Impacts of Climate Change on Water Availability in the Caribbean

The adverse effects of climate change have become more well known, and will affect humans and the environment in almost every aspect of life. One of the biggest ways climate change will affect humans is by threatening drinking water. A place where this will be most notable is small island developing states, or SIDS. The Caribbean, a region made up of over 7,000 islands (World Atlas, 2022), 13 independent countries, and 15 dependencies which are home to over 44 million people (World Atlas, 2022). Climate change will cause water availability in the Caribbean to become less predictable. This is highlighted in the IPCC's Fourth Assessment Report, which states, "small islands are especially vulnerable to the effects of climate change and Caribbean islands are likely to experience increased water stress" (IPCC, 2007). This will look like a continuation of warming in average temperatures, lengthening of seasonal dry periods, increases in frequency of occurrence of drought conditions, increases in intensity in storms and extreme weather, and a continuing in the risk of saltwater intrusion. These effects on water availability will be more severe due to poor data collection, poor water management, a limited capacity to adapt, and a limited capacity to store water resources.

In the Caribbean there are three main sources of water; these are rainfall, surface water, and groundwater. All three of these sources closely affect and rely on each other. Rainfall is the main source of freshwater for the Caribbean, except for the Bahamas and Antigua (Impact Consultancy Services Inc., 2002). In the Caribbean there is a distinct dry period seen between December and March to April; while peak rainfall coincides with hurricane season from June to November, and is heavier at the start and end of the season (Cashman et al., 2004). Rainwater is especially important in Jamaica, as many residents rely on rainwater harvesting systems to meet potable water needs. This can be seen especially in more remote communities where access to public water supply is low (Aladenola et al. 2016). In some countries cisterns, which are part of rainwater harvesting systems, are required by building codes if the house is not connected to public water supply (CGTC, 2019).

Surface water consists of streams, rivers, lakes, reservoirs and wetlands (American Geosciences Institute, 2022). In the Caribbean, surface water comes from a mixture of North Atlantic surface water, the Amazon River, and local freshwater runoff from South America

(BDO Trinidad and Tobago, 2010). Surface water is not as heavily relied on as rainfall and groundwater, but is still an important factor in influencing groundwater.

In areas such as the Bahamas and Jamaica, freshwater is readily available as groundwater, which is recharged by rainfall. Groundwater exists as lenses which can 'float' on top of saline water due to freshwater being lighter (Cashman, 2013). Groundwater can be thousands of years old, but is usually harvested after only being underground for a few decades (Water Education Foundation, 2022). In some cases, groundwater can flow naturally to the surface in the form of springs, but is mostly harvested through wells or pumps (Water Education Foundation, 2022). This process is called abstraction, but if too much groundwater has been removed from the source it can lead to over abstraction and causes saltwater intrusion by replacing the abstracted freshwater with saline water due to upwelling (Cashman, 2013). Over abstraction in conjunction with sea levels rising, is the main threat to these groundwater supplies, which will be discussed in further detail later on.

The most known effect of climate change is a warming in average temperatures. This is a threat to water availability. An annual warming between 1 and 5 degrees Celsius is expected in the Caribbean by 2080. This warming will not be uniform across the entire region, and instead it will be greater in the northwest Caribbean, including Jamaica. Warm spells and heat waves, such as what the Caribbean will be seeing, can lead to higher evaporation losses in surface water and reduce water quality due to phenomena such as algal blooms (Cashman et al., 2010).

Another issue is the lengthening of seasonal dry periods. As stated previously, the Caribbean has a distinct wet and dry season, and with climate change it is expected that these periods will be characterized with more extreme precipitation and drought respectively (Center for Climate and Energy Solutions, n.d.). Due to this, the seasonality of water availability is a bigger issue than water availability throughout the year, and higher demands will coincide with the dry season (Cashman et al., 2010). A study was conducted in the Pusey district of St. Catherine, Jamaica on precipitation rates in the area. The study found that the average number of dry days in a year was 111 days, and the average maximum number of consecutive dry days during the dry season was 17 days (Aladenola et al., 2016). The IPCC Fourth Assessment Report suggested that decreases in mean annual precipitation are likely in regions such as the subtropics, and this decrease can be up to 20% in some cases (IPCC, 2007). Models show that changes in monthly rainfall patterns could decrease between 25% to 50% based on location in the Caribbean and anticipated warming scenarios (IPCC, 2007). These long term shifts in seasonal weather patterns will affect run-off production that characterizes renewable freshwater supplies (Cashman et al., 2010). Both surface and groundwater will be affected by decreases in precipitation, surface water resources could see a decrease during the dry season causing a reduction in water production up to 50% and groundwater could experience decreases in recharging due to it relying on 20% to 25% of the rainfall (Cashman et al., 2010).

Droughts occur when warmer temperatures increase evaporation, which reduces the amount of surface water in the area (Center for Climate and Energy Solutions, n.d.). Droughts can also create a positive feedback loop in some scenarios. When dry soils and reduced plant cover absorb more solar radiation and get hotter, it can cause the formation of high pressure systems which further suppresses rainfall. This causes dry areas to become even drier (Center for Climate and Energy Solutions, n.d.). From 2014 to 2016 a severe drought occurred in Puerto Rico that forced 1.2 million people to ration water (Climate Adaptation Science Centers, 2018). This drought, and others like it, will become more frequent in the Caribbean as the climate continues to warm and the region experiences drier conditions. Unfortunately, as of 2021, Puerto Rico had been dealing with varying degrees of drought conditions for seven years (Natural Resources Conservation Service Caribbean Area, 2022). A status report for December 2021 from the U.S. Drought Monitor stated; “Drought conditions continue to worsen across most of Puerto Rico and all of the U.S. Virgin Islands without significant relief expected until the start of the wet season in April (Natural Resources Conservation Service Caribbean Area, 2022).”

Climate change is causing tropical storms to increase in intensity due to an increase in sea surface temperatures (Joseph, 2020). After tropical storms, cyclones, and heavy precipitation episodes, contamination of groundwater and surface water occur frequently (Cashman et al., 2010). Floods caused by this extreme weather can affect water quality due to soil erosion. Along with the topsoil being eroded, animal waste, feces, pesticides, fertilizers, sewage, and garbage are swept along with it, having a large impact on groundwater (The Caribsave Climate Change Risk Atlas, 2012). In countries where the majority of potable water is pumped into reservoirs, supplies can be disrupted due to power outages caused by these events as well (Cashman et al., 2010). Saltwater intrusion can also be caused due to storm surges in low lying coastal areas (Cashman, 2013). With their increased intensity, these extreme weather events will cause more damage, and further adverse effects.

Saltwater intrusion into groundwater is already a threat to the quality and availability of freshwater supplies on many Caribbean islands. The biggest contributor of saltwater intrusion is sea level rise. This will continue to be an issue as global mean sea levels could potentially rise at a rate of 1.0 to 7.0 mm/year for many decades in the future (IPCC, 2007). In the Caribbean, sea levels will continue to rise at a rate between 5.0 and 10.0 mm per year for the next several decades (Cashman, 2010). This will have a greater effect on low-lying coastal areas, as aquifer size is partially controlled by land mass size (Cashman, 2013). This demand is higher in these more vulnerable coastal areas, and the combination of over abstraction and sea level rise, will increase the incidents of saltwater intrusion (The Caribsave Climate Change Risk Atlas, 2012). In Jamaica, around 86% of available water comes from 23,000 wells including boreholes, coreholes, and pumping wells (The Caribsave Climate Change Risk Atlas, 2012). These two factors have already caused a loss of around 10 million cubic meters of groundwater annually, which is 10% of all exploitable groundwater in Jamaica (The Caribsave Climate Change Risk Atlas, 2012).

While there are many threats to water availability in the Caribbean, there are some short term solutions to mitigate the impacts of climate change on this region's drinking water. One solution is the use of desalination plants, which purify saline water and turn it into potable freshwater (Werft, 2016). The most common methods for desalination are reverse osmosis and distillation. A case study of this is seen in Barbados. The country experienced a 1 in a 100 year drought where over 3,000 households and the island's main hospital were regularly without water. After this event a desalination plant was built in anticipation of future droughts, and some countries now rely on desalination plants to meet water demands (Cashman et al, 2013). While this is a potential solution, it still has its downsides. The biggest of these being its cost, which could continue to increase due to salinity levels in the oceans expecting to rise. This makes it more expensive to filter the salt out, and uses more energy during the process (Werf, 2016). The cost of these plants can be cut down by using renewable energy (Werft, 2016), but Caribbean countries will have to weigh the advantages and disadvantages of desalination as a way to mitigate the effects of climate change on water availability if they are able to afford it.

Better management and data collection is needed throughout the Caribbean as the exact amount of water resources available are currently unknown, and up to 60% of the resources could be unaccounted for (Cashman et al., 2010). Having an understanding of how much water is available is the first step in being able to manage the water properly. Good water management will require better infrastructure and policies aimed to protect water resources. Strides in water management are being taken in some Caribbean countries. In 2013 in Jamaica, the Ministry of Water, Land, Environment, and Climate Change, was created with the duties of providing oversight and responsibility for policy, legislation, and monitoring of all water agencies (Cashman et al., 2014). Including all of these under one ministry shows a commitment to an approach in water management that will be required to provide adequate water security, but policies still need to be updated to include climate change (Cashman et al., 2014). While there are strides in the policy of water management, creating the proper infrastructure is not going to be easy for many countries of the Caribbean. An example of this is that the wet and dry seasons are both becoming more extreme, which will require both flood management infrastructure and drought mitigation systems to protect public water supply (Quarless, 2015).

Rainwater harvesting systems are already used in many Caribbean countries and involve collecting rain from rooftops and storing it in cisterns. During periods of heavy rainfall though, the cisterns may overflow, causing these households to lose usable water (CGTC, 2019). Increasing the storage capacity of these rainwater harvesting systems between 2.5 to 4.0 cubic meters per four person household can help meet water demand during dry spells and water shortage periods (Aladenola et al., 2016). This will allow households to catch water during these heavier times of precipitation and to be able to store it during the dry season and droughts for longer. Another factor involving the efficiency of rainwater harvesting systems that has not been researched yet, is the catchment efficiency based on roof type (Carbon Green Technology Center, 2019). If more research can be done on this topic, households' ability to catch rainwater can increase even more to alleviate water stress.

With threats to water availability, short term solutions are needed for residents of the Caribbean to survive, but they are not the only thing that should be done. Global water demand is projected to increase by 55% by 2050 (Quarless, 2015), so it is vital that we implement strategies to limit the effects of climate change, on top of solutions that can mitigate the stresses climate change is currently causing. Water is a basic need for all living organisms and we must treat the water crisis as a threat to life. The U.N. Security Council has already been called "to recognize water as one of the top security concerns facing the global community" (Bigis, 2012).

Governments across the world must step up, as action now will prevent the water crisis from becoming detrimental to small island developing states such as the Caribbean and its inhabitants.

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