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Sustainable Hazard Mitigation: Exploring the Importance of Green Infrastructure in Building Disaster Resilient Communities

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Abstract

Natural disasters continue to plague the United States, undermining the nation's ability to build disaster resilient communities. Although structural and non-structural mitigation measures are currently in place to lessen the impact natural disasters have on society, little attention has been given to the construction of green infrastructure as a sustainable hazard mitigation strategy. The purpose of this article is to explore the benefits of green infrastructure as a sustainable hazard mitigation strategy and offer recommendations to public sector entities to build disaster resilient communities.

Keywords: Natural Disaster, Green Infrastructure, Sustainable Hazard Mitigation

Introduction

Natural disasters pose significant threats to the physical, social, and economic wellbeing of communities on a national and international scale. This was evidenced when Hurricane Katrina in August of 2005 killed over 2,000 individuals, destroyed or damaged nearly 300,000 homes, and caused roughly $96 billion in damages (Townsend, 2006). Likewise, Hurricane Sandy in October of 2012 wreaked havoc along the East Coast killing 147 individuals and damaging or destroying over 650,000 homes (Sullivan & Uccellini, 2013). At the international level, the earthquake turned tsunami in December of 2004 affected a combination of thirteen Asian and African countries and resulted in over 200,000 deaths (Kathiresan & Rajendran, 2005). In light of the devastation caused by these events and others, there is a need for communities to adopt sustainable hazard mitigation measures to build disaster resilient communities.

Sustainable hazard mitigation is “a concept that links the wise management of natural resources with local economic and social resiliency" (Mileti & Gailus, 2005). Examples of sustainable hazard mitigation measures include the construction of green infrastructure such as green streets, bioswales, and wetlands (Environmental Protection Agency (EPA), 2015). Green infrastructure is a viable hazard mitigation strategy as it helps to manage storm water, reduces flooding risks, and improves water quality (Jaffe et al., 2010). Although local, state, and federal governments across the United States are slowly recognizing the importance of investing in such sustainable hazard mitigation measures (Burby, Deyle, Godschalk, & Olshansky, 2000), additional scholarship is needed to address how communities can mitigate the effects of natural disasters by investing in green infrastructure.

The purpose of this article is to explore how the construction and protection of green infrastructure can serve as a sustainable hazard mitigation measure. The article commences with a discussion of the root problem that causes much of the disaster losses as well as a discussion of current mitigation strategies. Next, the author discusses the concept of green infrastructure as a sustainable hazard mitigation approach. Then, the article focuses on building disaster resilient communities and the current funding for mitigation in the United States. Finally, the article concludes with a set of recommendations for public sector entities.

The Root Problem

Natural disasters continue to devastate communities year after year. In fact, from 1980 to 2014, the United States experienced 3,400 disaster events, which resulted in roughly 20,600 deaths and $1,300,000,000,000 in total losses (Munich RE, 2015). A majority of these losses are a direct result of the interaction of three major systems: the physical environment, the built environment, and the human environment (Mileti & Peek, 2001). The physical environment consists of the natural elements such as water, wind, and earth and their corresponding hazardous event (e.g., hurricane, flood, tornado and earthquake). The built environment includes transportation networks as well as buildings and essential utilities (Handy, Boarnet, Ewing, & Killinhsworth, 2002). Finally, the human environment refers to the way individuals live within society including social demographics and cultural norms (Mileti & Gailus, 2005). These interactions together have resulted in lives lost, homes and businesses destroyed, and economies shattered.

These three systems are not static, but are constantly changing every year. First, the physical environment has seen a shift towards the potential cascading effects climate change may have on the frequency and magnitude of natural disasters (Mileti & Gailus, 2005). The built environment continues to expand and the protection of critical infrastructures (e.g., water and wastewater management, commercial facilities sector, nuclear plants, etc.) becomes an even greater challenge. For example, as a result of the tsunami that devastated much of Japan in 2011, a nuclear meltdown occurred at the Fukushima Nuclear Power Plant, causing the largest nuclear disaster since Chernobyl in 1986 (Haddow, Bullock, & Coppola, 2013). Lastly, the human environment continues to subject itself to the effects of natural disasters by living in hazardous areas such as along earthquake fault lines or on the coastline. According to the National Oceanic and Atmospheric Association (NOAA) (2013) in 2010, 39% of the US population resided in a coastal county and projections show the percentage to increase with each coming year. In addition, scholars have found that the lower an individual's socioeconomic status is the more vulnerable they are to the effects of natural disasters due to a lack of financial resources to mitigate and prepare for such events (Cutter & Finch, 2008).

Current Mitigation Strategies

Mitigation measures are classified dichotomously as structural, whereby engineering methods are employed, and nonstructural, whereby administrative methods are employed (Brody, Khang, & Bernhardt, 2010). Structural mitigation commonly refers to modifications of the built environment by using engineering designs to limit damages such as constructing dams, levees, and seawalls (Brody, Kang, & Bernhardt, 2010). Historically, structural mitigation measures have dominated communities throughout the United States to lessen the impact disasters have on people and property (Godschalk, 2003). The investment in such practices has not only limited physical losses, but also economic losses. The US Army Corps of Engineers (2006), found that while flood damages from 1991 to 2001 totaled nearly $45 billion dollars, the structural mitigation measures in place saved over $200 billion dollars in losses. However, scholars have expressed the limitations of implementing structural mitigation measures. First, the forces of the physical environment can exceed the design capacity of the structural mitigation measure causing more damage to occur than if no measure was in place at all (Larson & Pasencia, 2001). This is evident in the analysis of Hurricane Katrina where much of the City of New Orleans was destroyed when the levees did not hold due to poor maintenance and major design failures (Brody, Kang, & Bernhardt, 2010). Second, structural mitigation measures can lead to a false sense of security (Burby & Dalton, 1994). In fact, an estimated 20% of the city of New Orleans did not evacuate for Hurricane Katrina in part because of their reliance upon the levees as the primary flood protection measure (Brinkley, 2006; Montz & Tobin, 2008). Finally, structural mitigation measures can create adverse environmental impacts such as decreases in wildlife habitats and water quality (Birkland et al., 2003).

On the other hand, non-structural mitigation measures are in place, which focus on the physical and human environment. Examples of non-structural mitigation measures include land use regulations, revitalizing wetlands, public education, and insurance programs. The most widely implemented non-structural mitigation measure is the National Flood Insurance Program. (Brody, Khang, & Bernhardt, 2010). Established in 1968, the National Flood Insurance Program provides insurance to property owners living in flood hazard areas so long as the local jurisdiction continues to enact and enforce flood protection measures (Brody, Khang, & Bernhardt, 2010). The implementation of non-structural mitigation strategies are often more sustainable than engineering designs, using avoidance strategies to deviate from the development in hazard-prone areas. Even though both structural and non-structural mitigation measures have proven to be effective in reducing disaster losses, additional attention is needed to the investment of more sustainable hazard mitigation measures.

Green Infrastructure

Green infrastructure refers to the "interconnected network of green space that conserves natural ecosystems values and functions and provides associated benefits to human populations" (Benedict & McMahon, 2012). The adoption of green infrastructure strategies have been employed to address the risk of water hazards such as flooding, hurricanes, tsunamis and can take a number of forms, such as the construction of wetlands, green roofs, and buffer zones (see Table 1). Due to the multi-disciplinary approach of disaster management, scholars from a wide variety of disciplines such as climatology, meteorology, engineering, emergency management, and others have attempted to understand the effect green infrastructure has on the physical, built, and human environment (Mileti & Peek, 2001).

Scholars have studied the impact of green infrastructure on reducing flood and storm waters and sewer overflows. Kloss (2008) argues that the implementation of green infrastructure measures to manage storm waters reaps notable economic and environmental benefits. This is because green infrastructure uses vegetation, soil, and other natural resources to improve air quality reduce urban temperatures, and save on energy costs. Similarly, Rajan et al. (2011) explored the benefits of green infrastructure to manage storm water in the City of Philadelphia. The results of this study indicated a significant reduction of storm water volume could be achieved through the adoption of various green infrastructure measures. Jawdy, Reese, and Parker (2010) studied the effectiveness of green infrastructure and more specifically the use of bioretention cells, pervious pavements, green roofs, and tree planters to reduce the runoff volume of sewer systems in Nashville, Tennessee. The results suggest that green infrastructure measures significantly reduced the runoff volume of sewer systems. Finally, Guo and Correa (2013) conducted a study on behalf of the United States Department of Homeland Security and found that adopting green infrastructure as a flood mitigation strategy can save approximately $6.1 million dollars annually in flood-prone areas. Based on these studies, public sector organizations should further invest in green infrastructure to build disaster resilient communities.

Table 1. Examples of Green Infrastructure

Green Infrastructure	Description	Benefits
Green Roofs	Roofs of buildings that are covered with vegetation and soil.	Reduces runoff by absorbing rainwater
Bioswales	Vegetated conduits that are an alternative to conventional storm water sewers by absorbing and redirecting storm water.	Reduces storm water runoff and enhances local water quality.
Rain Gardens	Vegetated areas that collect and absorb storm water runoff from buildings and sidewalks.	Reduces storm water runoff and irrigation demands.
Green Streets	Streets and alleys that are designed with natural resources to store, infiltrate, and move storm water.	Reduces storm water runoff by creating a network of connected streets to improve drainage.
Buffer Zones	Protected area of land that runs adjacent to waterway.	Reduces storms water runoff and restricts development in hazardous areas.
Pervious Pavement	Paved surfaces that infiltrate, treat, and store rainwater.	Reduces impervious areas and storm water runoff.
Wetlands	A land area that is filled with water either permanently or seasonally.	Trap floodwaters and reduce flooding.

* Source: (EPA, 2015)

The costs incurred from implementing green infrastructure can be divided into direct financial costs and opportunity costs. The financial costs of implementing green infrastructure projects can vary depending on the size and scope of the project as well as the resources necessary to complete the project. And opportunity costs refer to the potential monetary loss from deciding to implement green infrastructure rather than adopting more common mitigation measures such as dams and levees. However, despite these costs, the adoption of green infrastructure measures can reap environmental, social, and economic benefits (EPA, 2013). Environmentally, green infrastructure improves air quality, reduces carbon emissions, intercepts stormwater, and saves energy (Benedict & McMahon, 2010). Socially, green infrastructure can also serve as recreational amenities and improve aesthetics. Economically, green infrastructure can reduce construction costs incurred from implementing structural mitigation techniques as well as increase property values (EPA, 2013). In sum, adopting green infrastructure as a sustainable hazard mitigation strategy can have a lasting and positive economic and environmental impact.

Building Disaster Resilient Communities

Researchers and policymakers have widely used the concept of resilience to describe the way society reduces the threats posed by natural, man-made, and technological hazards (Haigh & Amaratunga, 2010). Much of the ecological literature focuses on the physical environment and defines resilience as "the amount of disturbance an ecosystem can withstand without changing self-organized processes and structures" (Haigh & Amaratunga, 2010). However, the engineering sciences view disaster resilience quite differently and perceive the concept as the ability of buildings and critical infrastructure to withstand the shock of a disaster (Cutter, Burton, & Emrich, 2010). For example, Bruneau et al. (2003) defines resilience with an emphasis on the robustness and redundancy of the built environment. In other words, infrastructures are deemed resilient if they are able to withstand a great shock without suffering significant damage and if the infrastructure has substitutable components ensuring operability. Finally, the application of resilience in emergency and disaster management discourse emphasizes the human environment's role and suggests the concept is the ability for a community to withstand the shock of the disaster and "bounce back" from adversity (Mileti, 1999). Despite the variations in terminology, building disaster resilient communities requires the coordination, collaboration, and financial support of various government entities.

The United States federal government has become increasingly interested in investing in the construction of disaster resilient communities (Cutter, Burton, & Emrich, 2010). The Flood Mitigation Assistance Program, for instance, was created as part of the National Flood Insurance Reform Act of 1968 as a pre-disaster mitigation strategy. Specifically, the Flood Mitigation Assistance Program provides funds to state and local communities for mitigation measures that reduce or eliminate the long-term risk of flood damage (Rose et al., 2007). In addition, the Hazard Mitigation Grant Program was created in 1988 under the Stafford Act as a post-disaster mitigation strategy in which the amount of funding given to the affected community is dependent upon the amount of damages (Rose et al., 2007). This is the largest source for hazard mitigation funding and allows states to identify feasible hazard mitigation projects that are cost-effective, environmentally sound, and sustainable (FEMA, 2015). To assess the benefits of such hazard mitigation programs, Rose et al. (2007) conducted a cost-benefit analysis of FEMA-funded hazard mitigation activities. The results of this study determined that the cost-benefit analysis for flood, wind, and earthquake hazard mitigation is $3.5 billion to $14 billion, respectively. This implies that Americans greatly benefit from FEMA's continued investment in mitigation.

However, despite FEMA's large investment in the aforementioned hazard mitigation programs, little emphasis has been placed on investing in green infrastructure. It was not until President Obama placed a greater focus on climate change, preparedness, and resilience, that environmental sustainability and the investment of green infrastructure obtained a higher stance on the political agenda. However, in the summer of 2014, the EPA launched the Green Infrastructure Collaborative in conjunction with six other governmental agencies to include the Department of Transportation, Department of Housing and Urban Development, Department of Defense, Department of Interior, Department of Agriculture, and Department of Energy as well as non-governmental and private sector entities to assist communities in implementing green infrastructure (EPA, 2015). The creation of the Green Infrastructure Collaborative is a starting point for underscoring the importance of sustainable hazard mitigation measures. However, even further actions can emphasize the importance of green infrastructure in building disaster resilient communities.

Recommendations

Implementing sustainable hazard mitigation measures presents significant challenges to the public sector. First, disaster issues are not salient and building disaster resilient communities is often a low priority until a disaster strikes. For example, following the release of nuclear agents at the Three-Mile Island Nuclear Plant in Pennsylvania in 1979, President Jimmy Carter signed Executive Order 12127 creating FEMA to coordinate all federal disaster responses (Haddow, Bullock, & Coppola, 2013). Prior to the establishment of FEMA, disaster management in the United States followed an ad hoc system (Haddow, Bullock, & Coppola, 2013). In addition, it is often difficult to persuade organizations to adopt sustainable hazard mitigation measures when money has already been invested in current development. Lastly, federal funding is both unstable and unpredictable due to changes in federal budgets, which in turn effects state and local entities' ability to invest in sustainable hazard mitigation measures.

Despite these challenges, there are a variety of steps the public sector can take to implement sustainable hazard mitigation measures. First, public organizations must begin preparing and planning for recovery purposes. Recovery plans should be written and should address the potential of using green infrastructure as a sustainable hazard mitigation strategy. Also, the public sector should network with political advocates to mobilize support for disaster issues. These individuals might be elected or appointed officials, educators, business owners, and interested citizens. In addition, the public sector must use the "window of opportunity" to emphasize the importance of investing in sustainable hazard mitigation measures. Furthermore, the public sector should tie disaster issues with more salient issues such as environmental or health issues. Also, public funding should be increased for communities to invest in green infrastructure projects. Lastly, public-private partnerships are necessary to obtain additional funding and resources to invest in sustainable hazard mitigation measures. Public-private partnerships are a unique funding mechanism whereby a project or program is funded jointly by a public and private organization. Specifically, communities should utilize the EPA's Community-Based Pubic-Private Partnership (CBP3) Program as it is designed to help local communities identify and establish private partners when developing green infrastructure.

Conclusion

The purpose of this article was to explore how the construction and protection of green infrastructure can serve as a sustainable hazard mitigation strategy. Based on extant literature, it is clear there are benefits to using green infrastructure as a sustainable hazard mitigation measure, and the adoption of such measures is needed to address the dynamic nature of disasters in the twenty-first century. Although this paper focuses on the adoption of green infrastructure as a sustainable hazard mitigation measure in regions devastated by flooding, hurricanes, and other water disasters, additional studies are needed to address other modes of sustainable hazard mitigation strategies in regions largely affected by land disasters (e.g., tornados and earthquakes). The author is hopeful that adoption of sustainable hazard mitigation measures will minimize disaster losses and that disaster resilient communities will prevail.

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