PAPER

Decentralizing infrastructure: expanding architectural practice towards equity and health

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Climate change impacts are not evenly distributed across the globe. Inequities also emerge at a local scale where buildings have the most perceivable impact, affecting anything from access and continuity of the public realm to microclimates. Design decisions can exacerbate or mitigate microspatial inequities—i.e. significant local variation in environmental hazard exposures, like heat, air pollution, and flooding. Green Infrastructure (GI) is a range of nature-based solutions with the potential to mitigate environmental hazards. Decentralizing GI is critical to health and resilience, building redundancy and capacity through a distributed network of smaller system nodes that are less prone to cascading failures. Architecture projects can support decentralization, targeted mitigation, and incremental implementation; however their contribution to urban resilience, health, and environmental justice needs to be better characterized to support rationalized expansion of such approaches. This requires ways to explore complex and dynamic interactions of buildings within and beyond site boundaries, including: (1) methods for measuring local variation in hazards at relevant spatial scales and (2) tools for modeling the impacts of interventions in inclusive conversations with local stakeholders. This research examines an equity-focused approach to co-designing GI in architecture projects, using data and tools to inform and measure the impact of individual building projects and, eventually, networks of projects. In collaboration with the city of Chelsea, MA, our transdisciplinary team is studying sensor networks and a participatory modeling process to demonstrate how architecture projects can generate and leverage local knowledge about microspatial inequities and mitigation by GI to advance broader community health goals. Co-design activities around one pilot site reveal how decentralization becomes a significant paradigm shift—even among practitioners—eliciting ideas about maximizing capacity, connectivity, co-benefits, and shared responsibility. This paper examines the term decentralization in a multidisciplinary discourse, shares lessons from a specific context, and discusses implications to architectural practice.

INTRODUCTION

Global and Local Inequities

According to the most recent report by the Intergovernmental Panel on Climate Change, the effects of climate change are not evenly distributed across the globe, with the poorest countries in the developing world suffering a disproportionate share of impacts to their economies, cultures, and ecosystems, and thus to their quality of life and human health.[1] When comparing countries, this report identifies the United States as having relatively low vulnerability but points to regional inequities that make urban ethnic minorities significantly more vulnerable. Socially vulnerable populations that live with the legacy of historic social, economic, and environmental inequities often live in the most threatened, neglected, and physically vulnerable environments. The construction and operation of the built environment is one of the leading causes of global climate change, and potentially one of the solutions. As recent as 2019, buildings were responsible for the largest share (37%) of global carbon emissions causing climate change compared to any sector of the economy.[2] The industry invests significantly in efforts towards energy efficiency, decarbonization, and resilience; yet population growth and urbanization counteract many gains, as more resouces and land are needed for building, and more people are placed in the most threatened environments. This is a growing challenge for human and planetary health.

Environmental inequities also emerge at a hyperlocal scale, from one neighborhood to another, or even one side of the block to another. At this scale, the built environment has the most perceivable impact on people, affecting many quality-of-life factors from universal access to microclimates. The material, form, and surface of buildings and infrastructure can exacerbate or mitigate microspatial inequities—that is, significant local variation in environmental hazard exposures, like heat,[3] air pollution,[4] and stormwater,[5,6] which in turn can affect physical and mental health differently based on where people live or work. While some of the mechanisms by which climate hazards are exacerbated locally are relatively well understood (e.g. Urban Heat Island or UHI), few models are available to predict these significant local variations at a high-enough resolution for architects to respond to. In fact, when presented with climate science and projections city planners need to develop specific resilience plans to adapt infrastructure and individual buildings, but often find, like the City of Cambridge, Massachusetts, "additional work is needed to translate how those changes will present at the local level".[7] If the connection between local built environment characteristics and local environmental conditions could be better characterized or predicted, architects and planners would be better equipped to modify the built environment to improve those conditions, and in turn, be better positioned to reshape antecedents for environmental health inequities.

Global and Local Solutions

Rapid advances in technology make quantifying and tracking microspatial inequities increasingly possible. Environmental sensors report conditions at a precise location in real time, and a network of sensors can be leveraged to model the detailed landscape of hazards across a community or city. Sensors, however, are expensive, but there are other opportunities for estimating hyperlocal hazards using remotely sensed data, most notably heat and landcover information generated by the United States Geological Survey's LandSat products, collected by satellites. In addition, projects can coordinate infrastructure data with known geophysical dynamics to generate proxies for hazard risk, in lieu of directly measuring the hazards themselves. For instance, a study used public data on building heights and road widths in Boston, MA to estimate the intensity of the 'urban canyon' that can intensify air pollution.[8] Combined with estimates of vehicular emissions derived from aggregated mobile phone data records, the risk for air pollution on all streets they approximated, demonstrating that there were marked street-by-street disparities in air pollution risk within neighborhoods that were almost entirely uncorrelated with the risk of extreme heat. Though less precise than both local and remote sensing, such approaches can point to areas of high risk or concern.

Another reason to downscale data on environmental hazards is to build consensus around equitable solutions. No solutions are universal; particularly in underserved communities where space is tight and tradeoffs are inevitable. Furthermore, different interests and needs manifest as diverse priorities on what impacts to address and what benefits to enhance. [9,10] Green infrastructure is no exception, as residents grapple with the need for healthier environments as much as the need for housing, transportation options, and parking. This diversity of priorities may quickly lead to conflict and gridlock that interfere with solution-building without adequate support for democratic deliberation where concrete solutions are fully examined and trade-offs explicitly resolved This is critical for urban planners to develop policies and guide public investments to mitigate hazards with more context-specific and equitable approaches, and for designers working in these contexts. Understanding how planners use local environmental data to evaluate individual development projects, and how this science-based approach could transform the architectural design processes, is the focus of our research.

Increasingly, mitigation of and adaptation to climate-related health hazards efforts involve nature-based solutions. In planning and design, efforts often address regional or global systems and industries, whether it is reforestation, coastal wetland restoration, solar or wind energy farms, new bio-based material development, etc. In contrast, thinking locally about mitigating harm may involve building compact and using green infrastructure (GI) for added capacity (e.g. stormwater interception in trees) and co-benefits (e.g. beautification as well as shading for thermal comfort and lower energy costs); and doing so equitably to improve resilience and reduce burden on the most affected communities. But in the densest and most socially vulnerable neighborhoods, where GI could be most impactful, interventions may be limited by public funding and space. In the United States, GI is traditionally planned and implemented in the public realm, limited to small or medium size green space in parks or transportation rights-of-way. To build enough capacity in dense environments may require targeted, locally specific solutions and a distributed network of development sites, including private sites, without shifting the cost or burden to communities that are already disproportionately affected. Some cities try to recruit private sites to expand green infrastructure goals with policy, some using 'carrots' such as the green roof density bonus in Chicago,[11] and others 'sticks' such as groundwater infiltration requirements triggered by increase in building footprints in Boston.[12] However, one-size fits all policies often target economic interests more than environmental justice,[13] thus are less able to address microspatial inequities. This led to our hypothesis—if planners and designers can adequately characterize how the built environment affects the intensity of hazards at a micro-scale, then theoretically they could modify it in specific ways to mitigate specific impacts to vulnerable communities.

PROBLEM: EXPANDING THE ARCHITECTURAL SITE

Developing an equity-focused approach to co-design GI into architecture projects for highly vulnerable areas requires exploring buildings' complex and dynamic interactions within and beyond site boundaries using: (1) methods for measuring local variation in hazards at relevant spatial scales and (2) tools for modeling the impacts of interventions in inclusive conversations with local stakeholders. This research develops such an approach using data and tools to inform and measure the impact of individual building projects and, eventually, networks of projects. The goal is to better characterize how building projects can directly contribute (or not) to objectives of ecological regeneration, urban resilience, health, and environmental justice. The research seeks to answer questions of interests to designers, planners and community activists:

- How can architectural sites define better GI goals that maximize capacity and co-benefits in the most vulnerable areas?
- How can data on microspatial hazards foreground equity in planned developments?
- How can science-based visualization and modeling tools make the design and approval processes more inclusive?

While this multi-year community-engaged research is ongoing, this paper is focused on important concepts and preliminary findings that begin to address the first question. When working collaboratively to align architectural development and green infrastructure goals to address local hazards, decentralization emerges as a transformative and transformed concept, expanding from its dominant meaning in the literature to provide new ways by which to understand the agency of architecture in a larger urban landscape. This paper examines the term decentralization in a multidisciplinary discourse and its implications for equity-focused design, shares preliminary lessons from co-design activities in a specific context, and discusses broader implications to the practice of architecture.

LITERATURE REVIEW

Shifting Scales of Green infrastructure

A traditional definition of GI is focused on landscape features for managing stormwater quantity and quality –as an "interconnected network of open spaces and natural areas," extended in cities by "other landscape-based drainage features... to restore, protect, and mimic natural hydrologic functions within the built environment." [14] A more expansive definition of GI goes beyond sotrmwater, and could include any constructed system that designs and engineers nature-based solutions to provide ecosystem services, from energy to food and materials, resulting in co-benefits to economies, human and planetary health. GI is more connected to landscape and civil engineering than architecture, and is considered a decentralized solution because it functions locally, as close to the source as possible (to reduce runoff, provide cooling, remove pollutants from air or water, reduce energy demand, etc) as opposed to collecting or distributing from a centralized location at higher energy use levels.

The scale of the challenge of climate change inspires big solutions that can match the scale of centralized gray infrastructure systems (e.g. coastal marsh restoration instead of sea walls); but these can share challenges of implementation (cost, land ownership, technical complexity) and the risks of cascading failure. In large scale GI projects the co-benefits (e.g. access to green space, mitigation of UHI, beautification) or tradeoffs (loss of other land uses) may also be limited or concentrated. Decentralizing GI is critical to resilience, by building redundancy and capacity through a network of smaller system nodes that better distribute co-benefits and are less prone to cascading failures.

Revisiting Decentralization

Decentralized GI is defined as "small scale dispersed facilities that are located near or at the point of use."[15] A seminal white paper suggested that the term 'distributed' is better focused on the benefits and advantages it offers, rather than what it is not (centralized)—describing it as "extending from centralized infrastructure," with the possibility of being integrated or networked (distributed-networked or distributed-integrated).[16] In civil engineering and architecture, the use of the term decentralization is mostly concerned with local supply (water, energy, transportation) to reduce energy and cost.[17] Decentralization of resources like water supply is especially important for resource-stressed places,[18] making net zero water buildings part of a 'one-water' infrastructure system.[19] In that sense, the use of the term decentralization implies buildings or building sites as semi-independent or, in the most extreme cases, off-the-grid, with every building being its own water infrastructure. While this form of decentralization seems more sustainable and resilient, the independence paradigm may be less efficient if "each project must maximize the implementation of technology in each individual site without considering the optimal scale of performance of each system."[20] The risk is reducing interdependence, i.e. the possibility of contributions to other sites or surrounding areas at lower costs. In contrast, the literature on decentralization of outflows, e.g. wastewater, seems more focused on lowering burden on centralized infrastructure and reducing downstream impacts. [21, 22]

Decentralized GI solutions include urban tree canopy, swales or rain gardens on roads, and vegetated surfaces on roofs of low buildings;[23] all of which can contribute to mitigating microspatial health impacts for varying distances with decreasing benefit away from their location, as examined in studies focused on heat,[24] pollution,[25] and flooding.[26] Their incrementalism aligns with the scale, ownership and timeline of architecture projects. There are precedents for connecting architecture project size to GI performance, e.g. requirements for retaining rainfall that falls on impervious surfaces on site.[27] Buildings like the Watershed in Seattle by Weber Thompson take this further by also treating stormwater runoff from an adjacent bridge and alley, using GI in private sites to expand public GI. [28] Others like the Gewerbehof Prisma Nuremberg integrated GI into buildings, including a tiered system of roof terraces, facades, courtyards, and atria, which filter stormwater before infiltrating under building foundations. [29] Private investments in GI enable architecture to contribute to urban landscape performance, albeit with varying cost-benefits. Similar to campus planning, each architecture project is seen as an opportunity to advance landscape restoration goals.[30]

Architecture as Reparative Infrastructure

The fiduciary responsibility of architects, as governed by contractual obligations,[31] can limit considerations beyond the building footprint and its users, addressing local context in the sense of fit and connectivity, but considering environmental impacts more abstractly. For example, community input may be limited to zoning or planning review with abutters to secure building approvals. Yet buildings are part of socio-ecological systems[32] that affect human and planetary health downstream for generations. While the profession has made significant progress in reducing additional direct harms, it often falls short of repairing harms already inflicted in vulnerable communities.

Moving beyond "make no harm" means to repair. Some exceptional AIA COTE Top Ten award winning architectural projects like the Vancouver convention Center by LMN Architects,[33] not only reduce environmental impacts, but also build habitat, restore ecological flows, improve air quality, and connect humans and nature. Yet, to build equity through reparative and regenerative design, the profession must expand beyond extraordinary projects in extraordinary sites, to work at different scales and levels of ambition within the most vulnerable communities, and to measure the impacts.

METHOD

Goal

This project tests an equity-centered and science-based process of co-design to support designers, planners and community stakeholders thinking beyond the site boundaries or individual concerns, to stitch individual projects back into a regenerative landscape, coordinating site goals with districts or municipal goals. In collaboration with the city of Chelsea, MA, we are studying sensor networks and the participatory modeling tool fora.ai to demonstrate how architecture projects can generate and leverage local knowledge about microspatial inequities and mitigation by GI to advance broader community health and equity goals. These community-specific goals could include, for example, reducing flood damages to low-income housing areas, reducing particulate matter near residential neighborhoods, or reducing temperatures during heat emergencies .

fora.ai is a participatory modeling (PM) online platform that includes a set of organizational features, visualization and modeling tools, and facilitation and sense-making approaches to support all the iterative steps in a collaborative modeling cycle: problem definition, preference elicitation, collaborative scenario design and simulations with parsimonious models, deliberation of tradeoffs across solutions, and implementation.[34] With such a structure, fora.ai was designed to enable groups to explore complex, real-world problems; to collectively design solutions to these problems and test them for rapid feedback, to enhance social learning, promote collective problem-solving, and support democratic decision-making.[35] While the early version of the tool and initial workshops were developed for flooding, the broader project will be exploring multiple hazards and potential mitigation benefits of GI, guided by community interests.

Context

Chelsea is a small town centrally located in the industrial harbor of the metropolitan region of Boston, Massachusetts (USA), crisscrossed by ships, major commuting and freight highways, diesel commuter trains, near fuel storage tanks for the nearby airport. Its population of nearly 40,000 is 66% Hispanic, 47% foreign-born, over 70% speak a language other than English at home, with a median household income of 76% the state median household income (MHHI).[36] Pockets of Chelsea combine multiple factors of Environmental Justice communities[37] (language isolation, and/or minority status, concentrated poverty as low as 25% of MHHI), with density, traffic ,UHI, and air pollution. (Figure

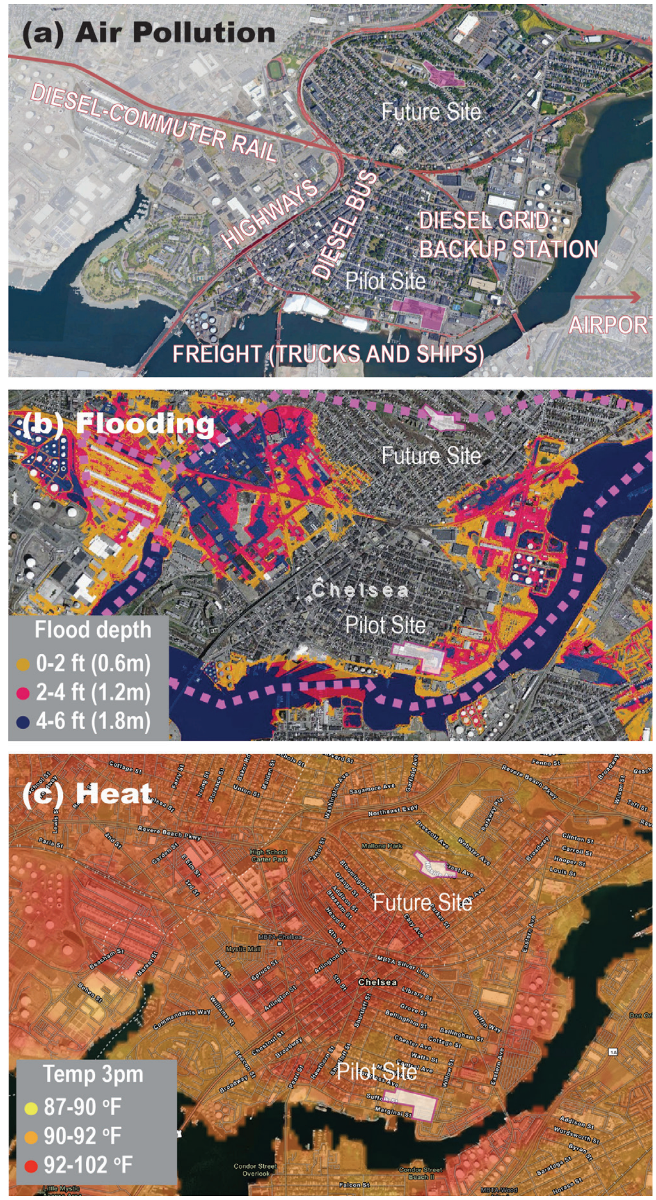

Figure 1.Primary Hazards in the City of Chelsea,. (a) Air Pollution sources (by author), (b) Sea Level Rise Flooding risk (source: Boston Harbor Association), (c) Heat (source: Museum of Science and Northeastern University). The three maps show the location of the pilot site under construction (south east near the coast) and the future site (in early design) being considered for future phases of community engagement (north central).

1) Low-lying areas of Chelsea are also threatened by sea level rise and storm surge. The governing structure has a city council that selects a town manager and gives planners multiple roles and responsibilities, e.g. coordinating environmental, economic and housing development. The city has no official mandates on GI, but planners who negotiate special permit conditions have a strong interest in advancing GI goals by setting specific landscape criteria for major development projects, which have to be negotiated with other community priorities.

Figure 2. (a-b) Existing conditions of industrial site (c-d) Renderings of proposed design. Credit: RODE Architects.

Pilot Site

Working with the city of Chelsea we identified a pilot site that was ready for construction, where 'before-and-after' impacts could be measured during the first 2-year grant period, to test the characterization of microspatial inequities, observe change generated by a single architectural project and validate models. The industrial waterfront site was completely impermeable. (Fig.2 a-b) The redevelopment will maintain the industrial use, but make significant changes, including modest GI goals. The new building designed by RODE architects will be a freight forwarding facility with more green buffers, underground stormwater storage and infiltration, that reorganizes truck traffic further away from residential streets to the north. (Fig.2 c-d) The developer transferred a small parcel for a pocket park to the northwest of the site. Because we think the new conditions could change the UHI nearby, we are doing baselining of temperature and aiming to understand neighborhood Air Quality impacts of traffic before shipping restarts and after traffic recommences.

Team and Process

The transdisciplinary team includes researchers from Architecture, Environmental Engineering, Urban Informatics, Data Science, and Participatory Modeling and Planning; working with planners in the City of Chelsea, and engaging developers, designers, and eventually community members. While many activities (sensing, modeling) happen in parallel, this paper focuses on modeling activities around the pilot site, testing impacts of GI design scenarios. This process included:

1. Characterizing inequities, modeling an area of the city around the pilot site, using publicly available data supplemented by site surveys (for this early phase of the work we focused only on stormwater-related flooding hazard; but the platform for heat modeling is currently under development for future phases of the work).

2. Cross-model validation, comparing our model with engineering models provided by the design team.

3. Workshop with city planners to test the facilitation process with fora.ai before engaging community in PM.

4. Community experiments in co-design (future phase): working with the city to identify sites in early stages of planning and design, to engage community participants.

DISCUSSION OF PRELIMINARY FINDINGS

Learning from the Pilot Site

Practitioners were given baseline flooding scenarios before and after the proposed redesign. The positive impacts of the single project were most visible within the site boundary, on the street crossing the site east-west. (Fig.3) Participants were divided into two groups to create and simulate design scenarios that build on this proposal. (Fig.4) In group 1, they agreed to try a single

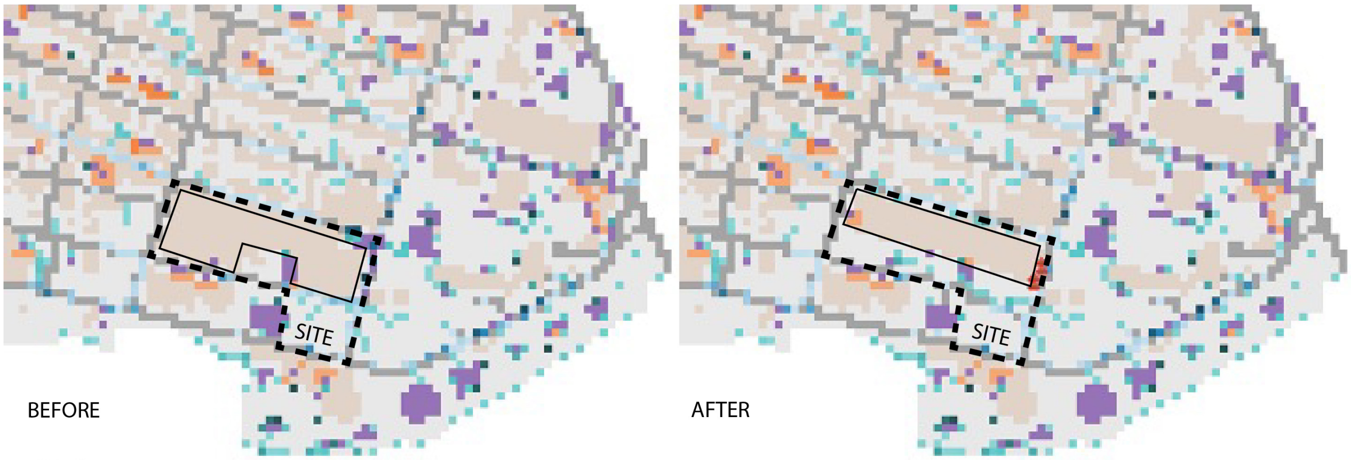

Figure 3. Baseline simulations of flooding for two scenarios: existing conditions before demolition of the pilot site buildings (left) and after redevelopment in the future, which reduced building footprint and increased GI (right) using the L-GrID simulation engine that runs fora.ai. Pixelation is inherent to the modeling platform, which works in a grid of cells 10m x 10m (32.8 ft x 32.8 ft). Colors indicate: Purple: flooding over 1", Light Blue to dark Blue: shallow to deep ponding, Orange: building damages.

intervention at a time to see the incremental effects. Group 2 intended to start with the most ambitious plan, to scale back or “trim,” but instead the results of each scenario encouraged them to do an incremental expansion. In both cases the first scenario (not shown for Group 2) concentrated building-based GI strategies (primarily green roofs) within the private parcel to test how much they can increase the capacity and external benefits before attempting GI in surrounding public areas.

Upon seeing the limited improvements from a green roof strategy, group 1 pursued a concentrated strategy, adding GI on “problem areas” outside the site i.e. low points (wetlands acting as a kind of sponge downstream). Despite incremental improvements to total flooded areas, the model reported low levels of capture and infiltration. Their last scenarios then shifted GI areas to more but smaller disconnected patches in low points, achieving a higher improvement but still relatively low GI capacity used. Group 2 pursued a more dispersed approach after their first green roofs scenario, which was nealry identical to the first scenario of group 1 (Fig.4, top-left). In scenario 2 (Fig.4, top-right) Group 2 expanded GI along streets with swales and pavers leading to low points in the area (upstream), achieving moderate improvements in impacts to neighbors, and higher utilization of the GI capacity. The maximum gains happened in the last scenario for Group 2 (Fig.4, bottom, right) where the swale corridor was continuously connected from the pilot site to the worst flooding areas, and thickened upstream.

The fora.ai allowed participants to visualize contributions of each scenario in a single representation, instead of seeing one set of results at a time, to better understand the impacts of multiple strategies relative to the baseline, i.e. aggregate improvements or deterioration. While the focus was flooding in this stage of the project, practitioners mentioned UHI and habitats as important drivers to maximize GI (co-benefits) and felt they could not judge scenarios based on one hazard (this function is still in development). Despite the high cost and limited impact on flooding, a participant said they were “feeling defensive about green roofs,” and... “will continue pushing for them.” There is support for this intuition in the design community, as explained by a leading practitioner of GI, green roofs are often eliminated from designs due to costs because they are unfairly compared to site-based strategies that are only a backup for resilience, and because cost avoidance (e.g. energy savings and durability of building components) are not accounted for.[38] Our modeling and PM tools do not yet include direct metrics for health, as the focus is on the effect of GI on environmental conditions as a proxy or an antecedent to health. A natural next step in this work is integrating evidence-based health metrics (e.g. mold potential from flooded building) could potentially expand and support more complex conversations about trade-offs and co-benefits.

Although decentralization was not an explicit topic of the workshop, one participant expressed that their biggest realization was that decentralization is more effective than concentration. They acknowledged the draw of visibility, i.e. concentration is more noticeable, it signals action. Legibility is important in design culture—maximizing site potential in terms of performance and experience. Unsurprisingly, in celebrated GI projects green space is nearly pervasive, clustered closer to a natural or wild condition. But the contrast between these two groups’ scenarios align with the literature that shows that isolated green spaces have limited effect.[39] A network of smaller GI can, for example, slow flow and feed modestly larger ‘sponge’ spaces. Decentralizing GI across multiple locations and types, and as group 2 attempted, connecting large installations with corridors along the public realm, can be more a more effective use of GI capacity and distribute benefits both upstream and downstream.

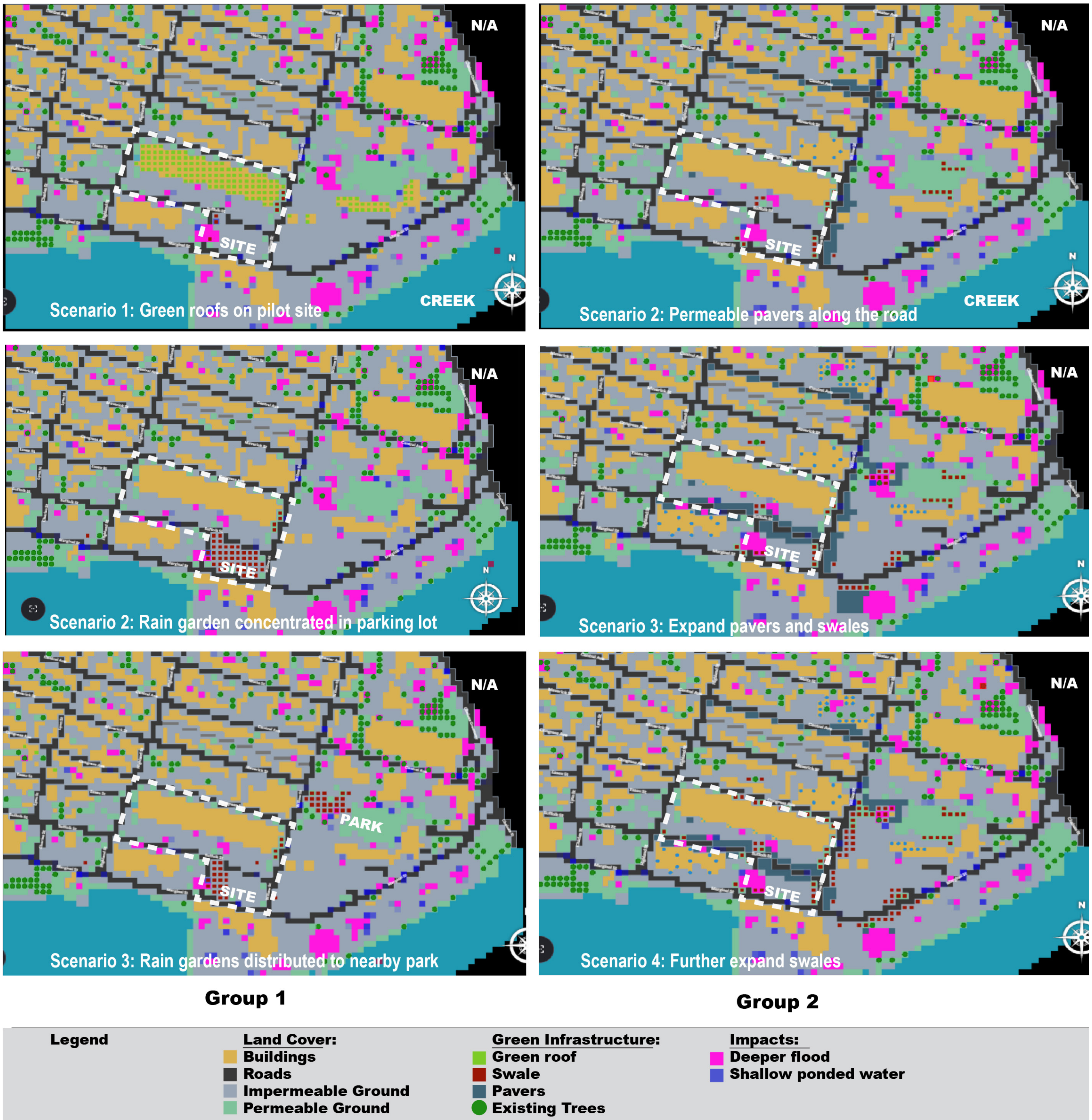

Figure 4. Workshop scenarios designed by City of Chelsea planners. Pixelation is inherent to the L-GrID modeling platform, which works in a grid of cells 10m x 10m (32.8 ft x 32.8 ft). The area modeled is 382,400 square meters (~0.4 sq km). Group 1 (left) had concentrated patches on specific sites. Group 2 (right) distributed GI into a corridor of swales connecting the site and low points.

In response to the shortcomings of concentrated approaches, a participant commented that although rain barrels may not be as effective as large GI, "everyone can have a rain barrel, and they get a sense that they are helping." This is also a form of signaling, in this case, of collaboration and shared responsibility. Although modeling shows the relative impact of smaller efforts as negligible, the exercise suggests an ambition to connect efforts and create an environment that supports the resolution of trade-offs and cooperation (e.g. rain gardens in houses may be more palatable than trees that reduce parking in overburdened communities). A future workshop could test whether engaging municipality, resident, and developer in equity-focused and science-based conversations about big site projects doing relatively

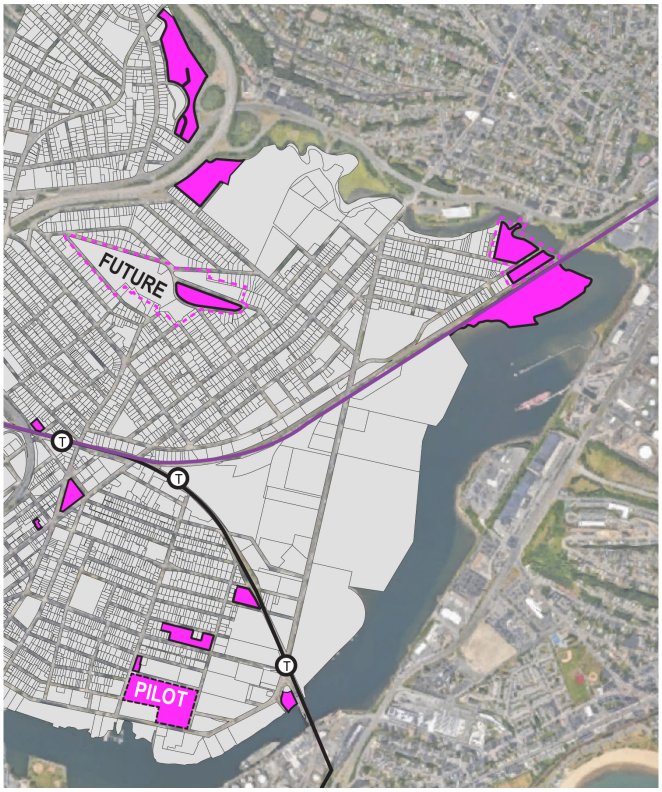

Figure 5. A map of Chelsea parcels, showing pilot site and proposed future sites (pink) developed in collaboration with the City of Chelsea after planners experimented with the PM process. These future major developments are located in critically vulnerable areas of the city (high flood, air quality, and/or heat hazard) where equity is a concern due to socially vulnerable populations.

big things, becomes a catalyst to consider many smaller efforts as part of a connected and coordinated system.

Future sites

Following the workshop, the research team had conversations with city planners about applications of this process to future sites. Their targets were major redevelopment projects, primarily for housing (new construction of mixed income housing or renovations of subsidized housing) where equity is a primary concern, as well as some GI projects near City Hall and a survival center in downtown. (Fig.5). City planners believe this data can support the coupling of grey and green infrastructure to: (1) evaluate impacts of major projects on centralized infrastructure where the city is undertaking upgrades, for example what are the inputs on stormwater infrastructure that will be in the process of being retrofitted over a 50-year period, or what are the effects in air quality from changes in land use or transportation; and (2) improve the community engagement process to build support for and adoption of GI.

This data can help planners understand how major projects change the loads on the system. In the context of special permit projects, it could help define specific criteria for open space development. The city of Chelsea has typical zoning requirements for percentage of open space and Floor:Area Ratio (FAR) but does not dictate the performance of these open spaces unless the project is going through a special permit. Planners are considering a checklist of minimum metrics to provide, but they believe our process could help make metrics more specific to relevant impacts.

A site of immediate interest for the city is located at the top of the hill (upstream from the pilot site), which they suspect will change loads on various basins in the city. Surrounding residents are wealthier and more vocal than those on downstream sites, and more narrowly focused on immediate tradeoffs like parking. The next phase could reveal whether this equity and science-based approach foreground impacts on communities downstream. In the words of our main partner in the city, "Outreach typically asks people for their opinion, but never completes the loop to understand what the implication of their opinion is?" They hope that our approach could open up a more genuine collaboration with communities and lead to more effective conversations around GI in development projects. The team began outreach and planning for a future workshop with designers, community members, and city officials focused on this new site.

CONCLUSION

An equity-centered, science-based PM processes can be a catalyst for decentralization, integrating architecture into a coordinated system of private and public GI space at multiple scales. It facilitates aspirational discussions about design as much on cultural aspects (legibility, signaling) as much as on the technical. Surprisingly decentralization is not an obvious answer early on, but it can become a significant paradigm shift in rethinking green infrastructure, even among practitioners.

Identifying high impact architecture projects can be a productive space in which to negotiate the performance of specific sites with potential GI changes to the surrounding fabric (block, neighborhood, region). This transdisciplinary method can expand traditional site analysis in architecture practice, which relies on more static regional climate data, intuitions, and rules of thumb; and can improve community engagement, which often seeks approval rather than co-authorship, to co-generate knowledge about social context, microclimates, hydrology, and ecosystem functions within and beyond the site boundary. Next steps in this work are to integrate health metrics in the results of the tool, to expand the conversations about relevant impacts and tradeoffs. Lastly, while this work centers the PM work on a single site, we are beginning to look at multiple sites along corridors in the city of Boston, working with community groups and city planners to support neighborhood scale design. Future work will need to examine the potential for coordination of decentralized sites as a larger and cohesive regional system.

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