INTERNATIONAL MONETARY FUND

Assessing Climate Change Risks

Potential Output Losses and Gains from Strengthening Resilience

Zamid Aligishiev

SIP/2025/030

IMF Selected Issues Papers are prepared by IMF staff as background documentation for periodic consultations with member countries. It is based on the information available at the time it was completed on December 17, 2024. This paper is also published separately as IMF Country Report No 25/9.

2025
APR

SELECTED ISSUES PAPER

 SIP/2025/030

IMF Selected Issues Paper
Western Hemisphere Department

Assessing Climate Change Risks—Potential Output Losses and Gains from Strengthening Resilience, The Bahamas
Prepared by Zamid Aligishiev*

Authorized for distribution by Swarnali Ahmed Hannan
April 2025

***IMF Selected Issues Papers* are prepared by IMF staff as background documentation for periodic consultations with member countries.** It is based on the information available at the time it was completed on December 17, 2024. This paper is also published separately as IMF Country Report No 25/9.

ABSTRACT: The Bahamas is highly vulnerable to the effects of climate change, including gradual sea level rise, biodiversity loss, and intensifying hurricanes. Together, these challenges threaten to undermine the country's potential output over the long term by inflicting damages to physical assets and eroding natural capital, which is vital to its tourism-driven economy. Importantly, these risks are unevenly distributed with smaller islands being more exposed and sensitive than the larger, more developed ones. Addressing these disparities as well as closing economy-wide adaptation needs through investments in structural resilience can unlock large potential output gains.

RECOMMENDED CITATION: Aligishiev, Zamid. Assessing Climate Change Risks—Potential Output Losses and Gains from Strengthening Resilience. IMF Selected Issues Paper (SIP/2025/030). Washington, D.C.: International Monetary Fund

JEL Classification Numbers:	Q54, H54
Keywords:	The Bahamas; Climate Change; Resilient investment
Author's E-Mail Address:	zaligishiev@imf.org

SELECTED ISSUES PAPERS

Assessing Climate Change Risks

Potential Output Losses and Gains from Strengthening Resilience The Bahamas

Prepared by Zamid Aligishiev[1]

[1] The author would like to thank Emanuele Massetti and Emilio Fernandez-Corugedo for insightful discussions on adaptation policies and the application of the Markov-Switching DSGE model. Thanks are also due to members of the BHS team—Swarnali Ahmed Hannan, Shane Lowe, Maria Alexandra Castellanos, and Beatriz Garcia-Nunes—for their valuable comments and suggestions.

INTERNATIONAL MONETARY FUND

THE BAHAMAS

SELECTED ISSUES

December 17, 2024

Approved By
Western Hemisphere Department

Prepared By Zamid Aligishiev (WHD).

CONTENTS

ASSESSING CLIMATE CHANGE RISKS—POTENTIAL OUTPUT LOSSES AND GAINS FROM STRENGTHENING RESILIENCE[1]

The Bahamas is highly vulnerable to the effects of climate change, including gradual sea level rise, biodiversity loss, and intensifying hurricanes. Together, these challenges threaten to undermine the country's potential output over the long term by inflicting damages to physical assets and eroding natural capital, which is vital to its tourism-driven economy. Importantly, these risks are unevenly distributed with smaller islands being more exposed and sensitive than the larger, more developed ones. Addressing these disparities as well as closing economy-wide adaptation needs through investments in structural resilience can unlock large potential output gains.

A. Exposure to Sea Level Rise and Hurricanes

1. The Bahamas face significant climate change risks due to high exposure to hurricane damage, rising sea levels, and heavy reliance on tourism (IMF, 2022). The Bahamas, an archipelago of over 700 islands, is highly vulnerable to climate change, with 80 percent of its land area less than 1.5 meters above sea level. It is particularly exposed to tropical cyclones. The country has been hit by six major hurricanes and several tropical storms in the last decade, including a category 5 hurricane Dorian in 2019. The country's dependence on tourism, which contributes about 50 percent to GDP, makes it especially susceptible to the worsening effects of climate change, including more frequent hurricanes and rising sea levels.

2. Climate change will likely intensify tropical cyclones, leading to higher damages in the future. In 2019, Hurricane Dorian caused $3.4 billion in damage to physical assets, amounting to 25 percent of The Bahamas' GDP. Over the past decade, natural disasters have averaged 3.2 percent of GDP in annual damages. Climate-related disasters—such as floods, droughts, and hurricanes—are becoming more frequent and severe due to rising global temperatures and sea levels (IPCC, 2021). Acevedo (2016) projects that hurricane-related damages in The Bahamas will increase by 31 percent under 3°C warming and by 42 percent under 4.3°C. Moreover, natural protective barriers, like mangroves and coral reefs, are at risk due to sea level rise and warming water temperatures. As these ecosystems degrade, they lose their ability to buffer against increasingly intense hurricanes, potentially leading to amplified hurricane damages (Silver et al, 2019).

3. Climate change may severely reduce the land area of the country and undermine productivity of agriculture and fisheries. Sea levels are projected to rise by nearly 0.5 meters by the end of the century, even with strong international efforts to keep global temperatures in line with the Paris Agreement goal. Given The Bahamas' naturally low elevation, this would place about 41 percent of the land and 22 percent of the population below sea level, likely putting private assets

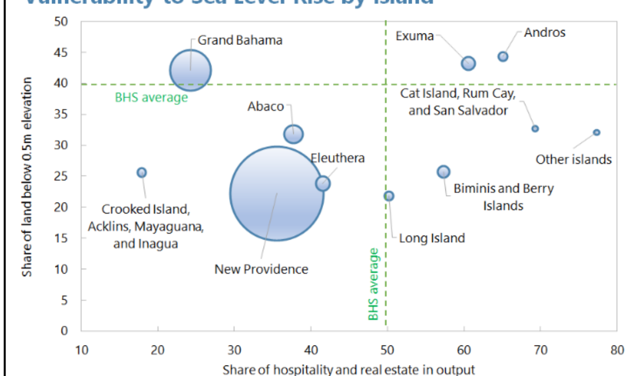
[1] Prepared by Zamid Aligishiev (WHD).

and public infrastructure at risk. Rising sea levels and intensified storm surges could further strain already scarce freshwater resources, posing significant challenges to agricultural productivity. Meanwhile, rising sea surface temperatures and water acidification could diminish available marine fish stocks, impacting oceanic biodiversity and food security.

4. **The Bahamas, with nearly half of the Caribbean's sandy beaches and vital coral reefs and mangroves, faces significant risk.** Without adaptation measures, a 0.5 m sea level rise could cause the complete loss of up to half of sandy beaches located near hotel infrastructure (Spencer et al., 2022). In addition, the inundation of mangroves and the bleaching and degradation of coral reefs would lead to a loss of biodiversity, further reducing the country's attractiveness to tourists over time. This combination of factors could lead to a gradual decline in tourist inflows if adaptation strategies are not implemented.

5. **The impact of sea level rise across The Bahamas is expected to be substantial, however the degree of vulnerability will differ across islands.** Islands where hospitality and real estate form a larger part of the economy are anticipated to suffer greater land loss, making them not only more exposed to rising sea levels but also more economically sensitive. While these islands (Exuma, Andros, Cat Island, and other smaller family islands) contribute only 5.1 percent of national income and 7 percent of the population, they may experience disproportionately higher income losses. These islands are also likely to have a lower capacity to adapt to climate change compared to more developed islands like New Providence and Grand Bahama.

Vulnerability to Sea Level Rise by Island



Sources: National authorities, Climate Central, and IADB.
Note: The size of each bubble represents the output of its corresponding island.

6. **Building structural resilience is a critical priority for Caribbean and Central American economies, which are particularly vulnerable to the effects of climate change.** With the anticipated intensification of natural disasters and rising sea levels, adaptation policies typically involve a combination of investing in the protection of physical assets—both public and private—and relocation of exposed populations and assets to safer areas through planned retreat. According to IMF (2024), safeguarding government infrastructure from the impacts of hurricanes can bolster macroeconomic stability and improve long-term economic performance in the Caribbean and Central America.

7. **For countries relying on tourism, the policy framework should also provide comprehensive strategy on protection of natural capital from the impacts of climate change.** This requires a deeper understanding of how climate change will affect key elements of natural capital essential for tourism—such as coral reefs and sandy beaches—as well as how climate risks are geographically aligned with areas where tourism infrastructure is concentrated. Assessments need to evaluate the costs and benefits of protection and accommodation strategies, such as

constructing breakwaters, artificial reefs, or beach nourishment, and how these measures would affect vulnerable populations and productivity across different areas/islands of the country.

B. Quantifying Climate Risks in The Bahamas

8. Staff estimates output losses due to sea level rise and the intensification of natural disasters using a dual-pronged approach. Economic losses from intensification of hurricanes and permanent land inundation are calculated separately. They are later combined to produce total potential output losses. Importantly, this analysis does not shed light on the cost-effectiveness of different adaptation strategies (e.g., hard protection, nature-based solutions, planned retreat). However, it does translate a given risk reduction achieved through general adaptation efforts into avoided output losses.

9. Output losses from land inundation (slow onset event) are assessed using a two-sector output accounting framework that explicitly incorporates natural capital. This approach estimates public and private capital losses based on the proportion of the population exposed to sea level rise over time, while natural capital losses are approximated using projections of sandy beach erosion in Spencer et al. (2022).[2,3] These losses are then incorporated into sector-specific production functions to calculate the long-term reduction in real output levels. Nontraded output is produced using private capital, public capital, and labor inputs, which are substitutes. Traded sector is assumed to additionally rely on natural capital, which is complementary to other factors of production:

$$Nontraded: \quad Y_{NT,t} = (K_{t-1}^{G})^{\alpha_G} (N_{NT})^{1-\alpha_K} K_{NT,t}^{\alpha_K}$$

$$Traded: \quad Y_{T,t} = \left[\gamma (K_{t-1}^{N})^{\theta} + (1-\gamma)\left((K_{t-1}^{G})^{\alpha_G} (N_T)^{1-\alpha_K} K_{T,t}^{\alpha_K}\right)^{\theta}\right]^{\frac{1}{\theta}}$$

where $Y_{i,t}$, N_i, and $K_{i,t-1}$ are output, labor input, and physical capital for sector $i \in T, NT$; K_{t-1}^{G} is the stock of public capital; and K_{t-1}^{N} is the stock of natural capital. The input shares are governed by α_K, α_G, and γ. Importantly, θ is negative, meaning that natural capital is complementary to other factors of production in the nontraded sector. This setup assumes that firms operating in the traded sector will have difficulty substituting decayed natural capital with more labor or physical capital. Additionally, it accommodates a natural pace of adaptation and resilience of governmental assets. However, the capacity for natural adaptation and the degree of resilience differ between

[2] To remain conservative and align with the arguments presented by Davidson-Arnott and O'Brien-Delpesh (2023), the analysis assumes half of the projected sandy beach losses from Spencer et al. (2022). Furthermore, exposed physical assets are proportionate to exposed population. The analysis assumes that 50 percent of exposed assets are destroyed due to sea level rise in less developed islands and 20 percent in more developed ones. A similar assumption is made for the government infrastructure.

[3] In this approach, natural capital deterioration in the traded good sector takes place solely due to sandy beach erosion. A similar transmission channel could be at work for agrifood sector, where fish is a key export. However, insufficient data prevents calibration of this channel. The effects of introduced species on natural capital is also disregarded for similar reasons.

larger and smaller islands. Public adaptation initiatives effectively address these disparities, resulting in an improved projection of total output.

10. A Markov-switching dynamic general equilibrium model, developed by Fernandez-Corugedo, Gonzalez, and Guerson (2023), is used to evaluate the impact of recurring tropical hurricanes. This model assumes the economy switches between two states: one affected by disaster shocks and another without such shocks. A hurricane destroys a share of the country's capital stock (both public and private), which undermines economy-wide output while the capital stock is being rebuilt, through:

$$Y_t = [K_{t-1}^N]^{\omega}\left[z_t(K_{t-1}^G)^{\alpha_G}(N_t)^{1-\alpha_K}K_t^{\alpha_K}\right]^{1-\omega}$$

where Y_t is total output, K_{t-1}^N is the stock of natural capital (including land), z_t is productivity, K_{t-1}^G is the stock of public capital, N_t is the labor input, and K_{t-1} is the stock of private physical capital. The elasticity of output to various production inputs are captured by the respective parameters (ω, α_G, α_K). A key feature is the distinction between two types of public capital—standard, which is vulnerable to disasters, and resilient, which remains intact during disasters. Public adaptation efforts result in a larger share of resilient capital.

11. Both frameworks are calibrated using recent data, capturing salient features of The Bahamas' economy. Table 1 outlines the key parameter values employed in this analysis. Additionally, hurricanes inflict damages amounting to 7.3 percent of GDP per event, reflecting the average losses from past major disasters. These damages are assumed to increase in line with projections in Acevedo (2016). The probability of hurricane occurrence matches historical patterns but is assumed to remain constant with climate change. Additionally, resilient investments are estimated to cost the government 25 percent more than standard investments.

12. The illustrative analysis quantifies output losses under three adaptation scenarios.

- *Scenario 1: No adaptation.* Neither the public nor private sector takes preemptive measures to adapt to climate change. Capital losses are substantial due to permanent inundation and the repeated impact of hurricanes.

- *Scenario 2: Protection of physical assets.* The public sector invests in safeguarding people, private assets, and government infrastructure from permanent submersion through a mix of hard protection measures, nature-based solutions, and planned retreat. Additionally, the government ensures that its infrastructure is resilient to natural disasters.

- *Scenario 3: Protection of physical assets and natural capital.* In addition to the measures listed in the second scenario, the government invests in preserving natural capital through measures like breakwater construction, coral reef and mangrove protection, and beach nourishment programs.[4]

C. Potential Output Losses from Climate Change and Benefits from Adaptation

13. Over the long-term, sea level rise and natural hazards expose The Bahamas to severe losses in potential output in the *no adaptation scenario (Scenario 1)*. The effects of sequences of disaster shocks accumulate over time, weighing permanently on macroeconomic outcomes. Staff estimates indicate that the prevailing natural disaster profile reduces current potential output level by about 8 percent, relative to a counterfactual without tropical storms. These losses are projected to rise under severe global warming scenarios (Acevedo, 2016). By 2100, combined with losses from permanent inundation, the additional potential output losses could be between 8.3 percent of GDP under intermediate GHG emission scenario (SSP2-4.5) and 11.1 percent of GDP under a severe global warming scenario (SSP5-8.5). A breakdown of these losses suggests that the export-oriented traded sector is particularly vulnerable due to its heavy reliance on natural capital, like sandy beaches, coral reefs, as well as arable land and fish stocks.

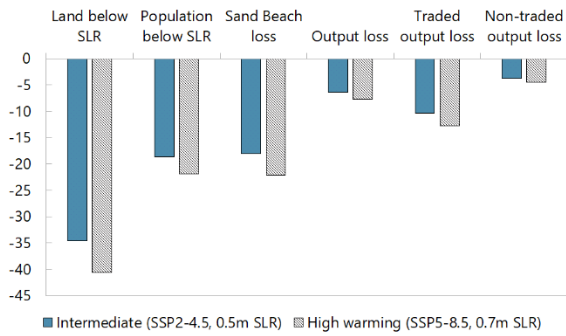
14. Investing in protecting physical assets (*Scenario 2*) partially offsets the impact of climate change on growth, but traded output losses remain sizeable. Structural resilience typically involves making public infrastructure, like roads, bridges, airport runways, and schools, climate-proof, effectively representing a shift from standard to resilient capital. These efforts also encompass building protective infrastructure, like seawalls, artificial reefs, and flood barriers, or strategically relocating vulnerable assets to safer zones. Public investment in adaptation yields a long-term increase in the level of GDP of around 5.5-6.8 percent once physical assets are secured. However, sea level rise undermines growth in the traded sector since the natural capital remains vulnerable. While the tourism sector benefits from preserving a larger average stock of physical capital, the growth dividends are limited due to the complementarities between physical and natural capital, meaning the output gains from protection are smaller if natural capital is not explicitly included in adaptation strategies.

15. Implementing adaptation measures aimed specifically to reduce exposure of natural capital (*Scenario 3*) could reduce long-run traded output losses and ease pressures on future export and fiscal revenues. Beach nourishment, such as dune restoration, along with resilient infrastructure like artificial reefs and breakwaters, can limit coastal erosion in key tourist areas by directly offsetting sediment loss and promoting natural sediment accumulation. These measures would help The Bahamas to avoid costs associated with relocating tourism-related physical assets and reduce potential output losses further, from 2.8-4.3 under *Scenario 2* to 1.2-2.3 percent of GDP

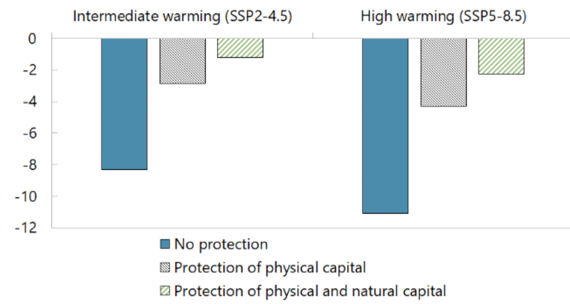
[4] To demonstrate the benefits of enhancing structural resilience, the analysis assumes that protective measures ensure 80 percent of the exposed private physical assets are safeguarded against permanent inundation. Additionally, a similar share of government infrastructure is made resilient to both permanent inundation and the effects of hurricanes. The protection of natural capital similarly assumes that 80 percent is preserved from the impact of climate change.

under *Scenario 3*, and supporting fiscal and export revenues. A comprehensive resilience building strategy could also help stabilize output during climate shocks, potentially reducing uncertainty in fiscal and foreign exchange income streams.

Losses from Slow Onset Events by 2100
(Percent, relative to no climate change)



Total Output Losses from Climate Change by 2100 and Adaptation
(Percent, relative to no climate change)



Source: IMF staff calculations.

Table 1. The Bahamas: Calibrated Parameters and Initial Values

Definition	Value	Definition	Value
Potential GDP growth rate	1.5	Share of traded goods in total output	40
Private investment to GDP	23	Share of domestic demand for traded output	10
Private consumption to GDP	59	Share of imported capital goods in total investment	50
Public investment to GDP	2	Share of imported goods in domestic consumption	27
Public consumption to GDP	20	Annualized (implicit) interest rate on domestic debt	4
Net exports to GDP	-4	Share of hotel rooms in New Providence and Grand Bahama	70
Share of natural capital resistant to climate change on New Providence and Grand Bahama	70	Depreciation rate of private capital	5
Share of natural capital resistant to climate change on other islands	50	Depreciation rate of non-resilient public capital	7.5
Share of exposed physical assets resilient to climate change on New Providence and Grand Bahama	70	Depreciation rate of resilient public capital	3

Sources: National authorities and IMF staff calculations.

Table 1. The Bahamas: Calibrated Parameters and Initial Values (concluded)

Definition	Value	Definition	Value
Share of exposed physical assets resilient to climate change on other islands	60	Public investment efficiency	50
Share of exposed public capital resilient to SLR on New Providence and Grand Bahama	75	Traded sector: Labor share in production	42.7
Share of public capital resilient to SLR on other islands.	30	Traded sector: Capital share in production	18.3
Share of physical capital located in New Providence and Grand Bahama	69.4	Traded sector: Elasticity of output to public capital	0.15
Traded sector: Natural capital share in the production function	39	Non-traded sector: Elasticity of output to public capital	0.15
Non-traded sector: Labor share in production	60	Non-traded sector: Capital share in production	40

Sources: National authorities and IMF staff calculations.