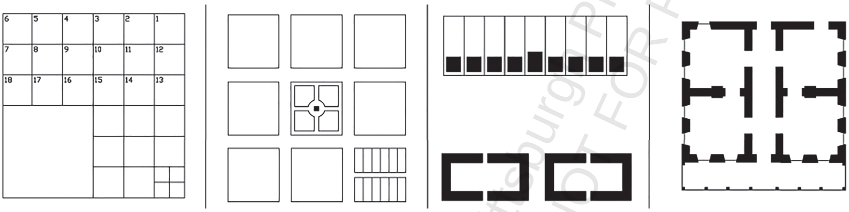
URBAN INFRASTRUCTURE

HISTORY OF
THE URBAN ENVIRONMENT

Martin V. Melosi and Joel A. Tarr, Editors



URBAN INFRASTRUCTURE

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Green Infrastructure and Climate Risk in New York City

A Historical Perspective

Yaella Depietri and Timon McPhearson

Most narratives about historic disasters provoked by natural hazards recount catastrophic impacts and emphasize the sensational aspects of the event. Think, for instance, of the volcanic eruption in Pompei (Italy) in AD 79, or of the earthquake that devastated Lisbon (Portugal) in 1755. These events are primarily remembered for the exceptional magnitude of the natural hazards and their huge impacts on well-developed societies. However, catastrophes need to be considered not just as the result of the extreme hazardous event but also as embedded in historical patterns of vulnerability and risk.[1] Urban planning decisions, the type of infrastructure developed, the environmental, economic, social, and institutional settings, and the types of responses to a certain threat have continuously evolved, leading to different historical configurations of vulnerability and risk.

Though natural hazards have occurred in all periods, it is only in the modern epoch that societies have more actively engaged in reducing risk from these events by attempting to reducing the vulnerability (i.e., the predisposition to suffer harm) and/or exposure of the system. This contrast with adopting beliefs that attribute catastrophic events and their impacts to inevitable and unavoidable acts of nature, or of witches and divinities.[2]

While in preindustrial times, societies adapted to risk mainly at the individual or at the small group level, through the modification of human behavior, with the advent of the Enlightenment, societies started to actively work to control, or even to suppress, extreme events through technological solutions and engineered works.[3] More recently, however, the long-term effectiveness and sustainability of hard infrastructure to reduce risk has been questioned, as it does not tackle long-term risk in a sustainable and robust manner. This is especially true of engineered works such as such as coastline and flood defenses. That sort of hard infrastructure tends to produce new risks due to the false sense of security it generates, for instance by encouraging inhabitants to settle in areas exposed to infrequent, but high impact, events.[4]

To oppose these trends, system designers are shifting paradigms from a technocratic approach, focused on control and optimization, to one aiming at sustainability and long-term robustness (or resilience).[5] Green infrastructure (biophysical structures, ecosystems, and their services) and hybrid infrastructure (a blend of biological-physical and engineering elements) are advanced as a substitute or as a complementary strategy to hard infrastructure to reduce climate risk and overcome some of the limitations of engineering approaches.[6] For example, in the context of flood management, paradigms have shifted from an engineering approach aimed at suppressing or diverting potentially disrupting waters to one of "living with water," involving the restoration of rivers to their natural path and seasonal rhythm.[7]

Research on ecosystem features or hybrid approaches to climatic risk reduction is rapidly expanding, although these approaches are not entirely new.[8] In this chapter, we focus on green and hybrid infrastructures (including green urban spaces) and how they have contributed to reducing the risks of hydro-meteorological hazards in New York City over the past 140 years. We look specifically at how New Yorkers have depended on green or hybrid infrastructures to cope with risk to heat waves and floods during this period. We conclude by deriving best practices for today's implementation of these approaches.

In what follows, we review relevant literature on climate risk in urban areas and the history of green infrastructures in cities. We also introduce the social-ecological-technological systems (SETS) framework that we subsequently use in our analysis. We then present our methodology and case study. Results are presented in the third section. The final sections discuss the findings and present a conclusion.

Climate Risk and Adaptation in Urban Areas

Urban areas located in a floodplain or on a coast are particularly exposed to natural hazards such as inland floods, coastal storms, and hurricanes.[9] Cities see risks mount as most urban surfaces are paved, which reduces water infiltration, increasing flood risk and causing the Urban Heat Island (UHI) effect, which in turn increases the risk from catastrophic heat waves.[10] Besides these challenges, cities have to face impacts from climate change, which is projected to increase the likelihood and intensity of extreme climate events.[11]

To protect cities from these hazards, planners have relied, at least since the second half of the twentieth century, primarily on engineering approaches or hard infrastructure.[12] However, due to the periodic failures of such systems to cope with the most intense events, the expansion of cities, climate change, and environmental degradation, many hard infrastructures need to be supplemented by less traditional approaches to improve the overall sustainability of urban SETS.[13]

Low-regret measures are measures that are flexible, reversible, and do not preclude other solutions or affect future choices or activities, including environmental processes. Green infrastructure often meets many of these criteria. Hybrid solutions (green-grey) can even be better tailored to limit climate risk in the urban context, due to the high demand in services and limited space for infrastructure implementation.[14] But what is the potential of these infrastructures in the context of urban climatic risk and what can be learned from the past? What are the limitations of green infrastructures, which may also degrade in the face of increasing environmental stress? These are some of the questions addressed in this chapter.

The Historical Perspective on Green Infrastructure in Cities

Green areas in and around cities have transitioned from being a source of provisioning services (e.g., food, timber, clean water) to one of cultural services (e.g., recreation, aesthetic enjoyment, spiritual fulfillment, sense of place) and regulating services (e.g., water regulation, air purification, cooling). This transition has mainly occurred with the advent of industrialization and urbanization. Urban and peri-urban green areas have progressively ceased to be viewed as an untapped resource (e.g., of timber or food). Instead, planners and the public increasingly see green space as a source of escape, recreation, and fresh air.[15] In the post-industrialization era, human well-being in urban areas has become further dependent on the quantity, distribution, and accessibility of green areas.

At the end of the nineteenth century in Europe, Sir Ebenezer Howard developed the idea of the Garden City with the intention of bringing the benefits of living in rural areas into the city. Sir Patrick Geddes and Lewis Mumford furthered Howard's ideas through the concept of Regional Planning. This approach stressed the importance of incorporating the assessment of environmental components, such as soil, climate, and terrain, into urban planning to improve livability and quality of life.[16] In some European countries, planners established greenbelts around cities in order to separate the city from the countryside, while

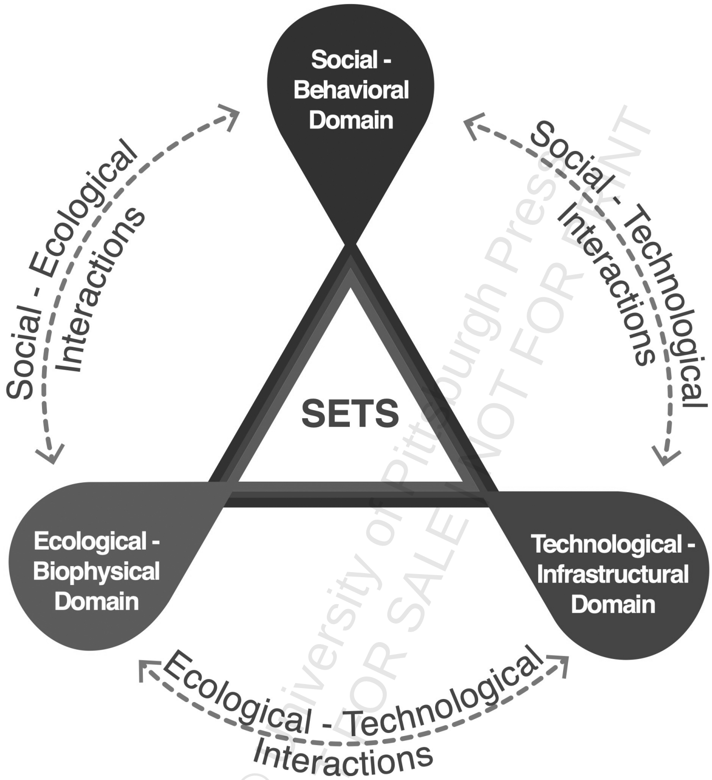

Figure 2.1: The social-ecological-technological systems (SETS) framework. Source: Yaella Depietri and Timon McPhearson (2017).

keeping its urban character.[17] These also provided a source of agricultural products and an opportunity for landscape restoration.

The additional ecological benefits of urban green spaces and greenbelts (in terms of biodiversity conservation and as a source of cultural and recreational services) were fully recognized with the rise of the global environmental movement in the 1970s.[18] By the 1980s and 1990s, the growth of the environmental agenda and its rejection of the industrial ethos led planners to revisit and update the Garden City.[19] Despite the many benefits brought by this planning model, some critics argued that the application of the Garden City without sufficient land use controls led to suburban sprawl, which caused the urbanization of vast tracts of land that could instead have been preserved as a greener resource.[20]

Green urban spaces and areas (which are integral part of the network of green infrastructure in cities) have thus changed value and function because of the evolving needs and demands of urban dwellers and the emergence of different urban planning paradigms.[21] This brief historical overview also suggests that green urbanists and planners have historically neglected the potential for urban and peri-urban green areas to reduce risk from natural hazards, prioritizing other types of benefits.

The Need for Systems Approaches: The SETS Framework

In tackling urban climatic risk from an infrastructure perspective, the ecological and technological components, as well as the social components of urban systems at risk, often need to be discussed together.[22] In our analysis, we adopt the SETS framework depicted in figure 2.1 for this purpose.[23] The SETS approach aims to overcome the limitations of a purely socio-technological approach, which excludes the system's ecological components, or of a purely socio-ecological approach, inclined to overlook the critical role of technological constituents of urban systems.[24] The SETS framework is applied here to analyze more comprehensively changes in infrastructure and their interplay with climate risk in the important case of New York City over the past 140 years.

Case Study Description: New York City

New York is the most populous city in the United States, with 8.4 million people in 2020 according to US Census Bureau, and the largest in terms of economic activity. The metropolitan area was home to more than 20.1 million inhabitants in 2020 (also according to the US Census Bureau), making the urban area one of the few megacities of the developed world.

The city is still ecologically rich, with 110 km^2 of city parkland, of which approximately 40 percent reflects the pristine vegetation of the area, including some freshwater wetlands, salt marshes, rocky shorelines, beaches, meadows, and forests.[25] Urban forestry research has estimated the city to have 5.2 million trees covering 44,509 acres and that canopy from tall trees covers 24 percent of the city land. The number of trees fluctuates, with losses occurring during storms or other causes of death and increases through replanting. The Million Trees NYC initiative, for instance, planted one million trees in the city in the last decade.[26]

The city has continuously been at risk from climatic hazards. Heat waves represent the largest cause of death due to natural hazards in the city, while hurricanes and coastal storms are responsible for most of the hazard-related economic losses.[27] Inland flooding is the most frequent natural hazard in NYC, but historically such floods have caused the least human and economic loss. That may be changing, as a large inland flooding event that occurred on September 1, 2021, left thirteen people dead and economic losses in the order of a billion dollars, suggesting that such events could become more of a problem in the future.[28]

A large fraction of New York City's infrastructure systems (for energy, transportation, water supply, wastewater treatment, and for communication) lies within three meters above mean sea level, exposing it to increasingly severe coastal storms and sea level rise.[29] New York's infrastructure is also aging, reducing its adaptability to increasingly frequent floods.[30]

According to the New York City Emergency Management (NYCEM) agency, the Department of City Planning, and the Mayor's Office of Recovery and Resiliency, land flooding can best be remediated by improving drainage systems, employing green infrastructure, providing floodwater storage, managing surface water run-off, or increasing land and street elevation.[31] To manage risk from heat waves, the city government has developed a system of cooling centers available to residents, combined with education, alerts, and outreach to people without access to air conditioning at home. The city and private utilities have also taken steps to reduce strains on the energy system in periods of extreme heat.

Methodology

We took meteorological data from the National Oceanic and Atmospheric Administration (NOAA), recorded at the station of Central Park (40.7889°–73.9669°), located at 39.6 meters of altitude, between January 1, 1876, and May 28, 2016. This allowed us to focus on extreme heat and extreme precipitation events in our effort to explore climate related hazards trends in New York City.[32] To identify extreme heat wave events, we adopted the definition of the New York City Panel on Climate Change (NPCC), which describes such events as occurring over three consecutive days with maximum temperatures at or above 90°F (about 32.2 °C). For floods we adopted a precipitation threshold of 1.75 inches (4.4 cm) of rain per hour, which can cause flooding in locations of the city where sewers were built after 1960.[33] Based on these criteria, we identified an initial set of extreme heat and precipitation events. Then we created a second set, including only the top extreme events (i.e., heat waves which lasted six or more days—thirty-seven events in total—and extreme precipitation events above 3.5 inches of rain, or about 8.9 cm —fifty-one events in total). We used this subset of events to search accounts in *New York Times* (NYT) articles published one day following the date of the onset of the event and two days after its end date. In this way, we collected information about the impacts of the extreme events on the SETS and, when possible, coping strategies implemented by the city or its population during and after each event. Further, in the case of inland flooding, information related to the impacts of the extreme event on the green infrastructure itself was collected, as this can further exacerbate overall losses on the SETS.

A similar methodology, based on meteorological and newspaper data, was applied by Barriendos and Rodrigo.[34] Indeed, social scientists and historians have long relied on newspapers as a source of historical data.[35] However, there are some issues regarding the validity of these data. Newspapers might differ widely in their reporting practices, news coverage, and potential bias.[36] In our case, it is important to acknowledge that the NYT's reporting can present biases, as was documented in the case of adherence to the norm of balance in the context of global warming early in the twenty-first century, or in the coverage of conflicts, gender in sports reporting, or politics generally speaking.[37] During the eighteenth and nineteenth centuries, newspapers were often associated with political parties. The NYT was founded in 1851 by Henry Jarvis Raymond, who greatly contributed to the formation of the Republican Party. It was financed by Edwin B. and Christopher Morgan, also from the Republican (earlier the Whig) Party. Later, in the 1880s, the paper transitioned to more independent, less ideological journalism, although it was particularly tailored to attract a specific type of audience, namely the liberals or "well to do."[38]

Despite this, among the studies using a single source of newspaper data, the NYT is the most frequently used in the case of documenting conflict situations and specifically for events occurring in NYC.[39] In addition, despite potentially carrying information targeting a specific audience, the type of target audience has varied during the period considered, while the journal represents a continuous source of information for the entirety of this period.

Results

Heat Stress and Green Infrastructure in NYC over the Past 140 Years

Coping Strategies

During approximately the first 90 of the 140 years considered in this study, New Yorkers most commonly coped with extreme heat through travel to urban parks, beaches, and the countryside, as well as through the distribution of ice by the police. During the June 1876 heat wave, the NYT reported huge throngs in the city green areas, such as Central Park, where it was reportedly difficult to move due to the crowding.[40] The resorts and beaches outside the city were packed and the concentration of people jammed traffic in and out of the city. During the June 1880 heat wave, tens of thousands of New Yorkers would swim, enjoy the breeze, and escape the heat in Coney Island, Brighton Beach, the Rockaways, and other seaside resorts.[41]

At the end of the nineteenth century, complementary coping strategies were commonly adopted. August 4, 1896, saw the onset of a heat wave that lasted nine days, with maximum temperatures beyond 90° F, as measured in Central Park.

Total deaths amounted to 651 and 1258 cases of heat prostration were recorded. During this event, ice was distributed for free by the police to poorer communities. There were distribution points where mostly children were applying for ice.[42]

At the beginning of the twentieth century, hundreds of poor people still camped in the streets to escape the heat, especially during the night, sleeping outside. Beaches and all exit-points of the city were packed with excursionists. With the expansion of automobile ownership in the mid-twentieth century, NYC residents who intended to flee to cooler areas (i.e., the mountains, the seaside, and Long Island) often got stuck in traffic instead. Overall, the last decades of the nineteenth and the first half of the twentieth centuries were characterized by a reliance mostly on the ecological component of the SETS (through green infrastructure) to cope with extreme heat.

During the August 1955 heat wave, a record number of people reportedly bought newly mass-produced air-conditioning units and fans.[43] Despite this, heavy traffic was still recorded on the routes to the Jersey Shore, Long Island, and the Catskills, as New Yorkers sought relief from the heat. During the July 1961 heat wave, 1.2 million people visited Coney Island and 875,000 visited the Rockaways.[44] In the 1980s, air-conditioning was installed in many but not all trains and metros. But heading to beaches, pools, parks, and zoos (in which polar bears and seals, playing in their icy and blue pools, were the most popular) was still a common practice to deal with heat stress.[45] Water pressure was regularly down due to the opening of fire hydrants, which impeded the work of firefighters. The city frequently had to declared water emergencies, banning the watering of lawns and the opening of fire hydrants. Also, in this period, while many people would go to the beach, others would opt for taking extended rides in the air-conditioned train cars while reading and eating fruits. Some would ice-skate in Midtown Manhattan (multiple ice-skating rings were indeed built around the second half of the twentieth century, such as the Wollman Rink in Midtown Manhattan or the Lasker rink in Central Park), while others would simply refrain from venturing outdoors.

Despite the shift from a quasi-exclusive reliance on the ecological component of SETS to increasingly technological solutions, Central Park and the beaches were still reported to be crowded as late as the July 1987 heat wave, although attendance was reported to be down dramatically compared to the normal crowd of a hot summer day, perhaps also because of water pollution warnings.[46]

In 1988, 60 percent of residences in the city had air-conditioning, up from 25 percent just twenty years earlier. Despite this, it was reportedly still common to see some people coping with heat by staying in parks all night. At the beginning of the 1990s, falling levels of water reservoirs and related water shortages were an issue in the city, mainly due to residents uncapping fire hydrants to seek relief from heat.[47] At that time, though, movie theaters and appliance stores saw a further remarkable increase in audience or sales as people sought relief by venturing into cool, dark cinemas or by buying fans and air-conditioners. Meanwhile, business tripled for indoor ice-skating rinks, as skaters sought refreshment during the July 1993 heat wave.[48]

The last decades of the twentieth century marked a clear transition between a reliance on the ecological component of the SETS to technological means (principally air-conditioning) to cope with heat stress. In the 1990s and in the early 2000s, the city faced increasingly frequent power outages and blackouts, denoting a fragility of the technological component of the SETS. Electricity use rose to record levels during the numerous heat waves affecting the city in this period. ConEdison (the energy company in NYC) distributed tons of dry ice for backup refrigeration in the case of blackout. The city opened cooling centers in schools and other community centers (especially encouraging the elderly to stay in them), converted fire hydrants into temporary fountains, and kept pools open longer than usual.[49] Officials discouraged other water recreation due to high pollution levels.[50]

More recently, on July 14, 2013, a heat wave occurred in New York City and lasted for seven days, with average maximum temperature of 95° F (or 35° C) and peak temperatures as high as 106° F (about 41° C). The heat caused twenty-six excess deaths. Elderly people flocked to cooling centers.[51] Residents sought refuge in libraries (such as the New York Public Library), buses, museums (such as the Metropolitan Museum of Art), or in supermarkets where, in some cases, it was so cold that the city handed out parkas.[52] This denoted a clear preference for the expanding technological component of the SETS in coping with extreme heat, characterized by the reliance on air-conditioning. However, going to downtown Manhattan or Bowling Green and taking a ferry to Staten Island were still considered to be effective strategies to cope with heat during this extreme event.[53]

Impacts of Heat on Urban Green Infrastructures

The increasing intensity and frequency of heat events also had a negative impact on the green infrastructural alternative. Green infrastructures in the urban context not only provide services to reduce climate risk but can themselves be affected by climatic hazards, in some cases further exacerbating the overall impact on the SETS.[54] Regarding impacts of heat waves on urban green infrastructures, at the end of the nineteenth century and beginning of the twentieth, dozens of horses would die during an extreme event, while hundreds needed to be treated for heat stress. As horses were prostrated by heat, ambulances (carried by horses at that time) could not be sent out and the distribution of ice and of nonalcoholic drinks was also impeded or delayed, all further exacerbating the health crises. This is an example in which the ecological component of SETS had an impact on the social component.

Furthermore, due to insufficient rainfall connected to periods of extreme heat, peri-urban fruit, vegetables, and garden production was often reduced in and around the city, not least as it was threatened by the excessive use of water by the city dwellers during periods of heat stress. In the August 1953 event, peach, apple, tomato, corn, and cabbage crops were reported to be heavily damaged in the region, causing city prices for these items to skyrocket.[55] Some small streams dried up, killing fish. Premature autumn scenes appeared, with trees turning yellow and orange and leaves falling. This impact on the ecological component of the urban SETS also likely affected its social component, diminishing the cultural, aesthetical value of green urban areas.[56] Water scarcity and air pollution increased during this critical period, as did the widespread repercussion on the social component of the SETS.

Inland Flooding and Green Infrastructure in NYC in the Past 140 Years

No information related to inland flooding and green infrastructure's role in reducing risk was available in the material analyzed. This would have required an in-depth quantitative analysis of the interactions between changes in land cover and changes on flood impacts, but this was beyond the scope of our study. We focused instead on the available qualitative information describing damages imparted by floods on local, urban green infrastructure. As mentioned, these often cause impacts on other two components of the SETS, further exacerbating climate risk, impacts, and losses.

In this respect, the most documented impacts were the fall of hundreds of trees and the damage to crops and gardens during extreme precipitation events. Direct deaths caused by uprooted and falling trees were reported during heavy rain and wind events. Transportation was often delayed by uprooted trees. This represents a clear detrimental interaction between the ecological and the technological components of the SETS during extreme precipitation events. Similarly, communication and power lines were affected by falling trees (causing power outages), especially during the twentieth century. Extreme precipitation events regularly overwhelmed the drainage system, causing overflows in streets and rivers, as well as discomfort and different types of nuisances. Fallen leaves clogged storm drains, signaling again a negative interaction between the ecological and the technological component of the SETS, which often also directly exacerbates flooding. Coastal flooding severely eroded beaches, affecting the cultural and economic value of the landscape. When horses were the main means of transportation, many horses would drown in a flood event, hampering the movement of people and goods. Also in the past, landslides interrupted railway service, mainly in the areas surrounding the city, causing difficulties for commuters. Despite this, heavy rains provided benefits too, recharging aquifers and reservoirs and cleaning streets (a positive interaction between different components of the SETS). This was a particularly welcomed benefit, especially in the age of heavy urban usage of horses, at the end of the nineteenth century and the beginning of the twentieth.

No clear trend was detectable in the data collected with respect to the interactions between green infrastructure and extreme precipitation events in New York City. However, it can be noted that some greater consequences to the disruption of the SETS occurred when falling limbs or trees hit phone, telegraph, and electric lines, interrupting power and communication. These lines are now underground in much of the city.

Discussion

In the case of heat waves, our historical analysis documented how New Yorkers have continuously interacted with, and benefited from, urban and peri-urban green areas during extreme events. For instance, New Yorkers have turned to green infrastructure to cope with heat stress by visiting cooler green areas, a strategy that dates back at least to the beginning of the period analyzed. Trees have proven to cool streets and neighborhoods effectively and are considered as an important complementary strategy to reducing heat stress and energy use in NYC.[57] However, as documented in a companion study, only with the advent and increased affordability of air-conditioning and the spread of cooling centers did the mortality and morbidity related to heat waves significantly decline in the city. This suggests that an effective coping strategy needs to rely on different components of the SETS. [58]

Obstacles to the Implementation of Green Infrastructure in Urban Areas

The design and implementation of green or hybrid infrastructure to address climate risk in a more effective and sustainable way are still in their infancy. Indeed, this approach remains mostly a discursive exercise.[59] The results of our analysis aim at contributing to this discussion and, hopefully, catalyzing the implementation of this approach, not least by pondering some expectations related to the implementation of green infrastructure to reduce climate risk in cities.

While green infrastructure is being increasingly advocated as an all-encompassing solution to reduce climate related risk, we suggest that some caution needs to be employed regarding the potentiality of the approach. The effectiveness of local green infrastructure in adequately meeting demand for services in the urban context is often quite limited.[60] Previous studies suggested that green infrastructure in cities frequently needs to be accompanied by a reduction of the threat at the source (e.g., in the case of air or water pollution).[61] In addition, it is important to take into consideration that green infrastructures are often not distributed equitably in cities, generating, or widening, disparities in inhabitants' access to greener, cooler, and less disaster-prone areas.[62]

We suggest that a comprehensive approach, which considers a variety of possible infrastructure types (including ecological as well as social and technological solutions), needs to be considered if we want to reduce climate risk effectively and sustainably in cities. It should also be considered that urban sustainability transitions are regularly constrained by previously implemented urban planning solutions or "materialized ideals of the past."[63] Paradigm shifts in the urban context, such as the adoption of an ecosystem-based approach, often fall short of the ideal, being expressed within the urban fabric only in a fragmentary way. Path-dependency in agency and in institutional processes limit or hamper their implementation.[64] Financial speculation has been a great obstacle to the preservation of green spaces in urban areas despite the known benefits of such spaces.[65] A final limitation, according to Keeler et al., is that the value of green infrastructure tends to decline if services have already been replaced by built infrastructures.[66] A way to circumvent this situation is by adding and complementing capacity to the current hard infrastructure system through green infrastructure. This also presents numerous advantages, as it is considered as cheaper (at least in the short term); is perceived to be more predictable in outcome; and is considered more congruent with common, traditional, and institutional views on how to reduce climate risk.[67] This approach has been called "incremental" or "managerial," although in some ways it can perpetuate the technocratic approach.[68]

Synergies between Different Approaches

Significant reduction in damages, losses, and infrastructure breakdown can nonetheless be obtained through technological advances coupled with more flexible green infrastructure, particularly under condition of a changing climate. In this context, and to address multiple hazards at once, synergies need to be identified during the design and implementation of different types of infrastructure.

In 2010 the city of New York committed to a plan to implement green infrastructure for stormwater management, which foresaw the investment of $5.3 billion and saving approximately $1.5 billion compared to a scenario of pipes and tanks improvements.[69] The New York City Department of Environmental Protection (NYCDEP) Green Infrastructures Program was officially launched in 2011 to enhance the distribution of green roofs, rain gardens, and bioswales on city-owned properties. One of its primary objectives was to improve the management of stormwater by directing the flow toward structures composed of vegetative elements, soil, or stones that can relieve the traditional drainage system of the city.

However, to date, there is no concrete plan in NYC to address flooding synergistically by increasing water infiltration while reducing the urban heat island through the same green approach. There is limited coordination in addressing risks originating from different hazards, which is exacerbated in the case of green infrastructure implementation in the city.[70] Trees provide cooling benefits of about 1°C for green areas in NYC.[71] Rosenzweig et al. have concluded that trees can reduce peak electricity demand in neighborhoods, significantly reducing the risk of power outages.[72] The authors found that the best strategy is to implement a mixture of green roofs and tree planting, which would lead to a reduction in air temperature of 0.4°C on average but up to 1.1°C in some areas of the city while improving water infiltration.

Some research is addressing these issues. Klein-Rosenthal et al. investigate different strategies to reduce the urban heat island in New York, with a synergistic outcome related to storm water management, particularly in the case of green roofs.[73] Hazard-specific approaches could also be overcome by adopting a multihazard approach.[74]

Positive as well as negative interactions between different components of the SETS in the context of urban climate risk are still not carefully examined. For example, is important to consider that trees can be uprooted by the hundreds during extreme winds and precipitation events, interrupting traffic and threatening life. This requires a careful choice of species to minimize damage during storms, while still taking advantage of their cooling and water-infiltration functions in the soil and related benefits.

Conclusions

In this chapter, we analyzed how New Yorkers have coped with heat waves and inland flooding over the past 140 years, including the role of green infrastructure in mitigating extreme weather events. We found that green infrastructure has historically provided significant opportunities to seek relief from heat; however, complementary approaches and technological advances (e.g., the introduction of air-conditioning in the case of heat waves) were essential to significantly reduce heat stress. These progressively became the best types of approaches to address the threat.

While the ecosystem-based (sustainable) approach is gaining momentum among policy- and decision-makers to reduce risk to natural hazards worldwide, it is important to identify the strengths as well as limitations of this approach. Ecosystem restoration clearly contributes to the reduction of climate risk in cities and helps in releasing pressure on the water and energy infrastructure, while at the same time improving the well-being of the city's inhabitants.[75] But, as our study suggests, this needs to be complemented with technological solutions to reduce risk effectively. A mix of green and engineered approaches in the urban context seems indeed necessary to tackle urban climate risk.

Our study elucidates the danger of seeing one innovation (or a revisited remedy) as a panacea, which might lead planners to exclude other approaches, often perceived as outdated. We should instead move from one paradigm to the next with caution, carefully considering all the social, ecological, and technological factors and the multiple solutions (new or old) available to tackle the problem.

Thus, while we acknowledge that green infrastructures are often the missing piece of the puzzle in dealing with climate and disaster risk, our historical analysis shows that this approach is not entirely new and has its own shortcomings. We can indeed learn from the past while measuring our expectations for the future. Publicizing green infrastructure as an all-encompassing solution can be misleading. We will instead need to merge ecological, technological, and social solutions while transitioning to a more sustainable and resilient urbanism.