The Bahamas

Grant Agreement: 101003687
Call identifier: H2020-LC-CLA-2020-2
Project full title: PROVIDE – Paris Agreement Overshooting – Reversibility, Climate Impacts and Adaptation Needs

D4.1 Four review reports on key overshoot adaptation challenges in Iconic Regions and Cities: The Bahamas

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Abstract:

Impacts of overshooting the Paris Agreement temperature thresholds will materialise globally but be particularly consequential for vulnerable regions. This report represents the initial stocktaking of overshoot adaptation challenges in the four Iconic Regions and Cities in focus for PROVIDE: Arctic Fennoscandia, with a focus on Bodø, Norway; Iberian Mediterranean, with a focus on the Lisbon Metropolitan Area; the Upper Indus Basin, with a focus on Islamabad; and The Bahamas, with a focus on Nassau.

Due date: 31.08.2022
Actual submission date: 31.08.2022
Publication date: 31.08.2022
Project start date: 01.09.2021
Project duration: 36 months

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101003687.

Dissemination Level
PU Public

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Glossary

Unless otherwise stated, the terminology in the report follows conventions developed by the IPCC WGII.

CONCEPT	DESCRIPTION
Adaptation challenges	Factors that make it harder to plan and implement adaptation actions.
Adaptive capacity	The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.
Ecosystem service	Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as (1) supporting services such as productivity or biodiversity maintenance, (2) provisioning services such as food, fibre, or fish, (3) regulating services such as climate regulation or carbon sequestration, and (4) cultural services such as tourism or spiritual and aesthetic appreciation.
Exposure	The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, *livelihoods,* service provision, *ecosystems,* and environmental resources.
Limits to adaptation	A limit to adaptation is reached when adaptation efforts are unable to provide an acceptable level of security from risks to the existing objectives and values and prevent the loss of the key attributes, components, or services of ecosystems.
Overshoot	Pathways that first exceed a specified global warming level (usually 1.5°C, by more than 0.1°C), and then return to or below that level again before the end of a specified period of time (e.g., before 2100). Sometimes the magnitude and likelihood of the overshoot is also characterized. The overshoot duration can vary from at least one decade up to several decades.
Risk	The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change.
Tipping point	A level of change in system properties beyond which a system reorganizes, often abruptly, and does not return to the initial state even if the drivers of the change are abated.
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Executive Summary

The 1.5°C Paris Agreement long-term temperature goal sets ambitions for global climate action to avoid the most devastating impacts of climate change. However, under current emissions trajectories, overshooting 1.5°C is a distinct possibility.

Even if we only temporarily exceed 1.5°C in the near term, we could still cross climate thresholds in ways that would severely limit our adaptation options. This would impact people and places around the world, but nowhere will this be felt more than in vulnerable regions.

To date, adaptation and urban planning do not routinely consider the implications of temporary overshoot of 1.5°C and what this would mean for sea level rise, extreme heat, extreme weather events, flooding and their impacts locally or for whole regions. To bridge this gap, the PROVIDE project is undertaking research on temperature overshoot scenarios and their expected impacts, so we can better understand under which conditions these impacts can be avoided.

This report looks at adaptation challenges in four iconic case study regions and cities:

- Arctic Fennoscandia, with a focus on Bodø, Norway.
- the Iberian Mediterranean, with a focus on the Lisbon Metropolitan Area.
- the Upper Indus Basin, with a focus on Islamabad.
- The Bahamas, with a focus on Nassau.

The findings are based on the review of relevant literature and stakeholder workshops undertaken by in-region experts, along with analyses of the structural profile of the urban environments in focus.

The four regions are very different, both in climatic and socioeconomic settings, but all are experiencing the consequences of climate change, including risks connected to more frequent and more serious severe weather events. Examples range from deadly heatwaves, hot and dry summer with forest fires, and extreme precipitation events that lead to flooding and increased risk for landslides (and avalanches). Whole ecosystems are also changing and could eventually vanish in response to shifts in the climate, including snow and ice habitats, agroforestry, and coral reefs. In the cities in focus, the built environment has often reduced the capacity of the natural environment to buffer the impacts of climate change, including intensive precipitation and extreme heat.

A common feature for all iconic regions – despite their differences – is that impacts from a changing climate are exacerbated by socio-economic factors, such as inequalities and lack of financial and human capital. Furthermore, pressures from urbanisation and migration makes adaptation more challenging. Lack of adequate adaptation governance and incentives is another common feature. These social factors affect adaptive capacity and thus create “soft” limits of adaptation.

There are also significant similarities between the adaptation challenges faced by the iconic cities. In all four cities, vulnerability to various climatic risks have increased because of anthropogenic activity, such as the urbanization of coastal areas, construction leading to discontinuity of green-blue structures, and the intensity of the built-up space. All four places have possibilities to address their respective climatic risks, but they also face challenges related to a high degree of private land ownership along with governance regimes without sufficient coherence for the needs related to climate adaptation and mitigation.

The Bahamas

The Bahamas is an archipelagic small island developing state (SIDS) with high levels of climate change risk. More than 70% of the Bahamian population resides on the capital island of New Providence, concentrating much of the population and assets in a small geographic space of 207km^2.

Key climate hazards and adaptation challenges include:

- Increased intensity of tropical cyclones
- Sea level rise
- Ocean acidification and warming
- Flooding
- Increased atmospheric warming

High exposure to these hazards is related to the entire nation being classified as a coastal zone due to low elevations and small land area of the islands.

The Bahamas has limited adaptive capacity, which also contributes to high levels of risk. Adaptation constraints, including economic and financial challenges, make it difficult for individuals and government actors to adapt, while weak institutional capacities have led to fragmented and ad hoc adaptation approaches. The stakeholder workshop highlighted that a particularly pressing constraint is lack of capacity. While there are efforts being made within various government agencies to consider climate change, there is a lack of trained personnel that is experienced and knowledgeable about the particular aspects of climate change that are relevant for each of the various sectors. Limited progress in implementing the National Adaptation Policy as well as the lack of a national adaptation plan were also identified as key constraints for adaptation.

The range of observed impacts in the country exemplify how soft limits to adaptation have already been reached. Recent hurricanes have caused catastrophic damage, injustices and loss of lives and livelihoods on islands throughout the country. In 2019, Hurricane Dorian caused damages of USD 3.4 billion, over a quarter of annual GDP. The focus of adaptation efforts on ecosystem-based adaptation, such as coral reef and mangrove restoration, may face hard limits to adaptation if global warming exceeds 1.5°C.

The analysis of urban spatial structure has focused on the island of New Providence and the capital Nassau. The urbanized area of New Providence is located on the eastern half of the island, along the coastal zone. Nassau city is a low-rise sprawl. Nassau's modern growth began just over 200 years ago as the population grew along with the built-up areas. When the tourist economy began to develop, population levels and the city expanded along the east coast of the island and today the urbanized area covers more than one-third of the island. The mobility network on the island is challenged by a lack of room to expand and a lack of public transport network.

New Providence is a low-altitude island mainly composed of sand, coral, lakes, and ponds and with many areas of high ecological value, where inland wetlands play an important role in water management by collecting and store rainwater away from homes and roads. However, uncontrolled urbanization and a lack of long-term urban planning leads to increasing risks that surface water features become polluted by industrial and urban runoff. During the rainy season, buildings along these shallow basins affect their ability to prevent flooding and because of its low relief and large urban areas, New Providence is often inundated.

The urban structure in the coastal zone also makes New Providence more vulnerable to the impacts of hurricanes and other tropical storms that cause extensive flood and wind damage. The coastline and its storm and flood security under a rising sea level should be further investigated.

1. Introduction

1.1. The PROVIDE project

Overshooting the Paris Agreement temperature thresholds is a distinct possibility. Potential impacts would be global in scope, with consequences which may be particularly severe where changes are abrupt, irreversible, or adaptation limits are exceeded. The aim of the EU-funded project, *Paris Agreement Overshooting – Reversibility, Climate Impacts and Adaptation Needs* (PROVIDE), is to create climate services that incorporate comprehensive information on impacts under overshoot pathways from the global to the regional and local urban level, directly feeding into adaptation action. This includes:

- Producing global multi-scenario, multisectoral climate information that integrates and quantifies impacts across scales.
- Providing comprehensive risk assessments of overshooting by assessing climate system uncertainties and feedbacks, and the potential (ir)reversibility of climate impacts.
- Co-developing a generalizable overshoot proofing methodology for adaptation strategies to enhance adaptation action in response to overshoot risks.
- Identifying and prioritizing overshoot adaptation needs in four highly complementary case study regions.
- Integrating the project outcomes into a PROVIDE Climate Service Dashboard, designed to complement established climate service platforms.
- Interacting and collaborating with a wide variety of stakeholders, to ensure usability and wide dissemination of project results and outputs.

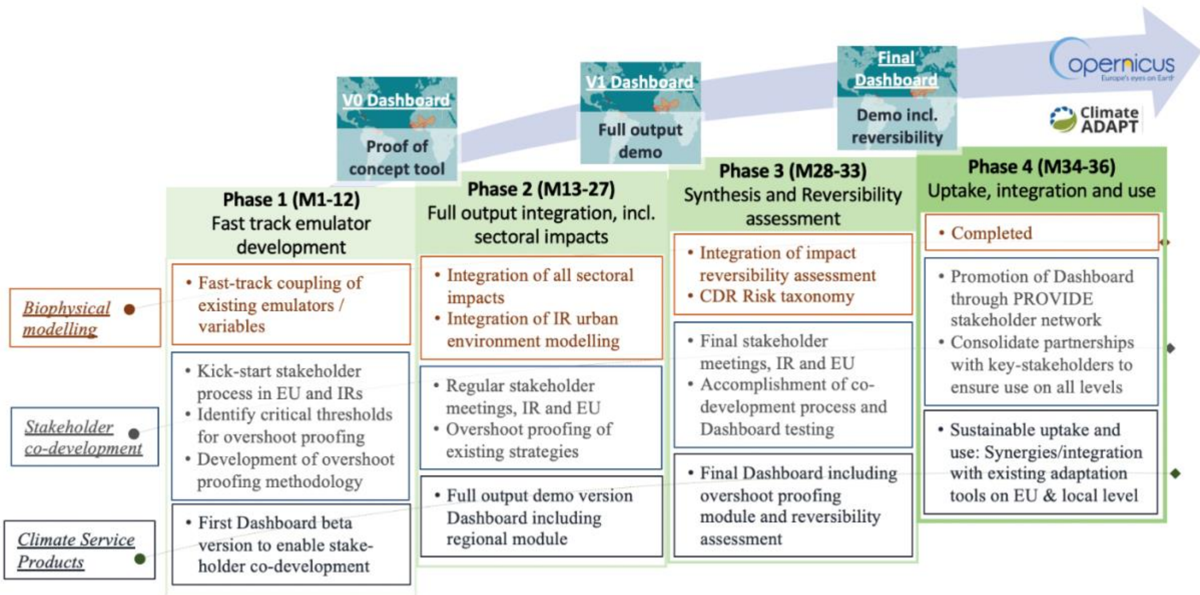

Figure 1.1. The PROVIDE project at a glance.

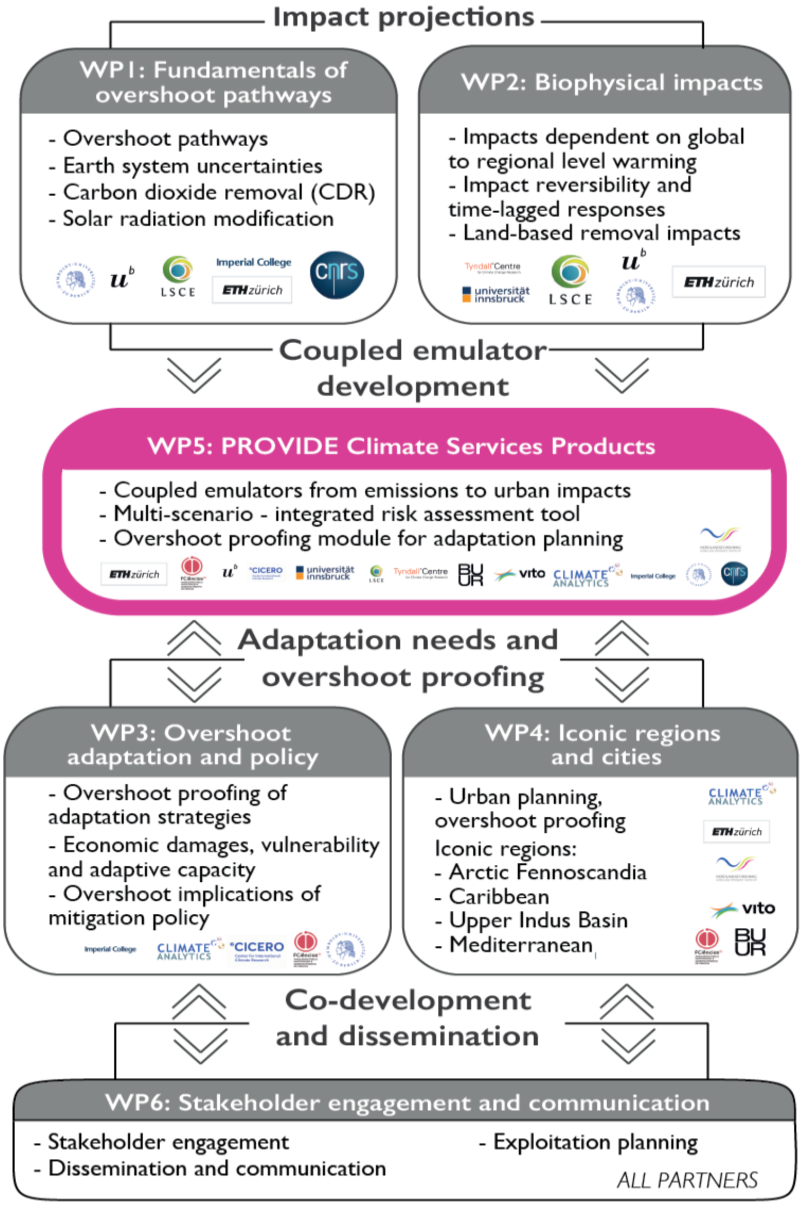

Figure 1.2. PROVIDE is organized in interlinked work packages.

1.2. Iconic Regions and Iconic Cities (WP4)

PROVIDE assesses regional and local impacts of overshoot pathways and the required adaptation responses in four Iconic Regions (IR), including a focus on selected urban environments within those regions. These regions and cities are places where physical risks overlay with specific socio-economic vulnerabilities. The Iconic Cities (IC) were selected to serve as places where the PROVIDE Overshoot Proofing Methodology can be co-developed with local and regional stakeholders. They will provide entry-points for raising awareness about the need for enhanced adaptation action under overshoot scenarios and offer a practical testbed for generalisable urban planning approaches.

Figure 1.3. Region in focus for PROVIDE.

The regions and cities in focus for PROVIDE are:

1. Arctic Fennoscandia, with a focus on Bodø, Nordland County, Norway.
2. Iberian Mediterranean, with a focus on the Lisbon Metropolitan Area, Portugal.
3. Upper Indus Basin, with a focus on Islamabad, Pakistan.
4. The Bahamas, with a focus on Nassau.

The IRs span over diverse climate zones, different environments, and different social and cultural contexts. They thus represent different adaptation challenges. Nevertheless, some conclusions are relevant across the regions, which will be particularly important for developing a generalizable overshoot proofing methodology and a Climate Services Dashboard that is credible and useful in a wide range of contexts.

2. The Bahamas

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2.1. Overview of The Bahamas

2.1.1. Physical Characteristics

The Bahamas is an archipelagic small island developing state (SIDS) comprising of over 700 low-lying islands and cays (Figure 2.1) and is part of the Caribbean. The country has a sub-tropical climate and is positioned between two major warm ocean currents which provide some seasonal variability. The rainy season is from May to October with the hurricane/tropical cyclone season extending from June to November. Rainfall generally occurs in the form of intense showers, accompanied by strong and gusty winds.

The Bahamas extends over 100,000 square miles (260,000 square kilometres) of sea, stretching over a distance of approximately 760 miles (1223 kilimetres) from northwest to southeast (The Commonwealth of The Bahamas 2005). The total land area is approximately 5,380 square miles (13,934 square kilometres). The country is mostly flat and low-lying in elevation with the highest point being found on Cat Island at only 206 feet (63 meters). The islands are comprised of calcium carbonate, the result of coral reefs which became dry land when sea levels dropped hundreds of centuries ago.

Figure 2.1.: Map of The Bahamas

2.1.2. Economic characteristics

The Bahamas is one of the wealthier nations in the Caribbean region with a GDP per capita of US$25,194 in 2020 (The World Bank 2021). The national economy is driven by tourism and financial services (Government of The Bahamas 2016). Tourism employs about half of the labour force and contributes approximately 60% to the GDP. The financial services sector employs about 10% of the labour force and contributes approximately 15% to the GDP. These two sectors are vulnerable to external stressors and shocks and have experienced volatility in recent years due to changing financial regulations and the COVID-19 pandemic. However, the government projects an economic rebound as tourism improves which will reduce domestic unemployment and increase government revenue (Central Communications Unit 2022).

Despite the relatively high GDP, there is marked income inequality and uneven development with serious infrastructure gaps and challenges in public education and health care systems (The Government of The Bahamas 2018). Development is further challenged by the need to strengthen public institutions and increase accountability, transparency, and effectiveness in the public sector.

Like many SIDS, The Bahamas relies primarily on imports to satisfy basic goods needs, including fuel, food, medicine, and building supplies. The COVID-19 pandemic has reignited discussions on the need to diversify the economy and reduce reliance on imports, through investing in light manufacturing, technology, agriculture and fisheries, extractive industries, and renewable energy (US Department of State 2022).

2.1.3. Demographic characteristics

Approximately 29 islands of The Bahamas are inhabited. The 2010 census counted a total population of 351,461 people, with approximately 70% of the population located on the island of New Providence which hosts the capital city of Nassau (Department of Statistics 2012). Grand Bahama Island is the second most populous island, with about 15% of the population. The other islands, collectively referred to as Family Islands, have much smaller populations and are much less densely populated. The primary language of The Bahamas is English. However, there are many residents of Haitian descent and Haitian Creole is the second most used language.

The 2019 Human Development Index (HDI) for The Bahamas was 0.814, placing the country in the very high human development category and above the average of 0.766 for countries in Latin America and the Caribbean (UNDP 2020). However, there are high levels of inequality with approximately 13% of the population living in poverty, and 25% of those living in poverty being children between the ages of 5-14 years (The Government of The Bahamas 2018). While an inequality adjusted HDI is calculated for 152 countries, due to data unavailability, this statistic is not available for The Bahamas.

There has been a steady increase in informal settlements throughout the islands of the country, mostly concentrated in the islands of New Providence, Abaco, Exuma and Eleuthera (The Government of The Bahamas 2018). A 2018 survey of informal settlements on New Providence alone found 1,410 residents in 428 households. Informal settlements generally have high population densities and housing structures which are illegally constructed with non-durable hazardous material and do not meet building codes. These settlements also often lack sewage disposal systems and access to water.

2.1.4. Governance system

Since independence in 1974, The Bahamas has had a parliamentary democracy with peaceful transition of government over the past 48 years (Government of The Bahamas 2016). The Parliament consists of two chambers: an appointed Senate and an elected

House of Assembly. Her Majesty the Queen, represented by the Governor General is also part of the Parliament. The Prime Minister is the elected head of government of The Bahamas. The Parliament is mandated by the Constitution to make laws for the peace, order and good government of The Bahamas and to approve the government's budget. The Parliament also maintains oversight of government financial matters.

Gender inequality is evident in government with historically low percentages of women elected to the House of Assembly. The 2021 national elections resulted in an unprecedented high of 18% of House of Assembly seats being held by women (7 out of 39 seats).

In addition to the Parliament, which address national issues, there is also an elected local government for Grand Bahama and the Family Islands (Commonwealth Local Government Forum 2020). Local government is responsible for hospitals and clinics, the supply of public potable water, the upkeep of public schools and other government buildings and general health and sanitation. Local government is not empowered to raise revenue and is funded by the national/central government. There is no local government for New Providence.

2.2. Climate risks and impacts

2.2.1. Key hazards

A range of climate hazards are relevant for The Bahamas. Hurricanes are a regular occurrence, with a hurricane affecting at least one of the many islands of the country every two years on average (Pathak et al. 2021). Projections of increased intensity of tropical cyclones due to climate change are a major hazard for the country. Climate modelling of projected changes in tropical storms suggest that rainfall associated with tropical cyclones could increase by 20-30% and that maximum wind speeds could increase by 2-11% (Community et al. 2020).

Sea level rise is another key hazard. With more than 80% of The Bahamas' land surface area being less than 1 m above sea level, along with limited land mass, sea level rise poses an existential threat for coastal communities. Sea level rise projections for the Caribbean by 2100 relative to the 1980-1999 mean span a large range, from an increase of 0.13 meters to 1.45 meters (Community et al. 2020).

Changes in precipitation are also projected for The Bahamas with longer dry seasons and shorter wet seasons. These changes may have serious implications for the water sector, as the country relies on replenishment of groundwater aquifers through precipitation as there are no rivers, streams, or other sources of surface water.

Figure 2.2. Land projected to be below tideline in 2100 with temperature increase of 2C: New Providence, The Bahamas. Source: Climate Central, 2022.

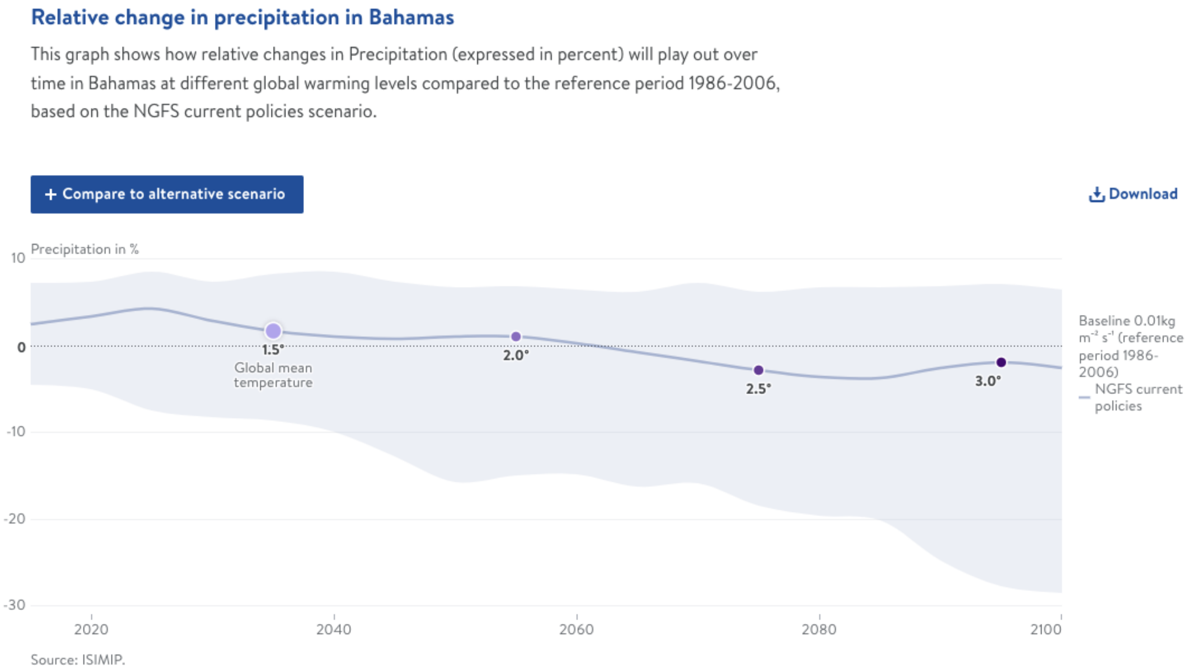


Figure 2.3. Relative changes in precipitation. Source: Climate Impact Explorer.

Ocean acidification and warming are also key hazards for The Bahamas. With 5% of the world's coral being found in The Bahamas and with the world's third longest barrier reef, ocean acidification and warming are significant hazards for coastal ecosystems which provide ecosystem services and foster biodiversity. Projections indicate that if global temperatures exceed 1.5°C of warming, approximately 99% of coral reefs will be at risk of destruction (IPCC 2018).

2.2.2. Key components of exposure

The entire nation of The Bahamas is classified as a coastal zone, due to the very flat land and small land area of the many islands (Horsley and Witten 2004). The majority of critical infrastructure – including major road networks, infrastructure, energy systems, transportation hubs, and housing – are located in close proximity to the actual coastline. These characteristics of The Bahamas mean that there is high exposure of people and assets to climate hazards.

More than 70% of the Bahamian population resides in New Providence, concentrating people and assets in a small geographic space. The island of New Providence has an area of 207km^2, with a length of 34km and width of 11km. There is limited land area available for relocation of communities or infrastructure that are located directly along the coast, thereby contributing to high exposure to climate hazards for the capital island in particular.

Migrant communities that live in informal settlements are disproportionately exposed to climate hazards as they are often located in informal housing areas that are located in areas that are prone to flooding. For example, the majority of deaths and missing people from the 2019 Hurricane Dorian were from informal settlements located on the island of Abaco. Informal housing that did not meet building codes, along with the location of these communities in low-elevation areas, resulted in even higher exposure than the rest of the island.

2.2.3. Key components of vulnerability

The Bahamas has been consistently identified as one of the most vulnerable SIDS to climate change, due in part to limited adaptive capacity along with high exposure to increasing climate hazards (Pathak et al. 2021). There are a number of constraining factors that contribute to low adaptive capacity as detailed in Table 2.1. Limited land area constrains the feasibility of adaptation measures while economic and financial constraints make it difficult for both individuals and government actors to adapt. The lack of human personnel with climate change expertise as well as significant challenges with institutional capacities also contribute to low adaptive capacity. Low awareness of climate change risks, despite high vulnerabilities, along with the prioritization of other development challenges – such as poverty, education, and crime – are also key factors that influence vulnerability to climate change for The Bahamas.

Table 2.1. Adaptation constraints: The Bahamas.

CONSTRAINTS	OVERVIEW	SOURCES
Physical	Limited land area constrains the feasibility for some adaptation measures such as accommodation or retreat.	(Petzold et al. 2018)
Economic	Structural barriers including poverty, gender inequality and unemployment have resulted in significant inequality and exacerbated challenges faced by vulnerable groups. Reliance on tourism and financial services increases economic vulnerability to extreme climate events.	(The Government of The Bahamas 2018)
Financial	Budget constraints to fund adaptation which involves high upfront costs. No national budgeting for adaptation.	(Government of The Bahamas 2016)
Human Capacity	Lack of human personnel with climate change expertise. Capacity challenges with the National Statistical Institution (human resources and infrastructure). Institutional capacity deficiencies within environmental management agencies.	(Government of The Bahamas 2016; The Government of The Bahamas 2018)
Governance Institutions Policy	2005 National Adaptation Policy is out of date and lacks an implementation plan, resulting in limited implementation thus far.	(Government of The Bahamas 2016; The Government of The

	Economic development priorities may take precedence over adaptation with large scale developments, particularly in the tourism sector, taking place along the coast without considering climate risks. Lack of long-term coastal protection strategy. Lack of coordinated or organized efforts among government, NGOs and private sector in coastal protection resulting in small efforts scattered across coastlines which may result in maladaptation. Weak land use planning for New Providence with a history of mangrove deforestation and concentration of construction along the coast. Lack of enforcement of existing regulations, leading to illegal sand mining and destruction of coral reefs and mangroves. Multiple government agencies responsible for coastal protection: Ministry of Works, Ministry of Environment, Ministry of Health. Fragmented environmental legislation and management.	Bahamas 2018; Petzold et al. 2018)
Information Awareness Technology	Awareness of climate change risks relatively low and focused on risks of tropical storms. Lack of reliable data on local sea-level trends. Inadequate data on the majority of SDG indicators, including SDG13. Inadequate disaggregated data by geography and gender. In general public, discussions on climate change focus more on mitigation than adaptation, e.g., banning plastic bags, need for renewable energy Short-term attention paid to climate change, particularly after an extreme hurricane or after significant international attention (e.g., Paris Agreement, COP26) with limited long-term adaptation developed and implemented.	(The Government of The Bahamas 2018; Thomas and Benjamin 2018a; Petzold et al. 2018)
Social/ Cultural	Social inequalities influence who is impacted by climate change and also affects knowledge and perceptions of climate change, with vulnerable groups having the least adaptive capacity and facing highest risks. Climate change not a significant priority in comparison to other pressing issues such as economic development, health, education, and crime.	(Petzold et al. 2018)

Despite the many constraints that limit adaptive capacity, there are some opportunities or enabling conditions that may contribute to reducing vulnerability, as detailed in Table 2.2. Climate change has gained recent and increasing attention since the impacts of the 2019 Hurricane Dorian, with more of the general public and governmental officials paying attention to climate change as risk for the country. Reports that have been developed and submitted by the government to various United Nations bodies (e.g., Sustainable Development Goals Voluntary Report, United Nations Framework Convention on Climate Change Nationally Determined Contribution), do identify that capacity constraints to address climate change as a critical issue. There has been some attention paid to the need to adapt in the draft National Development Plan and an initial Climate Change Adaptation Policy was developed in 2005, although these initiatives have yet to be implemented.

Table 2.2. Enabling conditions: The Bahamas.

Opportunities/ Enabling Condition	Overview	Sources
Awareness raising	Climate change has gained increasing attention in The Bahamas, particularly after the impacts of 2019 Hurricane Dorian. While there have been limited awareness raising efforts specifically on climate risks, there are a number of opportunities: Politically aware and engaged population on key public policy issues. Widespread newspaper readership, traditional and social media, and active radio media with multiple "all talk" radio stations discussing topical issues of the day. Public broadcasting company with nation-wide television and radio coverage. Government information services agency with a website that has information on government policies and programs.	(The Government of The Bahamas 2018)
Capacity building	National Development Plan identifies vulnerable groups where specific attention should be paid including persons living in poverty, persons living with disabilities, Family Island residents, the elderly, at-risk youth, youth falling behind academically, unemployed persons, migrants, children with obesity, single parents, women, and men with criminal records. National Development Plan details clear actions, outputs, and outcomes to improve capacity building for adaptation. Caribbean Community Climate Change Centre (5Cs) has hosted training for government officials on using the CCORAL climate change risk management tool.	(Government of The Bahamas 2016)
Tools	Emerging and Sustainable Nassau Project prepared a study on natural hazards and risks for New Providence (inland flooding, coastal flooding, and salinization of fresh-water table) and a proposed urban land use plan.	
Policy	2005 National Adaptation Policy contains adaptation policy directives for multiple sectors. Climate change entrenched in one of the four pillars of the National Development Plan. National Development Plan aligned with Sustainable Development Goals, including Goal 13 on Climate Action. National Development Plan details clear actions, outputs and outcomes to improve adaptation policy.	(Government of The Bahamas 2016)
Learning	Series of strong hurricanes affecting the country has increased contemporary experience with disaster risks.	

2.2.4. Observed impacts

There is a lack of systematic assessment of climate-related impacts in The Bahamas, with the majority of impacts that are assessed being those associated with the most extreme of events (Thomas and Benjamin 2018b). Recent hurricanes have caused catastrophic damage, injustices, and loss of lives and livelihoods on islands throughout the country. Most recently, Hurricane Dorian in September of 2019 hit the second and third most populous islands of the country, Grand Bahama, and Abaco, causing damages of approximately US$3.4 billion, over a quarter of The Bahamas' GDP (IDB 2020). Prior to this, Hurricanes Maria, and Irma (2017), Hurricane Matthew (2016) and Hurricane Joaquin (2015) affected other islands causing damages of over US$1.1billion.

In addition to these economic damages, hurricanes have also caused non-economic losses to ecosystems and communities. While there is no systematic assessment of ecosystem losses post-hurricane, a study on coral reefs after Hurricane Dorian found that 25-30% of reefs suffered severe damage, including major structural damage, high levels of debris, heavy siltation, and widespread bleaching (Dahlgren and Sherman 2020). Non-economic losses associated with displacement due to hurricanes in The Bahamas include lack of access to health care, poor living, and health conditions such as lack of running water and electricity, loss of sense of place, and loss of connection to community (Thomas and Benjamin 2019).

Assessment of impacts from slow onset events is scarce and anecdotal. However, significant coastal erosion is already identified as an issue for New Providence, where there is evidence of undercutting, exposed beach, and exposed vegetation (Petzold et al. 2018).

2.2.5. Projected risks

The risk of relative change in annual expected damages from tropical cyclones increases significantly with warming. With 3°C of warming, damages are near to 40% higher compared to current levels -which already pose significant economic challenges.

Changes to the ocean, including higher sea surface temperatures and rising ocean acidity, are projected to lead to further bleaching of coral reefs and erosion of coastal areas, putting terrestrial and marine biodiversity at risk and also threatening coastal areas with higher incoming waves and more extensive storm surges (The Government of The Bahamas 2018).

As a result of several hazards, including changes to precipitation patterns and sea level rise, The Bahamas is expected to face significant risks to water security. Freshwater resources are already finite and inadequate, requiring seawater reverse osmosis which currently supplies more than 50% of The Bahamas' potable water supply (The Government of The Bahamas 2018). Declining freshwater availability and drought are significant risks with particularly high risks for the southernmost islands where reverse osmosis technologies are less feasible due to small economies of scale (Community et al. 2020). Sea level rise is projected to increase the risk of increasing contamination of freshwater through affecting the islands' groundwater lenses. Increasingly intense extreme weather events may also damage wastewater treatment and collection systems and flood septic tanks, also increasing the risk of contaminating groundwater.

Tourism, the main economic sector for The Bahamas, is also projected to be at high risk. Most tourism properties currently lie in a storm surge zone and the extent of properties within the zone increases as sea levels rise (Pathak et al. 2021). While sea level rise alone poses a threat, the main risks are projected from sea level rise in combination with tropical cyclones. With 1 m of sea level rise, a Category 1 hurricane is projected to impact 34% of the tourism infrastructure on New Providence. A Category 3 hurricane will affect 69% of infrastructure and a Category 5 storm will affect 83% of tourism infrastructure. Additionally, properties are also at risk of coastal erosion with over 60% of infrastructure being located within 100 meters of the coastline. Given the economic importance of tourism for The Bahamas, and for New Providence in particular, the risks of climate change have far-reaching implications for economic development.

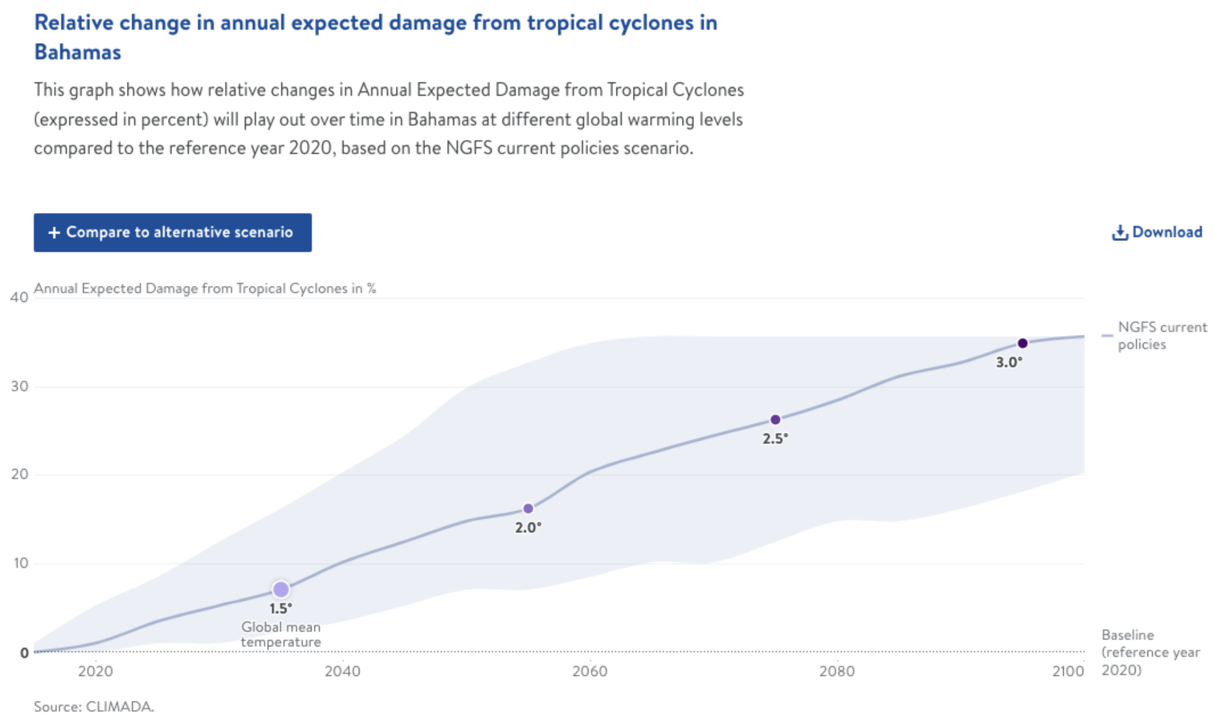


Figure 2.4. Relative change in annual expected damages from tropical cyclones, Source: Climate Impact Explorer

2.3. Adaptation policies, plans and strategies

To date, the most comprehensive adaptation policy is the National Policy for Adaptation to Climate Change which was developed in 2005. The policy establishes objectives for adaptation and key actions that are needed to address climate change for different sectors (Government of The Bahamas 2005). The policy does not link adaptation options identified to particular global warming scenarios. Risks of climate change that are identified are largely qualitative.

The policy identifies the government as the major facilitator of the implementation of the policy directives and provides a framework for advancing capacities to effectively adapt to climate change. However, there has been little adoption of the actions outlined in the policy. For example, while the policy advises against particular actions that would increase vulnerability to climate change, these actions continue to take place, such as continuing developing in low-elevation areas that are already susceptible to flooding (Thomas et al. 2015).

There has also been limited development of any sectoral adaptation policies or plans which are a key recommendation of the report. However, there have been some recent developments, which are detailed in Table 2.3. Most notably, The Bahamas recently gained funding approval from the Green Climate Fund to develop a National Adaptation Plan, which has the potential to significantly advance adaptation for the country. The process is expected to begin in mid-2022.

Table 2.3. Upcoming adaptation policies/plans/strategies.

Policy/Plan/Strategy	Lead Agency	Status/Expected Completion
Agriculture Adaptation Plan	Ministry of Agriculture	Late 2022
Health National Adaptation Plan	Ministry of Health	2023

Technology Needs Assessment	Ministry of Environment/ Department of Environmental Protection and Planning	Late 2022
Third National Communication	Ministry of Environment/ Department of Environmental Protection and Planning	Late 2022
National Adaptation Plan	Ministry of Environment	Expected to begin in mid-2022

While there are few dedicated adaptation policies or plans, there are a number of related policies and plans that refer to the need to adaptation. The draft National Development Plan: Vision 2040, was developed in 2016 and identifies the need for adaptation to climate change (Government of The Bahamas 2016). Goal 11 of the plan focuses on the natural environment and includes climate change adaptation as a key strategy. The plan identifies the need to increase research and development in climate change adaptation and to have an 80% increase in islands of The Bahamas that have climate change adaptation plans by 2025. However, the plan disproportionately focuses on mitigation with a goal of a 70% increase in homes using alternative energy sources in 2025, increasing the number of partnerships with green technology firms to build capacities in green technology, increasing green foreign direct investment flows by 2025 and increasing by 50% the share of renewable energy in total energy consumption. Regardless of these goals, the plan is still in draft form and has not been formally accepted or enacted by the government.

There are also some island-specific plans that refer to adaptation, although these also have not been formally accepted or enacted by the government and it is not clear whether these are being used to guide planning or development. The Sustainable Nassau Plan was developed in 2018 and identifies the need for and specific activities to support sustainable urban growth in Nassau (Inter-American Development Bank 2018). Adaptation actions identified as needed for Nassau include mangrove replanting, beach and coral reef restoration, replanting of native plants, removal of invasive species, and encouragement of low impact development techniques such as roof gardens and porous pavement. The plan also recommends the design and implementation of a coastal management plan, identifying natural barriers to protect infrastructure from storm surges and regulations against development in low-lying and floodable areas.

2.4. Implemented adaptation projects and programs

There have been some ad hoc adaptation projects that have been implemented in The Bahamas by a range of actors. NGOs have been the ones that have largely led these efforts. The Nature Conservancy is currently implementing a nature-based community adaptation project, focused on developing community-based adaptation plans. The Bahamas National Trust is similarly working with fisheries communities on some of the islands, focusing on developing specific adaptation plans for these groups. As noted in the IPCC Working Group II report, most adaptation action is focused on planning rather than implementation.

In addition to the few projects that focus specifically on adaptation, there have also been infrastructural projects that have focused on reducing coastal erosion, without an explicit link to climate change. In New Providence, man-made coastal protection schemes such as groynes, sea walls, dikes and beach nourishment have been implemented in a piecemeal fashion, largely concentrated along the northern coast (Petzold et al. 2018). The private sector and individuals have also implemented ad hoc adaptation measures, largely in response to coastal erosion (Petzold et al. 2018).

2.5. Adaptation governance and key adaptation actors

The Department of Environmental Planning and Protection (DEPP) within the Ministry of the Environment and Natural Resources currently serves as the national climate change office.[1] DEPP is responsible not only for climate change but also for the prevention or control of pollution, the regulation of activities and the administration, conservation and sustainable use of the environment and for connected purposes. DEPP also manages multilateral environmental agreement, including The Bahamas' participation in the UNFCCC and the Paris Agreement. With so many different responsibilities and limited staff, DEPP has identified capacity challenges as key factor affecting progress in climate change adaptation.

A three-person climate change unit has also been established within the Office of the Prime Minister, responsible for implementation of the government's multi-agency priorities related to climate change, including a recently introduced carbon credits bill.

DEPP has also established a National Climate Change Committee (NCCC), comprised of representatives from a range of government agencies, NGOs, academia, and the private sector. Members of the NCCC are detailed in Table 2.4.

Table 2.4. Members of The Bahamas' National Climate Change Committee.

Agency	Category
Bahamas Agricultural Health and Food Safety Authority	government
Bahamas Chamber of Commerce and Employees Confederation	NGO
Bahamas Maritime Authority	government
Bahamas Power and Light	Quasi-government
Bahamas Protected Areas Fund	
Bahamas Reef Environment Educational Foundation (BREEF)	NGO
Department of Agriculture	government
Department of Environmental Planning and Protection	government
Department of Gender and Family Affairs	government
Department of Marine Resources	government
Department of Statistics	government
Disaster Management Unit (Social Services)	government
Forestry Unit	government
Meteorology Department	government
Ministry of Environment and Natural Resources	government
Ministry of Public Works	government
Ministry of Tourism	government
Ministry of Transport and Local Government	government
National Emergency Management Agency	government
Port Department	government
Sustainable Development Unit at Office of the Prime Minister	government
The Nature Conservancy	NGO

[1] https://www.depp.gov.bs/

University of The Bahamas	academia

2.6. Spatial structural and strategic profile of the city of Nassau

This section summarizes an evaluation of the capacity of the spatial structure of the island New Providence and the city of Nassau. The urbanized area of New Providence is located on the eastern half of New Providence, along the coastal zone. Nassau city is a low-rise sprawl. The city only really urbanized in the 18th century with a stretch of some 15 blocks along the coast, where the harbour and colonial buildings are. The town’s fabric was made up of English-style masonry houses aligned to the property line, placed on large plots of land. Nassau's modern growth began just over 200 years ago as the population grew along with the built-up areas. After the Second World War, the Nassau airport reverted to civilian use and developed as the largest airport in The Bahamas and the largest international gateway into the country. Population levels exploded in New Providence at that time as the tourist economy began to develop, and the city extends to the east coast of the island. The wealthier residents continued to spread east and west during the 21st century. Today, the urbanized area covers more than one-third of the island. Land use on New Providence is directly related to the primacy of the city of Nassau as the major Bahamian urban area. The mobility network on the island is challenged by a lack of room to expand and a lack of public transport network. As such, there are no cross-island public transport routes to allow users to travel directly from one side to another. The current mobility and transport system in New Providence does not appear to be supporting the island’s economic, social, or environmental well-being.

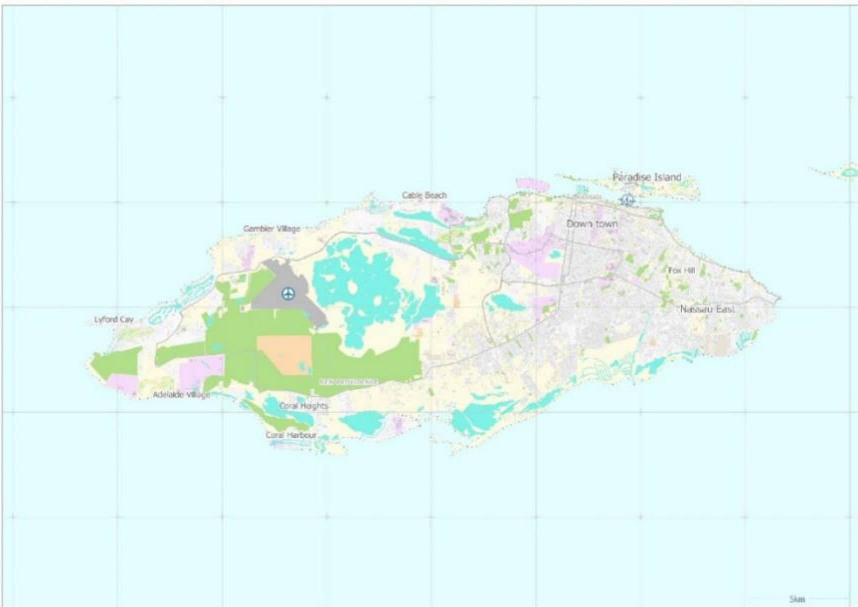


Figure 2.5. Base map of New Providence, image by BUUR/PoS 2022

New Providence is an island of low altitude mainly composed of sand, coral, lakes, and ponds. The ecological value here is high and the scenic quality makes New Providence a unique place. Almost a quarter of the island is occupied by nature elements (inland water, forest, and national parks). Wetlands on the island not only provide habitats for a wide variety of wildlife species but also play an important role in water management. However, uncontrolled urbanization and a lack of long-term urban planning and urban management vision on the island lead to a very severe water resource situation in New Providence. Surface water features may be polluted by industrial and urban runoff. The only source of freshwater in the country is rainfall. Thus, inland wetlands fulfil an important function as water catchments, influencing the condition of the island's freshwater lens. During the rainy season, inland wetlands can collect and store water away from homes and roads. Nevertheless, a lot of building was and is still built along these shallow basins. Consequently, the ecosystem's ability to prevent flooding is diminished. Due to low relief and large urban areas, the New Providence is often inundated.

For New Providence, hurricanes and other tropical storms that cause extensive flood and wind damage are two major climate risks. The urban structure in the coastal zone makes New Providence more vulnerable here. This is due to the proximity of most buildings and functions to the coast, but also to the strong urbanization of the area that makes natural water management difficult. The coastline and its storm and flood security under a rising sea level should be further investigated. Much of the New Providence coastline consists of long, flat coral formations interrupted by small beaches, estuaries, and wetlands – this appears to be a resilient system. The urbanized coastline is also well protected by port and marina infrastructure. However, in both cases, it is not certain that this protection will hold up to increasingly extreme weather events along the coast, and in that case, the spatial structure of the island is very vulnerable. The adaptation strategies are structured around restructuring coral reefs and underwater plants, beach restoration mangrove protection, and infrastructure adjustments.

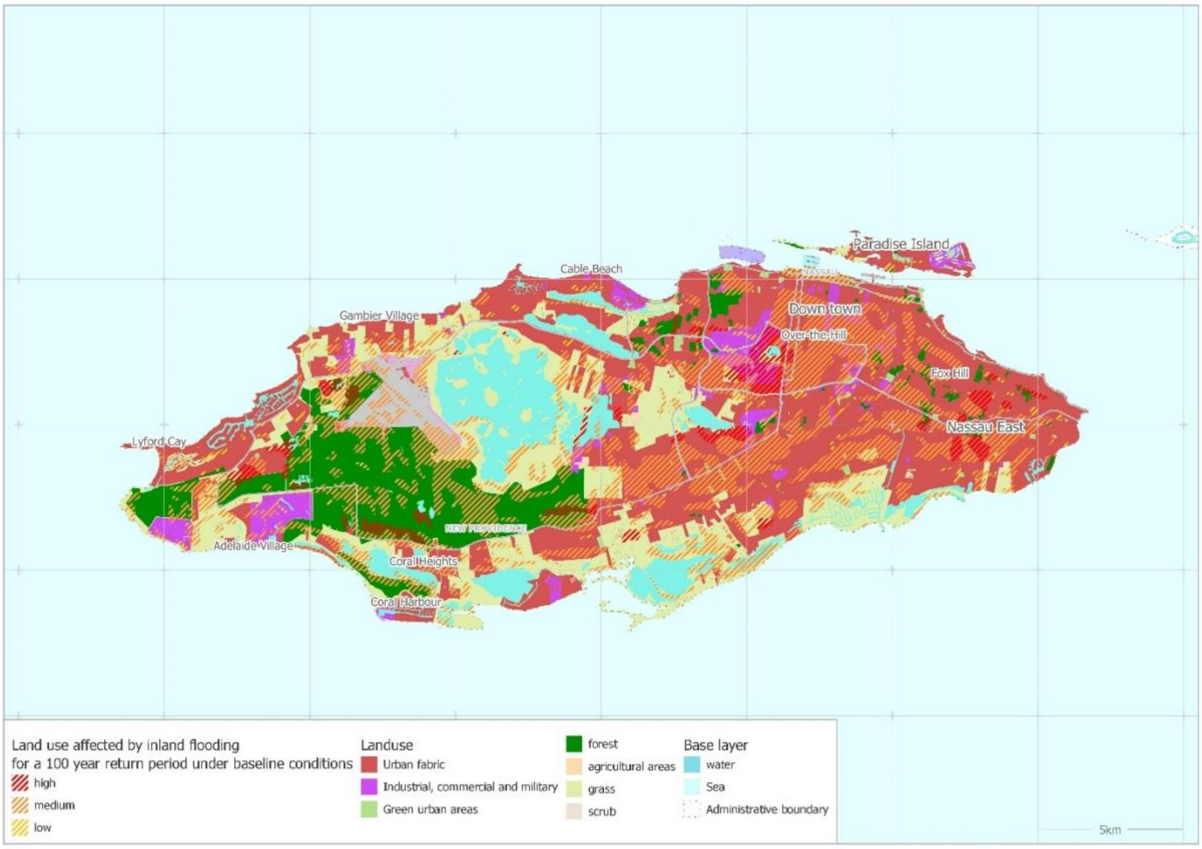


Figure 2.6. Land use affected by inland flooding (BUURpos, 2022)

2.7. Insights from stakeholder engagement meeting

2.7.1. Workshop purpose and setting

The first PROVIDE Stakeholder Engagement Meeting in the Iconic City of Nassau was held on April 22, 2022, in a virtual setting. Invitations to the meeting were coordinated by the

PROVIDE team who sent out official invitations on behalf of the project to all members of the National Climate Change Committee (NCCC) and to other individuals that were identified by NCCC members as relevant to adaptation planning for the country. These included representatives from government agencies, NGOs, the private sector, and academia. The meeting language was English. There was a total of 12 participants. The meeting was supported and moderated by the PROVIDE team.

2.7.2. Overshoot and limits to adaptation

Participants were introduced to the PROVIDE project and to key concepts used in the project, including overshoot and limits to adaptation. Participants were asked to share their views on the relevance of PROVIDE for The Bahamas and familiarity or questions about key concepts. Participants expressed support for the project and that there is a need to focus on adaptation. However, there was very limited familiarity with concepts of overshoot or limits to adaptation. There were some questions about the effects of changes to the ocean affecting the ability of coastal and marine ecosystems to provide critical ecosystem services, such as protection from coastal erosion and flooding. This was the most direct engagement with the limits to adaptation concept among the group. It was noted by participants that capacity building in this area would be welcomed.

2.7.3. Adaptation in the Bahamian context: tools, constraints, opportunities

After a presentation highlighting the current state of national adaptation that was gleaned from a review of the literature, participants were invited to provide their inputs on the current state of adaptation as well as constraints and opportunities. Participants expressed that the most pressing constraint is lack of capacity. While there are efforts being made within various agencies to consider climate change in ongoing responsibilities, there is a lack of trained personnel that is experienced and knowledgeable about the particular aspects of climate change that are relevant for each of the various sectors. The lack of progress with implementing the National Adaptation Policy as well as the lack of a national adaptation plan were also identified as key constraints for adaptation. In terms of opportunities, The Bahamas will soon embark on developing a national adaptation plan and participants did express that output from PROVIDE could help to inform that process. Other participants asked about how PROVIDE relates to other adaptation planning tools that have been introduced to the country, such as the CCORAL tool which provides guidelines for risk management and adaptation planning. It was determined that outputs from PROVIDE could complement these other tools by providing information on different levels of risk that will need to be adapted to at various levels of global warming.

Participants were very interested in development of the PROVDE Dashboard and indicated that projections for the entire island of New Providence, instead of only the small area of the city of Nassau, would be most helpful. The indicators of damages from tropical cyclones as well as heat stress were most supported by participants. Participants indicated interest in providing further feedback on development of the Dashboard when further progress is made.

Presentation of the spatial analysis of New Providence based on limited publicly available data was made by the BUUR team, see Appendix for details. Participants identified further public information sources of spatial data, including some data on coastal hazards that was completed by Stanford University. Participants recommended contacting the Inter-American Development Bank to get spatial data that was part of the Sustainable Nassau project. However, participants were unable to state whether the Sustainable Nassau plans were actually being used to guide planning or activities in the city.

3. Structural and strategic profile: New Providence and Nassau, The Bahamas

Lead author: Séverine Hermand, BUUR Part of Sweco

Contributing author: Mario Doneddu, BUUR Part of Sweco

3.1. Introduction

The Bahamas is an island nation located in the northwest corner of the Caribbean Sea. It spread out over 700 islands and 2,400 uninhabited islets. The majority of the population lives on six islands: Abaco, Andros, Eleuthera, Exuma, Grand Bahama, and New Providence, which includes the capital city of Nassau. The island of New Providence sits in an east-west direction on the edge of the Great Bahama Bank opposite Andros (see Chapter 2 for further detail).

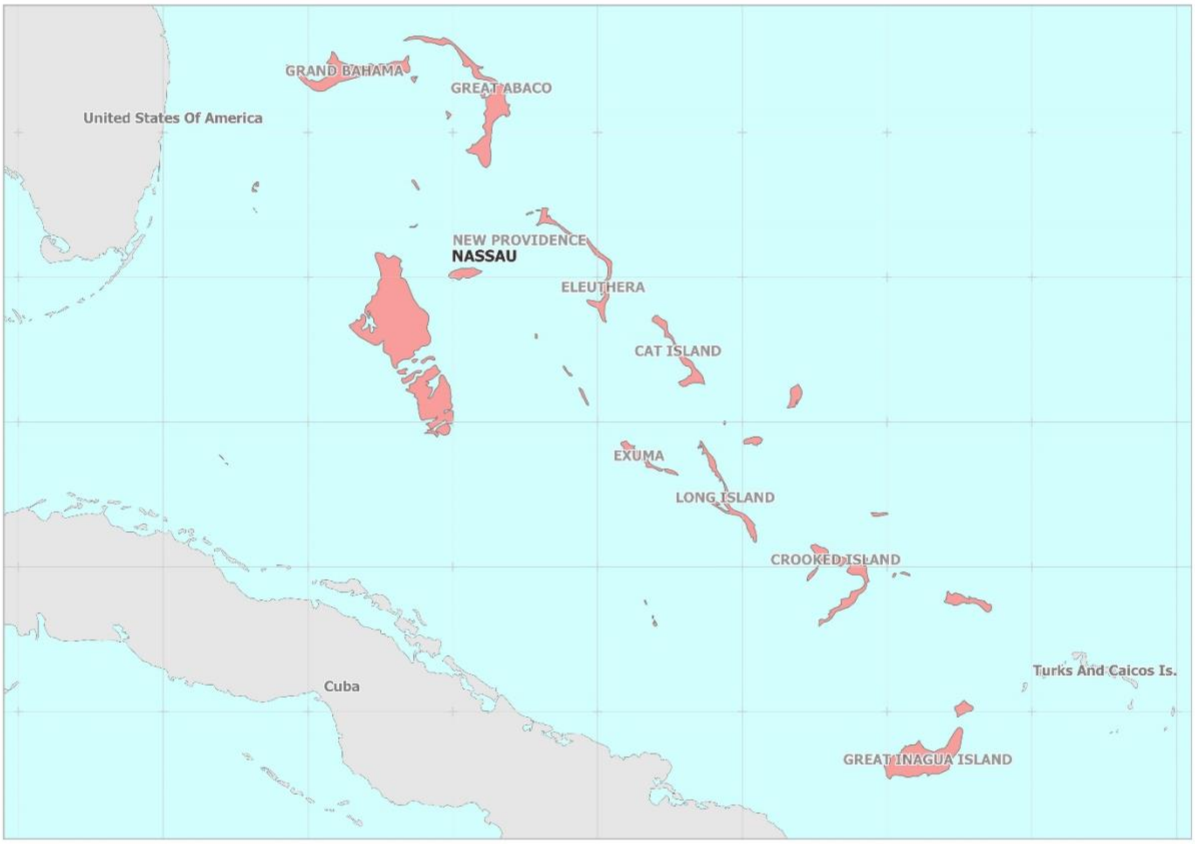


Figure 3.1 Localisation Nassau, image by BUUR/PoS 2022

New Providence is a cay, an island of low altitude (5 meters maximum) mainly composed of sand and coral, 34 km long and 11 km wide, dotted with lakes and ponds, the most important of which is **Lake Killarney** in the centre. The island has a surface area and a population density close to that of the island of Malta (respectively ~200 km² and 1,578.18 inhab./km² in 2007) and is also approximately 50% urbanized. The configuration of the island has allowed the development of marinas around it, such as Sandyport, Old Fort Bay, Lyford Cay, Coral Harbour, Port New Providence or Fox Hill Creek, which are for the most part Gated communities, secure and exclusive communities.

Nassau is the capital and the largest city of the Bahamas. Its low-rise sprawl dominates the eastern half of New Providence.

On the west of Lake Killarney is **Lynden Pindling International Airport**, formerly known as Nassau International Airport, which is the largest airport in the Bahamas and the largest international gateway into the country (Figure 3.2).

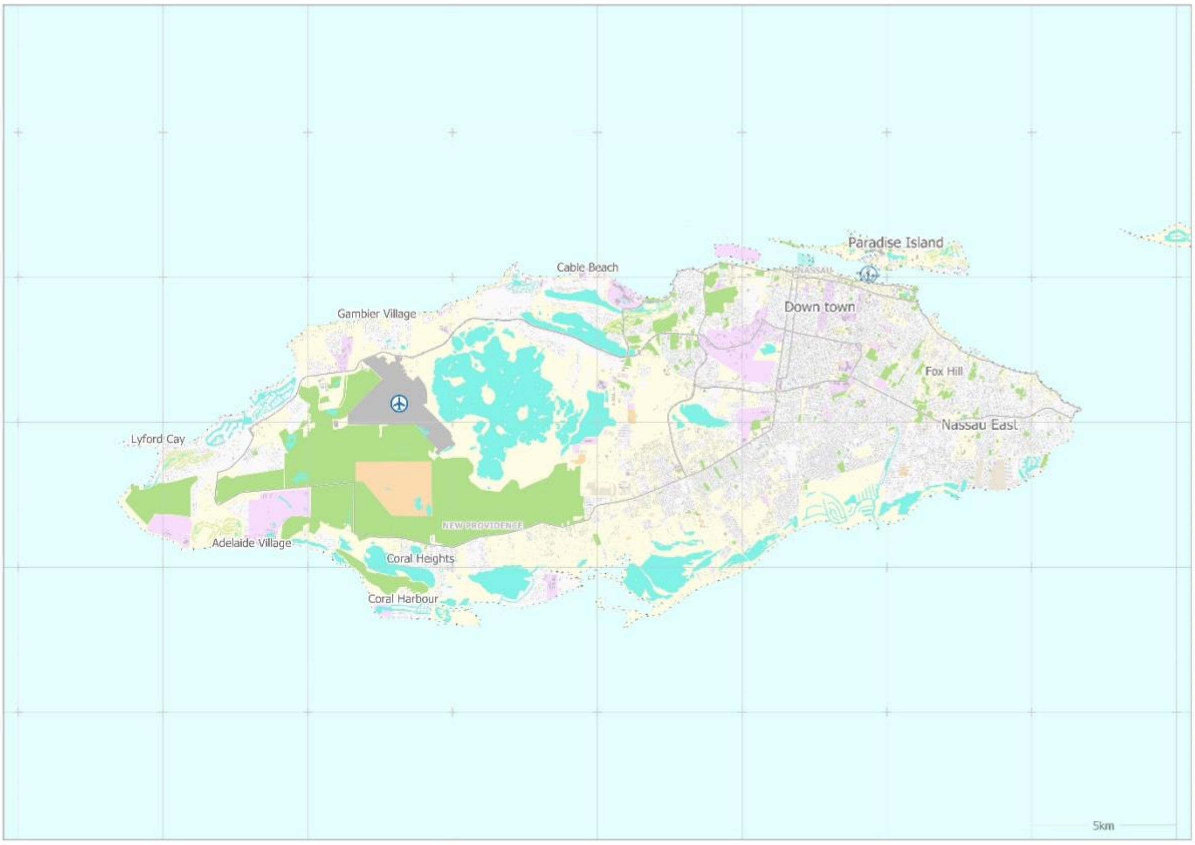


Figure 3.2 Base map New Providence, image by BUUR/PoS 2022

3.1.1. New Providence and Nassau: context & history

The history of Nassau and New Providence is long and complex; thus, we present only a few highlights in this paragraph.

Nassau is the site of the House of Assembly and various judicial departments. The Bahamas and Nassau in particular were a haven for pirate activities in the 17th century, resulting in the city being sacked and burned in 1703 in an attempt to eliminate the problem (Joan Albury 1975). Nassau's modern growth began just over 200 years ago with the migration of American Loyalists and enslaved Africans. As the population of Nassau grew, so did the built-up areas. The city first became overcrowded and then burst its bounds to spread over much of the 207 km^2 (80 square miles) of New Providence. By 1980, Nassau's island officially contained 135,000 people, 65% of the Bahamian total, compared with 46,000 (54%) in 1953 and 12,500 (23%) in 1901. The 1980 figures gave New Providence a population density of 4,400 per km^2 (1,700 per square mile), compared with the Bahamas' overall average of 101 per km^2 (39 per square mile), and the combined average of less than 7,7 per km^2 (3 per square mile) for Andros and Inagua, the two largest islands (Michael Craton 1986). Independence for the Bahamas was celebrated in Nassau on 9 July 1973.

Today the city dominates the entire island and its satellite, Paradise Island with approximately 70% of the population located on the island of New Providence which hosts the capital city of Nassau (Cf. Section 2.1). Population levels exploded in New Providence after the Second World War as the tourist economy began to develop (Sealey 1990).

The 1788 heart of Nassau was just a few building blocks (Government House and the harbor), but the town gradually expanded (Figure 3.3). Indeed, the city of Nassau area corresponds historically to the small area where Charles Towne arose in the 18th century. It was a stretch of some 15 blocks along the coast where the harbor and colonial buildings appeared (West and East bay street). The town's fabric was made up of English-style masonry houses aligned to the property line, placed on large plots of land.

The largest concentration of African descent lived in the "Over-the-Hill" suburbs of Grants Town and Bain Town to the south of the city of Nassau, and until about 30 years ago was the most populous part of the city. Most of the European-descent inhabitants lived on the island's northern coastal ridges. During the 20th century, the city spread east to Village Road and west to Fort Charlotte and Oakes Field. This semicircle of residential development (Figure 3.3) was the main area of settlement until after the Second World War and marks a distinct phase in the city's expansion, the outer boundary to this zone being the effective limit of the continuous built-up area. The wealthier residents continued to spread east and West (to Lyford Cay).

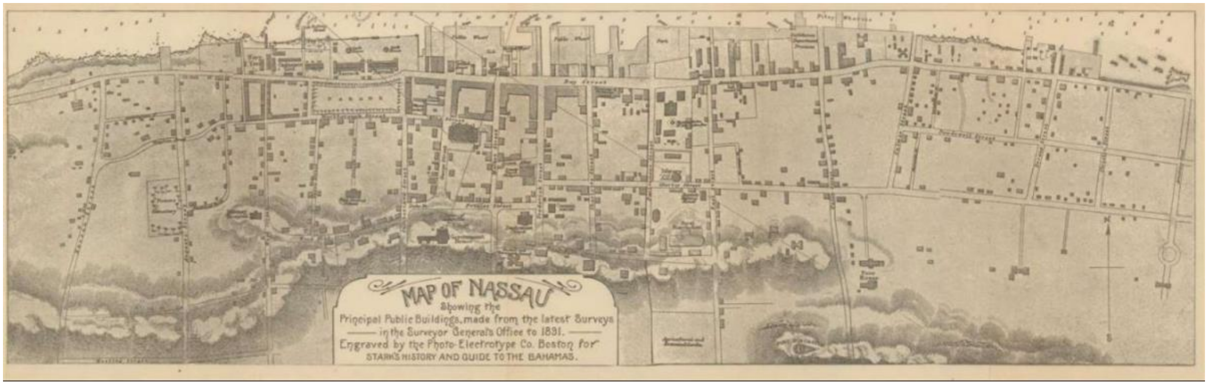


Figure 3.3 Map of Nassau showing the principal public buildings, made from the latest surveys in the Surveyor General's Office to 1891. Source: James Henry Stark 2018

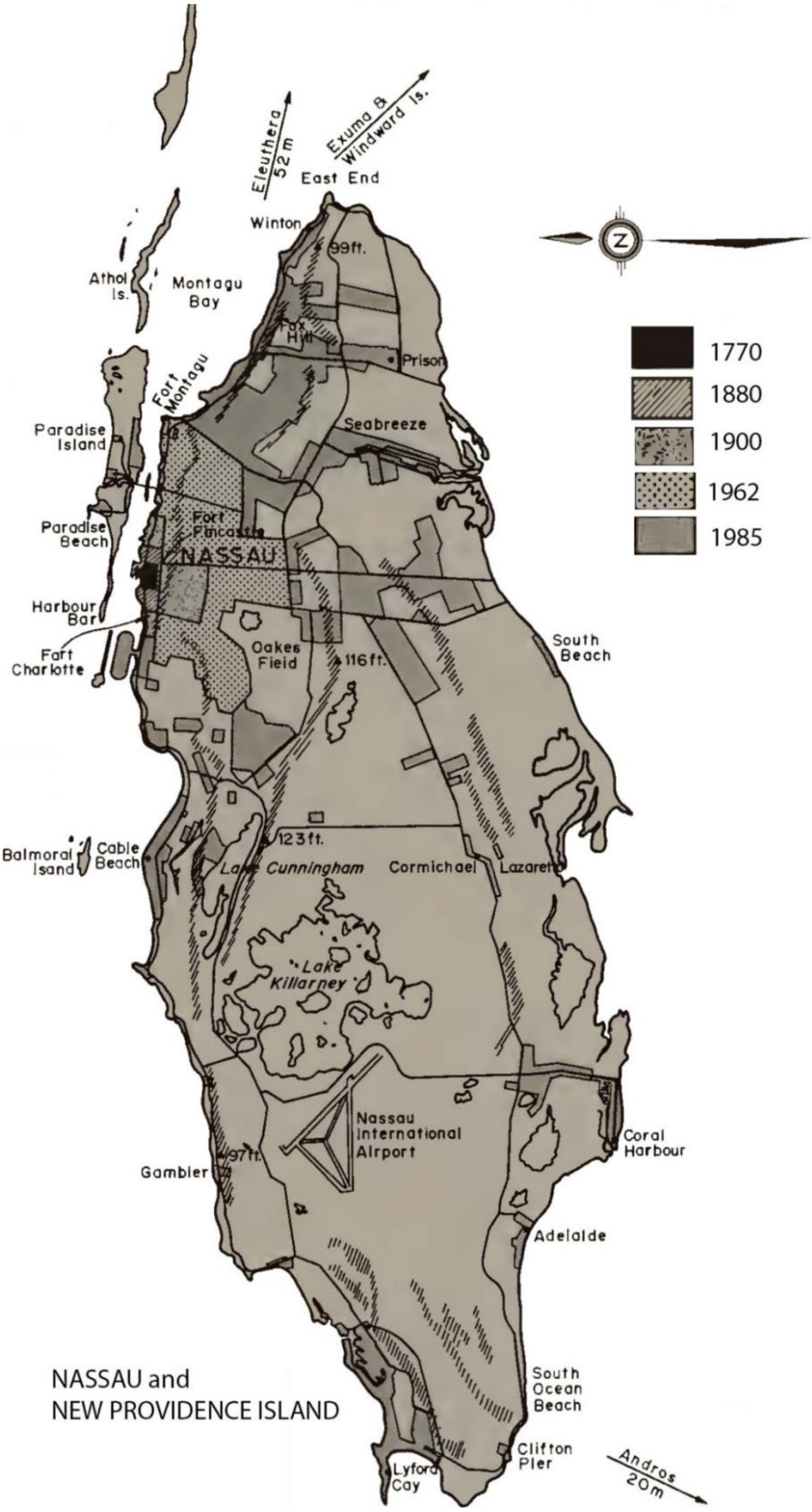


Figure 3.4 Historical map Nassau and New Providence;. Source: Michael Craton 1986

3.2. Structural profile

3.2.1. Soil & topography

New Providence is somewhat unusual when compared to other Bahamian islands, as it contains **a broad expanse of large ridges**. The relief of the ridges on New Providence (Figure 3.5**Error! Reference source not found.**) shows variability and distinct trends both from north to south and from west to east the highest relief ridges (with some peaks > 30 m) are confined to within 2 km of the north-western, northern, and north-eastern coasts of the island, with one exception. This one ridge stretches 12 km along an axis trending NW-SE, with the innermost portion being almost 5 km inland. The southern portion of the island is dominated by low-relief ridges (generally not exceeding 10 m) trending generally east to west or ENE-WSW (Reid 2010).

The majority of New Providence Island's land is composed of young and very pure **limestone**. Both characteristics are of considerable significance to agriculture. The purity means that only calcium carbonate is available to plants from the geology (much in the way of nutrients comes from the air, and via decaying vegetation such as humus). The soils, due to the mix of acid and calcium carbonate produce soils which are alkaline (Little 1977). As acid conditions are generally bad for crops, Bahamian land avoids this growth. Moreover, the Bahamas soils are alkaline, usually in the range of 7.5 to 8.5 on the PH scale brings problems for water drainage, knowing that anything over 7 to 8.3 offers challenges for the ability of a plant to absorb water.

Figure 3.5 Topography Providence Island, image by BUUR/PoS 2022. Data: KPA 2022 https://geo.ngu.no/

3.2.2. Water

Water is a crucial function of the small island ecological system. Like many tropical islands, natural freshwater supplies in the Bahamas consists of freshwater aquifers, sitting in a lens on top of a lower saltwater layer.

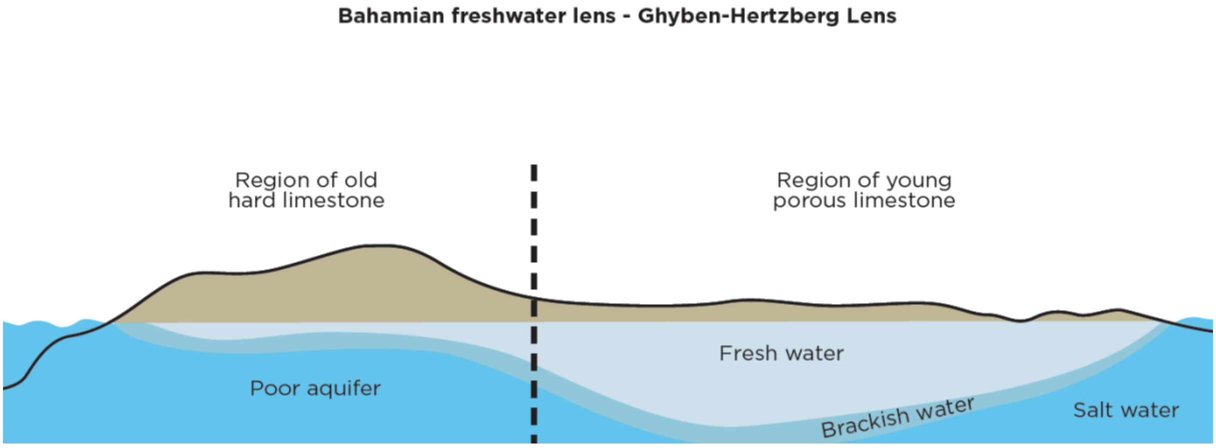


Figure 3.6 Fresh water aquifer location. Source: Wyatt, Alan 2018

This resource is dependent on rainwater and is susceptible to salinization if over-pumped.

The water resource situation is very severe on New Providence (with 70% of the population), water supply is from local groundwater and 30% of water is transported by barge from Andros Island, 75 km to the west. All water is from groundwater except small supplies from roof catchments and desalination of seawater. There are no major surface water sources because of the porous nature of the soil and rock. No major irrigation is carried out (Ekwue 2010).

The island's terrain is low and flat with a few small lakes and mangroves swamps (Figure 3.7). The southern coast of the island between Adelaide and Cay Point is dominated by lagoons and ponds. These areas are brackish or saline throughout the year. The biggest lake on the island, Lake Killarney, located in the centre of New Providence, is surrounded by marshlands. The lake is quite shallow, only a meter or so deep, and is also brackish. These features should not be considered sources of freshwater. Surface water features may be polluted by industrial and urban runoff. The only source of freshwater in the country is rainfall. Thus, inland wetlands fulfil an important function as water catchments, influencing the condition of the island's freshwater lens. With the help of plants growing in these areas, e.g., mangroves, excess nutrients are removed from the water before it reaches the ground water table. During the rainy season, inland wetlands can collect and store water away from homes and roads. Nevertheless, a lot of building was and is still built along these shallow basins. Consequently, the ecosystem's ability to prevent flooding is diminished. Due to low relief and large urban areas, New Providence is often inundated.

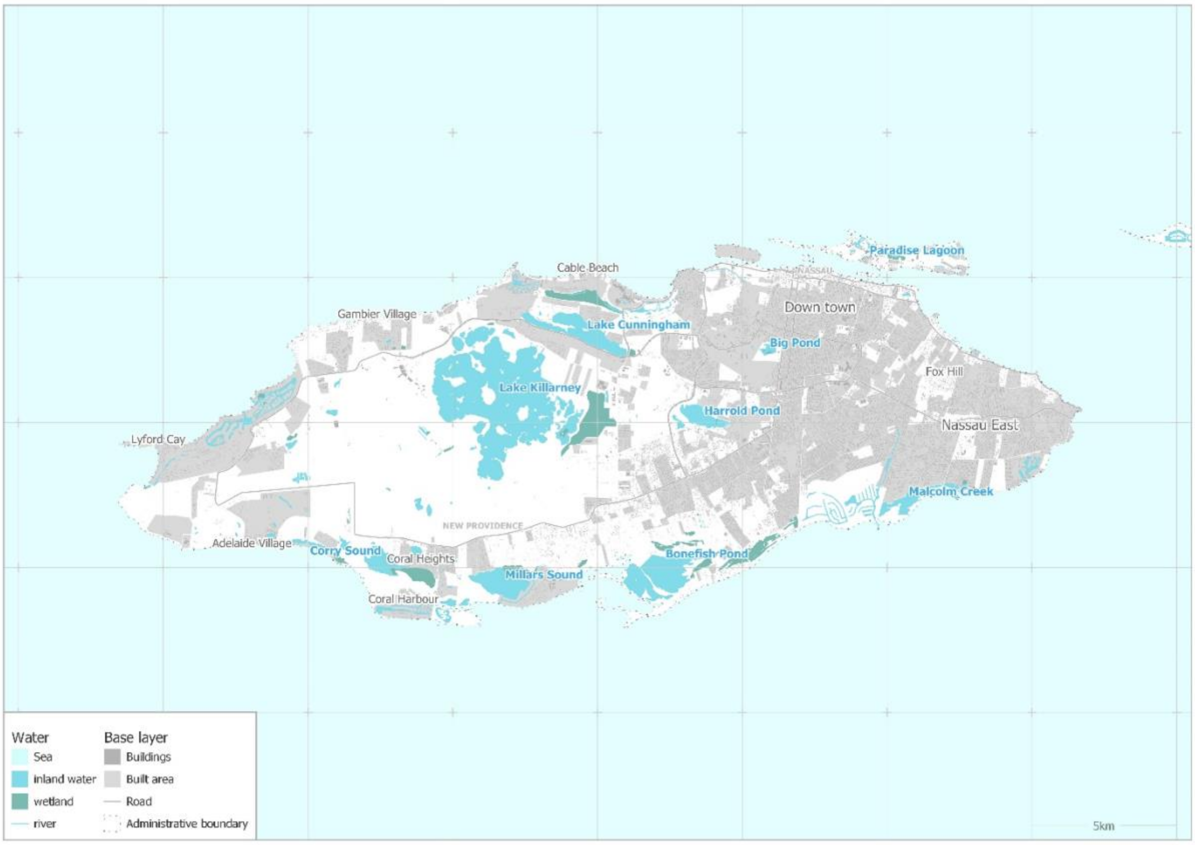
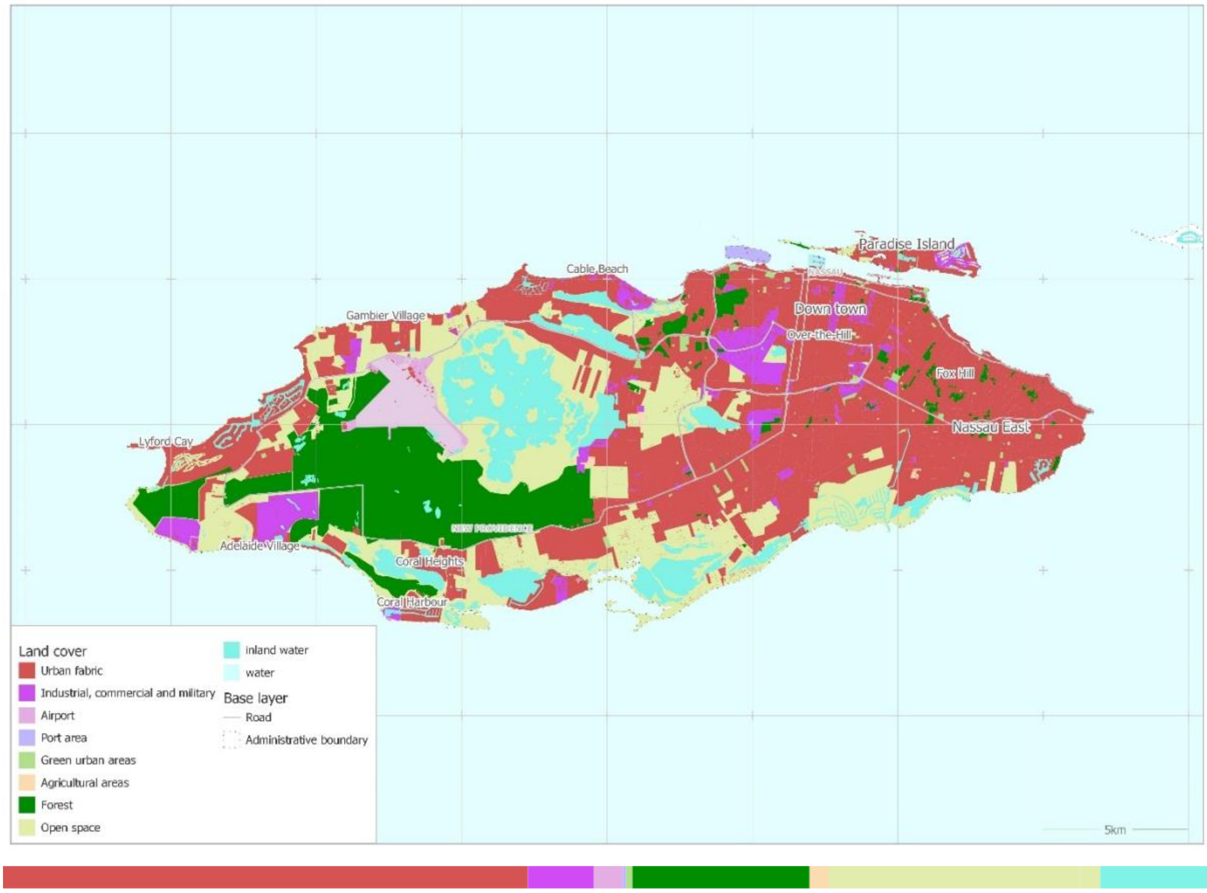


Figure 3.7 Water system New Providence, image by BUUR/PoS 2022. Data: open street map, 2022

3.2.3. Land cover

A large part of the economic activities of the country is concentrated on New Providence. Inland water covers more than 10% of the total surface island areas and forest 15% (Figure 3.8). Thus, almost a quarter of the island is occupied by nature elements. The residential capital stock is concentrated in the populated areas, specifically, in part east of the island and on the north-west coastland. In total, the urbanized area of the island covers more than one-third of the island. However, according to the Sustainable urban Nassau (IDB 2018), 367,500 persons will be living on the island by 2045. The expected housing demand can be met with an additional 6,186 homes while the land use mix could change to include 54% of urbanized space and 46% of natural areas. Due to urbanization and soil quality, agriculture is negligible on New Providence (>2% of total island surfaces).



Urban fabric 43.5%
Industrial, commercial and military 5.5%
Airport 2.4%
Port area 0.3%
Green urban areas 0.5%
Forest 14.7%
Agriculture 1.6%
Open space 20.8%
Inland water 9.1%

Figure 3.8 Land cover map, image by BUUR/PoS 2022. Data: open street map, 2022

3.2.4. Ecology

The Bahamas islands consist of landscapes including vast Caribbean Pine forests, mangrove swamp areas, Blackland coppice, sandy and rocky shores as well as tidal creeks. There are also marine landscapes including blue holes, relatively large coral reef areas, open ocean areas and a huge bank system consisting mainly of the Great and Little Bahama Banks. In total there are 32 national parks in the archipelago of which four are located in New Providence[2] (Figure 3.9).

In the south lies **Bonefish Pond**, a coastal wetland area which is the most visited national park on the island. In the centre South, **Harrold and Wilson Ponds** include two shallow freshwater bodies. The park protects valuable freshwater wetlands, coppice, and pinelands. Located in southwestern New Providence the **Primeval Forest** supports a diverse collection of plants and animals. This old-growth woodland is representative of the early evergreen tropical hardwood forests of the Bahamas. The last national park on the island lies in the heart of the capital. The **Retreat Garden** is an urban green oasis garden of palms and rare tropical plants. Formerly a private home, the estate was the first

[2] Bahamas national trust: https://bnt.bs/explore/new-providence/

national park in New Providence. Next to the national parks, the island contains natural reserves of a different character.

Many are located in the wetlands and are protected habitats for birds like Lake Cunningham or Waterloo. Some are marine reserves, like South West Marine Managed Area. Also, a lot of forests are protected, like Carmichael North and South and Corry Sounds, both with wetlands that are real bird paradises.

Wetlands are important to The Bahamas because they absorb and store water, lessening the impacts of storms and floods, as well as cleanse water of pollutants and recharge groundwater supplies. Wetlands also provide important habitats for a wide variety of wildlife species. They are known as the greatest carbon sinks on the planet. According to the Global Forest Watch (GFW), in 2010, New Providence had 344kha of tree cover, extending over 26% of its land area. In 2021, it lost 1.55kha of tree cover, equivalent to 596kt of CO_2 emissions.

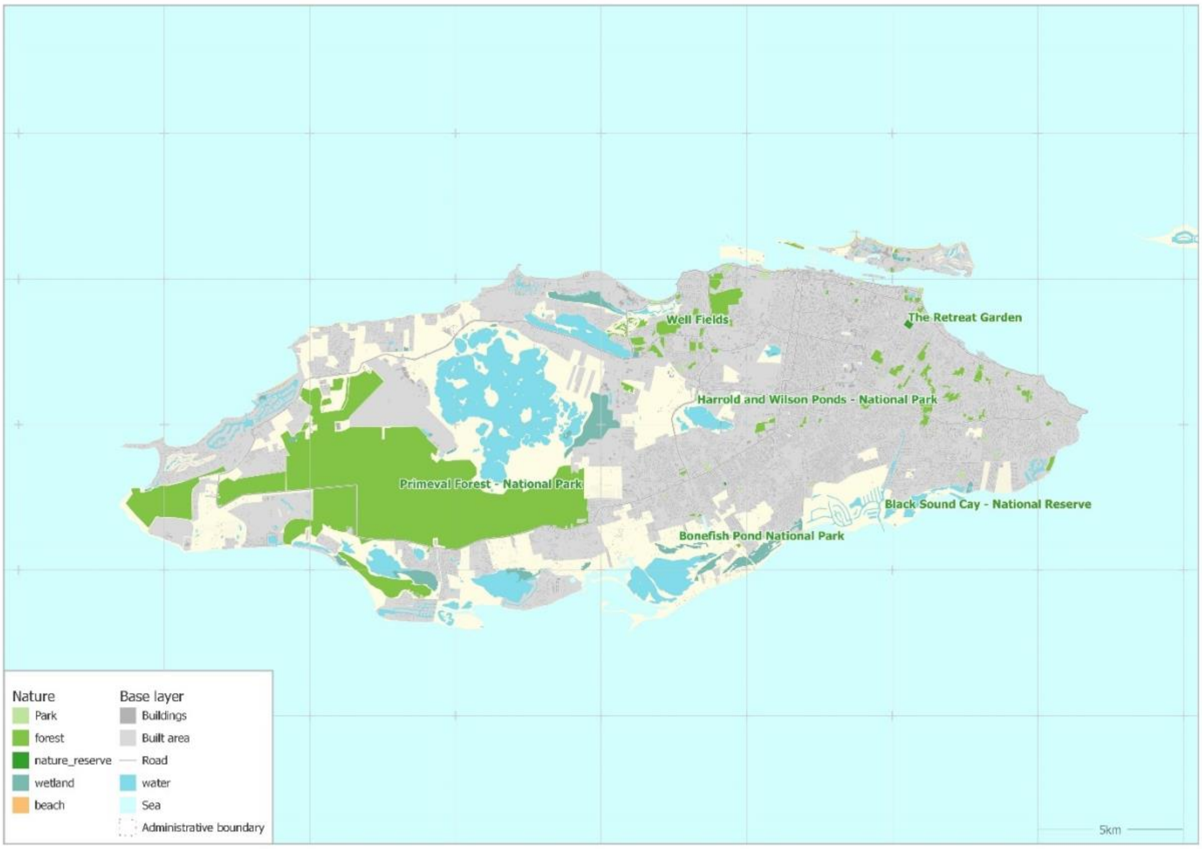


Figure 3.9 Nature map, image by BUUR/PoS 2022.
Data source: open street map, 2022

3.2.5. Transport and networks

According to the Sustainable Nassau plan, the current mobility and transport system in New Providence does not appear to be supporting the island's economic, social, or environmental well-being. The ongoing increase in private vehicle ownership and use continues to harm citizen safety, air quality, overall quality of life and citizen mobility. The existing road network (Figure 3.10) is challenged by a lack of room to expand, and traffic is often congested and chaotic. Congestion is a serious problem in that many intersections exceed their design capacity (Transportation Public Policy and Change in New Providence). Public transportation routes have remained essentially unchanged since

2000 despite new growth areas throughout the island. There are currently 23 bus routes. While routes extend to most parts of the island, their orientation is towards downtown Nassau. As such, there are no cross-island routes to allow users to travel directly from one side to another. Thus, users who want to travel across a need to transfer through downtown and take a second bus.

Despite the island's relatively flat topography, bicycle use is very low in New Providence. There are no facilities for bicycles. The narrow roads of Nassau do not encourage the use of bicycles and can make their use dangerous. Thus, without specific accommodation for bicycles and light motorized vehicles, there is a continued dominant reliance on the car.

Figure 3.10 Mobility New Providence, image by BUUR/PoS 2022

3.2.6. Land use

New Providence mimics the global trend in urbanization with its proportion of the population increasing from 54% in 1953 to 70% in 2010. The total island population is expected to grow by approximately 27% between 2015 and 2040 (IDB 2018). Such a high concentration of the population in the capital begets a natural accrual of public, economic, and infrastructure resources. Yet, despite the perceived employment opportunities, poor planning has exacerbated the woes accompanying urbanization, namely crime and social stratification. Land use on New Providence is directly related to the primacy of the city of Nassau as the major Bahamian urban area. The specific island uses are the port activities of Nassau and, the airport sites near Nassau. As a popular cruise ship destination, Nassau is known for its beaches, coral reefs, shallow waters, tropical climate, and other amenities of tourism. It retains many of its characteristic pastel-colored British colonial buildings, such as the pink-hued Government House (Figure 3.11) and the Public Library Building.

Figure 3.11 Government House © 2022 worldatlas.com

The Historical centre of Nassau effectively represents two distinct communities (Figure 3.12) that at one time formed the centre of city life: Downtown Nassau and Over-the-Hill. Despite the rapid urban growth of the city, Nassau's downtown today remains empty and disconnected from the rest of the city. This area is almost entirely commercial without homes and living spaces. This area was built mostly using the local limestone deposits of New Providence's natural ridge. Beyond the ridge is Over-the-Hill.

The Over-the-Hill community was originally established as freed-slave settlements in the 1800s. Today several areas of the community are deteriorated with dilapidated building structures, lack of basic infrastructure and have a shortage of clean, safe public spaces.

On the east and central south of the island, the urban fabric is characterised as low to medium density in comparison to the two previous communities, which are the highest densely built areas of New Providence.

The build-up area of the island is also organised around several gated community. New Providence hosts in its coastal areas some of the most luxurious and prestigious gated communities as a form of a residential community working as islands inside the island as Port New Providence waterway and Lyford Cay.

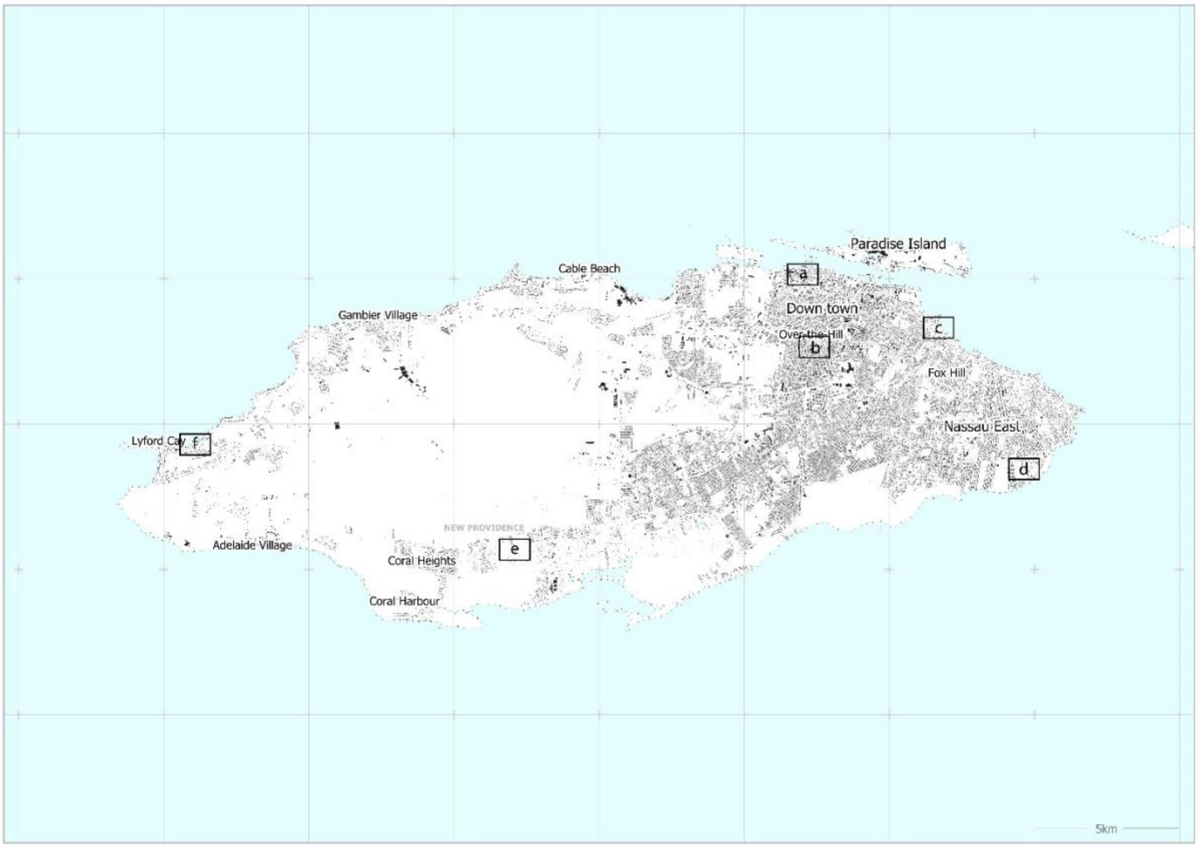
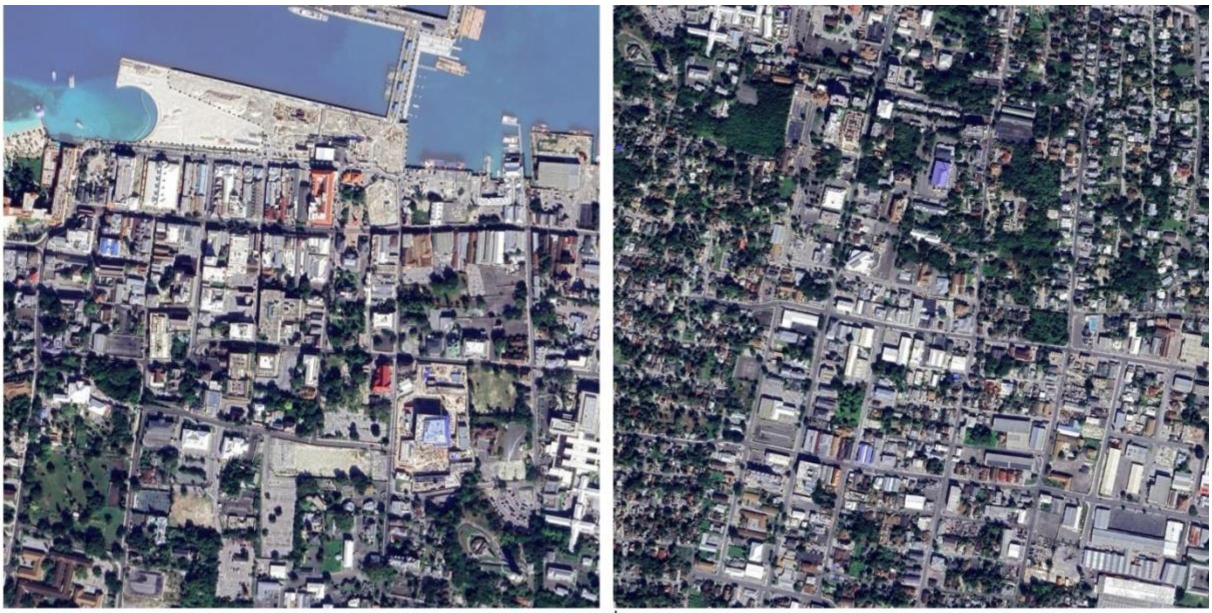


Figure 3.12 Building morphology, image by BUUR/PoS 2022



a. b.

Figure 3.13 a. Downtown Nassau; b. Over-the-Hill (google earth images)

c. e.

Figure 3.14 c. East Nassau ; e. South-Centre New Providence

d. f.

Figure 3.15 d. Port New Providence waterway; f. Lyford Cay

From the building analysis, it appears that there are few qualitative open spaces, and the disconnection of public space in the centre of Nassau decreases the attractivity for walking or using another way of transportation than private transport. The presence of private development all around the coastland makes the disconnection from the waterfront more predominant.

3.3. Strategic profile

3.3.1. Local climate risks

Climate change is exacerbating the vulnerability of the island, with temperatures steadily rising, sea level rising, and average annual rainfall decreasing and becoming increasingly erratic.

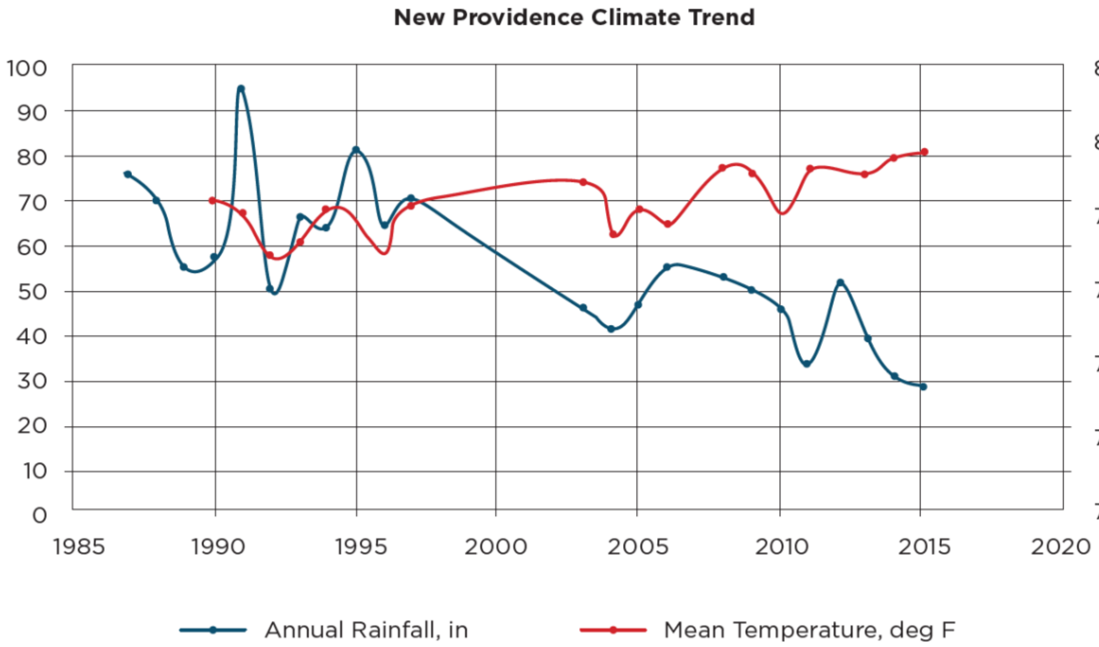


Figure 3.16 Recent changes in rainfall and temperature - New Providence. Source: Wyatt, Alan 2018

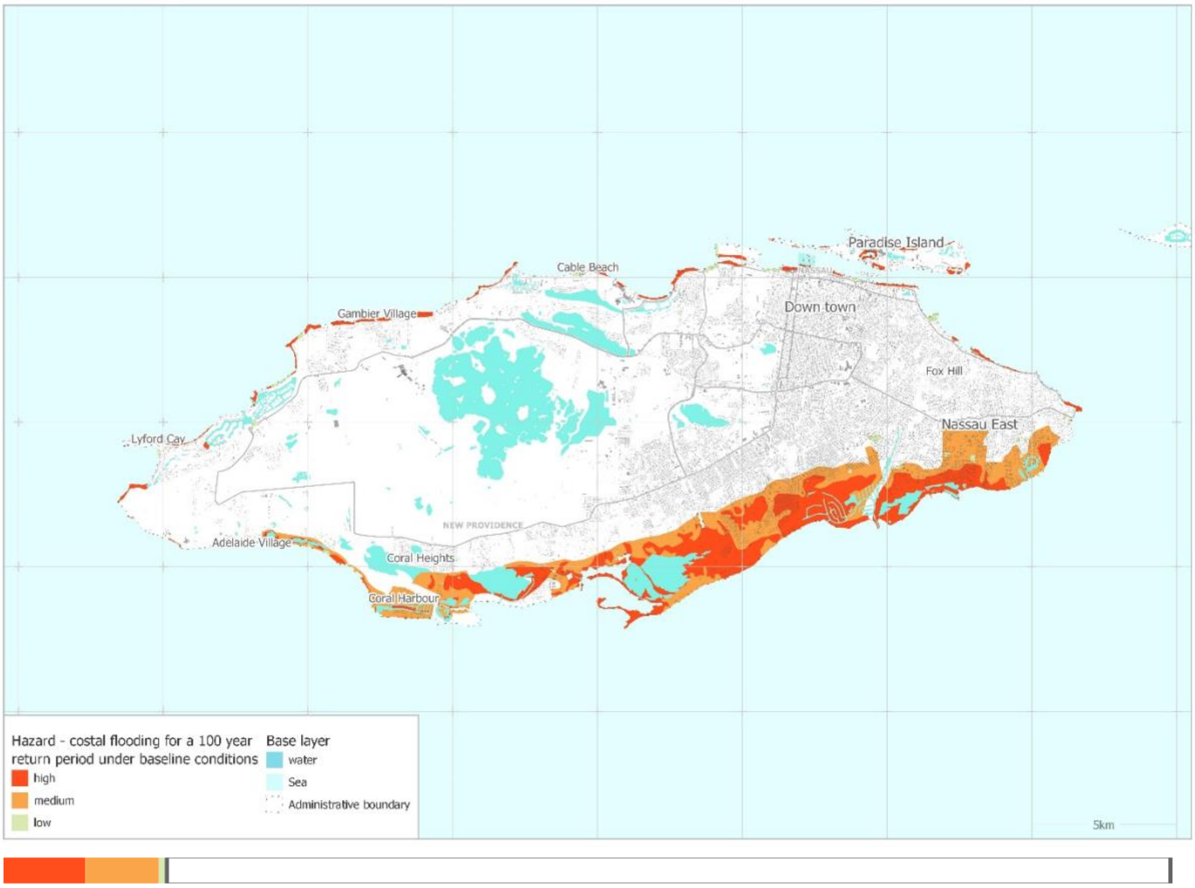
3.3.2. Sea level rise

Island such as New Providence are obviously sensitive to sea level rise. In general, three broad groups of adaptation strategies can be distinguished: (physical) protection measures, risk avoidance through changing land use, and disaster management.

- (Physical) protection measures
  - construction of new infrastructure
  - adaptations to buildings
  - natural buffers such as wetlands
- Risk avoidance through land use change
  - new developments only outside risk zones
  - relocation of activities and infrastructure away from risk zones
- Disaster management
  - modelling & risk analysis
  - warning systems
  - emergency plans
  - insurance

New Providence is the seat of the capital city Nassau and the most densely populated island in the Bahamas. It is also the most exposed island in the country, to be impacted by hurricane winds, with nearly a tenth of its total shoreline currently highly exposed. The most exposed areas on New Providence are primarily along the southern coast of the island where it is positioned on a shallow tongue of the Great Bahama Bank (Figure 3.17).

The adaptation strategies are structured around restructuring coral reefs and underwater plants, beach restoration mangrove protection, and infrastructure adjustments.



hight 6.9%
medium 6.3%
low 0.5%
no hazard 86.5%

Figure 3.17 Costal flooding, image by BUUR/PoS 2022
Source: IDB 2018 and open street map

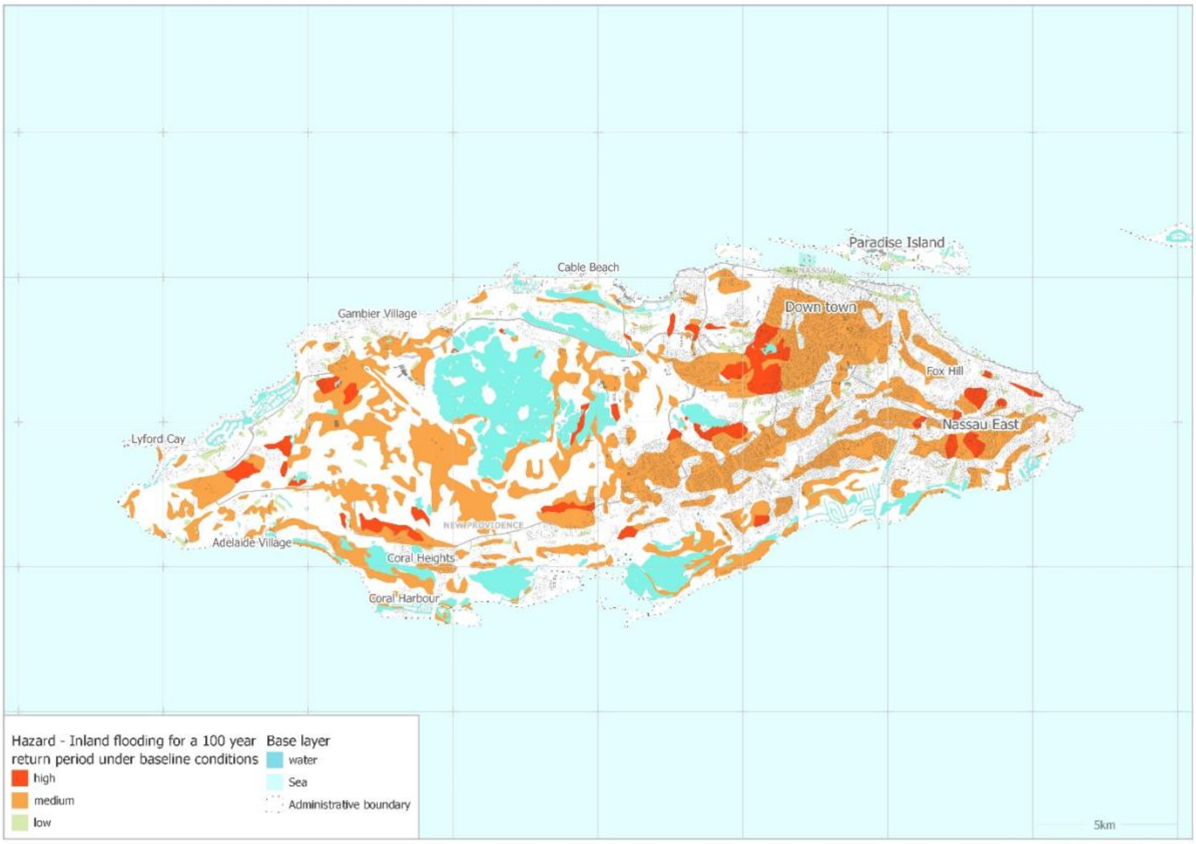
3.3.3. Pluvial and fluvial flooding

The expected increase in precipitation amounts, both average and during extreme weather events, also brings an increase in the risk of inland flooding in New Providence, especially in the urban area of Nassau. Here, runoff precipitation from the city's paved surfaces meets precipitation water discharged through open or channeled waterways. Despite the calcareous characteristics of the soils of New Providence (which are highly permeable), they rapidly become saturated due to the high-water table and the slow seepage process.

According to the sustainable Nassau plan, New Providence is considered highly vulnerable to groundwater salinization, both because the freshwater lenses are being overexploited and due to contamination.

Adaptation strategies for this type of flooding, consist of both measures to protect against the floods themselves, and strategies that reduce the amount of rainwater runoff, such as buffering and natural infiltration. In certain circumstances, accelerated drainage can also be a solution.

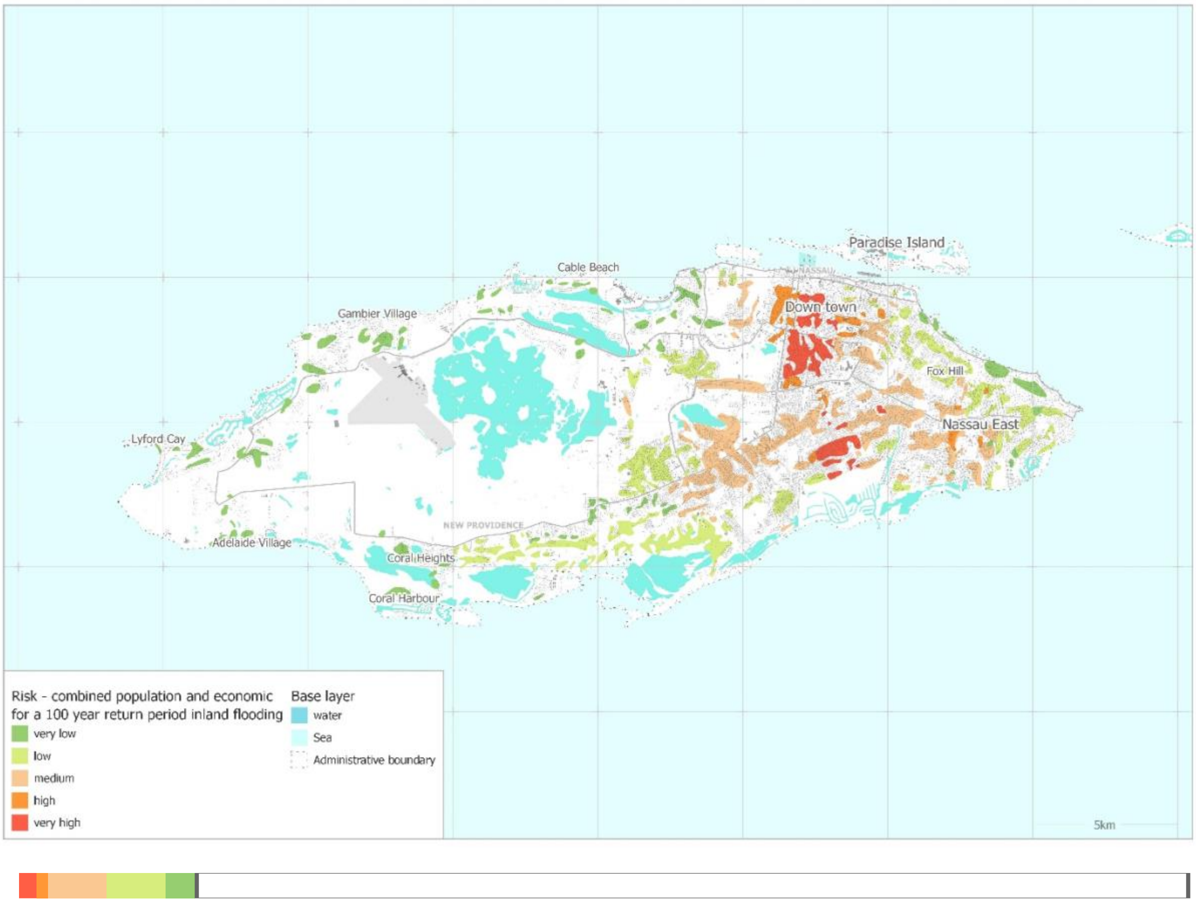
- Flood protection
    - protection measures on a building scale
    - physical protection infrastructure
    - temporary (emergency) protection
    - warning systems
    - insurance
- Water buffering
    - lakes, ponds & wetlands
    - water squares & other urban above-ground buffering
    - storage sewers & other underground buffering
    - rainwater harvesting & storage
- Infiltration
    - increasing soil permeability (reduction of impermeable surfaces)
    - natural buffering systems
    - bioswales & infiltration strips
    - underground infiltration systems (horizontal/vertical)
- Drainage
    - improving above-ground drainage
    - above ground drainage systems
    - underground reverse drainage (including infiltration)
    - underground drainage systems



high 4%
medium 28%
low 2%
no hazard 66%

Figure 3.18 Inland flooding, image by BUUR/PoS 2022
Source: IDB 2018 and open street map

The vulnerable people in the centre of Nassau are the first impacted by the floods (Figure 3.19). In this area of the island, there is a high density of population and a large number of buildings exacerbating the risk. In addition, the IDB estimated an increase of 8-13% in economic losses due to flooding.



very high 1.5%
high 1%
medium 5%
medium 5%
low 2.5%
no risk 85%

Figure 3.19 Risk – Combined population and economic (BUURpos 2022)
Source: IDB 2018 and open street map

The land use and flood analysis (Figure 3.20) shows a need to reinforce the planning of coastal zones and regulate residential construction along beaches of New Providence.

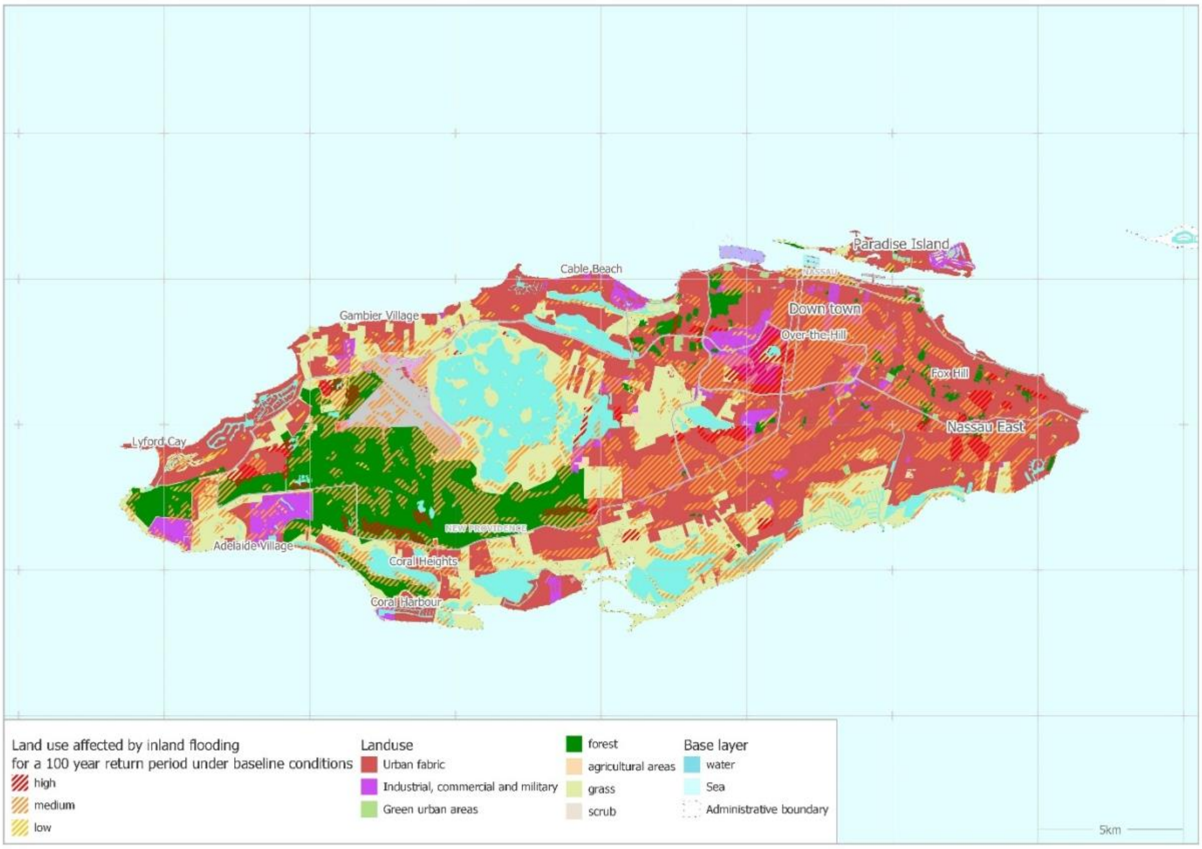


Figure 3.20 Land use affected by inland flooding (BUURpos, 2022)

In May 2022, the Ministry of Works and Utilities adopted a "comprehensive Disaster Management" strategy to mitigate the issue of flooding in New Providence. Drainage cleaning, a pilot drilling project, an aggressive maintenance program, conventional wells, and installation of new systems in open spaces are among the mitigation measures that the Ministry is using and/or proposing.

The following subchapter will look at how the urban system works today in Nassau Center, which is severely impacted by flood events, and how green space can help with infiltration as well as buffering rainwater.

3.3.4. Regulation systems: green-blue network

Figure 3.21 depicts a fragmented urban tissue as well as potential zones of built densification (red symbols). This urban pressure on land reduces infiltration and water buffering capacity in the event of flooding.

Furthermore, dwindling trees and vegetation can contribute to increased stormwater runoff and erosion.

Another potential issue stems from an inability to adequately integrate green space planning, buffering spaces (blue symbols), and road infrastructure as buffering zones (green symbols).

Figure 3.21 Green-blue system of Nassau center image by BUUR/PoS 2022

4. Bibliography

Ekwue E (2010) Management of water demand in the Caribbean region: current practices and future needs. The West Indian Journal of Engineering 32:28–35

IDB (2018) Action Plan "Sustainable Nassau: Empowered people, revitalized city"

James Henry Stark (2018) Stark's History and Guide to the Bahama Islands: Containing a Description of Everything on or about the Bahama Islands, Forgotten Books

Joan Albury (1975) The Story of The Bahamas, MacMillan

Little BG (1977) Land Resources of the Bahamas: A Summary. Land Resources Division, Ministry of Overseas Development

Michael Craton (1986) A history of the Bahamas Hardcover, 3rd edition. San Salvador Press

Reid SB (2010) The Complex Architecture of New Providence Island (Bahamas) Built by Multiple Pleistocene Sea Level Highstands

Sealey NE (1990) The Bahamas today an introduction to the human and economic geography of the Bahamas. Macmillan Caribbean, London

Wyatt, Alan (2018) Case Study: Performance-based Contract for NRW Reduction and Control - New Providence, Bahamas. IDB

Adger WN, Arnell NW, Tompkins EL (2005) Successful adaptation to climate change across scales. Global Environmental Change 15:77–86. https://doi.org/10.1016/j.gloenvcha.2004.12.005

Alfieri L, Dottori F, Betts R, et al (2018) Multi-Model Projections of River Flood Risk in Europe under Global Warming. Climate 2018, Vol 6, Page 6 6:6. https://doi.org/10.3390/CLI6010006

André K, Baird J, Gerger Swartling Å, et al (2017) Analysis of Swedish Forest Owners' Information and Knowledge-Sharing Networks for Decision-Making: Insights for Climate Change Communication and Adaptation. Environmental Management 59:885–897. https://doi.org/10.1007/S00267-017-0844-1/TABLES/4

Aparicio Á (2017) ScienceDirect-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY. ScienceDirect Transport adaptation policies in Europe: from incremental actions to long-term visions. Transportation Research Procedia 25:10–15. https://doi.org/10.1016/j.trpro.2017.05.277

Austin SE, Biesbroek R, Berrang-Ford L, et al (2016a) Public Health Adaptation to Climate Change in OECD Countries. International Journal of Environmental Research and Public Health 13:. https://doi.org/10.3390/IJERPH13090889

Austin SE, Biesbroek R, Berrang-Ford L, et al (2016b) Public Health Adaptation to Climate Change in OECD Countries. International Journal of Environmental Research and Public Health 13:. https://doi.org/10.3390/IJERPH13090889

Barceló A, Nunes L (2011) Iberian Climate Atlas - Air Temperature and Precipitation (1971-2000)

Batllori E, de Cáceres M, Brotons L, et al (2019) Compound fire-drought regimes promote ecosystem transitions in Mediterranean ecosystems. Journal of Ecology 107:1187–1198. https://doi.org/10.1111/1365-2745.13115

Bedia J, Golding N, Casanueva A, et al (2018) Seasonal predictions of Fire Weather Index: Paving the way for their operational applicability in Mediterranean Europe. Climate Services 9:101–110. https://doi.org/10.1016/J.CLISER.2017.04.001

Berkhout F, Bouwer LM, Bayer J, et al (2015) European policy responses to climate change: progress on mainstreaming emissions reduction and adaptation. Regional Environmental Change 15:949–959. https://doi.org/10.1007/S10113-015-0801-6/FIGURES/4

Berry PM, Brown S, Chen M, et al (2015) Cross-sectoral interactions of adaptation and mitigation measures. Climatic Change 128:381–393. https://doi.org/10.1007/S10584-014-1214-0/TABLES/1

Bird DN, Benabdallah S, Gouda N, et al (2016) Modelling climate change impacts on and adaptation strategies for agriculture in Sardinia and Tunisia using AquaCrop and value-at-risk. Science of The Total Environment 543:1019–1027. https://doi.org/10.1016/J.SCITOTENV.2015.07.035

Birgit Bednar-Friedl, Robbert Biesbroek, Daniela N. Schmidt (2022) Climate Change 2022: Impacts, Adaptation and Vulnerability, IPCC. IPCC

Blöschl G, Kiss A, Viglione A, et al (2020) Current European flood-rich period exceptional compared with past 500 years. 560 | Nature | 583:. https://doi.org/10.1038/s41586-020-2478-3

Bruno Soares M, Alexander M, Dessai S (2018) Sectoral use of climate information in Europe: A synoptic overview. Climate Services 9:5–20. https://doi.org/10.1016/J.CLISER.2017.06.001

Bryan K, Ward S, Barr S, Butler D (2019) Coping with Drought: Perceptions, Intentions and Decision-Stages of South West England Households. Water Resources Management 33:1185–1202. https://doi.org/10.1007/S11269-018-2175-2/TABLES/2

Bukowski JJ (2011) Sharing water on the Iberian peninsula: A Europeanisation approach to explaining transboundary cooperation. Water Alternatives 4:171–196

Cabos W, de la Vara A, Álvarez-García FJ, et al (2020) Impact of ocean-atmosphere coupling on regional climate: the Iberian Peninsula case. Climate Dynamics 54:4441–4467. https://doi.org/10.1007/S00382-020-05238-X/FIGURES/17

Capela Lourenço T (2015) Changing climate, changing decisions: Understanding climate adaptation decision-making and the way science supports it

Cavelier R, Borel C, Charreyron V, et al (2017) Conditions for a market uptake of climate services for adaptation in France. Climate Services 6:34–40. https://doi.org/10.1016/J.CLISER.2017.06.010

Central Bank E (2021) Climate-related risk and financial stability ECB/ESRB Project Team on climate risk monitoring. https://doi.org/10.2866/913118

Central Communications Unit (2022) Government Revenue Continues to Rebound. In: Ministry of Finance. https://bahamasbudget.gov.bs/2021/news-centre/latest-news/2022/02/03/government-revenue-continues-rebound/. Accessed 9 Feb 2022

Christel I, Hemment D, Bojovic D, et al (2018) Introducing design in the development of effective climate services. Climate Services 9:111–121. https://doi.org/10.1016/J.CLISER.2017.06.002

Commission E, Centre JR, Cammalleri C, et al (2020a) Global warming and drought impacts in the EU : JRC PESETA IV project : Task 7. Publications Office

Commission E, Centre JR, Demirel H, Christodoulou A (2018) Impacts of climate change on transport : a focus on airports, seaports and inland waterways. Publications Office

Commission E, Centre JR, Dottori F, et al (2020b) Adapting to rising river flood risk in the EU under climate change : JRC PESETA IV project : Task 5. Publications Office

Commission E, Centre JR, Feyen L, et al (2020c) Climate change impacts and adaptation in Europe : JRC PESETA IV final report. https://doi.org/doi/10.2760/171121

Commonwealth Local Government Forum (2020) The Local Government System in The Bahamas

Community C, Change C, Entity A (2020) Request for Support from the Project Preparation Facility (PPF). 1–12

Copernicus E Fire Weather Index | Copernicus. In: 2022. https://climate.copernicus.eu/fire-weather-index. Accessed 27 May 2022

Couasnon A, Eilander D, Muis S, et al (2020) Measuring compound flood potential from river discharge and storm surge extremes at the global scale. Natural Hazards and Earth System Sciences 20:489–504. https://doi.org/10.5194/NHESS-20-489-2020

COUNCIL OF THE EUROPEAN UNION - General Secretariat (2008) The Albufeira Convention. Delegations will find annexed a note from the Portuguese and Spanish delegations on the above subject, which will be dealt with under “other business” at the meeting of the Council (Environment) on 3 March 2008.

Cramer W, Marini K, Guiot J (2020a) MedECC (2020) Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future. First Mediterranean Assessment Report
Cramer W, Marini K, Guiot J (2020b) MedECC (2020) Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future. First Mediterranean Assessment Report
Dahlgren C, Sherman K (2020) Preliminary Assessment of Hurricane Dorian's Impact on Coral Reefs of Abaco and Grand Bahama. 1–28
de' Donato FK, Leone M, Scortichini M, et al (2015) Changes in the Effect of Heat on Mortality in the Last 20 Years in Nine European Cities. Results from the PHASE Project. International Journal of Environmental Research and Public Health 12:15567. https://doi.org/10.3390/IJERPH121215006
Department of Statistics (2012) 2010 Census of Population and Housing. Nassau, Bahamas
di Giuseppe F, Vitolo C, Krzeminski B, et al (2020) Fire Weather Index: The skill provided by the European Centre for Medium-Range Weather Forecasts ensemble prediction system. Natural Hazards and Earth System Sciences 20:2365–2378. https://doi.org/10.5194/NHESS-20-2365-2020
Dincă AI, Surugiu C, Surugiu M, Frenţ C (2014) STAKEHOLDER PERSPECTIVES ON CLIMATE CHANGE EFFECTS ON TOURISM ACTIVITIES IN THE NORTHERN ROMANIAN CARPATHIANS: VATRA DORNEI RESORT CASE STUDY. HUMAN GEOGRAPHIES-Journal of Studies and Research in Human Geography 8:1843. https://doi.org/10.5719/hgeo.2014.81.27
Dosio Alessandro (2020) Mean and extreme climate in Europe under 1.5, 2, and 3°C global warming. In: JRC PESETA IV project –Task 1 (ed)
Dottori F, Szewczyk W, Ciscar JC, et al (2018) Increased human and economic losses from river flooding with anthropogenic warming. Nature Climate Change 2018 8:9 8:781–786. https://doi.org/10.1038/s41558-018-0257-z
Douville H (2021) Water Cycle Changes. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change
Dudout A, Vitulano C, François C (2021) Exploring The Implementation Of The EU-Taxonomy For Financial Institutions - European Taxonomy for Sustainable Activities
Duijndam S, van Beukering P (2021) Understanding public concern about climate change in Europe, 2008–2017: the influence of economic factors and right-wing populism. Climate Policy 21:353–367. https://doi.org/10.1080/14693062.2020.1831431
Ercin E, Veldkamp TIE, Hunink J (2021) Cross-border climate vulnerabilities of the European Union to drought. Nature Communications 2021 12:1 12:1–10. https://doi.org/10.1038/s41467-021-23584-0
European Environment Agency (2019a) Climate change adaptation in the agriculture sector in Europe. https://doi.org/10.2800/537176
European Environment Agency (2019b) Adaptation challenges and opportunities for the European energy system : building a climate-resilient low-carbon energy system. Publications Office
European Environment Agency (2017) Water management in Europe : price and non-price approaches to water conservation
European Environment Agency (2019c) Adaptation challenges and opportunities for the European energy system : building a climate-resilient low-carbon energy system. Publications Office
Fargeon H, Pimont F, Martin-StPaul N, et al (2020) Projections of fire danger under climate change over France: where do the greatest uncertainties lie? Climatic Change 160:479–493. https://doi.org/10.1007/S10584-019-02629-W/FIGURES/6

Feyen L, Ciscar JC, Gosling S, et al Climate change impacts and adaptation in Europe : JRC PESETA IV final report.

Forzieri G, Cescatti A, e Silva FB, Feyen L (2017) Increasing risk over time of weather-related hazards to the European population: a data-driven prognostic study. The Lancet Planetary Health 1:e200–e208. https://doi.org/10.1016/S2542-5196(17)30082-7

Füssel HM (2007) Vulnerability: A generally applicable conceptual framework for climate change research. Global Environmental Change 17:155–167. https://doi.org/10.1016/j.gloenvcha.2006.05.002

Gerveni M, Fernandes Tomon Avelino A, Dall'erba S (2020) Drivers of Water Use in the Agricultural Sector of the European Union 27. Environmental Science and Technology 54:9191–9199. https://doi.org/10.1021/ACS.EST.9B06662/SUPPL_FILE/ES9B06662_SI_001.PDF

Government of The Bahamas (2016) The National Development Plan of The Bahamas. Nassau

Government of The Bahamas (2005) National Policy for the Adaptation to Climate Change. Nassau

Greve P, Kahil T, Mochizuki J, et al (2018) Global assessment of water challenges under uncertainty in water scarcity projections. Nature Sustainability 2018 1:9 1:486–494. https://doi.org/10.1038/s41893-018-0134-9

Guiot J, Cramer W (2016) Climate change: The 2015 Paris Agreement thresholds and Mediterranean basin ecosystems. Science (1979) 354:465–468. https://doi.org/10.1126/SCIENCE.AAH5015/SUPPL_FILE/GUIOT.SM.PDF

Gutierrez JM (2021) Atlas. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change . R Yu and B Zhou

Haasnoot M, Winter G, Brown S, et al (2021) Long-term sea-level rise necessitates a commitment to adaptation: A first order assessment. Climate Risk Management 34:100355. https://doi.org/10.1016/J.CRM.2021.100355

Halkos G, Skouloudis A, Malesios C, Evangelinos K (2018) Bouncing Back from Extreme Weather Events: Some Preliminary Findings on Resilience Barriers Facing Small and Medium-Sized Enterprises. Business Strategy and the Environment 27:547–559. https://doi.org/10.1002/BSE.2019

Hanger S, Haug C, Lung T, Bouwer LM (2015) Mainstreaming climate change in regional development policy in Europe: five insights from the 2007–2013 programming period. Regional Environmental Change 15:973–985. https://doi.org/10.1007/S10113-013-0549-9/FIGURES/5

Harcourt R, Bruine de Bruin W, Dessai S, Taylor A (2019) Investing in a good pair of wellies: how do non-experts interpret the expert terminology of climate change impacts and adaptation? Climatic Change 155:257–272. https://doi.org/10.1007/S10584-019-02455-0/TABLES/1

Hewitt CD, Allis E, Mason SJ, et al (2020) Making Society Climate Resilient: International Progress under the Global Framework for Climate Services. Bull Am Meteorol Soc 101:E237–E252. https://doi.org/10.1175/BAMS-D-18-0211.1

Horsley and Witten (2004) Integrated Coastal Zone Management

IDB (2020) Assessment of the Effects and Impacts of Hurricane Dorian in the Bahamas | Publications

Inter-American Development Bank (2018) SUSTAINABLE NASSAU

IPCC (2018) Summary for Policymakers. In: Allen M, Babiker M, Chen Y, et al. (eds) Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change,. In Press, p 24

IPMA (2015) Portal do Clima. In: http://portaldoclima.pt/pt. http://portaldoclima.pt/pt

Jones B, O'Neill BC (2016) Spatially explicit global population scenarios consistent with the Shared Socioeconomic Pathways. Environmental Research Letters 11:084003. https://doi.org/10.1088/1748-9326/11/8/084003

Jongman B, Ward PJ, Aerts JCJH (2012) Global exposure to river and coastal flooding: Long term trends and changes. Global Environmental Change 22:823–835. https://doi.org/10.1016/J.GLOENVCHA.2012.07.004

Leitner M, Mäkinen K, Vanneuville W, et al (2020) Monitoring and evaluation of national adaptation policies throughout the policy cycle. Publications Office

Luís S, Freitas FEP, Rodrigues N, et al (2017) Beliefs on the local effects of climate change: Causal attribution of flooding and shoreline retreat. Journal of Integrated Coastal Zone Management 17:19–28. https://doi.org/10.5894/RGCI-N86

Malhi Y, Franklin J, Seddon N, et al (2020) Climate change and ecosystems: threats, opportunities and solutions. Philosophical Transactions of the Royal Society B 375:. https://doi.org/10.1098/RSTB.2019.0104

Mangan S, Bryan KR, Thrush SF, et al (2020) Shady business: the darkening of estuaries constrains benthic ecosystem function. Marine Ecology Progress Series 647:33–48. https://doi.org/10.3354/MEPS13410

Marani M, D'Alpaos A, Lanzoni S, et al (2007) Biologically-controlled multiple equilibria of tidal landforms and the fate of the Venice lagoon. GeoRL 34:L11402. https://doi.org/10.1029/2007GL030178

Marbà N, Duarte CM (2010) Mediterranean warming triggers seagrass (Posidonia oceanica) shoot mortality. Global Change Biology 16:2366–2375. https://doi.org/10.1111/J.1365-2486.2009.02130.X

Marques E (2016) Atlas Digital AML: Socio-Economia. Atlas Digital - Área Metropolitana de Lisboa 1–28

Martinez GS, Linares C, Ayuso A, et al (2019a) Heat-health action plans in Europe: Challenges ahead and how to tackle them. Environmental Research 176:108548. https://doi.org/10.1016/J.ENVRES.2019.108548

Martinez GS, Linares C, Ayuso A, et al (2019b) Heat-health action plans in Europe: Challenges ahead and how to tackle them. Environmental Research 176:108548. https://doi.org/10.1016/J.ENVRES.2019.108548

Marzeion B, Levermann A (2014) Loss of cultural world heritage and currently inhabited places to sea-level rise. Environmental Research Letters 9:034001. https://doi.org/10.1088/1748-9326/9/3/034001

Merkens JL, Reimann L, Hinkel J, Vafeidis AT (2016) Gridded population projections for the coastal zone under the Shared Socioeconomic Pathways. Global and Planetary Change 145:57–66. https://doi.org/10.1016/J.GLOPLACHA.2016.08.009

Merz B, Blöschl G, Vorogushyn S, et al (2021) Causes, impacts and patterns of disastrous river floods. Nature Reviews Earth & Environment 2021 2:9 2:592–609. https://doi.org/10.1038/s43017-021-00195-3

Miller JL, Pescaroli G (2018) Psychosocial capacity building in response to cascading disasters: A culturally informed approach. International Journal of Disaster Risk Reduction 30:164–171. https://doi.org/10.1016/J.IJDRR.2018.04.018

Ministerio de Medio Ambiente Plan Nacional de Adaptación al Cambio Climático

Ministerio para la Transición Ecológica y el Reto Demográfico (MITECO) (2020) Plan Nacional de Adaptación al Cambio Climático 2021 - 2030

Moretti A, Pascale M, Logrieco AF (2019) Mycotoxin risks under a climate change scenario in Europe. Trends in Food Science & Technology 84:38–40. https://doi.org/10.1016/J.TIFS.2018.03.008

Oberlack C, Eisenack K (2018) Archetypical barriers to adapting water governance in river basins to climate change. Journal of Institutional Economics 14:527–555. https://doi.org/10.1017/S1744137417000509

Paprotny D, Vousdoukas MI, Morales-Nápoles O, et al (2018) Compound flood potential in Europe. Hydrology and Earth System Sciences Discussions. https://doi.org/10.5194/HESS-2018-132

Pathak A, van Beynen PE, Akiwumi FA, Lindeman KC (2021) Impacts of climate change on the tourism sector of a Small Island Developing State: A case study for the Bahamas. Environmental Development 37:100556. https://doi.org/10.1016/J.ENVDEV.2020.100556

Peñuelas J, Sardans J, Filella I, et al (2018) Assessment of the impacts of climate change on Mediterranean terrestrial ecosystems based on data from field experiments and long-term monitored field gradients in Catalonia. Environmental and Experimental Botany 152:49–59. https://doi.org/10.1016/J.ENVEXPBOT.2017.05.012

Petzold J, Ratter BMW, Holdschlag A (2018) Competing knowledge systems and adaptability to sea-level rise in The Bahamas. Area 50:91–100. https://doi.org/10.1111/area.12355

Pina I, Correia J, Costa L (2018) Plano Metropolitano de Adaptação às Alterações Climáticas: Volume II Avaliação de Impactes e de Vulnerabilidades

Pinkse J, Gasbarro F (2016) Managing Physical Impacts of Climate Change: An Attentional Perspective on Corporate Adaptation: https://doi.org/101177/0007650316648688 58:333–368. https://doi.org/10.1177/0007650316648688

Piontek F, Drouet L, Emmerling J, et al (2021) Integrated perspective on translating biophysical to economic impacts of climate change. Nature Climate Change 2021 11:7 11:563–572. https://doi.org/10.1038/s41558-021-01065-y

Presidência do Conselho de Ministros Diário da República, 1.ª série - N.º 147 - Resolução do Conselho de Ministros n.º 130/2019. 2019

Presidência do Conselho de Ministros Diário da República, 1.ª série - N.º 147 - Resolução do Conselho de Ministros n.º 56/2015. 2015

Ranasinghe R (2021a) Climate Change Information for Regional Impact and for Risk Assessment. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

Ranasinghe R (2021b) Climate Change Information for Regional Impact and for Risk Assessment. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

Ranger N, Reeder T, Lowe J (2013) Addressing 'deep' uncertainty over long-term climate in major infrastructure projects: four innovations of the Thames Estuary 2100 Project. EURO Journal on Decision Processes 1:233–262. https://doi.org/10.1007/S40070-013-0014-5/TABLES/4

Räsänen A, Jurgilevich A, Haanpää S, et al (2017) The need for non-climate services – Empirical evidence from Finnish municipalities. Climate Risk Management 16:29–42. https://doi.org/10.1016/J.CRM.2017.03.004

Reimann L, Merkens JL, Vafeidis AT (2018) Regionalized Shared Socioeconomic Pathways: narratives and spatial population projections for the Mediterranean coastal zone. Regional Environmental Change 18:235–245. https://doi.org/10.1007/S10113-017-1189-2/FIGURES/3

Roberts CM, O'Leary BC, Mccauley DJ, et al (2017) Marine reserves canmitigate and promote adaptation to climate change. Proc Natl Acad Sci U S A 114:6167–6175. https://doi.org/10.1073/PNAS.1701262114

Romagosa F, Pons J (2017) Exploring local stakeholders' perceptions of vulnerability and adaptation to climate change in the Ebro delta. Journal of Coastal Conservation 21:223–232. https://doi.org/10.1007/S11852-017-0493-9

Ruffault J, Curt T, Moron V, et al (2020) Increased likelihood of heat-induced large wildfires in the Mediterranean Basin. bioRxiv

Ruiz-Ramos M, Ferrise R, Rodríguez A, et al (2018) Adaptation response surfaces for managing wheat under perturbed climate and CO2 in a Mediterranean environment. Agricultural Systems 159:260–274. https://doi.org/10.1016/J.AGSY.2017.01.009

Salvador P, Alonso-Pérez S, Pey J, et al (2014) African dust outbreaks over the western Mediterranean Basin: 11-year characterization of atmospheric circulation patterns and dust source areas. Atmospheric Chemistry and Physics 14:6759–6775. https://doi.org/10.5194/ACP-14-6759-2014

Schleussner C-F, Pfleiderer P, Andrijevic M, et al (2021) Pathways of climate resilience over the 21st century. Environmental Research Letters. https://doi.org/10.1088/1748-9326/abed79

Schweitzer MD, Calzadilla AS, Salamo O, et al (2018) Lung health in era of climate change and dust storms. Environmental Research 163:36–42. https://doi.org/10.1016/J.ENVRES.2018.02.001

Seneviratne SI, Donat MG, Pitman AJ, et al (2016) Allowable CO2 emissions based on regional and impact-related climate targets. Nature 2016 529:7587 529:477–483. https://doi.org/10.1038/nature16542

Spinoni J, Barbosa P, Bucchignani E, et al (2020) Future Global Meteorological Drought Hot Spots: A Study Based on CORDEX Data. Journal of Climate 33:3635–3661. https://doi.org/10.1175/JCLI-D-19-0084.1

Spinoni J, Naumann G, Vogt J v. (2017) Pan-European seasonal trends and recent changes of drought frequency and severity. Global and Planetary Change 148:113–130. https://doi.org/10.1016/J.GLOPLACHA.2016.11.013

Swart R, Biesbroek R, Binnerup S, et al (2009) Europe Adapts to Climate Change Comparing National Adaptation

Taylor AL, Dessai S, Bruine de Bruin W (2014) Public perception of climate risk and adaptation in the UK: A review of the literature. Climate Risk Management 4–5:1–16. https://doi.org/10.1016/J.CRM.2014.09.001

The Commonwealth of The Bahamas (2005) National Policy for the Adaptation to Climate Change. National Policy for the Adaptation to Climate Change 51

The Government of The Bahamas (2018) The Bahamas Voluntary National Review on the Sustainable Development Goals to the High Level Political Forum of the United Nations Economic and Social Council. 1–159

The World Bank (2021) World GDP per capita

Thomas A, Benjamin L (2018a) Perceptions of climate change risk in The Bahamas. Journal of Environmental Studies and Sciences 8:. https://doi.org/10.1007/s13412-017-0429-6

Thomas A, Benjamin L (2018b) Management of loss and damage in small island developing states: implications for a 1.5 °C or warmer world. Regional Environmental Change 18:2369–2378. https://doi.org/10.1007/s10113-017-1184-7

Thomas A, Benjamin L (2019) Non-economic loss and damage: lessons from displacement in the Caribbean. Climate Policy 1–14. https://doi.org/10.1080/14693062.2019.1640105

Thomas A, Benjamin L, McNamarah C (2015) A Situational Analysis of the Environment of The Bahamas. Nassau, Bahamas

Toreti A, Cronie O, Zampieri M (2019) Concurrent climate extremes in the key wheat producing regions of the world. Scientific Reports 2019 9:1 9:1–8. https://doi.org/10.1038/s41598-019-41932-5

UNDP (2020) The Next Frontier: Human Development and the Anthropocene. Human Development Report 2020 130–158

Urbieta IR, Franquesa M, Viedma O, Moreno JM (2019) Fire activity and burned forest lands decreased during the last three decades in Spain. Annals of Forest Science 76:90. https://doi.org/10.1007/s13595-019-0874-3

US Department of State (2022) 2021 Investment Climate Statements: The Bahamas. Washington, DC van Ginkel KCH, Botzen WJW, Haasnoot M, et al (2020) Climate change induced socio-economic tipping points: review and stakeholder consultation for policy relevant research. Environmental Research Letters 15:023001. https://doi.org/10.1088/1748-9326/AB6395

van Valkengoed AM, Steg L (2019) Meta-analyses of factors motivating climate change adaptation behaviour. Nature Climate Change 2019 9:2 9:158–163. https://doi.org/10.1038/s41558-018-0371-y

Visser H, Petersen AC, Ligtvoet W (2014) On the relation between weather-related disaster impacts, vulnerability and climate change. Climatic Change 125:461–477. https://doi.org/10.1007/S10584-014-1179-Z/TABLES/1

Watts N, Amann M, Arnell N, et al (2021a) The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. The Lancet 397:129–170. https://doi.org/10.1016/S0140-6736(20)32290-X/ATTACHMENT/99E3AE6D-2A80-4E0E-9A12-B93D7F5B913E/MMC5.PDF

Watts N, Amann M, Arnell N, et al (2021b) The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. The Lancet 397:129–170

Xu C, McDowell NG, Fisher RA, et al (2019) Increasing impacts of extreme droughts on vegetation productivity under climate change. Nature Climate Change 2019 9:12 9:948–953. https://doi.org/10.1038/s41558-019-0630-6

Zscheischler J, Westra S, van den Hurk BJJM, et al (2018) Future climate risk from compound events. Nature Climate Change 2018 8:6 8:469–477. https://doi.org/10.1038/s41558-018-0156-3