THE CASE OF GREEN INFRASTRUCTURE IN NEW YORK CITY (USA): ECOLOGICAL SPONTANEITY AND INFRASTRUCTURALIZATION IN THE CONTEXT OF SETTLER COLONIALISM, CAPITALISM, AND WHITE SUPREMACY

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Introduction

Green Infrastructure (GI) remains variably defined in different national, municipal, and disciplinary contexts. Here we draw upon a recent synthesized definition, to define GI as "… a system of interconnected ecosystems, hybrid elements, and environmentally conscious technologies providing contextual social, environmental, and technological functions. As a planning concept, GI brings attention to the ways these subsystems function in relation to one another to deliver benefits to human society, ecosystems, and built infrastructures," to examine the ways in which complex ecological networks are planned for and managed in relation to built infrastructure systems (Grabowski et al. *now in press*). Such a definition retains the important elements of ecological and landscape planning utilized in a diverse array of cultural and institutional settings (Eisenman 2013), as well as the dominant framing of GI in the United States that adds 'green elements' to existing built environment systems such as buildings, transportation networks, and storm and sanitary sewer systems (Grabowski et al. *now in press*). We do so by examining GI in NYC through a social-ecological-technological systems (SETS) lens (Grabowski et al. 2017). A SETS approach allows for in depth exploration of how GI as a novel planning concept intersects with the historical and contemporary co-production of urban ecosystems by social, ecological, technological, and physical forces.

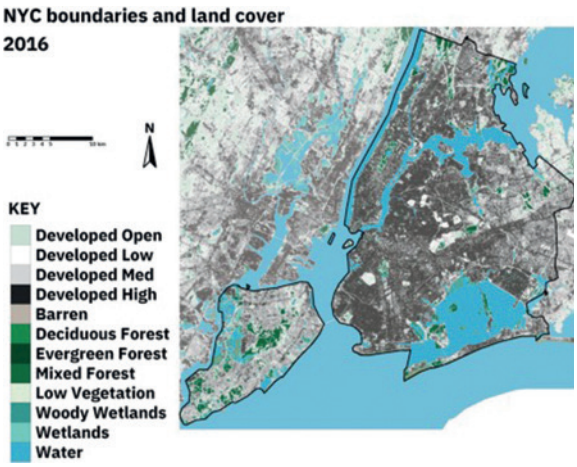
Examining GI through SETS highlights 1) the self organizing aspects of ecosystems in the past and present, including how they are connected and fragmented, 2) the role of human agency and social structures in creating social-ecological dynamics, including formal and informal management, ownership, and jurisdiction, and, 3) the restructuring of urban ecosystems and landforms in relation to built infrastructures. From this point of view, SETS provides a heuristic for understanding an otherwise irreducibly complex system, wherein each dimension is interdependent with the others. From this point of view, the relationships between each dimension provide desired ecological goods and services (Keeler et al. 2019).

The ecological agency of local, regional, and intercontinental ecological actors shapes the ecosystems enclosed by the socially constructed boundaries of NYC (Figure 1). Emphasizing agency avoids 'mechanizing' complex species behaviors, instead focusing on the ways in which diverse species interact with and make up the environment and each other (Andersson and McPhearson 2019), such as salt-marsh grasses trapping coastal sediments and building extensive habitat for other species. Outside of ecological science, the frameworks of new materialism call for an embrace of ecological subjectivity, relationality, and meaning outside of human frames of reference (Alaimo 2016). From this perspective, humans serve as one of many ecological engineers and agents, who may exert an outsize influence on some ecological and environmental processes while being potentially overwhelmed by others (e.g. viruses, hurricanes), a constant tension present in 'managing' the environment.[1] Such a framing creates a conceptual foundation for the second dimension of GI, namely how social and ecological relationships affect fundamental characteristics of the urban ecosystem. Through this lens, we can see that human capacity to understand and transform ecological and environmental processes often relies on intergenerational observations on the effects of particular interventions, and not solely abstracted or theoretical knowledge. This type of knowledge is carried by specific individuals, which may or may not be reflected in institutions, necessitating an understanding of both formal and informal systems of managing and relating to the environment. These systems of knowledge are

[1] The term 'management' stems from the French *managere,* which literally means to 'put under the hand' and originally referred to the breaking of a horse. Management thus refers to the 'putting nature under the hand' in order to achieve some desired schema or purpose, and even if extended through technologies, still critically depends upon the skill, knowledge, and capacities of the manager.

thus fundamentally shaped by systems of power, which has been partially addressed by social-ecological systems (SES) approaches (Folke et al. 2007). However, urban GI cannot be solely understood as a social-ecological system (SES). SES approaches fall short because of the extensive relationships of ecosystems and built-infrastructure, and the ways in which the SETS, not the SES, performs specific infrastructural roles. These include the regulation of stormwater and preventing overflows from the city's combined storm and sanitary sewer system through a system of rain gardens, bioswales, permeable pavers, green roofs, and streetside stormwater planters often containing trees (NYC 2010, McPhearson et al. 2013b). Here we focus on these within city efforts, although the larger SETS certainly encompasses the cities extensive source water protection programs connecting reservoirs, aqueducts, and water treatment facilities with land acquisition, management, and diffuse forms of environmental regulation across the Hudson and Delaware basins (NYC 2013; NYC 2018), building off of a legacy of regional planning stemming from the 1930s. These hybrid programs illuminate the transformation of ecosystems into infrastructures, attendant with evolving but de forms of expertise and social organization that regulate *social* relationships with the *environment* through and for *technical* systems. Below, we elaborate on each of these key dimensions of GI in NYC.

Figure 1. Map of New York City and coarse forms of Green Infrastructure. GI in the city is formally managed through site scale facilities such as bioswales, street trees, and green roofs, but is fundamentally situated within broader patterns of managed and self-organized ecological patches which can be sensed remotely and classified as land covers of different broad ecological types and development intensities. This image of reclassified National Land Cover Data (NLCD) highlights how remnant patches, large managed green areas such as parks, and coastal systems are distributed in relation to different intensities of built development.



Methods

We review previously disparate literature on the environmental history, ecology, and environmental management of NYC, reinterpreting the evolution of GI within the city as a function of complex interactions within the social-ecological-technological system of NYC. We combine this review with qualitative analysis of formal plans and policies in NYC pertaining to GI specifically, as well as the broader challenges facing the social-ecological-technological system of NYC. Plans included in this analysis were obtained from iterative documents searches detailed in Grabowski et al. (*accepted in revision).*

Results and Discussion

1. Environmental and Ecological Agency in NYC

NYC occupies the ecologically rich estuary of the Hudson river which drains most of upstate NY, along with parts of Vermont, Massachusetts, and Connecticut. The city's climate is temperate, although contains diverse ecosystem types dominated by temperate mixed and broadleaf forests, and has been found to be a regional biodiversity hotspot (McPhearson and Wijsman 2017). The city itself sits on a post glacial granitic and metamorphic geology, with extensive soft shoreline deposits of glacial till and deposited sediments, and occupies a mixing zone influenced by the circumpolar jet stream and warm Atlantic-Gulf Stream. These opposing environmental forces expose the city to climatic extremes of both tropical and winter storms. Notably, hurricanes such as Sandy (2012), will likely increase in frequency and severity under future climates (Lin et al. 2016), as will heat waves (Ortiz et al. 2019). The city has also experienced major blizzards, most notably in 1888, although more recent storms have deposited ~ 1 m of snow in a single event. Additionally, ice storms, which can have severe impacts on the electrical distribution system and topple trees, are likely becoming more frequent in future winters (Klima and Morgan 2018). All of these extreme weather phenomena are shaped by both multi-decadal climatic variations, such as the North Atlantic Oscillation, as well as meso-scale processes such as sea breezes. While much of NYC is built on bedrock, its underlying geology and landforms have been increasingly submerged by sea level rise since the last glacial maximum circa ~18,000 YBP. NYC also sits within a regional zone of isostatic glacial rebound which causes a relative sinking of the underlying continental geology, which combined with increases in the mass and temperature of the world's oceans and regional patterns of ocean circulation, is causing rapid regional sea level rise, conservatively projected to increase 0.5 m by 2100 (Sallenger et al. 2012).

This dynamic coastal environment is a home for a diverse permanent and seasonal flora and fauna, with numerous migratory animals including intercontinentally travelling birds, sharks, and fishes using the estuary during part of their life cycles. The coastal mixing zone historically supported massive shellfish reefs that were gradually extirpated by over-exploitation, habitat destruction, and water pollution, although are now the focus of major restoration efforts (Wakefield 2019; NYC 2018; 2013). While urbanization destroyed pre-colonial mast forests, more recent efforts like the million trees NYC initiative) have expanded city wide tree canopy in addition to 4000 ha of spontaneously assembling natural areas (Pregitzer et al. 2018). This complex mosaic of self-assembling habitats also includes poorly studied ruderal plant communities unevenly distributed throughout the city (McPhearson

and Wijsman 2017), and extensive coastal marsh habitats of both freshwater and saltwater types whose hydrologies have been extensively modified by human activities in the coastal environment and throughout the estuaries watersheds (Montalto and Steenhuis 2004).

Vertebrates also form an important part of the overall ecological community. White tailed deer in particular have been extensively studied for their roles in shaping vegetative structure and composition (McPhearson and Wijsman 2017). Urban coyotes, racoons, and opossums, along with extensive bird populations, all participate in shaping the urban ecosystem in ways that remain poorly understood. Although most species are hypothesized to decline with with increasing degrees of urbanization, the persistence of acculturated species that dwell within humans as well as their built environment, and numerous species introductions have have created a rich ecological mosaic which includes numerous rare and threatened species (McPhearson and Wijsman, 2017). Invertebrates likewise play important, if often hidden roles, in structuring fundamental physical and chemical properties of urban soils, as in the case of invasive earthworms. Additionally, invertebrates play important roles as vectors of infections diseases, and have functional relationships with both vegetative and mammalian ecologies, an important disservice of urban ecosystems that is actively studied and managed (Van Acker et al. 2019).

While we cannot do justice to the voluminous literature detailing ecological intricacies of the city, we draw upon the above literature to illustrate the point that despite being the most densely populated city by humans in North America, New York City remains a vibrant, novel, and diverse ecological system created by dynamic forces not under human control. Additionally, our examples above illustrate the partial nature of urban ecological knowledge, in that most ecological knowledge of the city is partial and rapidly evolving, and is derivative, not constitutive of the ongoing complex relationships between non-human organisms, a dynamic environment, and the human activities shaping them.

2. Social-ecological relationships

The area currently known as New York City occupies the unceded lands of the Lenape people. These lands and ecosystems were co-constituted through complex forms of land use and management since time immemorial. These diverse cultural practices have been well documented in oral traditions, and include coppicing, transplanting, selective harvests, targeted dispersal, and periodic burning (Deloria 1997). Oral traditions across the continent detail many stories of cultural submergence and resurgence following major periods of glaciation (Deloria 1997), which disrupted the archaeological record, which keeps pushing back its estimates of human habitation.

Despite overwhelming evidence (e.g. Gilio-Whitaker 2019; Cronon, 2011), ongoing debates in conservation consistently seek to minimize the role of Native knowledge and land use in shaping precolonial ecosystems. This refusal to admit Indigenous forms of knowledge that contradict and destabilize settler-colonial and archaeological imaginaries, reinforces the explicit racism and cultural discrimination of treating partial archaeological records as 'hard evidence' (Deloria 1997). These larger dynamics are mirrored by the coloniality of much of the current urban planning discourse and development practices (Miller 2020), replete with narratives stemming from the concepts of *terra nullis* and the doctrine of discovery (Barry and Agyeman 2020).

We hope to make clear that it is impossible to understand the current ecological conditions of New York City without understanding the role of indigenous knowledge and land management in shaping ecological communities, as well as shaping the settler imaginary and urban identity. For example, the world famous 'Wall Street' was named after the wall built to fortify the Dutch settlement as part of their military occupation of the island of Manhattan, and Shell Point is named after a site of shell middens that marked numerous fishing and and year round habitation sites throughout the area (Connolly 2018; Zarrelli 2016). We must also consider ongoing efforts of cultural resurgence of Lenape peoples as part of a deeper and broader process of honoring treaty and Native rights and relations to land, of which no small part requires addressing how ecological genocide shaped ecosystems across North America.

Many accounts of the history of New York City mention in passing the role of the Lenape in shaping the regional ecosystem, but often move on from mythology of rightful (if misunderstood) purchase of lands which are nevertheless fraudulent and genocidal, often centering colonial actors in an epic struggle against taming the wilderness (Gilio-Whitaker 2019). Colonial accounts of pre-European habitation strive to both romanticize native peoples and their relation of land, and historicize narratives of settlement within a larger, and often racist, narrative of migration and cultural exchange, claiming Native history as a component of their own place based cultural lineage (Deloria 1997). Many agreements allowing settler occupation of lands were agreements for joint use and occupation, and not exclusive ownership (Gilio-Whitaker 2019). Early on New Amsterdam under the Dutch was a cosmopolitan trading post that welcomed many refugees from Spanish and English warfare throughout the Caribbean, and served as the chief importation center for the Trans-Atlantic Slave trade of Africans (Horne 2018). For nearly one hundred years prior to the Colonial Revolt of 1776, a these should be a continuous sentence and paragraph.

indentured laborers and militants, and made possible by the labor of stolen Africans. Settler colonialism transformed regional ecosystems from large old growth mast forests of widely spaced mature trees often approaching 100m in height, and managed for nuts, oils, diverse fruits, and game, into agricultural systems prioritizing pasture and row crop agriculture (Cronon 2011). While many accounts privilege a settler centered narrative of history, more recent historical work highlights the ambivalent nature of the early settler colonial project, in that a variety of relations were possible at multiple overlapping frontiers, which nevertheless developed into a hegemonic project of

ethnic and ecological cleansing to make way for colonial settlement (Gilio-Whitaker 2019).

Accounts of the settling of New York City are no different, and often obscure the violent regional conflicts between colonial powers that led to the ousting of the Dutch (Horne 2018), and subsequent anglicization of the region's settlers. Both of these processes marked by fractious warfare between colonizing powers who required the support of indigenous nations in their internecine struggles. While examining the history of colonization in depth is also outside of the scope of this paper, we wish to make it clear that the violent process of colonization lasted longer than the 'settled' history of New York City, given that relations with Natives, which culminated in their systematic extermination and removal, did not become 'settled' until the late 19th century (Gilio-Whitaker 2019). While some tribes saw the ousting of the English colonial government as potentially politically advantageous, the new United States of America instead systematically limited their economic and political development and ultimately pursued their total eradication and removal (Gilio-Whitaker 2019), in spite of which they have persisted within the city limits (Connolly 2018) and beyond.

From early on, colonization and the intensification of settler agriculture quickly led to ecological issues, including poor sanitation and the spread of transmissible diseases (McNeur 2014). Early signs of ecological changes in the surrounding ecosystem were regulated by colonial and American governments alike, to little avail, as water quality deteriorated, regional economies shifted to further prioritize trade and the import of food stuffs previously obtained through local aquaculture, agriculture, hunting, fishing, and gathering from indigenous agroecosystems (Cronon 2011). Large migratory fisheries, notably salmon, shad, sturgeon, and alewives were progressively stressed by land and wetland conversion, overfishing, and regionally extirpated by coffin nail of numerous small and large dams All of these processes accelerated the collapse of aquatic ecosystems accompanying the international commodification of beavers, their subsequent extirpation, and the large scale loss of aquatic habitat (Cronon 2011).

Colonization entails a shift away from the relations between humans and other beings that result in complex ecological mosaics, towards a formal system of rationalized resource extraction supported by the standardization and regulation of land ownership with notions of common good also serving a larger arc of expropriation (Gilio-Whitaker 2019). The resultant logic of control and capitalization continues to reshape regional ecosystems at the expense of ecological systems co-produced through traditional and relational land management practices. The ecological abundance co-produced by Native peoples and ecological agents, remains ontologically appropriated by those celebrating the economic abundance of the present city borne of international trade, including the export of Indigenous peoples as slaves, and the large scale import of enslaved Africans and Carribeans (Horne 2018), speculation over the value of land (Stein 2019), and the rise of industrial modes of production (McNeur 2014).

The project of slavery based settler colonialism has been described as a transition from a settler society that contained racism to a settler society based on racism, or one whose material well being fundamentally depended upon the expropriation of bodies and land justified by white supremacy (Horne 2018). It is no small wonder then that even though New York City is now arguably one of the most culturally and racially diverse cities in the world, enormous inequalities persist in insidious ways, including tremendous disparities based on race and ethnicity in life expectancy, labor market participation, exposure to industrial toxins and air pollution, education access, policing, transmissible diseases (including Covid-19), housing, police violence, access to green space, and tree canopy (Pulido 2017, 2018; Neckerman et al. 2013). These disparities extend to environmental hazards such as urban heat (Hoffman et al. 2020) and flooding (Herreros-Cantis et al. 2020).

Disparities in ecological amenities and hazards are inseparable from long standing racist patterns of real estate development and associated federal and local policies (Rothstein 2017). These include the purposeful clearance of Black and minoritized communities through urban renewal such as the displacement of the community of Seneca Village during the creation of the city's iconic Central Park (Low 2019). In this sense, urban greenery has a history of use as a weapon against people of color and the poor, a practice which continues today through uneven patterns of policing of the use of park spaces, as well as aggressive 'green' real estate development gentrifying portions of the city (Gould and Lewis 2016). These profound inequalities are defining characteristics of the social-ecological arrangements of NYC and other cities in settler colonial states (Pulido 2018). While long hidden in plain sight, they are now increasingly taken up in the discourse around sustainable design and the acknowledgement of the need to recenter indigenous relations with land, and address the horrors of settler-colonialism and persistent racism (Low 2020).

In spite of persistent environmental racism, numerous community gardens and grassroots initiatives have improved access to food, medicine, and recreational opportunities for marginalized communities (Balick et al. 2000), and form a rich part of the overall *biocultural* diversity of NYC. The cultural tapestry of the city is likewise shaped by global, national, and regional histories of migration and displacement. NYC was a major center importation of enslaved Africans, and, through Ellis Island, also became a premier center for importing central and eastern European labor to meet growing demand in regional cities' mills and industries through the late 19th and early 20th century. These waves of migrations occured before racist backlash against the prevalence of immigrants throughout America led to bans on immigration of Jewish peoples and Central and Eastern Europeans in 1923, which were not lifted until *after* WWII despite knowledge of Nazi Germany's systematic exterimation of those same peoples. Clashes between immigrant communities, Blacks who had long resided in the city, and Southern Blacks that had emigrated during the Great Migration, were increasingly frequent in this period, and formed one of the little recognized drivers for reform planning and the creation of a city wide network

of green spaces in the city. The idea that different races and ethnicities had different requirements, and should be granted differential access (or not) to different types of park facilities was firmly ingrained in early park planning efforts (Cranz 1982) which coincided with large scale programs of urban renewal and slum clearance, as well as the significant restructuring of the coastline through fill, dredging, and armoring (Wakefield 2019). Increasing immigration from the Colonial territory of Puerto Rico in the 1950s, also significantly impacted the social-ecological dynamics of the city, which became increasingly 'latinized' with major diasporas fleeing US backed conflicts in Central and South America, with major waves of emigration accelerating from the 1970s onwards (Grosfoguel and Georas 2001). Together these forces resulted in a complex mosaic of social-ecological relations manifest in different uses of private green space, parks, and access to green infrastructure throughout the city. Additionally, numerous 'vacant' lots throughout the city, resulting from complex social and technological dynamics affecting the use and value of land, have also contributed heavily to the persistence and health of urban ecosystems (McPhearson and Wijsman, 2017). These rich structured and spontaneous social relationships interwoven with self-organizing ecosystems, are what form the basis of the urban nature of NYC that has been progressively 'infrastructuralized.'

3. The infrastructuralization of ecosystems

While maritime cultures in what is now known as NYC had long relied on coastal infrastructures, the colonial notion of infrastructure generally operated vis-a-vis natural systems in an unabashed project of 'taming' nature for the purposes of social (narrowly defined) benefit, which is reproduced in current discourse (Wakefield 2019). Increasingly, as the city's resource base was decoupled from its local social-ecological system, and instead implicated in global commodity flows of sugar, cotton, rum, and slaves, the regulation of local waterways took on increased importance. NYC was a nationally significant harbor for these commodity flows, and was a principal site of the application of the regulatory authority and engineered infrastructures of the Army Corps of Engineers through the Rivers and Harbors act. The regulation of waterways for the purposes of navigation, included restrictions on dumping and the creation of maritime structures without express approval of the Corps. This regulatory framework became the foundation of current efforts to manage waterways through dredging and using resultant spoils in 'restoring' and reshaping coastal ecosystems (Wakefield 2019). Restructuring of coastal habitats alongside extensive continental and regional railway systems, profoundly reshaped the opportunities for previously waterbound businesses, and created a regional commuting public whose daily life was now entrusted to a new class of technical and corporate 'experts' (Revell 2005). It was during this same period that the city's water supply system was created, both of which were dependent upon novel bureaucratic structures that increasingly managed many aspects of daily life for New Yorkers, including coastlines, parks, storm, and sanitary sewers, albeit often in separate city departments with little accountability to one another, and whose 'rational' integration formed the basis for major reform efforts. The creation of physical infrastructures and the social infrastructures required to plan, design, and operate these complex infrastructure systems continue to profoundly shape the nature of NYC (Gandy 2003). They do so through two primary means, 1) the purposeful structuring of urban habitats by human engineers and other actors, as well as introducing novel toxins into the urban environment and 2) the transformation of ecological agents into infrastructure, often through their incorporation into hybrid facilities such as green roofs, streetside planters, and larger engineered ecosystems like restored coastal wetlands and blue belts.

Hybrid ecological-engineered facilities form the basis for the city's formal green infrastructure programs. In NYC, major conceptual and political struggles continue over how urban nature becomes circumscribed and delimited when it is referred to and managed as 'infrastructure.' In particular, the circumscription of GI to engineered stormwater facilities has large consequences for what types of services can be provided by urban GI, with claimed multi-functional benefits generally not being included in siting or planning criteria (Kremer et al. 2016) much to the detriment of multi-hazard management (Depietri and McPhearson 2018). Such disjunct in the potential versus the planned purposes GI is striking given long standing efforts of coordinating tree planting between the NYC department of Parks and the Department of Environmental Protection that sought to create more integrated tree corridors connecting parklands (NYC 2013). Currently, controlling combined sewer overflows are the highest priority for the city's GI programs, though managing heat waves as well as local and coastal flooding are also serious concerns, albeit with less dedicated funding and planning (NYC 2017; NYC 2013). Attempts to 'catch up' to changing environmental conditions through an infrastructuralization of urban nature makes it clear that complex interplays between environmental forces and the social processes framing desirable and necessary relationships with them continue to drive the deployment of the GI concept in NYC. Were it not for Hurricane Sandy and the already experienced impacts of climate change, would NYC be as aggressively pursuing an infrastructuralization of nature? While the answer cannot be known, it is clear that the administrative roots of managing nature through technical run deep; managing storm and sewer water with GI is the result of attempts to comply with environmental regulations stretching back to 1899, and the city's experience with avoided filtration of drinking water through source water protection translates conceptually to a program of avoided treatment through diversion, infiltration, and vegetative filtration of storm runoff. However, Hurricane Sandy made clear that the accretionary fabric of complex interdependent technological infrastructures were vulnerable to environmental forces, and spurred a large scale regional effort to evaluate the feasibility of green and grey infrastructure systems to respond to sea level rise and increasing storm intensities. These initiatives have matured into an international research agenda for certifying and evaluating 'nature and nature based features +' for coastal protection (Bridges et al. 2015). In recent decades, city government has reacted to increasing environmental extremes in haphazard ways that limit long range and inclusive planning efforts (Friedman et al. 2019). Major obstacles to

a more robust and democratic notion of urban green infrastructure in the city include the fragmentation of sites of opportunity (McPhearson et al. 2013b), along with the fragmented governance structure of urban nature, which continues to privilege funding streams dedicated to single mission agencies (Meerow 2020). These politics in turn borrow their siloed structure from the current system of environmental regulation in the United States, which has generally failed to prevent the widespread and highly uneven, exposure of humans to human produced toxic chemicals (Chiapella et al. 2019). Aside from pro-development brownfield policies supported by federal funding, current green infrastructure efforts are largely silent on the legacy of contamination in the city, preferring to utilize the discourse of new urbanism and ecological securitization in promoting the benefits of livability and resilience of improved environmental conditions, which is not unique to NYC. However, as the one million trees program comes to a close, urban wild forest management becomes a major focus of new forms of partnerships between city agencies, non-profits, and foundations (Pregitzer et al. 2019), and novel legislation pertaining to green roofs (NY State Senate 2019) begins to manifest in concrete projects, certain social, political, and ecological tensions rise to the fore.

A central paradox of the greening of New York City results from its past and present inequalities in the distribution of environmental services and hazards. In the case of flood risk, development and resilience policies have allowed for continued population increases within the flood prone zone, resulting in a complex arrangement of both vulnerable and affluent communities at risk of flooding (Herreros-Cantis et al. 2020). In the case of more general urban greening, the use of tax-increment financing and other incentives to spur new development in poorer neighborhoods, has given rise to the phenomenon of 'green gentrification' (Gould and Lewis 2016). Together, these forces call for nuanced approaches to improve conditions in marginalized neighborhoods without displacing current residents, and to address managed retreat and housing affordability in the broader region. As the city struggles with aging infrastructures, changing environmental conditions (Revi et al. 2014), and the 'growth' imperative that sought to maintain property values despite population declines, city agencies have become increasingly beholden to real estate speculation as a driver of urban economic growth. Taken together, these forces have had structural consequences for city budgets, environmental quality, and the disruption of the balance of power that traditionally pitted industrialists against commercial and residential property developers (Stein 2019). At the same time, democratization of infrastructure expenditures through participatory budgeting show promise for incorporating diverse green elements outside of the formal regulatory GI programs, such as community farms, gardens, and forests (Campbell 2017). As environmental quality generally increases due to the continued global dislocation of polluting industries, and numerous efforts to restore urban ecosystems (NYC 2018), and implement greener infrastructures alongside 'green infrastructure' (NYC 2019), the central question becomes: can NYC adapt to a rapidly rising sea and changing climate while addressing long standing issues of social and environmental justice? Previous work has identified that a novel research-to-action nexus in the city may hold the keys towards unlocking new forms of urban ecological research and governance enabling sustainability transitions of the NYC SETS (McPhearson and Wijsman 2017), how this will take shape in new forms of infrastructure, and new social-ecological realities, remains a function of the combined skills and capacities of motivated and engaged actors operating in the context of global to local forces.

Conclusion: the Future is Green in NYC?

How NYC today seeks to use GI to provide a healthy urban environment for human and ecological health must directly confront how the city has been shaped by the forces of settler colonialism, racism, industrialization, the speculative real estate state, and ecological securitization. The last twenty years have seen widespread deployment of hybrid green infrastructure technologies to manage stormwater and prevent combined sewer overflows while sparking fears of green gentrification. In the face of a rising sea, the city has been progressively armored through huge influxes of expertise and capital for grey and green infrastructure projects, although the current redistribution of coastal hazards remain paradoxical and the resulting shifting of risk poorly understood. The city has planted a million trees in response to the intersecting hazards of climate change, and yet outcomes appear to be highly unequal. Current legislation on green roofs seeks to further integrate the built and natural environment for mutual benefit. NYC remains a critical laboratory for understanding how to re-integrate ecological elements into the urban fabric to provide multiple functions and benefits.

An increasing emphasis on understanding the social dimensions of urban nature promises to enrich dialogue and debate over the appropriate role of humans in the landscape. Given rates of sea level rise and climatic chaos, a key question pertains to the rates of transformation: can NYC adapt fast enough to the new environmental conditions that it, as a global center of finance and industry, has been a principle player in creating? Can NYC address its legacy and ongoing dynamics of white supremacy? Emergent participatory approaches show promise for community ownership of greening initiatives that can revitalize and stabilize neighborhoods, but the larger power dynamics and inequalities remain largely unaddressed. At present intersecting crises of Covid-19, climate change, systemic racism, and police brutality are shaking the social and economic foundations of the city and it appears impossible to disentangle the future of green infrastructure from the ways in which these deep seated social ills will be addressed. A greener future is possible, but it's impacts and costs will remain problematic and unequal until all those involved in its creation acknowledge and address the need for justice.

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