source: Own elaboration.



4.2.2.1. Exposure

Figures 87-94 provides an overview of the indicators used to construct the exposure subindex.

Figure 87: Number of family farms as a percentage of the total number of households.

Source: Own elaboration.

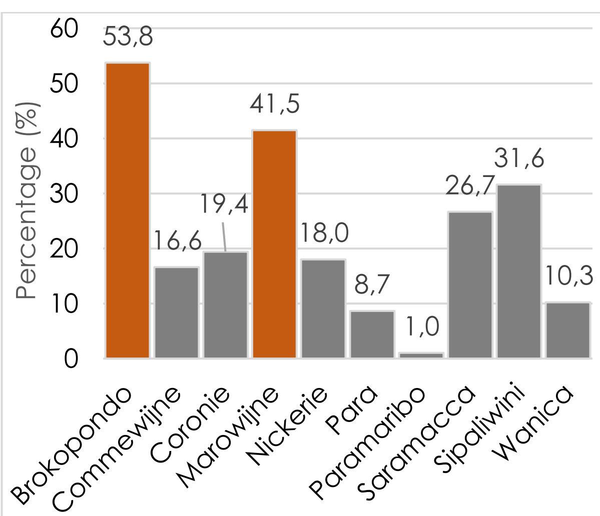


Figure 88: Number of animals (cattle, sheep, goats, pigs) per farm on average.

Source: Own elaboration.

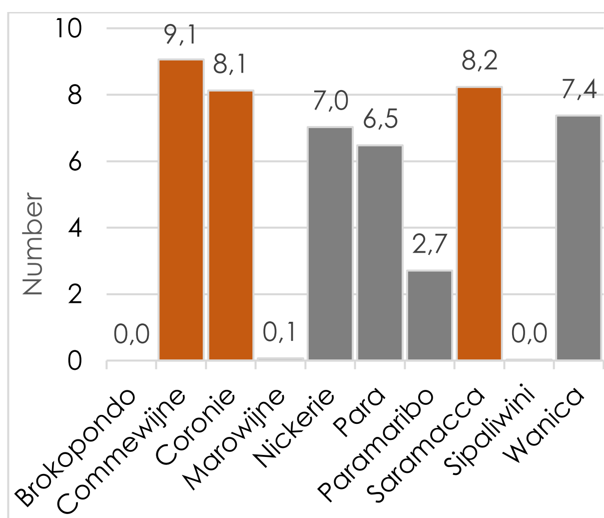


Figure 89: Agricultural land as a percentage of the total area of the district.

Source: Own elaboration.

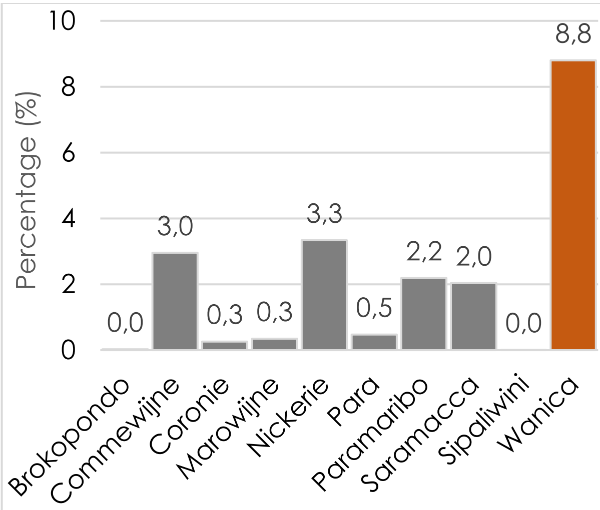


Figure 90: Number of hired workers as a percentage of the total population.

Source: Own elaboration.

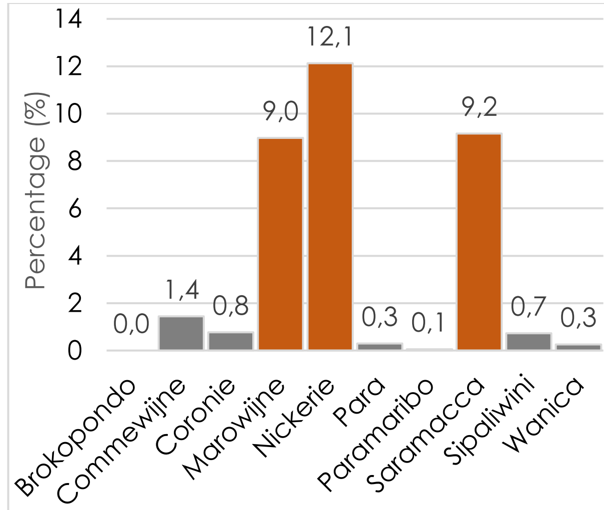


Figure 91: Number of farms with less than 2 ha of agricultural land as a percentage of all farms.

Source: Own elaboration.

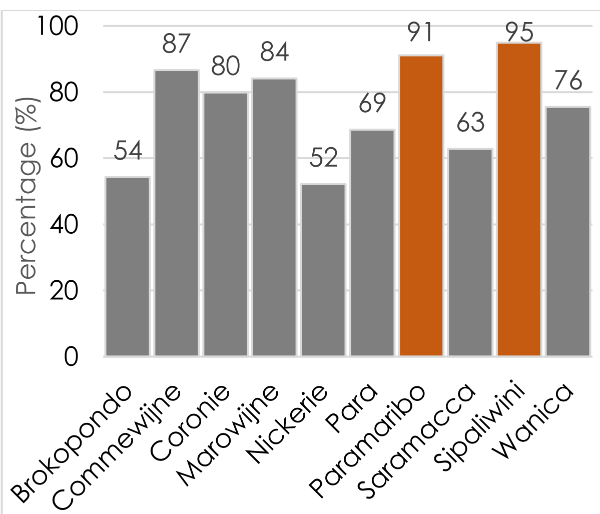


Figure 92: Percentage of the population whose income is less than half the GNI per capita of the district.

Source: Own elaboration.

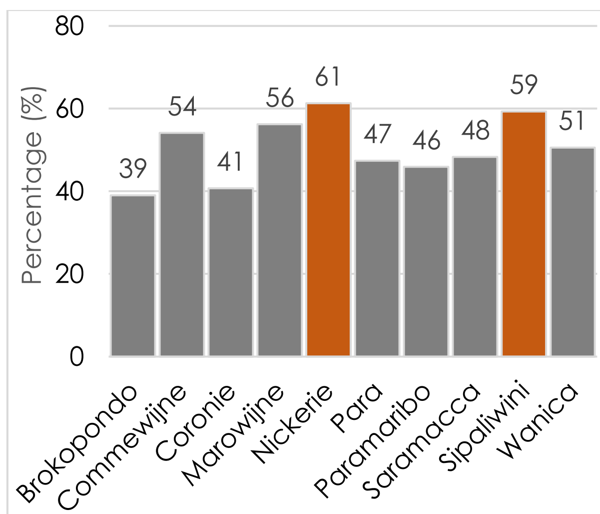


Figure 93: Percentage of children under the age of five that are stunted (-2 SD).

Source: Own elaboration.

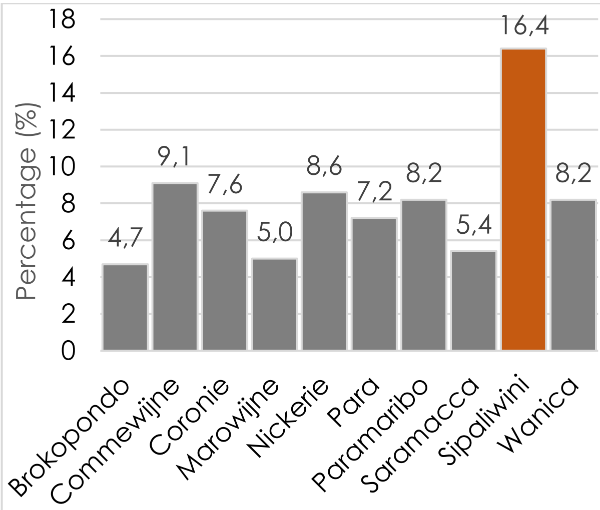
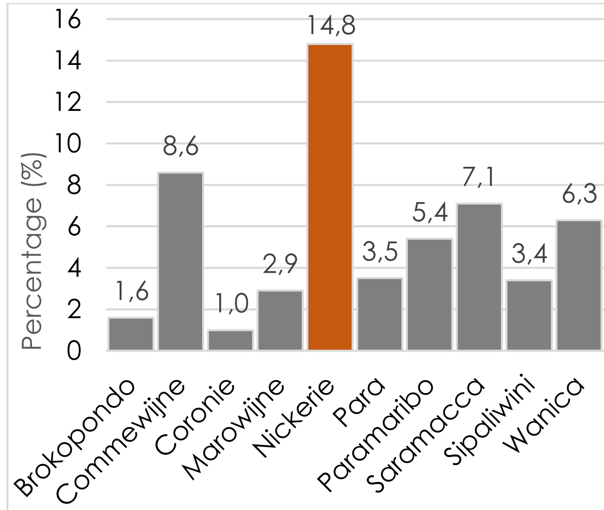


Figure 94: Percentage of children under the age of five that are wasted (-2 SD).

Source: Own elaboration.



Nickerie is the most exposed district (figure 85). It has the highest number of hired workers in agriculture as a percentage of the total population (12.5 %, whereas six districts score below 1 %) (figure 90), the biggest relative population with a low income (61.3 %) (figure 92) and the highest percentage of wasted children (14.8 %) (figure 94) out of all districts.

The second most exposed district is **Commewijne** (figure 85). It has the highest number of animals per farm on average out of all districts (9.1) (figure 88) and has a high percentage of agricultural land (16.6 %, whereas five districts score below 1 %) (figure 89), smallholders (86.6 %, whereas Brokopondo and Nickerie score just above 50 %) (figure 91), low income population (54.1 %) (figure 92), stunted and wasted children (9.1 % and 8.6 %, respectively) (figures 93-94).

Both Nickerie and Commewijne lie at the coast. Therefore, due to their location (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 depending on freshwater.

Brokopondo is the least exposed district (figure 85). Although it has the highest number of households which are family farms (53.8 %, followed by Marowijne with 41.5 %) (figure 87), it scores lowest on almost all the other indicators.

The second least exposed district is Para (figure 85). In contrast to Brokopondo, only 8.7 % of its households are family farms (in comparison, Paramaribo scores best on this indicator with only 1.0 %) (figure 87), however, the district performs less well on other indicators such as the number of animals per farm, where Para counts 6.5 on average per farm and Brokopondo counts 0 (figure 88).

4.2.2.2. Vulnerability

Figures 95-96 provide an overview of the indicators used to construct the vulnerability subindex.

Figure 95: Number of family farms with the farmer having received no formal education as a percentage of all family farms.

Source: Own elaboration.

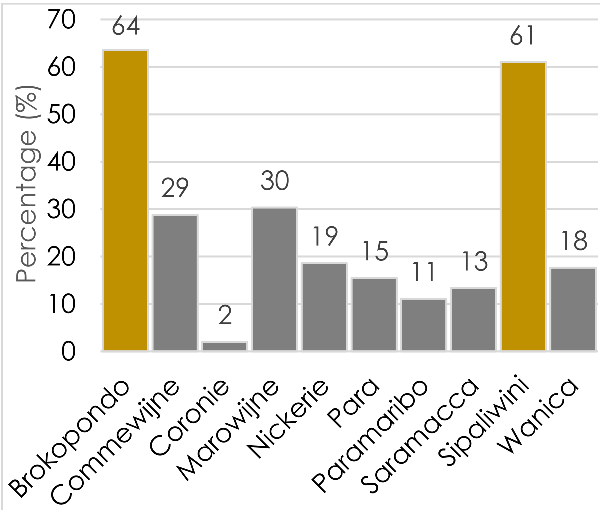
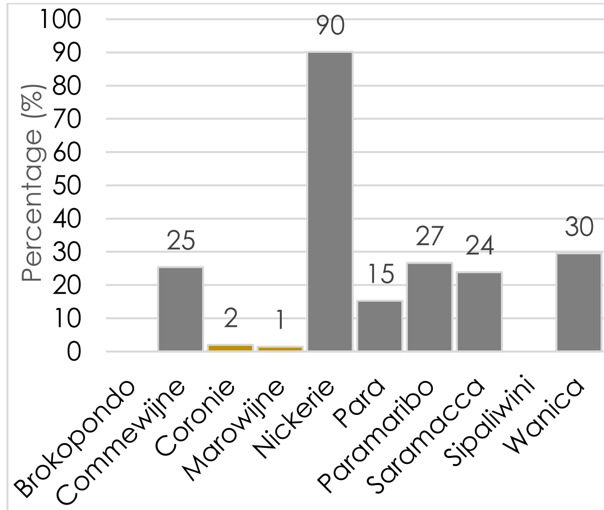


Figure 96: Number of farms with irrigation infrastructure as a percentage of the total number of farms[4].

Source: Own elaboration.



Although Brokopondo is the least exposed district, it is the most vulnerable (figure 86). This inverse relationship between exposure and vulnerability can also be found in Nickerie. Nickerie is the most exposed district but the least vulnerable.

Brokopondo and Sipaliwini are by the most vulnerable districts, because their farmers are the least educated, as 64 % and 61 % of them received no formal education, respectively (figure 95). 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 (only 19 % of farmers have no formal education) (figure 95) and the highest percentage of farms out of all districts (90.2 %) have irrigation infrastructure, whereas most other districts score between 15-30 % (figure 96).

4.2.2.3. Relevance of projected changes in climate hazards for the sector

15 of the projected changes in climate hazards are considered highly relevant for the sector and two were considered of medium importance (table 70). They concern the increase in temperature, sea-level, and decrease in relative humidity, precipitation in three seasons and increases in one season with overall more intense precipitation events.

[4] Irrigation infrastructure 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.

Table 70: Relevance of projected changes in climate hazards for the agriculture sector.
Source: Own elaboration.

Hazard indicator	Relevance	
Average daily temperature	High	Crop, livestock and fish production are directly related to optimum temperatures. Very 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 e.g. the oxygen content of water drops. Moreover, high temperatures increase the demand for water. This is an issue in areas where there is a water shortage or no irrigation infrastructure. High temperatures also affect the health of agricultural workers and food stability.
Maximum daily temperature		
Minimum daily temperature		
Frequency of hot days		
Frequency of hot nights		
Frequency of cold days	Low	As there is no frost in Suriname, crop, livestock and fish production are not affected.
Frequency of cold nights		
Accumulated yearly precipitation	High	Crop and livestock production are heavily affected by decreases in accumulated yearly precipitation or the number of rainy days, as both crop production and the production of fodder and water for animal consumption depend on water.
Number of rainy days per year		
Maximum precipitation in five days	High	Strong rainfall and downstream events such as the floods it provokes pose an important hazard to crop and livestock production.
Maximum precipitation in one day		
Short dry season precipitation	Medium	Short dry season precipitation is of medium importance for agriculture, and thus livestock production in terms of fodder availability.
Dry season precipitation	High	The dry season precipitation is of high importance for agriculture, and thus livestock production in terms of fodder availability.
Short rainy season precipitation	Medium	Short dry season precipitation is of medium importance for agriculture, and thus livestock production in terms of fodder availability.
Rainy season precipitation	High	Rainy season precipitation is of high importance for agriculture, and thus livestock production in terms of fodder availability, particularly in the interior (Sipaliwini, Brokopondo, Para), where slash-and-burn agriculture is rain-fed and may be negatively affected by excess rainfall.
Maximum daily winds	High	This affects crop production (e.g. 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 (e.g. bananas), as plants get damaged from strong winds.

Hazard indicator	Relevance	
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 close physical proximity to the sea.

4.2.3. Water

The following figures presents the results of the risk index for the water sector on exposure (figure 97) and vulnerability (figure 98).

Figure 97: Exposure of the water sector in the ten districts.

Source: Own elaboration.

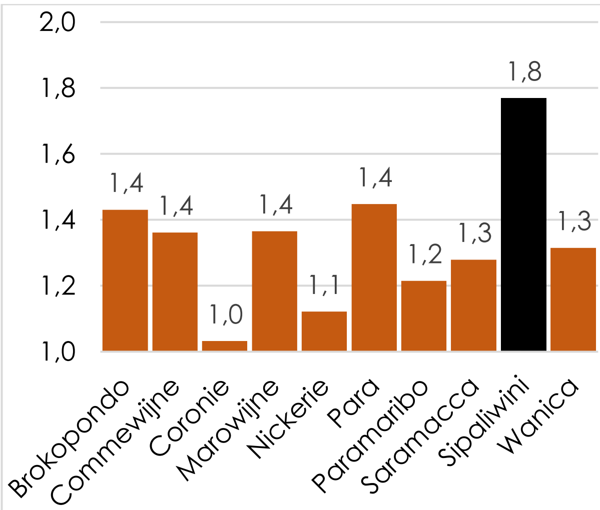
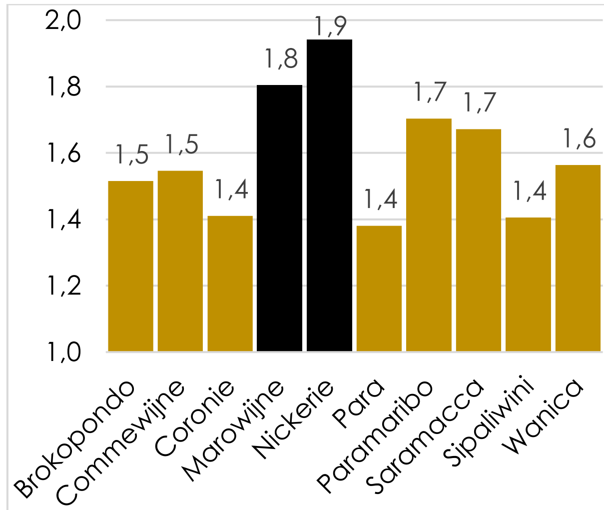


Figure 98: Vulnerability of the water sector in the ten districts.

Source: Own elaboration.



4.2.3.1. Exposure

Figures 99-101 provides an overview of the indicators used to construct the exposure subindex.

Figure 99: Number of households not using improved drinking water sources as a percentage of the total number of households.

Source: Own elaboration.

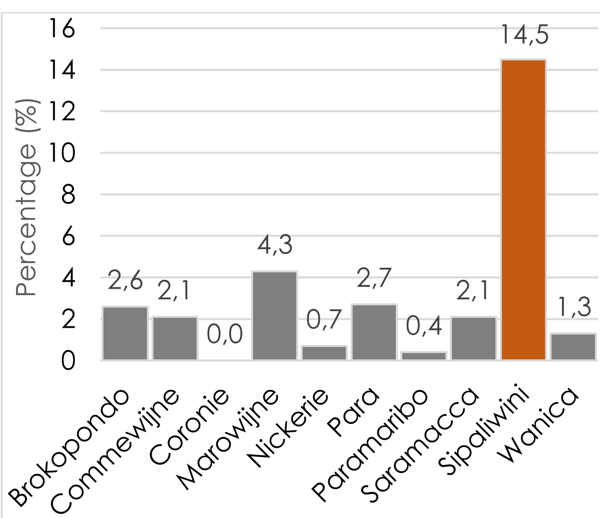


Figure 100: Number of households without drinking water available in sufficient quantities as a percentage of the total number of households.

Source: Own elaboration.

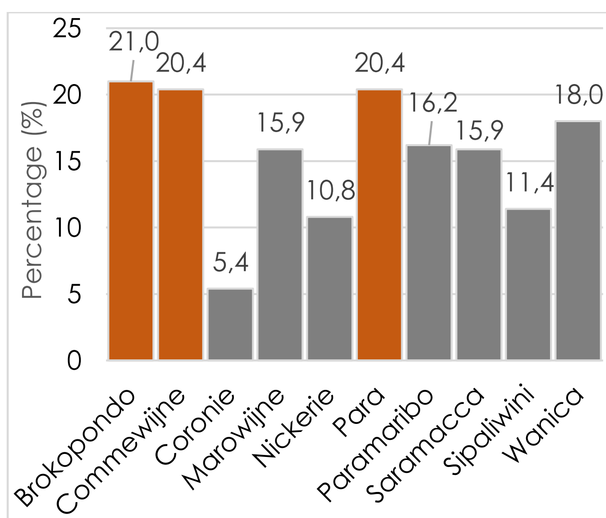
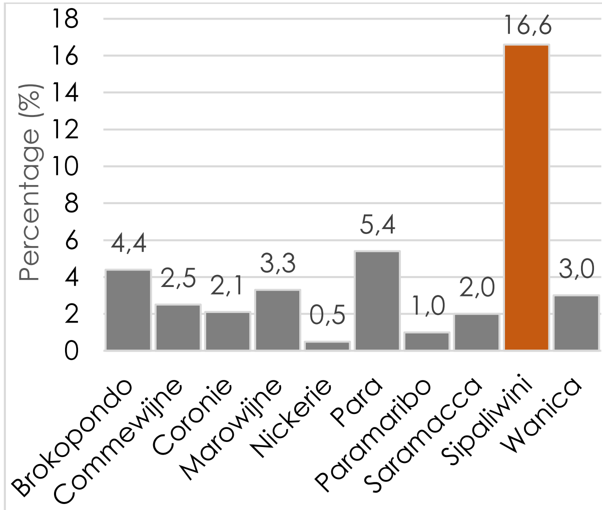


Figure 101: Number of household members without access to drinking water on premises as a percentage of the total number of household members.

Source: Own elaboration.



Sipaliwini is by far the most exposed district (figure 97). It has the highest percentage of households not using improved drinking water sources (14.5 %, whereas all other districts score below 5 %) (figure 99) and the without access to drinking water on the premises (16.6 %, whereas all other districts score below 6 %) (figure 101).

Coronie is the least exposed district (figure 97). It has the lowest percentage of households not using improved drinking water sources (0 %) (figure 99) and suffering from low drinking water availability (5.4 %, whereas most other districts score between 15-21 %) (figure 100) 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 101).

The second least exposed district is **Nickerie** (figure 97), 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 101). This is more than in any other district.

4.2.3.2. Vulnerability

Figures 102-104 provide an overview of the indicators used to construct the vulnerability subindex.

Figure 102: SWM and DWV water production (m^3/day) per capita[5].

Source: Own elaboration.

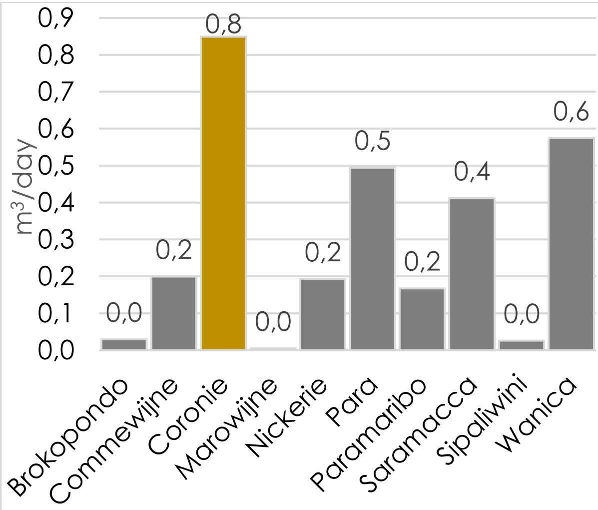


Figure 103: Storage capacity (m^3/day) per capita[6].

Source: Own elaboration.

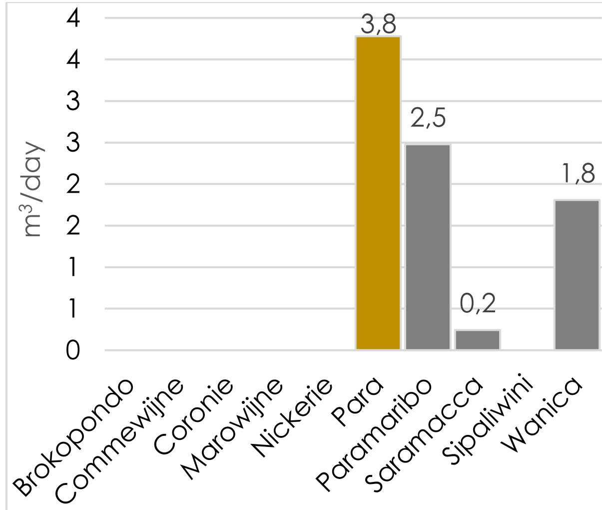
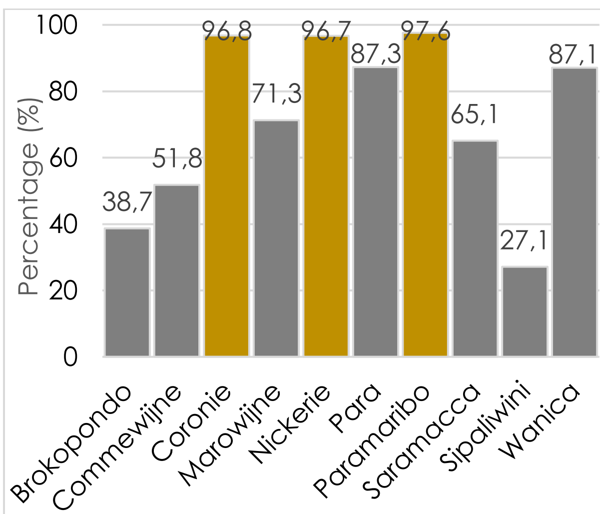


Figure 104: Number of households which main source of drinking water is not rainwater collection as a percentage of the total number of households.

Source: Own elaboration.



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[5] Water production 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.

[6] 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. 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.

Nickerie is the most vulnerable district (figure 98). It scores fairly low on water production (figure 102) and only 3.3 % of households have alternative sources of drinking water (rainwater collection) (figure 104).

The second most vulnerable district is **Marowijne** (figure 98). It has the lowest water production (figure 102), however, almost 29 % of households have alternative drinking water sources (figure 104).

The least vulnerable districts are Para, Sipaliwini and Coronie (in order of ascending vulnerability) (figure 98). **Para** has the highest water storage capacity out of all districts (3.8 m^3/day/capita, whereas Saramacca only stores 0.2 m^3/day/capita) (figure 103). Para also performs third best on water production (0.5 m^3/day/capita, whereas other districts such as Marowijne produce none) (figure 102), but fourth worst on alternative sources of drinking water (with only 12.7 % of households collecting rainwater) (figure 104). **Sipaliwini** has the second lowest water production (figure 102), however, it performs best on alternative sources of drinking water with nearly two thirds of households collecting rainwater (figure 104). **Coronie** has the highest water production out of all districts (0.8 m^3/day/capita) (figure 102), though only few households collect rainwater (3.2 %) (figure 104).

4.2.3.3. Relevance of projected changes in climate hazards for the sector

13 of the projected changes in climate hazards are considered highly relevant for the sector and one was considered of medium importance (table 71). They concern the increase in temperature, sea-level, and decrease in precipitation overall and in the four seasons but with more intense precipitation events.

The analysis also underlines Sipaliwini's low vulnerability. Its excellent performance on rainwater collection as a source of safe drinking water in combination with more intense precipitation events and a wetter rainy season in the interior to harvest rainwater give it an advantage over other districts in dealing with climate change impacts on the water sector. Also, Sipaliwini is not affected by sea-level rise. However, this low vulnerability may be necessary in order to compensate for the high increases in temperature and decreases in precipitation during the dry and short dry seasons in Sipaliwini in comparison to the rest of the districts (tables 67-68).

Table 71: Relevance of projected changes in climate hazards for the water sector.

Source: Own elaboration.

Hazard indicator	Relevance	
Average daily temperature **Maximum daily temperature** **Minimum daily temperature** **Frequency of hot days** **Frequency of hot nights**	High	Higher temperatures negatively impact water quality (e.g. lower dissolved oxygen levels) and availability. They also increase the demand for water.
Frequency of cold days **Frequency of cold nights**	Low	These indicators do not affect the water sector greatly.
Accumulated yearly precipitation **Number of rainy days per year**	High	Decreased precipitation can negatively impact water availability in surface and groundwater sources (i.e. unconfined aquifers). 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.
Maximum precipitation in five days **Maximum precipitation in one day**	High	Intense precipitation events can cause damage to water works' infrastructure (wells, treatment facilities). 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.
Short dry season precipitation **Dry season precipitation** **Short rainy season precipitation**	High	Drier seasons affect water availability (rainwater, surface and groundwater) and thus the water quality of surface and groundwater.
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". In the interior precipitation increases. The effects will be beneficial, as more rainwater can be collected.
Maximum daily winds **Gale wind days** **Strong wind days**	Low	These indicators do not affect the water sector greatly.

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.

4.2.4. Forestry

The following figures presents the results of the risk index for the forestry sector on exposure (figure 105) and vulnerability (figure 106).

Figure 105: Exposure of the forestry sector in the ten districts.

Source: Own elaboration.

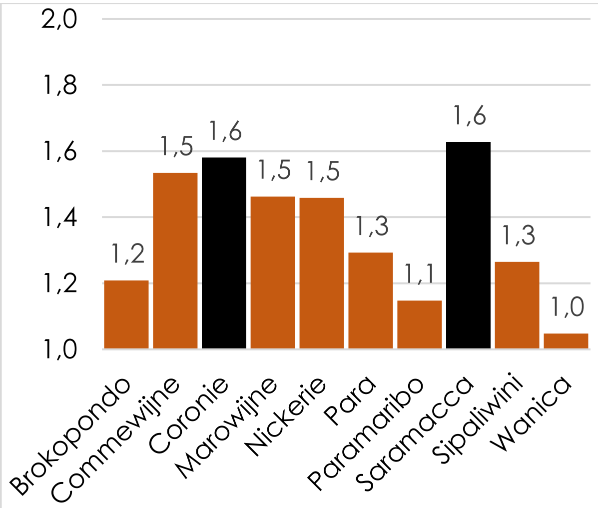
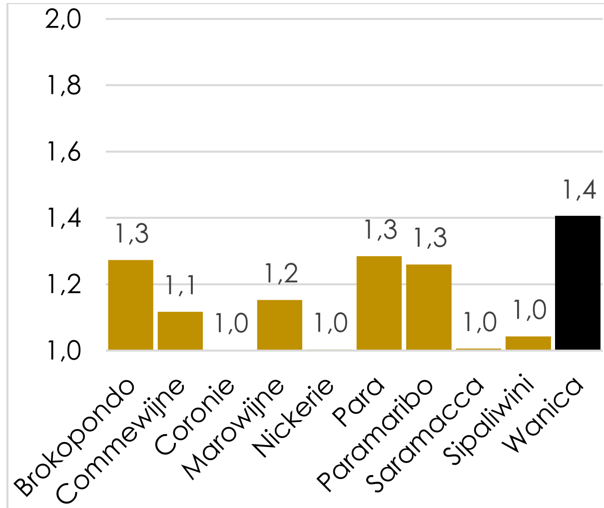


Figure 106: Vulnerability of the forestry sector in the ten districts.

Source: Own elaboration.



4.2.4.1. Exposure

Figures 107-109 provides an overview of the indicators used to construct the exposure subindex.

Figure 107: Area of mangroves as a percentage of the total area of the district.

Source: Own elaboration.

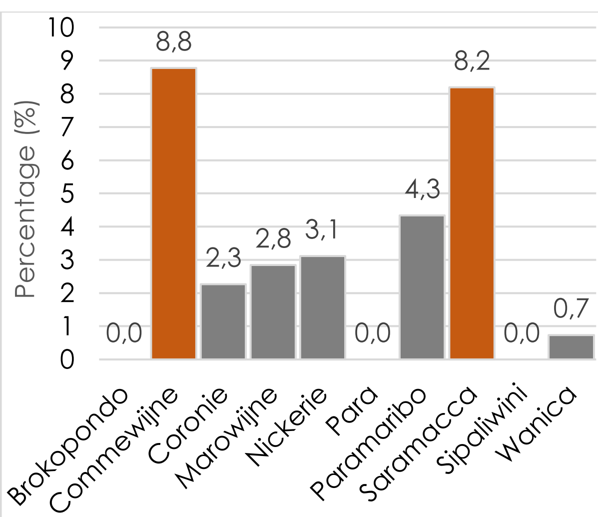


Figure 108: Area of open savanna and swamp as a percentage of the total area of the district.

Source: Own elaboration.

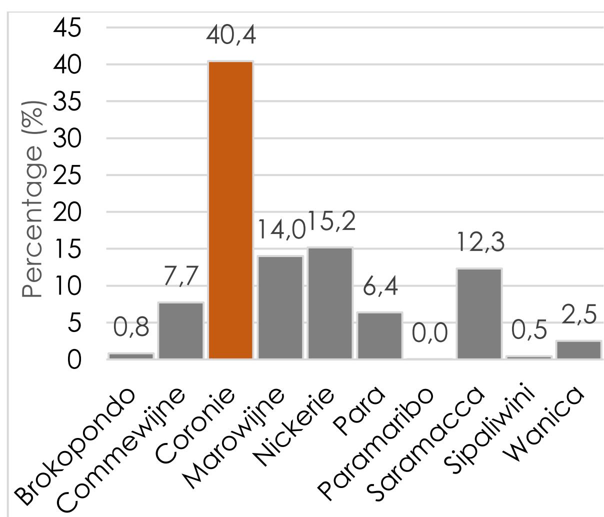
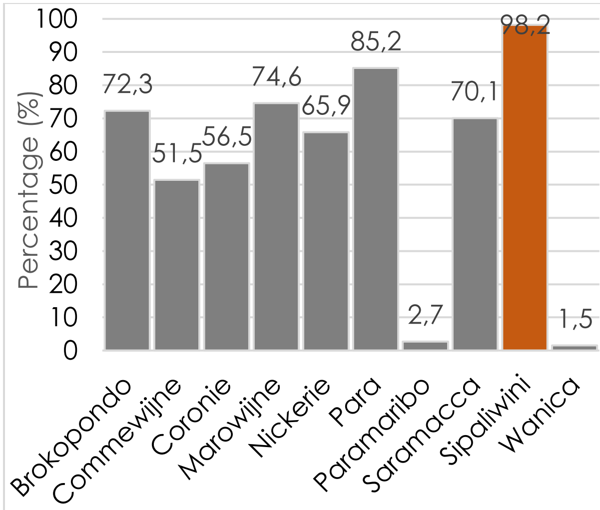


Figure 109: Area of forest as a percentage of the total area of the district.

Source: Own elaboration.



Saramacca is the most exposed district (figure 105). It has the second highest mangrove cover (8.2 %, only beaten by Commewijne with 8.8 %, and 2-3.5 times that of those other districts which have mangroves, i.e. excluding Brokopondo, Para and Sipaliwini which do not lie at the coast) (figure 107). Saramacca also has a fairly high savanna and swamp cover (12.3 %, comparable to that of Marowijne and Nickerie) (figure 108). This is the indicator where **Coronie**, the second most exposed district, scores highest with 40.4 % due to the Coronie swamp (figure 108). Both Saramacca and Coronie score fairly neither high nor low on other forest cover (56.5 % and 70.1 %, respectively) (figure 109). This is where Sipaliwini scores highest (98.2 %), followed by Para (85.2 %), Marowijne (74.6 %) and Brokopondo (72.3 %) (figure 109).

Wanica is the least exposed district, as it consistently scores between lowest and fourth lowest on all indicators (figures 107-109). The second and third least exposed districts are Paramaribo and Brokopondo, respectively, despite Paramaribo scoring higher on mangrove cover (figure 107) and Brokopondo scoring higher on other forest cover (figure 109).

4.2.4.2. Vulnerability

Figures 110-112 provide an overview of the indicators used to construct the vulnerability subindex.

Figure 110: Deforested area between 2000 and 2015 as a percentage of the total forested area.

Source: Own elaboration.

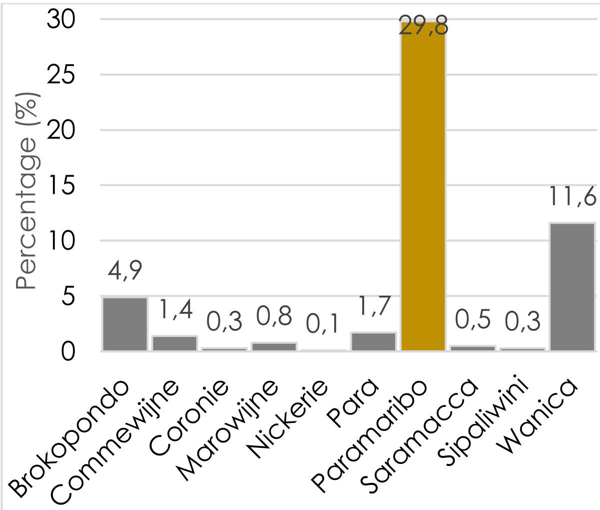


Figure 111: Number of Amerindian and Maroon settlements per 10 km² forest area.

Source: Own elaboration.

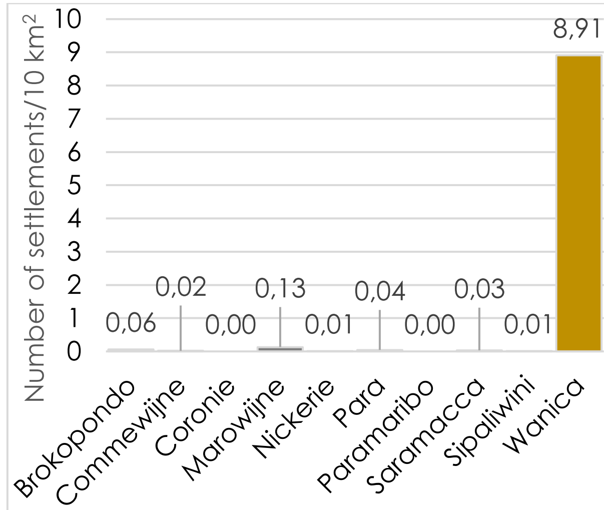
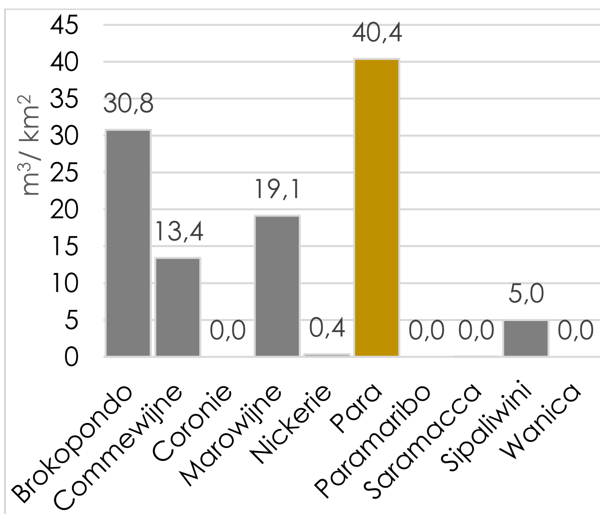


Figure 112: Volume (m³) of roundwood produced per km² forest.

Source: Own elaboration.



Wanica is the most vulnerable district (figure 106). It has the second highest deforestation rate (11.6 %, whereas most other districts score below 2 %, with only Paramaribo scoring higher with 29.8 %) (figure 110). These numbers reflect that Paramaribo and Wanica are the smallest districts with the least forested area (figure 109). Therefore, deforestation is noted very easily. Moreover, Wanica has the by far highest density of Amerindian and Maroon settlements, followed by Marowijne (figure 111), however, Wanica has no considerable roundwood production (figure 112).

The second, third and fourth most vulnerable districts are Para, Brokopondo and Paramaribo, respectively (figure 106). **Para** has a fairly high deforestation rate (figure 110), settlement density (figure 111) and the highest roundwood production per km^2 forest (40.4 m^3) (figure 112), although Sipaliwini is the biggest roundwood producer, but has a high forest area. **Brokopondo** has the third highest deforestation rate (4.9 %) (figure 110) and second highest roundwood production per km^2 forest (30.8 m^3) (figure 112). **Paramaribo** has the highest deforestation rate (figure 110).

Although the second most exposed district, **Coronie** is the least vulnerable district. The second least vulnerable district is **Nickerie**. They perform consistently low on all indicators (figure 110-112).

4.2.4.3. Relevance of projected changes in climate hazards for the sector

13 of the projected changes in climate hazards are considered highly relevant for the sector and four were considered of medium importance (table 72). They concern the increase in temperature and sea-level, and the decrease in precipitation and humidity.

Table 72: Relevance of projected changes in climate hazards for the forestry sector.

Source: Own elaboration.

Hazard indicator	Relevance	
Average daily temperature	High	Higher temperatures and less precipitation contribute to droughts and forest fires. These particularly affect savannas and swamps wherever they occur throughout the country.
Maximum daily temperature		
Minimum daily temperature		
Frequency of hot days		
Frequency of hot nights		
Frequency of cold days		
Frequency of cold nights		
Accumulated yearly precipitation		
Number of rainy days per year		
Maximum precipitation in five days	High	The rise in intense precipitation events can lead to the flooding of forests by overflowing rivers.
Maximum precipitation in one day		
Short dry 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).
Dry season precipitation		
Short rainy season precipitation		
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 on intense precipitation events (see above).
Maximum daily winds	Low	These indicators do not affect the forestry sector greatly.
Gale wind days		
Strong wind days		
Relative humidity	High	Reduced relative humidity contributes to droughts and forest fires. These particularly affect savannas and swamps wherever they occur throughout the country.
Sea-level rise	High	Sea-level rise provokes erosion and saltwater intrusion which affect coastal mangroves wherever they occur throughout the country.

4.2.5. Infrastructure

The following figures presents the results of the risk index for the Infrastructure sector on exposure (figure 113) and vulnerability (figure 114).

Figure 113: Exposure of the infrastructure sectors in the ten districts.

Source: Own elaboration.

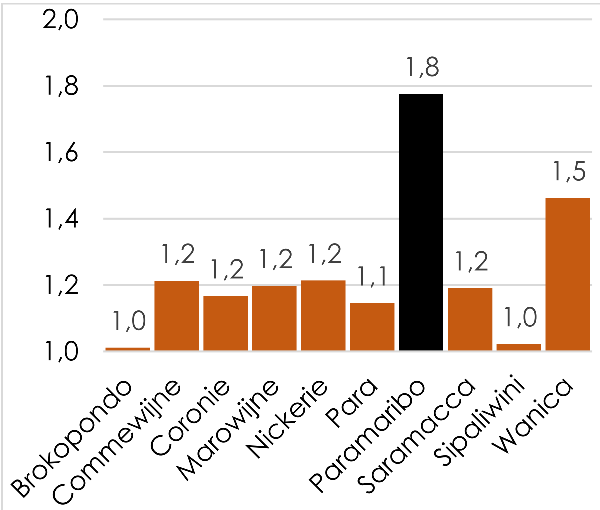
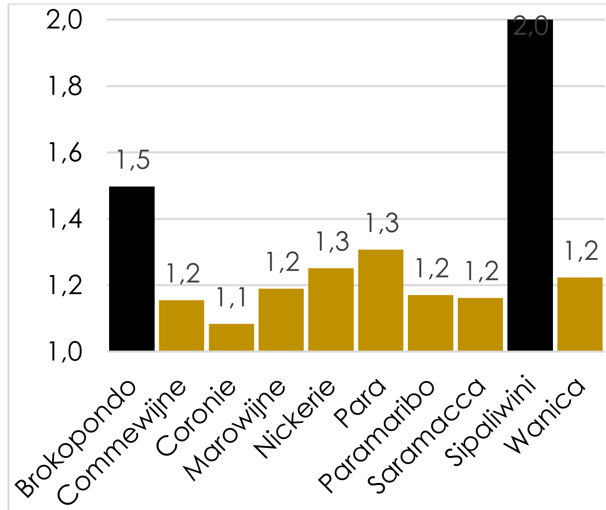


Figure 114: Vulnerability of the infrastructure sectors in the ten districts.

Source: Own elaboration.



4.2.5.1. Exposure

Figures 115-120 provides an overview of the indicators used to construct the exposure subindex.

Figure 115: Km of road per km² area.

Source: Own elaboration.

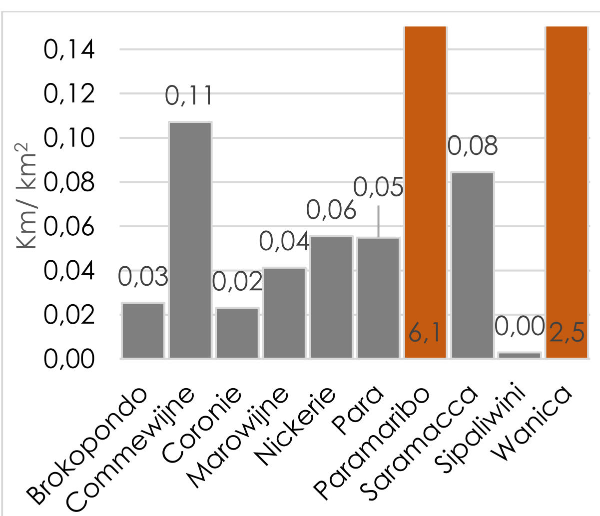


Figure 116: Number of certified harbors per capita (x 100,000).

Source: Own elaboration.

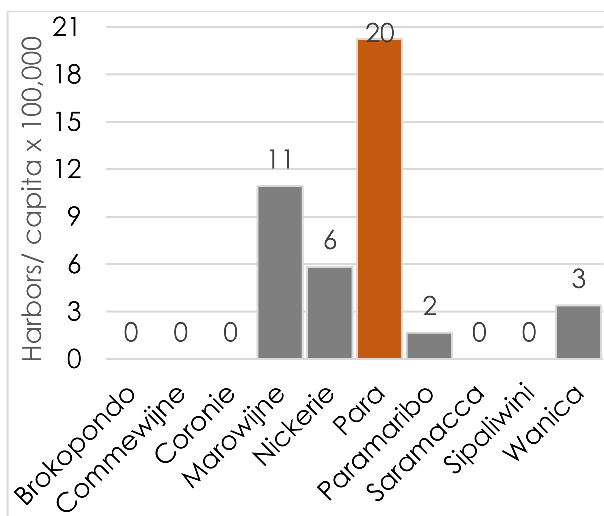


Figure 117: Number of electricity connections as a percentage of the total number of people.

Source: Own elaboration.

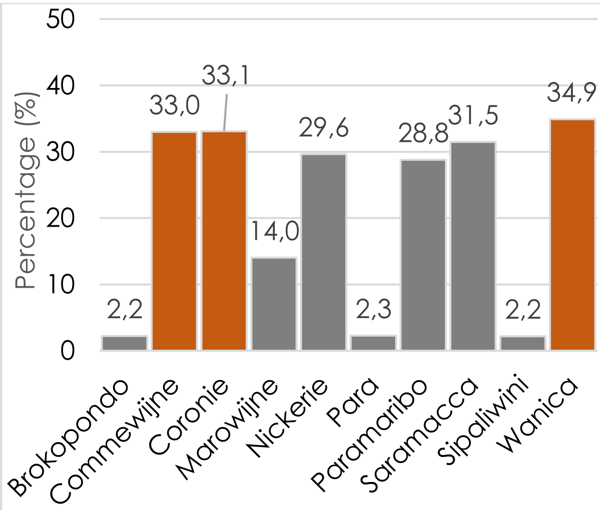


Figure 118: Coastline (km) per area (km²) x 1,000.

Source: Own elaboration.

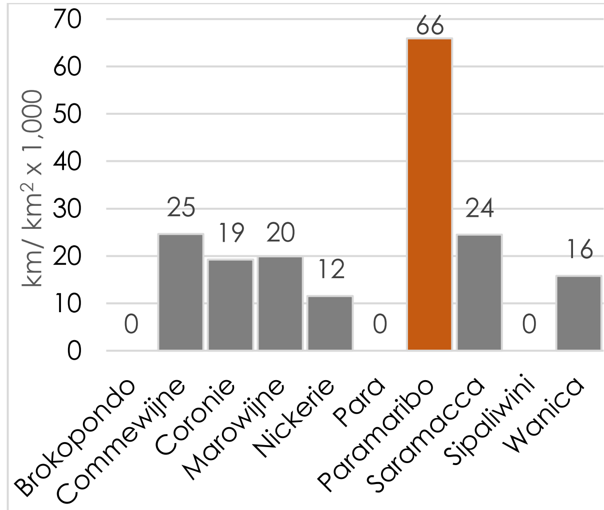


Figure 119: Number of people as a percentage of the total population of Suriname.

Source: Own elaboration.

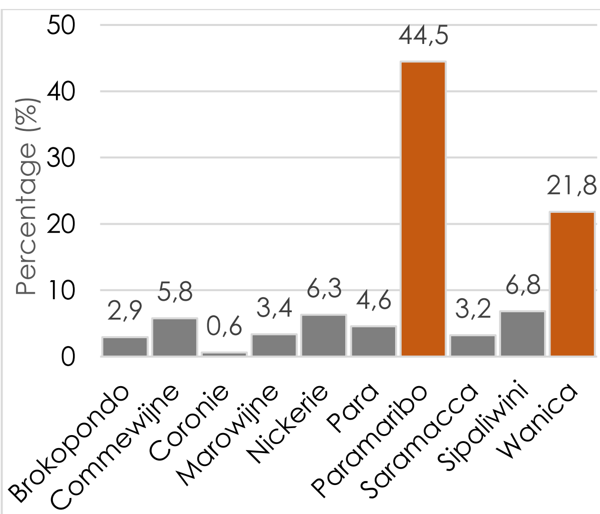
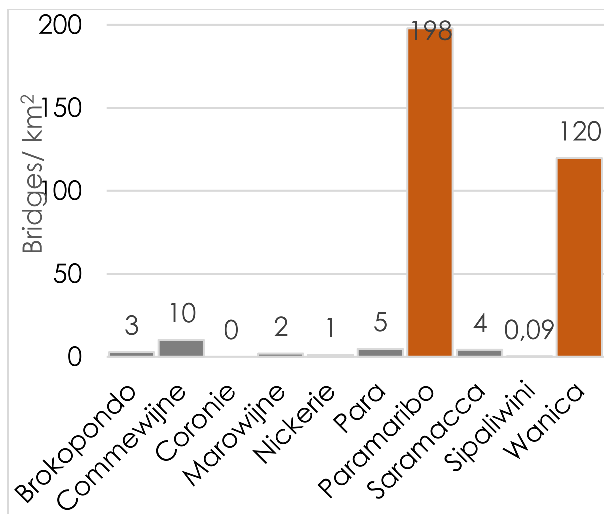


Figure 120: Number of bridges per km2 area.

Source: Own elaboration.



Paramaribo is by far the most exposed district (figure 113). It scores highest for several indicators: It has the highest road density of all (6.1 km of road per km², whereas most other districts score below 0.1 km of road per km², with only Wanica having a comparable road density of 2.5 km of road per km²) (figure 115). In addition, it has the longest coastline per area (66 km per km² area, around 2.5-5 times that of other districts with a coastline) (figure 118), the highest fraction of the country's population (44.5 %, whereas in most other districts less than 7 % of the population live, with only Wanica having a comparable population of 21.8 % of the total) (figure 119) and the highest density of bridges (198 per km² area, whereas most other districts have below 10 bridges per km² area, with only Wanica having a comparable density of 120 bridges per km² area) (figure 119). Not surprisingly, **Wanica** is the second most exposed district.

Brokopondo and **Sipaliwini** are the least exposed districts (figure 113). They have little transport infrastructure (roads, bridges, harbours), little penetration of household electricity connections (figure 117), a low share of the population and no coastline.

4.2.5.2. Vulnerability

Figures 121-125 provide an overview of the indicators used to construct the vulnerability subindex.

Figure 121: Length of non-novel roads as a percentage of all roads.

Source: Own elaboration.

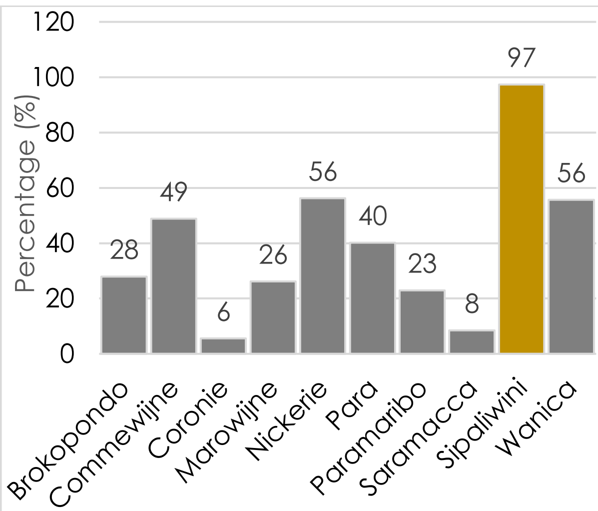


Figure 122: Number of non-novel bridges as a percentage of all bridges.

Source: Own elaboration.

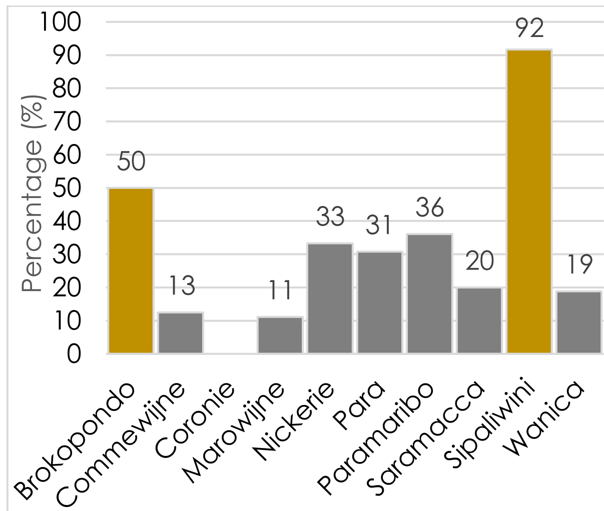


Figure 123: Percentage of dwellings without a finished roof.

Source: Own elaboration.

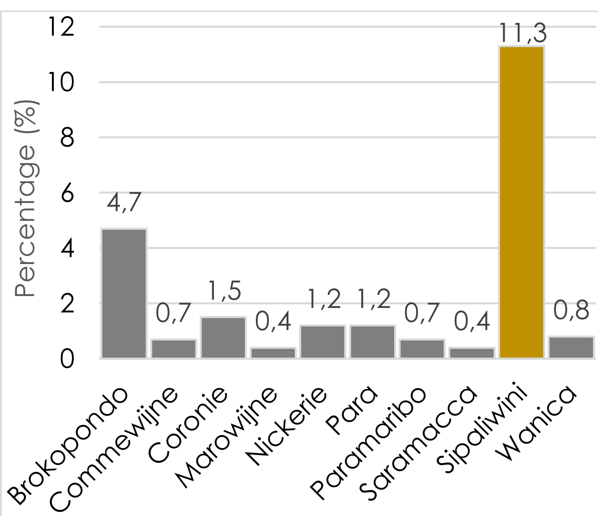


Figure 124: Percentage of dwellings without finished walls.

Source: Own elaboration.

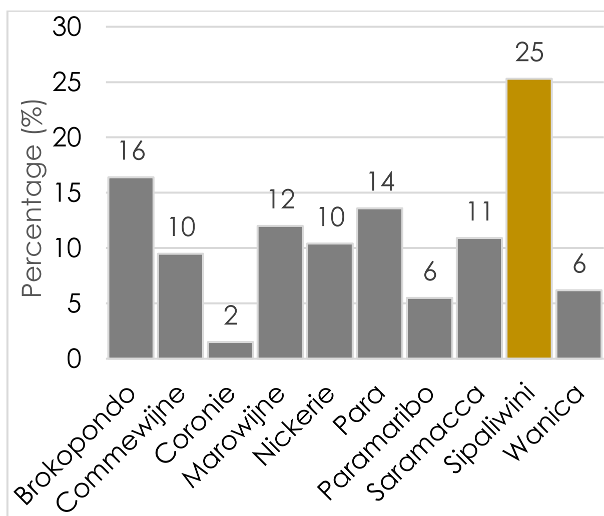
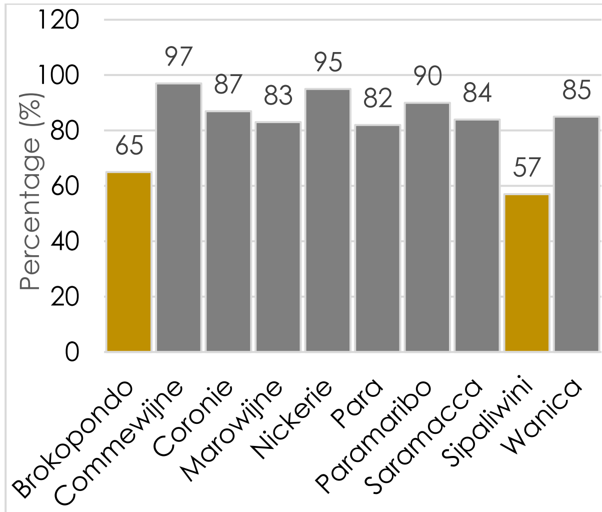


Figure 125: Primary completion rate[7].
Source: Own elaboration.



Although **Sipaliwini** and **Brokopondo** are the least exposed districts, they are also the most vulnerable districts (figure 114). Sipaliwini scores highest for all indicators. It has the highest percentage of non-novel roads (97 %, the next highest score being 56 % in Nickerie and Wanica and as low as 6 % in Coronie) (figure 121), non-novel bridges (92 %, the next highest score being 50 % in Brokopondo and as low as 11 % in Comewijne) (figure 122), dwellings without a finished roof (11.3 %, whereas most other districts score below 1.5 %, with only Brokopondo scoring 4.7 %) (figure 123), dwellings without finished walls (25 %, at least double the percentage of most other districts, with Brokopondo scoring 16 %) (figure 124), and the lowest primary completion rate (57 %, whereas all other districts score above 80 %, with the exception of Brokopondo with 65 %) (figure 125).

Coronie is the least vulnerable district (figure 114). It has the smallest proportion of non-novel roads (figure 121) and dwellings without finished walls (2 %) (figure 124).

4.2.5.3. Relevance of projected changes in climate hazards for the sector

16 of the projected changes in climate hazards are considered highly relevant for the sector and one was considered of medium importance (table 73). They concern the increase in temperature, sea-level, and decrease in precipitation overall and in the four seasons but with more intense precipitation events.

The analysis also underlines the coast's high exposure to climate hazards, as sea-level rise and winds only affect the coast.

[7] 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.

Table 73: Relevance of projected changes in climate hazards for the infrastructure sector.
Source: Own elaboration.

Hazard indicator	Relevance	
Average daily temperature	High	With increasing temperatures (and less cold days and nights that allow for some cooling off) 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 both in on- and off-grid areas (the latter of which have to cater for an increased demand for electricity by providing more fuel or fuel-powered electricity generators, or alternative means of energy generation such as PV panels).
Maximum daily temperature		
Minimum daily temperature		
Frequency of hot days		
Frequency of hot nights		
Frequency of cold days		
Frequency of cold nights		
Accumulated yearly precipitation	High	Decreases in accumulated yearly precipitation and the number of rainy days have limited effects on buildings and telecommunications. However, they have negative effects on the navigability of rivers (a prominent mode of transport in the interior) and hydropower generation (at Afobaka, supplying electricity to the coast). Therefore, the whole country is affected, albeit differently.
Number of rainy days per year		
Maximum precipitation in five days	High	Both indicators show an increase pointing towards more intense precipitation events. These intense precipitation events can result in floods which lead to loss and damage of infrastructure assets and the unnavigability of rivers and roads.
Maximum precipitation in one day		
Short dry season precipitation	High	As precipitation decreases throughout the country in these seasons, the effect is the same as for "accumulated yearly precipitation" and "number of rainy days per year".
Dry season precipitation		
Short rainy season precipitation		
Rainy season precipitation	High	At the coast precipitation decreases and the effect is the same as for "accumulated yearly precipitation" and "number of rainy days per year". 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

Gale wind days		telecommunication infrastructure. At the seaside they can cause higher waves, too, 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.
Strong wind days		
Relative humidity	Low	These indicators do not affect the infrastructure sector greatly.
Sea-level rise	High	Sea-level rise leads to coastal and riverbank erosion, flooding and associated loss and damage of infrastructure assets.

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5. Capacity building

This chapter aims at identifying strengths, weaknesses, opportunities and threats across sectors (chapter 5.1) and for each one of the four sectors (chapters 5.2-5.5) in relation to the exposure and vulnerability factors identified and analyzed previously.

5.1. Cross-sectoral

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

Strengths

- The Meteorological Service of Suriname is the country's voice for weather and climate and as such included in all relevant international commitments, national policies and legislation. 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.
- Potential climate change impacts on different sectors are efficiently mapped through reporting efforts (2NC, NAP, National Communication on Climate Services, etc.).
- 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 (standards of research, knowledge, skills, equipment) 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 (e.g. Natin Agriculture, 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, they receive information on natural sciences thanks to various interventions, such as the World Wide

Fund for Nature (WWF) Guiana 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, e.g. the Global Environment Facility (GEF) project on Climate Change Awareness Education for the Youth: Green Ambassadors; a project on community-based adaptation to climate change and biodiversity conservation within the Johanna Margaretha Plantation (district 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 (Hour) Day , World Water Day , and World Ocean Day to raise public awareness, including on climate change. In particular, 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.

Weaknesses

- Policies, laws and regulations are insufficient and/or outdated, not enforced, not monitored, evaluated and revised.
- There is a lack of human, financial and technological capacity in the ministries and their agencies to consistently implement policies, laws and regulations.
  E.g. the Meteorological Service has a number of 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 anymore).
- 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.
  E.g. 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.

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.

Threats

- There is a high technical staff turn-over with each electoral cycle. Ministries and institutions are also changing and/or being dissolved/ newly created. In combination with poor knowledge management, this undermines the progress of institutions.
- With the recent elections in 2020, already developed plans (e.g. the NAP 2019-2029) may not be implemented or their implementation may be delayed.
- A lot of highly qualified technical staff is retiring. On the other hand, 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 developments will push society to make environmentally unfriendly but cheaper choices.
- Suriname's economy depends on extractive industries on oil and mining, which generally are environmentally unfriendly.

5.2. Agriculture

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

Strengths

- 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 thus 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 thus 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 Global Climate Change Alliance Plus Initiative (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 fisherfolk 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 in 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.
- Despite the fact that 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.

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 the local market and is dependent on inputs from 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 no or a 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. This increases their vulnerability.
- There is little public awareness on the need for freshwater conservation, which also impacts agriculture as it is dependent on irrigation. This increases the sector's vulnerability.
- 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.
- Due to lack of finances, 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.

Opportunities

- The conditions for growth in the livestock sector are favorable and there are already some 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 e.g. UNDP and FAO have submitted grant applications to donors for sustainable mangrove management projects.
- Suriname has enough land and water with which 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.

Threats

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

5.3. Water

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

Strengths

- 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.
- The BOG has provided guidelines for the construction for 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 (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 programmes 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 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 after only two seminars in 2016 and 2017 due to a lack of political commitment and mandate.
- The Water Forum Suriname has organized a number of 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 a number of articles in newspapers, for instance on the World Water Day. In addition, it actively participates in water-related workshops. Moreover, it annually award 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 comprehensive report ("Comprehensive Report for the Implementation of Integrated Water Resources Management comprising a Situation Analysis and an Action Plan for implementing IWRM in Suriname").

Weaknesses

- The regulations on wastewater disposal, interinstitutional 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, i.e. an institution which 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 (e.g. BOG, WLA, Meteorological Service, SWM, 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 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 integrated water resource management.
- 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 only project-based and limited to sharing data/ knowledge.
- Drinking water is being used for purposes other than human consumption, e.g. toilet flushing, cars washing. 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.

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. Data-exchange between MDS and WLA took place already. The possibility of transforming both existing institutions into privatized institutions (eventually falling under a Ministry), similar to NIMOS’ institutional structure, could make investments in equipment and human capital more feasible and cost-efficient.
- There are a number of international cooperation projects which are promising: GCCA+ project on water boards (funded by the European Union and UNDP), and WLA, ADEKUS and BUZA working on defining the boundary of the Marowijne river (funded by the French Development Cooperation).
- The construction of the surface water treatment plant in Commewijne using desalinization technology is a new experience and learning process. If successful it can be used as blueprint for other areas.
- Some companies have wastewater disposal plants in order to comply with international standards. This is an opportunity to increase knowledge on wastewater disposal in the public sector, too.

Threats

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

5.4. Forestry

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

Strengths

- 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.

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, there is a lack of political awareness of, and 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 was 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. Thus, the unsustainable use of forests is more likely to occur, making them prone to degradation and eventually the effects of climate change.
- Land tenure of Suriname's forested area still remains unclear, as it relates to land right 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 human and financial 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 eventually the effects of climate change.
- There is a lack of technical and financial capacity for SFM related to logging. Sustainable forest management enhances 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. Thus, more concessions are needed to harvest the same economic benefit. This encourages deforestation and results in a greater vulnerability of the forestry sector.

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 with planning and implementing ecosystem management which can reduce the vulnerability of forests.
- External funding for the compensating carbon sequestration and other forest-related ecosystem services are available (e.g. 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.

Threats

- There is an information gap: The forestry (logging) sector is negatively perceived by society, which overall does not value SFM options and related development potentials.

5.5. Infrastructure

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

Strengths

- 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 well aware of the threats 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/ 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; UNDP Suriname with the GCCA+ project creating awareness among the population regarding protective infrastructure

Weaknesses

- Vulnerable people in the coastal areas are not aware of the hazards they are exposed to.
- People lack the skills and education to make informed decisions on how to adapt to climate change. There is no such content in the curriculum.
- There is no financial support for people whose livelihoods are destroyed by disasters.
- There is a lack of practical application of knowledge to increase the resilience of the built environment in policy-making and management decisions. Research findings and new insights are not used in decision-making and planning.
- Understaffing and a lack of operational means are issues the infrastructure sector is facing.

- The OW, in charge of all building/ construction permits in the country, has limited capacities to technically review building/ construction plans, provide guidance and technical studies on the design of building/ 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/ storm water in the city of Paramaribo. Financial and management constraints (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 interinstitutional 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 (e.g. OW, NH, TCT, Regional Planning) are responsible for regulation and management of the infrastructure sector. However, they do not act in a concerted manner, affecting the quality of public services due to conflicting operational goals of these agencies.
- Adaptation initiatives to protect mangrove (green protective infrastructure) are dependent upon external, donor-funded Interventions (e.g. Conservation International, UNDP).
- There is no effective early warning system for disasters. There are no disaster risk reduction training opportunities.
- Mainly due to political reasons market-based electricity tariffs have not fully been explored and implemented.

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-state.

Threats
None other than the ones mentioned in the chapter on cross-sectoral threats.

5.6. References

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6. Responses taken to reduce climate risk

This chapter aims at identifying some of the more recent responses that were taken to enhance strengths, take advantage of opportunities, as well as reduce the weaknesses and threats identified in the previous chapter, first across sectors (chapter 6.1) and then for each one of the four sectors in detail (chapters 6.2-6.5).

6.1. Cross-sectoral

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, reduce its weaknesses and threats.

- The Law has been 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. Moreover, 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.

6.2. Agriculture

The government has taken the following responses to enhance its strengths, take advantage of opportunities, reduce its weaknesses and threats in the agriculture sector.

- 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 on increasing 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 employments. 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 IADB 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 policy-making. Expected results will include an improved production and production management and better operation of water boards which contribute to the statistics information systems.

6.3. Water

The government has taken the following responses to enhance its strengths, take advantage of opportunities, reduce its weaknesses and threats in the water sector.

- In 2016 the Government identified the need to develop a roadmap for 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" (started in 2014) 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/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 financed by the IADB was approved. The project aims at improving the efficiency and quality of the services provided by the SWC to over 3,700 households. 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).

6.4. Forestry

The government has taken the following responses to enhance its strengths, take advantage of opportunities, reduce its weaknesses and threats in the forestry sector.

- There is a common interest for the development of alternative livelihoods in the interior. This can reduce the vulnerability of forest-dependent people.
- With regards to the logging sector, efforts have been made over the past years to increase the ambition of indigenous and tribal communities to upgrade and scale up operations for the exploitation of their community forest. 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 improved law for nature conservation has been developed, which also benefits sustainable forest management and thus 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 law 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. Besides 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.

6.5. Infrastructure

The government has taken the following responses to enhance its strengths, take advantage of opportunities, reduce its weaknesses and threats in the infrastructure sector.

- The updated Building Code (pending for finalization) emphasizes the strengthening roof structures against climate hazards.
- Improved institutional capacity has resulted from various training workshops (for example on the use and development of hydrological models). Communication between stakeholders has intensified, too, 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 dyke 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 e.g. for urban development in Paramaribo and Wanica.
- With the IADB-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.

6.6. References

Inter-American Development Bank (IADB). (2010). *Suriname will improve its water supply system with support from the IDB*. Retrieved from https://www.iadb.org/en/news/suriname-will-improve-its-water-supply-system-support-idb.

United News. (2020). *Overheid wil samen met private sector wateroverlast te lijf gaan.* Retrieved from https://unitednews.sr/overheid-wil-samen-met-private-sector-wateroverlast-te-lijf-gaan/

7. Recommendations

This chapter provides recommendations on how to improve the SWOT analysis, first across sectors (chapter 7.1) and then for each one of the four sectors in detail (chapters 7.2-7.5).

7.1. Cross-sectoral

The following recommendations can reduce climate risk across all sectors.

- The Environmental Framework Act should be fully enforced.
- Community-based adaptation, pilots and other participatory approaches should be fostered.
- Institutions should strengthen their knowledge management so that no knowledge gets lost between electoral cycles due to staff turn-over.
- There should be more and better cooperation agreements between government institutions, government institutions and research institutes, and 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 become a strong coordinating entity that assures various actors execute their functions in a concerted manner.
- The Environmental Framework Act provides a great basis from which to take climate action. However, sectoral legislative pieces should be updated and/or complemented, too.
- 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.

  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.

  Also, the change in movement of the ITCZ and in El Niño/ La Niña and their impacts on precipitation and temperature regimes and consequently the availability of water demand further investigation.

  A study on the economics of climate change in Suriname would be very 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.
- 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 also decrease climate change impacts by protecting its assets.

7.2. Agriculture

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

At the coast

- Farmers should start to engage in steady cultivation and not cultivate on the basis of market demand.
- More information on the need for vegetables should be gathered in order 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 assuring 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.

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.

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 it will be possible to introduce tested and proven interventions that will mitigate the negative effects associated with climate change.

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, 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.

Rice production

- Rice producers and rice 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.

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/or rehabilitated. More donors should be attracted for mangrove conservation.
- Education on the importance of mangroves should be provided.

Fishery

- The legislation in the fishery sector should be updated.

Livestock

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

7.3. Water

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

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 e.g. formal 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/ 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. In particular, the government should take the lead in designing cross-sectoral systems on climate observation, integrated water resource, risk and disaster management.

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 source of revenues 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.

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 still in the concept phase and policies and acts for water management in boundary rivers are lacking. Action is needed.
- The wastewater disposal guidelines and standards should be improved.

7.4. Forestry

The following recommendations can reduce 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:

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 forest 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 reducing their dependency on the government, e.g. by promoting NTFP, ecotourism, medicinal plants and agroforestry practices, and creating training and education opportunities for forest-based communities.

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 properly 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 controlled forest management (SFM, including Reduced Impact Logging), by increasing the efficiency of the forest sector through appropriate taxation (reviewing timber charges) and by increasing the added value of wood production (reducing the proportion of roundwood exports in favor of processed products).

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 towards 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.

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 well-being as well as in economic diversification.

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

7.5. Infrastructure

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

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 (e.g. farmers, fishermen) towards 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 on 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 favour adaptation by land owners, tenants and other users (Government of Suriname, 2019).

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).

Protective infrastructure

- An effective early warning system should be introduced.
- Buffer zones and dikes should be developed along the coastline and rivers (Government of Suriname, 2019).
- Regular maintenance and frequent inspections of infrastructure should be conducted and areas which require investment for improvements should be identified (Government of Suriname, 2019).

Energy

- Energy conservation and efficiency for domestic and commercial uses should be promoted (Government of Suriname, 2019).
- The development of renewable off-grid electricity should be fostered (Government of Suriname, 2019).

- An energy building code for housing and infrastructure should be developed (Government of Suriname, 2019).

7.6. References

Government of Suriname. (2019). *Suriname National Adaptation Plan (NAP) 2019-2029*.

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8. Conclusions

The **second chapter** on the background of Suriname provides an introduction to bio-gepgraphic and socio-economic cross-sectoral aspects as well as sectoral conditions. This chapter informs the selection of exposure and vulnerability indicators that compose the risk index in chapter four.

Suriname is 16.4 million ha large, divided up into ten administrative districts and has almost 600,000 inhabitants, of which over 40 % live in the capital Paramaribo. The country's climate can be characterized as wet tropical, with stable temperatures and great variations in rainfall, owing to the intertropical convergence zone that moves across the country twice yearly. Both environmentally and socio-economically, the country is divided into two regions: The densely populated coast (north), where agriculture and infrastructure predominate, and the sparsely populated hinterland/ interior (south), which is almost completely covered in forest.

3.2 % of Suriname's surface is used for **agriculture** purposes, mostly in the young and old coastal plain where large- and small-scale agricultural activities are conducted, respectively. In the hilly and mountainous interior agriculture is mainly limited to shifting cultivation practices that sustain local consumption. The sector con be divided into four product categories: 1) Fishery (including aquaculture), 2) crops, 3) livestock and 4) flowers, ornamentals and fruits. The fishery and crop (rice, bananas, vegetables) categories are the most important ones for the sector, and the country exports many products in these categories. Thus, the sector contributes about 7 % to the GNP and employs about 12 % of the economically active workforce. Agriculture is also important for guaranteeing the food security of the Surinamese population, as 8 % of the population are malnourished and 24 % of women suffer from iron deficiency.

Suriname is one of the most **freshwater** rich countries. People at the coast have good quality groundwater in abundance. In the interior people mainly rely on surface water (from rivers, freshwater swamps, lakes) for drinking water and other purposes. Freshwater has several important functions in Suriname's economy and society: Human consumption, agricultural irrigation, hydropower, transportation, domestic uses. Overall, 98.2 % of the population have access to improved sources of drinking water. Whereas the SWM supplies the coast, the DWV supplies the interior. In the districts of Paramaribo, Wanica and a part of Para up to 90 % of the households have a septic tank for treatment of wastewater, however, a great percentage of them is dysfunctional due to bad design or insufficient maintenance.

93 % of Suriname's area is covered with **forests**, which is why Suriname classifies as an HFLD country. 80.4 % of forests are high dryland forests, 2.7 % savannas and 14.8 % mangroves, swamps, marsh and creek forests. Sipaliwini and Para are the districts with the highest relative forest cover (98-78 %). Sipaliwini and Brokopondo are the districts with the highest absolute forest cover. Paramaribo and Wanica are the districts with the lowest relative and absolute forest cover, which is why their deforestation rates are highest, although Sipaliwini has the highest absolute deforestation. Deforestation divers are urban development, agriculture and mining, but there are 16 protected areas covering 14 % of the country's surface. In 2017, the forestry and tourism sector contributed 2.5 % and 3.5 % to the country's GDP, respectively. Roundwood production and export are important economic activities of the sector. A gradual expansion of timber production took place over recent years from 176,516 m^3 of roundwood produced in 2000 to 1,083,758 m^3 in 2018.

With regards to **infrastructure**, the main energy carriers in Suriname are fuel, electricity, LPG and biomass. Fuel is mostly consumed by the transport sector and for off-grid electricity generation. LPG is consumed by coastal households for cooking, and biomass by rural households for the same purpose. Over 85 % of the population have access to electricity, of which 79 % are connected to the national grid. The main energy producers are Staatsolie (which extracts fuels and runs the Afobaka hydropower plant), NV EBS (which runs EPAR and ENIC) and DEV (in charge of rural electrification). With regards to transportation, the road system of Paramaribo and Wanica accounts for 52 % of the total. On the contrary, the hinterland consists of an extensive network of rivers and airfields, but a poorly developed road system.

The second chapter closes with a review of the **national policy and legal framework** and **environmental management structure**. Important climate change policies are 1) the NDC (2020), which includes mitigation actions in four out of six emitting sectors (forestry, electricity, agriculture and transport) which together cover an estimated 70 % of the country's emissions. The NDC also refer to adaptation, however, the 2019 NAP describes how the NDC commitments on adaptation are to be achieved by focusing on the strategic national level, and economic sectoral level (for which water resources, sustainable forestry, energy, agriculture, livestock and fisheries are prioritized), 2) the SNC, which details adaptation measures for agriculture, water, ecosystems (forests) and infrastructure, 3) the REDD+ strategy, which implementation results in the participation in the REDD+ mechanism and results-based payments, 4) the NCCPSAP, which has 13 national planning themes, including on agriculture, animal husbandry and fisheries, drinking water, SFM, infrastructure, energy and housing, 5) the OP, in which utilization and protection of the environment is one of four priorities, 6) the Environmental Framework Act, which establishes the NMA as the cross-sectoral lead entity on all environment-related matters by merging NIMOS and the Environmental Coordination Unit. Important ministries in the four sectors include the LVV, RH, OW, GB, EAS, RAS and RD.

The **third chapter** analyzes historic and future climate in Suriname for four different time horizons (historic 1990-2014, near future 2020-2039, mid-term future 2040-2069 and long-term future 2070-2099); Two scenarios, ranging from intermediate to severe (SSPS2-4.5 and SSPS5-8.5); Eight locations (the whole country and 1) BigiPan MUMA, 2) Paramaribo, 3) Brokopondo, 4) Albina, 5) Tafelberg Natural Reserve, 6) Kwamalasamutu and 7) Upper Tapanahony).

For the historic data, measurements from 35 stations run by the Meteorological Service of Suriname and the ERA5 dataset were used. For the future projections, a multimodel approach based on three CMIP6 GCMs (HadGEM3-GC31, MIROC6 and IPSL-CM6A) was employed. For both analyses, data was downscaled to a 10 km resolution. The variables that form part of the analysis, and the outcome of the analysis are provided in the following table:

Table 74: Climate variables analyzed and projected, their historic trend and future projections. Source: Own elaboration.

Variables	Historic trend	Future trend
Average daily temperature	These indicators are very 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.
Maximum daily temperature		
Minimum daily temperature		
Frequency of hot days	These indices are very homogeneous throughout the country.	Those are days which can be dangerously hot and nights during which sleeping is difficult. The two indices increase everywhere.
Frequency of hot nights		
Frequency of cold days		These two decrease and almost disappear, and are less important in a tropical climate.
Frequency of cold nights		
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.
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.
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 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.
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.	These indicators are projected to vary very little. The main patterns visible in the historical

Variables	Historic trend	Future trend
Gale wind days	These are very rare (less than two per year).	map change very little in all scenarios and timeframes.
Strong wind days	These occur mostly at the coast and in the center and southeast of the country.	
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.
Sea-level rise	N/A	This indicator increases the same for all districts, more so in scenario SPS5-8.5 and the further into the XXI century.

The **fourth chapter** combines the results of chapter 2 (socio-economy) and chapter 3 (climate) in a risk analysis. Risk is the product of climate hazards, exposure to these climate hazards and vulnerability of the exposed elements to the climate hazards. In order to define climate risk for each one of the sectors, the sectors were analyzed for factors which determined their exposure and subsequent vulnerability. The results were illustrated in impact chains. Moreover, in order to construct a numeric risk index, it was necessary to match each vulnerability and exposure factor with quantitative indicators (33 in total, table 75). The 19 climate variables from the previous chapters (excluding sea-level rise) provided the hazard indicators which completed the risk index. Overall, the risk index was constructed on a five-step procedure: 1) Selection of indicators, 2) data quality check, 3) normalization, 4) weighing and 5) aggregation.

Paramaribo and Wanica have the highest historic hazard subindex, and Nickerie the lowest. Nickerie remains the district with the lowest hazard subindex in all future scenarios and timeframes. In the SSPS2-4.5 scenario Sipaliwini becomes the district with the second highest and highest hazard subindex in the near/mid- and long-term future, respectively, followed by Paramaribo and Wanica. In the SSPS5-8.5 scenario Sipaliwini becomes the district with the third and second highest hazard subindex in the near/mid- and long-term future, respectively, with Paramaribo and Wanica occupying the ranks close-by.

Commewijne and Paramaribo are the most exposed districts, owing to their high scores on exposure in agriculture, water and forestry, as well as infrastructure, respectively. Brokopondo is the least exposed district with very low scores on exposure in agriculture and infrastructure.

Sipaliwini and Brokopondo are the most vulnerable districts, owing to their high scores on vulnerability in agriculture and infrastructure. Coronie is the least vulnerable district with very low scores on vulnerability in forestry and infrastructure.

Overall, Paramaribo, Sipaliwini and Wanica are the districts most at risk, and Coronie and Nickerie are the districts least at risk. This historic image persists throughout the different scenarios and timeframes.

Table 75: Exposure and vulnerability variables used in the risk index across the four sectors. Source: Own elaboration.

Sector	Description	Unit
Agriculture	**Exposure**	
	Farms	Number of family farms as a percentage of the total number of households
		Number of animals (cattle, sheep, goats, pigs) per farm on average
		Agricultural land as a percentage of the total area of the district
	People employed on farms	Number of hired workers on farms (2008) as a percentage of the total population (2012)
	Small-holders	Number of farms with less than 2 ha of agricultural land as a percentage of all farms
	Poor people	Percentage of population whose income is less than half of GNI per capita of the district (2009)
	Food insecure people	Percentage of children under the age of 5 that are stunted (-2 SD) (2018)
		Percentage of children under the age of 5 that are wasted (-2 SD) (2018)
	Vulnerability	
	Education of farmers	Number of family farms with the farmer having received no formal education as a percentage of all family farms
	Irrigation infra-structure	Inverted number of farms with irrigation infrastructure as a percentage of the total number of farms
Water	**Exposure**	
	Population not using improved drinking water sources	Number of households not using improved drinking water sources as a percentage of the total number of households
	People with in-adequate water availability	Number of households without drinking water available in sufficient quantities as a percentage of the total number of households
	People with in-adequate access to water	Number of household members as a percentage of the total number of household members without access to drinking water on premises
	Vulnerability	
	Un-sustainable water supply	Inverted SWM and DWV water production (m3/day) per capita
	Storage capacity	Inverted storage capacity (m3/day) per capita
	Alternative water resources	Number of households which main source of drinking water is not rainwater collection as a percentage of the total number of households
Forest	**Exposure**	
	Coastal forests	Area of mangroves as a percentage of the total area of the district

Sector	Description	Unit
	Savanna forest and peat (swamp) areas	Area of open savanna and swamp as a percentage of the total area of the district
	Forest cover	Area of forest (excluding savannas and swamps) as a percentage of the total area of the district
	Vulnerability	
	Land tenure	Number of Amerindian and Maroon settlements per 10 km^2 forested area
	Deforestation	Deforested area between 2000 and 2015 as a percentage of the total forested area
	Existing degradation	Volume (m^3) of roundwood produced per km^2 forest
Infrastructure	**Exposure**	
	Infrastructure	Km of road per km^2 area
		Number of bridges per km^2 area
		Number of certified harbors per capita (x 100.000)
		Number of electricity connections as a percentage of the total number of people
	Coastlines	Coastline (km) per area (km2)[8]
	People	Number of people as a percentage of the total population in Suriname
	Vulnerability	
	Weather resistant building	Percentage of dwellings without finished roof
		Percentage of dwellings without finished walls
		Length of non-novel roads as a percentage of all roads
		Number of non-novel roads as a percentage of all bridges
	Education	Inverted primary completion rate

The **fifth chapter** provides a SWOT analysis across sectors and for each sector in particular, keeping the vulnerability and exposure factors used in the risk analysis in mind.

Some of the most important strengths include the SMNR Master's degree, primary education and awareness raising activities related to the environment, as well as the capacity building that forms part of the preparation of Suriname's third national communications and various other cooperation projects.

Weaknesses include insufficient policies, laws and regulations; a lack of human, financial and technological implementing capacity; a lack of research and information; a lack of interinstitutional cooperation and coordination; and a lack of public and political awareness.

Opportunities include international and regional networks and cooperation, as well as Suriname's status as a forest-rich country which can attract PES.

Threats include the high technical staff turn-over with elections; the lack of young trained human capital to replace retiring staff in public institutions; the current unfavorable economic situation, which can lead society to prioritize non-green development options; the overall dependency of Suriname's economy on extractive industries such as oil and mining.

[8] This indicator accounts for sea-level rise.

The **sixth chapter** looks at recent responses to enhance strengths, take advantage of opportunities, as well as reduce the weaknesses and threats identified in the previous chapter. The most significant response across sectors has been the adoption of the Environmental Framework Act. This creates one entity, the NMA, for environmental management, policy and strategy by merging the NIMOS and Environmental Coordination Unit. This will greatly enhance coordination and efficiency in the implementation of environmental strategies, including those related to climate change such as the NAP.

The **seventh chapter** provides final recommendations, such as the full enforcement of the Environmental Framework Act; strengthening the public sector's knowledge management; enhancing the cooperation between the government and research institutions, also to foster evidence-based decision-making; funding R&D; providing more education and awareness raising activities on climate change and its impacts as well as engaging the private sector in finding solutions to problems stemming from climate change impacts.