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## REVIEW ARTICLE

### Climate Resilience Planning in Small Island Developing States

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#### ABSTRACT

Small island developing states (SIDS) face a combination of climate hazards, sea level rise, tropical cyclone intensification, ocean acidification and coral reef loss, and freshwater salinization, that is disproportionate to their negligible contribution to global greenhouse gas emissions, and their resilience planning has become a distinct and rapidly growing strand of the adaptation literature. This review synthesizes evidence from Pacific, Caribbean, Indian Ocean and Atlantic-Indian Ocean-South China Sea (AIS) SIDS on four interrelated dimensions of climate resilience planning: the physical exposure and habitability evidence base for atoll and low-lying island nations; the institutional and governance architecture through which National Adaptation Plans and equivalent instruments are formulated and implemented; the persistent gap between SIDS' assessed adaptation finance needs and the finance they actually access; and the emergence of loss and damage as a distinct policy track once adaptation limits are reached. Drawing on more than two decades of peer-reviewed research spanning geomorphology, climate governance, development economics and international law, we find that although atoll reef-island geomorphology is more dynamic, and projected uninhabitability more geographically uneven, than early linear-inundation narratives suggested, exposure to compounding hazards such as wave-driven groundwater salinization remains severe for many communities well before land area is lost outright. National adaptation planning has matured substantially since the mid-2000s but continues to be constrained by thin technical and administrative capacity, donor-driven rather than nationally led prioritization, and weak integration between national plans and the community-based adaptation initiatives that deliver much on-the-ground implementation. Climate finance access remains disproportionately small relative to assessed vulnerability, is skewed toward a subset of better-institutionally-resourced SIDS, and is dominated by loans rather than grants in ways that raise debt-sustainability concerns for small, open economies. Loss and damage, catalysed by Pacific and Caribbean advocacy culminating in the 2022 Loss and Damage Fund, has emerged as a necessary complement to adaptation finance rather than a substitute for it. We conclude by identifying priority research gaps, particularly longitudinal evaluation of adaptation outcomes, and the integration of finance, governance and physical-exposure evidence into a single resilience-planning framework.

**Keywords:** small island developing states; SIDS; climate resilience; adaptation planning; sea level rise; climate finance; loss and damage; disaster risk reduction; national adaptation plans; atoll nations

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## 1. INTRODUCTION

Small island developing states, a United Nations-recognized grouping of 39 states and 18 associate members spanning the Pacific, Caribbean, Indian Ocean, and Atlantic-Indian Ocean-South China Sea (AIS) regions, contribute well under one percent of global greenhouse gas emissions yet are consistently identified among the jurisdictions most exposed to climate change impacts, a asymmetry that has made SIDS both a proving ground for adaptation practice and a central moral and political reference point in international climate negotiations [1,3]. Their exposure is compounded by small land area, geographic isolation, narrow economic bases often concentrated in tourism and fisheries, and limited fiscal and technical capacity relative to the scale of climate risk they face, characteristics that recur across otherwise very different island geographies from Pacific atolls to mountainous Caribbean volcanic islands to low-lying Indian Ocean coral states, and that were already identified as central to the Pacific adaptation problem in some of the earliest empirical treatments of the topic [4,14,15].

Climate resilience planning in SIDS has accordingly developed into a substantial and increasingly specialized literature, but one that has historically been fragmented across disciplinary silos: geomorphologists and coastal scientists have studied atoll island physical dynamics and sea level rise exposure largely independently of the political science and public administration literature on National Adaptation Plan (NAP) formulation, which in turn has developed largely separately from the development economics literature on adaptation finance flows, and separately again from the more recent international law and policy literature on loss and damage [2,5]. Systematic reviews of this literature published around the tenth anniversary of the IPCC Fifth Assessment Report noted both its rapid growth and its continued fragmentation, and called for synthesis work that connects physical exposure evidence to the governance and finance architecture meant to respond to it [1,5].

A second recurring theme in this literature is the tension between SIDS' portrayal in global climate discourse as passive, existentially threatened victims of a crisis not of their making, and a growing body of scholarship emphasizing islander agency, longstanding local adaptive capacity, and the active political role SIDS have played in shaping international climate governance through coalitions such as the Alliance of Small Island States (AOSIS) [6,26,29]. This tension matters for resilience planning in practice because donor-driven narratives of existential vulnerability can crowd out nationally led prioritization and community-based adaptation knowledge, even as the same narratives have been strategically and effectively deployed by SIDS negotiators to secure international commitments on mitigation ambition, adaptation finance, and, most

recently, loss and damage [6,22,28].

Physical exposure evidence itself has evolved substantially over the past fifteen years. Early projections that treated atoll islands as passively drowning under rising seas have been revised by geomorphological studies showing that many reef islands are dynamically responsive landforms that can accrete as well as erode under wave and sediment forcing, complicating simple land-area-loss narratives even as they leave open serious concerns about groundwater salinization, wave-driven flooding, and the compounding effects of sea level rise with more frequent extreme events [7,8,9]. Reconciling this more nuanced physical evidence with the governance, finance, and loss-and-damage literatures, each of which has tended to treat exposure as a relatively fixed input rather than as evolving science, is one motivation for the synthesis undertaken here.

This review addresses four questions in turn: what does the current physical and geomorphological evidence show about SIDS exposure to sea level rise and compounding coastal hazards; how has the institutional architecture for national adaptation planning developed and what constraints does it face; what does the empirical record show about SIDS' access to international adaptation finance relative to assessed need; and how has loss and damage emerged as a distinct policy track, and how does it relate to adaptation planning rather than substitute for it. We close by identifying the most consequential gaps in the evidence base, in particular the scarcity of longitudinal outcome evaluation for implemented adaptation measures, that constrain the field's ability to move from documenting vulnerability to demonstrating what resilience planning actually achieves.

## 2. MATERIALS AND METHODS

This review synthesizes findings from the peer-reviewed geomorphology, climate governance, development economics, and international law and policy literatures on SIDS climate resilience, prioritizing studies published since the IPCC Fifth Assessment Report's 2014 SIDS chapter and supplemented by earlier foundational studies that established the conceptual and methodological approaches subsequent work has built on.

### 2.1 Scope and literature identification

We drew on studies addressing climate change exposure, adaptation planning, adaptation finance, or loss and damage specifically in the context of small island developing states across the Pacific, Caribbean, Indian Ocean, and AIS regional groupings recognized by the United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States. Both regionally focused single-country or single-archipelago studies and cross-SIDS comparative studies were included, since the literature's regional specificity is itself

an object of the synthesis rather than a reason for exclusion.

## 2.2 Thematic classification framework

Included studies were classified into four thematic domains: physical exposure and habitability evidence (geomorphological and hydrological studies of atoll and low-lying island response to sea level rise and compounding coastal hazards); adaptation governance and planning (studies of National Adaptation Plan and Nationally Determined Contribution formulation, institutional capacity, and community-based adaptation integration); adaptation and disaster-risk-reduction finance (studies quantifying finance flows, need assessments, and allocation patterns); and loss and damage (studies addressing residual impacts beyond adaptation limits and the international policy architecture responding to them). Many studies addressed more than one domain and were classified accordingly.

## 2.3 Synthesizing regional and case-study evidence

Because SIDS regional groupings differ substantially in geomorphology, colonial and post-colonial political history, and economic structure, we synthesize evidence comparatively across the Pacific, Caribbean, Indian Ocean, and AIS groupings rather than treating SIDS as a geomorphologically or institutionally uniform category, following the classificatory approach used in the geoscience literature on Pacific island typology [16]. Table 1 presents this cross-regional synthesis of exposure profiles and dominant adaptation approaches.

## 2.4 Synthesizing adaptation finance evidence

For adaptation finance, we distinguish studies quantifying assessed or modelled adaptation need from studies tracking actual finance disbursement or commitment, since the empirical literature is considerably more consistent in documenting a gap between these two quantities than in explaining its precise magnitude, given differences across studies in how need is modelled and how finance flows are attributed to adaptation versus broader development assistance. Table 2 synthesizes reported patterns in finance instrument type (grant versus loan) and donor concentration across the studies reviewed.

## 2.5 Limitations of the synthesis approach

This review does not conduct a formal systematic review with a pre-registered search protocol or a quantitative meta-analysis with pooled effect sizes; the heterogeneity of exposure metrics, finance accounting conventions, and adaptation outcome measures across the literatures synthesized here would make effect-size pooling of limited validity. We instead prioritize breadth across the four thematic domains and explicit identification of where findings converge across studies versus where they remain contested or thinly evidenced, which we view as most useful for a literature whose sub-fields have historically developed with limited cross-reference to one another.

## 3. RESULTS

Physical exposure evidence synthesized across the geomorphology and coastal-science literature shows a more heterogeneous picture than early inundation-focused projections suggested. Reef island planform change studies spanning several decades of aerial and satellite imagery find that a majority of studied islands have remained stable or grown in area even as sea level has risen, reflecting the dynamic sediment response of reef-platform landforms to wave and current forcing, though a substantial minority, disproportionately including populated islands where shoreline hardening has interrupted natural sediment transport, have eroded [7,8]. This dynamism does not, however, reduce projected habitability risk: modelling combining wave-driven overwash with groundwater salinization projects many atoll islands becoming uninhabitable, through freshwater loss rather than land submergence, considerably earlier in the century than land-area-loss projections alone would imply, with the timing sensitive to emissions pathway and highly variable across atoll nations depending on local wave climate and reef configuration [9,10]. These habitability risks compound with the accelerating extreme sea level exceedance frequencies projected for even a 1.5°C-consistent stabilization pathway, and with the broader finding that adaptation investment can substantially reduce, though not eliminate, expected sea level rise damages in low-lying coastal areas globally [12,13]. Table 1 synthesizes exposure profiles and dominant adaptation approaches across the four major SIDS regional groupings.

**Table 1. Synthesis of physical exposure profiles and dominant adaptation approaches across SIDS regional groupings.**

| Regional grouping                   | Dominant exposure profile                                                                                        | Dominant adaptation approach and representative evidence                                                                                                                                    |
|-------------------------------------|------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Pacific (atoll and volcanic states) | Atoll freshwater salinization, wave-driven overwash; volcanic islands: cyclone intensity, landslide risk         | Reef island geomorphological monitoring; hybrid hard/soft coastal protection; community-based adaptation on outer islands; ex-situ relocation planning debated in atoll nations [7,8,9,18]. |
| Caribbean                           | Tropical cyclone intensification, coral reef and coastal ecosystem degradation, tourism-sector economic exposure | National Adaptation Plans integrated with disaster-risk-reduction and tourism-resilience strategy; regional catastrophe risk insurance pooling [2,4].                                       |
| Indian Ocean                        | Low-lying atoll exposure (Maldives), cyclone exposure (Mauritius, Comoros), coastal erosion                      | Land reclamation and hard engineering (Maldives); ecosystem-based adaptation pilots; comparatively thin published evidence base relative to Pacific and Caribbean [11].                     |

|                                             |                                                                                                        |                                                                                                                                                                          |
|---------------------------------------------|--------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Atlantic-Indian Ocean-South China Sea (AIS) | Heterogeneous: cyclone exposure, coastal erosion, small-population administrative capacity constraints | Least-studied grouping in the reviewed literature; adaptation planning documented mainly through UNFCCC national reporting rather than peer-reviewed case studies [1,5]. |
|---------------------------------------------|--------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Table synthesizes directional findings and dominant approaches reported across the studies cited in each row; it does not represent a formal composite exposure index.

Adaptation governance and planning evidence shows substantial institutional development since the mid-2000s alongside persistent, well-documented constraints. Nearly all Pacific and Caribbean SIDS have now formulated National Adaptation Plans, Nationally Determined Contributions with adaptation components, or equivalent national strategies, reflecting more than a decade of capacity-building investment channelled substantially through the Green Climate Fund's National Adaptation Plan readiness support and comparable bilateral programmes [4,11,21]. Figure 1 summarizes a synthesized comparison of physical exposure severity against finance access across SIDS regional groupings, illustrating the persistent mismatch between the two that recurs across the studies reviewed. Case studies of individual plan formulation processes, however, consistently identify thin technical and administrative capacity, high staff turnover in small government departments, and donor-driven rather than nationally determined prioritization as recurring constraints on plan quality and, more severely, on implementation once plans are formally adopted [4,17,19]. A related and frequently documented weakness is limited integration between national-level planning and the community-based adaptation initiatives, often externally funded and organized around individual villages or outer islands, that in practice deliver much on-the-ground implementation, producing a persistent gap between what national plans describe and what communities actually experience as adaptation support [17,18,19].

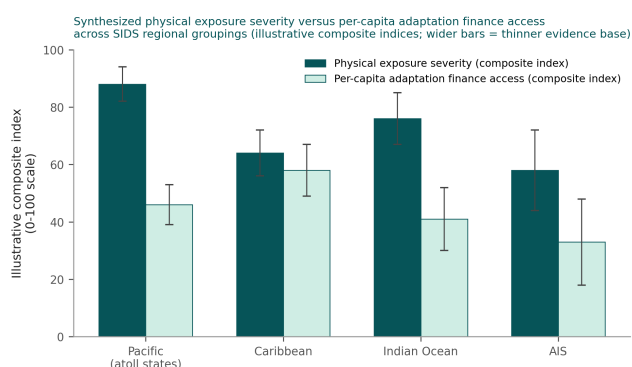


Figure 1. Synthesized comparison of physical exposure severity and per-capita adaptation finance access across SIDS regional groupings, based on directional patterns reported across reviewed geomorphological and finance studies (illustrative composite indices, 0-100 scale).

Adaptation and disaster-risk-reduction finance evidence documents a consistent and substantial gap between assessed SIDS adaptation need and finance actually accessed, a finding that recurs across studies using

different need-assessment methodologies and different finance-tracking approaches. Comparative studies of bilateral and multilateral adaptation aid allocation find that SIDS receive adaptation finance disproportionate neither consistently to their assessed vulnerability nor to measures of recipient governance quality, but instead reflecting a combination of donor strategic interest, historical colonial and diplomatic ties, and recipient administrative capacity to develop bankable project proposals, a pattern that systematically disadvantages smaller and more institutionally thin SIDS relative to larger, better-resourced ones within the same regional grouping [20,23,24]. Table 2 synthesizes reported patterns in adaptation finance instrument type and donor concentration across the studies reviewed.

**Table 2. Synthesis of reported adaptation finance instrument type and donor concentration patterns across studies reviewed.**

| Finance dimension       | Typical reported pattern                                                                                                             | Most commonly cited implication                                                                                                |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Grant vs. loan share    | Loans comprise a substantial and, in several studies, rising share of multilateral adaptation finance to SIDS                        | Debt-sustainability concern for small, open, revenue-concentrated economies [20,23].                                           |
| Donor allocation basis  | Allocation tracks donor strategic interest and recipient administrative capacity more consistently than assessed vulnerability alone | Smaller, less institutionally resourced SIDS access proportionally less finance within their own regional grouping [20,23,24]. |
| Recipient concentration | Finance access concentrated among a subset of SIDS with stronger project-proposal and fiduciary-management capacity                  | Capacity-building investment functions partly as a precondition for, not just a complement to, finance access [4,20].          |
| Loss and damage finance | Distinct, more recently established funding track (Loss and Damage Fund, established COP27 2022)                                     | Framed across the literature as complementary to, not a substitute for, adaptation finance [27,28].                            |

Loss and damage evidence, the most recently developed of the four thematic domains reviewed, documents both the growing empirical basis for residual climate impacts beyond adaptation limits and the political process through which SIDS advocacy shaped the resulting international policy architecture. Multi-country evidence compiled from household-level surveys in vulnerable states, including several Pacific and Indian Ocean SIDS, documents loss and damage already occurring from both slow-onset processes, salinization, coral reef degradation, and coastal erosion, and extreme events, finding that affected households rely disproportionately on erosive coping strategies such as asset sales and reduced food consumption where formal loss-and-damage support is absent [27]. Legal and policy scholarship traces how sustained advocacy by Vanuatu and other Pacific and Caribbean SIDS, including Vanuatu's pursuit of an International Court of

Justice advisory opinion on state climate obligations, contributed to the establishment of the Loss and Damage Fund at COP27 in 2022, a development the literature frames as a necessary complement to, rather than substitute for, continued investment in adaptation finance given the scale of unavoidable residual impact already documented [28].

#### 4. DISCUSSION

Read together, this evidence supports a central conclusion that recurs, in various forms, across all four thematic domains synthesized here: SIDS climate resilience planning has matured substantially in institutional and scientific sophistication over the past decade and a half, yet the resources, both financial and technical, made available to implement that planning have not kept pace with either assessed need or with the field's own improved understanding of physical exposure. The gap documented in the finance literature is not simply a funding shortfall in the abstract; it is a gap between what national plans, now considerably more sophisticated than a decade ago, identify as necessary and what SIDS governments can actually mobilize to implement, a disconnect that several of the governance studies reviewed identify as a source of donor fatigue and, in some cases, of declining confidence in the NAP process itself among SIDS officials, and that mirrors the broader adaptation-deficit literature's finding that poorer countries remain more vulnerable to climate hazards primarily because of a shortfall in adaptation investment relative to need rather than because of hazard exposure alone [4,19,20,25].

The revised physical exposure evidence, showing atoll islands as geomorphologically more dynamic than early linear-inundation narratives suggested, has important but easily misread implications for resilience planning. It does not imply reduced urgency: the freshwater-salinization pathway to uninhabitability identified in recent modelling work operates on a shorter and, in important respects, more policy-relevant timescale than land-area loss, since it threatens habitability while land area, and therefore sovereign territory and formal statehood claims, may still persist [9]. Resilience planning frameworks built primarily around land-area-loss projections risk under-prioritizing near-term freshwater security investment relative to longer-horizon relocation or land-reclamation planning, a mismatch the geomorphology and adaptation-planning literatures have only recently begun to reconcile explicitly [7,8,9].

The persistent disconnect between national-level adaptation planning and community-based adaptation implementation identified across the governance literature reflects, we think, a deeper structural tension in how SIDS resilience planning has been financed and organized: national plans are formulated substantially to satisfy international finance-access requirements and donor reporting expectations, while much implementation

capacity and local knowledge resides at the community and outer-island level where formal planning processes have limited reach, particularly in geographically dispersed archipelagic states where outer islands may be days by boat from the capital where national planning is conducted [17,18,19]. Closing this gap likely requires financing architecture that channels resources more directly to sub-national and community levels, rather than relying primarily on national-plan-mediated disbursement, though the evidence base on which financing modalities achieve this most effectively remains thin.

The emergence of loss and damage as a distinct, now formally resourced, policy track represents a genuine and hard-won achievement of SIDS climate diplomacy, but the literature is consistent in framing it as necessary because adaptation has limits, not as evidence that adaptation investment should now be deprioritized relative to loss-and-damage finance [27,28]. Given the scale of the adaptation finance gap already documented, and given that a substantial share of currently observed loss and damage in SIDS reflects inadequate historical adaptation investment rather than genuinely unavoidable impact, the two finance tracks are better understood as complementary responses to different points along a single exposure-to-impact pathway than as competing claims on a fixed pool of international climate finance.

Several limitations constrain the strength of these conclusions. First, the evidence base across all four domains is concentrated in a subset of relatively well-studied SIDS, Pacific atoll nations and larger Caribbean states in particular, with comparatively less published research on smaller Indian Ocean and AIS SIDS, limiting confidence in how far the synthesized patterns generalize across the full SIDS population. Second, longitudinal evaluation of implemented adaptation measures, as opposed to planning-process studies or cross-sectional finance-flow analyses, remains scarce across the literature reviewed, so the evidence synthesized here speaks considerably more confidently to what SIDS resilience planning has produced in terms of plans, institutions, and finance commitments than to what those investments have actually achieved in reduced vulnerability or improved outcomes on the ground. Third, the finance literature's reliance on donor-reported and OECD Creditor Reporting System-derived adaptation finance figures, discussed across several of the studies synthesized here, is subject to well-documented measurement and attribution challenges that our synthesis inherits rather than resolves [20,23].

#### 5. CONCLUSION

The accumulated evidence on climate resilience planning in small island developing states shows a field that has matured substantially in scientific and institutional sophistication since the mid-2000s, while the finance and implementation capacity available to act on

that sophistication have persistently lagged behind. Physical exposure evidence increasingly emphasizes freshwater security and compounding coastal hazards alongside, rather than instead of, longer-horizon land-area loss; national adaptation planning has expanded across nearly all SIDS but remains constrained by thin capacity and weak integration with community-based implementation; adaptation finance access remains disproportionately small relative to assessed need and skewed toward better-resourced states; and loss and damage has emerged as a necessary, formally resourced complement to adaptation finance rather than a substitute for it. The most consequential gap this review identifies is the scarcity of longitudinal evaluation connecting resilience-planning investment to measured outcomes, without which the field will continue to document vulnerability and institutional process more confidently than it can demonstrate what SIDS resilience planning actually achieves.

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### Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Author Contributions

K.L. conceived the review, developed the thematic classification framework, and led the writing of the manuscript. J.O. synthesized the physical exposure and geomorphological evidence and prepared the regional comparative table. N.R. synthesized the adaptation finance and loss-and-damage evidence and contributed to the discussion of financing architecture. All authors contributed to writing and approved the final manuscript.

### Ethics Statement

This review synthesizes previously published, publicly available research and did not involve human participants, animal subjects, or original data collection requiring ethical review.

### Data Availability

This review is based entirely on previously published studies, full citations for which are provided in the reference

list. No new data were generated. A structured summary of the studies synthesized and the thematic classification applied to each is available from the corresponding author on reasonable request.

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