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Planning for Climate Change Adaptation Through Nature-Based Solutions

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Planning for Climate Change Adaptation Through Nature-Based Solutions

by

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Dedication

Dedicated to my grandpa, John Howard Wolcott, for instilling in me a love of science and the outdoors. I would also like to dedicate this professional report to my best friend, Sam, for her unconditional love until the end.

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I would like to acknowledge my parents, Lynn and Dave Archer, for dealing with "Grad School Jordan" and constantly believing in me. My siblings, Zach, Rebecca, Nate, Annie, and Avery, for listening to me complain about school for the last 18 years. My friends, Lauren Chaloupka, Madison Graham, Nicole Haggerty, and Jorge Losoya, for keeping me laughing and reading some drafts. And lastly, leap year, for giving me an extra twenty-four hours on this professional report.

Abstract

Planning for Climate Change Adaptation Through Nature-Based Solutions

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A changing climate has been of mounting concern for the last decades, leaving scientists, policy makers, planners, and everyday citizens scrambling for ways to adapt to a new normal. The impacts of climate change are vast and quickly altering the planet around us, and we must begin to adapt to these impending changes. The goals of this professional report are to inform about what Nature-Based Solutions are and how they can be integrated into planning concepts to combat climate change impacts, acknowledge successful case studies, recognize knowledge gaps, and create recommendations for implementation and future policies. This is done through an extensive and comprehensive literature review, as well as case study analysis of three different examples of Nature-Based Solutions and their impact on climate change adaptation.

This report provides an overview of the history of Nature-Based Solutions, the different types of Nature-Based Solutions, and how they can help adapt to a changing climate. It also focuses on the impacts of a changing climate on urban areas, methods of adaptive planning for a changing climate, and the health and social impacts of Nature-

Based Solutions. Three case studies are presented: stormwater management in Staten Island, New York; urban cooling and greening in Phoenix, Arizona; and coastal management on the Island of Barbados. Lastly, I include a section on policy recommendations and conclusions for greater implementation of Nature-Based Solutions in planning.

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INTRODUCTION

A rapidly changing climate has been of growing concern for the last decades, leaving scientists, policy makers, planners, and everyday citizens scrambling for ways to adapt to a new normal. Urban areas are home to over fifty percent of our human population, and this percentage is only expected to increase in the coming decades (Enzi et al. 2017). The impacts of climate change are vast and quickly altering the planet around us. Sea-level rise, increased air and noise pollution, biodiversity loss, higher frequency of storms and flooding, and an increase in heat waves and the Urban Heat Island are just some of the impacts for which we must adapt. Grey infrastructure has been implemented for far too long as the only way of mitigating and adapting to a changing climate and is no longer sustainable compared to other options being presented. Recent efforts have been made by cities to respond to the climate change crisis through mitigation by the reduction of greenhouse gases, but far fewer cities have taken the necessary step towards planning for adaptation. Adaptation focuses on long-term strategies to reduce the amount of risks and exposure to risks and to improve the overall coping ability of cities (Depietri & McPhearson 2017).

Nature-Based Solutions can combat climate change by decreasing the amount of building with grey infrastructure, increasing public health, and conserving biodiversity for the world, all key elements in successful planning. They are our next line of defense against the impacts of a changing climate, and research regarding them needs to be further explored. Nature-Based Solutions could lead to more successful, sustainable, and implementable adaption plans for the future, and planners need to start making decisions that include them.

This report is broken down into four separate sections: Introduction, Adaptive Planning for a Changing Climate, Case Studies, and Policy Recommendations and Conclusions. The Introduction includes a short history of Nature-Based Solutions, the different types of Nature-Based Solutions, and how they can help adapt to a changing climate. The next section, Adaptive Planning for a Changing Climate, focuses on the impacts of a changing climate on urban areas, methods of adaptive planning for a changing climate, and the health and social impacts of Nature-Based Solutions. The following section, Case Studies, explores three different types of Nature-Based Solutions in Staten Island (New York), Phoenix (Arizona), and The Island of Barbados. Lastly, I include a section on Policy Recommendations and Conclusions for greater implementation of Nature-Based Solutions in planning.

METHODS

The methodology for this professional report will be based on an extensive and comprehensive literature review, as well as case study analysis of three different examples of Nature-Based Design and their impact on climate change adaptation. Research on this topic is uncommon, and although it has been increasing there are still not many ways to accurately research this topic without field work or interviewing community members who have experienced the successes and failures of Nature-Based Solutions. I will be focusing on literature and reports already written and case studies focused on The Staten Island Bluebelt, Phoenix, Arizona, and The Island of Barbados.

HISTORY OF NATURE-BASED SOLUTIONS

Designing with nature is a notion that has been around for decades, thanks to Ian McHarg's 1969 Publication, *Design with Nature*. In it, McHarg proclaimed frustrations with America's land use codes and relaxed environmental regulations, and called for more stewardship of the biosphere from the humans that call it home. The book also provided an outline for the use of "suitability mapping," a technique using a multi-layered map of an area's environmental features to find the most "suitable" parcels of land to build, a practice commonly used by planners today (McHarg 1969). *Design with Nature* was a stepping stone in of a string of environmental policy achievements. After the book's publication, the 1970s brought the National Environmental Policy Act (1970), the establishment of the Environmental Protection Agency and the White House Council on Environmental Quality (1970), the Clean Water Act (1972), the Endangered Species Act (1973), and CERCLA or Superfund in 1980 (Fleming et al.. 2019).

From the influence of McHarg and many others came the concept of Nature-Based Solutions. In the early 2000s, World Bank published, *Biodiversity, Climate Change, and Adaptation: Nature-Based Solutions from the World Bank Portfolio* (World Bank 2008), to highlight the importance of harnessing biodiversity conservation for the use of climate change mitigation and adaptation. Nature-Based Solutions focus on cost-efficiency, replicability of solutions, harnessing public and private funding, and ease of communicating and understanding the practice (Pauleit et al. 2017). The European Commission defines Nature-Based Solutions as those "which are inspired by, supported by or copied from nature" (European Commission 2015). The reliance on nature to provide useful blueprints is hardly a foreign concept. Take a look at how airplanes mimic the shape of birds, or how Velcro imitates that of sticker burrs stuck in your hair. Replicating designs found in nature is known as "biomimicry," and the replication of bigger ecological systems, such as wetland recreation, is called "ecomimicry" (Kronenberg 2016). These processes and functions work so well in nature, it only makes sense to replicate them.

Nature-Based Solutions are broadly recognized and referred to by many names, including: ‘building with nature,’ ‘living shorelines,’ ‘engineering with nature,’ ‘ecological engineering,’ ‘green infrastructure,’ ‘ecosystem-based adaptation,’ ‘ecosystem-based disaster risk reduction,’ ‘natural water retention measures’ (Pontee et al.. 2016). Regardless of how it is referred to, these green and blue spaces within urban areas are becoming more and more recognized for their capacity to conserve biodiversity and generate additional environmental, economic, and social benefits (Kabisch et al. 2016).

Lafortezza has identified the four main goals of Nature-Based Solutions as 1) to develop sustainable urbanization to inspire economic growth and improve the environment, 2) to restore degraded ecosystems, increase resilience and withstand societal challenges, 3) to develop climate change adaptation and mitigation strategies for the purpose of improving resilience and enhancing carbon storage, and 4) to improve environmental risk management and resilience using Nature-Based Solutions to provide greater benefits than traditional methods and offer the reduction of multiple risks (Lafortezza 2018).

TYPES OF NATURE-BASED SOLUTIONS

Before introducing the categories of Nature-Based Solutions, the concept of hard versus soft infrastructure must be discussed. Hard or “grey” infrastructure refers to solutions that use entirely engineered structural features. Examples include seawalls, breakwaters, levees, traditional stormwater drainage, and more. Hard infrastructure is often costly to install and maintain, has long-term effects on the environment, tend to have low flexibility, and can cause disastrous events if they fail. For instance, the failure of the New Orleans levees in 2005 caused extensive damage in the wake of Hurricane Katrina (Pontee et al. 2016). However, “hard” infrastructure has offered society so much in terms of health and safety. This is seen in clean drinking water through water treatment facilities, sewage collection, standardized irrigation and transportation systems through canals, and so much more (Pontee et al. 2016).

Soft infrastructure refers to solutions that use nature as a well-functioning ecological system to manage and mitigate risks while actively restoring the environment. Soft infrastructures are more flexible than hard infrastructures and go beyond just the functions of buffering and protecting; they additionally provide ecosystem services, services that are provided to us through nature. Representations of soft infrastructure in coastal areas include healthy oyster and coral reefs, coastal salt marshes, mangrove forests, sand beaches and dunes. In urban or more inland areas, forests, parks, street trees, and green infrastructure solutions are examples of soft infrastructure (Depietri & McPhearson 2017). Soft infrastructure options are thought to be a low-cost alternative that are cheaper and easier to maintain than hard engineering structures, although questions of short- and long-term cost are still being researched. In addition, the provision of environmental services can be more effective than hard infrastructure in some cases.

Lastly is a combination of both hard and soft infrastructures, termed hybrid infrastructure. Hybrid brings together the best of hard and soft infrastructure to provide both ecosystem services and human engineering to mitigate and manage risks (Depietri & McPhearson 2017). An example of hybrid infrastructure is the restoration of a wetland, with the inclusion of a small levee. The wetland restoration acts as the soft infrastructure, and the additional levee as the hard infrastructure.

Nature-Based Solutions

The notion of Nature-Based Solutions is very broad in scope, and for many is an umbrella term for multiple policy objectives. These objectives are many, and include biodiversity conservation, the enhancement of ecosystem services, disaster risk reduction, addressing equity issues, and fostering economic growth and practicing sustainability (Pauleit et al. 2017). Nature-Based Solutions already provide us with primary production, nutrient cycling, climate regulation, water purification, recreational opportunities, spiritual importance, and more. These functioning ecosystems and the services they provide may be the best adaptation strategy to a rapidly changing climate.

Ecosystem-Based Adaptation

Ecosystem-based adaptation is defined as ecosystems that have the ability to "harness the capacity of nature to buffer human communities against the adverse impacts of climate change through the sustainable delivery of ecosystem services" (Littlefield et al. 2019). Ecosystem-based adaptation is a widely used international strategy, and is capable of being applied at many different scales and sectors. It is considered to entail more of a social-benefits approach than other versions of Nature-Based Solutions, and has a limited scope in that it focuses specifically on climate change adaptation. Ecosystem-based adaption is heavily embedded in ecosystem services and climate change adaptation and mitigation. At its core it works to build adaptive capacity to a changing climate and risks never before encountered, and to build resistance and resilience in human systems (Pauleit et al. 2017). An example of ecosystem-based adaptation is the improvement of mangrove forest management in South Florida. Mangrove forests offer protection from storms, waves, sea level rise, and also provide a number of goods for the local communities. Better management of these forests is an adaptation the locals have made to buffer their communities against the conditions associated with a changing climate (Doyle et al. 2003).

Figure 1: Red Mangrove Forest in South Florida. Source: blogspot.com

Urban Green Infrastructure

Urban green infrastructure is "any variety of stormwater-management techniques, installations, or systems that use vegetation, soils, and natural processes as compared to engineered systems" (Littlefield et al. 2019). Typically covered in vegetation, these spaces can be privately or publicly owned and include a variety of maintenance and management regimes. Green infrastructure can be implemented at different spatial dimensions. Ahern describes the different implementable scales as the metropolitan region and city scale, the district neighborhood scale, and as individual site scales (Ahern 2007).

Urban green infrastructure includes permeable paving, bioretention planters or bioswales, rainwater harvesting techniques, green or vegetated roofs, green walls and even indoor plants. The most common of these techniques is green or "vegetated" roofs. Green roofs are isolated patches of novel ecosystem, consisting of "membranes, engineered substrate (the growing medium), and assemblages of plants placed atop buildings or other structures" (Sutton 2015, Page 2). Their benefits include stormwater retention, temperature reduction, noise capture, and social health benefits. Multiple studies show that green roofs can have an impact on the surrounding microclimate, such as decreasing the temperature of an urban area (Xing et al. 2017). Types of green roofs include: edible, recreational, rolled-out green carpets, and shed roofs that include mounds with perennial grasses and flowering plants (Xing et al. 2017). An example of a green roof is located at the University of Texas Dell Medical Center. The green roof was placed with the goal of helping patients find peace and tranquility in the medical center's urban area (Lady Bird Johnson Wildflower Center, 2020).

The second most common implementation of urban green infrastructure is the green wall. Green walls are split into three types, the Traditional Green Façade in which climbing plants, typically vines, use a trellis or façade for support; the Double-Skinned or Green Curtain wall, which uses a detached trellis with the goal of separating the green wall from the structural building wall; and Perimeter Flowerpots, where hanging pots or shrubs are planted around the building to form a green curtain (Xing et al. 2017).

Figure 2: Traditional Green Façade in San Antonio, Texas. Source: Jordan Linhart

Ecosystem Services

Ecosystem services are the last of the identified Nature-Based Solutions used for adapting to a changing climate. These services were recognized in the early 1970s, with a rise in environmental regulations and policies. The conservation movement highlighted all the services provided to us by ecosystems and led to the radical acceptance of nature's abilities. Ecosystem services are services that are provided to us through nature and are split into four separate categories; supporting, cultural, regulating, and provisioning. Supporting ecosystem services are those that support life on this planet, such as food production, soil formation, and photosynthesis (Pauleit et al 2017). Cultural ecosystem services are those which we intrinsically value, such as biodiversity and habitat, stewardship, aesthetic, recreation, and education. Regulating ecosystem services are those that regulate the planet and keep the ecosystem clean, such as clean air, storage of carbon, purification of water, flood control, and cooling temperatures. Lastly are provisioning services: these services provide us with our basic needs of food, shelter, water, and they include clean water, fish, animals, wood, and pollination.

Figure 3: Ecosystem Services Diagram. Source: metrovancouver.org

NATURE-BASED SOLUTIONS AND A CHANGING CLIMATE

The impacts of a changing climate are largely determined by the dynamic interactions of the atmosphere, the oceans, the land, and the glaciers and ice sheets, the major components of the climate system. This epoch in geological time has been termed "the Anthropocene," and is viewed as a period of time when humanity has had such a dominant influence on the climate and the environment that it has changed. Human activities of various types are currently altering the earth's energy and climate balance, the primary cause being an increase in carbon dioxide through the burning of fossil fuels like coal, natural gas and petroleum.

Human activities such as deforestation, agriculture, urbanization, and more have impacted the earth's ecosystem in unimaginable ways. Periods of high soil moisture evaporation are now longer and warmer, leading to very dry and even drought conditions. Warming in the Arctic has been double the global average for the last two decades. Dry subtropical environments have expanded towards the poles, and average precipitation has increased over mid- and high-latitude land areas. There is now a greater likelihood of intense rainfall causing increasing runoff and higher river levels and increased potential for flooding in many areas of the globe. Oceans are also warmer, and continue to warm, leading to an increase in storm frequency, including hurricanes and typhoons. Warming oceans also play a role in decreasing the biodiversity of the ocean's inhabitants such as coral, hard-shelled creatures including diatoms, dinoflagellates, lobsters, crabs, and more. Rapid melting of heavier snow and ice has also begun to cause major flooding and severe changes in hydrological land cover, and loss of habitat for artic dwellers such as polar bears and penguins. Biodiversity loss and a general reduction in the functioning of ecosystems and the services that they provide is coupled with the changing climate. Changes in patterns of infectious diseases, and the impacts on food yields and fresh water supplies are also results of a changing climate (Kabisch et al. 2016).

Risk and vulnerability to all of these things and more are a product of a changing climate. There are and will continue to be a growing number of humans vulnerable to natural hazards as the result of "socio-economic, physical, and environmental processes that characterize a social-ecological system" (Kabisch et al. 2016, Page 39). An increasing rate of urbanization has exacerbated the impacts of hazards through poor urban management, inadequate planning, high urban population density, inappropriate construction, ecological imbalances and infrastructure dependency. The time to begin adapting to a changing climate is now, and Nature-Based Solutions continue to offer excellent results.

ADAPTIVE PLANNING FOR A CHANGING CLIMATE

IMPACTS OF A CHANGING CLIMATE ON URBAN AREAS

Sea Level Rise

Warming oceans and melting sea ice are both effects of a changing climate, and are the leading causes of the local and global rise in sea level. The volume of the ocean is increasing as a result of an increase in the amount of water mass in the oceans (from melting sea ice), and the thermal expansion of ocean water as its temperature increases. Changes in salinity may also have an impact on sea level, but there is not much proof to confirm this (Littlefield et al. 2019). Projections show that sea-level will continue to rise in more than 95% of the ocean area in the coming decades (IPCC 2014). Small islands and other low-lying coastal regions are expected to be the most affected by sea-level rise. The changes in availability of light, amount of salinity, and temperature could impact ocean species as well as the ecosystem services they provide. Oyster reefs, coral reefs, mangrove forests, and freshwater marshes could all be impacted negatively by rising sea levels. The estimated economic losses due to sea-level rise is high, approximately 5% of global gross domestic product is expected to be lost due to flooding (Bellard et al. 2019). It is also important to note that climate change risks, including sea-level rise, are unevenly distributed and are generally greater for disadvantaged and low-income communities (IPCC 2014). Studies show that the amount of flooded land area due to sea-level rise will displace 0.2 to 4.6 % of global population by 2100. Average global flood losses could reach $52 billion in US dollars by 2050 and impact 136 of the world’s largest coastal cities (Littlefield et al. 2019).

Storm Frequency and Flooding

Climate change is bringing more frequent and extreme weather events such as summer storms, flash flooding, and hurricanes (Enzi et al. 2017). The average amount of precipitation over mid-latitude land masses has increased since 1901, and extreme precipitation events over most mid-latitude land masses and wet tropical regions will likely become more intense and more frequent (IPCC 2014). Changes in extreme weather and climate events have been related to human impacts. These include an increase in sea level and an increase in the number of precipitation events in a number of regions, which can bring greater risks of flooding at a regional scale. Impacts from recent climate related extremes and their increased frequency, for example, droughts, floods, cyclones, and hurricanes, reveal significant vulnerability and exposure of ecosystems and many human systems, too.

Heat Waves and Urban Heat Island

Urban heat island is seen as one of the major climate problems of urbanization. Heat extremes are responsible for more deaths across the globe than any other weather-related event. A relevant case study would be the 1995 heat-wave in Chicago that killed over 700 people, and left thousands more suffering from heat illnesses (CDC 2009). These extremes are caused by a combination of the Urban Heat Island Effect seen in urban areas, and the increase of greenhouse gases in Earth's atmosphere (Larsen 2015).

The heat island is caused by the increase of dark surfaces such as asphalt and roofing in urban areas which have low albedo, meaning they absorb more heat energy from the sun than they reflect. Stone et al. specifies four main contributors to Urban Heat Island, "the use of dark, dense paving and building materials; the three-dimensional form of buildings, which absorb solar radiation and restrict air circulation; a reduced abundance of vegetation, which decreases shade and restricts evapotranspiration; and the addition of waste heat from the anthropogenic sources mentioned above" (Stone et al. 2014). The vegetation that would have otherwise absorbed the heat has been decreased by the amount of dark, impervious surfaces (Littlefield et al. 2019). Vegetation in the urban area would have also increased the amount of evapotranspiration (evaporation of water from plants that helps to cool the atmosphere) and shade, also decreasing the impacts of an urban heat island (Enzi et al. 2017). Lastly, there is an increase in heat though a larger amount of human activity in the area, such as driving cars and using air conditioning and heating units (Emilsson & Sang 2017). According to the IPCC Report released in 2014, the frequency of heat waves is increasing, and it is likely that human influence, such as greenhouse gas emissions, has more than doubled the occurrence of heat waves in some locations (IPCC 2014).

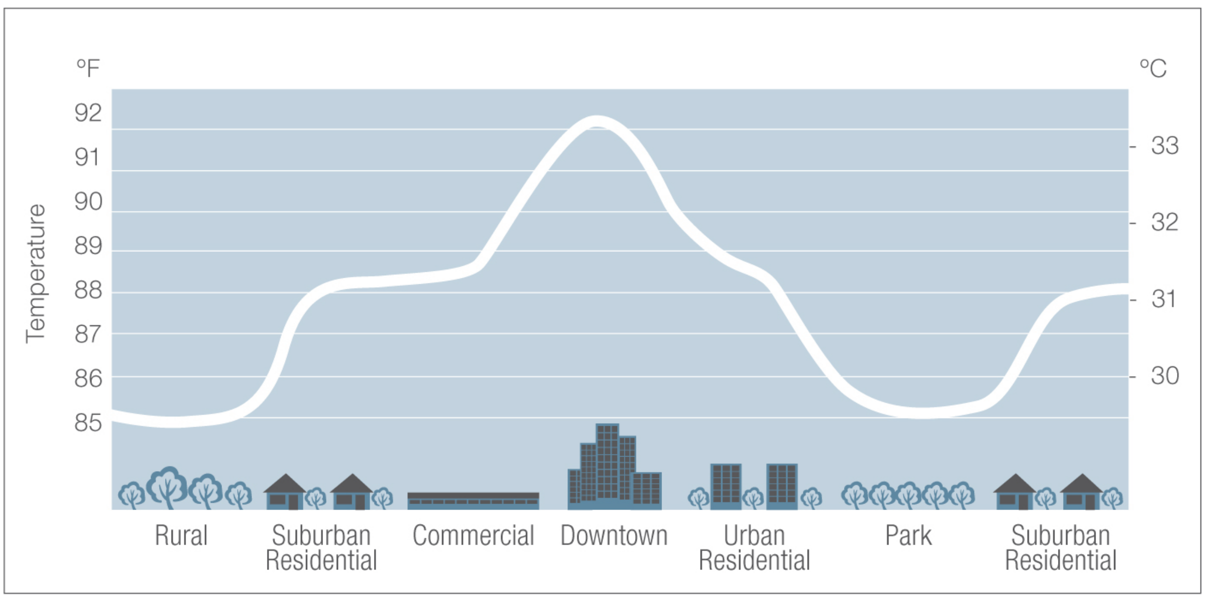

Figure 4: Urban Heat Island Effect. Source: Blue Steel Construction

Biodiversity

To put it simply, biodiversity is the "variability of life" (Xing et al. 2017). The changing climate has led scientists to believe the projected changes in temperatures, rainfall, extreme events and increases greenhouse gases, could have devastating impacts on the livelihoods of many singular species (Emilsson & Sang 2017). The list of potential impacts is long, starting with population dynamics, distribution patterns, species interactions and ecosystem services, and a change in the temporal seasons. Recent range expansion of numerous species has led to an increase in invasive species and changes in biodiversity and biogeography for many areas of the world (Essl et al. 2019). A case study that has worried scientists for years is the northward migration of tree species. A changing climate reduces the ability for certain tree species to thrive in their current habitat, so they are forced to migrate northward to more suitable habitats, with temperatures and precipitation they can withstand (Lafleur, 2010). Urban habitats have the ability to both conserve and destroy biodiversity, and using Nature-Based Solutions in urban areas increases the effort for conservation rather than destruction of these valuable and irreplaceable ecosystems.

METHODS OF ADAPTIVE PLANNING FOR A CHANGING CLIMATE

Sustainable Urban Drainage Systems

Sustainable Urban Drainage Systems (SUDS) are a nature-based solution to urban flooding. The continued compaction of soil and increase of impervious surfaces in urban areas has decreased the amount of soil infiltration and increased the amount of water runoff, which consequently increases flood risk. Sustainable Urban Drainage Systems aim to slow down and reduce the quantity of surface water runoff and reduce risk of flooding and pollution to urban water bodies. Examples of SUDS include rainwater harvesting systems, green roofs, permeable pavements, bioretention systems, trees, bioswales, basins, retention ponds, and wetlands. SUDS can improve public health by adding nature to an urban environment, create amenity values in certain areas, provide recreation opportunities, capture carbon, and support local biodiversity and ecological services. SUDS have been found to offer cost savings of between 10% - 85% compared to traditional drainage approaches (Davis & Naumann 2017).

Figure 5: Rainwater Harvesting Barrel in San Antonio, Texas. Source: Jordan Linhart

Urban Green and Blue Infrastructure

Implementation of urban green and blue infrastructure has been proven to maximize cooling efforts in a city and decrease the urban heat island effect. In order for the biggest decrease in temperature, green and blue spaces should be abundant in the city center where the majority of the heat is likely concentrated, as opposed to smaller parks and bodies of water spread throughout the city (Emilsson & Sang 2017). Other studies concluded that urban parks on average are 1.8 to 3.6 degrees Fahrenheit cooler than non-green sites during the day. Urban street trees and urban forestry also examples of urban green and blue infrastructures. Urban trees have a cooling effect at the street level, but it depends heavily on the tree species and the orientation and width of tree. Green roofs and green walls can also regulate urban temperature at the site scale, particularly impacting the microclimate of the space. The extension of the cooling effect of green space beyond its boundaries is likely but uncertain with no current data to prove otherwise, especially at the wider city and metropolitan scales (Baro and Gomez-Baggethun 2017). Implementation of urban green and blue infrastructure also offers an attractive return on investment. Adding green and blue space to an urban area can increase property values, reduce noise pollution by 1 to 10 decibels, help cut heating and cooling costs, and provide citizens with an easier connection to nature (Baro and Gomez-Baggethun 2017).

Urban Gardens

Urban gardens can promote habitat for diverse plant species, as well as ornamental and cultivated species, and can sometimes include non-native and invasive species. These urban gardens can attribute to microclimate regulation because they allow for local cooling through evapotranspiration and run off regulation as a contribution to climate adaptation goals (Cabral et al. 2017). The addition of plants and pollinating plants to an urban area can also improve air quality. Air quality can be improved through the absorption of gaseous compounds in the stomata of the plants, that act as natural filters for the air. Similarly, to other forms of green infrastructure, noise pollution can also be reduced by vegetation in urban gardens. Plants can act as a sound buffer and can reduce the amount of sound decibels heard in the city (Xing et al. 2017)

Figure 6: Urban Community Garden in Jacksonville, Florida. Source: foodtank.com

Urban Wetlands and Riparian Forests

Urban wetlands and riparian forests are very efficient spaces for water and substance regulation. They provide services such as pollutant fixation, flood water retention, water purification, carbon storage, and more. The types of environments are ideal for particularly dense urban areas as they provide a nature-based solution for two major climate change risks: flooding and drought. These ecosystems both provide the service of groundwater, inter-water, and surface water flow regulation. They also provide immense cooling aspects in an urban area (Haase 2017). Natural and constructed wetlands have been effectively used to retain surface water, recharge groundwater, and filter out pollutants. These ecosystems provide services that are typically more cost-effective than a hard-engineered solution and are more permanent with less upkeep involved (Littlefield et al. 2019)

HEALTH AND SOCIAL BENEFITS OF NATURE-BASED SOLUTIONS

Health Impacts

An abundance of health benefits has been identified with the introduction of Nature-Based Solutions into highly urbanized areas. High levels of urbanization have been shown to significantly decrease mental health in both men and women, and the introduction of green space into urban areas have been associated with increases in mental health, and reductions in obesity, headaches, dry and itchy skin, and increases in pain tolerance (Xing et al. 2017, Braubach et al. 2017, Enzi et al. 2017). Green spaces and Nature-Based Solutions enhance opportunities for physical activity and reduce exposure to noise and air pollution, and excessive heat. This increase in physical activity leads to decreases in cardiovascular disease, obesity, and diabetes. An overall increase in availability of green space is linked to a reduction in mortality (Braubach et al. 2017). In hospitals, the availability of green space, and access to "horticulture therapy" reduced stress, depression, and anxiety in the patients involved (Lafortezza et al. 2018).

Unfortunately, an associated increase with green spaces, including trees, flowering plants, and grasses also means an associated increase in exposure to allergens, infections transmitted through insects (e.g., malaria, Zika virus, and Lyme disease), and chances of risk and injury in the spaces (Eisenman, T. S. 2019). These risks can be mitigated and eliminated to some degree through proper planning techniques, design, maintenance and operation of the green space. Lafortezza et al. suggest that heightened exposure to natural microbes can enhance immune system functioning, and studies have demonstrated that increased biodiversity in the environment around cities and homes are linked with a decrease in allergy in many people (Lafortezza et al. 2018). Increases in nature and increases in health across the board go hand in hand.

Social Impacts

Along with health benefits, there have been a multitude of social benefits associated with and increased in Nature-Based Solutions and green space. Lafortezza et al. describes how green spaces and Nature-Based Solutions can be used as a place-making tool for a community (Lafortezza et al. 2018). These spaces bring together residents, and increase social cohesion and feelings of pride for their environment. Local parks, green belts, and watering holes in neighborhoods have been known to bolster feelings of pride in residents (Xing et al. 2017). Social isolation is a predictor of morbidity and mortality and green space can play an important role in socialization, and promote a sense of community (Braubach et al. 2017). Greener cities are known to give residents feelings of a better quality of life, leading to healthier happier citizens, with high productivity at work and a reduction in absence from work (Enzi et al. 2017). A greater enjoyment and pride of green spaces and Nature-Based Solutions will likely increase job opportunities and investment in certain sectors. The term “green collar labor” describes those workers impacted by the rise in Nature-Based Solutions. Growth in the number of workers specializing in plant nurseries, environmental restoration, and management and conservation would be a consequence of increasing Nature-Based Solutions (Xing et al. 2017).

Equity Impacts

Green space and Nature-Based Solutions are not equally accessible to all population groups. Specifically, people of color and low-income populations have less accessibility to these spaces (Braubach et al. 2017). The availability of good quality green space across all social gradients is considered essential to tackle public health inequalities, and to create an environment focused on equity. An example of this is seen in Phoenix, Arizona, where the tree canopy cover is often concentrated in wealthier neighborhoods (Depietri & McPhearson 2017).

There is accumulating evidence from many studies that urban green spaces may be "equigenic," meaning that the health benefits linked with the access to green space may be strongest among the disadvantaged groups (Braubach et al. 2017). Uneven distribution of and access to urban and green spaces have been related to a number of interlinked factors including: historic land use development, park management and design, and political boundaries of the time (Braubach et al. 2017). City planning departments are now using threshold values that look to benefit all populations of people, and new plans for green spaces are subjected to an equity lens before implementation (Kabisch & Bosch 2017). Other vulnerable populations to unequal treatment are the elderly and children, who are restrained in their capacity to behavioral adaptation as well as transportation needs and must also be considered from an equity lens (Kabisch & Bosch 2017). Studies show increasing social and equity benefits from community gardens as well. The resulting social cohesion and the sharing of common values, goals, and aims are further enhanced in lower income and minority communities (Cabral et al. 2017). Without considering where and how green spaces and Nature-Based Solutions are implemented, they could lead to more, or heighten the already existing inequalities of urban spaces (Depietri & McPhearson 2017)

NATURE-BASED SOLUTIONS FOR URBAN AREAS – CASE STUDIES

STATEN ISLAND BLUEBELT

Staten Island is a borough of New York City located in the southwest section of the city, closest to the state of New Jersey. It is the least populated of all of the New York City boroughs and is home to one of the Best Management Practices in sustainable stormwater management at a district or neighborhood level of scope. For the last 35 years, the Staten Island Bluebelt has been an ecologically-rich and extremely cost-effective stormwater management technique, having saved the community approximately $80 million dollars as of 2003 (Ham & Klimmek 2017). After struggling for years with a major combined sewer overflow problem, the borough brought in renowned designer Ian McHarg to study the areas and make recommendations for a plan.

The resulting plan had two principle components: 1) to construct a separate sanitary sewer system, and 2) build a separate stormwater system using the existing wetlands (Ham & Klimmek 2017). The plan included extensive revegetation at or near wetlands areas to reduce the velocity and quantity of runoff, which also helped in the filtering of water as the new aquatic plants removed pollution by bioremediation. The plan was a multiscale approach that addressed watersheds, sub-watersheds, and isolated wetlands with a goal of connectivity throughout the borough.

The plan is designed to safely hold, treat and transport stormwater runoff and boost native habitats, all the while providing significant cost savings to the New York City Department of Environmental Protection (Mehrotra et al. 2010). Although the plan started with an initial focus on stormwater management, it has created many other benefits including wildlife habitat, recreational trails, wetland protection and conservation. Other proven benefits of the Bluebelt include sediment removal, discharging chemical pollutants, and filtering of water, and reduction of stream velocities resulting in less channel erosion (Mehrotra et al. 2010 and Gumb et al. 2007).

The residents of Staten Island are expecting rising sea levels and increased rainfall due to a changing climate and believe the Bluebelt can offer a "natural and effective solution" for future stormwater management (New York City Environmental Protection, 2020). The Staten Island Bluebelt is considered a Best Management Practice for stormwater, and highlights "beneficial infrastructure" through water quality monitoring and stormwater management. The Bluebelt has received six awards, including the Institute for Sustainable Infrastructure's Envision Silver Award in 2017.

Figure 7: Staten Island Bluebelt Watersheds. Source: NYC Environmental Protection

Best practices for planners suggest the buffering of urban areas from coastlines and riverbanks to reduce their exposure to flooding. Cities should begin to elevate urban structures, expand greenbelts, and begin incorporating natural buffers against natural hazards (Wagner et al. 2016). Other best practices encouraged by practitioners are buyouts, elevated structures, dune nourishment, and buried seawalls (Wagner et al. 2016, Gumb et al. 2007). Mehrotra discusses the success of the Bluebelt through the implementation of a rigid and robust maintenance program (Mehrotra et al. 2010). The maintenance program has been successful through "consideration of maintenance in design, short-term and long-term maintenance plans, as well as community education and involvement" (Mehrotra et al. 2010, Page 2).

Figure 8: Staten Island Bluebelt. Source: NYC Environmental Protection

TREE AND SHADE MASTER PLAN – PHOENIX, ARIZONA

The City of Phoenix, Arizona is known for its desert atmosphere, and incredibly hot summers. Phoenix summers have maintained an average temperature of 104 degrees Fahrenheit, making them some of the hottest in the United States (Middel et al. 2015). Shade and relief from the heat are difficult to come by as city maintained urban forest is less than 1% of the city (Middel et al. 2015). Researchers in Phoenix have also documented that these higher temperatures are correlated with lower-income neighborhoods, making heat related illness and death higher to more vulnerable populations (Stone et al. 2014). The Urban Heat Island in Phoenix causes an increase in outdoor water use, energy demand of cooling, lowers air quality, decreases thermal comfort, and increases illnesses and mortality related to heat stress (Middel et al. 2015). In order to counter these impacts, the City of Phoenix developed a Tree and Shade Master Plan, with the goal of having a tree canopy cover of 25% for the entire city by 2030 (City of Phoenix 2010).

Figure 9: Phoenix's Tree and Shade Master Plan. Source: Google

The Tree and Shade Master Plan outlines three goals: (1) educate the public on the benefits of trees; (2) increase canopy cover to 25% and protect existing trees; and (3) improve planting, maintenance, and irrigation practices (Middel et al. 2015). Trees provide various ecosystem services and socio-economic benefits, including, "air quality improvement, higher property value, reduced building energy-use, noise mitigation, reduction of storm water runoff and flooding, reduced street maintenance costs, carbon sequestration, creation of wildlife habitats, and recreational opportunities for residents" (Middle et al. 2015, Page 185). Trees can also moderate the climate through evapotranspiration, alteration of wind patterns, and surface shading, where air and surface temperatures are reduced by trees intercepting incoming solar radiation (Larsen 2015).

Models predict an increase in tree canopy cover from the current 10% to the City of Phoenix goal of 25% could result in a 3 to 4-degree Fahrenheit temperature reduction at the local scale and could offset the higher amount of warming predicted for the future (Larsen 2015). Stone et al. modelled combinations of heat management strategies involving vegetation enhancement and albedo enhancement in Phoenix, and found these techniques were estimated to offset expected heat related mortality by a range of 40 to 90% (Stone et al. 2014)

As the climate continues to change, heat extremes are predicted to increase and planners need to be ready to adapt to these changes (IPCC 2014). Implementing techniques for mitigation against higher heat in planning must start now. These techniques could be a Tree and Shade Master Plan like that of Phoenix, or using cool pavements, relying on cool roofs (roofs capable of reflecting or absorbing albedo, "green" roofs), increasing vegetation in an urban area, or reducing waste heat from cars, trucks, and air conditioning units (Larsen 2015). Using Nature-Based Design and combining the ecosystem services of urban air quality, carbon sequestration, stormwater management, and microclimate regulation into one green-infrastructure benefit has practical advantages for municipal funding and implementation. Likewise, with all green solutions, improved planting, maintenance, and irrigation practices are also necessary.

Figure 10: Citizen Tree Planting in Phoenix, Arizona. Source: Google

CARIBBEAN ISLAND OF BARBADOS

Known as a “SIDS”, or a Small Island Developing State, the Caribbean island of Barbados is just one of the islands most at risk for a changing climate, and the inevitability of sea-level rise. The inundation of low-lying lands, beach and shoreline erosion, and saltwater intrusion in coastal aquifers are most likely to occur between 2025 and the mid-21st century, leaving the island defenseless against the changing climate. The island relies almost entirely on natural resource tourism, and the potential economic loss for the Caribbean region is 2-3% of its gross domestic product annually. It is projected that a 100-year flood on the island will wipe out, or damage 70% of all coastal hotels (Mycoo 2019, Brewster 2007).

Figure 11: Coastal Erosion on Barbados. Source: Mycoo and Chadwick 2012

To manage and adapt to rising sea levels and a changing climate, the island has pushed for many “softened” forms of engineering, including ecosystem-based adaptation, integration of landscaping, beach nourishment, planned shoreline retreat, and coral reef transplantation efforts. Ecosystem-based adaptation is used to address reef damage and coastal erosion resulting from sea level rise and increasing storm surge. Reefs play a role in ecosystem-based adaptation since they serve as natural breakwaters. The coral reef transplantation project is also currently in the works because coral are an essential component of Barbados’ beaches and a major asset for sustainable tourism. The island is also promoting beach nourishment, which is restoration that “occurs by bringing sand from inland sites or adjoining beach segments, or by hydraulically pumping sand onshore from an off-shore site” (Mycoo 2019). Other forms of ecosystem-based adaptation include maintaining existing vegetation, re-vegetation where it has been lost, and coral reef replanting as strategies for long-term adaptation. Failure to adapt to a changing climate will result in coral reef damage, beach loss, and erosion of beach front tourism accommodations, all of which will impact the island of Barbados (Mycoo 2019 and IPCC 1990).

Mycoo and Chadwick point out that as necessary as it is to begin the shift towards ecosystem-based adaptation and “soft” infrastructure, there are times when “hard” infrastructure is the more practical and less costly choice. These “hard” infrastructure approaches used by the Island of Barbados include seawalls, revetments, groynes, and a breakwater (Mycoo and Chadwick 2012).

When planning for coastal communities and the impacts they will face due to climate change and sea-level rise, risk assessment is key. The identification and quantification of coastal hazards and climate change impacts are integral for planners to assess coastal vulnerability (Mycoo and Chadwick 2012). Much like the other case studies provided, strategic management is also important. A successful plan must be constantly managed to establish sustainable coastal and shoreline adaptation (Brewster 2007). The management of these shorelines and coasts can be monitored thorough the continual creation of hazard and risk maps, and by continually education the public, as well as tourism managers and politicians.

Figure 12: Coral Restoration off the coast of Barbados. Source: National Geographic

CONCLUSION AND POLICY RECOMMENDATIONS

CONCLUSION

The need for nature and green spaces in our daily lives is apparent now more than ever. I am writing this Professional Report in the midst of a global health emergency, the COVID-19 Crisis, in which many of us are in “stay-at-home” orders and our only escape is to the parks and green spaces outside of our homes. The changing climate is impacting the planet in numerous ways, sea-level rise, increased air and noise pollution, biodiversity loss, more frequent storms and flooding, and an increase in heat waves and the Urban Heat Island to name a few. To adapt to these changes, we must develop and implement sustainable, resilient policies and structures. Grey infrastructure is no longer the answer to a changing climate, and Nature-Based Solutions should be considered as an alternative. Nature-Based Solutions are our next line of defense against the impacts of a changing climate, and implementing these solutions can combat climate change, increase public health, and conserve biodiversity for the planet.

POLICY RECOMMENDATIONS

- ***Increasing public awareness***: According to Maibach, the awareness of Nature-Based Solutions, what they are, what they do, and what they provide, needs to be more publicly known. All of the decision makers should be highlighted throughout the implementation process, the community leaders, national leaders, business leaders, individuals and families. Participatory action is key, and is advocated as “co-design, co-creation, and co-management” (Pauleit et al. 2017). Scientists are trained to share what they know, but the bulk of their messages are primarily to colleagues in a similar profession, and not to the general public. Maibach suggests simplifying messages to increase message reception, message repetition, and highlighting and identifying trusted messengers (Maibach 2019). Simplifying messaging is a way to mitigate the risk of confusing those who need to receive the messages most. Messages must be simplified so that all who are intended to receive them, can understand them, and act upon them. To make sure a message is simplified, Maibach suggests using test groups and assessing whether all of the group understands what they are receiving and what is being asked of them. Message repetition is another way to increase the public's awareness of Nature-Based Solutions. Repetition of messages "increases message persuasiveness cognitively and affectivity" (Maibach 2019). Lastly, is the importance of trusted messengers. To deliver a message, those delivering the message need to be someone or a group of people that are widely trusted and accredited in the community. To successfully deliver a message, it is important there are multiple trusted sources involved on the same platform. A simplified way of delivering these messages is proposed by Ham & Klimmek, by way of sharing environmental best practices via an online platform. This method of delivery can help to promote investments in natural infrastructure, and provide the basis for developing similar initiatives (Ham & Klimmek 2017). Kabisch et al. suggests the demonstration and sharing of information, minimization of compartmentalization, and the fostering of participatory processes will promote agents of change in favor of Nature-Based Solutions (Kabisch et al. 2017).

- ***Adaptation mainstreaming***: Adaptation mainstreaming refers to "the inclusion of adaptation considerations into all sector policy and practice in order to reduce climate risk" (Wamsler et al. 2017). Its two principle origins are risk reduction and environmental policy integration. Adaptation mainstreaming builds on the past frameworks that have been developed for mainstreaming climate adaptation, environmental policy, disaster risk reduction, and other domains of similar interests. In order to support adaptation mainstreaming, there is a need for more manuals, guidelines, and frameworks for the implementation of the Nature-Based Solutions. Examples of these frameworks can be seen in the Netherlands and the United Kingdom. In the United States, the 'living shorelines' projects on the East Coast is an example of a large-scale nature-based solution implementation (Pontee et al. 2016). Wamsler proposes four approaches to support adaptation mainstreaming, 1) reduce hazard exposure, 2) reduce vulnerability, 3) prepare an effective response, and 4) prepare an effective recovery (Wamsler et al. 2017).

- ***Partnership opportunities***: The successful implementation of any project begins and ends with the right partnerships. In order to foster the uptake in Nature-Based Solutions, there is a dire need to forge new networks and to develop trans-disciplinary, inclusive partnerships and governance approaches. These partnerships must include a diverse range of stakeholders, from local communities and indigenous peoples, to policy-makers, scientists, non-governmental organizations, governments, and businesses to address all issues of implementation. Ham & Klimmek describe these partnership opportunities as fostering "holistic approaches to managing natural capital" (Ham & Klimmek 2017). A prime partnership opportunity is with the private sector. In 2014, the private sector was the largest source of climate finance, devoting approximately $243 billion to climate related investments. Citizens also act as a key partnership opportunity. Citizens have the ability to support sustainable development, and are promoted by governments because they are seen as more democratic and effective. There are multiple examples from around the world of citizens restoring the landscape's ecological function and enhancing well-being. This has been done through community gardens, building nature friendly spaces, or restoring rivers and creeks. A prime example of citizen involvement is in Austin, Texas, with the Save Our Springs (SOS) Alliance, which led the effort to conserve lands that drained to the Edwards Aquifer and Barton Springs network.

- ***Financing and governance***: Financing for Nature-Based Solutions could come from multiple sources, including municipal tax revenues, fee for municipal services, or fiscal transfers from other government levels. For best results, a benefit cost analysis should be done for each proposed project, and the creation of cross-disciplinary and cross-departmental planning and decision-making teams could lead to better performance and higher chance of implementation (Droste et al. 2017). Three market-based instruments able to assist the implementation of Nature-Based Solutions are price instruments, quantity instruments, and fiscal instruments. Crucial to governmental aspects are urban development plans and zoning approaches. These are essential tools for policy, urban decision-making, and the incorporation of Nature-Based Solutions into implementable plans. For planning, it is recommended that plans create long-term stability, provide monitoring and evaluation, guidelines, quality criteria, and frameworks, while also considering social and environmental trade-offs. To strengthen business opportunities for Nature-Based Solutions, lessons learned from previous practices should be promoted, as well as incentivizing new investments in Nature-Based Solutions, and decrease investor uncertainty. Droste et al. recommends, 1) a reorganization of the decision-making structure within municipalities to free up funds to finance Nature-

Based Solutions, 2) organizing alliances and public-private partnerships with an interest in green and sustainable building, and 3) integrating ecological indicators in municipal fiscal transfer systems (Droste et al. 2017). Governance must also adapt to new challenges by using flexible approaches. This suggests bringing together new networks of society, nature-based solution ambassadors and practitioners to consider social cohesion and socio-environmental factors when implementing Nature-Based Solutions. The more inclusion of integrative and transdisciplinary participation, the better (Kabisch et al. 2016).

FUTURE RESEARCH

- ***Provide stronger evidence and assess effectiveness***: Future research in Nature-Based Solutions needs to provide stronger evidence that Nature-Based Solutions are a successful way to adapt and mitigate against a changing climate. More study needs to be done across the transdisciplinary fields of ecology, architecture, urban planning, and public health (Kabisch et al. 2016). Other areas of research include the relationship between Nature-Based Solutions and society, successful design of Nature-Based Solutions, and implementation aspects of Nature-Based Solutions. Lafortezza proposes more use of remote sensed imagery to understand and assess Nature-Based Solutions, and how they could enable vulnerable communities to better adapt to water, food and energy shortages resulting from a changing climate (Lafortezza et al. 2018). Other topics imbedded in Nature-Based Solutions that need additional research include the effectiveness of Nature-Based Solutions at different scales, the impacts of urban soil management, evaluation of hybrid infrastructure approaches, and identification of social and environmental synergies and trade-offs within Nature-Based Solutions (Kabisch et al. 2017).

- ***Address barriers and gaps in knowledge****:* Barriers of Nature-Based Solutions include fear of the unknown, the disconnect between long- and short-term actions and goals, and the paradigm of growth (Kabisch et al. 2017). There are knowledge gaps in long-term feasibility and benefits of Nature-Based Solutions, as well as a lack of systematic mainstreaming (Wamsler et al. 2017). Fragmented climate policy across the world, and a focus on municipal self-reliance and governing, political resistance, and dominant interests are obstacles in the way of nature-based solution implementation (Wamsler et al. 2017, Droste et al. 2017).

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