 doi:10.20944/preprints202101.0061.v1

*Article*

# Climate Change Adaptation on Small Island States: an assessment of limits and constraints

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**Abstract:** Small Island States (SIDS) are among the nations most exposed to climate change (CC) and are characterised by a high degree of vulnerability. Their special nature means there is a need for more studies focused on the limits to CC adaptation on such fragile nations, particularly in respect of their problems and constraints. This paper addressed a perceived need for research into the limitations of adaptation on SIDS, focusing on the many restrictions which are unique to them. The main research question raised by this study was that how and to what extent the challenges by human activities (e.g., agriculture and tourism) posed to coastlines of SIDS could be addressed. This paper identified and described the adaptation limits they have, by using a review of the literature and an analysis of case studies from a sample of five SIDS in the Caribbean and Pacific regions (Barbados, Trinidad and Tobago, Cook Islands, Fiji, Solomon Islands, and Tonga). The findings of this research showed that an adaptable SIDS is characterised by awareness of various values, appreciation and understanding of a diversity of impacts and vulnerabilities, and acceptance of certain losses through change. The implications of this paper are two-fold. It explains why island nations continue to suffer from the impacts of CC, and suggest some of the means via which adequate policies may support SIDS in their efforts to cope with the threats associated with a changing climate. This study concluded that, despite the technological and ecological limits (hard limits) affecting natural systems, adaptation to CC is not only limited by such complex forces, but also by societal factors (soft limits) that could potentially be overcome by more adequate adaptation strategies.

**Keywords:** Limits; Adaptation; Small Island Developing States; Impacts; Sustainable Development; Policy-making

## 1. Introduction

Small Island Developing States (SIDS) (Lobendahn et al., 2010) was first recognised as a distinct group of developing countries facing particular social, economic and environmental vulnerabilities at the Earth Summit in 1992, especially in the context of Agenda 21 (Chapter 17 G). Since the Earth Summit, various international frameworks and measures were discussed by the United Nations (UN), in order to assist SIDS in their sustainable development efforts. This includes the Barbados Programme of Action (UN, 1994), the Mauritius Strategy (UN, 2005), and the SAMOA Pathway (UN, 2014), among others. SIDS are distinct from other developing countries in a variety of ways. Firstly, they are usually small in size, with limited resources and access to technologies. Secondly, their economies are also small and relatively fragile, heavily relying on tourism as a source of revenues. Besides, they are characterised by a certain degree of vulnerability to climate change (CC) and its impacts (Robinson, 2019).

Not only are SIDS particularly vulnerable to CC, but they also suffer severe financial losses when affected by climate change-related extreme events (Bush, 2018). Many SIDS has used a scenario-based approach to evaluate possible impacts, vulnerability and CC adaptation, mainly in the first round of their national communications presented as part of their UNFCCC responsibilities. This approach is based on the use of outputs from general circulation models to provide scenarios for future CC. There are also global projections from the Intergovernmental Panel on Climate Change (IPCC) reports (e.g., The Fifth Assessment Report - also referred to as 'AR5'). The AR5 provides the updated status of knowledge regarding CC adaptation, which is the adjustment to the effects of current or expected climate conditions (IPCC, 2016). The UN recognises 58 SIDS, which are spread over oceans and seas (UN-OHRLLS, 2018). All of them are tropical or subtropical but are a diverse group, ranging from countries larger than Germany (Papua New Guinea) to tiny coral islands (Tuvalu). Although SIDS may differ significantly in culture, history, geography, or socio-economic circumstances, they share similar challenges of development such as smallness, remoteness and exposure to natural hazards (Barnett 2011; Connell 2013; Connell 2015). Global CC continues to impact communities, ecosystems and many facets of the 65 million people who inhabit SIDS (Wong et al. 2014). Due to their small populations, limited resources, remoteness, susceptibility to hazards, and fragile ecosystems, communities are extremely vulnerable to the effects of CC (Leal Filho, 2015). Sea-level rise (SLR), changes in rainfall patterns, increase in frequency and intensity of extreme weather events, ocean acidification and coral bleaching are the impacts of CC (Nurse et al., 2014). The accelerated increase in SLR has received much attention among the changes already observed as it leads to coastal erosion, deterioration of land and property, rise in flood frequency, saltwater intrusion, and a myriad of ecological changes. A study by Leal Filho (2018), stated the need to pay special attention to the impacts of CC on coastal areas on SIDS.

Low-lying SIDS are even more vulnerable to the effects of CC because they have relatively scarce natural resources and limited options for adaptation. The difference between adaptation constraints, obstacles, barriers and limitations in SIDS is negligible; as stated by Robinson (2018), the line is not separate and often the word 'limit' is used as 'obstacle',' constraint' and/or 'barrier'. Based on her study, two main factors are driving SIDS to their limits: the first is budget/income restriction (government expenditure), and the second is the characteristics of natural resources (availability). She discusses that the previous studies (e.g., Morgan, 2011; Klein et al. 2014) present different typologies of adaptation limits. Their typologies include physical and ecological, technological, social and economic limits. Physical and ecological limitations should be considered in this

 doi:10.20944/preprints202101.0061.v1

context as natural adjustment limitations, associated mainly with nature from ecosystem thresholds to geographical and geological limitations. Technological limitations occur when the "technology required for a specific method is not accessible or very expensive" or when the technology is simply unable to "maintain" the changes needed for a successful adaptation (Morgan, 2011). As Adger et al. (2009) pointed out, social limits depend on the objectives of the adaptation of an actor, which are principles, and that the limits of individual and social drivers vary according to knowledge and ethics, culture and risk attitudes. The economic limits arise when the costs of adaptation exceed the costs of the averted impacts. CC also interacts differently along the coastlines of SIDS with a variety of human activities and other drivers of change. Extreme weather and climate impact a wide range of SIDS-supporting economic activities such as agriculture and tourism and cause additional risks for many small islands and atolls at low altitudes (Wong et al. 2014). Unfortunately, solutions to address these challenge remain elusive (Bruckner, 2013), because they often overlook the limits to adaptation (Nurse and Moore, 2005; Nurse et al., 2014; Shultz et al., 2019). Hence, this article discusses this issue. The subsequent parts of this paper will introduce and discuss the climate risks faced by SIDS and outline their limits of adaptation. In this way, the aims of this paper are as follows.

Firstly, the paper fosters a greater understanding of the main CC and climate-related hazards on selected examples of the Pacific and the Caribbean Small Island States. Secondly, it helps understand the ecological, technological and social limits to adaptation, particularly in the SIDS. Thirdly, it presents some case studies on policymaking, influences and opportunities related to CC in Barbados, Cook Islands, Fiji, Solomon Islands, Tonga, and Trinidad and Tobago, as examples of SIDS. The novelty of the objectives lies in the investigation of projected CC impacts and vulnerabilities in the suggested case studies. More importantly, the study objectives attempt to address the most appropriate adaptation and resilient strategies and measures to mitigate the vulnerability of settlements, ecosystems and the economy in the coastline regions. Finally, the discussion focuses on several opportunities offered by CC, and the role of policies are discussed in detail. This study will contribute to a better judgment of policy contexts and suitable policy choices, and present evidence on limits to adaptation and adaptive capacities crosswise the suggested case studies.

In addition, the results of this study provide the framework for understanding and explore the unavoidable climate-related impacts for the prevention and reduction of future risks. Therefore, the main result of the results is to generate up-to-date information on how and where specific adaptation limits are addressed, and losses and damages occur. Therefore, this study will be beneficial to researchers, scientists and policy-makers working in the field of CC, SIDS and sustainability through strengthening the core scientific basis by focusing on the areas where climate adaption strategies are overlooked.

## 2. Risks and hazards and opportunities associated with climate change on SIDS

It is now well established that SIDS are exposed to a variety of climate-induced hazards that are increasing in frequency and severity. SIDS share several sustainable development challenges, despite their geographical and cultural diversity, including low resource availability, small but often rapidly growing populations, geographic isolation, exposure to hazards, excessive dependence on imports, and susceptibility to global trade. Extensive ocean-atmosphere interactions such as trade winds, El Niño and the monsoons, tropical cyclones and hurricanes, and especially SLR, are influencing the climate of SIDS. Combined with their socio-economic fragility, these climate features make SIDS one of the most vulnerable countries in the world, and their inhabitants face a wide range of pressures (Kelman, 2014).

The Fifth Assessment (AR5) of IPCC in 2014 provides scientific evidence that human impacts, especially greenhouse gas emissions, are the primary factor in global warming and resulting CC and SLR. A special report (IPCC 2018) warned about the many consequences increased temperatures may have on coastal areas, as a result of SLR.

CC effects are linked to rapid occurrences, such as more frequent and severe storms and coastal flooding, and slow-onset processes, such as SLR land degradation and increased sea surface temperatures (SST). Phenomena such as ocean acidification and changes in the water cycle are also part of the process (IPCC 2014; Nurse et al. 2014; Wong et al. 2014). Failure to adapt and mitigate the impacts of CC, and the associated risks posed, would lead to the loss of livelihoods, coastal settlements, infrastructure, ecosystem services, and economic stability in many island communities (Nurse et al. 2014). Box 1 outlines some examples of threats and impacts of CC, SLR and climate-induced hazards in the SIDS.

There are some examples of changing CC, sea-level rise, drivers and climate-related hazards, and their associated impacts in the Pacific and Caribbean SIDS as follows. SIDS are particularly vulnerable to marine climate changes due to their reliance on marine resources and the concentration of settlements in coastal regions. The future risks associated with the changing climate drivers (such as sea-level rise (SLR), increase in air/sea temperature, and changing patterns of rainfall, and their current impacts) include loss of adaptive capacity and ecosystem services critical to lives and livelihoods in small islands (Nurse et al. 2014).

There is a growing consensus that the extent and frequency of climate and climate-related risks will increase as climate warming increases, especially on small islands (IPCC 2014; Nurse et al. 2014). Extreme weather and climate affect a wide range of economic activities that support the SIDS and pose an additional risk for many small, low-lying islands and atolls (Wong et al. 2014). Much of the Pacific islands' population, infrastructure, agriculture and freshwater resources is situated on the coastal zone and thus, vulnerable to sea-flooding, inundation, erosion, and damage from tropical and extratropical cyclones. Also, food supplies are at risk due to the islands' dependence on coastal fisheries (Bush 2018; Kelman and West, 2009; Howes et al., 2018; IPCC 2014). Negative impacts of floods often occur mainly due to the lack of public understanding about the crucial role of the drainage systems play during wet seasons. There is often a lack of regulatory frameworks for the construction sector (Chmutina and Bosher, 2015).

A proper understanding of CC is a risk management challenge that also opens up a wide range of opportunities to integrate adaptation with economic and social development and to reduce future warming initiatives. The difficulty of designing appropriate CC response strategies and building public support for such strategies stems partly from the inherent complexity of the problem. Some of this complexity is associated with the physical science of CC, but there are also many social, economic, ethical, and political challenges to understand and respond to CC (IPCC, 2015; Public Agenda, 2017). The possibilities associated with CC in SIDS include the protection and enhancement of rural livelihoods and social wellbeing and the improvement of resilience of people, communities and ecosystems (FAO, 2017). For countries around the world, options include a mix of technology advance to reduce air pollution; develop investment in renewable energy, energy efficiency, and public transport in urban areas; improve waste and water management; and enhance disaster planning (Attri et al., 2017). However, there will be costs for action to be taken, and if we did not take action, there would be costs. Investing today in cost-effective energy conservation and development of clean energy can pay off tomorrow at lower cost-economic, social and environmental aspects (Public Agenda 2017).

## 3.Limits to adaptation

CC adaptation is known to be an ongoing process, with no end-point (Barnett et al., 2015). Previous studies have suggested that even though adaptation methods may prevent possible impacts of CC, there are clear limits that inhibit their effectiveness. It is thus vital to identify and define these limits, as it can help improve adaptation methods and prevent maladaptation. The term "limits to adaptation" should not often be confused with "barriers to adaptation". The former refers to absolute thresholds (Evans et al., 2016), while the latter is mutable. Due to the specific characteristics of the persons concerned, the specific systems involved and the broader context underlying the operation of individuals and systems present limitations and obstacles to adaptation (Moser and Ekstrom, 2010). In other words, adaptation's most critical issues do not relate entirely to science, but to the interaction of behaviours and institutions that facilitate such behaviours in the political, environmental, social and economic spheres. This indicates that adaptation in human systems is as crucial as the adaptation in natural systems and could at least for the short term, be even more urgent (Barnett and Palutikof, 2014; Javeline, 2014). For this paper, "limits to adaptation" is defined as: Variable thresholds which make it challenging to implement climate change adaptation measures. An example of how these thresholds vary is the lack of a CC policy today, with no governance systems in place to implement CC adaptation. This may subsequently change when such a climate policy is prepared and implemented. So, the limits (initially imposed by the lack of a policy) are removed once it is in place.

Limits to CC adaptation can be broken down into both "hard" and "soft" categories (Barnett et al. 2015). Hard limits refer to thresholds existing in physical systems that may induce irreversible damage if exceeded. They are generally dependent on the rate of CC (IPCC, 2016). In ecosystems, for instance, hard limits may be associated with the inability to adapt to changes in climate since these exceed their physiological capacity (e.g. droughts). Soft limits (e.g., technological and socio-economic options), on the other hand, maybe described as those that may change over time.

In some cases, the options to overcome these limits may not be available initially. In the absence of means and space to move in exposed populations, some soft limits can become hard limits, particularly when intangible types of damage are taken into account. However, they may be developed in the future, unlike hard limits which offer no such options (Barnett et al., 2015, Vaha 2018). Based on the study by Barnett et al. (2015), some barriers can become limits in terms of adaptation; in this way, some limits to adaptation can be overcome and converted into barriers to new technologies, cultures, values, or governance systems. Mechler et al. (2020) stated that in cases where hard limits are transgressed, financial, technical and legal support is necessary.

Phenomenologically speaking, there are four typical limits to CC adaptation as follows:

1)Ecological limits: refer to situations in which ecosystems and organisms face a decline in functionality and diversity due to their inability to adapt. A vital example of an ecological limit is coral bleaching. Healthy corals are typically able to survive in modestly warm temperatures. However, a slight rise above the average temperature may result in the occurrence of coral bleaching. Continued exposure to these higher temperatures may induce coral mortality (Schmutter et al., 2017). A better understanding of the extent of the ecological limits leads to the proper policy selection based on Barnett's (2001) study, which could form a basis on which to monitor changes and communicate conclusions covering all ecological areas.

2)Economic limitations occur when the financial costs for adaptation exceed the amount needed to fix the damages brought about by CC. Economic limits are seen, for instance, in adaptations initiatives concerning the rise of sea-levels. The cost to protect surrounding areas from rising seas levels may be initially bearable. However, as the sea-level rises and claims more areas, the cost of protecting the areas may sometimes exceed the value of the items being protected (Schmutter et al., 2017). Mostly because the cost of damage to critical settlement facilities is even higher, economic cost for SIDS will be a significant concern. Besides, the costs of rising sea levels, as a percentage of GDP, will be high given the small size of SIDS economies (Mycoo, 2018).

3)Technological limitations refer to cases where technology is unable to avert the impacts of CC. A significant problem here is the difficulty in monitoring and evaluating some adaptation methods, due to the lack of universal metric systems. CC impacts manifest in a multitude of ways, and the lack of multilateral systems to monitor adaptation methods is a further limit to adaptation (Hoad, 2015; Grydehøj and Kelman 2017; Robinson, 2018). Furthermore, research has demonstrated that insufficient technical capabil-

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ity encourages the use of already existing technology, providing little room for innovation and improvements. As CC worsens, the demand for low-cost, reliable and long-term technologies will increase. If not addressed, these may lead to adaptation deficits (van den Homberg and McQuistan, 2019). Mycoo's (2018) study showed that the use of technology, land-use planning and ecosystem-based adaptation policies would involve drought-proofing Caribbean SIDS. A key conclusion of his research was that, given the limited capacity of human, technical and financial resources, prioritising practical adaptation options is essential for Caribbean SIDS.

Social limits are observed when people decide that adaptation methods have failed due to their inability to protect things, they consider necessary. Adger et al. (2009) suggested that four elements are inherent in any society that help to limit its effective adaptive response. Successful adaptation experiences resulting from the different social priorities and values could be limited or could not be adapted in a different context. It was found that social limits were observed because adaptation efforts were influenced by external factors (Evans et al., 2016) which the local stakeholders cannot influence, such as global warming.

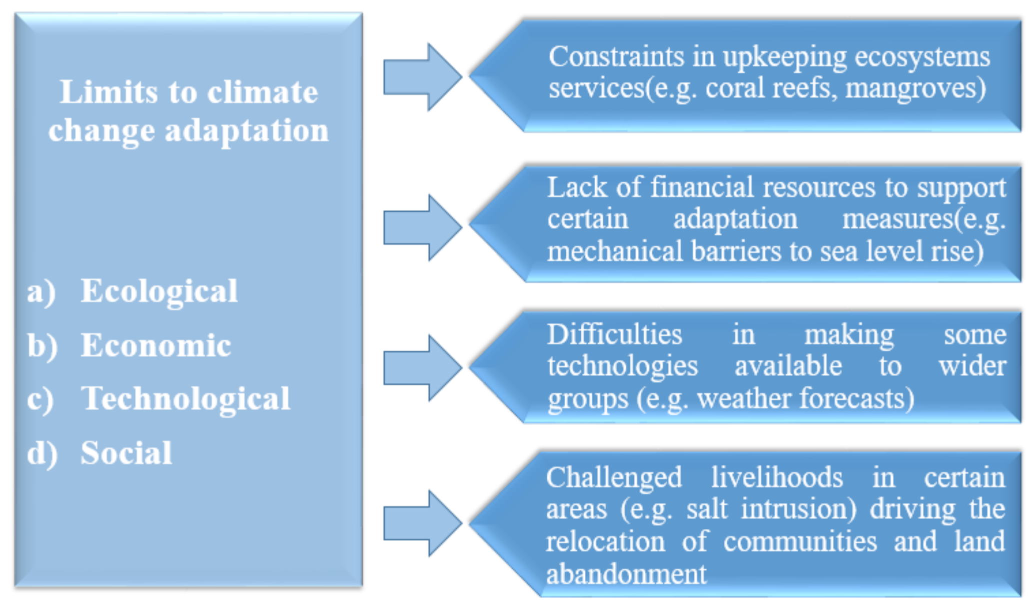


**Figure 1.** Some examples of the limits to climate change adaptation.

Some recent studies have shown that a range of other, unclassified limits, exist with regards to CC adaptation and human physiology. For instance, the temperature of the human body may reach fatal levels when exposed to extended periods of extreme heat (Wheeler and Watts, 2018). A high percentage of the global population is at the moment exposed to heat events annually, and these induce numerous fatalities among the most vulnerable groups such as the elderly or those with other chronic diseases. The percentage of fatalities is expected to increase by 48% in low emission cases and 74% in high emission cases (Mora et al., 2017).

The inability to correctly define -and overcome- the limits to CC adaptation poses a considerable threat to the practical advancement of strategies and methods used in the future to curb the global climate crisis. It is vital to be able to understand the limits to CC adaptation, as well as the role of soft and hard adaptation approaches, may be developed and deployed to reduce the impacts of CC.

## 4. Methodology

### *4.1. Data collection*

 doi:10.20944/preprints202101.0061.v1

The methodological approach combines the review of literature on CC on island nations, and an analysis of case studies from a sample of SIDS in the Caribbean and Pacific regions, which both aimed at identifying their limits to CC adaptation. The rationale behind this choice of methodology is two-fold. Firstly, it allows a comprehensive overview of the works published to date regarding CC on island nations. Secondly, they offer pertinent narratives of the CC mitigation and adaptation challenges they face. Furthermore, the case studies identify and document various trends, providing an appraisal of the limits to adaptation experienced in each country. It is believed that knowledge about the case studies may support SIDS in their efforts to cope with the many challenges posed by a changing climate.

In the first step, the sampled countries, including Barbados, Trinidad & Tobago, The Cook Islands, Fiji, Solomon Islands, and Tonga (Figure 2) have been selected. This list of countries and case studies is not exhaustive, and each island State could be considered in greater depth and detail. However, this study is aimed at providing a realistic account of opportunity over the challenge. Thus, this study presents some relevant geographic information on SIDS along with their limits to the adaptation of CC. The main reason for selecting these suggested case studies is to show the successes from which to learn and the gaps that need to be addressed for future development planning in SIDS. The examples from the Pacific include some of the larger SIDS, e.g., Fiji and Tonga. For example, in the Caribbean SIDS, most data are available only in Spanish, which makes it challenging to collect and analyse.

Nevertheless, Trinidad & Tobago is among the greatest SIDS, and relatively more information was available. Moreover, the most affected SIDS are all located in the Caribbean, demonstrating the region's vulnerability to natural hazards (e.g. hurricanes). We took these inclusion criteria of vulnerability to CC into account as the starting point, to put the main focus on the Caribbean and Pacific regions SIDS given the low number of studies conducting in these regions.

In the second step, a comprehensive literature review was conducted to discuss critical aspects highlighting lessons learnt from and for CC adaptation in SIDS in different regions. A broad search for relevant papers and reports on SIDS in different regions was conducted over the last 25 years (1994-2020) using major databases including Google Scholar, Web of Science, and Science Direct. The collection of secondary data includes the following significant keywords:

1. SIDS adaptation to climate change in the Caribbean and Pacific regions.
2. SIDS limits adaption and barriers.
3. SIDS soft and hard limits.
4. Typologies of SIDS adaptation limits.

Only research papers in English published in peer-reviewed international journals were the focus of the literature review. Also, international organisations, including the UN, the IPCC and the World Bank, have developed relevant reports that are used in this article. The study focused on studies explaining specific issues related to the keywords as mentioned earlier while reducing the initial large number of papers produced from various databases.

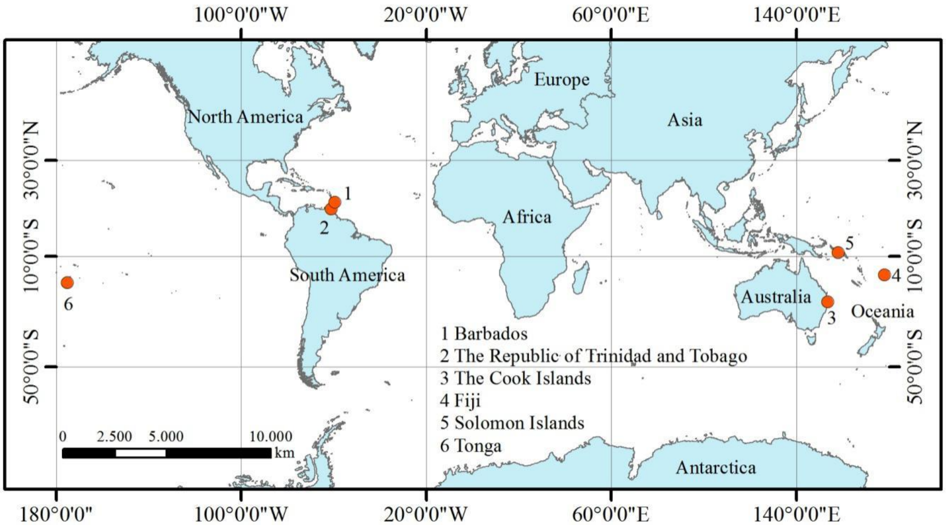


**Figure 2.** Schematic distribution of the six sampled islands.

*4.2. Qualitative data analysis*

As described in Figure 3, the transformation of descriptive (qualitative) data into (quantitative) measurements was achieved through a qualitative analysis in two steps. The figure shows all the measures to examine a wide range of topics (e.g., climate change adaptation in small island developing states). As mentioned above and shown in Figure 3, the qualitative analysis was implemented through three main steps. The first step was to collect extensive databases for the proposed case studies (1994-2020) from various sources (e.g., Google Scholar, Web of Science, and Science Direct) and narrowing the results down to the articles with keywords of SIDS, limits/barriers to climate adaptation, designing and implementing climate change adaptation policies. The second step was only to choose the studies that have close links with Caribbean and Pacific regions, and the last step was to choose those studies that had focused on the vulnerability of Caribbean SIDS and temperature warming beyond 1.5 ℃.

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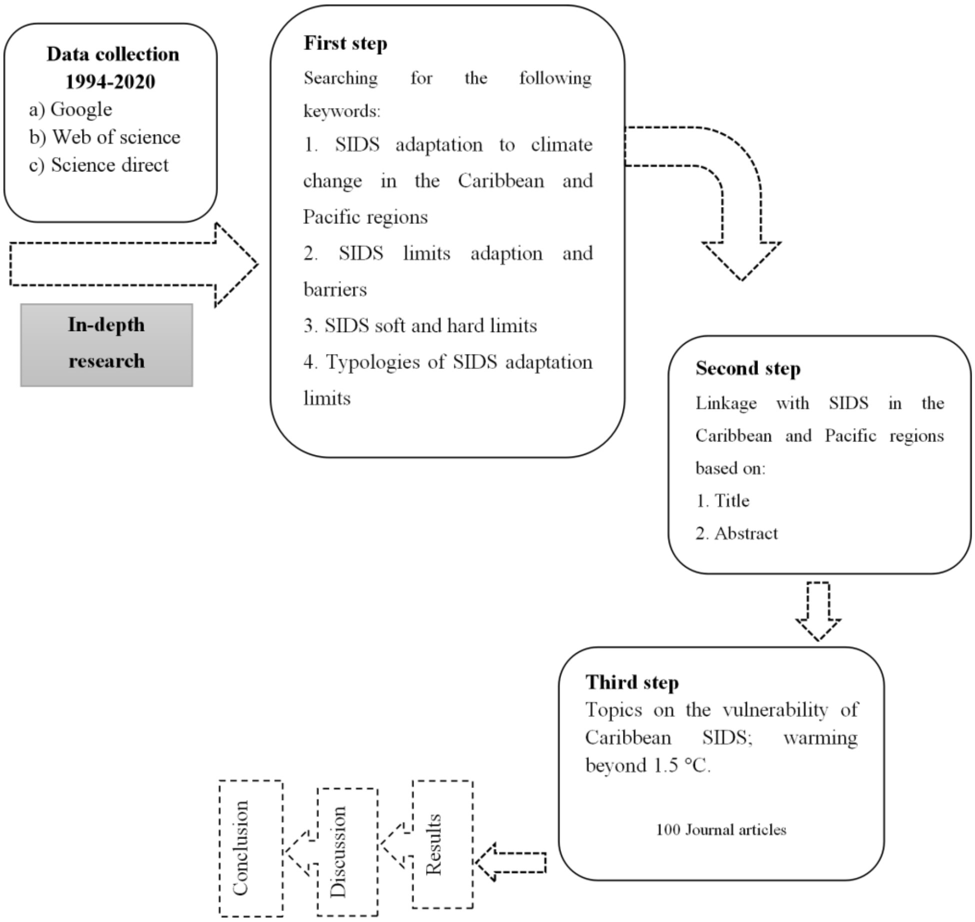


**Figure 3.** The main steps of data collection and analysis.

## 5. Results

Based on the data gathered from the sample, this section describes the status of governance and policymaking, the limits to adaptation experienced, and possible opportunities generated. The first result obtained is related to governance. One of the fundamental limits to CC adaptation is the presence of sound governance systems in place, which specifically oversees how a country handles CC, both in respect of mitigation and of adaptation. In this context, an investigation of the availability of CC policies was undertaken. This is a matter of central concern in financial terms as well, since donor support is often dependent on the existence of well organisation adaptation priorities and frameworks.

As shown in Table 1, most of the investigated SIDS have relevant CC policies, although some are less comprehensive than they should be. Capacity and accurately of climate studies have been significantly improved to implement appropriate policies, leading to a better understanding of the impact of ocean acidification on coral reefs on natural systems such as zonal shifts and adverse effects (Schmutter et al., 2017). Nevertheless, the information base is limited and usually not useful for national decision-making policies. In the context of the CC Policy on Adaptation and Mitigation Strategies, in Barbados, inter-agency communication, coordination and (limited) jurisdiction of national institutions remain insufficient (Mycoo and Chadwick, 2012). Trinidad & Tobago has a "National Climate Change Policy" and "Framework for the Development of a Renewable Energy Policy" discussing that there are limits such as land arability/soil chemistry and topography, categorised as a physical and ecological limitation (Middelbeek et al., 2014). Moreover, Middelbeek

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et al.'s (2014) study revealed that Trinidad & Tobago's community receives minimal institutional support to withstand flooding.

The Cook Islands has already developed climate-disaster risk reduction strategies to deal with frequent exposure to cyclones (Rubow, 2013). Further, as stated by Climate impacts are entangled with traditional leadership, tourism and emerging Christian eco-theologies in Rubow (2013) in the Cook Islands. In the case of Fiji, adaptation to CC is combined with risk management for disasters and community-based approaches. Nevertheless, there are specific technological limitations, such as modelling software/models and cell phone penetration, especially in the older demographic and more remote regions (Walshe et al., 2018). Recently, Solomon Islands has implemented adaptation programs (e.g. IFRC Preparedness). However, CC adaptation programs do not take into account the knowledge and capacity at the local level, which is likely to lead to failure and maladaptation (SPREP, 2009). It was reported that in Tonga, technical resources and public education/awareness were mostly limited. In Tonga, the development of an indigenous knowledge system plays a significant role in supporting the advancement and execution of SDGs (ABM 2011, 2014), as well as preparing for drought conditions in advance. The current promotion of higher education would help students to concede their problems and present sophisticated and innovative resolution strategies (GOT, 2016).

**Table 1.** Status of climate change policies on the investigated SIDS: Barbados, Trinidad and Tobago, The Cook Islands, Fiji, Solomon Islands, and Tonga.

| **Country** | **Status of policymaking** |
|---|---|
| Barbados | Has a climate change policy in a place whose focus is on adaptation and mitigation strategies. |
| Trinidad & Tobago | Has a "National Climate Change Policy" and "Framework for the Development of a Renewable Energy Policy", to promote mitigation and facilitate diversification of energy systems (GOTT, 2011; Couture and Gagnon, 2010). |
| Cook Islands | The frequent exposure to cyclones has led to the development of climate-disaster risk reduction strategies to be effectively mainstreamed into the enactment (CIG, 2012a). |
| Fiji | National climate change policies emphasise relocation |

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|---|---|
| | from vulnerable areas (McNamara and Des Combes, 2015). CC adaptation is combined with disasters risks management and community-based approaches to development. |
| Solomon Islands | Recently implemented adaptation programs include the IFRC Preparedness for CC Programme (PCCP) and the WWF Climate Witness toolkit. Some approaches are built on traditional practices (Handmer, 2003). |
| Tonga | As a consequence of CC impacts, the country continues to achieve its local SDGs and Sendai framework objectives (GOT 2015; UN 2016) targeting to build resilience by 2035 (GOT, 2016). |

A few examples of the positive influences of climate change are summarised in Table 2.

**Table 2.** Positive influences of climate change.

| **Country** | **Positive influences of climate change** |
|---|---|
| Barbados | The transformation of the energy system into renewable energy would help in the: i) Intensification of the economy; ii) Improvement of air quality; iii) Generation of employment options, and iv) Community-based cooperation (Hohmeyer, 2015). |

| | |
|---|---|
| Trinidad & Tobago | Diversification and establishment of renewable energy technologies (MEEI, 2017).<br>Conversion of the current urban focus into climate-smart development (UN Habitat, 2015), which involves the incorporation of advanced Renewable Energy Technologies into the energy mix (MoF, 2014). |
| Cook Islands | Early germination of mangoes in July (Newport and Tutangata, 2011).<br>40% increase in Skipjack tuna catch rates by 2035; numerous possible employment opportunities also flourish.<br>Adaptation Projects have enabled communities to restore their traditional methods of farming to ensure the constant supply of fresh food.<br>Climate adaptation Projects promoted gender equality and women's employment (ICCI, 2011). |
| Fiji | Awareness-raising and capacity building activities have endeavoured to engage young people in various ways (Barnett and Campbell 2010; Webb 2008).<br>The relief and development community of the island has built a perception for a long time that "the best time to 'build back better and stronger' is in the wake of a disas- |

| | |
|---|---|
| | ter" (Luetz 2008; Ong et al. 2016). The warmer climate and changing rainfall seasons benefitted farmers (FAO 2000; GOT 2015). |
| Solomon Islands | Temperature rise and drought imposed positive influences on people's agriculture, which allows them to be engaged in planting drought and heat-tolerant crops leading to sustainable agriculture (Havea et al., 2017). Temperature variations have enabled people to adapt better to respiratory diseases and retain better health (WHO, 2015). |
| Tonga | The transformation of the energy system into renewable energy would help in the: i) Intensification of the economy; ii) Improvement of air quality; iii) Generation of employment options, and iv) Community-based cooperation (Hohmeyer, 2015). |

Furthermore, since it is known that CC is also only characterised by limits, but may also be associated with opportunities, respondents have been asked to list the most important ones, according to their opinions. The data is summarised in Table 3.

**Table 3.** Possible opportunities generated by climate chang.

| **Country** | **Possible opportunities generated** |
|---|---|
| Barbados | The raised SST could be used as an advancement key to |

 doi:10.20944/preprints202101.0061.v1

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| | the ocean thermal energy conversions technologies (Singh and Ephraim 2016; Kempener and Neumann 2014). |
| Trinidad & Tobago | The seaweed invasion could be used as a source of bio-energy (Milledge and Harvey, 2016) and manure for producing better quality seedlings (Ramdwar et al., 2016). |
| Cook Islands | The introduction of heat and drought-resistant crops prototypes. Rainwater catchment areas have been invested in promoting agriculture avenues. The maritime sanctuaries are extended, and fishing restrictions are imposed (CIG, 2012b). A new Harbour is capable of enduring up to 500 cm in SLR and Category 5 cyclones (Asian Development Bank, 2015). |
| Fiji | The lead role of the Fijian government at COP 23 provided an opportunity to access international funding to enhance adaptive capacity (COP23 Fiji, 2017). |
| Solomon Islands | New adaptation plans are inspired by the lessons learned from the community-coordinated relocations happened in the coastal proximity (Lauer et al. 2013; Ha'apio et al. 2018; Luetz and Havea 2018). |

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| | The mainstreaming of disaster risk reduction measures should be integrated with the newest (re)construction stages. It was learned that chiefs might be more favourably disposed to their customary owned land being used for resettlement during the crisis (Ha'apio et al. 2018). The economic and development gains may lead to growth, jobs and long-term sustainable and climate resilience. |
| Tonga | Addressing climate-related hazards increased economic growth, job offers and long-term resilience (GOT 2015; MECC-NEMO 2010). Indigenous knowledge helps in reducing food and water scarcity through storing and planting drought-resistant crops and conserving water (ABM 2011, 2014). Incidentally, the local populace is mostly Christian by faith (Havea et al., 2017), wherefore adaptation stakeholders may leverage faith-engaged approaches for effective and locally meaningful responses to climate change (Luetz and Nunn 2020). |

Apart from the data gathered and summarised on the previous tables, further results from the case studies are provided. These are as follows.

*5.1 Barbados*

The IPCC has projected significant alterations in the weather of Barbados that may include altered routines of rainfall, elevated air temperature and SST, and increased daytime temperatures. The high probability and increased frequency of extreme catastrophic events are also expected, such as floods, droughts, SLR, heavy rains and intense tropical cyclone activity (Nurse et al. 2014). Additionally, the secondary impacts including algal blooms of Sargassum seaweed (Maréchal et al., 2017), transcontinental dust clouds (Prospero, 2006), and vector-borne diseases (Confalonieri et al. 2007; Van Bortel et al. 2014) have been observed.

*5.2 The Republic of Trinidad and Tobago*

The effects of CC on Trinidad and Tobago are multifaceted and impose its hazardous impacts on population health, agriculture, water resources, the ecology of coastal zones as well as tourism (GOTT, 2011). The negative impact of CC has resulted in SST increases, providing Sargassum seaweed with a suitable environment for expansion resulting in seaweed invasion and plaguing at island's coastlines in 2015 (Ramdwar et al., 2016). This phenomenon impacted the local fisheries and tourism industry (Milledge and Harvey, 2016) as well as its cleaning process cost approximately USD 454,000 to Tobago (Ramdwar et al., 2016). Trinidad and Tobago are legislatively obliged to take actions for acquiring a low carbon footprint because it has been a sanctioned signatory body of Kyoto Protocol and the UN Framework Convention on CC (UNFCCC).

*5.3 The Cook Islands*

The risks due to CC are multiple and high (ABM, 2014) including augmented ocean acidification and salinity, SLR, coral bleaching and disease, elevated salt spray pressure, and increased sea surface, land and air temperature (Rongo and Dyer 2015). Despite the escalating intensity of cyclones and droughts for the Cook Islands and southeast Pacific, their frequency will be decreased (ABM 2011; Newport, C., Tutangata, 2011; PCCSP 2011). A loss of around 36% Coral reefs since the 1990s to 2015 has been observed. Further coral area eradication between 25 to 65% by 2030, 50 to 75% (2055) and 90 to 100% by 2100 is predicted ( Newport, C., Tutangata, 2011); unless any strict actions are taken to restore coral reefs. The impact of coral reef extinction would be significant on marine ecology and the global economy. The eradication of the coral reef would lead to a 20% decline in the food supply, in production of lower zooplankton, algae and primary biomass. It will influence all other species by reducing marine habitats as well as interfering with marine ecology. For example, the Giant clams and green turtles may decline by 10-30%. On the other hand, invertebrates, pearl, clam, trochus, milkfish and marine ornamental that are considered as coral-dependent species are projected to diminish by 50% by 2035 and 90-100% by 2100 if the current A1B scenario continues (Newport and Tutangata, 2011).

*5.4 Fiji*

The changing climate and related risks due to extreme climatic events have impacted the Fijian economy and environment (e.g. coastal inundation, SLR, declining fishery stocks, agricultural produce and water shortages (Ferris et al., 2011). Many developments and infrastructure, as well as human settlements in Fiji, are located along with the coastal areas. They are projected to endure coastal degradation and damage due to SLR (Voccia, 2012). Fiji presided over Conference of Parties 23 which was hosted by UNFCCC secretariat in Bonn, Germany in November 2017. It was the first time when a small Pacific Island country is hosting one of the major international conferences, and this is perhaps the most significant opportunity for Fiji to showcase its presence in the global community.

 doi:10.20944/preprints202101.0061.v1

### *5.5 Solomon Islands*

The Solomon Islands (SI) are highly susceptible to the adverse impacts of climate-induced alterations (Barnett, 2011). Climatic events such as tropical cycle and related storms, changing precipitation patterns, droughts, SLRs, flooding in saltwater, heat stress and acidification of the ocean all threaten people's livelihoods and affect every economic sector of society (Aswani 2002; Rasmussen et al. 2009). The SI, located near the Pacific Ring of Fire, have a history of being affected by geophysical hazards. Therefore, coastal communities are well-acquainted with the risks and vulnerabilities arising from seaward exposure (Montz et al. 2017). Moreover, average local SLR is estimated to be 7-10 mm per year, which is equal to about three times the global average of 2.2 mm (Nunn 2013; AusAID 2010), thus situating local SLR in SI among the highest globally (Albert et al., 2016). Several parts of the country are now submerged under the sea (Albert et al., 2016). Secondary consequences of saltwater intrusion include the risk of food security crises (Birk, 2012). As in the other parts of the SI archipelago, the compound effects of CC and other issues have resulted in relocations of communities (Luetz and Havea 2018).

### *5.6 Tonga*

The Tonga archipelago has been affected by CC induced impacts such as temperature rise, changing rainfall seasons, droughts (MEECCDMMIC 2014; TMS 2016). However, increasing rainfall and humidity expedite the preservation of forest and mitigation through increasing carbon update, which in turn allows growth and development of young forests (ABM 2014; FAO 2000; MECC-NEMO 2010). Table 1 summarises the status of policymaking in the sampled countries. It reflects that aspects of policymaking are relatively weak overall. The subsequent parts of this paper will offer a more in-depth analysis of the mechanisms which play a role in their policy processes.

## 6. Discussion: the opportunities offered by climate change and the role of policies

The findings here presented outlined the many pressures faced by SIDS. When cross-checked against the literature they show that the economy and environment of SIDS have been impacted severely by climate extremes. Data from previous works (e.g. Leal Filho et al. 2018) recognise that even grossly adverse aggravating circumstances may nevertheless give rise to certain positive side-effects. These would be worth identifying and capitalising on even while efforts continue to ameliorate and redress the unavoidable and negative consequences of CC.

Focusing specifically on the environmental, climatic and sociocultural contexts of SIDS, this paper highlights pertinent opportunities that arise from case studies conducted in Barbados, The Republic of Trinidad and Tobago, The Cook Islands, Fiji, The Solomon Islands, and Tonga. In an attempt to establish the context for the subsequent discussion, a range of opportunities are presented, some of which are straightforward and to an extent common-sense in their approach. However, they may serve the purpose of supporting the mitigation and adaptation efforts on island nations. Opportunities include the following possible prospects:

a) Emphasis on education: progressive CC could benefit from an increased emphasis placed towards education, thereby strengthening the social and human capital, which can be expected to enhance efforts on in situ and ex-situ adaptation. This suggestion has already been advocated for atoll archipelagic environments elsewhere (Luetz, 2017) and seems broadly transferable to the situation of SIDS generally. Opportunities in this area also include raising grassroots awareness and capacity in areas of community-based adaptation (CBA). This extends from the construction of formal and informal settlements, the type of economic activities considered, correct knowledge on what to do in the event of extreme climate-related events, and the safeguarding in general of community resilience.

b) Improved information: when stakeholders and policy-makers are informed of the issues that are pertinent to their continued survival, they are then encouraged to become more engaged. Improved information needs to be accompanied by a systematic change in thinking and acting to facing these challenges in an anticipatory manner, which will take time to implement. Improved information needs to be accompanied by a systematic change in thinking and acting to facing these challenges in an anticipatory manner, which will take time to implement.

Some poor and highly vulnerable countries will have to adapt rather quickly to the adverse conditions created by CC. Such adaptation holds the promise that nations may leapfrog stages of development by adopting technologies that are more advanced and sustainable and that can thereby accelerate the pace of implementing climate-smart innovations that can lead to an overall increase in the quality of life. Hence, opportunities are raised that offer prospects of reductions in economic and developmental disparities. The implementation of policies intended to build capacities of nationals from SIDS to build, maintain, service and develop such leapfrog-technology would be crucial to instituting more effective contingency plans in anticipation of future extreme weather events.

As SIDS continue to urbanise, there will be emergent opportunities to leverage higher-density living for sustainable development. Reduced use of fossil fuels in transportation can both contribute to global decarbonisation efforts and concurrently rebound more promptly from extreme weather events by lowering their supply-chain dependence on globally sourced fossil fuel imports.

It is also anticipated that the pace of adaptation overall will be accelerated. Such acceleration should lead to a more rapid regulation and mainstreaming of post-fossil fuel technologies and the transformation of energy systems through ever-increasing uptake of alternative modes of transportation such as cycling and electric vehicles. Of course, the necessary infrastructure will need to be in place to cater for such changes, for example, electric vehicle charging points and roads which cater more appropriately for cyclists. Given the high rates of motor vehicle accidents in many SIDS, enhanced road safety is a compelling prospect and opportunity.

The vulnerability of small island environments in the face of CC has already engendered significant commitments and public pronouncements on the part of some SIDS towards carbon-neutrality. Such level of engagement demonstrates the intrinsic motivation and immediate investment on the part of low-lying archipelagic countries and communities to reduce their reliance on fossil fuel-derived development progressively. Thus, as wind farms and solar photovoltaic (PV) renewable energies are progressively mainstreamed, there will be arising opportunities for fostering energy independence. Apart from reducing their dependence from importing fossil fuels, the increase in renewable energies, if done in a way which sees revenue, job creation, and societal benefits, can create a multiplier effect which can benefit entire economies. This makes financial sense aside from mitigation and adaptation efforts in light of CC, as new commercial opportunities can help increase revenue in several ways (such as taxation and migration of skilled workforce).

Further, a host of opportunities may be found in the enlistment of private sector support for adaptation investments, including in areas of systems adaptation. Unfortunately, some SIDS will require intellectual and financial capital from other nations in order to implement some mitigation and adaptation strategies. More intensive governmental and private relationships should be developed in an attempt to bring relevant skills, technology, finance, and infrastructure to a given island state. When public and private partnerships tackle the pressing issues facing some SIDS, this innovative approach can deliver some long-lasting impact, and a diverse range of new opportunities may develop. The danger comes from the potential of exploitative relationships by one or more party members, whereby the interests of sustainable development are compromised for economic growth, which should be avoided.

Finally, in terms of paradigmatic approaches, it is conjectured that CC will further facilitate a shift in thinking from a predominantly reactionary to a more precautionary approach, also including disaster management (Luetz 2008; UNISDR-UNDP 2012). By shifting the mindset of policy-makers from dealing with challenges to leveraging opportunities, the result can shift the economies of SIDS onto more sustainable development trajectories. Of course, as extreme weather events continue to occur with increasing intensity and/or frequency, this may upset the kind of stable conditions required to promote change. Consequently, if a large proportion of resources is repeatedly spent recovering from events, it may be not easy to embrace this paradigm-shift in policymaking. (For reference, the exposure of SIDS to financial challenges in the wake of disasters was powerfully exemplified in the Maldives' experience of the Boxing Day Tsunami, which saw the archipelagic nation incur "estimated total damages equal to 62% of the nation's Gross Domestic Product" (Luetz 2017, p. 37) or after the hurricanes Maria and Irma in the Caribbean).

This is where a consortium of nations may stand to benefit from pooling their resources together to develop strategies and policies that can apply to many, if not all, SIDS. Instead of thinking in terms of national boundaries and territoriality, a SIDS-inclusive collaborative approach to sustainable development may be a way of systematically adopting measures which can a) reduce their vulnerability, and b) increase their resilience to CC.

In short, positions the presented here are rather multifaceted and holistic, broadly delineating that the consequences of CC may be concurrently negative, and yet offer opportunities. The analysis and synthesis presented by this case study suggest that it would be worth identifying and capitalising on opportunities, even while efforts continue to ameliorate and redress the unavoidable and negative consequences of CC.

Indeed, there will be complexities and limitations to the implementation of such opportunities. SIDS only have a finite amount of resources to rely upon. With many other pressing day-to-day, short-term challenges facing diverse stakeholders, duty bearers, policy-makers and decision-makers, implementation and adaptation of these strategies will require a substantial commitment from individual states or a multi-state consortium.

Finally, a recent paper (Robinson, 2019), based on summative content analysis techniques and semi-structured interviews with policy-makers, reported the limits of adaptation in the Caribbean SIDS. The primary limits are: finance; technical capacity; data and records; natural resources and characteristics; human resources; knowledge and understanding of the effects of the climate. Some policies to address these constraints include i) the depoliticisation of CC; ii) the prioritisation of good governance; iii) the improvement of the access of SIDS to international financing for adaptation, and iv) the road to a climate-resilient future through walking (Robinson, 2019).

## 7. Conclusions

This paper provided an overview of the extent to which CC affects SIDS, and outlined some of the limits experienced by island nations in coping with CC. The first part analysed the literature over the past 15 years, on the vulnerability of small island states to CC. In contrast, the second part presented a set of empirical case studies, where readers can see what the current trends are. The third part outlined some of the measures which are needed in small island states so that opportunities from CC can also be exploited. The main issue analysed on this study was "how and to what extent the challenges by human activities (e.g. agriculture and tourism) posed to SIDS could be addressed". Drawing on the study findings, it can be seen financing for adaptation and resilience-building is essential and urgent for SIDS, as they struggle to cope with the challenges posed by a changing climate.

These results also show that there are some limits which need to be overcome. For instance, SIDS adaptation plans should look for funds to build their adaptive capacity, with a particular emphasis placed on overcoming the problems (e.g. access to technologies) posed by economic constraints. Also in some cases improved governance structures are needed so as to foster an adequate and sustainable adaptation of SIDS to climate change.

Due to the geophysical characteristics of SIDS, limiting global warming to 1.5 degrees may alleviate the pressures CC poses to them. However, it cannot exclude the risks of damages to ecosystems, infrastructure and properties, which may be triggered by even lower temperature increases. This state of affairs suggests that, apart from global measures to mitigate CC by reductions in CO2 emissions, it is crucial to design and implement suitable adaptation measures, to allow SIDS to better cope with the short-term impacts of CC. These measures, when properly implemented, can:

1)Help to extend the limits to adaptation, reduce the effects of coastal erosion, saltwater intrusion, flooding and other phenomena, which currently pose a threat to the economies and livelihoods of inhabitants of small island nations.

2)Help alleviate poverty influenced by unsuitable climatic conditions which negatively influence economic activities and affect human well being.

3)Assist in reducing the hardships caused by extreme events, securing livelihoods and assisting in their sustainable development.

4)Foster territorial integration and cohesion by uniting the various parts of SIDS, which are often conceived in isolation.

A crucial implication of our findings is that adaptation responses are underpinned by diverse and contested values, underpinned by social-economic, ecological and technological considerations, and thus define mutable and subjective adaptation limits. The authors believe that given the diverse values of different actors, there is a compelling need to recognise implicit and hidden values and interests before purposeful adaptation interventions (e.g. improving the livelihoods of inhabitants of small island nations). As a consequence, we suggest that a governance framework is needed that can recognise and address the complexity of the manifestation of territorial integration. In this way, this study argues that despite the technological and ecological limits (hard limits) affecting natural systems, adaptation to CC is not only limited by such complex forces, but also by societal factors (soft limits) that could potentially be overcome.

While global reactions to CC uncertainty and IPCC projections have primarily focused on mitigation, SIDS need to have targeted adaptation goals, to handle existing and future risks. The conceptual contribution of this study envisions that CC poses constraints as well as significant systematic opportunities. Through the examples from various SIDS of their opportunities for CC mitigation and adaptation, this paper has outlined some potential action areas. Although the current literature mostly focuses on the problems caused by or associated with CC, the paper emphasises how positive influences can generate opportunities in multiple economic sectors. The presented case studies highlighted examples in agriculture, aquaculture, climate-proofing infrastructure, community development, education, health, migration, renewable energy, tourism and trade. For instance, higher land and sea surface temperature favour specific tourism destinations, alternative agricultural processes and drought-resistant crops can be mainstreamed rather than being seen as an alternative. The findings reported in this paper suggest that a resilient SIDS, therefore, relies on the i) knowledge of different values, ii) understanding of particular and variable impact vulnerabilities, and iii) acceptance through the changes in certain losses. Capacity to adapt is partly determined by technology and learning availability but mainly by the treatment of vulnerable populations and places within the context of social decisions.

One of the crucial messages of this paper is whether existing limits may constrain the adaptation capacity of communities, and their impact can be reduced utilising proper processes which may address their drivers. For instance, improved policies and political frameworks may help address the technical and social barriers, whereas more coordinated action may improve the chances to tackle the economic ones as well. All in all, a better understanding of the limits to adaptation may provide a better basis upon which their impacts can be reduced. Adapting to increased risks minimises future disruption costs, increases recovery time and enhances resilience. Further research examining the CC opportunities in SIDS should seek to gain a better understanding of the level of public support for such initiatives. Perceptions of decision and policy-makers, of the business community, and citizens should be also be investigated, so as to allow the development of policies which are fit-for-purpose for individual SIDS.

Furthermore, future research could also consider the potential for broader policy and strategy frameworks in SIDS as well as for multi-stakeholder cooperation, in order to maximise synergies and minimise duplications in respect of mitigation and adaptation efforts.

**Author Contributions:** The author contributes equally to the paper.

**Conflicts of Interest:** The authors declare no conflict of interest.

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