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Addressing Water Security Challenges in Caribbean Small Island Developing States to Increase Resilience against Climate Change Threats

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Abstract: *Caribbean Small Islands Developing States have been known to be more vulnerable than other states to the effects of Climate Change. As the effects become more evident in the region, the current vulnerabilities are at a high risk of being aggravated; in this case, freshwater access, quality and availability has become one of the biggest problems the islands face today. In order to create a more resilient future for CSIDS current issues need to be observed, analyzed and addressed. By looking at the Caribbean agenda in regards of water protection and distribution, agriculture, urbanization and tourism this paper looks to explore and provide a better understanding of the vulnerabilities faced by CSIDS. In addition, it will analyze the current methods used by the local people and policies implemented by governments and organization as a response to climate change threats on water. Lastly, the paper will offer some insights into possible future approaches that could increase the resilience of water resources.*

Key words: Water; Water Governance; Small Island Developing States; Caribbean; Climate Change; Development; Water Resource Management; Tourism; Agriculture; Urbanization; Sustainable Development; Conservation; Climate Change Adaptation

Introduction

Freshwater is inherently linked to the climate through the hydrological cycle due to the more frequent and abrupt changes in precipitation regimes. For this reason, a growing concern on freshwater availability has garnered focus to address issues of water accessibility and quality within the Caribbean region (Cashman, 2014). Caribbean Small Island Developing States (CSIDS) remain vulnerable to climate change because of their higher sensitivity to extreme heat, severe weather events, sea level rise and the associated governance related to water challenges (Cashman et al., 2010; Cashman, 2014; Mercer et al., 2012). However, these sensitivity factors can provide avenues of opportunities to create partnerships and bridge gaps of research through

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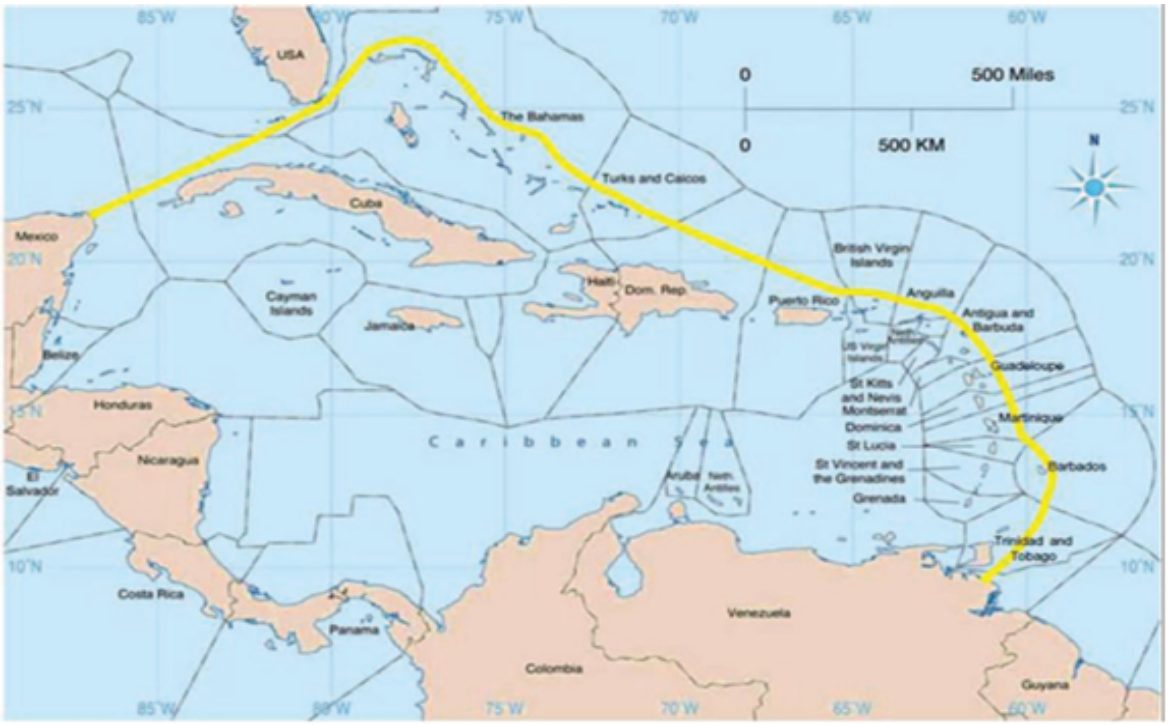
robust and collaborative processes to address some of the issues of water while becoming more resilient to climate-related hazards.

This research paper discusses current and future adaptations to climate change, implications of water security, and evaluates avenues of effective watershed management with the intent to sustain healthy ecosystems. By exploring how agriculture ('Big water'), tourism and urbanization ('Small water') have influenced freshwater resources in CSIDS, this paper argues that new strategies must take local circumstances into consideration in addition to local knowledge and traditional skills. By analysing the three major water governance paradigms (*Command and Control, Integrated Water Resource Management and Adaptive Management)* this paper looks at some of the weakness and strengths of current adaptation strategies being implemented (Belmar et al., 2016). Furthermore, early adoption of *Command and Control* to address water scarcity challenges has lead to contradictory mechanisms favouring large scale projects driven by economic development and the underutilization of mechanisms to improve conservation and efficiency.

We highlight the importance of good governance, the need for CSIDS to prioritize IWRM principles on the national agenda, the need for a redirected focus on infrastructure maintenance, and the need to improve water efficiency of both 'Big water" and "small water" sectors. For effective and sustainable water management solutions to be implemented, inclusivity in decision-making must be used in all sectors. There are different challenges to gain cooperation with multiple water users, including small farmers and industrial agriculture or large tourism corporations and local small-scale operations. To overcome these interest conflicts, stakeholders will have to identify "win-win" solutions that force everyone to work together to implement a



common goal for successful water management. *Figure 1* below provides a depiction of the CSIDS and the members involved in the resiliency building progress.

Figure 1: Map of the Caribbean Sea Region (Retrieved: Pulwarty et al., 2010)

Caribbean Island water resource characteristics and vulnerabilities related to water security:

Studies have shown that climate change is likely to have dramatic negative effects for Small Island Developing States (SIDS). There are several natural and socio-economic characteristics, which cause SIDS to have higher vulnerabilities; these include proneness to natural hazards, limited land resources, isolation and geographic remoteness, weak institutional capacity and social vulnerabilities. In this section, we examine unique vulnerabilities and impacts

through a water lens, specifically examining how addressing water security issues in Caribbean Small Island Developing States can increase resilience to climate change threats.

Although some islands use surface water such as rivers and streams and utilize rainwater-harvesting systems, typically the most sustainable source of naturally occurring freshwater resources in the Caribbean small island developing states is groundwater (Holding and Allen, 2016). The availability of freshwater varies from island to island based on their specific rainfall patterns and topography. One factor that makes the freshwater in the Caribbean so vulnerable is the fact that the water resources are quite limited and people often rely on a single source of supply, i.e. surface water, groundwater or rainwater (Pulwarty et al., 2010). Not only are small island developing states in the Caribbean often left vulnerable to seismic and climatological events due to their geophysical characteristics, it also makes them susceptible to low periods of recharge, and harmful environmental impacts (UNEP, 1998). One of the primary human-induced challenges with many small island developing states is regards to human settlement patterns. Although they have small geographic areas, many of the small islands have high populations densities which places more stress on the already limited water resources (Falkland, 1999). Due to the high population densities, increased urbanization, tourism growth and economic development within SIDS, there continues to be an increase of pressures over the available water resources (Cashman et al, 2010).

Due to the high vulnerability and the hydro-environmental limits regarding the freshwater resource in Small Island developing states, effective management, evaluation and development of the resource requires special consideration and care to ensure they are managed and developed in a manner that is sustainable (UNEP, 1998). While CSIDS share may of the same challenges faced by developing countries on a whole, such as inadequate management

resources and frameworks, they also face individual challenges distinctive to each of the Caribbean Islands (UNEP, 1998). For instance, limited access to freshwater resource, high susceptibility to climate variability, contamination and natural disasters are factors that are present in all the islands, but the gravity and management of each of these factors varies depending on the Island and their unique characteristics. These present further challenges for management of the freshwater resources such as development and freshwater constraints (UNEP, 1998).

These issues are irrespective of the effects climate change will have on water security and therefore the impacts of climate change will only exacerbate the existing water resource problems and add further pressure on a supply that is already over-stressed. A clear example is the island of Barbados, in addition to already being categorized as one of the most water scarce countries in the world (under 1000m^3/person/year), rates of abstraction are almost at their highest and the water distribution infrastructure is aging, resulting in high leakage levels (DEM, 2014). In addition to these factors, aquifer recharge rates are rapid and rely entirely on 1-3 wettest months of the year (DEM, 2014). Therefore, the sustainability of the resource in Barbados will be severely threatened by the predicted impacts of climate change. The small size, remoteness, natural vulnerability and limited resources makes it difficult for the islands to effectively manage the water sectors, which limits their capacity to address the threats climate change places on their vulnerable water resources (Overmars and Gottlieb, 2009).

As reported by the Intergovernmental Panel on Climate Change (IPCC), the islands within the Caribbean are expected to be impacted by climatic changes such as extreme weather events which involve increased maximum temperatures, increased drought, more intense rainfall patterns as well as the increase in hurricane frequency and intensity (Overmars and Gottlieb, 2009). Higher temperatures and reduced precipitation will result in reduced runoff, increased

evaporation and decreased soil moisture and this could therefore have negative implications on aquifer groundwater recharge and thus overall water availability by also affecting rainwater capture and harvesting (Cashman et al., 2010). Increased temperatures coupled with longer dry periods, will increase the demands for irrigation and thus this greater demand will place great reliance on the utilization of limited groundwater reserves (Pulwarty et al., 2010). Due to their geographical location, SIDS are already prone to natural disasters and with climate change expected to increase their frequency and severity in the region, they will create serious issues with contamination and water quality. Not only will sea level rise have significant impacts on settlements and infrastructure in low-lying coastal regions but it will add the risk of groundwater saline intrusion which could have serious implications for water resources by affecting the availability and quality of freshwater (Cashman et al., 2010).

According to Cashman et al. (2010), challenges regarding access maintenance, coverage and quality remain an increasing challenge in Small Island Developing States even though progress has been recognized with overall coverage and sanitation services. When addressing climate change, one of the major concerns highlighted for these islands is their adaptive capacity, saltwater intrusion, flooding, limited storage capacity and how these limitations will contribute to water scarcity within the region (Cashman et al., 2010). Recognizing the vulnerabilities that these states face when also dealing with climate change is crucial for policymakers, governments, organizations and local stakeholders to take appropriate measures when developing water resource plans to become more resilient to climate change. As indicated, SIDS are particularly vulnerable to climate change and its impacts and addressing these existing water resource issues and vulnerabilities in a collaborative way can increase resilience and reduce the environmental, social and economic repercussions it will impose.

Current Agenda

While some progress is being made with regard to climate change adaptation in some of the Caribbean small island developing states and there is clearly growing attention to its importance, the responses and measures as well as available budgets are still inadequate in the majority of cases in the region. The UNFCCC Small Island developing States and Climate Change report identifies some adaptation measures already taking place such as hazard mapping and improved forecasting systems (Antigua and Barbuda), strengthening of data collection systems (St. Kitts and Nevis), integrated coastal zone management strategies (Barbados, Grenada, Jamaica, St. Lucia) as well as climate change committees and regional cooperation activates (UNFCCC, 2005). However, all of these preceding initiatives typically focus on adaptation strategies that do not directly address the root of the problem or the underlying socio-economic and political issues surrounding water resources in the region.

As a region, the Caribbean small island developing states have formed the Caribbean Community Climate Change Centre (CCCCC), which works to implement and support climate action in the region. This centre prepared a Regional Framework for Achieving Development Resilient to Climate Change report that was approved in 2009, which outlined five strategies and twenty goals to cope with climate change and build social, economic and environmental resilience within the member states (CCCCC, 2017). While steps such as these are being made to address climate change, many of the countries in the Caribbean lack water resource management policy and legislative frameworks which are comprehensive as well as limited incentives to promote water use conservation and efficiency (Farrell et al, 2007). While some islands in the region are beginning to incorporate components of integrated water resource management (IWRM) into their agenda, there is still apparent fragmentation and lack of coordination of institutional arrangements (Farrell et al., 2007). With greater attention placed on strengthening

approaches towards sustainable water management, steps towards building resilience in the region can be achieved and in turn reduce the negative impacts of climate change.

Farrell et al. (2007) also noted that the situation in SIDS with regards to water resources is affected by poor management practices, coupled with availability issues and climate change impacts. In addition to the factors already highlighted, others which further add to the problem include, inefficient and inadequate water storage facilities, increasing demands resulting in unsustainable abstraction rates, contamination from agricultural practices and poor implementation of measures to improve water efficiency. In the process of addressing these issues, it must be remembered that measures being implemented must be targeted at the specific needs of small island developing states which also varies from island to island. There is no doubt that Small Island Developing States are particularly vulnerable to the impacts of climate change on their environments, population and overall economies and thus, greater emphasis should be placed on implementing strategies which build resilience, especially in the face of increasing impacts of climate change and water security issues.

Water Security & Governance

As SIDS face inexorable climate change, the role of effective governance and provisionary mechanisms of water become crucial for sustainable development (Farrell et al., 2007 & ECLA, 2015). With targets set to meet all 17 Sustainable Development Goals (SDGS), in particular SDG6 by 2030, collective solutions between all Caribbean nations to ensure everyone is on the same page is important to avoid significant economic and social inequalities. Historically, past governments have treated water as a socioeconomic good favouring those with the financial capacity to get adequate supply and excluding those suffering from poverty (Cashman, 2014; ECLA 2015 & Belmar et al, 2016). For this reason, the role of water governance, infrastructure and adaptations should address the nature of the problem and reduce

factors that increase vulnerabilities. The water management literatures highlight three major paradigms that have been proposed by Caribbean nations; *Command and Control (C&C), Integrated Water Resource Management (IWRM)* and *Adaptive Management (AM)* (Belmar et al., 2016).

Command and control is a policy paradigm that was adopted post World War II and as the name implies contributed to the development of catchments through hydraulic infrastructure such as dams and levees which proved beneficial in times of drought and water shortages (Belmare et al., 2016 & Cashman, 2014). Thus the issue of water security was addressed by preventing risks through calculated or predicted precipitation regimes via catchments (Belmare et al., 2016). However, this formal framework is critiqued for its disjointed consideration for environmental implications and neglects the cross level and cross scale challenges of water management decisions (for example, the linkages between land clearing and increased flash floods for development purposes is yet to be resolved). This has contributed significantly to the ideology that desalination plants can be a "sustainable" option to alleviate water scarcity (Cashman, 2012 & Belmar et al., 2016).

Integrated water resource management (IWRM) is an empirical concept built upon real world experiences for practitioner since the 1980s (Belmar et al., 2016). It became the dominant mode of water management after *the World Summit on Sustainable Development* in 2002. *The Global Water Partnership's* define IWRM as the *process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare without compromising the sustainability of vital ecosystems.* Enshrined in the IWRM paradigm are synergistic principles of resilience building concepts of ecosystem-based adaptations, which promotes the use of local and external knowledge about

ecosystems with a focus on the community level. Similarly, the IWRM principles account for cross-sectoral integration and promote decision making for policies at the lowest relevant level (watershed), to ensure inclusiveness and reduce fragmented or centric decisions (Belmar et al., 2016).

Adaptive Management, which gained popularity in the early 2000s, is considered to be a *deliberative and iterative* process that is transformative in nature encompassing multiscalar governance and partnerships in a nested or polycentric manner (Belmar et al., 2016). This paradigm aims to address water scarcity issues in the face of climate change due to increased variability. However, this process requires adaptive technological resources and surveillance equipment to feedback information to decision-makers, which may be beyond the financial capacity of least developed SIDS (Belmar et al., 2016). Additionally, polycentric governance, central to theories of adaptive management, may not be successful within SIDS due to strong cultural and social ties that can be created through social relationships, which are apparent amongst CSIDS (ECLA, 2015 Mercer et al., 2012 & Belmar et al., 2016). Furthermore, a polycentric style of governance fails to account for the scalar political influence that can arise from the high social capital inherent to institutions that govern CSIDS. Thus more focus may need to be focussed on the socio-political context where can lack of transparency and accountability can give informal hierarchies in governments seeking their own vested interest rather that the greater good of the state or region (Cashman, 2012 & Belmar et al., 2016).

Evidently, these types of resource management have all attempted to resolve water scarcity faced by CSIDS, but IWRM seems to hold the most promise. However, the *Command & Control* paradigm seems to favour economic development and thus persists as the dominant mode to address water challenges via; exploiting rainfall regimes through construction of large-

scale public infrastructure (Belmar et al., 2016). Consequently, such developments in turn increase the demand of water and poses negative impacts on the environment (ECLA, 2015). Therefore, the challenge underpinning good governance is the balance between appropriate political and regulatory oversight of water managers, service providers and skilled local knowledge capacity (Cashman, 2014). Hence, CSIDS governments must adopt policies which tackle the nature of the issues and provide rigid and endorsed frameworks to guide populations sustainably while building local level adaptations (Kashyap, 2004; Belmar et al., 2016 & Cashman, 2014). When it comes to dealing with water management, political, cultural, geographical and spatial variables need to be taken into consideration since it is a resource that is affected by all of these factors (Mercer et al., 2012 & Cashman, 2014). In the case of Caribbean SIDS, when looking at freshwater resource and its vulnerability to climate change, several factors need to be taken into consideration. By looking at how agriculture, wastewater, water quality and tourism in an ecosystem framework made up of sub-divisions of local users supplemented with international funding and skilled expertise, room for collaborations and sustainable development can be achieved.

Agriculture

Agriculture is one of the main economic sectors in CSIDS and it also uses up the most water of any land use activity, utilizing 70% of the global fresh water (ECLA, 2015). According to the UN-Water by the year 2050, agriculture will need to produce 60% more food globally and 100% for developing countries (ECLA, 2015). Agriculture water use is part of the "big water" problem in Caribbean small islands that needs to be addressed to ensure Caribbean nations have the capacity and resiliency to adapt to changing climate conditions. Conventional agriculture activities negatively affect water resources in different ways. The quantity of water used to grow

certain crops is often unsustainable putting severe stress on natural aquifers and available reservoirs. Chemical and nutrient pollution is another problem that is directly caused from agriculture when pesticides and fertilizers runoff and leach into fresh water supplies and contaminates them with harmful ingredients. A variety of solutions are needed to address unsustainable agriculture water use and create a sustainable environment for food production that protects valuable water resources in the Caribbean.

Addressing Agriculture Water Contamination

Water contamination from agricultural pollution is one of the most significant issues that are threatening Caribbean SIDS water resources. Climate change is expected to bring more severe storm surges and variable precipitation levels leaving existing water bodies extremely vulnerable to contaminants and runoff from fertilizer and chemical pesticides used in agriculture areas (UN ECLAC, 2015). Specific contaminants have been studied in Caribbean soils and freshwater sources to understand the extent of the agriculture pollution problem. Sierra et al (2015) studied carbon stocks and other contaminants in soil and water from export crops grown in Guadeloupe and analyzed how monoculture and undiversified crop farms had significantly more carbon levels measured in soils and groundwater resources. The study compared how smaller scale farmers who adopted more sustainable practices and diversified their crops, had significantly lower contaminants in their soil and subsequently lower levels of carbon and other pollutants in their water resources as well (Sierra et al, 2015). The case study showed eliminating the need for dangerous chemicals to control pests and adopting practices that reduce crop waste through traditional crop rotations and effective soil management can have a positive impact on surrounding water quality.

Chemical runoff into marine ecosystems contributes to serious marine ecosystem degradation because it affects the majority of species in watersheds that are necessary for keeping it clean and healthy. Studies have shown there is a direct link to waterborne diseases and illness from agriculture contaminants as these toxins are consumed through seafood and drinking water (Hernandez et al, 2007). For future communities living on Caribbean islands, there needs to be immediate intervention to protect valuable watersheds from being inconsumable from contaminants. Hernandez et al (2007) argue that applying solutions at the farm level is the best management practice to protect watershed resources in the Caribbean. To incentivize farmers to apply safer practices in agriculture and limit the use of harmful pesticides and fertilizers the costs need to be shared by all stakeholders benefiting from the industry. The solution must be inclusive in terms of collaborating with local farmers, agriculture ministries and private investors who profit from food production in the regions.

The short-term mindset is what often discourages any intervention in the agriculture sector to eliminate these harmful chemicals being used. Adopting a long term beneficiary approach for all parties involved will be necessary to implement action. Cuba is another case study that has proved sustainable agriculture can exist in the Caribbean with organic farming techniques including integrated pest management, crop rotation, composting and innovative soil conservation (Hurtado, 2013). Cuba is a Caribbean small island that had a unique agriculture transformation after the Soviet Union collapsed in 1990. Cuba relied on the Soviets to ship large quantities of chemical pesticides, fertilizers, fuel, and food imports during the Cold War causing Cubans to be left to fend for themselves after 1990. This resulted in Cuban farmers creating their own sustainable food production without heavy pesticide and fertilizer use, which initiated the movement towards organics and environmentally friendly agriculture. The new agriculture

practices kept harmful chemicals out of Cuba's water resources and have not dealt with any reported issues on water contamination from agriculture pollution (Hurtado, 2013).

Long-term use of fertilizer and chemical pesticide use is degrading soil and leading to unsafe contaminants entering water resources in Caribbean SIDS and a reorientation of their agriculture practices is necessary. Each nation has unique circumstances in relation to type of crops grown for trade and fertile land suitable to food production. However, there have been successful cases proving that sustainable agriculture practices without the use of dangerous chemicals exist and can be promoted at a regional and national level with cooperation from all relevant stakeholders.

Addressing Agriculture Water Use

The quantity of water used for agriculture presents a serious challenge for climate change adaptability. Lowering the amount of water needed per crop is the first step towards adapting to increasing periods of drought in the Caribbean. Additionally, the types of food that can accommodate these conditions must be mandatory. More efficient water management strategies are also necessary to be able to maintain sufficient water resources throughout the growing seasons. In Jamaica, rainwater harvesting has become a very successful low cost tool for rural farmers to improve water availability during dry seasons and become less reliant on groundwater resources (Emmanuel, 2011). Rainwater harvesting can be replicated in any Caribbean nation to provide small-scale farmers additional water supplies when needed. The Caribbean Policy Development Centre with support from the UN Women has also implemented a sustainable agriculture program that includes rainwater harvesting and water conservation education for communities in Barbados, Grenada and Jamaica. Women are provided workshops that teach them

how to harvest rainwater and grow new sustainable crops that use less water and can survive with the new climate conditions (UN Women, 2014). These strategies need to be promoted by regional governments in each country to promote these simple and feasible solutions for agriculture water use. Proper funding will be needed to scale up these strategies but they can be very cost effective solutions for water managers to promote.

Eudoxie & Wuddivira (2014) discuss how new water conservation technologies such as micro drip irrigation systems can save significant amounts of water in agriculture by focusing the water drops in the root of the crops. A study done on implementing low cost solar drip irrigation for small farmers in Peru showed that it was completely feasible for farmers to adopt this new technology even before government subsidies and it helped them save significant costs and water during growing seasons (Barreto & Duffy, 2009). There are clear micro solutions out there for farmers to increase water conservation that can be sustained with climate change, but a major barrier is awareness and accessibility of these solutions. Local governments, international NGOs and farmers must work cohesively to scale up adoption of these affordable solutions.

Integrated water management requires effective governance and cooperation from civil society and state authorities. For agriculture to transition from conventional unsustainable practices to sustainable and water efficient practices in the Caribbean, the state must be involved to support farmers. An ecosystem-based approach to integrated water management is important for agriculture because it puts the long term health of the surrounding environment first before short term food production revenue (UN ECLAC, 2015). The state needs to lead the movement towards a more sustainable agriculture sector that puts the future costs and disruptions of water resources as a common problem that everyone wants to prevent. This can be accomplished through the help of farmers starting to shift to more efficient and safe agriculture practices

immediately. As illustrated above, there have already been successful cases of small-scale farms using innovative solutions to protect and conserve water resources. More communities in the Caribbean island nations can adopt these strategies to help address the future risks to water resources from climate change.

Tourism Impacts on water resources

Tourism is considered to be one of the main "engines of growth in many island states within the Caribbean region" (Jayawardena & Ramajeesingh, 2003). By contributing to the growth of gross domestic product (GDP), creating employment, foreign exchange earnings and attracting capital investment, it has become a source of dependency for many of these states (Jayawardena & Ramajeesingh, 2003). Land and coastal resources have sustained the local populations for many years, but as tourism has become more popular over time, it has imposed new stresses to the different ecosystems present (Grandoit, 2005). This continues to be a growing problem as the climate, location and activities that are marketed for tourism purposes are the factors that can damage and even destroy the qualities of the land and coastal environments that make Caribbean islands attractive to tourists (Grandoit, 2005). In addition, as threats from climate change increase, the damage caused by tourism will be worsened as the ecosystem becomes more vulnerable.

The presence of tourism means that there is an increase in food, energy and water consumption as well as increased demand for urban planning as most of the tourism sector revolves around selling the idea of "sun, sand and the beach" (Grandoit, 2005). With a dramatic increase of 7% in visitors to the Caribbean islands in 2015, compared to 2014 data (Newhouse, 2016), there is evidence that there has also been an increase in chain hotels and boutique hotels

across the Caribbean region (Jessop, 2015). With the increased demand for infrastructure, it is crucial not to forget that small islands need to use the land available as efficiently as possible in order to meet the needs of all residents for water, food, building materials and a good quality of life (GDRC, n.d.). In this sense, tourism poses a greater threat to the livelihood of local people and the environment especially when it comes to water resources. For this reason tourism and tourists make up a large portion of the water demand, consuming up to three times more than the total local population consumption (Cashman, 2014). This is a troubling fact since currently, although there may be sufficient water resources to meet demand, the infrastructure is not able to close the supply-demand gap (Cashman, 2014). For this reason, the increased numbers of people travelling to these destinations pose a significant threat to the environments if there are no policies or regulations that ensure the proper use, distribution and protection of natural and environmental resources.

In order to attract tourists, islands are portrayed as exotic and unspoiled lands (Grandoit, 2005). The portrayal of the Caribbean as such, has meant the islands have had to conform to this unrealistic idea, which supports the neglect of the environment in exchange for short-term profit (Grandoit, 2005). As previously mentioned, governments and businesses treat water as a socio-economic good, which lead to the creation of local policies that have the tourism sector in their best interest instead of the environmental sector. For instance, water activities such as snorkeling and scuba diving are among the fastest growing pastimes in the world and they are also responsible for extensive damage to marine ecosystems (Davenport and Davenport, 2005). People are transported to sites through motor boats, which are known to damage coral reefs, seagrass meadows, and are significant threats to sea turtles who are not able to swim away fast enough and are likely to be hurt by boat propellers (Davenport and Davenport, 2005). In addition to the motor boats divers and snorkelers are also known to damage corals by kicking them with

their fins, taking pictures and even stirring silt that suffocates them (Davenport and Davenport, 2005). These damages are almost inevitable; governments have created Marine Protected Areas (MPAs) and regulations for the number of divers have been implemented in some regions (e.g. Cayman Islands), regardless the damage already done can take several years to heal and new harms are still caused by tourists (Davenport and Davenport, 2005).

In addition to water sports and activities effects, waste dumping, non-treatment of sewage, destruction of wetlands, salt ponds and many other outcomes are consequences that Caribbean islands have to deal with for conforming to the image of paradise that is sold for tourism (Grandoit, 2005). It can be argued that R.W. Butler's tourism cycle model (Holder, 1988) accurately describes the development and decline of tourism due to the fact that regions become less appealing to tourists as there is an increase of socio-environmental degradation and the place "sinks under the weight of social friction and solid waste" (Holder, 1988). For example, as there is an increase in the removal of forests and natural ecosystems in order to expand hotel accommodations and tourist facilities (Holder, 1988), there is an increased surface runoff and thus has resulted in lower water tables (Grandoit, 2005). The lack of available water has mostly affected local people, since they tend to have lower socioeconomic status than the people who stay at the resorts, and thus access to potable water becomes an issue of affordability and not accessibility.

Other actions that have had effects on the ecosystem include watersports, poor wastewater management of resorts and hotels, non-treatment of sewage, destruction of wetlands (Grandoit, 2005), the regular 'cleaning' of sandy beaches, which can become harmful to the environment (Davenport & Davenport, 2006), among others. These cause the erosion of beaches, breakdown of coral reefs, and marine and coastal pollution (Grandoit, 2005).

The reason why it is so important to take the tourism sector into consideration when talking about the positive development and resilience of the Caribbean islands is because the tourist sector uses almost all of the components of the environment (Grandoit, 2005). Land is used for the construction of resorts and hotels, as well as the beaches for entertainment and leisure; marine resources are used for sports, sewage waste and conversion of salt water into potable water; seafood is taken for tourist consumption and lastly the forests are used for tours, furniture, souvenirs and additional resources (Grandoit, 2005). All of these resources have to be distributed among the local population and tourists whilst keeping in mind that there should be an emphasis over the conservation of the environment. For this reason, it is imperative for policymakers to be aware of the consequences caused by economic and human activities on the environment and how to address these before they happen. Drastic changes in the way people view tourism might be needed, but with proper implementation and support it is possible to achieve a balance between tourism and environmental conservation.

Urbanization & Wastewater Treatment

Population growth, rising income levels coupled with high indebted levels of Gross Domestic Product (GDP) makes the Caribbean one of the most vulnerable regions to climate change and its associated weather related impacts (droughts, tropical storms and floods) (Cashman, 2012). To cope with these development challenges, CSIDS has transformed from being predominantly rural to the majority of the population being urbanized. The United Nation Department of Economic and Social Affairs (UNDESA) anticipates that by the year 2050 two-thirds of the global population will be living in cities. This expansion is keeping domestic water use on an upward trend, with the average person using more than double the amount that they

consumed a century prior (Cashman, 2014; ECLA, 2015). This is extremely concerning for tourism based economies such as Antigua, Bahamas and Barbados, which facilitate visitors that consume up to three times as much as the local population (Cashman, 2012).

With more than 65% of the region's populations living in urban or suburban regions, issues of pollution and overexploitation are posing serious threats to land and marine base ecosystems through alterations of the hydrological cycle (Cashman, 2014 & ECLA, 2105). This can be attributed to the increases in anthropogenic activities that alter the exchange rate of water between atmosphere, land and water bodies through the implementation of impervious surfaces (i.e. roads) (Cashman, 2012; Cashman, 2014). For instance, when large areas of trees are cleared for urban sprawls, there is a reduced buffering capacity during rainfall (ECLA, 2015). This can arise from several factors like increased rate of evaporation, greater pollution in the form of surface run-off, diminishing rate of groundwater infiltration and recharge, and more frequent and intense flow of stored water into surface bodies (Cashman, 2014; ECLA, 2015).

Urban sprawls such as cities are large importers of food and have been known to house industrial and manufacturing centers, which require large amounts of water to sustain functionality and development (ECLA, 2015). As a result, the majority of cities' water comes from outside its boundaries in the form of 'virtual water' or packaged as a commodity; this can create future threats for vulnerable populations who don't have the financial means to buffer price inflations to increase regional adaptive capacity (Cashman, 2014).

For CSIDS unplanned urban developments are a serious concern because of the alterations of catchments and stream flows for the purpose of development. For example, in Trinidad, large-scale development projects (i.e. hotels) in the upper watershed of Port of Spain has resulted in higher peak flows, major downstream flooding and high accounts of sediment loading. This increases future vulnerabilities and can be considered as a maladaptive approach

from a sustainable perspective (Cashman, 2014). Haiti can be a testament for the effects of catchment conversions and mass deforestation as they experienced road and hillside slope instability, landslides, mudflows and intense flooding during 2008 in Gonaives (Cashman, 2014). Urban developments do not only increase vulnerabilities to flooding by altering the natural flow of stormwater pathways via cities catchments, but also affects aquatic habitats and marine ecosystems through the copious disposal of untreated wastewater. Climate change is anticipated to exacerbate these aforementioned challenges (Cashman, 2014).

Wastewater reuse is now globally recognised as a resource for reducing water scarcity (Mercer et al., 2012 & Peters, 2016). However, throughout CSIDS wastewater recycling is not well recognized by public policies (with the exception Jamaica), but it plays significant relevance to economic and environmental development (ECLA, 2015). Often wastewater management, maintenance and infrastructure has to compete with other pressing economic and social issues, such as fiscal and trade matters, poverty and unemployment, and education and health (Cashman, 2014). This places significant relevance for the current status of wastewater treatment within the Caribbean region (ECLA, 2015).

As SIDS continue to develop in favour of economic prosperity, the supply of water for food production, health, industry and the demand for more urban expansion continues (ECLA, 2015). Furthermore, many researchers and programmes have confirmed the linkage between hydrological extremes and economic losses (Cashman, et al., 2015 & Cashman 2014). In reality, plans to address water related disasters, climate change adaptation and increasing recycling of wastewater disposal is still in infancy (ECLA, 2015). The lack of attention into this sector can result in several detrimental consequences such as increasing population levels causing further degradation to marine ecosystems (e.g. coral reefs) (Cashman et al., 2014; ECLA, 2015). This can be exacerbated, as the effects of climate change will likely cause an increase in demand for

resources to build regional adaptation. To date, desalination plants are the most popular adaptation method for resolving water scarcity challenges despite being extremely costly (Cashman, 2102). For this reason, attention should be diverted to service provision and management of wastewater facilities. As there is no reason to believe that similar approaches cannot be redirected to utilising wastewater as an alternative and more cost effective adaptation strategy to reduce water wastage (Cashman, 2014).

Increases in climate variability and more irregular precipitation regimes are forcing countries to develop new ways to create more adequate supplies of water in terms of quality and quantity (Peters, 2016). Although each country has variations with their biophysical properties (topography, size of land mass, urban sprawl), wastewater remains completely underdeveloped (ECLA, 2015). According to the Global Environment Facility-funded Caribbean Regional Fund for Wastewater Management (GEF- CReW), 85% of water entering into the Caribbean Sea remains untreated, and 51.5% of households lack sewage connections as reported by the Pan American Health Organization (ECLA, 2015). To put this into perspective, only 17% of households are connected to "acceptable" treatment systems (ECLA, 2015). This has contributed to the degradation of 80% of the coral reefs in the region, which can jeopardize local livelihoods and increase the marginalization between rich and poor classes (ECLA, 2015; Peters, 2016; Cashman 2014). However, these challenges, although bleak, can create room for sustainable development and foster the creation of innovative adaptive strategies.

Although wastewater management remains underdeveloped, the Eastern Caribbean has made some progress with 8% wastewater reuse within the tourism sector (Peters 2016). Caribbean islands such as Trinidad and Tobago, Grenada and St. Vincent and the Grenadines, where inadequate regulations of wastewater still prevail, prove that greywater and domestic

treatment are viable options (Cashman, 2014). Decentralising wastewater reuse technologies can have substantial improvements in water efficiency and reduce marine degradation (Cashman, 2014 & Peter, 2016). Furthermore islands that are more arid in nature such as Antigua, Barbuda, Trinidad or Barbados, could adopt methods that direct potable reuse; method in which purified municipal wastewater can be introduced into water treatment plants, providing an alternative to improve both quality and quantity of water (Peters, 2016).

In St.Lucia, Sandals resort has taken progressive action to utilize 33% of their consumed water and reuse it for irrigation purposes, which can also be adopted by many other resorts throughout the Caribbean (Peters, 2016). Additionally, in the Marriott hotel in St. Kitts, wastewater reuse has been used for beach resorts and spas and all the irrigation needs accounting for 17% of the total wastewater reuse. Strategies like these can provide multiple co-benefits, which can address water scarcity and build resilience to climate change. Peters (2016) suggest that if St.Kitts were to utilise 22.5% of surplus wastewater that is not utilised for the purpose of flushing toilets can contribute significantly to reduce the damages of flooding during the rainy season (ECLA, 2015 & Peter, 2015). In Barbados, hotels and resorts are required to install their own wastewater treatment plants, which can provide adequate supply of irrigation for golf courses. Wastewater can make up to 38% of domestic usage (hotel, resorts and houses) and if employed for irrigation or agriculture can reduce both ‘big’ and ‘small’ water demands (Peters, 2016). Though progress has been slow, the Caribbean has made substantial advancement from the last 60 years to addressing improvement in water supplies and adequate sanitation (Cashman, 2014). However, more focus should be directed towards building and maintaining local infrastructure both in the physical (pipelines and wastewater system) and social (local expertise) aspects.

Conclusion

In conclusion, CSIDS water resources are extremely vulnerable to climate change because of natural climate patterns from warming temperatures and human induced land use changes. Temperature increases and more severe weather events are intensifying drought periods, storm surges and sea level rise while human activities on Caribbean islands such as deforestation, unsustainable agricultural production, and new human settlement patterns are putting more stress on water resources used for consumption. In order to address these main water security challenges in relation to climate change, behavioural changes will be needed in the activities that affect water supplies the most; agriculture, tourism and domestic urban users. It will also be important for all stakeholders involved in these activities including state authorities, civil society, international NGOs and private sector actors to work cohesively to implement water security solutions and find "win-win" scenarios that will help CSIDS to adapt to future climate threats.

For large water users in the agriculture sector, new technological innovations and farming techniques will be required to preserve existing water resource levels and discontinue harmful contaminants from chemical inputs that are polluting water reservoirs and aquifers. These solutions can be adopted by successful small scale farming case studies that have already introduced more efficient water irrigation and organic soil and crop management techniques. Transformational policy changes can only be possible with a collaborative approach by farmers, state authorities and investors in the agriculture sector.

Tourism is the other major economic sector that needs to be part of the water security solution to adapt to climate change threats and challenges. An environmental conservation approach to tourism will be necessary to prevent further environmental degradation from continuing on valuable coastal ecosystems that provide protection and filtration for freshwater resources inland. By implementing stronger environmental policies, creating more Marine

Protected Areas and limiting the influence tourism has over environmental management there is a possibility to minimize the damage caused by tourism, yet continue to maintain it as a source of income for this region.

Finally, the human settlement patterns that are increasing urbanization will require planners and municipal level policy makers to invest in long term wastewater and potable water infrastructure for household consumption. Water efficient solutions such as wastewater reuse and recycling can help save significant amounts of water in domestic consumption and eliminates that need for additional water supplies. Integrated water management strategies and infrastructure needed to provide clean and sufficient amounts of water to households have not yet been adopted by the majority of cities in CSIDS, and for that to change all stakeholders need to be actively work together for win-win solutions that save costs and the environment.

The future costs of not acting urgently to address water security challenges in CSIDS will need to be acknowledged by all actors that rely on water resources in order for cooperation to take place. A long term mindset that replaces the current short term focused water management culture will need to be promoted throughout different industries and activities to create real sustainable solutions that will allow CSIDS to adapt to future climate change threats on their freshwater resources. Overcoming inclusive decision making barriers will be the most challenging aspect of improving water security, and identifying win-win solutions for both small scale and large scale water users will be needed to garner full cooperation.

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