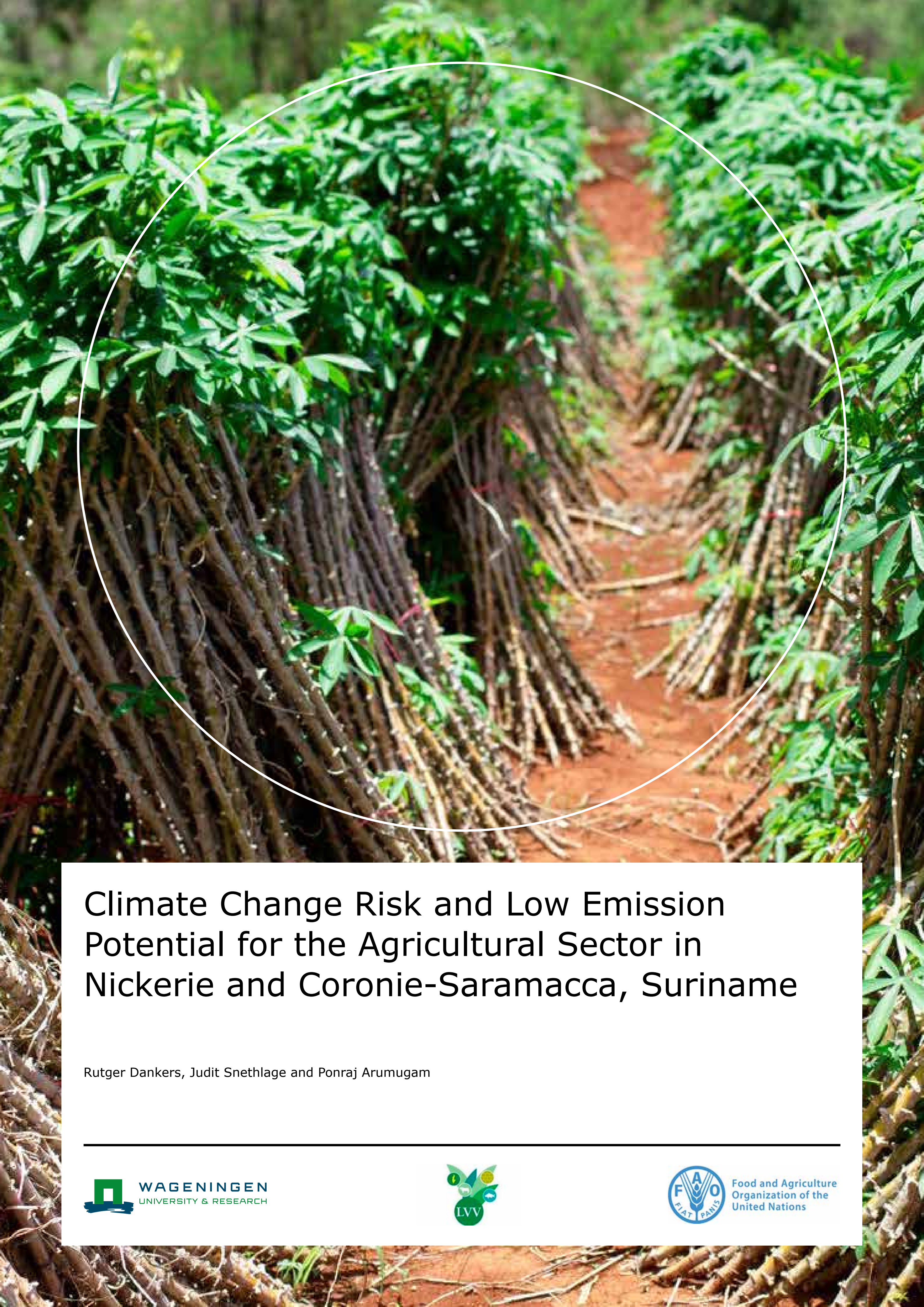

Climate Change Risk and Low Emission Potential for the Agricultural Sector in Nickerie and Coronie-Saramacca, Suriname

Rutger Dankers, Judit Snethlage and Ponraj Arumugam

WAGENINGEN
UNIVERSITY & RESEARCH

LVV

Food and Agriculture
Organization of the
United Nations

Climate Change Risk and Low Emission Potential for the Agricultural Sector in Nickerie and Coronie-Saramacca, Suriname

Rutger Dankers, Judit Snethlage and Ponraj Arumugam

This report was prepared for the Readiness Project of GCF; Improving the capacity of the Ministry of Agriculture of Suriname to build resilience to climate change in the agriculture sector (GCP/SUR/004/GCR).

Wageningen Environmental Research
Wageningen, February 2024

Reviewed by:
Project partners Readiness Project of GCF

Approved for publication:
Karin Andeweg

Report 3331
ISSN 1566-7197

Dankers,R., J. Snethlage, P. Arumugam, 2024. *Climate Change Risk and Low Emission Potential for the Agricultural Sector in Nickerie and Coronie-Saramacca, Suriname.* Wageningen, Wageningen Environmental Research, Report 3331. 88 pp.; 57 fig.; 17 tab.; 62 ref.

Een recente analyse van klimaatprojecties voor de regio Nickerie en Coronie-Saramacca laat de complexe uitdagingen zien die klimaatverandering met zich meebrengen. Met name in de landbouwsector worden deze uitdagingen duidelijk zichtbaar: stijgende temperaturen, verminderde jaarlijkse neerslag en een stijgende zeespiegel hebben directe gevolgen, zoals zoutwaterindringing en overstromingen. Vooral onder hoge uitstootscenario's in de tweede helft van deze eeuw worden deze effecten waargenomen. De huidige problemen waarmee rijstboeren in Nickerie worden geconfronteerd, tonen aan dat er een onderscheid tussen natuurlijke variabiliteit en lang termijn klimaatverandering is. Dit benadrukt de behoefte aan zowel korte- als lang termijn-aanpassingsstrategieën. Een effectieve risicoanalyse vereist verbeterde monitoring, delen van data en gegevens en een integrale aanpak die ecologische en sociaaleconomische factoren meeneemt. Binnen deze context, tonen belangrijke gewassen zoals rijst, banaan en kokosnoot verschillende gevoeligheden voor veranderende klimaatomstandigheden, waarbij kokosnoot robuuster gewas blijkt. Vooral bij aanhoudende droogte patronen, en in combinatie met hoge emissie scenario's, kan de ontwikkeling van geschikte infrastructuur voor het vasthouden van zoetwater noodzakelijk zijn. Het betrekken van boeren bij aanpassingsstrategieën is essentieel, waarbij een integrale aanpak met aandacht voor onbedoelde neveneffecten belangrijk zijn, door bijvoorbeeld aangepast watermanagement een verhoogde watervraag kan ontstaan. Om mogelijke risico's van verzouting te minimaliseren is de focus op een integrale benadering waar gewas, bodem en water centraal staan. Deze analyse benadrukt het belang van doordachte planning en grondige evaluatie van adaptatiestrategieën. Dit proces moet een inclusieve, iteratieve benadering volgen waarbij diverse factoren en belanghebbenden betrokken zijn.

The recent climate projections analysis for the Nickerie and Coronie-Saramacca study area highlights significant climate change challenges affecting agriculture, such as increased hot days and nights, decreased annual precipitation, and rising sea levels causing saltwater intrusion and coastal inundation, particularly underlined with high emission scenarios in the latter half of the century. Climate adaptation planning requires defined timeframes; changes in indicators are moderate until mid-century. Short-term challenges faced by Nickerie's rice farmers underline the influence of natural variability, distinguishing it from long-term climate change, thus needing distinct adaptation strategies for current versus long-term issues. Effective risk analysis depends on enhanced monitoring, data sharing, and considering environmental and social factors. Among crops, rice and banana are more vulnerable to future climate conditions, while adapting to long-term drying trends in high-emission scenarios may involve storing and using upstream freshwater with suitable infrastructure. Collaboration with farmers is crucial in identifying viable adaptation strategies. A systemic approach, accounting for trade-offs, is advised for agricultural changes, considering unintended effects like increased water demand due to altered water management. Addressing salinization requires multifaceted strategies integrating improved crop, water, and soil management. To mitigate maladaptation risks, careful design and assessment of adaptation strategies are vital. A comprehensive, iterative approach, entailing diverse factors and stakeholder involvement, is essential for cultivating resilient, sustainable responses to climate change.

Keywords: climate change risks, Suriname, low-emission agriculture, food security, saline adaptation agriculture

In 2003 Wageningen Environmental Research implemented the ISO 9001 certified quality management system.
Since 2006 Wageningen Environmental Research has been working with the ISO 14001 certified environmental care system.
By implementing the ISO 26000 guideline, Wageningen Environmental Research can manage and deliver its social responsibility.

Wageningen Environmental Research Report 3331 | ISSN 1566-7197

Photo cover: Shutterstock

Contents

Verification

Change log

Date	Description	Changes
2023-02-20	Incomplete draft for first consultation	
2023-02-27	Second incomplete draft	Additions to Chapter 3: ● Comparison reanalysis with observations ● Seasonal changes in precipitation ● Information on fluvial inundation
2023-03-10	Third incomplete draft	● Captions and references to figures and tables added Additions to Chapter 3: ● Information on coastal inundation Additions to Chapter 4: ● Updated information on elevation, soil ● Information on surface water and saltwater intrusion Additions to Chapter 5: ● Information on adaptation and low emission options
2023-03-31	Fourth draft	Additions to Chapter 3: ● Information added on wind speed including climate projections Additions to Chapter 4: ● Information on crop vulnerabilities added
2023-05-26	Final draft for review	References added Updates to Chapter 4: ● Updates to Section 4.3 (elevation, soil, surface water, irrigation, groundwater) ● Section 4.5 (vulnerability and risk assessment) added Updates to Chapter 5 Chapter 6: conclusions and recommendations added

Report: 3331
Project number: 5200047371

Wageningen Environmental Research (WENR) values the quality of our end products greatly. A review of the reports on scientific quality by a reviewer is a standard part of our quality policy.

Approved reviewer who stated the appraisal,

position: Project Partners

name: Consortium

date: 26-05-2023

Approved team leader responsible for the contents,

name: Karin Andeweg

date: May 2023

List of acronyms and abbreviations

AWD	Alternate wetting and drying
AWC	Available soil water capacity
CMIP6	Coupled Model Intercomparison Project Phase 6
DEM	Digital Elevation Model
EC	Electrical conductivity
ECMWF	European Centre for Medium-Range Weather Forecasts
ETCCDI	Expert Team on Climate Change Detection and Indices
FABDEM	Forest and Buildings removed Copernicus DEM
FAO	Food and Agriculture Organization of the United Nations
GAR	Gender Assessment Report
GCF	Green Climate Fund
IPCC	The Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
ISIMIP	Inter-Sectoral Impact Model Intercomparison Project
KAP	Knowledge Attitudes Practices Survey
LVV	Ministry of Agriculture of Suriname
MDS	Meteorological Department of Suriname
MICS	Multiple Indicator Cluster Survey
SOC	Soil organic carbon
SSP	Shared Socioeconomic Pathway
SWIRS	Suriname Water Resources Information System
TDS	Total Dissolved Solids
WCRP	World Climate Research Programme
WMO	World Meteorological Organisation
WRI	World Resource Institute

Summary

The analysis of recent climate projections for the Nickerie and Coronie-Saramacca study area reveals significant climate change hazards impacting agriculture. These hazards entail increased hot days and nights, reduced annual precipitation, and rising sea levels leading to saltwater intrusion and coastal inundation. The vulnerability of rice, mixed vegetables, coconut, and bananas is examined in relation to these climate risks. Adaptation planning must consider the temporal aspect, distinguishing short-term challenges from long-term trends. Improved monitoring, data collection, and sharing are essential for informed climate risk analysis and mitigation. Trade-offs in adapting agricultural systems and the need for a comprehensive approach to dealing with salinization are recognized. Collaborative adaptation strategies that include local context and complex interactions among social, economic, and ecological systems are needed to foster resilient responses to climate change in the region.

In the tropical context of Suriname, the vulnerability of the country’s agriculture sector to climate change is underlined. Key climate hazards affecting the sector include shifts in precipitation, higher temperatures, and increased wind speeds. This vulnerability is increased by Suriname’s low elevation coastal zone. The agriculture sector is prone to sea level rise and associated risks like coastal erosion, flooding, and increased salinity. The report highlights the significance of agriculture in Suriname’s economy, contributing to GDP and employing a substantial portion of the population. The focus regions of Nickerie, Saramacca, and Coronie, known for rice, mixed vegetables, coconut, and banana cultivation, face distinct climate challenges. The project report supports the government’s efforts, in collaboration with international organizations, to secure the agriculture sector’s resilience to climate change impacts, providing vital insights into the historical baseline and future climate projections for these regions.

1 Introduction

Situated in the tropics and with most of the economic and agricultural activities taking place in the low elevation coastal zone, Suriname is highly vulnerable to climate change and in particular to the effects of sea level rise (Castellanos et al., 2022). The agricultural sector is especially vulnerable due to its dependence on natural resources such as water, soil, and biodiversity, all of which are impacted by changes in climate conditions. Higher temperatures, higher evapotranspiration rates, and changing rainfall patterns can lead to changes in water availability, potentially reducing crop yields and limiting food production. Increases in heavy rainfall could lead to more frequent and/or intense flooding. Warmer temperatures and changing weather patterns can lead to the spread of pests and diseases, affecting crop growth and quality. And finally, sea level rise could result in saltwater intrusion, flooding, coastal erosion and land loss. In recent years, Suriname has already experienced coastal erosion and flooding, causing damage to infrastructure, agriculture, and ecosystems (Castellanos et al., 2022).

In this context, the Government of Suriname, supported by the Food and Agriculture Organization of the United Nations (FAO) Sub-Regional Office for the Caribbean in collaboration with the Office of Climate Change, Biodiversity and Environment (OCB) and other FAO divisions, is developing a proposal to the Green Climate Fund (GCF) to build resilience to climate change in the agriculture sector. In support of this process, this report aims to provide a description of the climate vulnerabilities and impacts of the agricultural sector in two regions in Suriname, providing a historical baseline as well as looking ahead at expected future changes in the climate.

1.1 Background: agriculture in Suriname

Agriculture is an important sector of the economy in Suriname. It contributes 12% of the country's GDP and accounts for 10% of total export earnings. The agricultural sector employs approximately 25% of the population and is concentrated within the coastal zone (Delvoye et al., 2018). Important export products include rice, bananas, fish, and shrimp. Other important crops include citrus and other fruits, vegetables, and coconut.

Key climate hazards for the agricultural sector in Suriname include changes in precipitation, higher wind speeds and higher temperatures (Solaun et al., 2021). Crops, plantations (flowers, ornamentals, and other fruits), and vegetable production are mostly affected by increases in rainfall, while high wind speeds mainly affect bananas. Due to the low elevation of most production areas, the agriculture in Suriname is especially vulnerable to sea level rise. Apart from the risk of coastal erosion and flooding, sea level rise may also increase salinity levels, which has a negative effect on rice production. Changes in the freshwater supply, either locally from changes in rainfall and evaporation or from river discharge from upstream areas, may have a further impact on salinity levels in the coastal zone. Salinization can have a major impact on crop yields (Qadir et al.,2014). Higher evaporation rates, more frequent droughts, irrigation with groundwater and excessive use of mineral fertilizers may exacerbate the problem and result in higher concentration of salts in the soil.

1.2 Study areas

The project will focus on two regions: a western region consisting of the district of Nickerie, and a central region with the districts of Saramacca and Coronie. All three districts are located in Suriname's low elevation coastal zone and accordingly vulnerable to climate change and in particular sea level (Figure 1.1).

Nickerie is the main area for rice cultivation in Suriname, while Saramacca is the region where most fruits and vegetables are produced. The main agricultural product from Coronie is coconut. This report focuses on the climate change risks for these three crops (rice, mixed vegetables, coconut) as well as bananas.

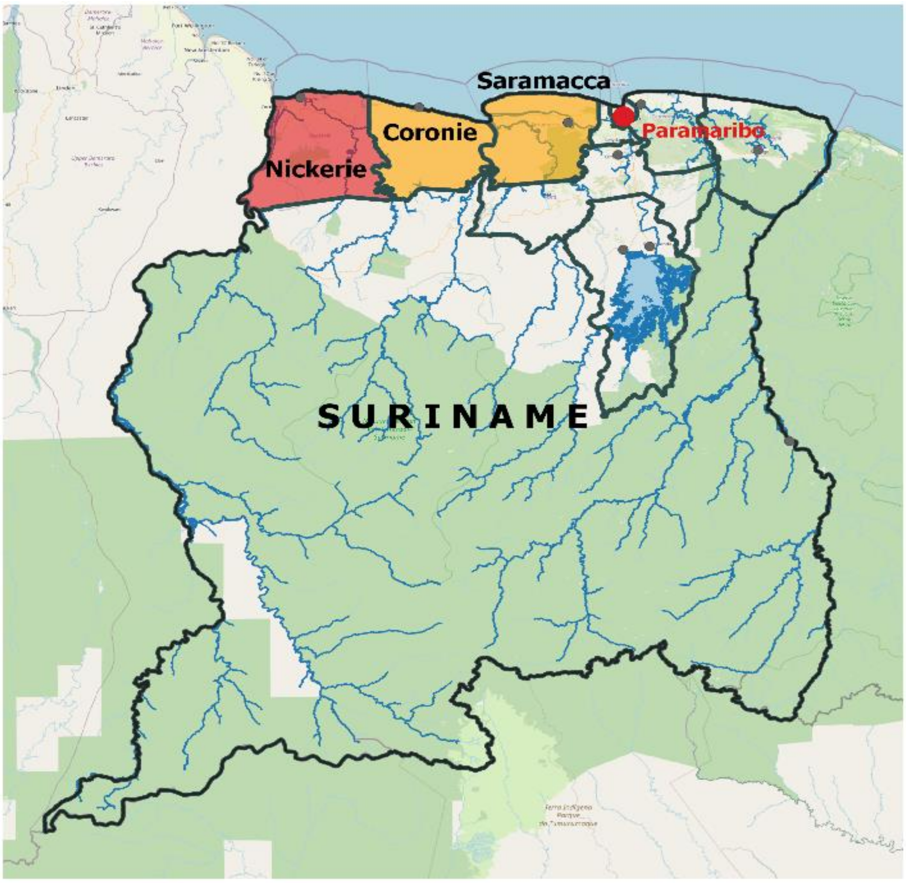

Figure 1.1 *Location of the study areas within Suriname. Background map from openstreetmap.org.*

1.3 Purpose of this report

This report provides an assessment of the vulnerabilities of the agricultural sector in the study areas to the effects of climate change. Following the accepted framework for climate vulnerability and risk, the assessment includes an analysis of the relevant climate hazards in Suriname, looking both at the historical past as well as projections of the future climate; this is discussed in Chapter 3. We also look at non-climatic factors that contribute to the vulnerability of the agricultural sector, including vulnerabilities of the four crops of interest; this is included in Chapter 4. Finally, in Chapter 5 we also look at adaptation options for some of the key climate hazards, including options for low emission agriculture.

2 Methodological framework

In analysing climate risks and vulnerabilities in the agricultural sector in the two study areas (the district of Nickerie and the two districts of Coronie and Saramacca) in Suriname, we adopt the framework as defined by the Intergovernmental Panel on Climate Change (IPCC, 2014) and the approach that has been set out jointly by the World Meteorological Organisation (WMO) and the Green Climate Fund (GCF) (Delju, et al., 2022).

In the IPCC framework, risk is understood as *the potential for adverse consequences for human or ecological systems* and arising from the dynamic interactions between *climate-related hazards* with *the exposure and vulnerability of the affected human or ecological system* to the hazards (see Figure 2.1). In other words, the potential for adverse impacts of climate variability and change depends not only on the occurrence of climate hazards (such as heatwaves, floods, and droughts) but also on the exposure of the system of interest to these hazards, and on the characteristics of the system, people or assets that gives rise to the negative consequences. A climate risk analysis therefore needs to look not just at the climate, but also evaluate factors that contribute to the other components of risk. As is the case for the climate hazards, exposure and vulnerability are dynamic, varying across temporal and spatial scales, and depend on economic, social, geographic, demographic, cultural, institutional, governance and environmental factors.

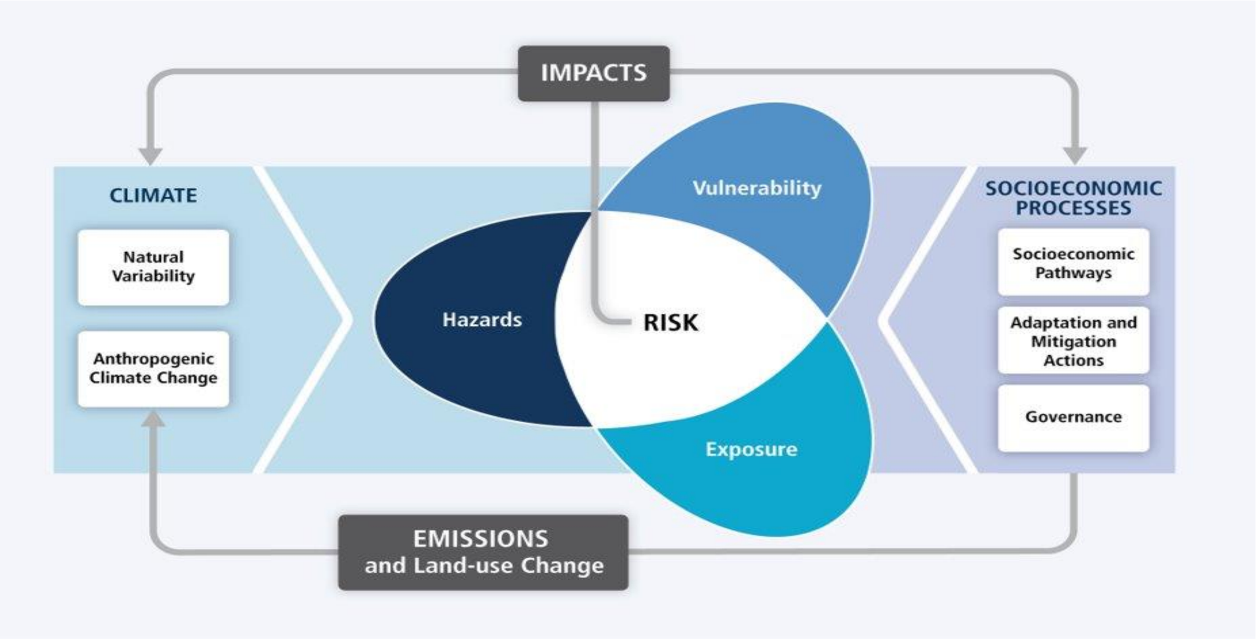

Figure 2.1 *Illustration of the concept of risk in the IPCC 5th Assessment Report (IPCC, 2014). The risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability. Source: IPCC (2014).*

A climate risk is always pertinent to the system (or asset, or community) being studied. In this report we focus on risks to the agricultural sector in Nickerie and Coronie-Saramacca with respect to four different crops (rice, coconut, mixed vegetables, and bananas). We evaluate the potential for direct impacts on crop productivity only and will not look at risks to the wider value chain, related to for example transport or market dynamics.

In evaluating climate risks, we broadly follow the approach outlined by WMO and GCF for developing the climate science information to be used in climate-related decisions (Delju et al., 2022). This methodology foresees four steps (Figure 2.2):

Step 1 – Identify the area of focus
Step 2 – Identify relevant climatic contributing factors and data
Step 3 – Identify relevant non-climatic contributing factors
Step 4 – Select effective climate actions.

This report supports the last three steps in this process, including the calculation of climate indicators that can be used to describe the past and current state of the climate, as well as to project future climate conditions. The analysis of climate indicators is discussed in more detail in Chapter 3. In Chapter 4 we look at non-climatic factors by calculating several vulnerability indices: metrics characterizing the vulnerability of a system, typically derived by combining several indicators assumed to represent vulnerability (IPCC, 2014). The last step, identifying effective climate actions, is supported by presenting and evaluating different mitigation options, which is done in Chapter 5.

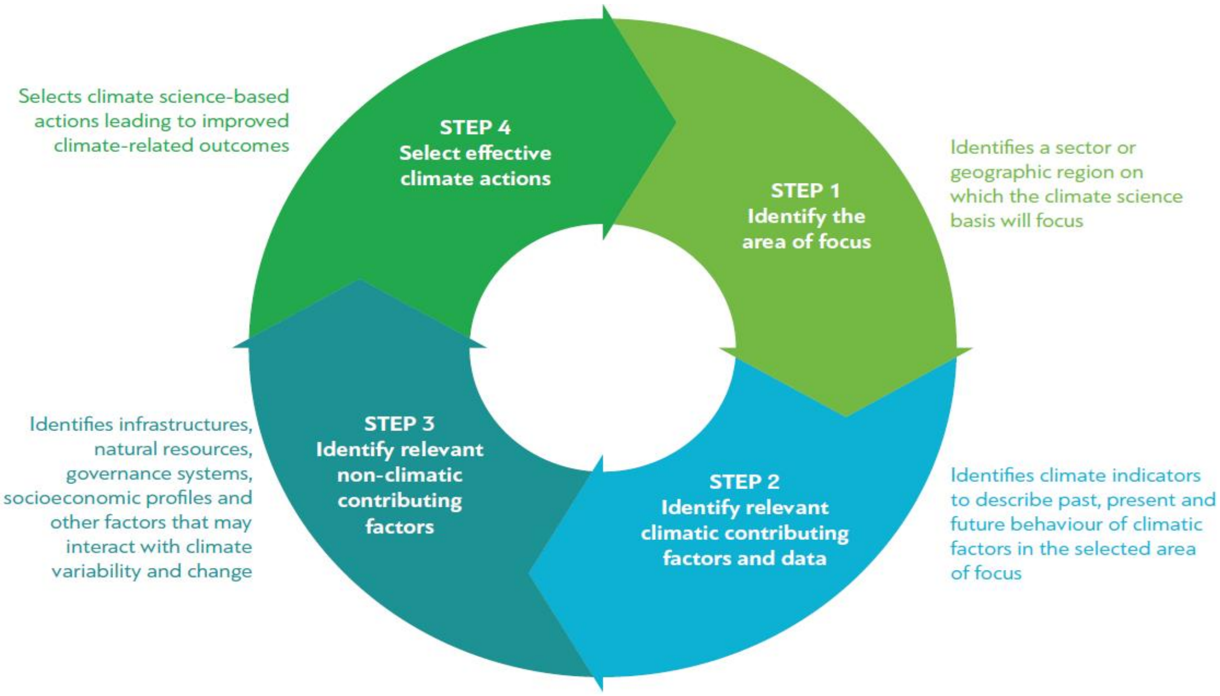

Figure 2.2 *Illustration of the concept of risk in the IPCC 5th Assessment Report (IPCC, 2014). The risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability. Source: IPCC (2014).*

In addition to essential climate variables, the choice of indicators is targeted specifically at salinisation as a major threat to agriculture in the study area. We can make a distinction between dynamic indicators (essentially indicators linked to climate change that can be projected into the future) and static indicators (indicators for which we have no reliable information about future changes and that are therefore based on historical information).

3 Climate hazard analysis

3.1 Introduction

In this chapter, we analyse historical trends, variability, and extremes, and projected future changes of relevant climate conditions in the two study areas in Suriname. Following the methodology of WMO and GCF (Delju et al., 2022), we do this by calculating a number of climate indicators that describe the climate characteristics relevant to agriculture in the region. The indicators we used are based on a set of widely accepted standard climate indicators as defined by the Expert Team on Climate Change Detection and Indices (ETCCDI) of the World Climate Research Programme (WCRP). Each index describes a particular characteristic of climate change (both changes in the mean and the extremes). Many indices are based on percentiles with thresholds set to assess moderate extremes that typically occur a few times every year, rather than once-in-a-decade weather events. The ETCCDI indices are calculated in a similar way across the world. Not all indicators are relevant to the climate in Suriname (such as, for example, the number of frost days per year); out of the 27 core indices we therefore selected the ones most relevant to the context of the study, supplemented with a number of bespoke indicators, as will be explained below.

In analysing climate projections, we make use of the latest available climate data that was used to underpin the latest Assessment Report of the IPCC (IPCC, 2021). And we account for the relevant uncertainties by looking at multiple climate scenarios and using the results from multiple climate models. In addition to meteorological variables such as temperature and precipitation, we also look at sea level rise and the likelihood of flooding, which should still be regarded as climate hazards in the IPCC framework (see Figure 2.1). The analysis is based primarily on global datasets, supplemented with local data to the extent available.

3.2 Methodology

3.2.1 Data sources: historical climate

The analysis of historical and current trends is based primarily on a climate model reconstruction of historical weather, more specifically the ERA5-Land reanalysis dataset. ERA5-Land provides a consistent view of climate variables over land at an enhanced resolution compared to ERA5 climate reanalysis of the European Centre for Medium-Range Weather Forecasts (ECMWF) (Muñoz Sabater, 2019). Reanalysis combines model data with observations from across the world into a globally complete and consistent dataset providing an accurate description of the climate of the past, going several decades back in time. Amongst other applications, the ERA5 climate reanalysis is used for regular State of the Climate bulletins of the Copernicus Climate Change Service of the European Commission[1]. Figure 3.1 gives an impression of the ERA5-Land precipitation and temperature over Suriname in the period 1991-2020, the most recent reference period for calculating climate normal.

3.2.2 Data sources: climate projections

In analysing future climate change, we make use of the latest available climate projections that underpinned the latest (6th) Assessment Report of the IPCC published in 2021 (IPCC, 2021). The climate simulations were produced by the Coupled Model Intercomparison Project Phase 6 (CMIP6). Specifically, we make use of a subset of CMIP6 models that have been bias-corrected and that are being used in the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) to project the impacts of climate change across affected sectors and spatial scales. The 5 ISIMIP climate models (GFDL-ESM4, IPSL-CM6A-LR, MPI-ESM1-2-HR, MRI-ESM2-0, and UKESM1-0-LL) were corrected for biases against the observational dataset W5E5, which is a combination of

---

[1] https://climate.copernicus.eu/climate-bulletins

ERA5 reanalysis data and precipitation data from the Global Precipitation Climatology Project (see Lange (2021) and references therein). Note the bias correction was done at a global scale and the quality of the resulting data will therefore vary across different regions. By analysing the results of all 5 ISIMIP climate models we can account, to some extent, for the modelling uncertainties in future climate projections.

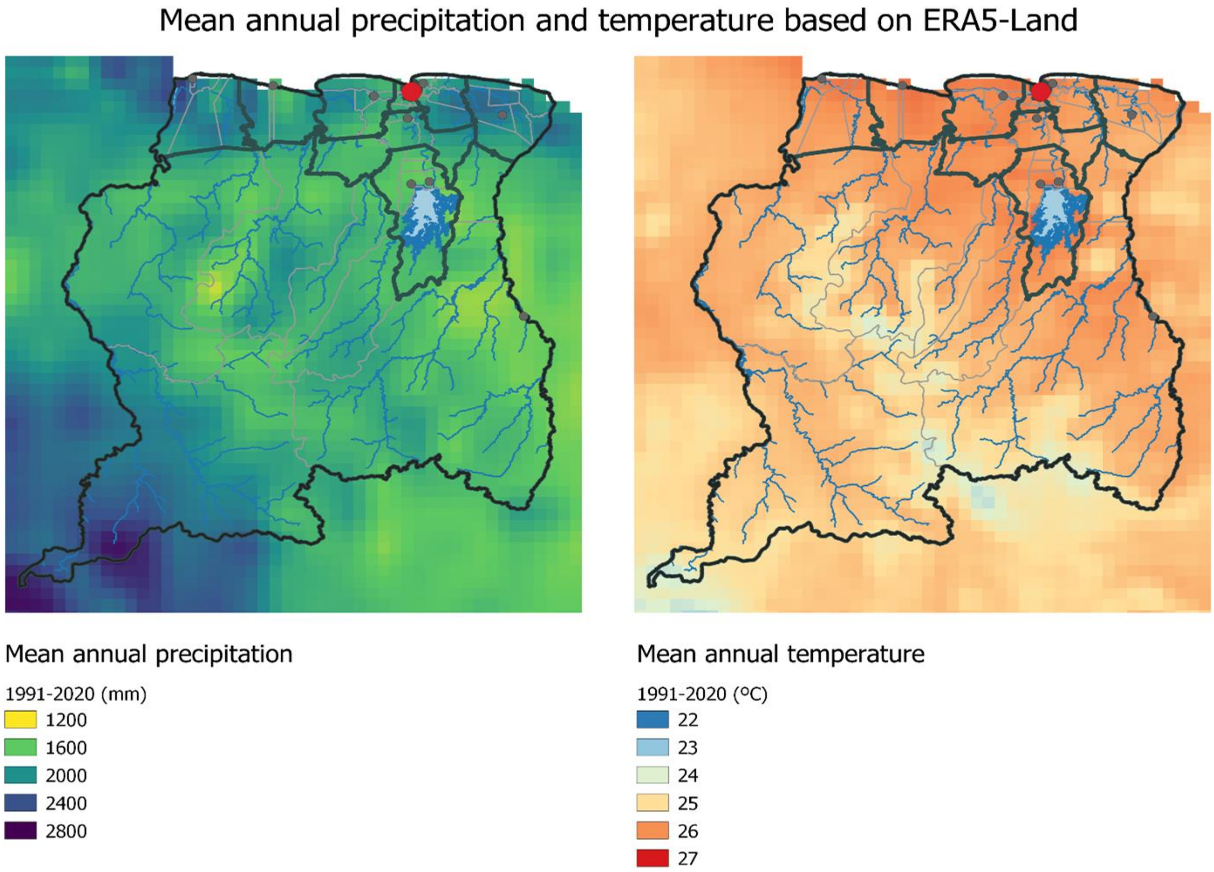

Figure 3.1 *Mean annual precipitation and temperature in 1991-2020 over Suriname based on the ERA5-Land dataset.*

We also look at three different emission scenarios or Shared Socioeconomic Pathways (SSPs) as used in the 6th IPCC Assessment Report: a scenario with low emissions (SSP1-2.6), a scenario with relatively high emissions (SSP3-7.0) and a scenario with very high emissions (SSP5-8.5). In principle no likelihood is attached to any of the SSPs, although the SSP5-8.5 is widely regarded as highly unlikely and should be regarded here as a worst-case scenario only.

3.2.3 Other data sources

Data on mean sea level rise were obtained directly from the latest IPCC Assessment Report, more specifically from the Interactive Atlas accompanying the Working Group 1 report[2]. We use projections of mean sea level for the region Northern South America, which encompasses Suriname.

While the IPCC provides projections of mean sea level, this gives only a partial picture of the hazards associated with sea level rise. Equally important are fluctuations around the mean: the actual water level fluctuates around the mean as a function of tides as well as meteorological conditions such as onshore or offshore winds, storm surges etc. In particular we are interested in the highest water levels that may be reached with a particular probability, e.g., a 10% chance of happening in a given year (commonly referred to as a ‘once-in-10-years’ event), or a 1% probability in a given year (a ‘once-in-100 years’ event). Information about this was obtained from the dataset “Global Sea level change indicators from 1950 to 2050 derived

---

[2] https://interactive-atlas.ipcc.ch/

from reanalysis and high resolution CMIP6 climate projections” from the Copernicus Climate Change Service (Muis et al., 2022). This dataset provides statistical indicators of tides, storm surges and sea level that can be used to characterize changes in sea level under climate change for locations across the globe, including the Suriname coast. The indicators are produced for three different 30-year periods corresponding to historical, present, and future climate conditions (1951-1980, 1985-2014, and 2021-2050) by a Global Tide and Surge Model using input from reanalysis and climate models. The future period is based on global climate projections using the high-emission scenario SSP5-8.5.

Furthermore, data on inundation from fluvial and coastal flooding were derived from the Aqueduct Floods Hazard Maps produced by the World Resource Institute (WRI) (Ward et al., 2020). The flood hazard is represented by inundation maps showing the flood extent and depth for floods with different probabilities (return periods). The scenarios that were used to produce the WRI inundation maps are based on the previous generation of climate scenarios, of which RCP8.5 is comparable to SSP5-8.5. The resolution of the flood hazard maps is 30 × 30 arc seconds — about 1 km × 1 km at the equator. Note the presence of flood defences is not accounted for in these hazard maps. Despite this limitation and the fact that the data are based on an older generation of climate scenarios, it was thought the flood hazard maps could still provide some useful additional insight into changes in inundation probability in the region.

3.2.4 Calculation of indices

Considering the relatively small size of the three districts and the absence of any major topographical features, the climate datasets were averaged across the three administrative regions. The climate indicators were calculated based on the resulting timeseries of daily regional averages. In addition, the indicators were also calculated based on the averages across the whole of Suriname, as well as three upstream areas that potentially could provide freshwater into the three districts (Figure 3.2): the combined area of the Coppename and Saramacca Rivers (providing freshwater to Coronie and Saramacca), the combined area of the Nickerie and Nani Kreek Rivers (providing freshwater mainly to Nickerie), and the Corantijn River (also providing freshwater to Nickerie). The Corantijn was taken separately from the Nickerie-Nani Kreek area as its catchment area reaches much further inland and therefore could exhibit different patterns of change.

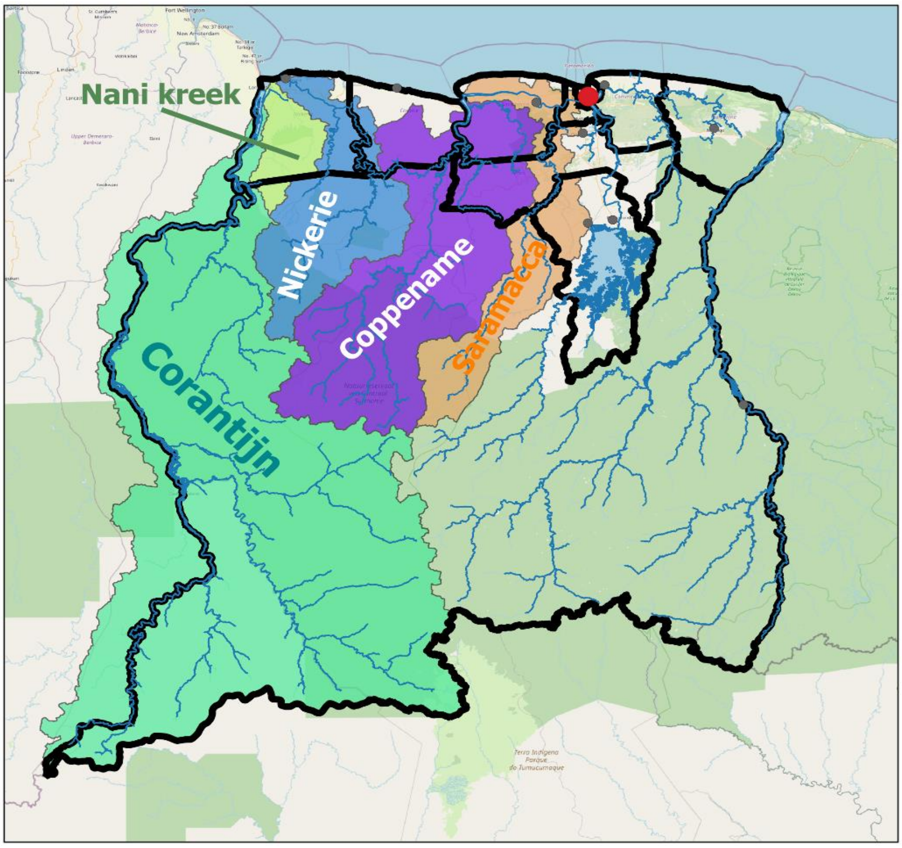

Figure 3.2 *Main river basins draining into the districts of Nickerie, Coronie and Saramacca.*

Although the climate indicators were calculated separately from the timeseries of all 7 regions (Nickerie, Coronie, Saramacca, Suriname, Coppename-Saramacca Rivers, Nickerie-Nani Kreek Rivers and Corantijn River), it was found that the resulting patterns were very similar. In presenting the results below we will therefore focus mainly on the district of Nickerie, supplemented with results from the other regions where appropriate. All the data processing was done mainly in Python, with some of the data extraction and regridding steps done with CDO. The calculation of climate indicators was done using the Python library icclim[3]. In total 26 indices were calculated, but not all are presented in this report, mainly for clarity of presentation: several indicators describe similar aspects (e.g., temperature extremes) and/or show patterns similar to the ones included in this report.

3.3 Temperature indicators

3.3.1 Mean annual temperature

Starting with the most basic index, Figure 3.3 provides an overview of the mean annual temperature in the three districts, as well as all of Suriname in the historical period. Due to the larger area that includes some highlands the average temperature over all of Suriname is about 0.5 degrees lower than in the three coastal districts. The interannual variability is relatively small with mean annual temperature in the coastal areas generally falling between 25 and 26.5ºC. Although no strong trend is apparent in the graphs, the average temperatures are higher in the most recent climatic period (1991-2020) compared to previous periods. Compared to 1951-1980, the mean annual temperature was 0.4ºC higher in Nickerie, and almost 0.5ºC higher in Coronie and Saramacca. Over all of Suriname the increase is about 0.3 degrees. These differences seem to be driven more by an absence of relatively cooler years in recent years, rather than an increase in the number of years that are unusually warm.

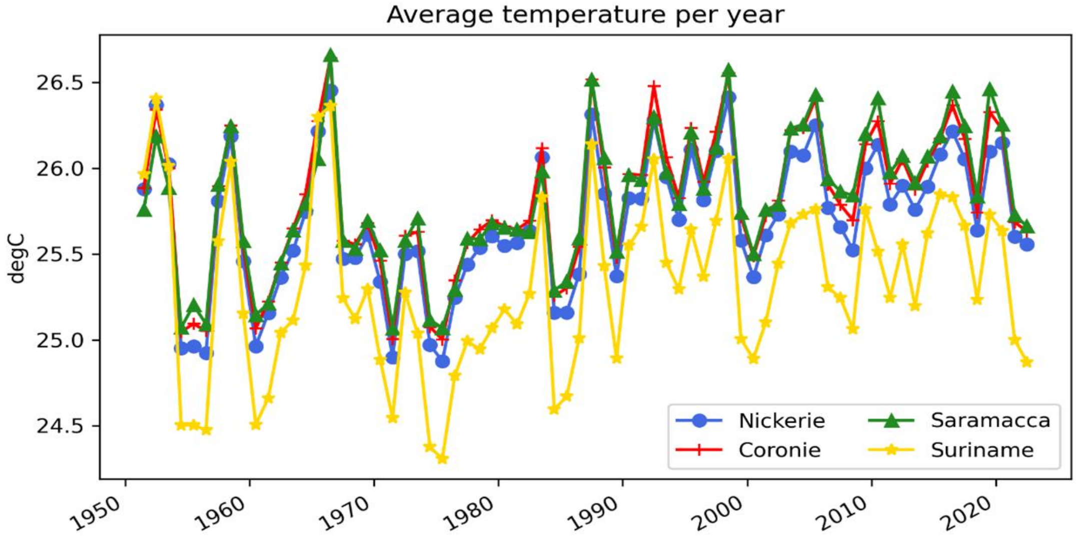

Figure 3.3 *Mean annual temperature in the districts of Nickerie, Coronie, Saramacca as well as all of Suriname in the ERA5-Land dataset.*

Comparing the ERA5-Land data directly with observations should be done with caution, as the latter are usually made at a single site, while the reanalysis data represent an average over a much larger area. Figure 3.4 shows monthly mean temperatures at the observation site at Nickerie Airport (5° 57' 23.69' 'N, 57° 2' 22.41'' W) and the corresponding temperatures at the nearest ERA5-Land grid cell in the years 2011-2022. Note that Nickerie Airport falls just outside the ERA5-Land mask, and so the grid represents an area to the south and east of the measurement site, with the centre point about 7.5 km south-southeast from Nickerie Airport. This may explain at least some of the bias we can observe, with ERA5-Land mean monthly temperatures about 1.3ºC cooler than the observations on average. Nevertheless, the reanalysis

---

[3] https://icclim.readthedocs.io/en/stable/index.html

dataset represents the variability in the observed temperatures very well, including the seasonal cycle averaged over longer periods (Figure 3.5). Figure 3.5 shows that also in the observations at Nickerie the mean annual temperature has risen by about 0.4 degrees between 1971-2008 and 2011-2021 and by a similar amount in ERA5-Land (note the unequal averaging periods).

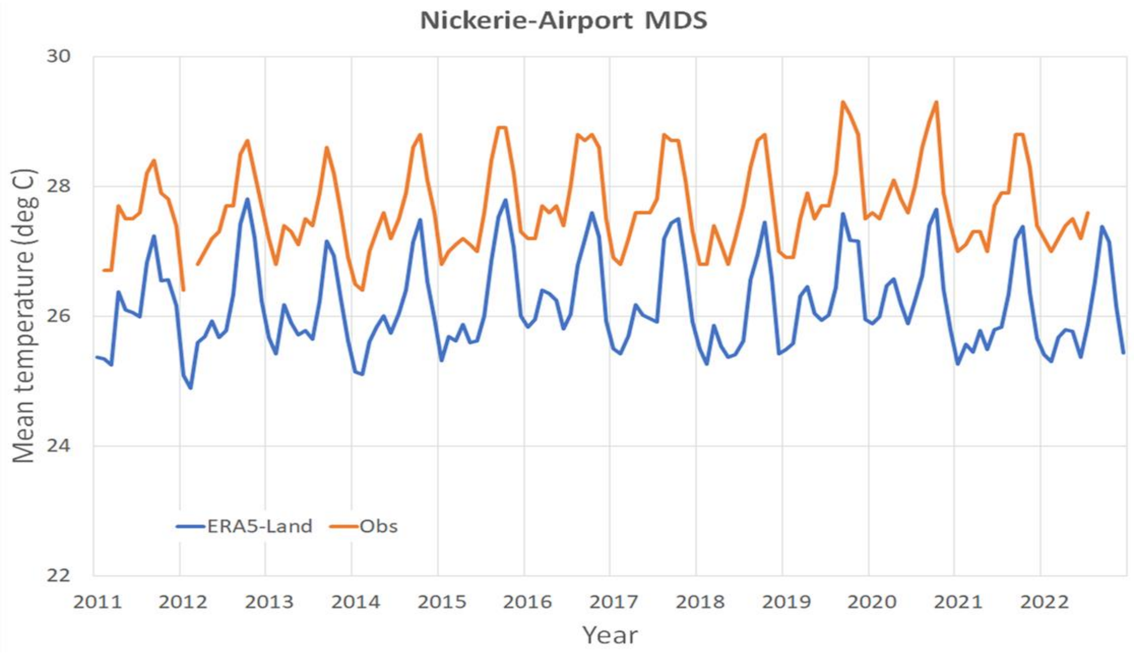

Figure 3.4 *Monthly mean temperature as observed at Nickerie Airport and at the nearest ERA5-Land grid point in 2011-2022. Note the observation site falls just outside the ERA5-Land mask, and the nearest grid point represents an area to the south and east of the weather station. Observation data courtesy of the Meteorological Department Suriname.*

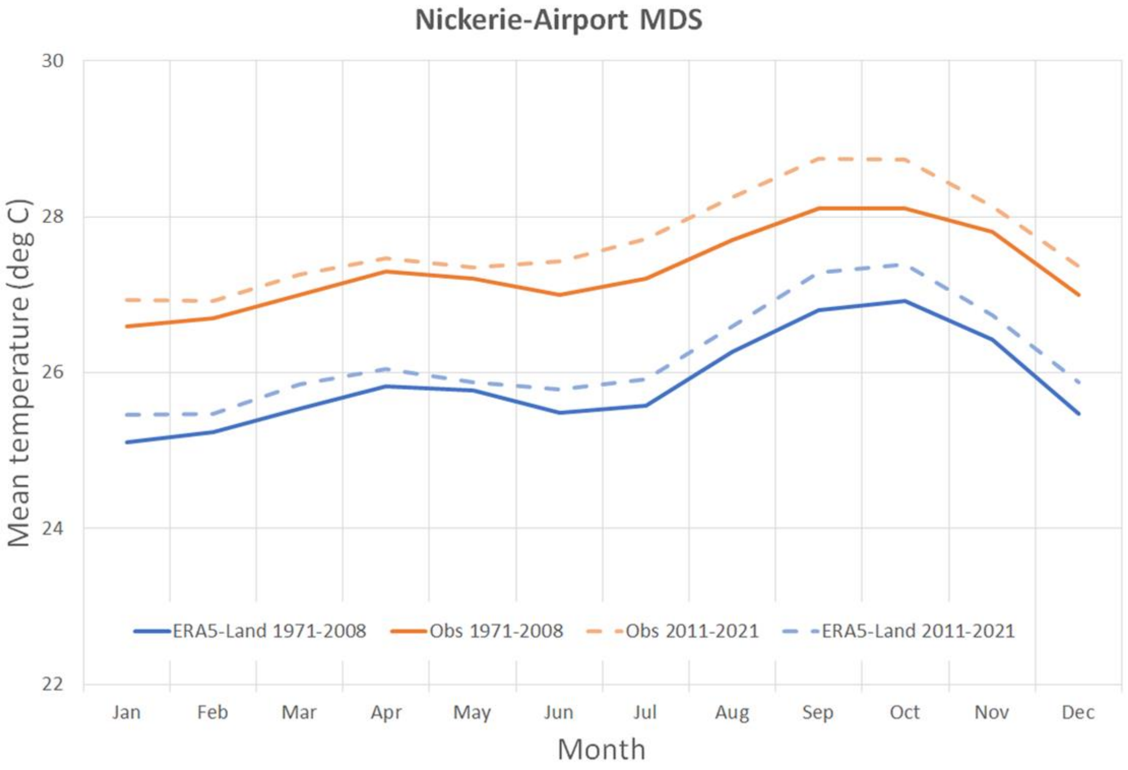

Figure 3.5 *Multi-annual mean monthly temperature observed at Nickerie Airport and at the nearest ERA5-Land grid point. Solid lines represent the monthly climatology in 1971-2008, dashed lines in 2011-2021.*

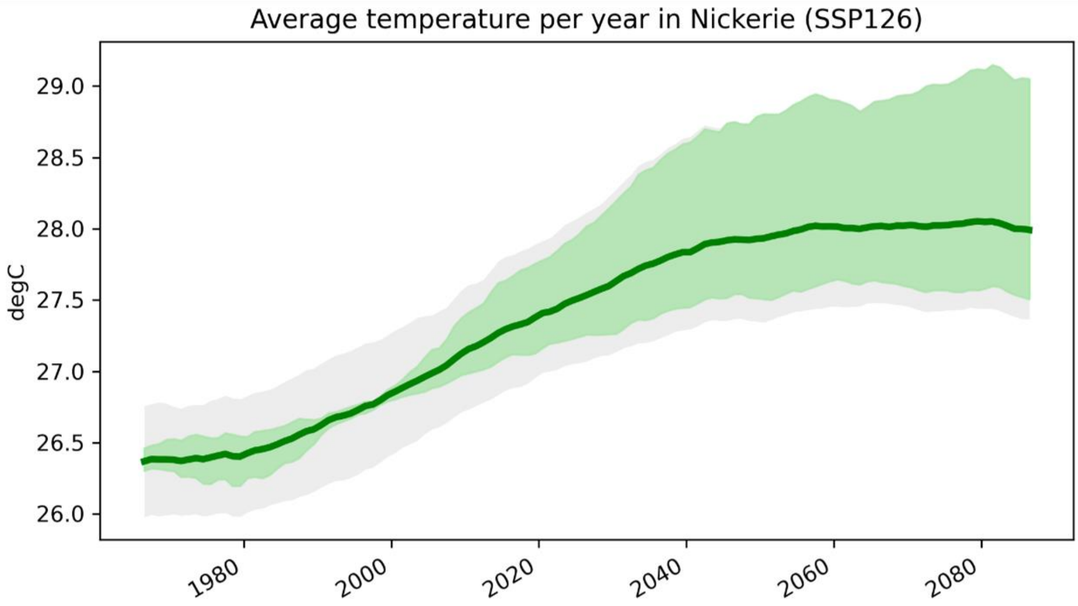

Figure 3.6 *Projection of mean annual temperature in Nickerie under scenario SSP1-2.6. The dark coloured line shows the multi-model ensemble average of 30-year average temperatures; the coloured shaded area shows the range (min and max) of 30-year average temperatures of the different models. The light-grey shaded area gives an impression of interannual variability and shows the 30-year average of the yearly minimum and maximum temperature value across the multi-model ensemble. Further into the future the shaded areas (partially) overlap as a single model (in this case UKESM1-0-LL) warms up more than the other models and is always the warmest in all years towards the end of the century.*

The climate projections for mean annual temperature in Nickerie are given in Figure 3.6 and Figure 3.7. These plots look different as we are now comparing multiple models with each other, and we focus on climatological (30-year) averages only. Instead of looking at an individual model, we focus on the average across the ensemble of models (the thick line in Figure 3.6) as well as the range (represented by the coloured shaded area) representative of the model spread and therefore the model uncertainty in the climate signal. Looking at the climate mitigation scenario SSP1-2.6 in the first instance, we note first of all that the models start from a higher baseline than in the ERA5-Land dataset. In 1951-1980, the multi-model mean of average temperature is well over 26ºC and almost 0.9 higher than in ERA5-Land. This suggests some residual bias remains in the climate model data; note though that the climate models have a lower resolution than ERA5-Land (approximately 55 km vs 11 km) so a direct comparison is probably only fair over larger land surfaces. Looking at the trends in the historical period, we note that the mean annual temperature in 1991-2020 is about 0.6 degrees higher compared to 1951-1980; in ERA5-Land the increase was 0.4ºC.

Throughout the remainder of the century the SSP1-2.5 scenario shows a further increase towards almost 28ºC at the end of the century (almost 1.0ºC warmer than in 1991-2020 and 1.6ºC warmer than in 1951-1980). Most of the warming occurs in the first half of the century, and stabilizes in the second half. However, the uncertainty increases as well with some models warming more than others; the warmest model (UKESM1-0-LL) is almost 1.9 degrees warmer in 2071-2100 compared to 1991-2020. In contrast, the coolest models project a warming of less than 0.7 degree in the same period.

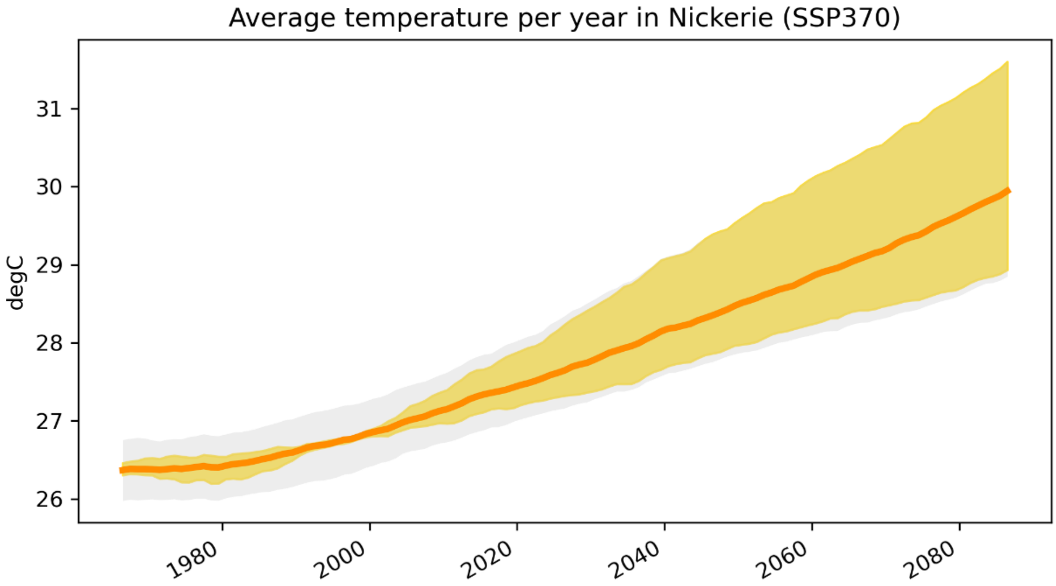

Figure 3.7 *As Figure 3.6, but for scenario SSP3-7.0.*

Comparing SSP1-2.6 with SSP3-7.0 (Figure 3.7), we see that in the latter the mean annual temperature continues to increase throughout the 21st century. In 2071-2100 the average warming across the ensemble is almost 3.2 degrees compared to 1991-2100, however with considerable spread ranging from +2.2ºC to +4.9ºC. Under the very high emissions scenario SSP5-8.5 (not shown) the warming is even higher: on average +3.6ºC in 2071-2100, ranging from +2.4ºC to +5.4ºC. As in SSP3-7.0, the warming continues to rise throughout the century.

3.3.2 Average daily maximum temperature

The average of daily maximum temperatures provides insight in temperatures that may be reached during daytime throughout the year. As with average temperature, no strong trend is visible in this indicator in the historical period. In the period 1991-2020 the average daily maximum temperature was about 0.25 degrees higher than in 1951-1980, in other words the increase in daily maximum temperatures was less than in the mean. Nevertheless, the ERA5-Land data suggest some years in the 20th century had higher maximum temperatures than in more recent decades (Figure 3.8).

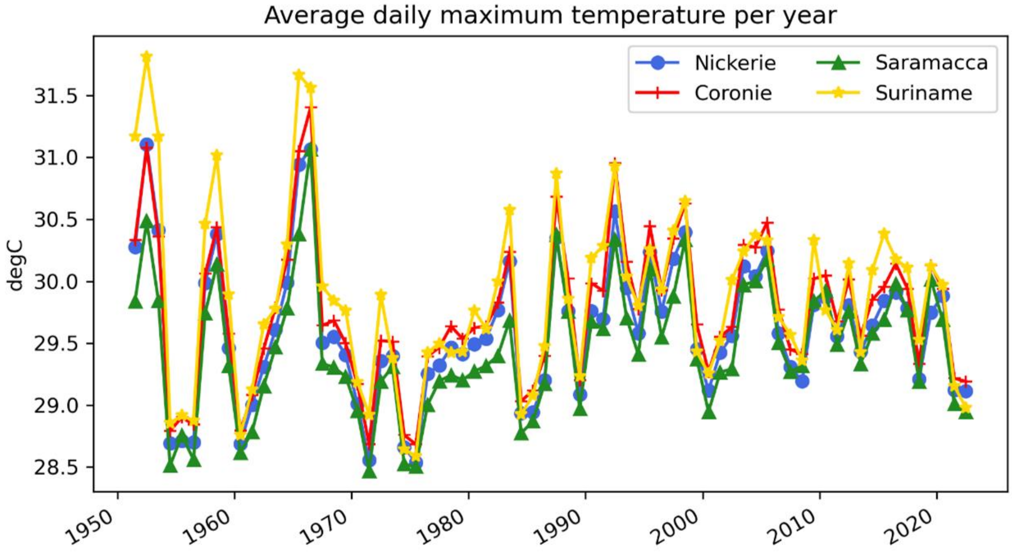

Figure 3.8 *Average daily maximum temperature per year in Nickerie, Coronie, Saramacca and all of Suriname in the ERA5-Land dataset.*

In the climate projections (not shown), the patterns of change in average daily maximum temperature are very similar to those in the mean temperature (Figure 3.6 and Figure 3.7). Under SSP1-2.6, the ensemble-average maximum temperature in 2071-2100 is 1.0ºC warmer than in 1991-2020, and 1.7ºC warmer than in 1951-1980, which is very close to the rise in mean temperature. Under SSP3-7.0 the ensemble-average maximum temperature is 3.2 degrees warmer than in 1991-2020, which again is almost the same warming as in the mean temperature. Under the very high emissions scenario SSP5-8.5, however, the ensemble-average maximum temperatures are projected to rise even more than the mean temperature (+4.1ºC in 2071-2100).

3.3.3 Average daily minimum temperature

The average of daily minimum temperatures provides insight into the lowest temperature that is, on average, reached during the night (Figure 3.9). First of all, we note that minimum temperatures are generally higher in the three coastal districts than across Suriname as a whole. Secondly, and in contrast to maximum temperature, an increasing trend in the historical period is more obvious from the timeseries. In 1991-2020, the average minimum temperature was 0.53ºC higher than in 1951-1980 in Nickerie, and 0.57ºC higher in Coronie and Saramacca. In Suriname as a whole the increase was about 0.4 degrees. In other words, not only is the daily minimum generally higher in the three coastal districts, it has also increased slightly more compared to the rest of the country.

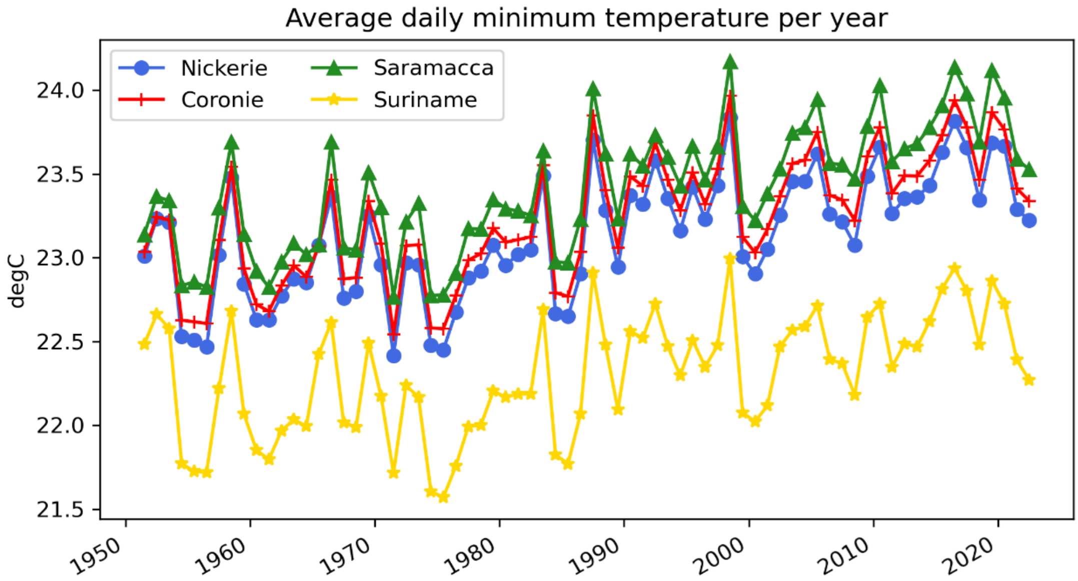

Figure 3.9 *Average daily minimum temperature in Nickerie, Coronie, Saramacca and all of Suriname in the ERA5-Land dataset.*

The climate projections for average minimum temperature project a further increase in minimum temperature, even under the SSP1-2.6 scenario (Figure 3.10). As with average temperature, the mean of the climate models starts from a somewhat too high baseline in the historical period, but the increase between 1951-1980 and 1991-2020 is very similar to what was seen in the ERA5-Land data (about 0.5 degrees). In SSP1-2.5 the average minimum temperature is by the end of the century on average about 1ºC higher than in 1991-2020, again with some uncertainty around this figure (+0.6ºC to +1.9ºC). This 1ºC warming is very similar to the rise in mean temperature in the same scenario.

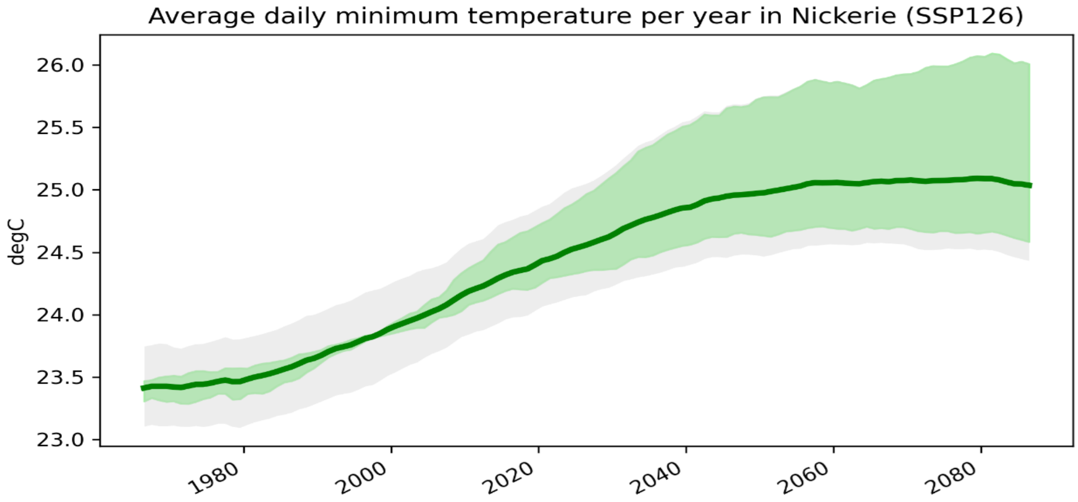

Figure 3.10 *Projection of daily minimum temperature in Nickerie under scenario SSP1-2.6. The dark coloured line shows the multi-model ensemble average of 30-year average minimum temperatures; the coloured shaded area shows the range (min and max) of 30-year average minimum temperatures of the different models.*

In the SSP3-7.0 scenario minimum temperatures continue to rise throughout the century. By the end of the century, the average minimum temperature is on average 2.8ºC (+2.1ºC to +4.0ºC) warmer than in 1991-2020 (Figure 3.11). Under SSP5-8.5, the increase over the same period is +3.4ºC (+2.7ºC to +5.0ºC). These figures are slightly lower than the corresponding increases in the mean temperature.

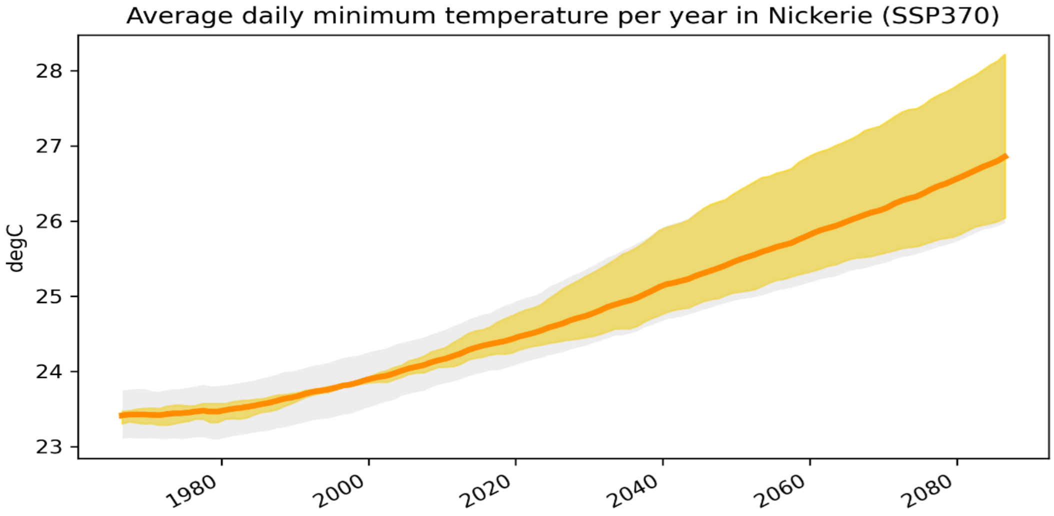

Figure 3.11 *As Figure 3.10, but for scenario SSP3-7.0.*

3.3.4 Number of very warm nights

One of the standard ETCCDI indicators is the number of tropical nights per year, where a tropical night is defined as a day where the minimum temperature is higher than 20ºC. In the Suriname context this indicator is not useful, as virtually all nights are warmer than this threshold already. Instead, we calculated the number of nights with minimum temperatures above two higher thresholds: 23ºC and 25ºC. According to the ERA5-Land dataset, minimum temperatures already stay above 23ºC in the majority of the nights in the three coastal districts, and especially in recent years (Figure 3.12). In Nickerie, the amount has jumped from on average 150 nights per year in 1951-1980 to more than 250 nights per year in 1990-2020. Even more notable is the increase in the number of nights above 25ºC: while this was a rare occurrence earlier in the 20th century (less than once per year in 1951-1980), this has been relatively common in Nickerie, Coronie and especially Saramacca in recent decades (Figure 3.13). In 1991-2020 the average number of nights this has happened ranges from slightly more than 6 per year in Nickerie to more than 12 per year in Saramacca.

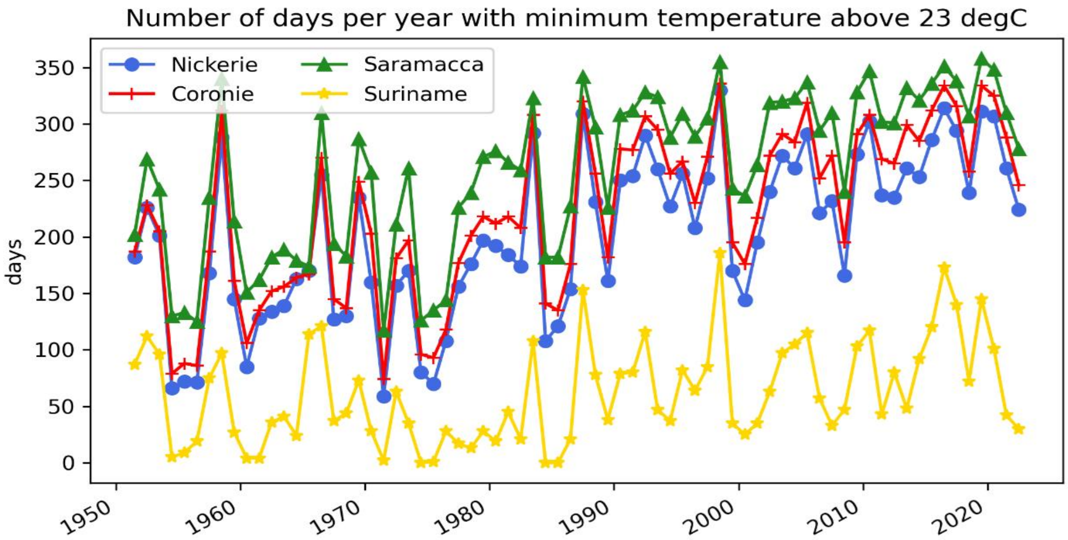

Figure 3.12 *Number of nights with minimum temperature above 23ºC in Nickerie, Coronie, Saramacca and all of Suriname in the ERA5-Land dataset.*

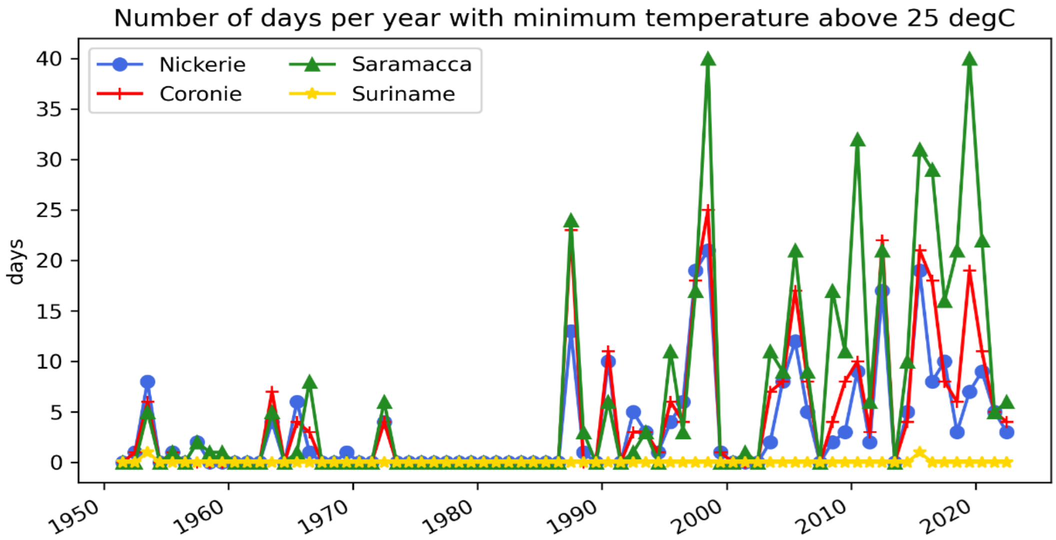

Figure 3.13 *Number of nights with minimum temperature above 25ºC in Nickerie, Coronie, Saramacca and all of Suriname in the ERA5-Land dataset.*

Looking at the climate projections, we see that even under the low emissions scenario SSP1-2.6 the number of very warm nights with a minimum temperature above 25ºC is projected to increase considerably, albeit with large model spread (Figure 3.14). Due to the remaining warm bias that was noted earlier the number of very warm nights in the historical period (on average 32) is higher than was observed in ERA5-Land, but nevertheless the increase is large, with the warmest models suggesting that the minimum temperature will be above 25ºC in the majority of the nights, if not almost all nights. The ensemble mean at the end of the century is 185 nights per year, an almost six-fold increase compared to 1991-2020.

Not surprisingly, the number of warm nights increases even more under SSP3-7.0, with all models projecting more than 300 nights per year with a minimum temperature above 25ºC (Figure 3.15). A very similar pattern occurs also under SSP5-8.5. Even when considering the warm bias in the historical period, such projections signal the potential for drastic changes in the thermal conditions at night.

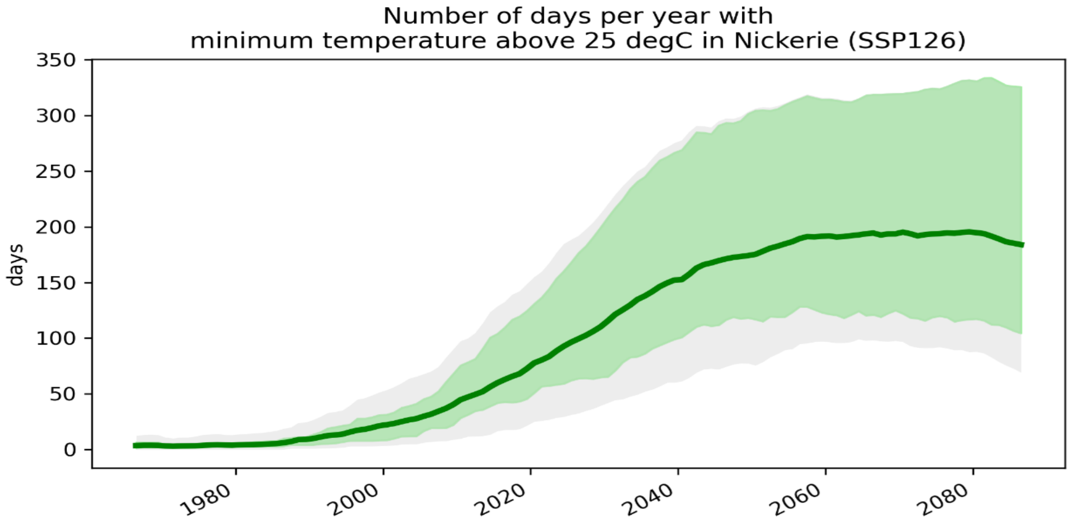

Figure 3.14 *Projection of the number of nights with a minimum temperature above 25 degrees in Nickerie under scenario SSP1-2.6. The dark coloured line shows the multi-model ensemble mean of the 30-year average number of very warm nights; the coloured shaded area shows the range (min and max) of the 30-year average number of very warm nights in the different models.*

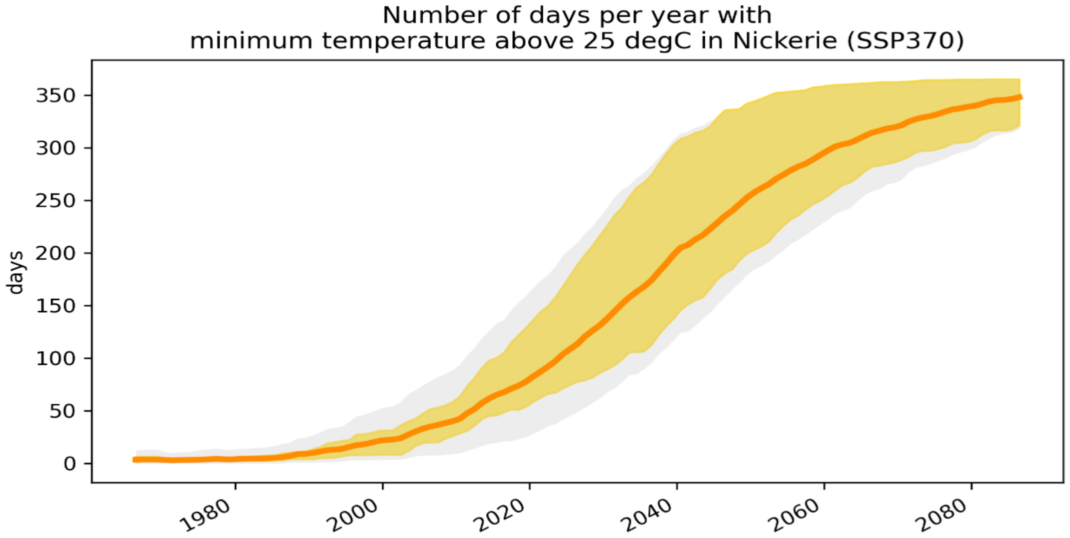

Figure 3.15 *As Figure 3.14, but for scenario SSP3-7.0.*

3.3.5 Number of very hot days

In addition to the standard ETCCDI indicators, we also look at the number of days with a maximum temperature of 35ºC or higher. This threshold is particularly relevant to rice cultivation. High temperatures above 35°C negatively affect the growth of roots and shoots and hampers pollination. However, the responses of rice to high temperature stress vary with the extent of temperature increase and its duration (Hussain et al., 2019). In tropical environments around the world, high temperature is already one of the major environmental stresses limiting rice productivity, with relatively higher temperatures causing reductions in grain weight and quality (Krishnan et al., 2011).

Looking at the historical period, days with a maximum temperature of 35 degrees or higher have been a rare occurrence in Suriname, and especially in the study areas (Figure 3.16). In the 1991-2020 climate reference period, the average number of days per year is less than 1 in Nickerie and Saramacca, and just above 1 in Coronie, compared to 3.4 days on average over all of Suriname. Interestingly, the ERA5-Land dataset suggests this was a slightly less infrequent event earlier in the 20th century, particularly when looking at Suriname as a whole (Figure 3.16).

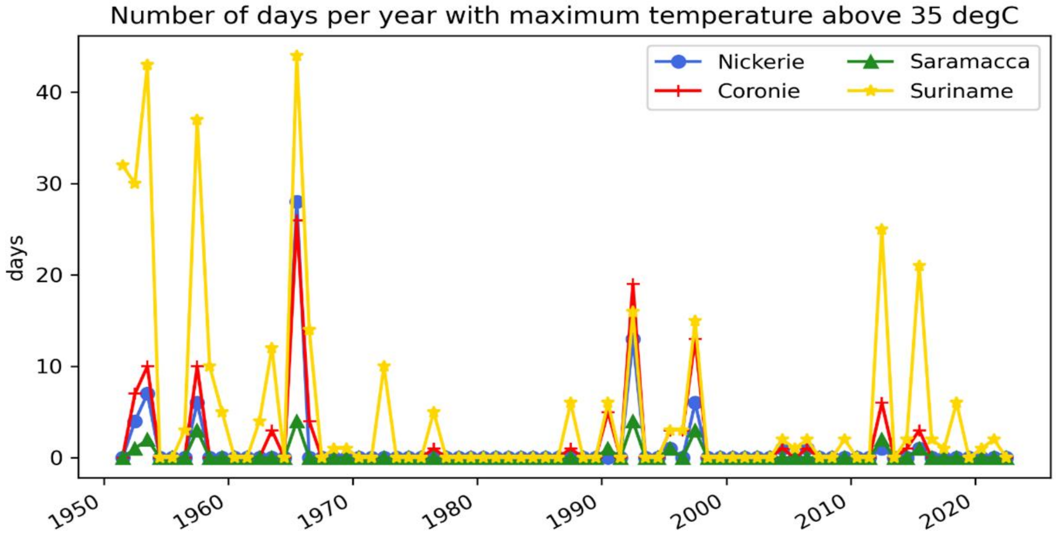

Figure 3.16 *Number of days per year with a maximum temperature of 35ºC or higher in Nickerie, Coronie, Saramacca and Suriname in the ERA5-Land dataset.*

The climate projections agree with the very low number of very hot days in the historical period, although the actual number of days with a maximum temperature of 35ºC or more (about 2 days per year in Nickerie in 1991-2020) is slightly above what was found in ERA5-Land. However, the number is projected to increase significantly. In the SSP1-3.5 the number of days per year peaks around mid-century at close to 20 days per year in 2041-2070 on average (Figure 3.17). However, the spread between models is also large, ranging from less than 5 to almost 60 days per year.

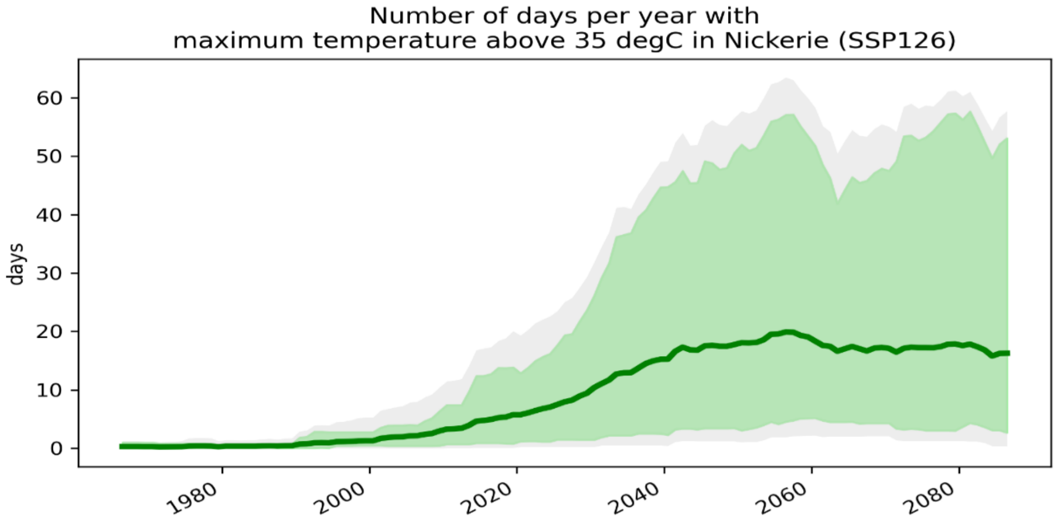

Figure 3.17 *Projection of the number of very hot days with a maximum temperature above 35 degrees in Nickerie under scenario SSP1-2.6. The dark coloured line shows the multi-model ensemble mean of the 30-year average number of very hot days; the coloured shaded area shows the range (min and max) of the 30-year average number of very hot days in the different models.*

However, of more concern are the changes under the higher emission scenarios. Under SSP3-7.0, the ensemble-mean number of days per year with a maximum temperature above 35ºC is above 150 days per year by the end of the century (2071-2100), ranging from 68 to 295 days in the individual models (Figure 3.18). Even the lowest number would mean that rice production would be severely hampered due to high temperatures alone during certain times of the year.

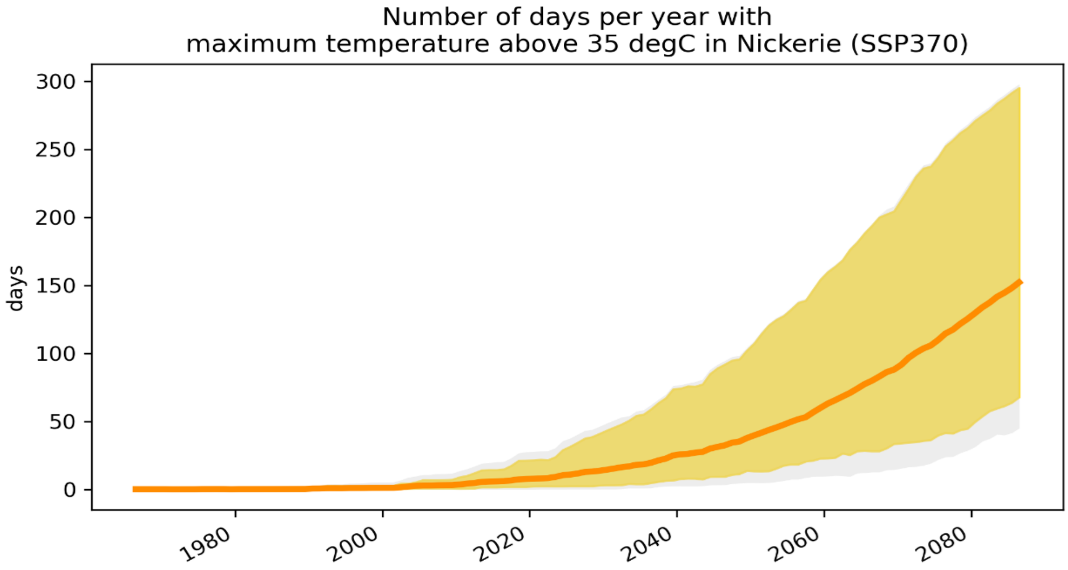

Figure 3.18 *As Figure 3.17, but for SSP3-7.0.*

The increase is even larger under SSP5-8.5, with the number of very hot days rising to almost 200 (98 to 339) days per year at the end of the century (Figure 3.19), suggesting rice production could be severely affected on the majority of days. Note in both scenarios the ensemble-mean number of very hot days remains below 50 days per year until approximately the middle of the century.

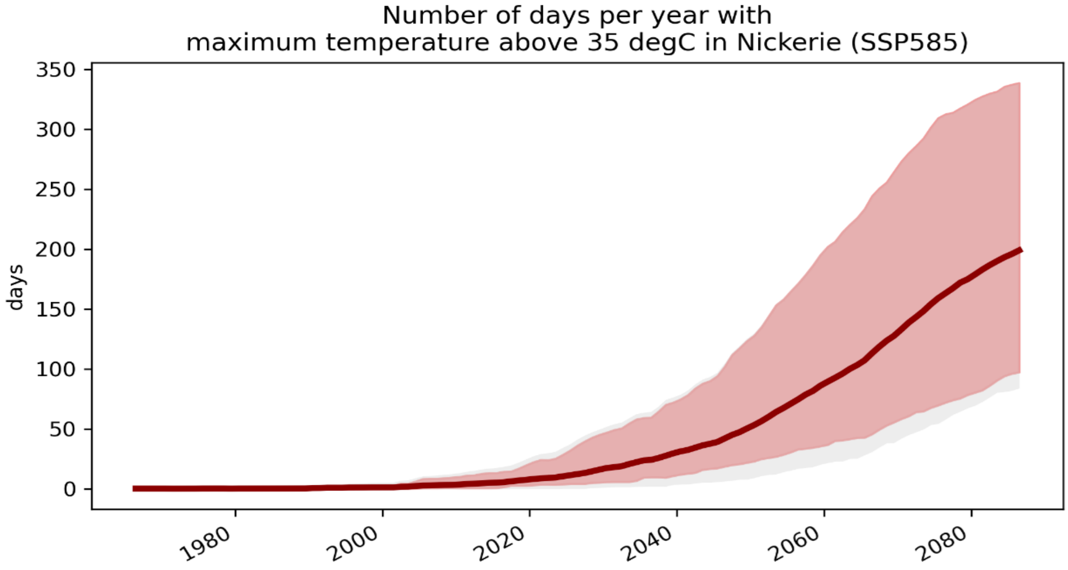

Figure 3.19 *As Figure 3.17 but for SSP5-8.5.*

Temperatures higher than 35ºC become a distinct possibility in the study area in the high emission scenarios. Maximum temperatures in excess of 38ºC, relevant to banana growth (see Section 4.4.2), do not occur in the climate simulations until about the 2040s. Under SSP3-7.0, the number of days with a maximum temperature higher than 38ºC is then projected to 23 days per year on average in the period 2071-2100. The model spread is large though, ranging from 0 to more than 70 days per year. Under SSP5-8.5, the projected increase at the end of the century is even larger, to 53 days (0 – 156 days) on average. Under SSP1-2.6, on the other hand, such hot days remain a very rare occurrence (less than 1 day per year on average in 2071-2100).

3.4 Precipitation indicators

3.4.1 Mean annual precipitation

Figure 3.20 shows the annual amount of precipitation in the historical ERA5-Land dataset. An increasing trend can be seen since around 1990; however in all three districts the average annual rainfall total in 1991-2020 is marginally lower than in 1951-1980, while being slightly higher than in the period 1971-2000. In all cases the differences between the climatic averages are less than 5%. The ERA5-Land also suggests annual rainfall in Nickerie is slightly higher than in Coronie, and notably higher than in Saramacca, a difference of about 12% (see also Table 3.1). The pattern of variability in the annual precipitation in the three upstream areas (Corantijn, Nickerie River – Nani Kreek, and Coppename – Saramacca Rivers) is very similar to that in the districts shown in Figure 3.20.

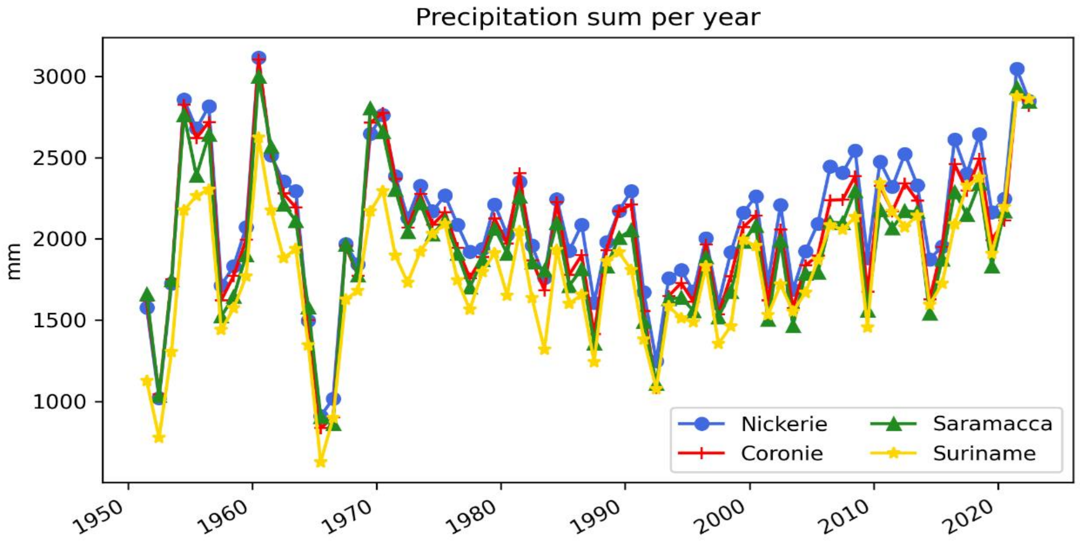

Figure 3.20 *Mean annual precipitation in the districts of Nickerie, Coronie, Saramacca as well as all of Suriname in the ERA5-Land dataset.*

Due to the high spatial and temporal variability of rainfall, comparing reanalysis data directly with observations is even more difficult than for temperature. To illustrate the large differences that may occur even at short distances, according to data from the Meteorological Department of Suriname (MDS) the total rainfall in the first two months of 2021 at Groot-Henar (5° 51' 19.73" N, 56° 53' 14.18" W), just over 20 km east-southeast from Nickerie Airport, amounted to 804 mm, almost 4 times higher than observed at Nickerie (216 mm) in the same two months. Such large differences are driven by the, to some extent, random occurrences of individual events, and comparing observations at a single site with reanalysis data representative of much larger areas should only done on much longer timescales, and then only if other factors that may cause local differences in rainfall (such as orography or coastal effects) are accounted for. With these caveats in mind, Figure 3.21 shows that the reanalysis data is able to reproduce the multi-annual monthly mean rainfall at Groot-Henar fairly well. Due to a lack of data a comparison of long-term trends was not possible at the time of writing.

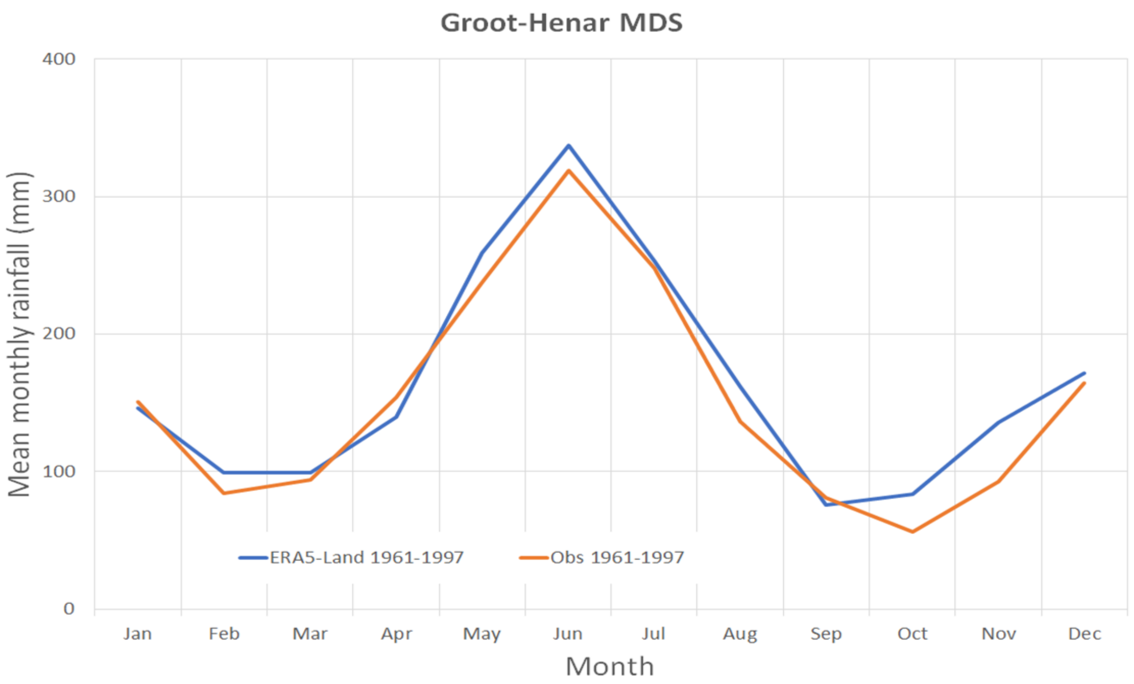

Figure 3.21 *Multi-annual monthly mean rainfall at Groot-Henar in the period 1961-1997, compared with ERA5-Land precipitation at the nearest grid point in the same period. Observation data courtesy of the Meteorological Department Suriname.*

Looking at the climate projections, we first of all see a large interannual variability (indicated by the grey area in Figure 3.23). Averaged over 30 years, the model uncertainty (indicated by the coloured area) is relatively small. In the historical period the ensemble-average annual rainfall total is about 11-18% lower than in ERA5-Land. Under SSP1-2.6 the models agree on a slight but consistent decline throughout the century to about 1650 mm/year in 2071-2100 in Nickerie, a decline of less than 5% compared to 1991-2020. Under SSP3-7.0 (Figure 3.22) we see a stronger decline throughout the century to about 1300 mm/year, a decline of almost 25%. Looking at the interannual variability (based on individual years occurring within the multi-model ensemble), years with an annual rainfall of about 1,000 mm are a distinct possibility towards the end of the century. In SSP5-8.5 the average annual rainfall declines slightly more to about 1260 mm/year or just over 25%. Noting again that the climate models start off from a baseline in the historical period that is too low, a 25% decline in the ERA5-Land annual precipitation would amount to about 1560 mm/year, although in individual years of course the annual rainfall may still be up to 30% lower than the long-term average. Note also that, even if the baseline rainfall in, e.g., Saramacca is higher than in Nickerie in the historical period, the relative decline is similar across all regions (Table 3.1).

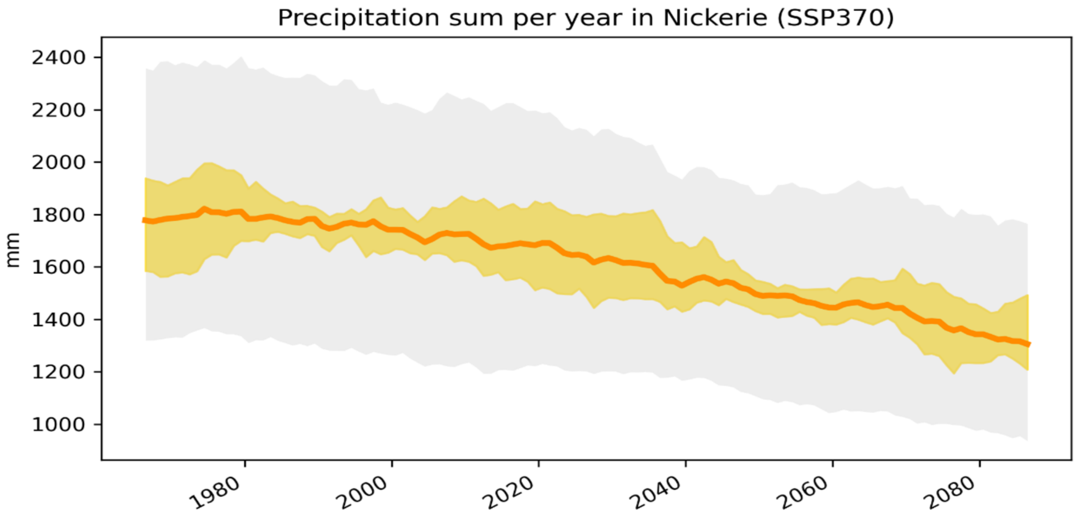

Figure 3.22 *As Figure 3.23, but for scenario SSP3-7.0.*

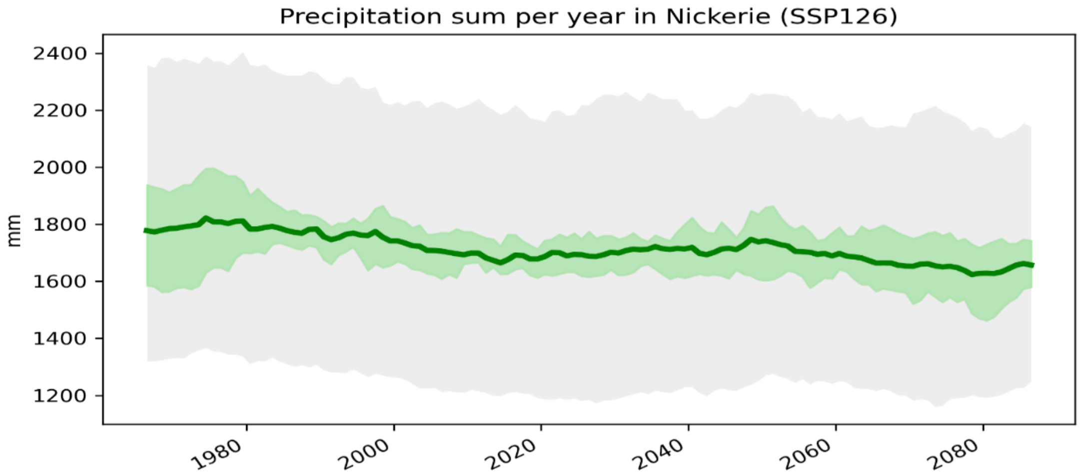

Figure 3.23 *Projection of mean annual rainfall in Nickerie under scenario SSP1-2.6. The dark coloured line shows the multi-model ensemble average of 30-year average rainfall; the coloured shaded area shows the range (min and max) of 30-year average rainfall of the different models. The light-grey shaded area gives an impression of interannual variability and shows the 30-year average of the yearly minimum and maximum annual rainfall totals across the multi-model ensemble.*

Table 3.1 *30-year mean annual precipitation sums in mm in different time periods in the ERA5-Land historical climate data, and the ISIMIP climate projections. The ISIMIP projections given are the ensemble mean of the 5 climate models.*

	Nickerie (District)	**Coronie**	**Saramacca (District)**	**Corantijn R.**	**Nickerie R. – Nani Kreek**	**Coppename – Saramacca**
ERA5-Land						
1951-1980	2,089	2,039	1,997	1,735	1,858	1,749
1971-2000	1,998	1,912	1,851	1,787	1,790	1,671
1991-2020	2,086	1,955	1,865	1,972	1,890	1,765
ISIMIP projections						
SSP1-2.6						
1991-2020	1,706	1,692	1,992	2,052	1,895	2,168
2041-2070	1,702	1,692	1,986	2,030	1,885	2,156
2071-2100	1,657	1,634	1,914	1,989	1,837	2,096
SSP3-7.0						
1991-2020	1,723	1,714	2,010	2,045	1,909	2,177
2041-2070	1,466	1,450	1,737	1,803	1,639	1,896
2071-2100	1,306	1,296	1,601	1,628	1,465	1,728
SSP5-8.5						
1991-2020	1,716	1,708	2,015	2,055	1,905	2,183
2041-2070	1,442	1,422	1,714	1,754	1,611	1,866
2071-2100	1,259	1,245	1,529	1,576	1,410	1,663

3.4.2 Seasonal changes

As can be seen in Figure 3.21, the rainfall in the study areas has a distinct seasonal pattern, with the months February-March and September-October being relatively dry. In Nickerie, these drier months correspond to the end of the two main rice growing seasons, May to October and November to April. Therefore, it makes sense to look at changes in the seasonal cycle of rainfall, in the historical past as well as future climate projections. Figure 3.24 shows the monthly mean rainfall in Nickerie in the reanalysis data over different climatic periods. No major shifts in the rainfall distribution can be discerned, and differences in the monthly rainfall totals between the different periods are relatively small, as was the case for annual rainfall totals. In the most recent decade (2012-2022), rainfall amounts have been higher than the climate normal particularly in the months February-May and also in November and December, lending some credibility to anecdotal evidence of longer wet seasons in this area. Compared to 1981-2010 (the preceding climate period), rainfall totals in 2012-2022 were 31% higher than normal in February and March, 37% in April, 26% in May, and even 46% in November. However, some significant variability is to be expected over shorter periods of time, and it is impossible to say yet whether these increases are part of an ongoing trend.

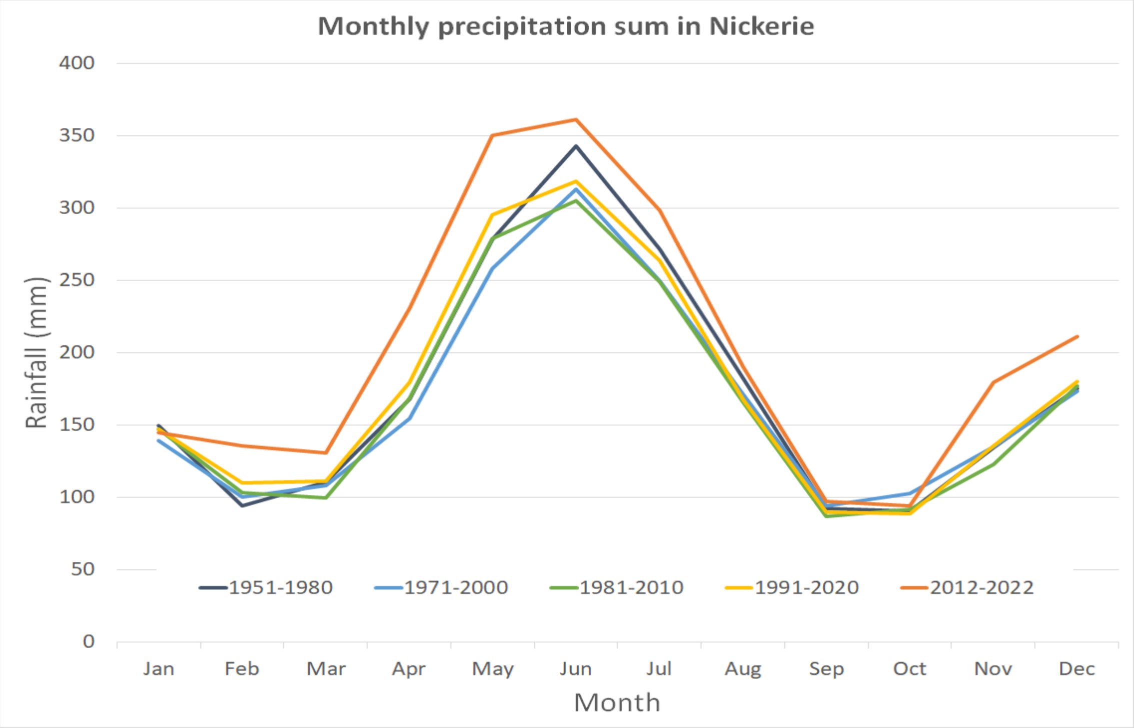

Figure 3.24 *Monthly mean precipitation in the district of Nickerie in the ERA5-Land dataset over different climatic periods, as well as the most recent decade (2012-2022).*

Indeed, the climate projections show, if anything, a trend towards a drier early dry season that is consistent across the scenarios. The bimodal distribution remains largely in place but even under the mitigation scenario SSP1-2.6 (Figure 3.25) a decline in rainfall in the months February to April is projected, amounting to 20% less precipitation in March in the period 2021-2050, 30% less in 2041-2070, and even 40% less in 2071-2100, on average across the models. This decline in rainfall early in the year is compensated for later in the year (e.g., on average +16% more precipitation in July, when monthly rainfall totals are much higher) in 2071-2100. During the second dry season (September to October/November) the changes are much smaller.

A similar pattern can also be observed in the other scenarios except that in SSP3-7.0 (Figure 3.26) and SSP5-8.5 a decline is projected in most months, especially towards the end of the century. But also in these scenarios the decline is largest in the first dry season, and much smaller in the main rain season and second dry season.

These changes in the monthly rainfall led to asymmetrical patterns of change if we look at the total rainfall sum received during the current main rice growing seasons. Total rainfall in the period May to September (inclusive) is roughly 75% higher than in November to March (inclusive); yet in all scenarios the rainfall is projected to decline more in the latter period. In the SSP1-2.6 scenario, rainfall in May-September is even projected to increase slightly by +5% on average across the models in 2071-2100 compared to 1991-2020; conversely rainfall in November-March is projected to decline by 6% in 2041-2070, and by 14% on average by the end of the century. In the high emission scenarios, rainfall decreases also in the May-September season (up to -15% on average in 2071-2100), but less so than in November-March. In SSP3-7.0 the decline in the November-March season is 22% in 2041-2070, and 36% in 2071-2100; in SSP5-8.5 it amounts to 43% on average by the end of the century.

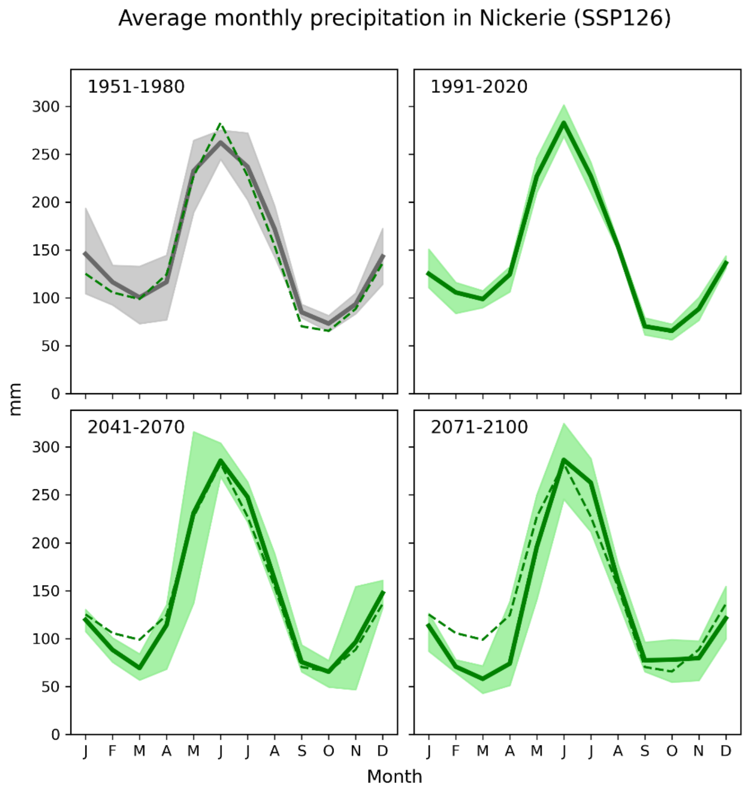

Figure 3.25 *Projection of average monthly rainfall in Nickerie under scenario SSP1-2.6 in different climatic periods. The dark coloured line shows the multi-model ensemble average of 30-year average monthly rainfall; the coloured shaded area shows the range (min and max) of 30-year average monthly rainfall in the different models. The dashed lines in the other plots show the ensemble average in the reference period 1991-2020 for comparison.*

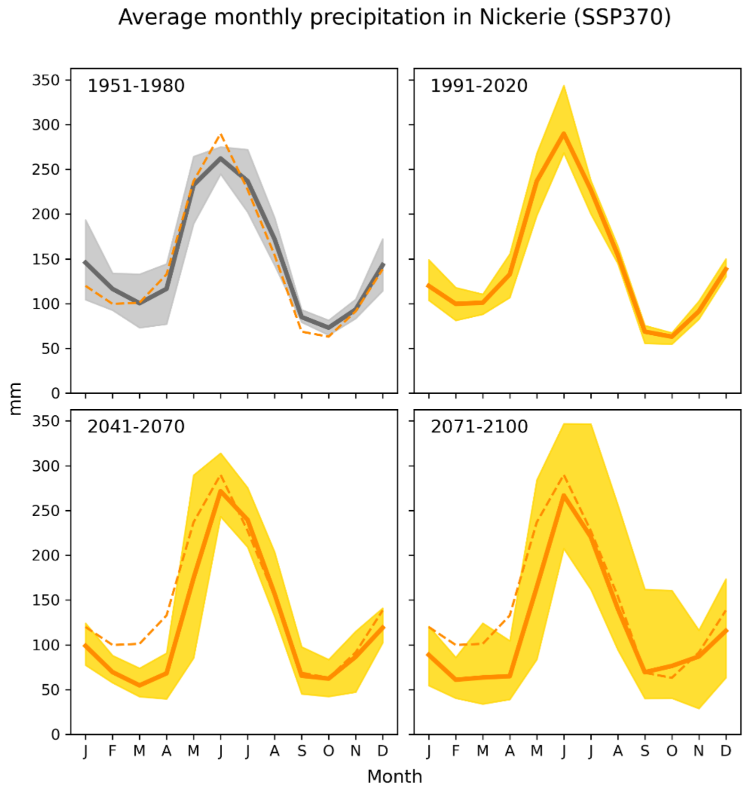

Figure 3.26 *As Figure 3.25, but for scenario SSP3-7.0.*

3.4.3 Consecutive dry days

One indicator that can be used is to look at changes in drought occurrence is the maximum number of consecutive dry days per year, or in other words the length of the longest dry spell. A dry day is usually defined as a day with less than 1 mm of rainfall. Due to its tropical wet climate, the longest dry spell is usually no longer than 8-10 days in the study region, compared to about 13 days in all of Suriname. According to ERA5-Land, individual years with dry spells up to 25 days have happened earlier in the 20th Century, especially in Saramacca, but the climatological averages are essentially the same (Figure 3.27). Also in the upstream river catchments there is no trend in the length of dry spells.

The climate projections show a general trend to less annual precipitation, and this is reflected in the dry spell length (Figure 3.28). In the historical period, the maximum number of consecutive dry days per year simulated by the models is, on average, higher than in ERA5-Land (17 vs 8 days). Under SSP1-2.6, a slight increase to about 21 days by 2080 can be observed, an increase of 4 days. The range across the models is 17 to 25 days and overlaps with the ensemble average in the historical period.

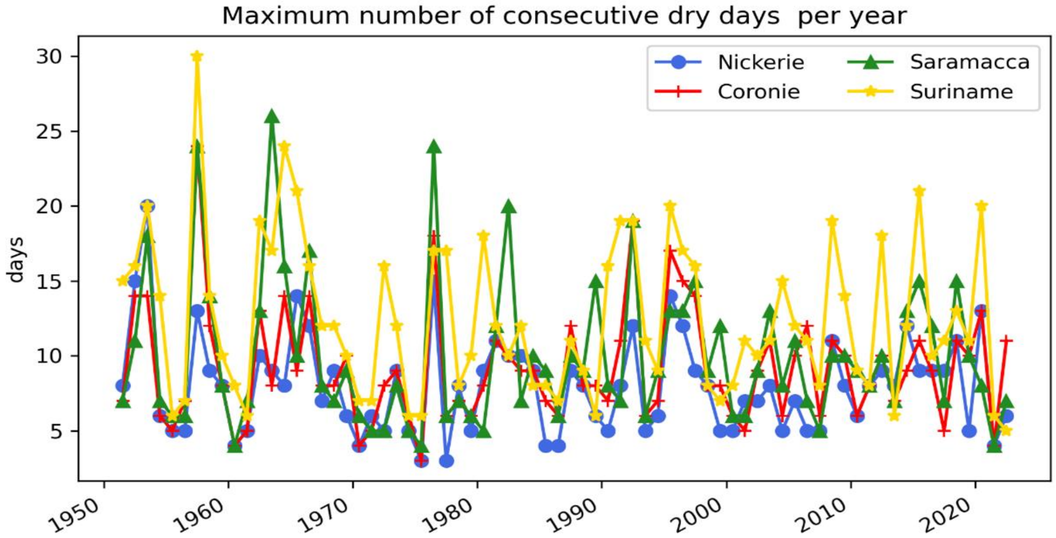

Figure 3.27 *Maximum length of dry spell per year in the districts of Nickerie, Coronie, Saramacca as well as all of Suriname in the ERA5-Land dataset.*

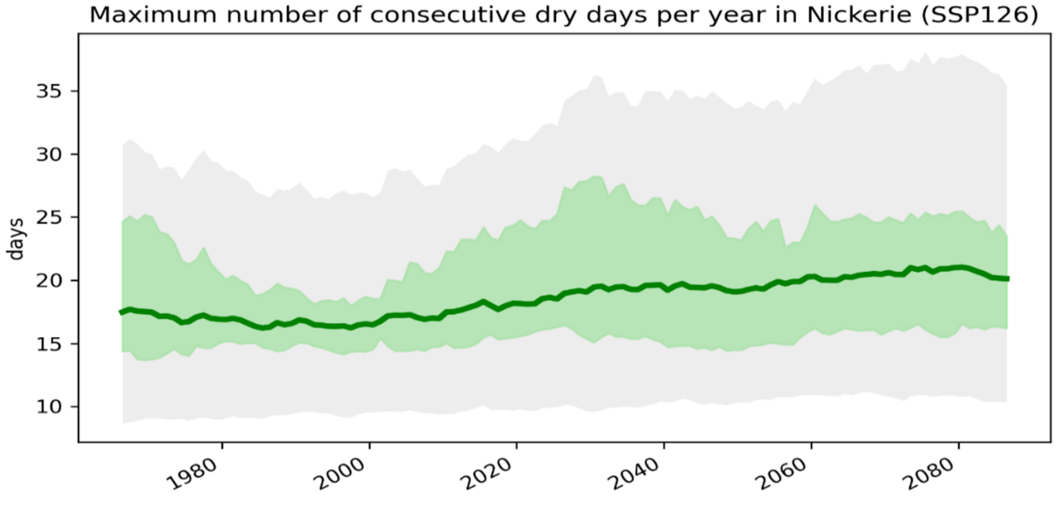

Figure 3.28 *Projection of maximum number of consecutive dry days (longest dry spell) per year in Nickerie under scenario SSP1-2.6. The dark coloured line shows the multi-model ensemble average of 30-year average number of days; the coloured shaded area shows the range (min and max) of 30-year average number of dry days of the different models.*

More significant changes can be seen under the higher emission scenarios. Under SSP3-7.0 (Figure 3.29) the longest dry spell length in Nickerie increases to 27 days (19 to 36 days) on average by the end of the century. This would amount to almost one month, but keeping in mind that the climate models start off from a baseline that is too high in the historical period (at least, compared to ERA5-Land), this could well be an overestimation.

Nevertheless, the year-to-year variability suggests that a dry spell of one month could occur in individual years. Under SSP5-8.5 the maximum number of consecutive dry days increases slightly more than under SSP3-7.0 to 28 days in 2071-2100, but with larger model spread, especially on the upper end (19 to 42 days). The patterns in the other districts as well as in the upstream catchment areas are very similar to what is shown here for Nickerie.

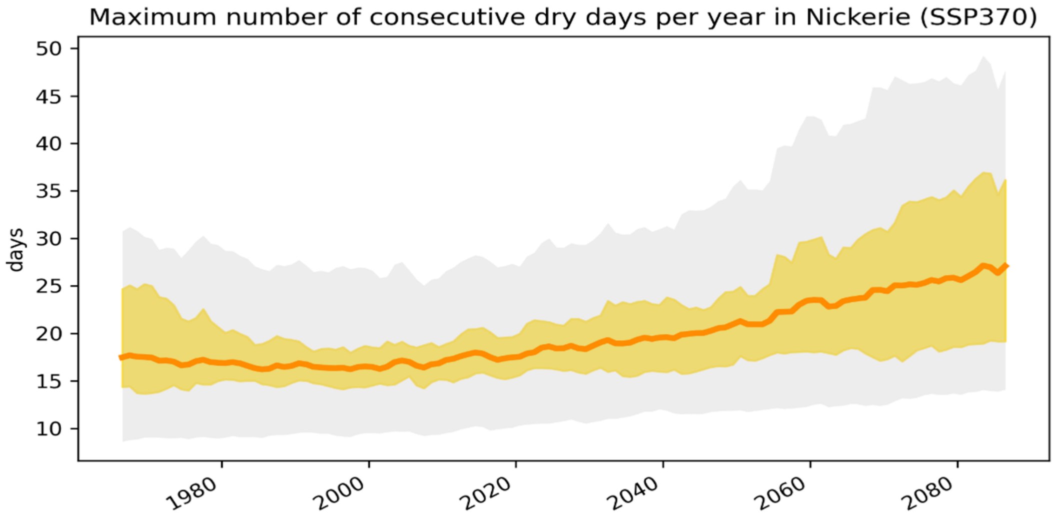

Figure 3.29 *As Figure 3.28, but for scenario SSP3-7.0.*

3.4.4 Very heavy precipitation days

There are several indicators in the ETCCDI set that can be used to characterize changes in heavy rainfall, here we first look at the number of very heavy precipitation days per year, i.e. days with 20 mm of rainfall or more. This indicator shows a notable increasing trend in the historical period, especially since the year 2000 or so (Figure 3.30).

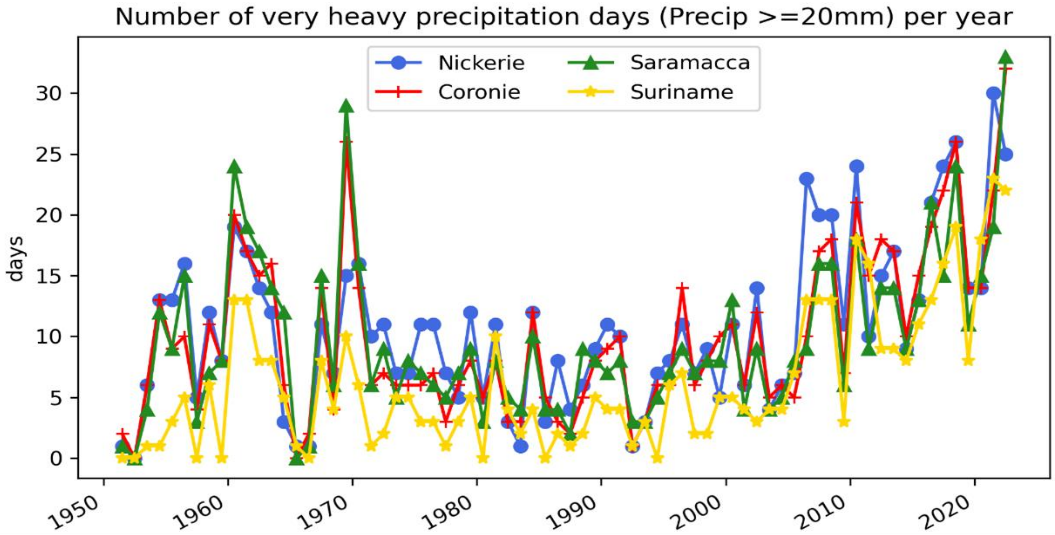

Figure 3.30 *Number of days per year with 20 mm or more precipitation in the districts of Nickerie, Coronie, Saramacca as well as all of Suriname in the ERA5-Land dataset.*

In Nickerie, the average number of very heavy rainfall days in 1991-2020 was just over 12 days per year, about 3 days more than in 1951-1980 and almost 5 days more than in 1971-2000. However, in the most recent decade (2012-2022) the number has been higher still (18.9 days on average). High values of 30 days or more were reached in particular in Nickerie in 2021, and in Coronie and Saramacca in 2022. A similar pattern can also be observed in the upstream areas where the number of heavy precipitation days in recent years exceed any previous years in the ERA5-Land dataset.

The climate models do not reproduce this recent trend, although the historical average (12.8 days in 1991-2020) is close to the average in ERA5-Land, but ranging across the models from 8 to 15 days per year. Under SSP1-2.6 there is no discernable increase in the number of very heavy rainfall days, with on average 13.4 days (7.5 to 16.9 days) in 2071-2100 (Figure 3.31).

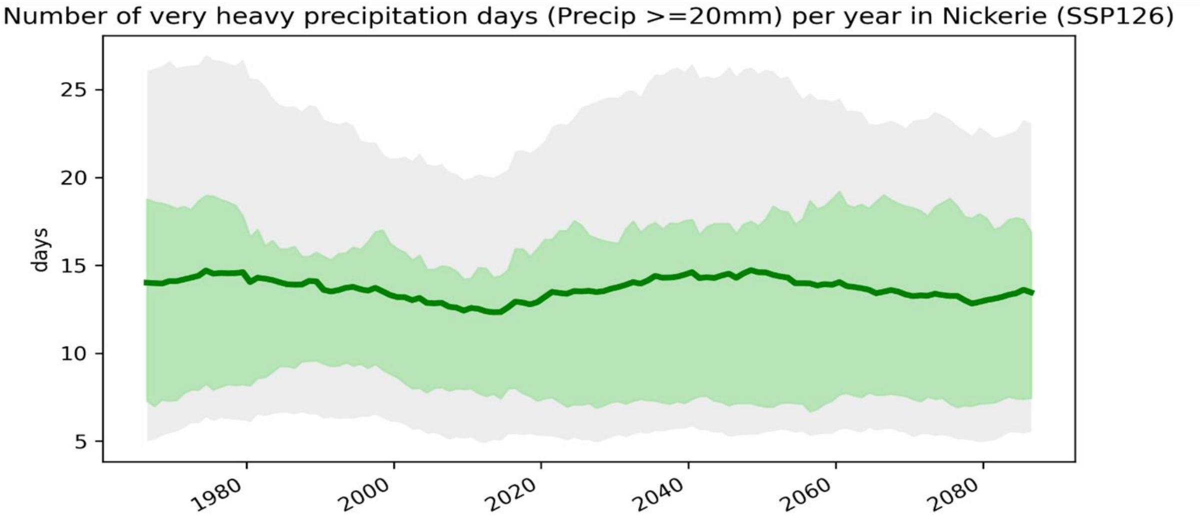

__Figure 3.31__ Projection of number of very heavy rainfall days (precipitation of 20 mm or more) per year in Nickerie under scenario SSP1-2.6. The dark coloured line shows the multi-model ensemble average of 30-year average number of days; the coloured shaded area shows the range (min and max) of 30-year average number of heavy rainfall days of the different models.

The higher emission scenarios project a decrease in the number of days with 20 mm of rainfall or more. Under both SSP3-7.0 and SSP5-8.5 the amount is projected to decrease from 13 to less than 10 days per year in 2071-2100 (see Figure 3.32).

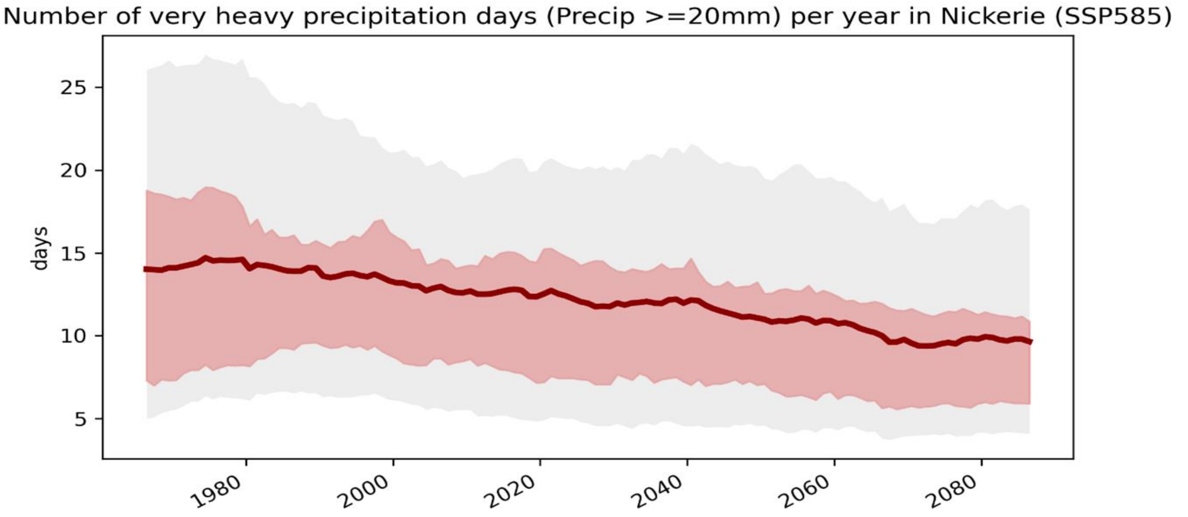

Figure 3.32 *As Figure 3.31, but for scenario SSP5-8.5.*

Other ETCCDI indices that are relevant to heavy rainfall, such as the number of extremely wet days per year (the number of days exceeding the 99th percentile of the daily rainfall distribution, in other words the rainfall amount you would expect to be exceeded on only 1% of the rain days) show a very similar pattern to what is shown here for the very heavy precipitation days: a notable trend can be observed in the historical data in the most recent decades, which is not supported by the climate projections that show, if anything, a slight decreasing trend going into the future. At this stage it is not possible yet to say whether the recent trend is only a short-term fluctuation or part of a longer-term climate trend. In the latter case the climate models might be missing some important mechanism that may lead to an increase in heavy rainfall days in the area as opposed to the projected (slight) decrease.

3.4.5 Maximum 5-day rainfall amount

The maximum 5-day total rainfall amount provides an indication of the amount of rainfall during wet spells, as opposed to a single wet day. Also in this indicator we can observe an increasing trend in the historical data (Figure 3.33): in Nickerie, the highest 5-day rainfall sum in 1991-2020 was 109 mm on average, an increase of 7% compared to 1951-1980, and 20% compared to 1971-2000. Also in this case the average over the last decade (2012-2022) is higher still (131 mm). A similar pattern is also seen in the other districts, and in the upstream catchment areas.

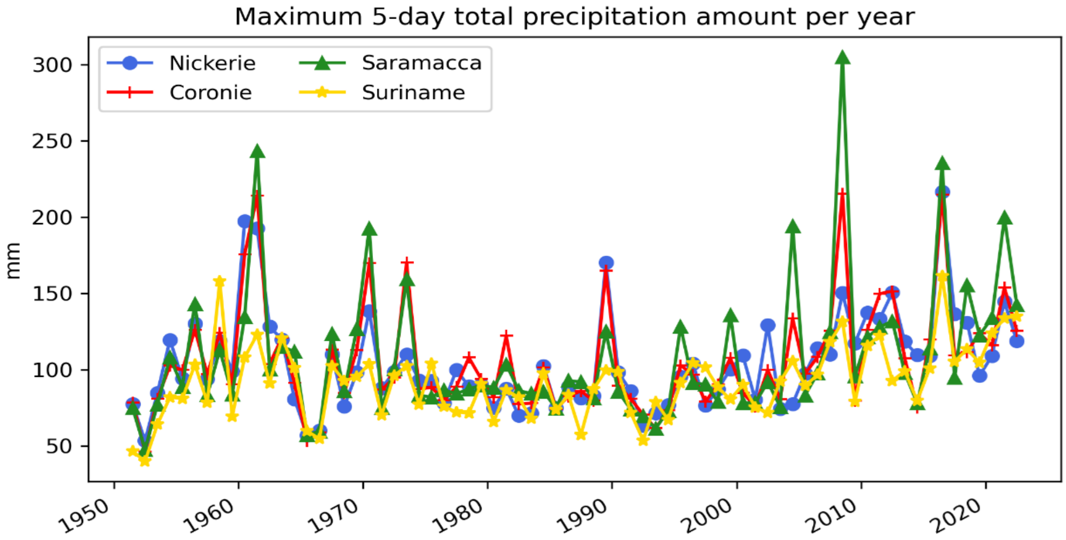

Figure 3.33 *Maximum 5-day rainfall total in the districts of Nickerie, Coronie, Saramacca as well as all of Suriname in the ERA5-Land dataset.*

Again, the apparent recent trend is not reproduced by the climate models,. The SSP1-2.6 scenario projects a slight but not significant increase of about +7% until the middle of the century, and little change afterwards. Under SSP3-7.0, we can see a decreasing trend reaching about -12% in 2071-2100 (Figure 3.34). It is worth noting this decrease is less than the decline in the annual rainfall total, suggesting that the rainfall amount during wet spells declines less than the average rainfall. Also worth noting is that under SSP5-8.5 the highest 5-day rainfall amount hardly declines at all, only -3% by the end of the century, all the more striking as the annual rainfall amount declined by over 25% in this scenario.

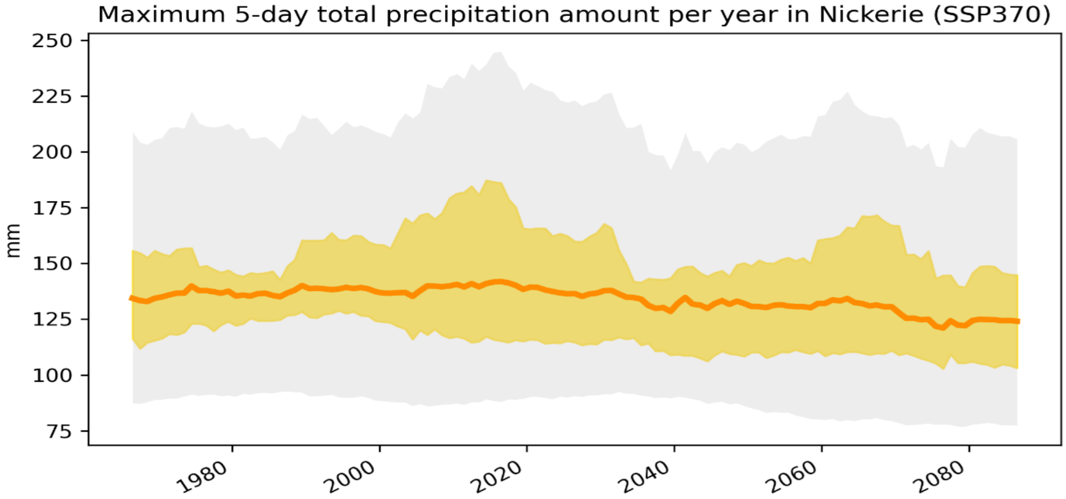

Figure 3.34 *Projection of the highest 5-day rainfall total per year in Nickerie under scenario SSP3-7.0. The dark coloured line shows the multi-model ensemble average of 30-year average rainfall amounts; the coloured shaded area shows the range (min and max) of 30-year average 5-day rainfall totals of the different models.*

3.5 Wind speed indicators

High wind speeds may cause damage to crops like bananas, and for this reason we also briefly look into ETCCDI indicators for wind. In this respect we are limited by data availability; ERA5-Land provides hourly values, but hourly values of wind speed may underestimate the wind speeds during strong but short-lived gusts. The ISIMIP3 data provide only daily wind data, meaning only indices based on mean daily wind speed could be calculated.

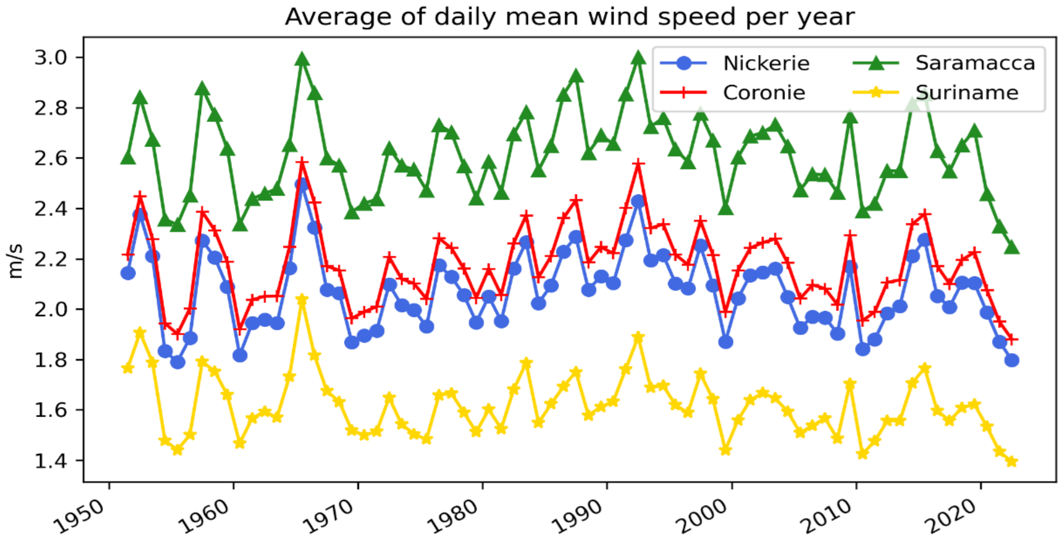

Figure 3.35 *Mean daily wind speed in the districts of Nickerie, Coronie, Saramacca as well as all of Suriname in the ERA5-Land dataset.*

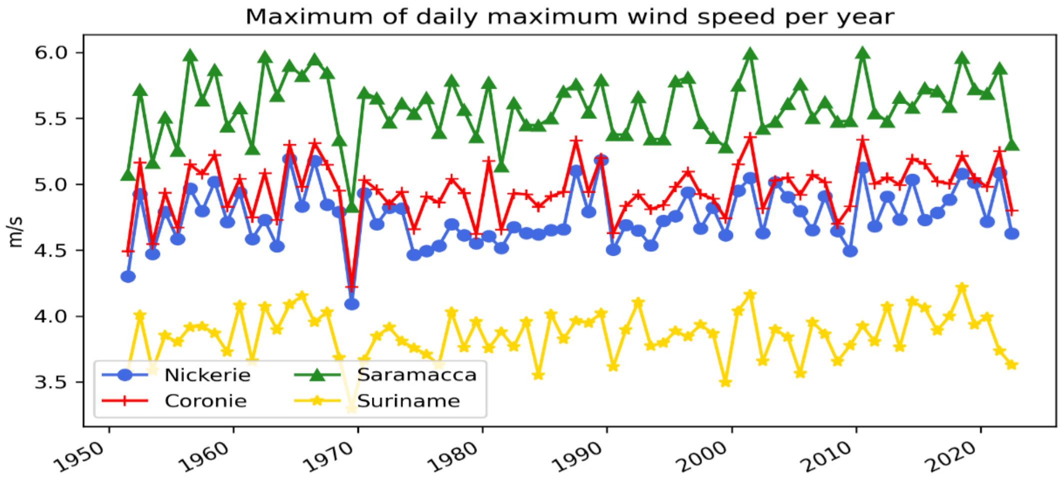

Figure 3.36 *Yearly maximum of daily maximum wind speeds in the districts of Nickerie, Coronie, Saramacca as well as all of Suriname in the ERA5-Land dataset. Note daily maximum wind speed is based on hourly wind speed values, and may underestimate the true wind speed experienced during short-lived gusts.*

The ERA5-Land dataset suggests wind speeds are higher in the coastal zone than in the interior (Figure 3.35), and somewhat higher in Saramacca than in Nickerie and Coronie. Nevertheless, strong winds are rare in Suriname. The yearly average of daily mean wind speeds usually falls between 2 and 3 m/s, which corresponds to force 2 on the Beaufort scale ("a light breeze"). Based on the hourly values, the maximum wind speeds reach to 5 to 6 m/s (3 Bft, "a gentle breeze" to 4 Bft, "a moderate breeze") (Figure 3.36). Not surprisingly, the number of calm days (days with daily averaged wind speed below 2 m/s) is fairly high, between 100 and 200 days per year in Nickerie and Coronie, albeit less common in Saramacca (usually between 50 and 100 days per year). Days with daily average wind speed above 10.8 m/s (6 Bft), another ETCCDI indicator, do not occur in the historical dataset.

The climate projections show very little signal for change in wind speed. Under the higher emissions scenario SSP3-7.0, a slight increase in daily mean wind speed is projected throughout the century (Figure 3.37). In Saramacca, this increase amounts to +5% by the end of the century; expressed in Beaufort, however, the mean daily wind speed remains the same at 2 Bft. Days with daily average wind speed above 6 Bft remain non-existent in any of the scenarios, including SSP5-8.5.

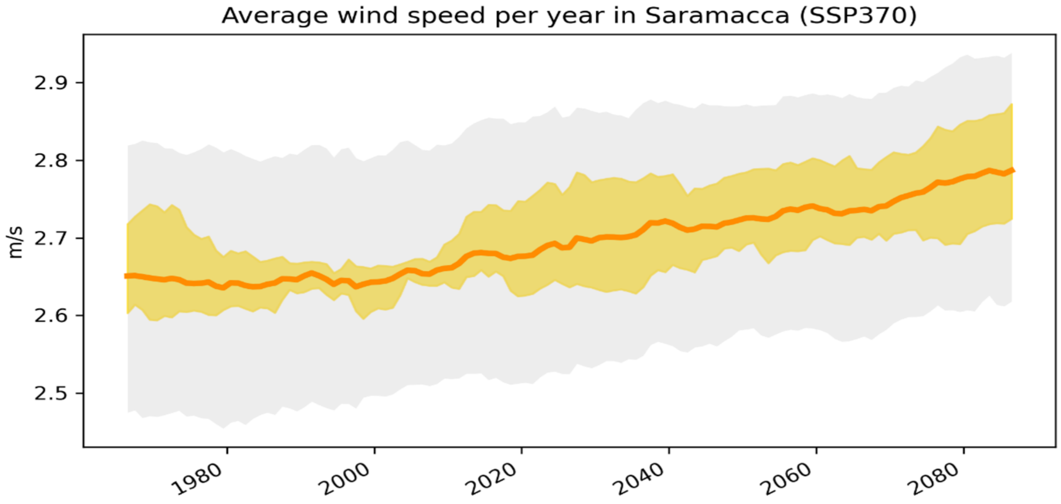

Figure 3.37 *Projection of the mean daily wind speed in Saramacca under scenario SSP3-7.0. The dark coloured line shows the multi-model ensemble average of 30-year average wind speed; the coloured shaded area shows the range (min and max) of 30-year average mean daily wind speeds of the different models.*

3.6 Sea level rise

Information on mean sea level rise along the North coast of South America was obtained from the IPCC (2021), since the Copernicus dataset (see section 3.2.3) was produced for only one climate scenario and runs only to 2050. As can be seen in the table below, more sea level rise may be expected in towards the end of the century. The SSP1-2.6 and SSP5-8.5 scenarios in Table 3.2 can be regarded as the lower and upper bound of expected sea level rise, respectively. As can be seen, there is actually little difference in expected mean sea level rise between the two scenarios until the middle of the century. Under the highest emission scenario, mean sea level is expected to rise by between 40 cm to over 1 m at the end of the century.

Table 3.2 *Median value and confidence interval for expected mean sea level rise in Northern South America at three time intervals under two scenarios. Source: IPCC WGI Interactive Atlas[4].*

	Median value (m)	**Confidence interval (5-95%)**	**Median value (m)**	**Confidence interval (5-95%)**
	SSP1-2.6		**SSP5-8.5**	
2021-2040	0.1	0.0 – 0.2	0.1	0.0 – 0.2
2041-2060	0.2	0.1 – 0.4	0.3	0.1 – 0.4
2081-2100	0.5	0.2 – 0.8	0.7	0.4 – 1.1

To obtain more insight into the fluctuations around the mean sea level, and in particular the highest water levels that may be reached with a particular probability, we look at the statistical indicators of total water level in the Copernicus dataset. Figure 3.38 provides an overview of the water levels that may be exceeded with a particular annual probability. Note the annual probability of exceedance is decreasing from left to right, in other words the higher water levels are increasingly unlikely to be exceeded in any given year. Care should be taken to take these values, derived from a global model that has neither been optimised nor validated for the Suriname coast, at face value, yet the model data suggest there’s a high annual probability of water levels exceeding 2m above mean sea level even in the historical period. There’s a small increase (5-20cm) in extreme water levels under the SSP5-8.5 scenario in the near future (2021-2050). Note that small increases in extreme water levels may translate in relatively large increases in the probability of exceeding one particular level: for example, the annual probability of exceeding 2.4m is about 4% in the reference period, and close to 20% in the scenario period.

---

[4] https://interactive-atlas.ipcc.ch/

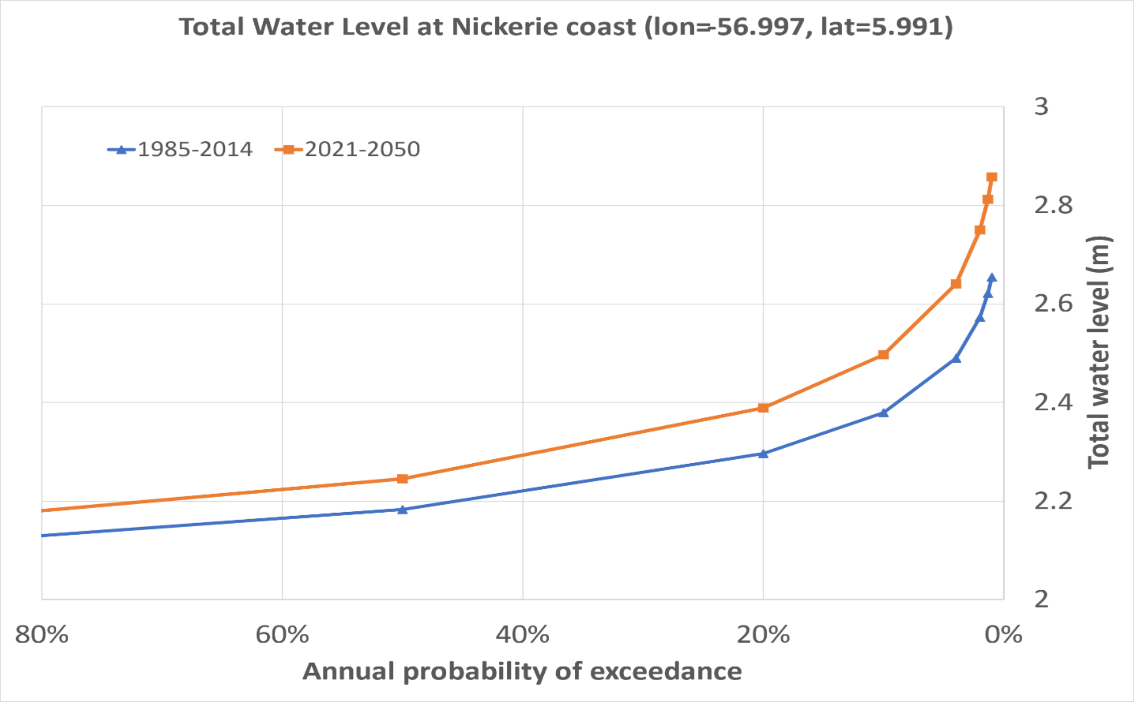

Figure 3.38 *Total water level annual probability of exceedance (ensemble mean value) in the Copernicus dataset Global sea level change indicators from 1950 to 2050 derived from reanalysis and high resolution CMIP6 climate projections, for a point on the Nickerie coast.*

3.7 Coastal and fluvial inundation

River flooding inundation data were derived from the Aqueduct Floods Hazard Maps[5] produced by the World Resource Institute (WRI) (Ward et al., 2020). The flood hazard is represented by inundation maps showing the flood extent and depth (m) for floods of several return periods for the current time (based on 1960–99 simulation) and future climate (2010–49, 2030–69, and 2060–99) at a resolution of 5 × 5 arc minutes (5′ × 5′). This equates to roughly 10 km × 10 km pixels at the equator. The hazard maps were re-gridded to 30 × 30 arc seconds (30″ × 30″)—about 1 km × 1 km at the equator. The Aqueduct flood hazard maps differentiate between coastal and fluvial flooding, and here we first focus on fluvial flood hazards.

The return periods (2, 5, 10, 25, 50, 100, 250, 500, and 1,000 years) represent annual probabilities of exceedance of 50%, 20%, 10%, 4%, 2%, 1%, 0.4%, 0.2% and 0.01% and are, in other words, increasingly unlikely to happen in a given year. The scenarios that were used to produce the WRI inundation maps are based on the previous generation of climate scenarios. Of the two scenarios used, RCP8.5 is comparable to the SSP5-8.5 pathway that has been analysed in this report so far. Baseline ("current climate" simulations are for the period 1960-1999 and the scenarios for three future timeslices: the 2030s (2010–49), 2050s (2030–69), and 2080s (2060–99). Note the presence of flood defences is not accounted for in these hazard maps.

Focusing on Nickerie (Figure 3.39), the Aqueduct Flood Hazard maps suggest very low flood depths (below 10cm) are possible already with an annual probability of 20%, with slightly higher depths simulated along Nani Kreek. More significant flood depths or 20-50cm are expected to occur with an annual probability of 2%, but even at higher return periods (lower levels of probability) the flood depth is not expected to exceed 50cm in most parts of the agricultural area in Nickerie.

---

[5] https://www.wri.org/data/aqueduct-floods-hazard-maps

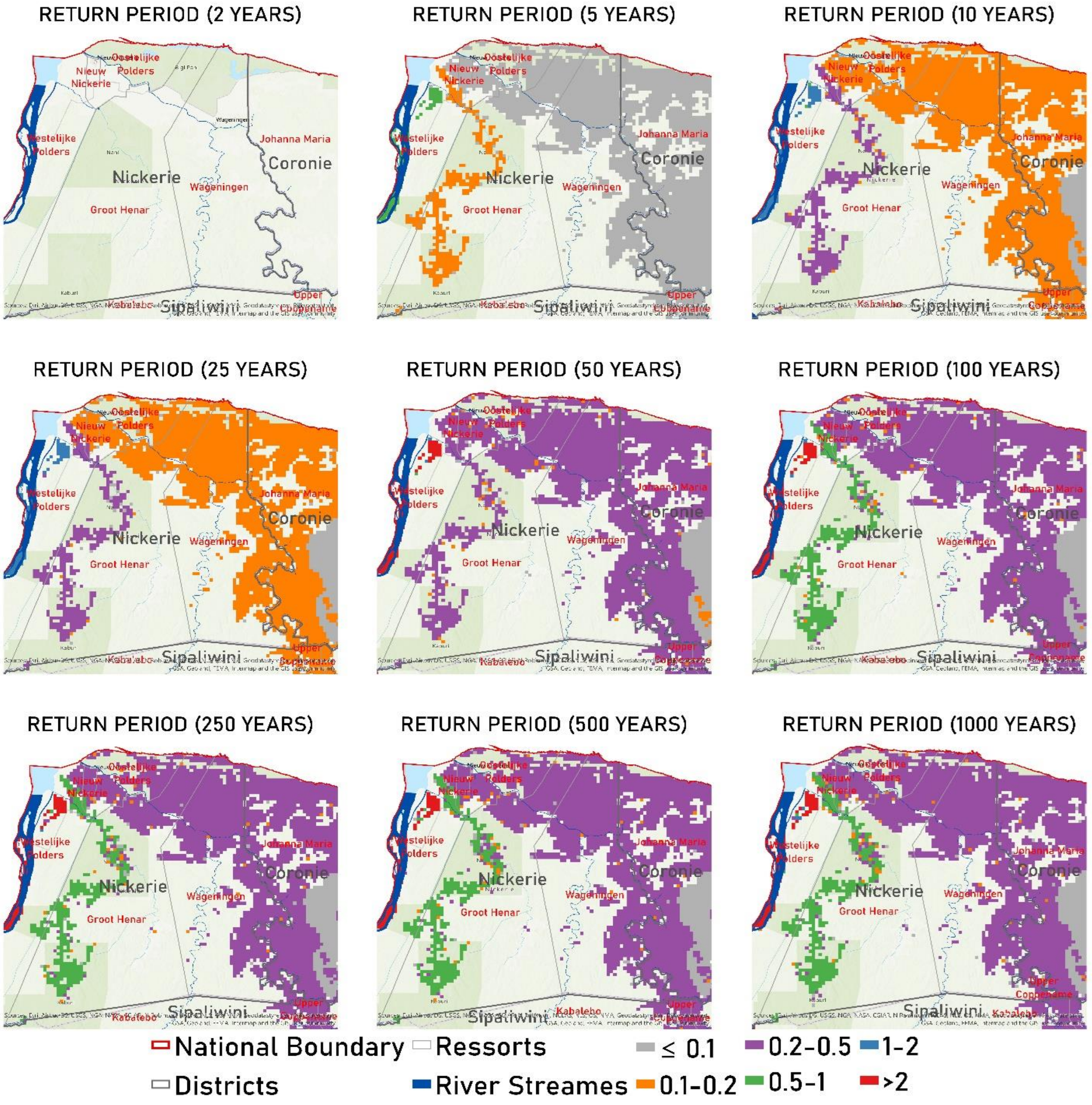

Figure 3.39 *Fluvial inundation depth at different return periods (annual probabilities) in the Aqueduct Floods Hazard Maps in Nickerie in the current climate.*

Because of the limitations in this global dataset, the projected *changes* in flood hazard are likely more relevant than the actual simulated inundation depths. Here we focus on the RCP8.5 scenario for floods that may be expected to occur relatively frequently (return periods 2, 5 and 10 years, in other words 50%, 20% and 10% annual probability; Figure 3.40) and more extreme floods (return periods 25, 50 and 100 years; 4%, 2% and 1% annual probability; Figure 3.41). Under this scenario, we see a small increase in simulated inundation depths for the more frequent floods, and little change for the more extreme floods (such as the 100-year / 1% annual probability flood level). Even for even more extreme floods such as the 1000-year / 0.1% annual probability flood level (not shown) the simulated inundation depths remain largely unchanged in most of the agricultural areas in Nickerie, apart from areas along the Nani Kreek where inundation depths are projected to increase.

To summarise the Aqueduct flood hazard across multiple flood events and multiple scenarios, we estimated the extent of rice growing areas in the different ressorts of Nickerie based on high-resolution land cover data from the Copernicus Global Land Service (Buchhorn et al., 2020), providing total crop area fractions at a 100x100m grid, with information from rice harvested area fraction from MAPSpam (You et al., 2017) at a 10x10km grid. The resulting distribution of rice growing areas suggests most (29%) of the rice to be grown in the Ressort Wageningen, and least (6%) in Westelijke Polders. Average inundation depths across the (potential) rice growing areas in the different Ressorts are included in Table 3.3. The general picture is that of very little change and even a slight decrease early in the 21st century under scenario RCP4.5. Under the high emissions scenario RCP8.5, a very small increase in inundation depth is simulated in some areas, most notably in Westelijke Polders, but overall inundation depths remain moderate. Relatively high depths of 0.5-1.0m are in the current climate simulated only in the rice growing areas of Westelijke Polders, and then only for flood events with a return period of 250y (annual probability of 0.4%) or more, rising to a 50-year return period / 2% annual probability under RCP8.5 by the end of the century.

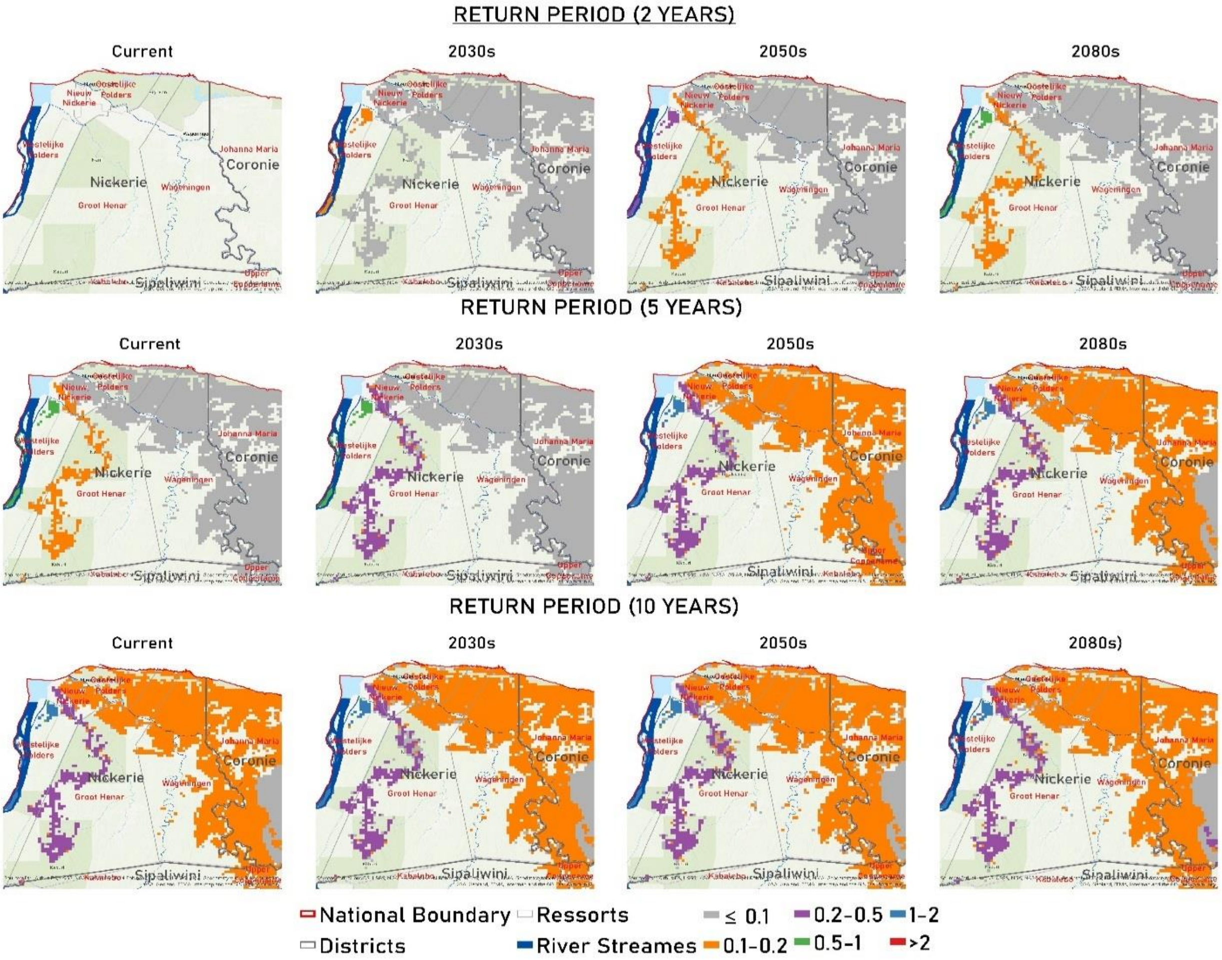

Figure 3.40 *As Figure 3.39, but for different time periods under scenario RCP8.5, for flood events with an annual probability of 10% or higher (return period 10y or shorter).*

Table 3.3 *Average fluvial inundation depths (in m) in the Aqueduct Flood Hazard maps, across the (potential) rice growing areas in the different resorts in Nickerie, for flood events with different return periods (annual probabilities) and under two emission scenarios. Flood events with a low return period (high annual probability) occur more frequently than those with long return periods (low annual probability). Changes in average inundation depth are shaded according to the direction of change (green: decrease in depth; blue: increase in depth) and may be the result of changes in the actual simulated inundation depth over areas that are flooded, or changes in the inundation extent, or a combination of both.*

Ressort	**Return Period (y) / Annual probability**	**Historical**	**RCP 4.5**			**RCP 8.5**		
		1980s	**2030s**	**2050s**	**2080s**	**2030s**	**2050s**	**2080s**
Groot Henar	2 / 50%	0.00	0.00	0.02	0.01	0.01	0.03	0.04
	5 / 20%	0.07	0.01	0.05	0.05	0.07	0.09	0.10
	10 / 10%	0.11	0.03	0.09	0.07	0.12	0.13	0.15
	25 / 4%	0.17	0.05	0.13	0.11	0.18	0.19	0.21
	50 / 2%	0.21	0.06	0.16	0.14	0.22	0.24	0.25
	100 / 1%	0.26	0.08	0.19	0.17	0.27	0.28	0.29
Nieuw Nickerie	2 / 50%	0.00	0.00	0.02	0.01	0.01	0.04	0.05
	5 / 20%	0.08	0.02	0.06	0.05	0.09	0.12	0.13
	10 / 10%	0.13	0.04	0.10	0.09	0.14	0.17	0.18
	25 / 4%	0.19	0.07	0.15	0.13	0.21	0.25	0.26
	50 / 2%	0.24	0.09	0.19	0.16	0.27	0.30	0.31
	100 / 1%	0.29	0.11	0.23	0.20	0.32	0.36	0.37
Oostelijke Polders	2 / 50%	0.00	0.00	0.01	0.01	0.01	0.03	0.04
	5 / 20%	0.06	0.01	0.05	0.04	0.07	0.08	0.09
	10 / 10%	0.10	0.02	0.08	0.07	0.11	0.12	0.14
	25 / 4%	0.15	0.04	0.12	0.10	0.16	0.18	0.19
	50 / 2%	0.19	0.06	0.14	0.13	0.21	0.22	0.23
	100 / 1%	0.23	0.07	0.17	0.15	0.25	0.26	0.27
Wageningen	2 / 50%	0.00	0.00	0.02	0.01	0.01	0.03	0.04
	5 / 20%	0.07	0.01	0.06	0.05	0.08	0.09	0.11
	10 / 10%	0.12	0.03	0.09	0.08	0.13	0.14	0.16
	25 / 4%	0.18	0.05	0.13	0.12	0.19	0.20	0.22
	50 / 2%	0.23	0.06	0.17	0.15	0.24	0.25	0.26
	100 / 1%	0.27	0.08	0.20	0.18	0.28	0.29	0.31
Westelijke Polders	2 / 50%	0.00	0.01	0.02	0.03	0.02	0.07	0.10
	5 / 20%	0.13	0.08	0.12	0.11	0.16	0.24	0.24
	10 / 10%	0.21	0.14	0.20	0.17	0.25	0.35	0.35
	25 / 4%	0.31	0.21	0.30	0.25	0.37	0.48	0.48
	50 / 2%	0.39	0.27	0.37	0.31	0.45	0.58	0.57
	100 / 1%	0.46	0.33	0.44	0.37	0.53	0.68	0.66

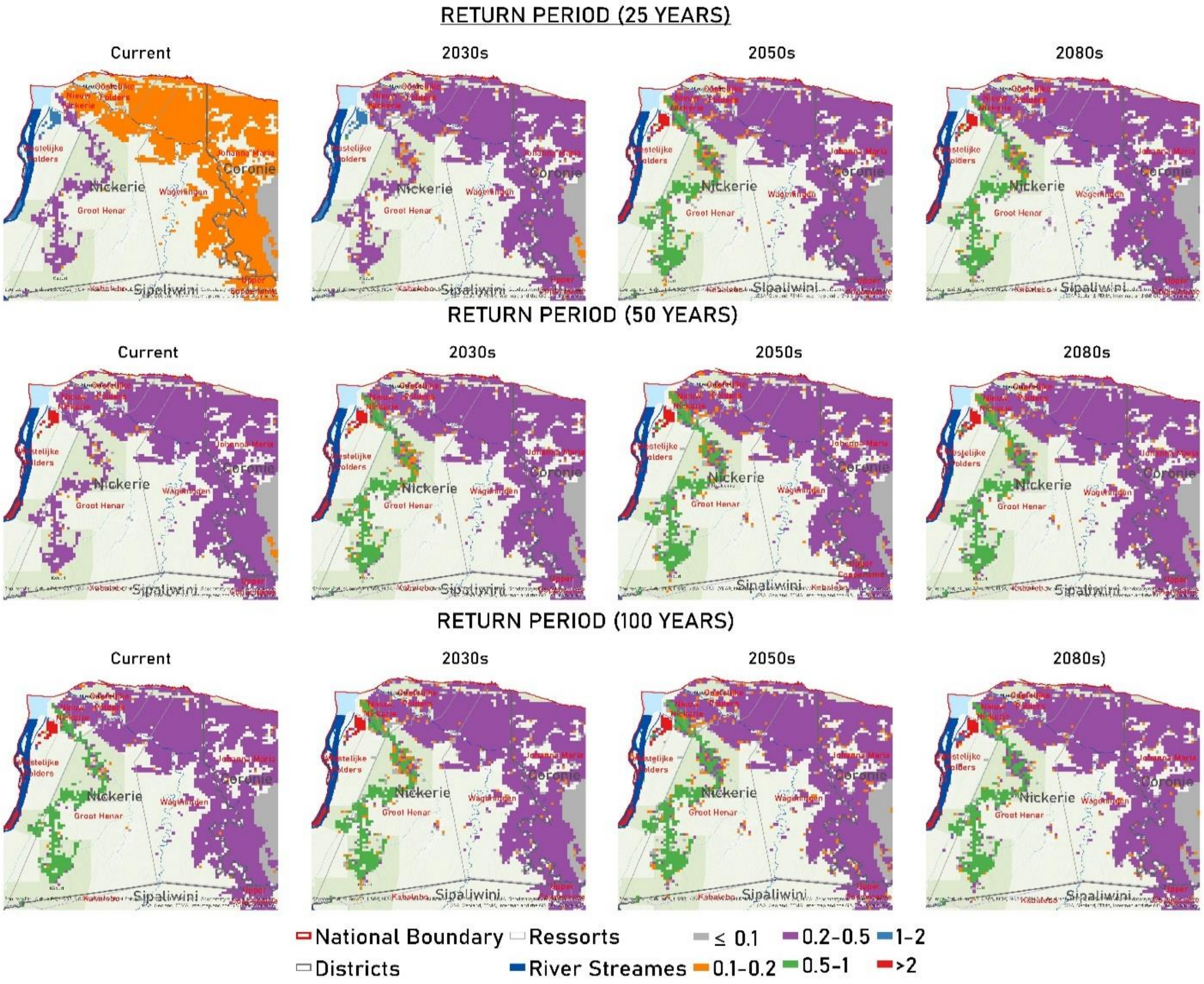

Figure 3.41 *As Figure 3.40, but for flood events with an annual probability of 4% or lower (return period 25y or longer).*

The Aqueducts coastal inundation maps show the simulated water depths with varying annual probabilities (return periods) in the current climate (Figure 3.42). Note the coastal inundation extent in the Aqueduct hazard maps is based on the assumption that all areas with an elevation below a particular water level that are hydrologically connected to the sea, are flooded (the "bathtub" method); neither the presence of flood defences, nor processes such as erosion are accounted for.

As can be seen, the flood extent is limited to areas directly on the coast, with the exception of one area in Oostelijke Polders that, according to these data, may be flooded at return periods of 10 years or longer (note this area is already permanent open water and swamp). At annual probabilities of 4% or less (return periods 25 years or longer), we can also see inundation depths being simulated along the Nickerie River, but not further than the town of Nieuw-Nickerie. Looking at the future time slices under scenario RCP8.5, the main difference we see is an extension of the inundated area further along the Nickerie River into the low-lying areas used for agriculture, even at flood levels with a relatively high annual probability (short return periods), albeit only towards the end of the century (Figure 3.43 and Figure 3.44). For flood events that are less likely (longer return periods) this change can already be observed by the middle of the century. Remember, however, that the resolution of these hazard maps is still rather coarse for a detailed local analysis.

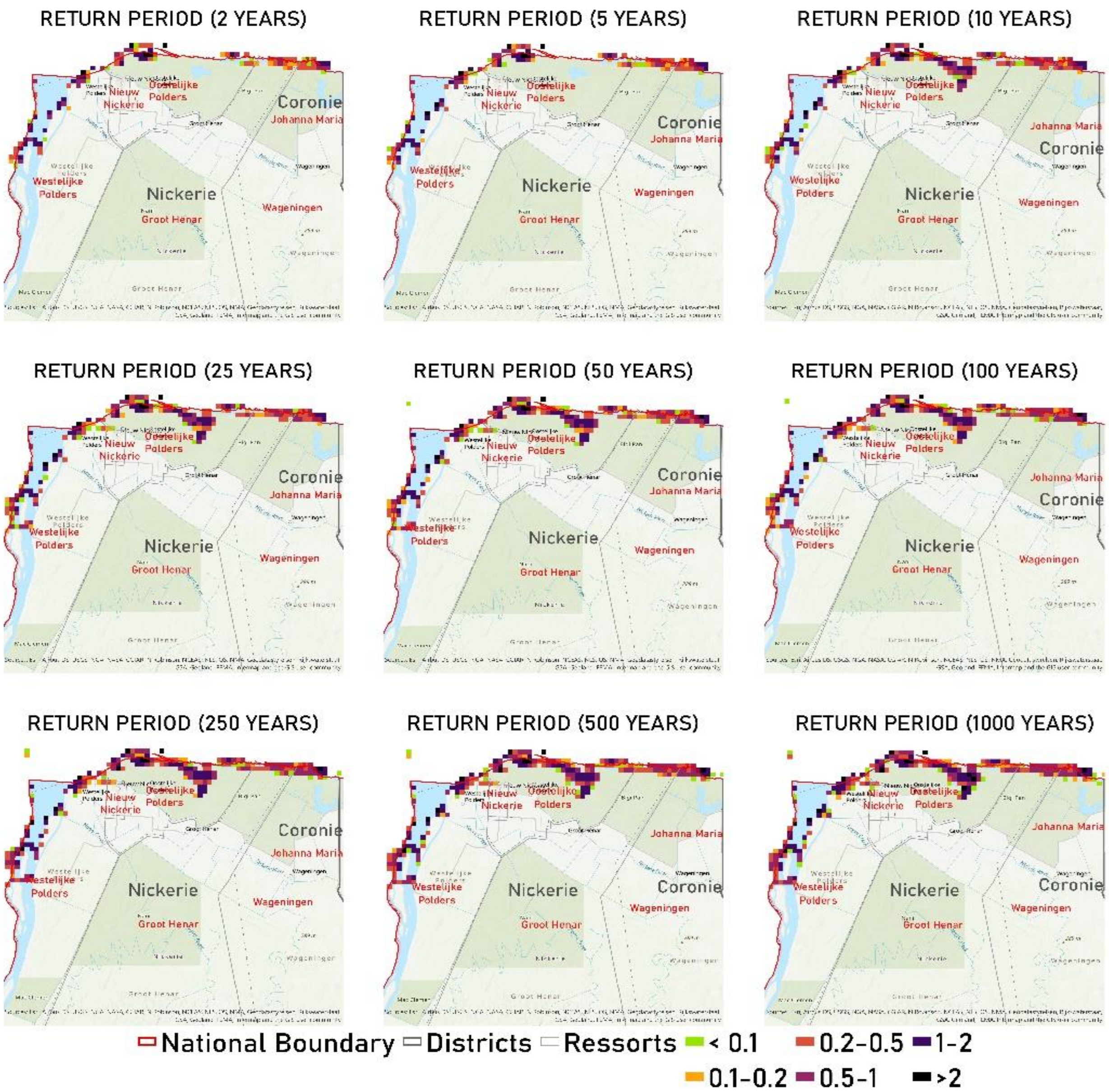

__Figure 3.42__ Coastal inundation depth (m) at different return periods (annual probabilities) in the Aqueduct Floods Hazard Maps in Nickerie in the current climate.

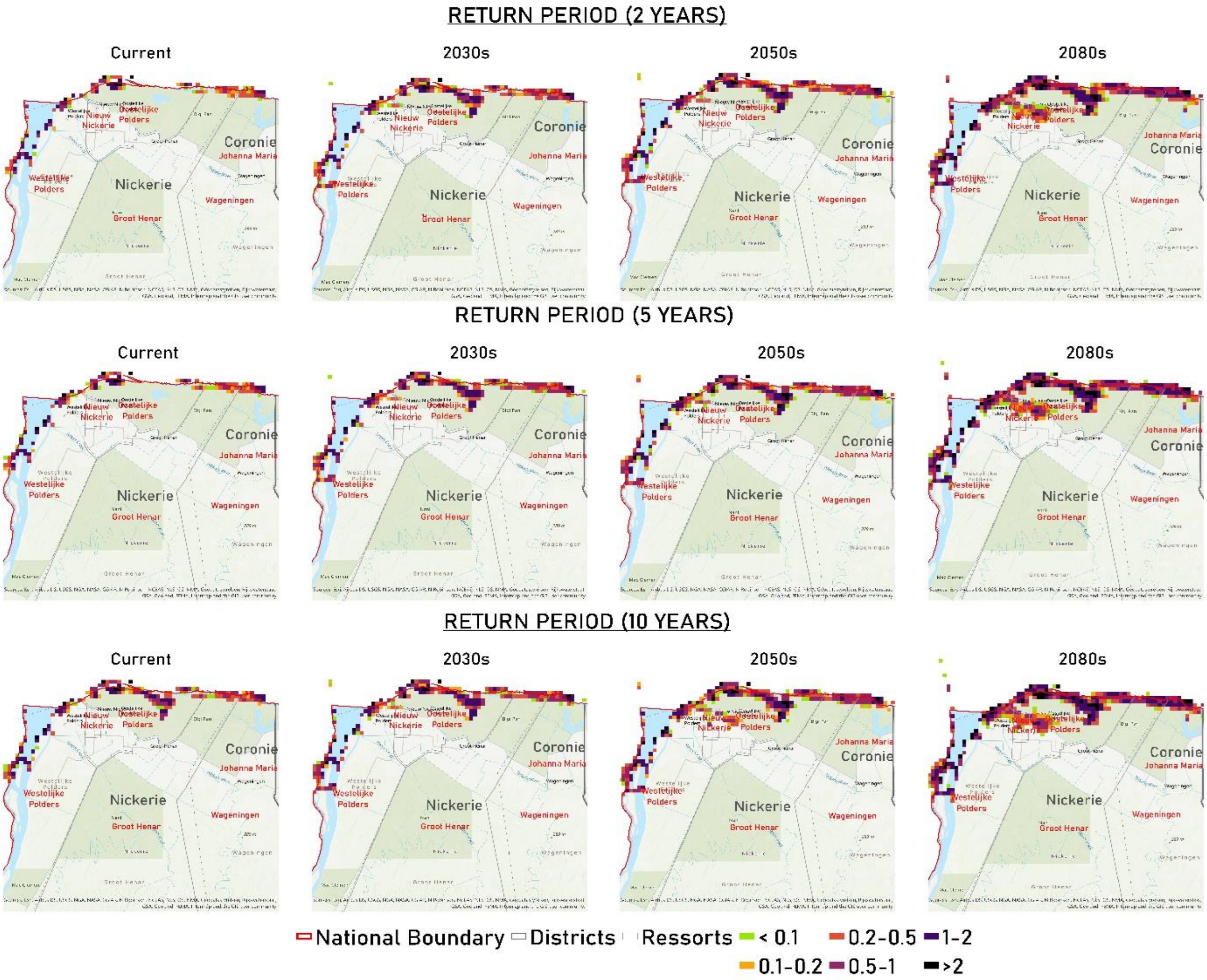

Figure 3.43 *Coastal flood inundation events with an annual probability of 10% or higher (return period 10y or shorter) for different time periods under scenario RCP8.5.*

3.8 Summary and conclusions

Temperature:

- Although a trend in mean temperature is not particularly obvious, the mean annual temperature in the period 1991-2020 is about 0.4-0.5 degree warmer in the three districts than in 1951-1980 in the historical data.
- The climate projections foresee a further rise in average temperature, stabilising at around 1ºC warmer than 1991-2020 in the SSP1-2.6 scenario and rising to +3.2ºC at the end of the century under scenario SSP3-7.0, and +3.6ºC under SSP5-8.5, with considerable model uncertainty.
- In the historical data there's a notable increasing trend in minimum temperatures, and the number of very warm nights with a minimum temperature above 23 or 25 degrees.
- This trend in minimum temperatures is set to continue under all climate scenarios.
- Under the higher emission scenarios SSP3-7.0 and SSP5-8.5, maximum temperatures of 35ºC or more may become a limiting factor to rice production in a significant part of the year, especially in the second half of the century.

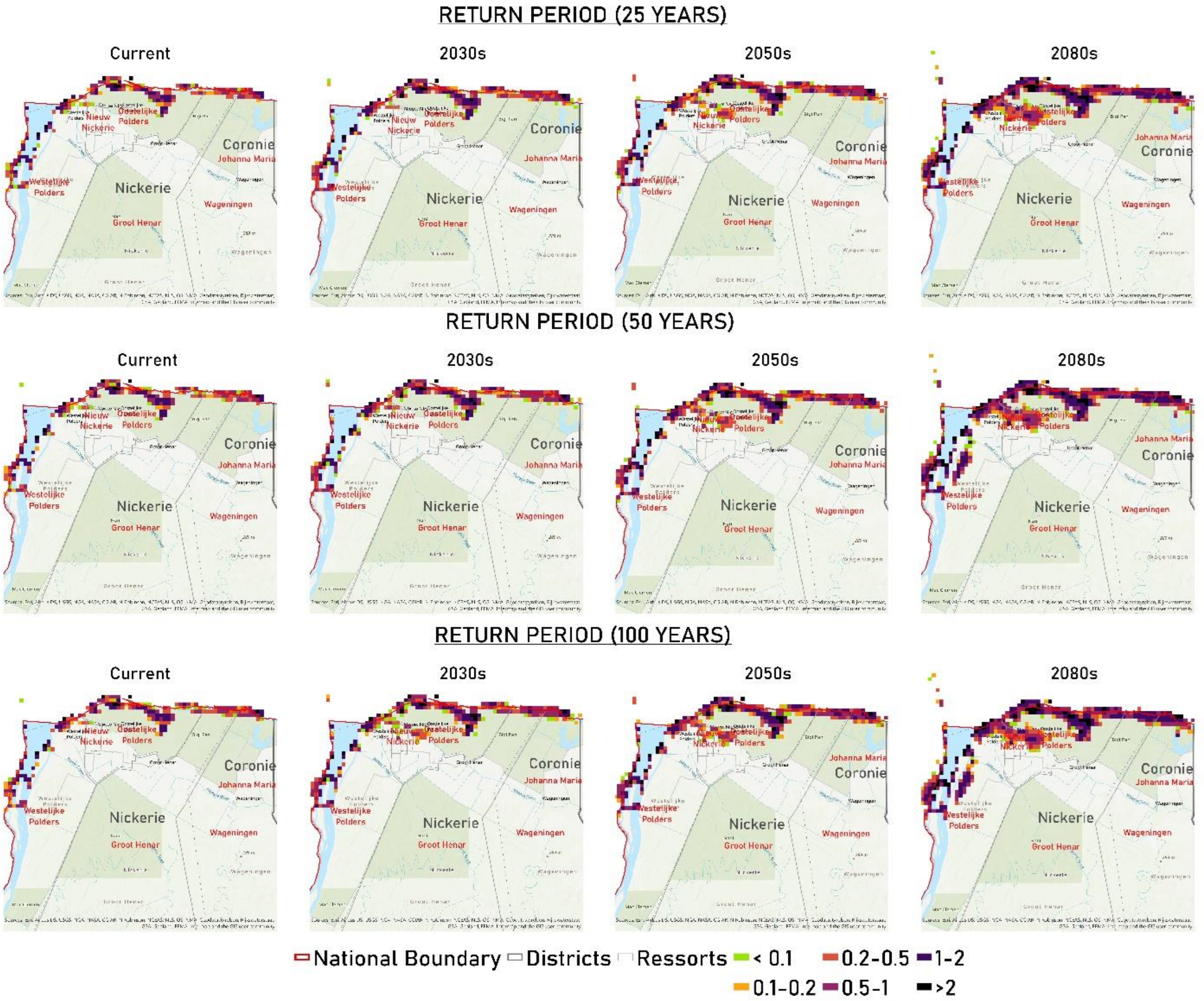

Figure 3.44 *Coastal flood inundation events with an annual probability of 4% or lower (return period 25y or longer) for different time periods under scenario RCP8.5.*

Precipitation:

- No clear trend in annual rainfall in the historical period: a slight upward trend can be seen since around 1990, however the average in the period 1991-2020 is actually marginally lower than in 1951-1980.
- The climate projections generally show a decline in annual rainfall going into the future. Under SSP1-2.6 this decline is very small (less than 5%) and probably not significant. Under higher emission scenarios (SSP3-7.0 and SSP5-8.5) the decline amounts to about 10-15% in the middle of the century, and up to 25% by the end of the century. Due to year-to-year variability the annual precipitation sum in individual years may well be lower than that still, and years with a rainfall total close to 1000 mm (about half of the current average of around 2000 mm per year) are a distinct possibility in these scenarios at the end of the century.
- Looking at the seasonal distribution of rainfall, no major shifts can be discerned in the long-term averages of monthly rainfall in the historical data. Yet, in the most recent decade (2012-2022), rainfall amounts have been higher than the climate normal particularly in the months February-May and also in November and December, lending some credibility to anecdotal evidence of longer wet seasons in this area. It is too early to tell whether this is part of a longer-term trend, or just shorter-term climate variability.
- Conversely, the climate projections show a trend towards a drier early dry season that is consistent across the scenarios. The bimodal rainfall distribution remains largely in place but even under the mitigation scenario SSP1-2.6 a decline in rainfall in the months February to April is projected, amounting to up to 40% less rainfall in 2071-2100, on average across the models.
- Looking at the two main (current) rice growing seasons in Nickerie, rainfall is projected to decrease more in the November to March season, compared to May-September, across all scenarios. As an extreme case, total rainfall in November-March is on average 43% lower in SSP5-8.5 by the end of the century, compared to a decline of 15% in May-September under the same scenario.

- No clear trend in the average length of the longest dry spell per year could be detected in the historical period. In the climate projections, the longest dry spell is projected to increase by 4 days in SSP1-2.6, and by 10-11 days in the higher emission scenarios. In the climate simulations, the latter brings the length of the longest dry spell close to one month, although this could be an overestimation since the models overestimate the number of dry days in the historical period. Nevertheless, year-to-year variability could mean that a dry spell of one month could occur in individual years.
- In contrast, a notable trend has been found in recent years in the number of very heavy rainfall days (days with 20mm of precipitation or more), at least in the ERA5-Land dataset. In the three coastal district this number has risen from around 7 days per year in 1971-2000 to 12 days in 1991-2020. In the most recent decade (2012-2022) this number has been higher still (almost 19 days per year on average) with the highest totals occurring in 2021 and 2022.
- The apparent recent trend in heavy rainfall days in the region is not supported by the climate projections that, if anything, show a slight decreasing trend in the number of days with very heavy rainfall going into the future. At this stage it is not possible yet to say whether the recent trend is only a short-term fluctuation or a longer-term climate trend, in which case the climate models might be missing some important mechanism that may lead to an increase in heavy rainfall days in the area as opposed to the projected (slight) decrease.

Sea level rise and inundation:

- Expected mean sea level rise along the North coast of South America is 0.2-0.3m by the middle of the century, and reaching 0.5 (0.2–0.8) m by the end of the century under scenario SSP1-2.6, and 0.7 (0.4–1.1) m under SSP5-8.5. A mean sea level rise in excess of 1m or more this century is therefore highly unlikely, but can, according to these figures, not be ruled out.
- Total water levels will fluctuate around mean sea level as a function of tides and weather conditions. According to the Copernicus dataset, water levels on the Nickerie coast more than 2m above the mean have a high annual probability even under historical climate conditions. The probability of reaching high water levels will increase further in the first half of the century. Care should be taken to take these values, derived from a global model that has neither been optimised nor validated for the Suriname coast, at face value, yet even in the scenario period total water levels in excess of 3m are highly unlikely (annual probability < 1%).
- Based on older climate scenarios, the Aqueduct flood hazard maps suggest relatively small changes in fluvial inundation depth across event types with different annual probability. Only under the high-emissions scenario RCP8.5 a slight increase in inundation depth is simulated in some areas. In Nickerie, the relatively highest inundation depths in agricultural areas are simulated in the ressort Westelijke Polders, in particular at more extreme (lower probability) flood levels.
- The Aqueduct flood hazard maps also suggest an increase in coastal flood hazard later this century along the lower reaches of the Nickerie River, including into areas upstream from Nieuw-Nickerie. However, considering the use of older climate scenarios and the relatively low resolution of this global product, further detailed modelling would be required to identify areas actually at risk.

Relevance to agriculture

We have presented historical and projected changes in a range of indicators to analyse potential changes in climate hazards. But which ones are the most relevant to the agricultural sector in the three districts of Nickerie, Coronie and Saramacca? The answer to this question depends to some extent on the timescales of interest: in the short-term, the increase in heavy rainfall that was noted in the ERA5-Land dataset seems highly relevant, especially if it has the potential to affect crop yield or farming operations. This increase in heavy rainfall is not supported by the climate projections. It is too early to tell whether this recent trend will continue, yet the number of heavy rainfall days (with 20 mm of rain or more) in ERA5-Land in recent years has been above the natural variability as simulated by the climate models for the current climate. Note the spatial resolution of the climate models is much lower than that of the reanalysis, which may affect their simulation of extreme rainfall. What this means for the projected changes in heavy rainfall going into the future, is impossible to say without further investigation.

In the long term, the climate projections point at the potential for higher temperatures, decreasing rainfall and overall drier conditions compared to the baseline, although in absolute terms the study area is highly unlikely to become water scarce in any of the accepted definitions. Under the high emission scenarios, extreme temperatures of more than 35ºC may become a limiting factor to rice growth, but more likely so towards the end of the century. Under these scenarios, coastal flood hazard may also be increasing especially along the Nickerie River.

4 Non-climatic indicators

4.1 Introduction

In the previous chapter we have looked extensively at changes in the climatic conditions in the two study regions (Nickerie and Coronie-Saramacca) in Suriname. Although there are some small differences, the climatic conditions and trends in the two regions, and indeed in the upstream catchment areas, are very similar. However, the vulnerability of the agricultural sector to these changes is largely determined by non-climatic factors, which are analysed in more detail in this chapter. These include factors that are related to the physical environment, the specific vulnerabilities of the different crops, as well as the social dimension of the agricultural sector in the three districts.

4.2 Data sources and methodology

Following the WMO-GCF approach that was discussed in Chapter 2, we analyse a number of non-climatic factors in this chapter that contribute to the overall climate vulnerability and risk of the agricultural sector in the study area. As local data were often missing or not available in digital format, much of this analysis is based on global datasets that are nowadays available to support regional and local studies. Many of the factors discussed in this chapter contribute to the overall climate risk, either through exposure and/or vulnerability, however the quality of the data does not allow for a comprehensive climate risk analysis. Where possible and appropriate, we have classified the data into indicators of higher and lower vulnerability.

A number of global datasets can be used to provide more insight into elevation differences in the study regions. In this report we have used FABDEM (Forest and Buildings removed Copernicus DEM) (Hawker et al., 2022). FABDEM is a global digital elevation model (DEM) at a 30-meter resolution with forests and buildings removed. The data uses a correction algorithm to remove biases within the Copernicus GLO 30 Digital Surface Model (DSM) arising from the presence of objects on the earth's surface. This has resulted in an improved dataset suitable for understanding flood risk in particular on a global scale or in data-scarce regions of the world. Extensive validation (Hawker et al., 2022) has shown FABDEM to be more accurate than other available global DEMs. Not only this, but the finer spatial resolution in comparison to some other global DEMs allows smaller topographic features to be represented.

Data on soil properties were derived from SoilGrids250m, a global soil mapping project that provides high-resolution soil property maps at a 250-meter spatial resolution. The project is a collaboration between the International Soil Reference and Information Centre (ISRIC) and the European Commission's Joint Research Centre (JRC). SoilGrids250m combines various sources of soil data, such as soil profiles, remote sensing data, and environmental covariates, using advanced statistical and machine learning algorithms. The resulting soil property maps include various physical, chemical, and biological soil properties, such as soil texture, organic carbon content, pH, and nutrient availability. These soil property maps have various applications, such as improving agricultural productivity, assessing soil erosion and degradation, and supporting land-use planning and management. SoilGrids250m data are freely available to the public through the SoilGrids website[6], where users can access the data and maps and download them for further analysis.

The determination of salinity risks in soil is greatly influenced by soil texture. To obtain a comprehensive soil map, the Food and Agriculture Organization's (FAO) vector dataset[7] based on the FAO-UNESCO Soil Map of the World was used. The Digital Soil Map of the World at a scale of 1:5,000,000 and in the Geographic projection (Latitude - Longitude) was employed.

---

[6] https://soilgrids.org/

[7] https://data.apps.fao.org/map/catalog/srv/eng/catalog.search#/metadata/446ed430-8383-11db-b9b2-000d939bc5d8

To assess the vulnerability of the study region to salinization based on water depth, a compiled dataset was utilized (Fan et al., 2013; 2017). This dataset includes global observations of water table depth sourced from government archives and literature, and data gaps were filled in by inferring patterns and processes through a groundwater model driven by modern climate, terrain, and sea level.

Other global datasets that were used in this report include the Global Surface Water Map (Pekel et al., 2016). This dataset contains maps of the location and temporal distribution of surface water from 1984 to 2021 and provides statistics on the extent and change of those water surfaces. These data were generated using 4,716,475 high-resolution scenes from Landsat satellites acquired between 16 March 1984 and 31 December 2021. Each pixel was individually classified into water / non-water using an expert system and the results were collated into a monthly history for the entire period and two epochs (1984-1999, 2000-2021) for change detection.

Information on the vulnerabilities of specific crops to different growing conditions could, in theory, be derived by correlating historic data on crop yield to meteorological conditions, for example. In practice, this is often difficult, especially if crop yield is available only on an aggregated (national) scale, as there are many factors that can influence production in a particular year, such as farmers' responses to market developments. For this study, information on the vulnerabilities of the crops of interest (rice, mixed vegetables, coconut and bananas) was therefore derived from the literature.

Social vulnerability is not the focus of this report; however, it was acknowledged as an important contributing factor to the overall climate vulnerability of the agricultural sector in the study area. The human dimension is covered in much greater detail in two related reports delivered by sub-consultants, but the most relevant factors have been summarised in section 4.5.

4.3 Physical Vulnerability

4.3.1 Elevation

In the low elevation coastal zone of Suriname, elevation is a primary factor as it drives both the probability of flooding and water logging as well as access to groundwater during drier periods. In Chapter 3 we have already seen that the low-lying areas of Nickerie, Coronie and Saramacca in which most agricultural activities take place, are exposed to inundation from both fluvial and coastal flooding. However, the effects of low elevation extend beyond the direct effects of inundation: even without flooding, low-lying areas are more vulnerable to salinization, water logging and flooding.

As mentioned, a number of global datasets can be used to provide more insight into elevation differences in the study regions. Here we focus on FABDEM that has a finer spatial resolution in comparison to some other global DEMs allowing smaller topographic features to be represented.

Figure 4.1 shows the elevation in the three coastal districts, together with cropland and grassland areas according to the National Land Use Land Cover Map 2015[8]. This overview confirms once more that most of the agricultural activities, as well as economic activities, take place within 10m of elevation from current mean sea level. We can use the hazard information obtained in Chapter 3 as a guide to classify different elevation bands into areas of high, medium, or low vulnerability to sea level rise. We have seen that in section 3.5 that high total water levels of above 2m may already be expected with high annual probability under current climate conditions, but that total water levels of more than 3m above mean sea level remain very unlikely, even in the climate projection for the period 2021-2050. We can thus classify the elevation according to the vulnerability scores in Table 4.1, resulting in the map shown in Figure 4.2.

---

[8] Created by SBB, NIMOS and other relevant key partners and available from https://www.gonini.org/

Table 4.1 *Classification of elevation bands into vulnerability score to sea level rise.*

Elevation range (m)	Vulnerability score
≤ 1.0	5 (highest)
1.0 – 2.0	4
2.0 – 3.0	3
3.0 – 4.0	2
4.0 – 5.0	1
≥ 5.0	0 (lowest/absent)

Please note the classification as shown in Table 4.1 is, by definition, subjective, and different choices could lead to different scores. Note also that high or low vulnerability to sea level rise is about more than just the probability of inundation and includes threats such as waterlogging and salinisation (see also Section 4.3.6), all of which we are trying to capture in one single index. In the absence of further detailed investigations on the many aspects of sea level rise, the classification in Table 4.1 and the resulting map provides a first insight into how the different areas compare to each other. Using these definitions, more than 85% of the combined cropland and grassland area in Nickerie, and about 45% in Coronie-Saramacca, falls in the two highest vulnerability classes (score 4 or 5) or, in other words, lies within 2m of the current sea level (Table 4.2).

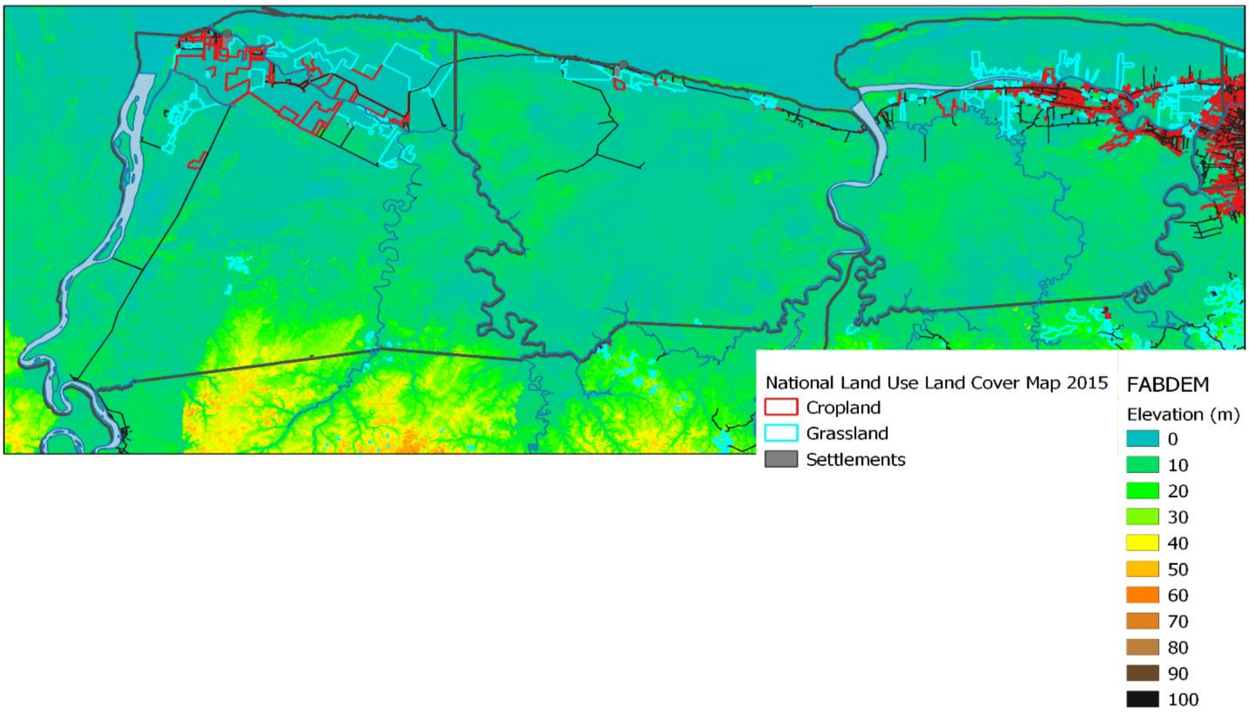

Figure 4.1 *Elevation in Nickerie, Coronie and Saramacca in the FABDEM global elevation model. Areas classed as cropland and grassland are shown with red and magenta outlines, respectively. Land use information was derived from the National Land Use Land Cover Map 2015.*

Table 4.2 *Statistics of FABDEM elevation values in the combined cropland and grassland areas in Nickerie and Coronie-Saramacca.*

	Nickerie	**Coronie + Saramacca**
Elevation (m)		
Mean	1.39	2.64
Median	1.07	2.18
Standard deviation	1.09	1.94
Minimum	-3.97	-0.13
Maximum	22.45	26.46
Vulnerability score (%)		
5 (highest)	42.8%	10.0%
4	42.6%	35.1%
3	7.9%	26.3%
2	4.0%	14.2%
1	1.0%	6.3%
0 (lowest)	1.7%	8.1%

4.3.2 Soil

In this report, we first look at a number of key soil parameters for crop growth from the SoilGrids250m dataset (Figure 4.3):

a. **Bulk density** is an important soil physical property that affects crop growth and development. It refers to the weight of soil per unit volume, including solid and pore spaces. Bulk density is influenced by soil texture, structure, and organic matter content as well as management practices. Sandy soils typically have relatively high bulk density since total pore space in sands is less than that of silt or clay soils. Finer-textured soils, such as silt and clay loams, that have good structure have higher pore space and lower bulk density compared to sandy soils (USDA, 2008). High bulk density can lead to poor root growth and limited water and nutrient uptake by plants, resulting in stunted growth and reduced yields. On the other hand, low bulk density can cause excessive waterlogging and poor soil aeration, leading to root diseases and reduced plant growth. The optimal bulk density for crop growth depends on several factors, including the soil texture, structure, and the specific crop being grown. An ideal bulk density for plant growth is between 1000 and 1400 kg/m³, although this can vary depending on the specific crop and soil type.

b. **Soil organic carbon (SOC)** is an important component of soil health that plays a critical role in supporting crop growth and productivity. SOC is the carbon stored in the soil because of the decomposition of organic matter, such as plant roots, crop residues, and animal waste. Maintaining adequate levels of SOC in the soil is important for supporting healthy crop growth and productivity. Practices such as adding organic matter to the soil, reducing tillage intensity, and practicing crop rotations can help maintain or increase SOC levels in the soil. This can lead to improved soil health, increased crop yields, and more sustainable agriculture.

c. **The clay content of soil** can have both positive and negative effects on crop growth, depending on the specific crop and management practices. Clay soils have a higher water holding capacity and nutrient retention than sandy soils, which can be beneficial for crop growth. Clay soils also tend to have higher cation exchange capacity (CEC), which allows them to hold more nutrients for plant uptake. Additionally, the small pore spaces in clay soils can help retain moisture during dry periods, reducing the risk of water stress for crops. However, clay soils can also present challenges for crop growth. They tend to be denser and harder to till than sandy soils, making it more difficult for plant roots to penetrate and access nutrients and water. Clay soils can also be prone to compaction, which can limit root growth and reduce crop productivity. In wet conditions, clay soils can become waterlogged, depriving plant roots of oxygen and increasing the risk of root diseases.

d. **Available soil water capacity (AWC)** is the amount of water that can be held in the soil between field capacity (the point at which the soil is saturated) and permanent wilting point (the point at which plants can no longer extract water from the soil). AWC plays a critical role in crop growth and productivity as it determines the water available to crops during the growing season. Practices such as conservation tillage, cover cropping, and the use of mulches can help improve AWC by reducing soil moisture loss and improving soil structure. Additionally, irrigation and drainage management can help ensure that crops receive the right amount of water at the right time to support healthy growth and yield.

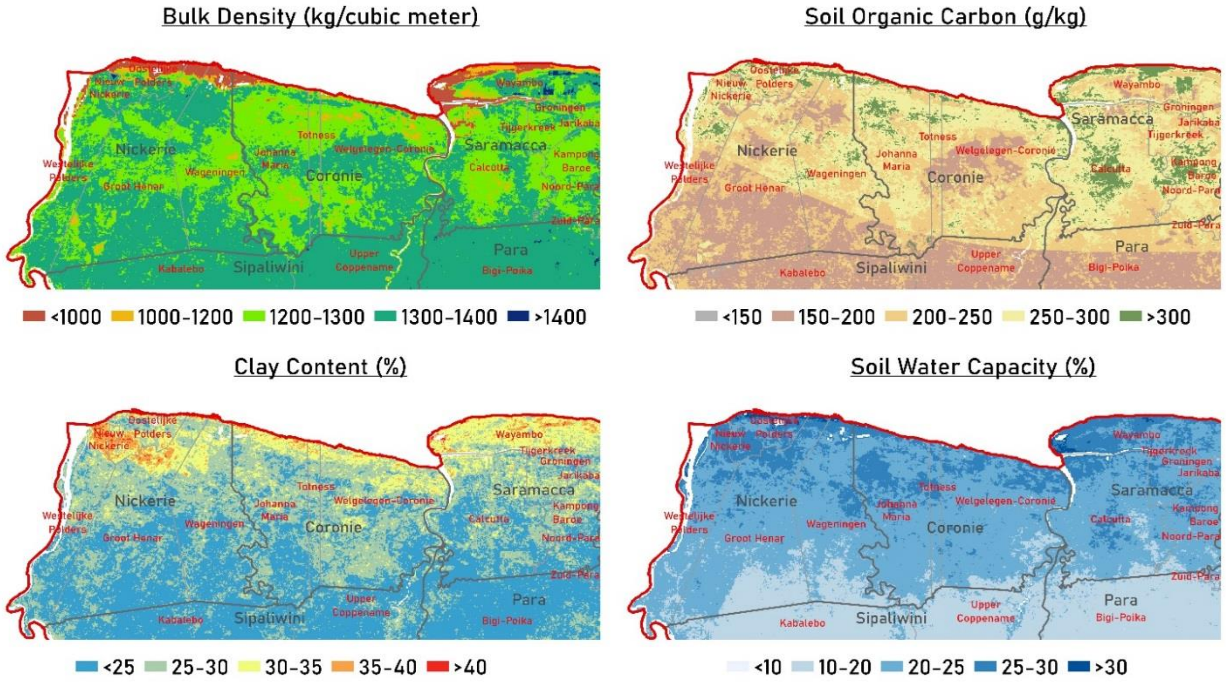

Figure 4.3 Bulk density, soil organic carbon, clay content and water capacity of soils in the study region according to the SoilGrids250m dataset.

Soil type and structure are also important with respect to salinity and the process of salinisation. Warrence et al., 2002 gives a clear description of the effects. It can affect soil physical properties by causing fine particles to bind together into aggregates. This process is known as flocculation and is beneficial in terms of soil aeration, root penetration, and root growth. Although increasing soil solution salinity has a positive effect on soil aggregation and stabilization, at high levels salinity can have negative and potentially lethal effects on plants.

When following normal irrigation practices, sandy soils will naturally be able to flush more water through the root zone than clay soils. The result is that sandy soils have a bigger resistance against higher salinity irrigation water because more dissolved salts will be removed from the root zone by leaching.

Another important aspect of soil texture concerns surface area. Because of the tiny size, a given volume of clay particles has far more surface area than the same volume of a larger sized particle. This simply means that clay soils are at a greater risk than coarse-textured soils for excess sodium to bind to them and cause dispersion. Sands have larger particle sizes, resulting in less surface area; correspondingly, they cannot accept as much sodium as clay particles.

Based on these insights, the soils in the study area can be classified into vulnerability classes according to soil texture. For this purpose, information on soil texture was obtained from the FAO-UNESCO Soil Map of the World (Section 4.2). The FAO soil map was used as it contains specific information on the sand-clay-silt distribution which can easily be linked with risks for salinization. Other datasets, including SoilGrids250m, do not include texture information or provide only a sand fraction or a clay fraction. Soil textures were assigned a vulnerability score according to Table 4.3, with the highest score (4) assigned to clay that has a higher vulnerability to salinisation than loam, as explained before. Sand has the lowest vulnerability score (0) as it holds less water and salts are washed out relatively easily. Please note that the resulting map (Figure 4.4) represents vulnerability to soil salinisation and does not account for the other beneficial or harmful effects of soil properties on crop growth.

Table 4.3 *Vulnerability scores assigned to FAO-UNESCO Soil Map of the World soil types.*

Soil type	Soil texture	Vulnerability score
AO	sandy clay	3
AP	sandy clay loam	2
FO	clay	4
GE	sandy clay loam	2
JE	sandy loam	1
ND	clay	4
NE	sandy clay	3
O	**0**	0
QA	sand	0
QF	sand	0
RE	sandy loam	1

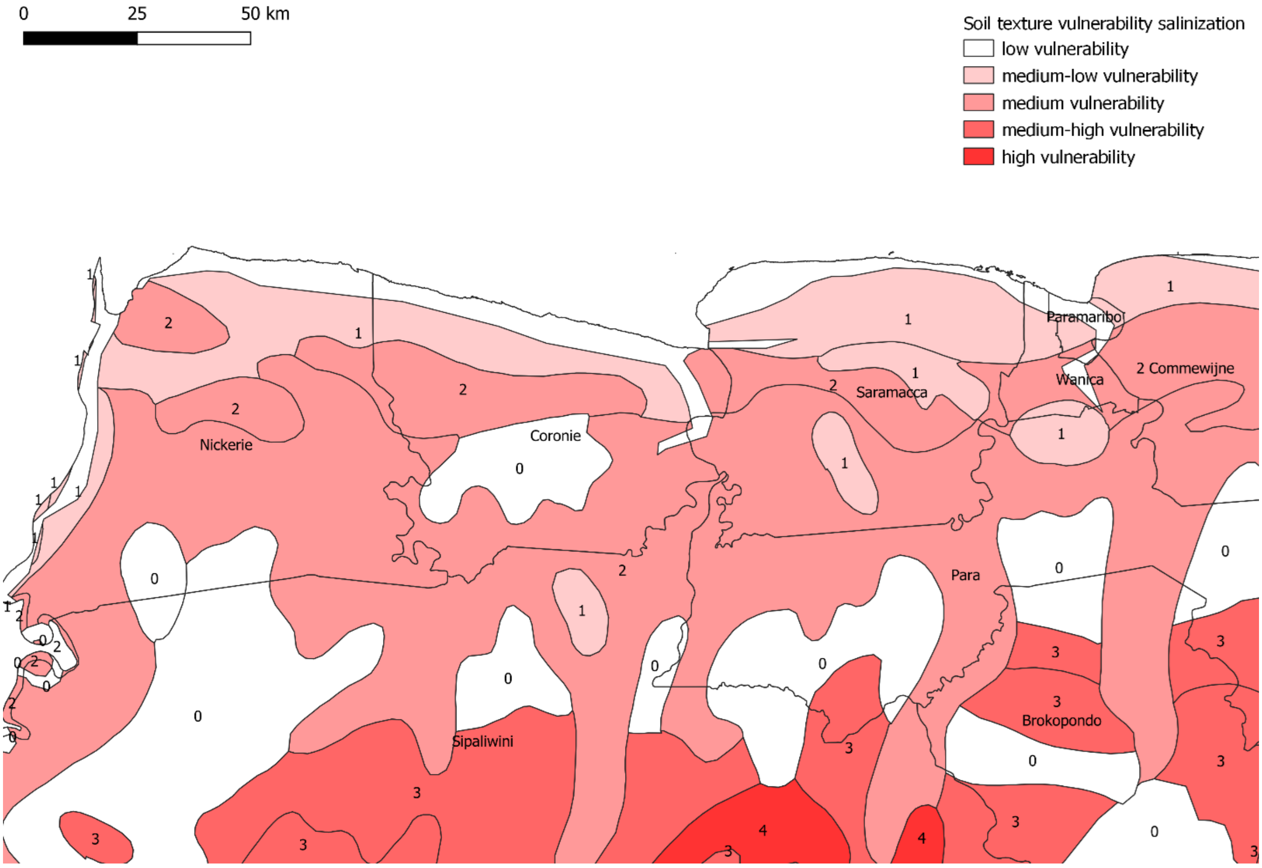

Figure 4.4 *Vulnerability to salinisation based on soil texture.*

As can be seen in Nickerie, Coronie and Saramacca are different classes that can be found. The highest class that can be found is a medium-high vulnerability. Highest risks can be found in Nickerie, where the rice plantations can be found. Coronie appears to have the lowest vulnerability for salinization. We base here the salinity vulnerability only on the soil texture; therefore the data must be combined with other indicators before making any judgements on the total vulnerability.

4.3.3 Surface water

Information about the presence of surface water was derived from the Global Surface Water Map (Pekel et al., 2016). Note the Global Surface Water Map provides information about the presence or absence of surface water, and not its cause. The presence of water on agricultural plots that was detected primarily in Nickerie (Figure 4.5), could therefore be due to waterlogging, paddy flooding for rice cultivation, irrigation, or indeed a combination of these. Neither does it provide information on the quality or salinity of the water. Nevertheless, we can see that surface water is present on many agricultural plots in Nickerie for a small part of the time (generally less than 10%) per year, but consistently across the years (more than 50% recurrence). Looking at changes between the two epochs, it is noteworthy that many of these agricultural areas fall in the category "new seasonal", suggesting that the seasonal presence of water is more prominent in the later period (since 2000).

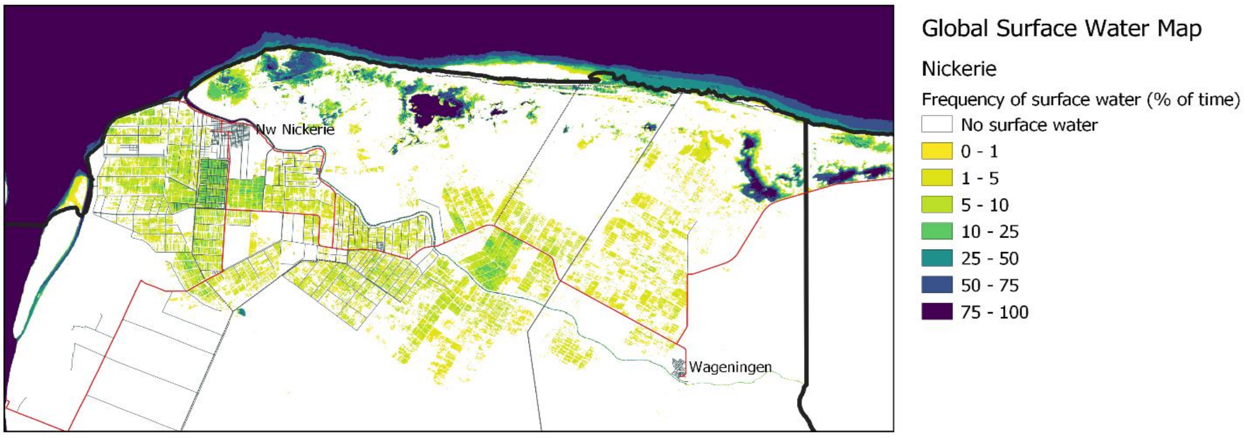

Figure 4 5 *Frequency of surface water presence in Nickerie in 1984-2021 as detected by satellite. Source: Global Surface Water Map (Pekel et al., 2016).*

A similar seasonal presence of surface water on agricultural lands cannot be detected in Coronie-Saramacca. Interestingly, the map showing changes between the two periods could also provide an indication of coastal erosion, in particular those areas along the coast that fall in the categories "new seasonal", "seasonal to permanent", and "new permanent". If this interpretation is correct, a retreat of the coastline is more prominent in Nickerie (Figure 4.6) and Coronie, and less so in Saramacca (Figure 4.7). Data from The Global Mangrove Watch[9] (Bunting et al., 2022) that, based on Synthetic Aperture Radar (SAR) global mosaic datasets from the Japan Aerospace Exploration Agency (JAXA), shows a loss in mangrove extent between 1996 and 2020 primarily on the Nickerie coast, support this. Note that coastal defences have been constructed in the past in both Nickerie and Coronie to combat erosion (Tjon Sie Fat, 2023).

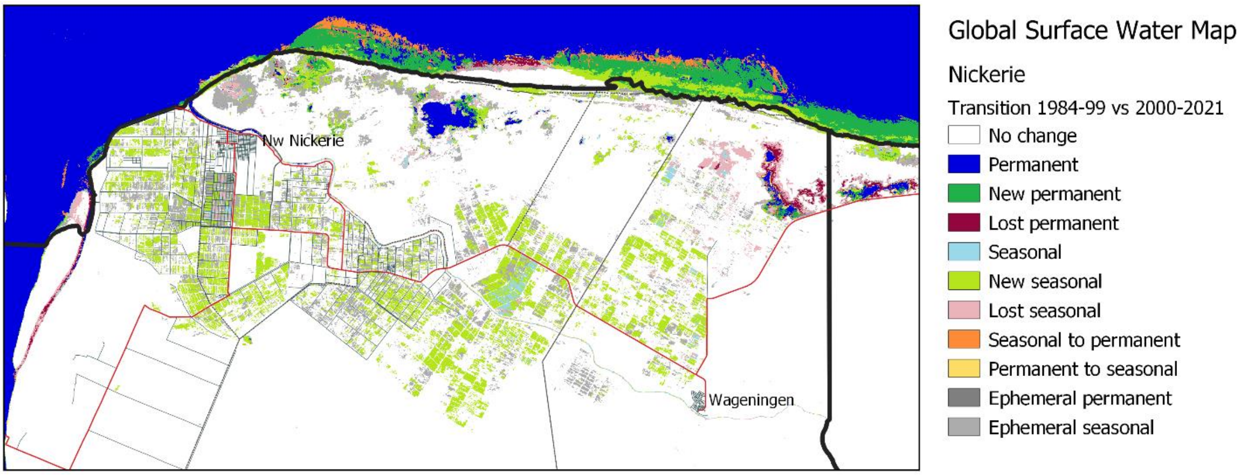

Figure 4.6 *Change in the frequency of surface water presence in Nickerie between 1984-1999 and 2000-2021. Classes describe the transition from the earlier to the later period, e.g., "new permanent" implies permanent water presence in the second period, but no water presence in the first; "lost seasonal" implies seasonal water presence in the first period, but no longer any water in the second. Source: Global Surface Water Map (Pekel et al., 2016).*

---

[9] https://www.globalmangrovewatch.org/

More local knowledge would be needed to use the information in the Global Surface Water Map in the vulnerability analysis. If the presence of surface water is predominantly caused by water logging, a higher frequency would imply a higher vulnerability of the area. Conversely, if the presence of water reflects irrigation practices, it would suggest a lower vulnerability, especially to limited water availability.

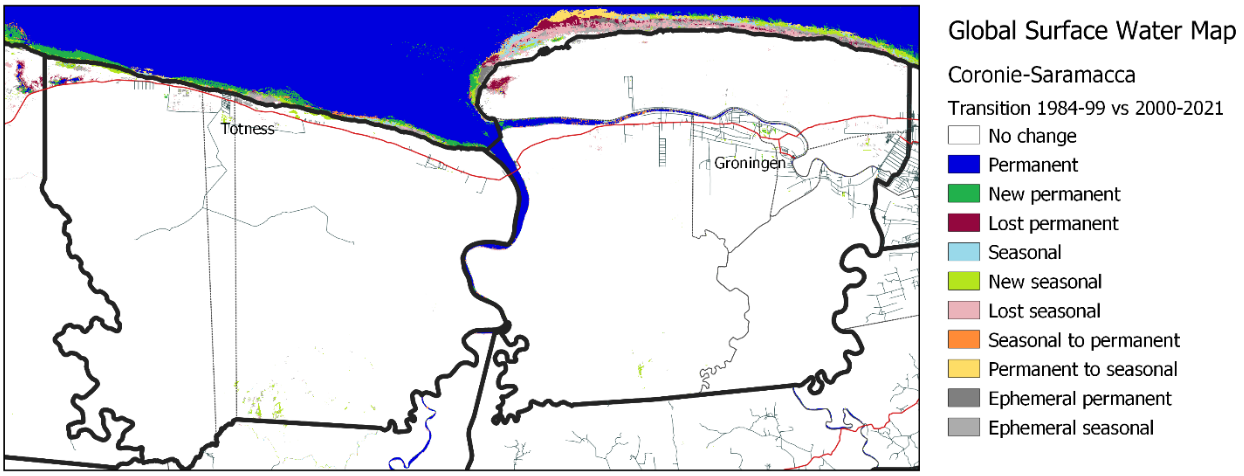

Figure 4.7 *As Figure 4.6, but for Coronie-Saramacca.*

4.3.4 Irrigation sources and practices

Across the world, different irrigation practices are being used, including flood irrigation, border irrigation, furrow irrigation, sprinkler irrigation and drip irrigation. Distinction can furthermore be made between the source of irrigation water, primarily either groundwater or surface water (non-conventional sources such as treated wastewater are not considered in this report).

According to the FAO (2015), the current irrigation area in Suriname amounts to 57000 ha, primarily used for rice production. The major irrigation technique is surface irrigation. 2000 ha of irrigated area is used for bananas, of which 1 100 ha uses sprinkler irrigation systems while the other 900 ha uses surface systems. Irrigation for bananas varies, depending on the weather. Much less irrigation is used in areas where rainfall is more evenly distributed. A very small number of farmers use localized irrigation. The total water withdrawal in Suriname was 615.9 million m^3 in 2006 with 8% coming from groundwater and 92% from surface water (FAO,2015). From global datasets it can be concluded that the irrigation intensification has increased over the years from 2001-2015 and therefore is presumed that in combination with climate change, this trend will continue (Nagaraj et al.,2021).

At the time of this study, no field or district level data have been identified on the location and sources of irrigation systems, making it impossible to create a vulnerability assessment map for the 3 districts. However, some general observations with respect to the impact of climate change. For example, in Chapter 3 it was noted that the climate projections generally show a decline in annual rainfall going into the future; this applies to both the study area itself as well as the upstream river catchments supplying freshwater into the region. This decline was very small under the climate mitigation scenario SSP1-2.6 but amounted to about 10-15% in the middle of the century, and up to 25% by the end of the century under the higher emission scenarios. We also noted that in individual years the annual precipitation sum may be lower still, with years with a rainfall total close to 1000 mm a distinct possibility towards the end of the century.

Taking an annual rainfall total of 1000 mm as a worst-case scenario, we can use the catchment areas of the upstream river basins to estimate the total rainfall fluxes over these areas. For example, according to the Suriname Water Resources Information System (SWRIS) website[10] the catchment area of the Nickerie River amounts to 10,100 km^2. An annual rainfall of 1000 mm over this area amounts to 10.1 billion m^3 of water, or about 16 times the 2006 total water withdrawal in Suriname. Similarly, 1000 mm of rainfall over the

---

[10] https://www.swris.sr/data/rivers/

Corantijn catchment area (67,600 km^2) amounts to 67.6 billion m^3 of precipitation or about 100 times the 2006 water withdrawal. Even allowing for significant evapotranspiration losses, these estimates suggest freshwater supply from the upstream areas should in principle be sufficient to meet current levels of irrigation demand, provided, of course, the appropriate infrastructure and management is in place to make use of this resource.

Of course, intra-annual variability in river discharge could still result in temporary mismatches between water supply and demand. If the supply of surface water for irrigation is seen as unreliable going into the future, it could mean that farmers will increasingly turn to groundwater as irrigation source as this is often more stable on the short term. Globally this trend has been already going on for years and is expected to continue in the future. Often, this leads to unsustainable situations where the groundwater is depleted. It also increases the risk of salinization, as groundwater is often more saline than surface water. In addition, a lack of adequate drainage systems poses a significant risk for salinization, as salts from irrigation must be properly drained from fields (Ritzema, 2014).

4.3.5 Groundwater table

The depth of the groundwater table may affect the vulnerability of agricultural systems in multiple ways. In drier periods, areas with high water table depths may be more resilient as water is available closer to the surface. Conversely, during wet periods these areas may be more prone to waterlogging. Areas with high groundwater tables are also more prone to salinization.

As local data on groundwater depths could not be identified for the study region, we use a global dataset that combines observations of water table depth compiled from government archives and literature with patterns and processes from a groundwater model forced by modern climate, terrain, and sea level (Fan et al., 2013; 2017). Focusing on the vulnerability to salinization in particular, an area may be classified as waterlogged when the water table depth is less than 3 meters, which is associated with increased soil salinity levels, as indicated by electrical conductivity (EC) and total dissolved solids (TDS) and has been documented by previous studies (Greene et al., 2016; Boonstra et al., 2002). To illustrate these patterns for the study area, we assigned a vulnerability risk score based on the depth of the water table, with the highest score for grid cells with a water table depth of less than 3 meters, and lower scores as the water table depth increases (Table 4.3). In Figure 4.8 can be seen that the risks for salinization based on water table depth is relatively high in the coastal areas as the water table depth is relatively close to surface level.

Table 4.4 *Assignment of vulnerability scores to groundwater table depths.*

Water table depth	Risk score
0 – 3 m	4
3- 6 m	3
6 – 9 m	2
9- 12 m	1
> 12 m	0

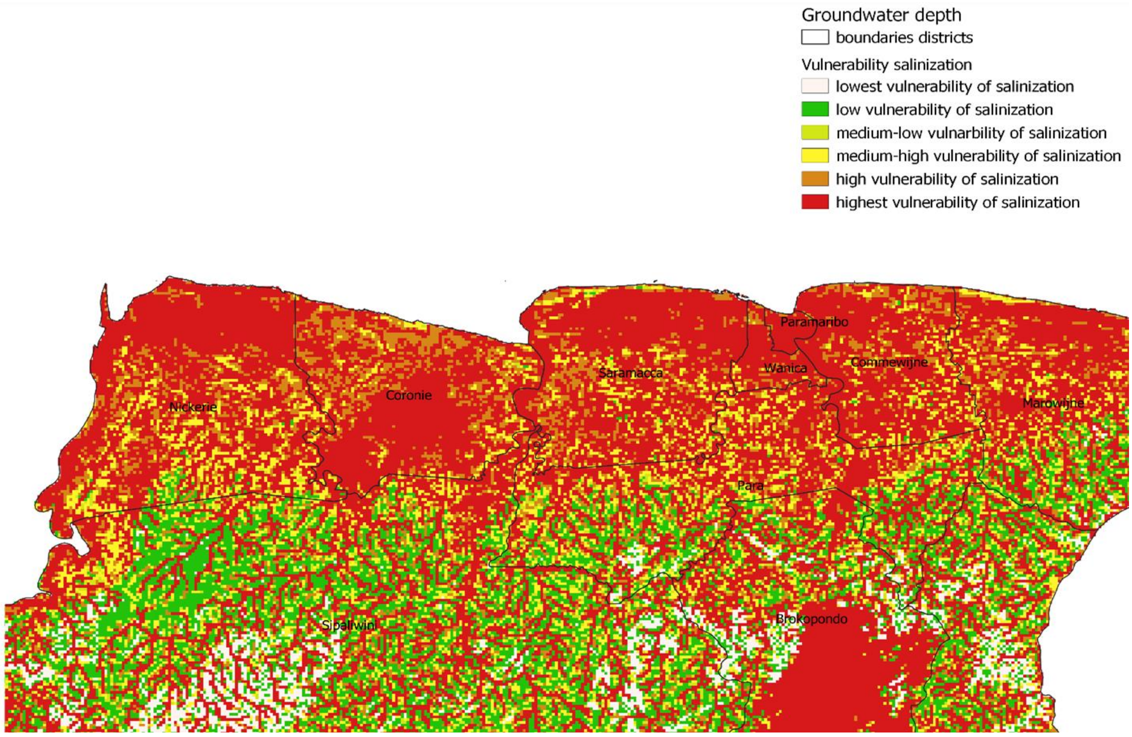

Figure 4.8 *Vulnerability to salinisation based on groundwater table depths according to Fan et al. (2013; 2017).*

4.3.6 Saltwater intrusion

Saltwater intrusion into rivers and estuaries, and more generally into coastal aquifers, is a complex problem depending on the dynamics of multiple factors. In rivers in particular, the level of intrusion depends primarily on the balance between intrusion of salt water from the sea on the one hand, and the supply of freshwater on the other. Disruption of this balance is greatest during periods of low river flows, and/or high sea levels due to tides, wind fetch or storm surges.

Because saline water has a higher mineral content than freshwater, it has a higher density and weighs about 2-3% more. Typically, the saline water will therefore intrude underneath the freshwater as a “tongue-shaped” structure. Freshwater supply from upstream limits the intrusion and the inland movement of saline water (Mohammed & Scholz, 2018); as a result, salinity levels will usually decrease when moving in an upstream direction. The extent and duration of the saltwater intrusion depends not only on the supply of freshwater but also on the sea level and the shape of the estuary or riverbed (STOWA, 2020). Because of the factors and processes involved, it will usually be limited to the lowest reaches of a river.

Direct data on the extent of saltwater intrusion in the study region has not been found during the current project and may not be available. An indication can be obtained from the Suriname Water Resources Information System (SWRIS) website[11] that provides an indication of the minimum and maximum saltwater intrusion in rivers in some of it maps; the basis for this information is however unknown.

---

[11] https://www.swris.sr/

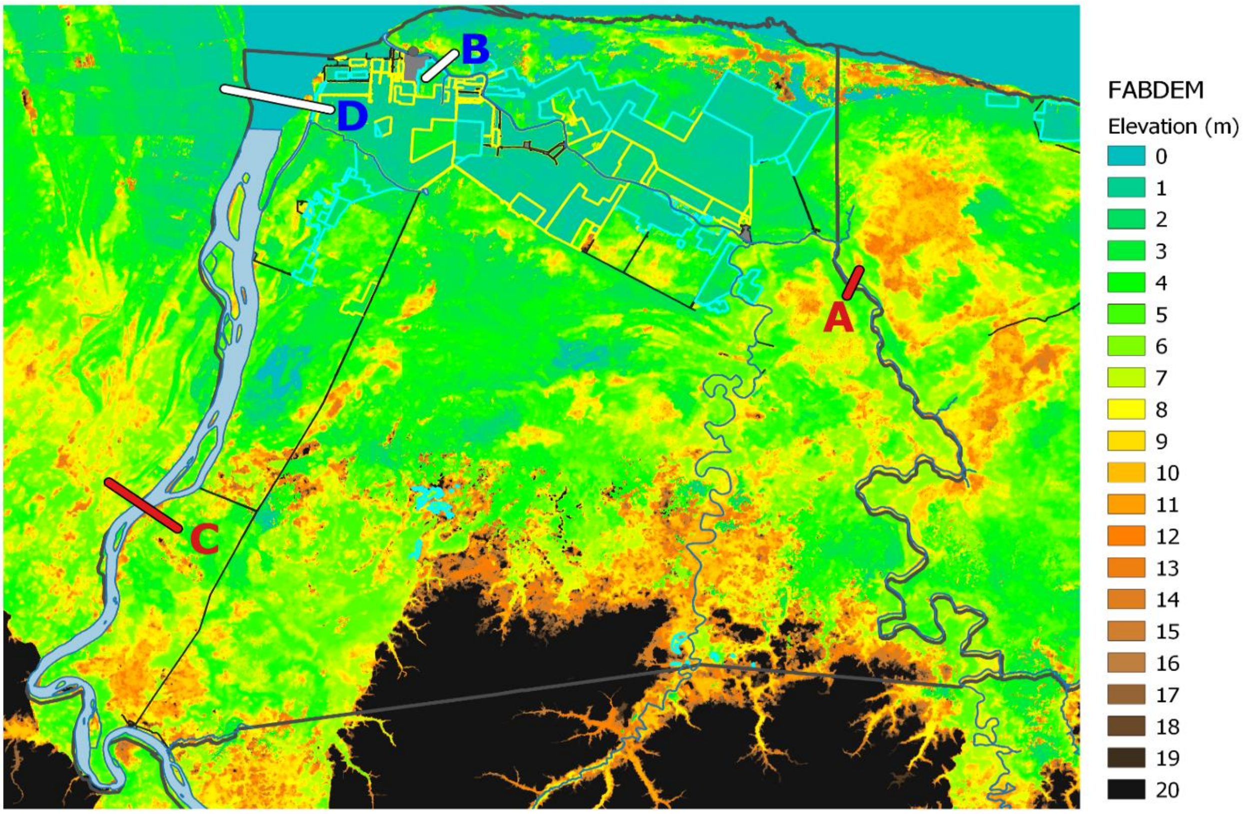

Figure 4.9 *Approximate location of minimum (B, D) and maximum (A, C) saltwater intrusion in the Nickerie (A, B) and Corantijn (C, D) Rivers, based on maps from SWIRS. The background shading shows altitude according to the FABDEM elevation data.*

The approximate location of the minimum and maximum extent of saltwater intrusion in the study area is indicated in Figure 4.9 and Figure 4.10 together with elevation data from FABDEM (note the elevation data have been scaled differently from previous figures). Focusing the Nickerie River, we can see that the point of maximum saltwater intrusion, some 10-15 km upstream of Wageningen, also marks the boundary with slightly more elevated terrain (roughly at 5-10m above sea level). We can also see that almost all of the cropland and grassland areas in Nickerie are situated downstream of this point and are therefore, presumably, already vulnerable to saltwater intrusion into the river system. The same could be said of the agricultural areas in Saramacca (Figure 4.10). Indeed, farmers on the right bank (northern side) of the Nickerie River downstream of Wageningen have already experienced problems with salinity levels in recent years, although this could also be attributed to infrastructure failings (I. Samoender, pers. comm., 2023).

In Chapter 3 we have seen that future scenario of climate change project an increase in mean sea level as well as total water level, as well as a reduction in rainfall totals in the upstream areas, especially under higher emission scenarios in the second half of this century. Presumably this means that the vulnerability of the low-lying agricultural areas of Nickerie and Saramacca to saltwater intrusion in will increase. Further detailed analysis will be necessary to determine the extent and severity.

In coastal aquifers, saltwater will also be pushed as a wedge underneath the freshwater because of its higher density. Ordinarily the inland extent of the saltwater wedge is limited because the volume of fresh groundwater, increases as land elevation gets higher. The extent of saltwater intrusion depends on factors such as the amount of precipitation, evapotranspiration, runoff, groundwater withdrawal, the presence of drainage and navigation channels, and the exact properties, characteristics, and dimensions of the aquifer. As a first order approximation, for every meter of fresh groundwater in an unconfined aquifer above sea level, there will be 40 meters of freshwater in the aquifer below sea level (in other words, saline groundwater may be found at depths below 40m) (Barlow, 2003). This number is based on a number of simplifying assumptions that may not be valid in the specific circumstances of the study area; nevertheless, the implication is that the likelihood of saltwater intrusion at relatively shallow depths in the groundwater reservoir is greatest in low-lying areas with a groundwater table close to sea level.

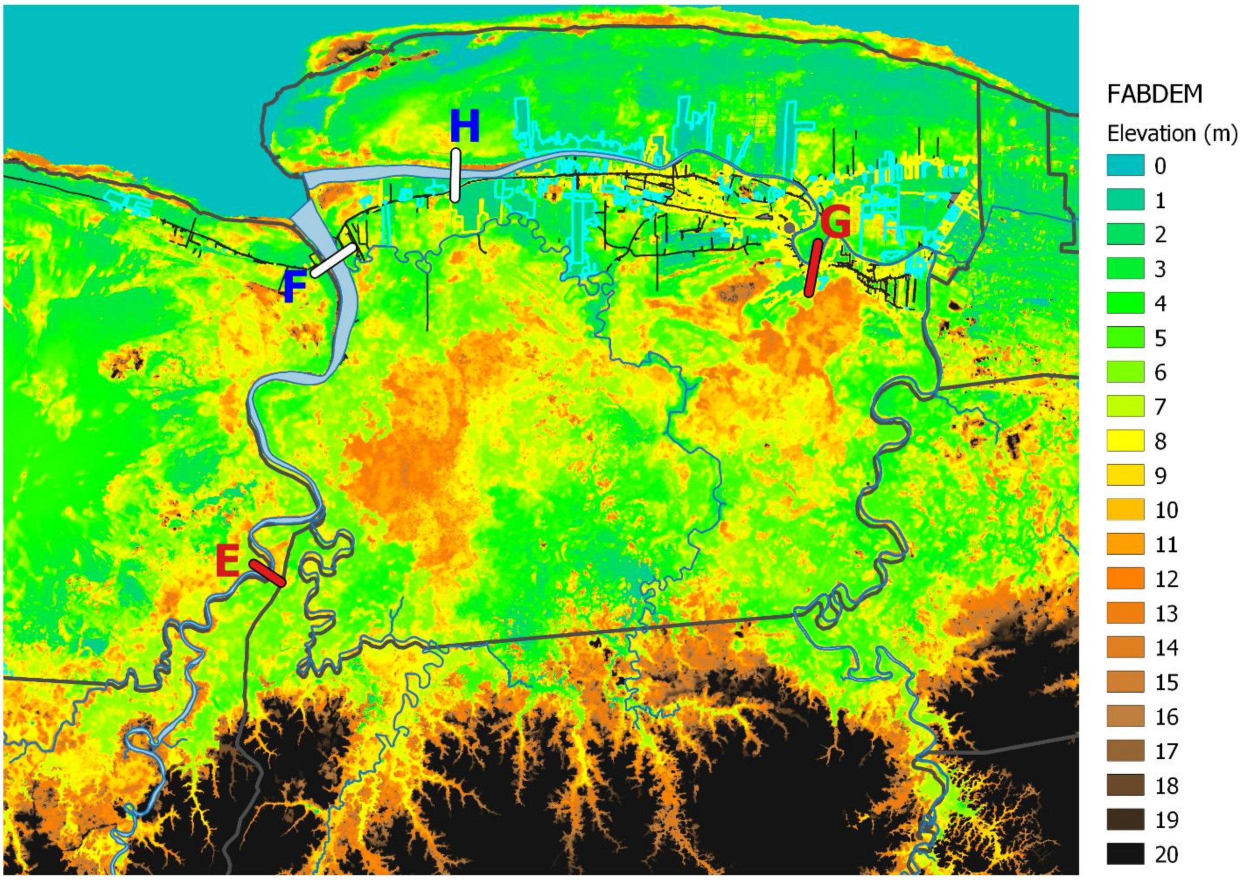

Figure 4.10 *Approximate location of minimum (F, H) and maximum (E, G) saltwater intrusion in the Coppename (E, F) and Saramacca (G, H) Rivers, based on maps from SWIRS. The background shading shows altitude according to the FABDEM elevation data.*

4.4 Crop vulnerabilities

4.4.1 Rice

Actual production

Statistics on rice production in Nickerie and in Suriname were obtained from the Ministry of Agriculture (LVV) in Suriname (LVV, 2020). These statistics cover the period 2014-2019. Focusing on Nickerie, the average production per ha peaked in 2017 at 4.9 tonnes. The reasons for this are not known, as 2017 does not stand out as an exceptional year with respect to the climate conditions. All in all, no clear trend in rice production can be detected, nor any individual years in which weather conditions have significantly affected the yield.

Table 4.5 *Paddy rice statistics for Suriname. Source: LVV, 2020.*

	unit	2014	2015	2016	2017	2018	2019	*Average 2014-2019*
PLANTED AREA								
Spring season rice	ha	30,733	30,595	30,516	29,854	29,908	29,214	*30,137*
Fall season rice	ha	31,478	31,753	32,197	29,450	29,340	30,971	*30,865*
Total planted	ha	62,211	62,348	62,713	59,304	59,248	60,185	*61,002*
According to farm size:								
Small farms	ha	26,483	27,433	27,594	26,643	26,204	26,237	*26,766*
Large farms	ha	35,728	34,915	35,119	32,661	33,044	33,948	*34,236*
According to district:								
Nickerie	ha	60,103	59,419	60,500	56,807	57,438	58,731	*58,833*
Other districts	ha	2,108	2,929	2,213	2,497	1,810	1,454	*2,169*
PRODUCTION								
Spring season rice	tonne	136,203	135,307	135,116	149,268	138,847	127,916	*137,110*
Fall season rice	tonne	139,648	141,151	142,961	140,163	135,069	146,350	*140,890*
Total production	tonne	275,851	276,458	278,077	289,431	273,916	274,266	*278,000*
According to farm size:								
Small farms	tonne	126,266	129,935	130,696	143,112	125,435	131,988	*131,239*
Large farms	tonne	149,585	146,523	147,381	146,319	148,481	142,278	*146,761*
According to district:								
Nickerie	tonne	270,014	266,236	269,916	280,730	267,744	268,897	*270,590*
Other districts	tonne	5,837	10,222	8,161	8,701	6,172	5,369	*7,410*
AVERAGE PRODUCTION PER HA								
Spring season rice	kg	4,432	4,423	4,428	5,000	4,642	4,379	*4,551*
Fall season rice	kg	4,436	4,445	4,440	4,759	4,604	4,725	*4,568*
National	kg	4,434	4,434	4,434	4,880	4,623	4,557	*4,560*
Small farms	kg	4,768	4,736	4,736	5,371	4,787	5,031	*4,905*
Large farms	kg	4,187	4,197	4,197	4,480	4,493	4,191	*4,291*
Nickerie	kg	4,493	4,481	4,461	4,942	4,661	4,578	*4,603*
Other districts	kg	2,769	3,490	3,688	3,484	3,410	3,693	*3,422*

The LVV statistics can be compared with data published on the website of the International Production Assessment Division (IPAD) of the US Department of Agriculture[12], that includes more recent information. These data are for the entire country, but from LVV (2020) we know that 96-98% of the total rice production takes place in Nickerie anyway. Taking a longer-term perspective, we see that the rice yield per ha has been increasing over the past decade (Table 4.5). The unusually wet conditions in recent years do not seem to have affected production, in fact the yields in 2021-2023 are among the highest in the series.

Table 4.6 *Rice production statistics for Suriname. Source: US Department of Agriculture.*

Market Year	Area (1000 ha)	Production (1000 tonnes)	Yield (tonne/ha)
2011/2012	57	148	4.1
2012/2013	51	141	4.4
2013/2014	58	165	4.5
2014/2015	62	174	4.5
2015/2016	59	169	4.5
2016/2017	63	175	4.4
2017/2018	59	182	4.9
2018/2019	56	173	4.9
2019/2020	60	173	4.6
2020/2021	62	180	4.6
2021/2022	60	183	4.8
2022/2023	61	186	4.8

---

[12] https://ipad.fas.usda.gov/countrysummary/Default.aspx?id=NS&crop=Rice

Crop vulnerabilities
The optimum temperature range for rice is around 25-30ºC, and the upper temperature range 35-38ºC (Wassmann et al., 2009a). Temperatures above 35°C for an extended period can be detrimental to rice in all crop growth stages, especially during the grain filling period which is critical for rice growth (Saud et al., 2022). At plant level, high temperatures during the day, but also at night, enhance the respiratory rates. As a consequence, higher temperatures will result not only in reducing the growth duration of the rice crop but also the duration for grain filling, resulting in lower yield and lower quality rice grain (Wassmann et al., 2009). It should be noted though that globally, rice is also grown in arid regions regularly exposed to even higher temperatures. Key success factors in these environments include sufficient water availability and low humidity to increase the effectiveness of evaporative cooling, as well as the use of heat-tolerant cultivars.

Current rice production systems rely on ample water supply and thus are, at least in theory, more vulnerable to drought stress than other cropping systems (Wassmann et al., 2009b). Drought stress is the largest constraint to rice production in the rainfed systems. At plant level, soil water deficit is an important environmental constraint influencing all the physiological processes involved in plant growth and development. Rice cultivation needs around 200 mm of cumulative rainfall during the grow-out period from transplanting to harvest to moisten the ground sufficiently for planting, and around 1000 mm of rainfall throughout the season (IRRI, 2007). In practice, irrigation is often used acting as a buffer against drought effects and giving some degree of resilience in rice production systems. In the absence of other potential climate-related stresses, higher concentrations of atmospheric CO2 may increase the water use efficiency of plants which could mean they may be better able to tolerate drought conditions (Wassmann et al., 2009b).

Although a semiaquatic plant, rice is generally intolerant of complete submergence and plants die within few days when completely submerged. There are, however, few varieties that are tolerant to complete submergence capable of surviving under water for about 14 days and to recover after the water recedes (Wassmann et al., 2009b). In coastal regions such as Nickerie, inundation with saline water poses an additional problem as rice is (moderately) salt-sensitive with a threshold electrical conductivity of 3 dS m^{-1} (Wassmann et al., 2009b). The FAO table for salt tolerances for crops also states the same value of 3 dS m^{-1}. However, the FAO classifies it as a saline sensitive crop (Annex 1. Crop salt tolerance data, n.d.). New rice varieties have been developed around the world with enhanced level of tolerance both for saline and sodic soils (Wassmann et al., 2009b).

4.4.2 Bananas

Actual production
According to statistics from the Ministry of LVV on the production of bananas (including cooking bananas) in the period 2014-2019, both the area and the total production have declined. Also yield (approximated as the total production divided by the planted area) has declined from 35 to 29 tonnes/ha (Table 4.5), however this decline is unrelated to weather conditions (I. Samoender, pers. comm., 2023). Around 46% of the total production of commercial bananas (excluding cooking bananas) comes from the Jarikaba estate in Saramacca; another 48% from plantations in Nickerie.

Table 4.7 *Banana production statistics for Suriname. Source: LVV, 2020.*

	unit	2014	2015	2016	2017	2018	2019	*Average 2014-2019*
Planted area	ha	2,945	2,633	2,633	2,482	2,213	2,182	*2,515*
Total production	tonne	101,702	89,438	80,929	79,395	64,234	63,286	*79,831*
Average production	tonne/ha	34.5	34.0	30.7	32.0	29.0	29.0	*31.5*

Crop vulnerabilities
Information on the specific vulnerabilities of banana growing was derived from Calberto et al. (2015) who provide information on the climatic conditions suitable for banana production, based on the Cavendish variety. With mean annual temperatures between 25 and 26.5ºC, mean annual rainfall in the range of 1500-2500 mm and less than 3 dry months per year (defined as months with less than 60 mm of rainfall),

current conditions in the study area are particularly favourable for banana production without additional irrigation.

Calberto et al. (2015) provide information on thermal conditions affecting banana production. Physiological heat stress starts at temperatures above 34ºC, and Calberto et al. assess areas with temperatures over 35ºC for at least three months per year. As described in Section 3.3.5, such temperatures may be expected to occur in the study region into the future. Under the climate mitigation scenario SSP1-2.6, the number of days per year with a maximum temperature more than 35º remains below 60 days per year in all models. Under the high emissions scenarios, however, the number of very hot days may rise to above 150 days per year by the end of the century (2071-2100), suggesting that banana productivity may be affected under these scenarios. Maximum temperatures in excess of 38ºC also become a distinct possibility in these scenarios but remain very rare occurrences under SSP1-2.6 (see Section 3.3.5).

Table 4.8 *Key temperature parameters for banana growth. Source: Calberto et al. (2015).*

Temperature (ºC)	Effect on banana growth
47	Thermal danger point, leaves die
38	Growth stops
34	Physiological heat stress starts
27	Optimum mean temperature for productivity
13	Minimum mean temperature for growth, field chilling
6	Leaf chlorophyll destruction
0	Frost damage, leaves die

Banana may suffer growth limitations below 1500 mm/year of rainfall, especially if there are more than three dry months (with less than 60 mm/month of rainfall) (Calberto et al., 2015). In Section 3.4.1 we saw that the mean annual rainfall is projected to decrease below 1500 mm per year in 2071-2100 in the two high emission scenarios but stays above this amount in SSP1-2.6. We also noted that the climate models start off from a baseline in the historical period that appears to be too low, at least compared with ERA5-Land. A similar decline of 25% in the reanalysis data would imply an annual precipitation of just above 1500 mm, although in individual years the rainfall amount could of course still be lower. Only in the highest emission scenario SSP5-8.5 and at the end of the century, more than three dry months per year occur on average across the ensemble (Section 3.4.2).

In addition to temperature and rainfall limits, wind damage is a major problem for banana producers worldwide. The majority of the cultivars can withstand winds of up to 40 km/h or 11 m/s (5 Bft) (Borges et al., 2007; Cauthen et al., 2013). As discussed in Section 3.5, the climate projections of wind speed are based on daily mean values, and data on changes in daily maximum wind speeds and wind gusts are not available (and would be highly uncertain, anyway). However, in the historical data the daily maximum wind speed did not exceed 6 m/s, and daily mean wind speed increased only slightly by about 5% in the higher emissions scenario SSP3-7.0. These findings suggest wind damage is currently not a major problem for banana cultivation in the study region and is unlikely to become a limitation in the future, even under higher emission scenarios.

Calberto et al. (2015) also provide a preliminary assessment of the risk of diseases under climate change, in particular Black Leaf Streak (BLS), one of the most important leaf diseases of banana. They suggest BLS may become more aggressive with increased temperatures. However, spore germination is primarily based on leaf wetness, suggesting BLS will continue to be a challenge primarily during the rainy periods. Unfortunately, few data, if any, on disease occurrence are available from producers in Suriname.

Regarding salinity, banana can be viewed as a sensitive crop. The FAO does not give any threshold value but states overall that fruits and vegetables are relatively sensitive for salinity. Also, Santana et al. (2020) confirm that banana has a clear response on increasing salinity even on low salinity levels in the irrigation water.

4.4.3 Coconut

Actual production

Statistics from the Ministry of LVV on coconut production show that the total planted area has remained more or less constant in the period 2014-2019. Total production and yield (calculated as total production divided by the planted area) peaked in 2016 and have remained at a level about 15% higher than in 2014-2015 (Table 4.8).

Table 4.9 *Coconut production statistics for Suriname. Source: LVV, 2020.*

	unit	2014	2015	2016	2017	2018	2019	*Average 2014-2019*
Planted area	ha	1,099	1,081	1,095	1,103	1,109	1,070	*1,093*
Total production	tonne	12,880	12,689	14,672	14,072	14,574	14,069	*13,826*
Average production	tonne/ha	11.7	11.7	13.4	12.8	13.1	13.1	*13*

Crop vulnerabilities

Ideal conditions for growing coconuts include a year-round warm and humid climate, a mean annual temperature of 27ºC, an evenly distributed rainfall of 1500-2500 mm per year, and relative humidity above 60% (Chan & Elevitch, 2006). Rainfall more than 2500 mm could result in diseases of the fruit and leaves. Depending on soil water conditions, more than one to three consecutive dry months (with less than 40 mm of rainfall) may significantly diminish yields, although the palms themselves will survive longer droughts. Coconut can grow in climates with a mean annual temperature between 21 and 30ºC and a mean maximum temperature of the hottest month below 37ºC. Although sand is its natural habitat, the coconut palm can grow on a wide range of soil types if these are well drained. It is furthermore relatively tolerant of saline soils, alkaline soils with a pH up to 8, and acid soils with pH 4.5 or higher. However, coconut is sensitive to waterlogging within 1m of the surface and will not survive more than 2 weeks of surface waterlogging (Chan & Elevitch, 2006). Research reveals that coconut seedlings can tolerate 8.32 dS/m EC of. At 25% SWS (16.32 EC) biomass production was decreased by 47% (Hebbar et al., 2021).

4.4.4 Mixed vegetables

Actual production

A wide range of vegetables is grown in Suriname. According to the statistics of the Ministry of LVV over the period 2014-2019, the most important of these (in terms of planted area and/or total production) include asparagus bean, aubergine, red (hot) pepper, and okra. The largest single category in the LVV statistics, however, is the class “other vegetables” which itself includes vegetables such as varied as cauliflower, paprika, bitawiri (bitter leaf), water spinach, lettuce, spinach, leek, and shallots. The other vegetables class accounted for 15% of the planted area, and 14% of the total production in tonnes. According to the LVV statistics, the total planted area for all vegetables was more or less constant in 2014-2018, but about 14% lower in 2019, with a corresponding drop in total production in the same year (Table 4.10). Key climatic challenges to vegetable production in Suriname include the risk of diseases during wet periods due to water logging, and a risk of pests during longer dry spells.

Table 4.10 *Vegetable production statistics for Suriname. Source: LVV, 2020.*

	unit	2014	2015	2016	2017	2018	2019	*Average 2014-2019*
Planted area	ha	1,436	1,399	1,471	1,390	1,442	1,232	*1,436*
Total production	tonne	24,569	24,142	26,839	24,723	26,124	21,877	*24,569*

Crop vulnerabilities

With many different types of vegetables being produced in Suriname, it is hard to provide a comprehensive assessment of the vulnerabilities to climate change. Although focused on conditions in Western Europe, a general overview of the mechanisms of how climate change may affect vegetables, including the effects of elevated CO2 concentrations, can be found in Bisbis et al. (2018). The optimal temperature range, moisture requirements, and tolerance for heat and drought will obviously depend on the species being considered as well as their ecological origin, and details on these for different vegetable crops, insofar as known, may be obtained from (Solankey et al., 2021). Any sudden changes in climatic factors like change in temperature, erratic precipitation can affect the different growth stages of plant growth like pollination, flowering, fruit setting, development and ripening because of the succulent and sensitive nature of vegetables. Increases in soil salinity can also be a major challenge in many vegetable growing areas (Solankey et al., 2021). An overview of the salt tolerance of different types of vegetables can be found in Maas and Grattan (1999)[13].

As an example, we briefly discuss the vulnerabilities of the two largest vegetable crops in Suriname in terms of planted area (asparagus bean) and production (aubergine), not including the "other vegetables" class. Asparagus (or long) beans can be planted in a wide range of climatic conditions but are very sensitive to cold temperatures. The crop can tolerate heat, low rainfall, and arid soils, but the pods become short and fibrous with low soil moisture[14]. Environments with full sunlight attaining daytime temperatures of 25-35°C with nighttime temperatures that stay above 15°C are preferred (National Research Council, 2006).

Aubergine or eggplant is a vegetable grown widely in countries with tropical and subtropical climates. Its demand for water is greatest during the blooming and fruit-forming periods. The growth of aubergine may slow down when the temperature is too high (> 30ºC), when there is not enough water, or in the case of excessive humidity combined with a high temperature (Adamczewska-Sowińska et al., 2016). Aubergine is also moderately sensitive to salinity (Ünlükara et al., 2010). Based on the limited information available for these two vegetable crops, we can already see that the sensitivity to high temperatures is likely to be different, and therefore also their vulnerability to projected climate changes in Suriname.

4.5 Social dimension

A detailed analysis of population aspects in the three districts, including data on indigenous and tribal communities and an assessment of gender inequality, can be found in the 2023 Gender Assessment of Nickerie, Coronie and Saramacca (Tjon Sie Fat, 2023). Here we only include several key findings that are most relevant to the agricultural sector in the study region.

The Gender Assessment Report (GAR) uses population data from the last national census in 2012, supplemented by data from the Multiple Indicator Cluster Survey (MICS) 2018, the Knowledge Attitudes Practices (KAP) Survey 2023 (Groene Groei Suriname, 2023 ref), and other sources. Based on the last census, Nickerie was the most populous district of the three, with an overall population that is higher than in the other two districts combined (Table 4.10).

Table 4.11 *General population statistics in Nickerie, Coronie and Saramacca based on the 2012 national census. Source: General Bureau of Statistics, cited in GAR 2023.*

District	Total population	Men	Women
Nickerie	34,233	17,653 (51.6%)	16,580 (48.4%)
Coronie	3,391	1,747 (51.5%)	1,644 (48.5%)
Saramacca	17,480	9,307 (53.2%)	8,173 (46.8%)

4.5.1 Wealth

The MICS 2018 study provides a wealth index, capturing information on long-term wealth by focusing on households' assets; note the index does not provide data on absolute poverty, current income, or expenditure levels. Table 4.10 shows the percentage of households by wealth index quintile in the three

---

[13] Available from https://www.fao.org/3/Y4263E/y4263e0e.htm

[14] https://plants.usda.gov/DocumentLibrary/plantguide/pdf/pg_viuns2.pdf

districts from poorest to richest. In Nickerie, 10.6% of the households are in the poorest wealth quintile. With just 5.7% in the poorest wealth quintile, Coronie scores better than the other two districts; almost a third of the households interviewed (32.5%) are in the middle wealth quintile. In contrast, more than 20% of the households in Saramacca falls in the poorest wealth quantile. In total, two-thirds of the households interviewed in Saramacca (are found in the poorest, second and middle wealth quintiles.

Table 4.12 *Percentage of households by wealth index quintile. Source: MICS 2018, cited in GAR 2023.*

Region	Poorest	Second	Middle	Fourth	Richest	Total
Nickerie	10.6%	21.2%	26.0%	21.6%	20.7%	100.0%
Coronie	5.7%	28.2%	32.5%	18.5%	15.0%	100.0%
Saramacca	21.6%	24.3%	20.8%	15.5%	17.7%	100.0%

4.5.2 Employment in agriculture

Although known as agricultural districts, the agriculture sector is not the largest employer in any of the three districts in the study area. Based on the 2012 census, agriculture was the second largest employer in Nickerie. Many jobs in the agricultural sector were held by men (88.9%); women hold a very low percentage of the jobs (11.1%). One of the issues here might be that women who do not hold regular jobs in the sector but who do work on the land or undertake other unpaid activities in the sector are probably not counted.

Also, in Saramacca agriculture was the second largest employer in the 2012 census. Most jobs in the agricultural sector were held by men (81.1%); women hold a low percentage of the jobs (18.9%). In both districts decision-making in agriculture is generally male dominated.

Due to its small size, employment sectors in Coronie were combined into different groups. The combined sector of agriculture, forestry, fishery, construction, mining, industry, utilities, and construction was the second largest employer, providing a total of 149 jobs, of which 20.1% held by women. Coronie has a few medium-sized rice farms that are usually family-owned businesses where decisions are taken by the family.

4.5.3 Land ownership

Based on the MICS 2018 survey, agricultural land is generally not owned by individuals (Table 4.12). The percentage of households owning agricultural land ranges from 50% in Coronie to only 15% in Nickerie. However, the 2023 KAP survey showed that about half of the agricultural land used by the respondents in Nickerie was either owned, rented or on loan from a third party; of this, 34% of the land male-owned and 14% female-owned.

Table 4.13 *Percentage of households owning agricultural land, farm animals and livestock, and dwellings. Source: MICS 2018, cited in GAR 2023.*

	Nickerie	Coronie	Saramacca
Owns agricultural land	14.8%	50.6%	47.1%
Owns farm animals/livestock	18.1%	35.6%	23.7%
Owns the dwelling	68.6%	72.3%	73.0%

4.5.4 Agricultural activities

Rice is cultivated in all three districts, but predominantly in Nickerie (43,000 ha) and to a lesser extent in Coronie (7,000 ha) and Saramacca (5,000 ha). Nickerie has the largest rice producing farming area in Suriname with modern processing facilities, research facilities, and rice export companies. The Multipurpose Corantijnpolder Project was introduced in the 1980s to ensure proper irrigation in expand production possibilities. In addition, Nickerie also has several large banana farms.

The Coronie District has a few medium-sized rice farms which are also mechanized. In contrast to the large-scale rice farms in Nickerie, these are usually still family enterprises where decisions are taken by the family. Coronie used to be known for its production of coconut oil, which has been in decline for many years due to a drop in demand. More recently, several small family farms in Coronie have now begun to process sustainable biological and virgin coconut oil. Coronie furthermore produces vegetables and fruits on a small scale on family farms for own use, while surplus is marketed through stalls along the road or through contacts in Paramaribo.

Also in Saramacca there are some small and medium-sized rice farms. The size of the farms determines the scale of mechanization. In addition, there is a large banana farm and several small farms that produce bananas. Saramacca is furthermore known for commercial vegetable production, usually on small and medium-sized, partially mechanized farms, often with mixed produce. Most of the commercial production of these small and medium-sized farms is for local and national consumption. In more recent decades some of the larger farms have started to produce for export as well. According to statistics from the Ministry of Agriculture, a significant proportion of the peanut production in Suriname takes place in Saramacca as well.

4.5.5 Indigenous and tribal communities

There are three indigenous villages in Nickerie, and four indigenous communities and two small Maroon communities in Saramacca. These communities are not engaged in planting large-scale commercial crops, but rely on rain-fed subsistence agriculture, fishing and hunting instead. Traditional food crops such as cassava, bananas, other root crops and limited kinds of vegetables are primarily grown for own use, but surplus produce is sometimes sold to outsiders. There are no indigenous and tribal Maroon communities in Coronie.

4.6 Vulnerability and risk assessment

In this chapter we have looked at a number of factors relevant to the vulnerability of the agricultural sector in the study area. Although detailed information and quantitative data are missing in many cases, a number of preliminary conclusions may be drawn about the key climate risks to the four specific crops of interest.

First of all, based on the climate scenarios presented in Chapter 3, we can look at the climate conditions at various thresholds relevant to the crops of interest (Table 4.13). Based on this summary, we can conclude that the climate risks remain very low to crops such as rice and bananas under scenario SSP1-2.6. Under the high emission scenarios, the risks to production increase throughout the century, and more rapidly so under SSP5-8.5. The projected increase in the number of very hot days and the projected decline in annual rainfall may become limiting factors to rice and banana in particular by 2071-2100.

Table 4.14 *Climatic conditions relevant to crop production in the ISIMIP climate projections for three different time horizons. The values given are based on the average across the five climate models (and averaged over 30 years); the values in brackets denote the minimum and maximum value across the multimodel ensemble.*

Climatic condition	**2021-2050**		**2041-2070**		**2071-2100**	
SSP1-2.6						
Nr of days with Tmax > 35ºC	13.7	(2.5 - 39.6)	19.9	(4.5 - 57.1)	16.3	(2.7 - 53.1)
Nr of days with Tmax > 38ºC	0.2	(0.0 - 0.9)	0.3	(0.0 – 0.9)	0.3	(0.0 – 1.3)
Mean annual rainfall	1714	(1625 – 1751)	1702	(1577 - 1773)	1657	(1579 – 1742)
Nr of months with rainfall below 60 mm	1	(0 – 2)	0	(0-3)	1	(0-4)
SSP3-7.0						
Nr of days with Tmax > 35ºC	18.7	(4.9 - 59.1)	51.8	(18.5 - 137.2)	152.2	(67.8 - 295.1)
Nr of days with Tmax > 38ºC	0.3	(0.0 - 1.3)	2.1	(0.0 - 10.4)	22.8	(0.0 - 73.9)
Mean annual rainfall	1574	(1467 - 1776)	1466	(1414 - 1515)	1306	(1209 - 1493)
Nr of months with rainfall below 60 mm	0	(0-5)	1	(0-6)	0	(0-7)
SSP5-8.5						
Nr of days with Tmax > 35ºC	24.2	(9.7 - 59.6)	74.7	(33.0 - 171.4)	198.9	(97.3 - 338.6)
Nr of days with Tmax > 38ºC	0.1	(0.0 - 0.6)	4.6	(0.0 - 19.8)	53.0	(0.2 - 155.6)
Mean annual rainfall	1596	(1514 - 1649)	1442	(1353 - 1514)	1259	(1123 - 1344)
Nr of months with rainfall below 60 mm	0	(0-5)	2	(0-6)	4	(0-8)

Rice:

- High temperatures in excess of 35ºC or 38ºC may become a limiting factor to rice production for a significant part of the year, but only under the high emission scenarios and in the second half of the century;
- A decline in the annual rainfall amount could become a constraint to rainfed rice systems, again in particular under the high emission scenarios and in the second half of the century. However, a simple estimate of the potential freshwater supply from upstream areas suggests that sufficient water should be available for irrigation even in dry years, provided the appropriate infrastructure and water management is in place and maintained;
- Most rice production in Suriname takes place in low-lying areas in Nickerie. These areas may be exposed to coastal and fluvial inundation, salt water intrusion and salinisation as the sea level rises. The projected sea level rise is relatively modest until the middle of the century (0.2-0.3m, see Section 3.6) but will continue thereafter, even in low-emission scenarios. Rice is generally seen as a salt-sensitive crop. However, without further detailed data and analysis it is hard to quantify these effects;
- Nickerie is also the most populous of the three districts in the study area, with agriculture being the second largest employer in Nickerie. This suggests human exposure to climate risks in the agricultural sector will also be the largest in Nickerie.

Bananas:

- As for rice, high maximum temperatures may become a constraint for banana production by the end of the century under the high emission scenarios, with the number of very hot days (maximum temperature of 35ºC or more) rising to above 150 days per year on average;
- Rainfall may also become a limiting factor under the high emission scenarios, especially in dry years, unless irrigation is applied more widely;
- We found no evidence for wind damage to become a limiting factor in the future, however climate projections of changes in the occurrence and wind speeds during gusts are missing;
- Little is know about the risk of diseases under climate change;
- Banana is seen as sensitive to the effects of salinisation. Detailed information about banana production areas is required to evaluate whether these areas are vulnerable to salinisation going into the future.

Coconut:

- As coconut can grow in climates with a mean annual temperature between 21 and 30ºC and a mean maximum temperature of the hottest month below 37ºC, it appears less vulnerable to the projected future

climate conditions than rice or banana, even in the high emission scenarios. Extended dry periods (less than 40 mm of rainfall per month) may diminish yields although the palms themselves will survive;
- Coconut is also relatively tolerant of saline soils, suggesting it is also less vulnerable to salinisation effects due to sea level rise;
- Coconut is, however, sensitive to waterlogging within 1m of the surface and will not survice more than 2 weeks of surface water logging. Detailed information about coconut production areas is required to evaluate whether water logging constitutes a significant risk in the future.

Mixed vegetables:
- With many different types of vegetables being produced in Suriname, it is not possible to provide a general assessment of the vulnerabilities to climate change. The optimal temperature range, moisture requirements, and tolerance for heat and drought depend on the species being considered;
- Asparagus (or long) bean, the largest vegetable crop in Suriname in terms of planted area (asparagus bean), can grow in a wide range of climate conditions and is tolerant to heat and low rainfall;
- Aubergine, the largest vegetable crop in terms of production, may suffer from growth limitations when temperatures are above 30ºC (which happens in all climate scenarios) or when there is not enough water available. Aubergine is also moderately sensitive to salinity;
- Most commercial vegetable production takes place in Saramacca, which is, when looking at the wealth index, poorer than the other two districts. This could mean the population of Saramacca is more vulnerable to any climate impacts on vegetable crop yields.

5 Mitigation options and potential for low emission development pathways

5.1 Introduction

As discussed in the previous chapters, climate risks in the study areas of Nickerie and Coronie-Saramacca include higher temperatures, sea level rise and, under high emission scenarios and in the second half of the century, a decline in the annual rainfall. In recent decades, an increase in heavy rainfall days and more generally in rainfall in the drier months has been causing problems for farmers in the region, as the terrain needs to be dry for harvesting. The low elevation of most agricultural areas in the three districts makes the sector vulnerable to saltwater intrusion and flooding.

There are many potential adaptation options available for existing agricultural systems, often variations of existing weather and (current) climate risk management (Howden et al., 2007). However, adaptation options that might be considered at a food systems or national level, such as moving crop production to different regions, may well be different from adaptation measures that can be taken at farm level. The discussion on prevention of salinity versus the adaptation to salinity is a widespread question that lives in the global community. However, in this chapter, we focus primarily on agricultural practices that can be implemented by individual farmers.

When discussing climate adaptation in agriculture, it is worth keeping the IPCC risk framework (Figure 2.1) in mind. Climate risks can be reduced not only by reducing the hazards (through climate mitigation) or exposure (for example by moving to different areas or enhancing field drainage), but also by reducing the vulnerability. This includes the vulnerability of the crops itself (for example by switching to salt-tolerant crops) but also the vulnerability of the farmers – for example, by introducing crop insurance schemes. The scope of adaptation in agriculture is, in other words, very broad. In this chapter we focus on adaptation measures that could be implemented at farm level, and more systematic changes in the food system fall outside the scope of this report.

Finally, it is worth remembering that the agricultural sector is not only affected by climate, but also a major driver of climate change. In considering adaptation options, it is therefore also necessary to look at opportunities for climate mitigation.

5.2 Potential adaptation options

The following brief overview of adaptation options in agriculture is based on the scientific literature as well as experiences in countries with a similar setting (such as Bangladesh).

5.2.1 Adaptation options for saltwater intrusion

There are a few strategies that can improve soil health and lessen the effects of saltwater intrusion in the short term (USDA, 2020). However, most of these are not long-term solutions. Farmers can remove excess salt from the soils through irrigation. Natural rainfall events will also help with this process. Farmers can also add gypsum to decrease excess salt in the soil and use compost and manure products with low salt levels. Cover crops, which help salt to leach down through the soil by increasing the flow of water, can also be grown on affected fields for one season. Farmers may be able to continue generating income on land impacted by saltwater intrusion by planting different crops that are salt and/or flood tolerant. Research may be required to determine how well different crop varieties can withstand salty soils and periodic flooding. Ideally, these crops could be planted and harvested with equipment that farmers already have.

Another tactic for adapting to saltwater intrusion is to add in conservation practices on or next to salt impacted fields. These practices can provide wildlife habitat, protect, and improve water quality, and may become income sources too. Some types of grasses that grow well on saline sites could be grown as a value-added biomass crop for mulch, animal/poultry house bedding, or biofuel. Eventually, if even fields used to grow salt tolerant crops become no longer farmable because the soil is too saline or wet, farming activities may need to be moved to different areas.

In summary, the following options are available to reduce the effects of salinisation:

- **Water management:** Applying a leaching fraction to the irrigation requirement and blending water for irrigation application (Peragón et al.,2018). With proper water management, salinization can be dealt with. Drainage is a vital part. Different kinds of drainage exist: biodrainage, surface drains, subsurface drains, tile drainage, and tubewells or vertical drainage. Sometimes tile drainage frameworks are not fit for expelling excess soil water. In such circumstances, mole drainage should be utilized (Singh,2021).
- **Improving soil health:** To make the soil in general more resilient to increased salinization, improvement in structure and health is a way of dealing with the effects and prevent to a certain extent the salinization. Techniques that can be applied are e.g., agro-forestry and conservation agriculture which are a mix of several soil strategies.
- **Crop selection:** Farmers can select rice varieties that are more tolerant of saltwater intrusion. Some rice varieties have been developed specifically for cultivation in saline environments, which can be more successful in such conditions for various geographical regions (i.e., Nhung et al., 2019).
- **Use of biochar:** Biochar is a type of charcoal that can be used to improve soil quality and reduce soil salinity. It can also improve crop yields and reduce greenhouse gas emissions. Biochar can be produced from agricultural waste or other organic materials and applied to rice fields to help mitigate saltwater intrusion (Sun et al., 2020).
- **Soil modification:** Using gypsum or lime can reduce soil salinity by replacing sodium ions with calcium ions. This will improve soil structure and increase water-holding capacity, allowing rice plants to access water more easily (Mukhopadhyay et al., 2021; Zhu et al., 2020). The feasibility of this and other adaptation options in the Suriname context, including the required operating costs, will need to be assessed.

5.2.2 Adaptation options for flooding

The following adaptation options exist to deal with more frequent flooding and water logging problems:

- **Improve water management:** Proper drainage systems could support by draining existing floods and decrease the longevity of water logging. Alternatively, implement water harvesting principles where water can be stored in larger storages above or underground (both have pros and cons).
- **Site selection:** Farmers, when possible, could choose fields with well-drained soils and avoid low-lying areas prone to flooding. This strategy might be difficult to achieve as the coastal areas of Nickerie and Coronie do not exhibit significant variation in height to make a substantial difference in flooding potential. On the other hand, even in flat areas small differences in microtopography (< 1m) and soil type can already make a difference.
- **Early maturing rice varieties:** Early maturing rice varieties with a shorter growing season can be planted to avoid flood damage. These varieties are more likely to mature before the onset of heavy rains and flooding (Rahman & Saha, 2008). These varieties may have as drawbacks that the yield is not as big or quality not as good as in conventional crops.
- **Raised beds:** Raised beds can be constructed in fields to elevate the rice plants and protect them from flooding. The beds can be made of soil or other materials like bamboo (Singh et al., 2009). This is a typical technique used in fields in Bangladesh to deal with salinity.
- **Crop diversification:** Farmers can diversify their crops to reduce the risk of flood damage to rice crops. Other more flood-resistant crops, such as water chestnuts or water spinach, can be grown alongside rice (Burchfield & Tozier de la Poterie, 2018). The practicalities of crop diversification in the Suriname environment will need to be assessed.
- **Improve the soil structure:** In this way the buffering capacity for soils increases and the flooding risks could decrease. Practices such as reduced tillage or no-till farming help minimize soil disturbance. By reducing or eliminating plowing or tilling, the natural structure of the soil is preserved, including the arrangement of soil particles, aggregates, and pore spaces. This allows for improved water infiltration, root

penetration, and nutrient availability. Other practices such as adding organic matter or applying mulch may also improve the soil structure.

At regional level, flood protection measures may also reduce the exposure of farms to flooding. For example, the construction of the Nickerie Sea Wall that extends from the mouth of the Nickerie River to the Corantijn River has reduced flooding and saltwater intrusion into the area.

5.2.3 Adaptation options for sustainable food production in high-risk areas

- **Conservation agriculture:** Conservation agriculture is an approach to farming that aims to promote sustainable and environmentally friendly agricultural practices. It involves a set of principles and practices designed to protect and improve soil health, enhance water management, and minimize the use of external inputs, such as synthetic fertilizers and pesticides. Conservation agriculture is based on three main principles: minimum soil disturbance, permanent soil cover, and crop rotation and diversification (see below).
- **Diversification of crops:** Growing a variety of crops can help reduce the risk of crop failure due to extreme weather events or diseases. Diversification also promotes soil health and reduces the reliance on a single crop, enhancing overall food security.
- **Water-efficient irrigation techniques:** In dry periods or years, adopting water-efficient irrigation techniques like drip irrigation or micro-sprinklers can significantly reduce water usage in agriculture. These methods deliver water directly to the plant roots, minimizing wastage and maximizing water efficiency.
- **Agroforestry:** Agroforestry systems, which combine trees with crops or livestock, can provide multiple benefits such as shade, nutrient cycling, and improved soil fertility.
- **Rainwater harvesting and storage:** Collecting rainwater during the wet season and storing it in reservoirs or tanks can provide a valuable water source during dry periods. This water can be used for irrigation, helping maintain agricultural production during water scarcity.
- **Soil conservation practices:** Implementing certain soil conservation practices, such as cover cropping and mulching, helps improve soil health. These practices enhance water retention, nutrient availability, and overall resilience of the agricultural system.
- **Use of drought-tolerant and resilient crop varieties:** Planting crop varieties that are adapted to high-risk conditions, such as drought-tolerant or disease-resistant varieties, can improve the chances of successful harvests. These varieties are specifically bred to withstand challenging environmental conditions.
- **Crop rotation and intercropping:** Implementing crop rotation and intercropping techniques can optimize resource use, improve soil fertility, and reduce pest and disease pressures. These practices help maintain productivity while minimizing the risk of crop failure.
- **Knowledge sharing and capacity building:** Promoting information sharing, training programs, and capacity building initiatives among farmers in high-risk areas can help disseminate best practices and innovative techniques. This empowers farmers to adapt to changing conditions and make informed decisions regarding sustainable food production.

5.3 Options for low emission agriculture

In addition to measures to adapt to changing climate and environmental conditions, several methods have been identified in the literature that can help reducing the emissions associated with agriculture. Several mitigation options that could be relevant to agricultural practices in the study area are summarised below.

- **Alternate wetting and drying (AWD) technique:** This involves intermittently drying and re-flooding the rice field instead of continuously flooding it. This reduces methane emissions from the soil and can reduce water usage by up to 30% (Ishfaq et al., 2020). This practice creates aerobic conditions in the soil, reducing methane production while maintaining crop productivity.
- **Organic amendments:** Using organic amendments such as compost, green manure, and crop residue in the soil can increase soil organic matter content, improve soil health, and reduce greenhouse gas emissions (Haque et al., 2021).
- **Controlled-release and enhanced efficiency fertilizers:** Using controlled-release fertilizers that slowly release nutrients to plants can reduce nitrogen losses, improve nutrient uptake by plants and minimize

nitrous oxide emissions. Enhanced efficiency fertilizers are fertilizers that are formulated to improve nutrient use efficiency by reducing nutrient losses and enhancing nutrient availability to plants. Examples include urease and nitrification inhibitors, which can reduce ammonia volatilization and nitrous oxide emissions, respectively. Other improved nutrient management techniques include implementing precision agriculture techniques, such as using soil testing and nutrient management plans; split application where the application of N fertilizer is split into multiple smaller doses throughout the growing season; and adjusting the timing of fertilizer application based on crop needs.
- **Integrated Pest Management (IPM):** IPM is a method that utilizes natural predators and biopesticides to control pests and diseases instead of synthetic pesticides. This can reduce pesticide use emissions and minimize environmental damage.
- **Mechanization:** The use of modern farming equipment such as laser land levellers, direct seeding machines, and transplanters can reduce the need for water and labour, as well as reduce emissions from diesel fuel (Hegazy et al., 2013).
- **Reduced tillage:** Reduced tillage involves minimizing the disturbance of the soil and leaving some crop residue on the soil surface. This can reduce soil erosion, improve soil health, and reduce carbon dioxide emissions.
- **Zero tillage:** Zero tillage involves planting crops without any prior tillage. This can reduce greenhouse gas emissions by preserving soil organic matter and reducing soil erosion.
- **Use of catch crops:** Catch crops, such as legumes or grasses, can be planted in between rice cycles crops to help preserve soil organic matter and reduce nitrous oxide emissions (Quintarelli et al.,2022).
- **Renewable energy use:** Adoption of renewable energy sources on farms, such as solar panels, wind turbines, or biomass digesters, can replace fossil fuel-based energy sources. Using renewable energy for farm operations, such as powering machinery, irrigation pumps, or processing facilities, helps reduce greenhouse gas emissions associated with agricultural activities.
- **Carbon farming:** Practices such as planting cover crops, restoring wetlands, implementing agroforestry systems, or adopting regenerative agriculture approaches promote carbon sequestration and contribute to low emission agriculture. These practices enhance soil organic carbon levels and mitigate climate change.

5.4 Regional Specific Adaptation Strategies

In the regions of Nickerie, Coronie, and Saramacca, farmers have been adapting to climate change with varying strategies. These options have been shared with the communities of Coronie, Saramacca and Nickerie. In Annex 1 the outcomes of the sessions have been shared. The following points can be mentioned when analyzing the outcomes of the consultation workshops.

Common adaptation strategies of the three regions:
- **Weather Extremes Response:** All regions are adjusting agricultural practices to cope with extreme weather, focusing on enhanced water management and soil cultivation.
- **Need for Training and Information:** There is a unanimous need across these regions for more education on adaptive agricultural techniques and disease control.

Differences between the regions:
- **Salinity Management:** Nickerie's strategy concentrates on salinity control along the Nickerie river through measures like the awarasluis rehabilitation, whereas Coronie emphasizes poldering and irrigation management.
- **Coastal Protection:** Unique to Coronie is the emphasis of the stakeholders on coastal protection projects.
- **Financial Support:** Both Nickerie and Coronie stress the need for accessible financing solutions, a point that is less emphasized in Saramacca.
- **Cultivation Methods:** While greenhouse cultivation is highlighted in Coronie and Saramacca, Nickerie focuses on adjustments in traditional farming and rice cultivation.
- **Pollination and Heat Challenges:** Exclusive to Saramacca is the focus on overcoming pollination issues due to high temperatures.
- **Water Management:** The use of piped water for irrigation to counteract salinity is specifically mentioned in Saramacca.

6 Conclusions and recommendations

- Based on an analysis of the most recent generation of climate projections in the region, key climate change hazards for the agricultural sector in the study area of Nickerie and Coronie-Saramacca include an increase in the number of hot days and nights, a decrease in the mean annual precipitation, and a rise in sea level with the associated hazards of saltwater intrusion and coastal inundation. Changes in these climatic conditions are more prominent under the high emission scenarios and in the second half of the century, although sea level is projected to rise by 0.5 (0.2 – 0.8) m by the end of the century even in the climate mitigation scenario SSP1-2.6.
- When planning climate adaptation measures, it is therefore important to establish a time horizon for when these measures need to be implemented and operated. Until the middle of the century, changes in many of the climate indicators presented in Chapter 3 are relatively moderate. Indeed, in recent years rice farmers in Nickerie have had more problems with exceptionally wet conditions as opposed to the projected drying in the long-term. Short-term trends can be the result from natural climate variability and may deviate from the expected climate change in the long term. It does imply, however, that adaptation measures that farmers may want to take to deal with problems they are facing currently, may well be different from what is required in the longer term.
- Better monitoring, data collection and sharing will allow for a more targeted climate risk analysis supported by better evidence, which is important to avoid maladaptation. This applies not only to the climate conditions, but also the environmental conditions and social aspects.
- Of the four crops of interest, rice and banana seem to be more vulnerable to projected future climate conditions than coconut. Rice production in the low-lying areas of Nickerie in particular may be especially vulnerable to flooding and saltwater intrusion.
- Farmers may be able to adapt to the long-term drying trend that is projected in the high-emission scenarios by benefiting from the freshwater supply from the upstream areas, provided the appropriate infrastructure and water management practices are in place and being maintained.
- A range of adaptation options can be found in the literature to deal with the climate risks identified in this report. However, it is of vital importance to understand the local context. Working with farmers and understanding which options are most viable and which options have been tried is key.
- The trade-offs need to be clearly identified when changing anything in the agricultural production system as they are not all are beneficial. For example, when changing water management practices, a side effect could be that it increases the leaching fraction, leading to a higher water demand. This might be undesirable in dry circumstances. Therefore, a system approach is promoted.
- Dealing with salinization is not achieved by implementing a single measure, as it touches upon various domains. A package of measures will be required to deal with salinisation problems. For instance, not only the water management should be improved but at the same time the soil health should be improved as well.
- It is important to carefully design and evaluate adaptation strategies to minimize the risk of maladaptation. This requires considering multiple factors and risks, including the local context, stakeholder engagement, scientific knowledge, and an understanding of the complex interactions between social, economic, and ecological systems. A comprehensive and iterative approach to adaptation planning is crucial to avoid unintended negative outcomes and foster resilient and sustainable responses to climate change.

References

Adamczewska-Sowińska K., Krygier M. & Turczuk J. (2016): The yield of eggplant depending on climate conditions and mulching. Folia Horticulturae, Vol.28 (Issue 1), pp. 19-24. https://doi.org/10.1515/fhort-2016-0003.

Barlow, P.M. (2003): Ground water in fresh water-salt water environments of the Atlantic Coast. U.S. Geological Survey Circular 1262.

Bisbis, M.B., N. Gruda & M. Blanke (2018): Potential impacts of climate change on vegetable production and product quality – A review. Journal of Cleaner Production, 170, 1602-1620, doi:10.1016/j.jclepro.2017.09.224.

Boonstra, J., H.P. Ritzema, W. Wolters, R.J. Oosterbaan, L. Res, A.M. van Lieshout, et al. (2002): Research on the control of waterlogging and salinization in irrigated agricultural lands: recommendations on waterlogging and salinity control based on pilot area drainage research. Karnal (India) / Wageningen (The Netherlands): CSSRI / Alterra-ILRI, 100pp.

Borges, A.L., L. da Silva Souza, A.M. Gomes Oliveira (2007): Banana. Chapter 2 in A.E. Johnston (Ed): Tropical Fruits of Brazil. IPI Bulletin No. 18, Horgen, Switzerland.

Bunting, P.; Rosenqvist, A.; Hilarides, L.; Lucas, R.M.; Thomas, N.; Tadono, T.; Worthington, T.A.; Spalding, M.; Murray, N.J.; Rebelo, L.-M. (2022): Global Mangrove Extent Change 1996–2020: Global Mangrove Watch Version 3.0. Remote Sens. 14, 3657, doi:10.3390/rs14153657.

Burchfield, E.K. & A. Tozier de la Poterie (2018): Determinants of crop diversification in rice-dominated Sri Lankan agricultural systems. Journal of Rural Studies, 61, 206-215, doi: 10.1016/j.jrurstud.2018.05.010.

Calberto, G., C. Staver and P. Siles. (2015): An assessment of global banana production and suitability under climate change scenarios, In: Climate change and food systems: global assessments and implications for food security and trade, Aziz Elbehri (editor). Food Agriculture Organization of the United Nations (FAO), Rome.

Castellanos, E., M.F. Lemos, L. Astigarraga, N. Chacón, N. Cuvi, C. Huggel, L. Miranda, M. Moncassim Vale, J.P. Ometto, P.L. Peri, J.C. Postigo, L. Ramajo, L. Roco, and M. Rusticucci, 2022: Central and South America. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1689–1816, doi:10.1017/9781009325844.014.

Cauthen, J., D. Jones, M.K. Gugerty & C. L. Anderson (2013): Banana and Plantain Value Chain: West Africa. EPAR Brief No. 239, doi:10.21955/gatesopenres.1114922.1.

Chan, E. & C.R. Elevitch (2006): Cocos nucifera (coconut). In: C.R. Elevitch (Ed.): traditional trees of Pacific Islands: their culture, environment, and use. Permanent Agriculture Resources, 816 pp, available from https://agroforestry.org/projects/traditional-tree-initiative.

Delju, Amir; Dilley, Maxx; Gallo, Ilaria; Horsburgh, Kevin; Ousman Jarju, Pa; Patel, Urvaksh D. (2022): Developing the Climate Science Information for Climate Action. Geneva: WMO, ISBN:978-92-63-11287-3

Delvoye, K., Parahoe, M., Libretto, H. (2018). Suriname: An Exposed Interior. In: Ungar, M. (eds) The 21st Century Fight for the Amazon. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-319-56552-1_8

Fan, Y., H. Li, G. Miguez-Macho (2013): Global patterns of groundwater table depth, Science, 339 (6122): 940-943, doi:10.1126/science.1229881.

Fan, Y., G. Miguez-Macho, E.G. Jobbágy, R.B. Jackson, C. Otero-Casal (2017): Hydrologic regulation of plant rooting depth, Proceedings of the National Academy of Sciences of the United States of America, Vol 114, No 40, 10572–10577, doi: 10.1073/pnas.1712381114.

FAO. 2015. AQUASTAT Country Profile – Suriname. Food and Agriculture Organization of the United Nations (FAO). Rome, Italy

Greene, R., Timms, W., Rengasamy, P., Arshad, M., Cresswell, R. (2016). Soil and Aquifer Salinization: Toward an Integrated Approach for Salinity Management of Groundwater. In: Jakeman, A.J., Barreteau, O., Hunt, R.J., Rinaudo, JD., Ross, A. (eds) Integrated Groundwater Management. Springer, Cham. https://doi.org/10.1007/978-3-319-23576-9_15.

Groene Groei Suriname (2023): Knowledge Attitudes Practices (KAP) Survey Report on Climate Change in the Agricultural Sector in Suriname, conducted for the project Improving the Capacity of the Ministry of Agriculture of Suriname to build resilience to climate change in the agricultural sector (GCP/SUR/004/GCR).

Haque, M.M.; Datta, J.; Ahmed, T.; Ehsanullah, M.; Karim, M.N.; Akter, M.S.; Iqbal, M.A.; Baazeem, A.; Hadifa, A.; Ahmed, S.; EL Sabagh, A. (2021): Organic Amendments Boost Soil Fertility and Rice Productivity and Reduce Methane Emissions from Paddy Fields under Sub-Tropical Conditions. Sustainability 2021, 13, 3103, doi: 10.3390/su13063103.

Hawker, L., Uhe, P., Paulo, L., Sosa, J., Savage, J., Sampson, C. and J. Neal, J. (2022): A 30 m global map of elevation with forests and buildings removed. Environmental Research Letters, 17(2), 024016, DOI 10.1088/1748-9326/ac4d4f

Hebbar K.B., Arya Santhosh, Abhin P. Sukumar, Neethu P., Ramesh S.V., Selvamani V. (2021): Effect of sea water substitution on growth, physiological and biochemical processes of coconut (Cocos nucifera L.) seedlings—A hydroponic study. Scientia Horticulturae, 280, 109935, doi:10.1016/j.scienta.2021.109935.

Hegazy, R., A. Schmidley, E. Bautista, D. Sumunistrado, M. Gummert, & A. Elepaño (2013): Mechanization in Rice Farming—Lessons Learned from Other Countries. Asia Rice Foundation’s annual rice forum 2013: mechanization in rice farming: status, challenges, and opportunities.

Howden,S.M., J.-F. Soussana, F.N. Tubiello, N. Chhetri, M. Dunlop, & H. Meinke (2007): Adapting agriculture to climate change. PNAS, 104 (50) 19691-19696, doi:10.1073/pnas.07018901.

Hussain, S., Khaliq, A., Ali, B., Hussain, H.A., Qadir, T., Hussain, S. (2019). Temperature Extremes: Impact on Rice Growth and Development. In: Hasanuzzaman, M., Hakeem, K., Nahar, K., Alharby, H. (eds) Plant Abiotic Stress Tolerance. Springer, Cham. https://doi.org/10.1007/978-3-030-06118-0_6

IPCC, 2014: Summary for policymakers. In: Climate Change 2014: Impacts,Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change[Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, doi:10.1017/9781009157896.

IRRI (2007): Water Management. IRRI Knowledge Bank.

Ishfaq, M., M. Farooq, U. Zulfiqar, S. Hussain, N. Akbar, A. Nawaz, S.A. Anjum (2020): Alternate wetting and drying: A water-saving and ecofriendly rice production system. Agricultural Water Management, 241, 106363, doi:10.1016/j.agwat.2020.106363.

Krishnan, P., Ramakrishnan, B., Raja Reddy, K., Reddy, V.R. (2011): High-Temperature Effects on Rice Growth, Yield, and Grain Quality. Advances in Agronomy 111, 87-206, https://doi.org/10.1016/B978-0-12-387689-8.00004-7.

Lange, S. (2021): ISIMIP3b bias adjustment fact sheet. Available from https://www.isimip.org/documents/413/ISIMIP3b_bias_adjustment_fact_sheet_Gnsz7CO.pdf

LVV (2020): Agrarische Statistieken 2014-2019. Suriname: Ministerie van Landbouw, Veeteelt en Visserij.

Maas, E. V., & Grattan, S. R. (1999). Crop yields as affected by salinity, agriculturaldrainage, Agronomy Monograph No. 38, R. W. Skaggs and J. van Schilfgaarde,eds., ASA/CSSA/SSSA, Madison, Wisc., 55–108.

Mohammed,R. & M. Scholz (2018): Critical review of salinity intrusion in rivers and estuaries. Journal of Water and Climate Change 9 (1), 1–16, doi:10.2166/wcc.2017.334

Muis, S., M. Irazoqui Apecechea, J.A. Álvarez, M. Verlaan, K. Yan, J. Dullaart, J. Aerts, T. Duong, R. Ranasinghe, D. le Bars, R. Haarsma, M. Roberts, (2022): Global sea level change indicators from 1950 to 2050 derived from reanalysis and high resolution CMIP6 climate projections. Copernicus Climate Change Service (C3S) Climate Data Store (CDS). DOI: 10.24381/cds.6edf04e0 (Accessed on 09-May-2023).

Mukhopadhyay, R., B. Sarkar, H.S. Jat, P.C. Sharma, N.S. Bolan (2021): Soil salinity under climate change: Challenges for sustainable agriculture and food security. Journal of Environmental Management, 280, 111736, doi:10.1016/j.jenvman.2020.111736.

Muñoz Sabater, J. (2019): ERA5-Land hourly data from 1950 to present. Copernicus Climate Change Service (C3S) Climate Data Store (CDS). DOI: 10.24381/cds.e2161bac (Accessed on 09-May-2023).

Nagaraj, D., Proust, E., Todeschini, A., Rulli, M. C., & D'Odorico, P. (2021). A new dataset of global irrigation areas from 2001 to 2015. Advances in Water Resources, 152, 103910.

National Research Council. 2006. Lost Crops of Africa: Volume II: Vegetables. Washington, DC: The National Academies Press. https://doi.org/10.17226/11763.

Nhung,T.T., P.L. Vo, V.V. Nghi, & H.Q. Bang (2019): Salt intrusion adaptation measures for sustainable agricultural development under climate change effects: A case of Ca Mau Peninsula, Vietnam. Climate Risk Management 23, 88-100, doi:10.1016/j.crm.2018.12.002.

Pekel, J.-F., Cottam, A., Gorelick, N. & Belward, A. S. High-resolution mapping of global surface water and its long-term changes. Nature 540, 418–422 (2016).

Peragón, J. M., Pérez-Latorre, F. J., Delgado, A., & Tóth, T. (2018). Best management irrigation practices assessed by a GIS-based decision tool for reducing salinization risks in olive orchards. Agricultural Water Management, 202, 33-41.

Qadir, M., Quillérou, E., Nangia, V., Murtaza, G., Singh, M., Thomas, R. J., ... & Noble, A. D. (2014, November). Economics of salt-induced land degradation and restoration. In Natural resources forum (Vol. 38, No. 4, pp. 282-295).

Quintarelli, V., Radicetti, E., Allevato, E., Stazi, S. R., Haider, G., Abideen, Z., ... & Mancinelli, R. (2022). Cover Crops for Sustainable Cropping Systems: A Review. *Agriculture*, *12*(12), 2076.

Rahman, Md. R. & S. K. Saha (2008): Remote sensing, spatial multi criteria evaluation (SMCE) and analytical hierarchy process (AHP) in optimal cropping pattern planning for a flood prone area, Journal of Spatial Science, 53:2, 161-177, DOI:10.1080/14498596.2008.9635156

Ritzema, H. P. (2014). Main Drainage Systems. Delft: UNESCO-IHE, 2014. 42 p.

Santana Júnior, E.B., E.F. Coelho, K.S. Gonçalves, J.L. Cruz (2020): Physiological and vegetative behavior of banana cultivars under irrigation water salinity. Rev. bras. eng. agríc. ambient. 24 (2), doi:10.1590/1807-1929/agriambi.v24n2p82-88

Saud, S., Wang, D., Fahad, S., Alharby, H.F., Bamagoos, A.A., Mjrashi, A., Alabdallah, N.M., AlZahrani, S.S., AbdElgawad, H., Adnan, M. (2022): Comprehensive Impacts of Climate Change on Rice Production and Adaptive Strategies in China. Frontiers in Microbiology 13.

Singh, Y., E. Humphreys, S.S. Kukal, B. Singh, Amanpreet Kaur, S. Thaman, A. Prashar, S. Yadav, J. Timsina, S.S. Dhillon, N. Kaur, D.J. Smith, P.R. Gajri (2009): Crop performance in permanent raised bed rice–wheat cropping system in Punjab, India. Field Crops Research, 110 (1), 1-20, doi:10.1016/j.fcr.2008.06.009.

Singh, A. (2021). Soil salinization management for sustainable development: A review. Journal of environmental management, 277, 111383.

Solankey, S.S., Kumari, M., Akhtar, S., Singh, H.K., Ray, P.K. (2021): Challenges and Opportunities in Vegetable Production in Changing Climate: Mitigation and Adaptation Strategies. In: Solankey, S.S., Kumari, M., Kumar, M. (eds) Advances in Research on Vegetable Production Under a Changing Climate Vol. 1. Advances in Olericulture. Springer, Cham. https://doi.org/10.1007/978-3-030-63497-1_2

Solaun, K., Alleng, G., Flores, A., Resomardono, C., Hess, K., & Antich, H. (2021). State of the Climate Report: Suriname.

STOWA (2020): Deltafact: Zoutindringing. Available from https://www.stowa.nl/deltafacts/zoetwatervoorziening/verzilting/zoutindringing

Sun, Yp., Yang, Js., Yao, Rj. et al. (2020): Biochar and fulvic acid amendments mitigate negative effects of coastal saline soil and improve crop yields in a three year field trial. Sci Rep 10, 8946, doi:10.1038/s41598-020-65730-6.

Tjon Sie Fat, A.L. (2023): Gender Assessment Nickerie, Coronie and Saramacca and Recommended Gender Plan for the Ministry of Agriculture of Suriname. Report prepared for Readiness project of GCF; Improving the capacity of the Ministry of Agriculture of Suriname to build resilience to climate change in the agriculture sector (GCP/SUR/004/GCR).

Ünlükara, A., Kurunc, A., Kesmez, G. D., Yurtseven, E., & Suarez, D. L. (2010): Effects of salinity on eggplant (Solanum melongena L.) growth and evapotranspiration. Irrigation and Drainage: The Journal of the International Commission on Irrigation and Drainage, 59(2), 203-214.

USDA (2008): Soil Quality Indicators: Bulk Density. USDA Natural Resources Conservation Service. Available from https://cafnr.missouri.edu/wp-content/uploads/2016/09/bulk-density.pdf

USDA (2020): Saltwater intrusion, a growing threat to coastal agriculture. USDA factsheet available from https://www.climatehubs.usda.gov/sites/default/files/SaltwaterIntrusion_April2020_508.pdf.

Ward, P.J., H.C. Winsemius, S. Kuzma, M.F.P. Bierkens, A. Bouwman, H. de Moel, A. Díaz Loaiza, et al. 2020. "Aqueduct Floods Methodology." Technical Note. Washington, D.C.: World Resources Institute. Available online at: www.wri.org/publication/aqueduct-floods-methodology.

Warrence, N. J., Bauder, J. W., & Pearson, K. E. (2002). Basics of salinity and sodicity effects on soil physical properties. Departement of Land Resources and Environmental Sciences, Montana State University-Bozeman, MT, 1-29.

Wassmann, R., S.V.K. Jagadish, S. Heuer, A. Ismail, E. Redona, R. Serraj, R.K. Singh, G. Howell, H. Pathak, K. Sumfleth (2009a): Climate Change Affecting Rice Production: The Physiological and Agronomic Basis for Possible Adaptation Strategies, Chapter 2 in D.L. Sparks (Ed): Advances in Agronomy, 59-122. Academic Press, doi: 10.1016/S0065-2113(08)00802-X.

Wassmann, R., S.V.K. Jagadish, K. Sumfleth, H. Pathak, G. Howell, A. Ismail, R. Serraj, E. Redona, R.K. Singh, S. Heuer (2009b): Regional Vulnerability of Climate Change Impacts on Asian Rice Production and Scope for Adaptation. Chapter 3 in D.L. Sparks (Ed): Advances in Agronomy, 59-122. Academic Press, doi:10.1016/S0065-2113(09)01003-7.

Zhu, H., J. Yang, R. Yao, X. Wang, W. Xie, W. Zhu, X. Liu, Y. Cao, J. Tao (2020): Interactive effects of soil amendments (biochar and gypsum) and salinity on ammonia volatilization in coastal saline soil. CATENA, 190, 104527, doi:10.1016/j.catena.2020.104527.

Annex 1 Consultation workshops

Consultatie Perceptie van boeren in Nickerie over Klimaatverandering
Datum: 6 november 2023
Lokatie: Vergaderzaal Distrikts commissariaat Nickerie

Vraag 1: Wat betekent klimaatverandering voor u?
Samenvatting: De boeren hebben een negatieve impact van klimaatverandering op hun gewasopbrengst ervaren, vooral in de afgelopen vier jaar met abnormaal hoge regenval. Dit leidde tot uitdagingen in grondbewerking, vooral voor kleine boeren zonder toegang tot machines. De opbrengsten zijn gedaald, met een verlies van 40% door wateroverlast, 30% door rattenplagen, en ongespecificeerde verliezen door droogte tussen 2021-2023. Ze wijzen op wateroverlast, droogte, en rattenplagen als oorzaken van deze veranderingen. De gevolgen voor hun landbouwactiviteiten omvatten opbrengstderving, minder irrigatiewater, verminderde inzaai, en verhoogde verliezen.

Vraag 2: Heeft u zich al aangepast aan klimaat verandering?
Samenvatting: In reactie op klimaatverandering hebben de boeren diverse aanpassingen doorgevoerd. Bij wateroverlast in 2020 hebben ze samengewerkt voor het onderhoud van de natte infrastructuur en overheidssteun gezocht voor extra waterpompen. Tijdens droogteperioden in 2021-2023 lag de focus op het onderhoud van irrigatie-infrastructuur en het zuinig omgaan met water. Ze zijn van plan hun management aan te passen, zoals het aanpassen van werktijden om arbeiders te beschermen, en het werken in shiftverband. De effecten van veel neerslag omvatten rattenplagen, slechte opbrengsten, en negatieve invloed op gewasgroei.

Vraag 3 Heeft u problemen met zoute grond en water?
Samenvatting: Boeren hebben verzilting gemerkt, vooral langs de Nickerie rivier. Dit probleem doet zich het meest voor tijdens droge seizoenen, wanneer zoutwater verder landinwaarts dringt. Ze zien aanhoudende droogte en klimaatverandering als oorzaken. Verzilting heeft geleid tot een aanzienlijke afname in gewasproductie (20-40% of meer). Momenteel zijn er geen actieve maatregelen tegen verzilting, behalve het niet zaaien op verzilte gronden. Er is een verwachting van toenemende verzilting in de toekomst, mede door zeespiegelstijging en temperatuurstijging.

Vraag 4: Heeft u de rijstbouw al aangepast tegen klimaatverandering? *Nee, maar we zouden rijst kunnen verbouwen die tegen verzilting kan*
Samenvatting: De boeren hebben de rijstteelt nog niet aangepast aan klimaatverandering. Ze overwegen rijstsoorten die bestand zijn tegen verzilting of overschakelen naar hooglandrijst die minder water nodig heeft. Voor deze aanpassingen ontbreekt het hen aan de benodigde technologie. Ze hebben behoefte aan training, expertise, en moderne uitrusting. Er wordt opgemerkt dat een goede werking van waterwegen en waterwerken kan helpen bij het verminderen van de kans op verzilting.

Plenaire opmerkingen:
- dit jaar is het extreem droog, Bigi Pan meer is opgedroogd
- Als de awarasluis wordt gerehabiliteerd kan kan het zoutwater in de nickerierivier worden teruggeduwd door het zoetwater van het wayambogebied
- In de extreme hitte kan er geen prestaties worden geleverd in het veld
- de produktiviteit is afgenomen, ook de produktie. Boeren moeten heel vroeg het veldop en eerder uit het veld omdat de hitte ondraaglijk wordt. Arbeid van een week duurt nu langer
- De boeren hebben behoefte aan meer informatie/voorlichting
- teelttechnieken moeten worden=aangepast, evenzo de rijstrassen, Adron moet resistente rassen veredelen. De rassen van Adron hebben een goede kwaliteit maar ondervinden veel last van ziekten en plagen
- boeren ervaren dat de regentijden veelnatter zijn dan normaal

- de mindshift dat klimaatverandering een feit is moet nog komen bij boeren
- boeren moeten zich ook aanpassen aan climate change, kleding, veel drinken en zichzelf beschermen, ook op dit gebied is voorlichting nodig
- Gender en rijstteelt: de mannen geven aan dat hun vrouwen een belangrijke rol spelen, ze geven emotionele steun, de problemen van het veld worden gedeeld met de vrouw als de mannen thuis komen van het veld. Samen denken ze na over oplossingen. Vrouwen merken gelijk op aan het gedrag van de mannen als er iets fout gaat in de bedrijfsvoering of op het veld. De rol van de vrouwen, alhoewel niet fysiek, wordt erkend door de mannen. De vrouwen helpen met het bedenken van oplossingen van problemen bij de rijstbouw. Ze geven ook morele steun bij slechte of mislukte oogst. Ze houden ook de financiële administratie bij, mannen geven aan dat de vrouwen daar goed in zijn. Bij gebrek aan inputs in het veld =worden de v=rouwen gebeld om die inputs aan te schaffen
- Vroeger konden boeren bellen naar het meteostation bij het vliegveld van Nickerie voor de weersverwachting. Het station werkt niet meer
- leningen voor de teelt worden verkregen bij lokale banken of bij de molenaars. De molenaars hanteren een hoge rente van 5% per maand, dat is 30% voor 6 maanden.

De minister van landbouw heeft toegezegd te werken aan een rentevoet van 5%/jaar voor leden van coöperaties bij NOVA.

Samenvatting: Dit jaar wordt gekenmerkt door extreme droogte, met effecten zoals het opdrogen van het Bigi Pan meer. Er is een voorstel om de awarasluis te rehabiliteren om verzilting in de Nickerierivier tegen te gaan. Boeren melden een afname in productiviteit en productie door de extreme hitte; werk in het veld wordt beperkt door de ondraaglijke temperaturen. Er is behoefte aan meer informatie en voorlichting over aangepaste teelttechnieken en rijstrassen. Boeren ervaren nattere regentijden dan normaal en moeten hun mindset en aanpak aanpassen aan klimaatverandering, inclusief beschermende maatregelen. De rol van vrouwen in de rijstteelt wordt erkend, vooral in emotionele ondersteuning en financiële administratie. Er zijn uitdagingen met het verkrijgen van accurate weersvoorspellingen en financiering, hoewel er plannen zijn voor betere leningvoorwaarden.

Adaptatiemaatregelen Nickerie

1. **Reactie op Weerextremen:** Boeren hebben zich aangepast aan veranderende weersomstandigheden zoals extreme droogte en neerslag, wat invloed heeft op hun gewasproductie. Dit omvat aanpassingen in waterbeheer en grondbewerking.
2. **Verziltingsbeheer:** Verzilting is een uitdaging, vooral langs de Nickerie rivier. Maatregelen zoals de rehabilitatie van de awarasluis en het aanpassen van teeltmethoden zijn nodig om verzilting tegen te gaan.
3. **Informatie en Training:** Er is een duidelijke behoefte aan meer informatie en voorlichting over aangepaste teelttechnieken, bestrijding van ziekten en plagen, en rijstrassen die beter bestand zijn tegen klimaatverandering.
4. **Financiële Ondersteuning en Voorzieningen:** Financiële uitdagingen, zoals hoge rentetarieven en gebrek aan toegankelijke leningen, beperken de mogelijkheden van de boeren. Er is behoefte aan betere financieringsmogelijkheden en ondersteuning

Consultatie Perceptie van boeren in Coronie over Klimaatverandering
Datum: 7 november 2023
Lokatie: Vergaderzaal ministerie van Regionale Ontwikkeling en Sport

Vraag 1: Wat betekent klimaatverandering voor u?
Samenvatting: In de afgelopen vijf jaar hebben boeren de gevolgen van klimaatverandering op hun gewasopbrengst opgemerkt, waaronder langdurige droogte, meer investeringen voor dezelfde productie, minder regen, maar ook extreme neerslag in de laatste twee jaar die de veeteelt en landbouwactiviteiten beïnvloedde. 2023 was extreem droog, terwijl de voorgaande jaren juist extreem nat waren. Ze ervoeren matige verliezen door deze klimaatsveranderingen. De oorzaken in hun gebied zijn onduidelijk, maar omvatten zaken als verzilting en het naderen van de zee.

Vraag 2: Heeft u zich al aangepast aan klimaat verandering?
Samenvatting: De boeren hebben verschillende acties ondernomen als aanpassing aan klimaatverandering. In regentijden maken zij hogere plantbedden, en in droge tijden lagere. Een geplande aanpassing is het gebruik van kassen voor de teelt, een methode die al door sommige boeren in Coronie wordt toegepast. De boeren uiten behoefte aan training en financiering voor deze klimaatadaptatiemaatregelen.

Vraag 3 Heeft u problemen met zoute grond en water?
- Heeft u in de afgelopen jaren gevolgen gemerkt voor uw hoofdgewas van verzilting?

Samenvatting: De boeren ervaren gemengde effecten van verzilting op hun landbouwgewassen. Sommigen melden schade aan tomatenplanten en verminderde productie door verzilting, terwijl anderen geen last ondervinden. De meningen over de oorzaken van verzilting lopen uiteen, variërend van nabijheid tot de zee tot niet-functionerende sluisdeuren. De gevolgen van verzilting zijn significant, met uitdroging van bomen en verlies van gewassen. Er zijn verschillende meningen over oplossingen, van inpoldering tot de acceptatie dat er weinig aan gedaan kan worden. De toekomstige verwachtingen over verzilting variëren eveneens.

Plenaire opmerkingen:
- De dijk van Coronie zou moeten worden doorgetrokken tot Jenny om kusterosie als gevolg van klimaatverandering, zeespiegelstijging te voorkomen
- bij de bouw van de zeedijk is ergeen betrokkenheid geweest van de lokale bevolking
- De gewassen die in Coronie worden geplant zijn: kokos, banaan, groentegewassen, tayerblad, cassave, antroewa, boulanger, sopropo, kouseband, papaya, watermeloen, mais
- Momenteel is het te droog en kunnen boeren niet planten
- Coronie heeft grootste zoetwaterzwamp voor irrigatie, maar staatsolie doet boringen in het zwamp, waardoor het water vervuild is
- opgemerkt wordt dat dit jaar maja bomen volop in bloei zijn en dragen, juist meer manja produktie
- kokos gedijt goed bij zout
- kennis bij de boeren ontbreekt welke gewassen zoutgevoelig zijn
- In de droge tijd is de wind ook zout. Cassavebladeren hebben een zoutlaag< 5ppt. Zout blijkt afwerend te werken voor ziekten en plagen. Het gaat erom dat er niet een te hoge zoutgehalte in de lucht zit, dan is het juist bevordelijk voor de produktie en het voorkomen van ziekten en plagen
- In de coroniezwamp zijner concessies gegeven voor schelpzand afgravingen, dit veroorzaakt diepe bassins in de regentijd met als gevolg overstromingen van landbouwarealen
- In coronie is vooral veeteelt geraakt door extreme regens de afgelopen 2 jaren (2020)
- in 2016 is de dam gebouwd, daarvoor kwam er zoutwater in de velden, maar de dam moet nog 20km worden doorgetrokken naar Jenny voor een algehele kustbescherming
- Er schijnt onduidelijkheid te zijn of er wel of geen sprake is van verzilting en waar. Het uitsterven van bomen alsgevolg van zoutwater is genoemd
- Ook een teveel aan zoetwater omdat het zoutwater zich niet meer kan mengen met het zoete zwampwater
- 2 rijstboeren in Coronie, 1 van het distrikt en1 van nickerie (t. Chander) beheren water in het zuidelijk deel(Coronie zwamp)
- 4000 ha in Coronie beschikbaar voor rijst. Echter kost het veel geld per ha. De lokale boeren hebben geen geld om paddie te planten, ze hebben geen securities voor commerciële banken
- Coronianen hebben het zelf ook verpest bij de Landbouwbank, ze hebben hun schulden niet afgelost of zijn achter met aflossen. Er moeten manieren gezocht worden om schulden van boeren bij de landbouwbank te

nivelleren. 1 ondernemer was komen investeren in Coronie en hebben boeren gelokt om grote leningen te nemen voor mechanisatie. De boeren konden die leningen niet terugbetalen, met als gevolg, neergang van de rijstbouw in dit distrikt
- Er zouden fondsen moeten komen voor kleinschalige rijstteelt
- 1 participant geeft echter aan dat vele schulden al zijn afbetaald
- boeren willen geen risico's nemen en vrezen dat de waterkerende dam van totness tot Burnside bij de grote regentijd breekt
- De rijstvelden zijn verladen en er staan= koeien op de velden die de rijst infrastruktuur hebben vernietigd
- SAMAAP zou mogelijkheden bieden, maar de drempel is te hoog voor kleine niet ontwikkelde boeren, ook al krijgen ze ondersteuning bij het formuleren en indienen van een projekt, vaak niet duidelijk waarom de aanvraag wordt afgewezen.

Samenvatting: De plenaire opmerkingen benadrukken de noodzaak van kustbescherming en betrokkenheid van lokale gemeenschappen bij infrastructuurprojecten, zoals de dijkbouw in Coronie. Er wordt een verscheidenheid aan gewassen geteeld, maar extreme droogte belemmert momenteel het planten. Vervuiling door boringen van Staatsolie en overstromingen door schelpzandafgravingen in de Coroniezwamp vormen een probleem. Ook is er onzekerheid over de mate van verzilting. Financiële problemen beperken de mogelijkheden voor de rijstbouw, en er wordt gesproken over de noodzaak van fondsen voor kleinschalige landbouw en een betere schuldenregeling.

Adaptatie maatregelen Coronie:
1. **Aanpassing van Teeltmethoden:** Overgang naar kassenteelt en aanpassing van plantbedden afhankelijk van het seizoen zijn belangrijke maatregelen.
2. **Beheer van Verzilting:** De noodzaak van betere oplossingen voor verzilting, zoals inpoldering van landbouwarealen en irrigatiebeheer.
3. **Kustbescherming:** Belang van kustbeschermingsprojecten en betrokkenheid van lokale gemeenschappen hierbij.
4. **Financiële Ondersteuning:** Behoefte aan toegankelijkere financieringsmogelijkheden voor kleinschalige landbouw en betere schuldenregelingen.

Consultatie Perceptie van boeren in Saramacca over klimaat verandering
Datum: 8 november 2023
Lokatie: Vergaderzaal ministerie van Landbouw, Veeteelt en Visserij

Vraag 1: Wat betekent klimaatverandering voor u?
Samenvatting:
Boeren hebben in de afgelopen vijf jaar een achteruitgang in landbouwproductie ervaren als gevolg van klimaatverandering. Dit omvat schade zoals afkalving van ringdijken, uitdroging van planten, algehele schade aan de aanplant, en een toename in de verspreiding van ziekten en plagen. Deze verliezen zijn voornamelijk opgemerkt in de jaren 2019-2020. De precieze omvang van de gevolgen van klimaatverandering op de landbouw is echter niet duidelijk gespecificeerd.

Vraag 2: Heeft u zich al aangepast aan klimaat verandering?
Samenvatting: Boeren zijn overgestapt van traditionele landbouw naar kassenteelt als maatregel tegen klimaatverandering. Ze plannen ook om bomen met penwortels te planten ter bescherming van hun aanplant tegen hitte en windstoten. Vanwege financiële beperkingen beginnen ze klein met deze aanpassingen, met de intentie om later uit te breiden.

Vraag 3 Heeft u problemen met zoute grond en water?
Samevatting: Boeren hebben gemerkt dat verzilting een aanzienlijke impact heeft op hun gewasproductie, vooral in de droge periode. Ze ervaren een productieverlies van meer dan 50% als gevolg van verzilting en hebben aangegeven behoefte te hebben aan trainingen en begeleiding. Om verzilting tegen te gaan, gebruiken sommige boeren leidingwater voor irrigatie. Details over verdere maatregelen of verwachtingen over toekomstige verzilting zijn niet gespecificeerd.

Plenaire opmerkingen:
- boeren ervaren regenseizoenen als “anders”, extreme regenval, begin en einde van seizoenen lijkt te zijn verander
- produktie van landbouwgewassen is volgens boeren sterk achteruitgegaan door de effecten van klimaatverandering
- door klimaatverandering lijkt er ook een bestuivingsprobleem te ontstaan, komkommer bijvoorbeeld wordt niet tot onvoldoende bestoven. De bijen blijven weg door de hitte
- de bijen blijken heel laag te vliegen en blijven korter voor bestuiving
- een oplossing kan zijn diversificatie: knolgewassen telen in de droge tijd
- biologische bladbemesting blijkt ook niet te werken door de hitte

Samenvatting:
Boeren merken veranderingen in de regenseizoenen, met extreem weer en verschuivingen in het begin en einde van de seizoenen. Deze klimaatveranderingen leiden tot een sterke achteruitgang in de landbouwproductie. Er zijn problemen met de bestuiving van gewassen zoals komkommers, mogelijk vanwege de hitte die bijen beïnvloedt. Diversificatie, zoals het telen van knolgewassen in droge perioden, wordt als mogelijke oplossing gezien. Biologische bladbemesting lijkt ook minder effectief te zijn door de hitte.

Adaptatie maatregelen Saramacca:
- Aanpassing van Teeltmethoden: Overgang naar kassenteelt en diversificatie, zoals het telen van knolgewassen, kunnen helpen omgaan met de effecten van klimaatverandering.
- Bestuiving en Hitte: Problemen met bestuiving door hitte vereisen alternatieve methoden om gewassen te bestuiven en te beschermen tegen extreme temperaturen.
- Waterbeheer: Het gebruik van leidingwater voor irrigatie om verzilting tegen te gaan en maatregelen om de effecten van extreme neerslag en droogte te beperken.
- Training en Voorlichting: Boeren hebben behoefte aan training en begeleiding om effectief om te gaan met de uitdagingen die klimaatverandering met zich meebrengt.

Overeenkomsten en verschillen tussen de adaptatiemaatregelen in Nickerie, Coronie en Saramacca:

Overeenkomsten:
Aanpassing aan Weerextremen: Alle drie regio's hebben te maken met extreme weersomstandigheden, zoals droogte en overvloedige neerslag, en nemen maatregelen zoals verbeterd waterbeheer. Behoefte aan Training en Voorlichting: In alle regio's is er een duidelijke behoefte aan informatie over klimaatadaptieve landbouwmethoden.

Verschillen:

- Verziltingsbeheer: In Nickerie ligt de focus op verziltingsbeheer langs de Nickerie rivier, terwijl in Coronie inpoldering en irrigatiebeheer voor verziltingsbeheer wordt benadrukt.
- Kustbescherming: Specifiek voor Coronie is de nadruk op kustbeschermingsprojecten.
- Financiële Ondersteuning: Terwijl in Nickerie en Coronie de nadruk ligt op financiële ondersteuning en toegankelijkere financiering, wordt dit in Saramacca niet expliciet vermeld.
- Teeltmethoden: Overgang naar kassenteelt wordt zowel in Coronie als Saramacca benadrukt, maar Nickerie focust meer op aanpassingen in grondbewerking en rijstteelt.
- Bestuiving en Hitte: Specifiek voor Saramacca is de aandacht voor bestuivingsproblemen door hitte, een punt dat niet in de andere regio's wordt genoemd.
- Waterbeheer: Het gebruik van leidingwater voor irrigatie om verzilting tegen te gaan is specifiek genoemd in Saramacca.

Wageningen Environmental Research
P.O. Box 47
6700 AA Wageningen
The Netherlands
T 0317 48 07 00
wur.eu/environmental-research

Report 3331
ISSN 1566-7197

The mission of Wageningen University & Research is “To explore the potential of nature to improve the quality of life”. Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 7,600 employees (6,700 fte) and 13,100 students and over 150,000 participants to WUR’s Life Long Learning, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.

To explore
the potential
of nature to
improve the
quality of life

Wageningen Environmental Research
P.O. Box 47
6700 AB Wageningen
The Netherlands
T +31 (0) 317 48 07 00
wur.eu/environmental-research

Report 3331
ISSN 1566-7197