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Creating GIS-Based Planning Tools to Promote Equity Through Green Infrastructure

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The Philadelphia Water Department, now known as Philadelphia Water (PW), has been coordinating with other city and private and non-profit stakeholders to install green infrastructure (GI) across the city as a means of addressing stormwater runoff as well as promoting social, economic, and environmental benefits such as improved health, job creation, and carbon sequestration. While many planning tools exist to assist in the development of green infrastructure projects, recent critiques have highlighted limitations in their considerations of non-environmental concerns, and several new planning tools have been proposed that use indexes and other need-based approaches to account for a wider range of potential program impacts. Even these new ideas, however, fail to systematically account for the possibility that not only desired GI benefits but also the impacts of specific GI projects may vary considerably from place to place. Based on our experiences with a community advisory board working to assess co-benefits of GI, we propose the inclusion of more interactive methods for incorporating community perspectives on the benefits of GI into GI planning methodologies to make them both more equitable and more responsive to community needs.

Keywords: equity, green infrastructure planning, stormwater, planning tools, community based planning, Philadelphia

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GREEN INFRASTRUCTURE FOR STORMWATER MANAGEMENT

In 2012, the US EPA approved *Green City, Clean Waters,* Philadelphia's green infrastructure approach to stormwater management. To reduce the incidence of combined sewer overflow events, PW proposed using "natural" systems such as tree trenches, rain gardens, and pervious pavement to manage stormwater, rather than traditional "gray infrastructure" approaches such as pipes and retention basins (City of Philadelphia Water Department, 2009). It presented a decentralized strategy that involved the cooperation of numerous city agencies, community partners, and citizens. The plan required PW to both directly invest and also leverage private investment in GI, with an expectation of approximately $3 billion being invested in the program over the first 20 years of implementation. In many ways Philadelphia's GI approach has been an experiment in stormwater management that requires a rethinking of PW's relationship with stakeholders. Instead of a top-down approach in which a single water utility was responsible for building one centralized infrastructure system, *Green City, Clean Waters* envisioned a series of potentially thousands of individual infrastructure projects implemented by a wide range of stakeholders to meet goals that extended beyond stormwater runoff reduction.

While Philadelphia was hailed as unique in proposing a combined sewer overflow control plan entirely based on the use of GI, it is far from the only city that has expressed interest or developed programs for city-wide promotion and implementation of GI for stormwater management. Following Philadelphia's lead, New York City and Washington DC have both incorporated GI into their stormwater strategies and the EPA has released guidance for small cities wishing to do this as well. One of the primary reasons for recent interest in GI for stormwater management is the understanding that GI can provide community benefits. PW commissioned a triple bottom line assessment of *Green City, Clean Waters*, arguing that it would provide economic benefits through job creation, social benefits through increasing recreational amenities and improvements in health, and environmental benefits of carbon sequestration and improved air quality (City of Philadelphia Water Department, 2009). This drew on a larger literature on urban greening that shows wide-ranging benefits of greening projects including crime reduction, improved physical and mental health, and increased property values in greened areas (Kuo and Sullivan, 2001; Tzoulas et al., 2007; Heckert and Mennis, 2012; Garvin et al., 2013).

One of the particular challenges for these types of GI programs is that they must be implemented as a large series of many small projects rather than as a single large-scale greened site. They further rely on implementation not only on public properties and rights-of-way but also on privately owned properties. This requires buy-in from myriad residents and stakeholders, presenting a challenge for planning, as the needs of varying stakeholders may differ considerably (Keeley et al., 2013) and necessitates the development of new planning tools that both educate stakeholders about the benefits of GI and help them make decisions about how to target investment to meet the particular needs of their communities.

Traditional approaches to green stormwater implementation have relied on engineering approaches that assess sites and determine potential forms of GI or that assess larger locations to determine the appropriate locations for GI. These approaches, however, have typically focused specifically on achieving stormwater management goals within a particular budget, without consideration of any additional benefits that GI might provide, the particular needs of the surrounding community, or the equitability of the overall distribution of GI. Once the ancillary benefits of GI are incorporated into planning, it becomes necessary to consider equity as a matter of environmental justice. If public money is being invested to ensure a range of community benefits beyond stormwater management, then it is imperative to consider to whom those benefits are accruing. In recognition of this limitation, several teams of researchers have recently proposed new tools and methodologies for GI planning processes that explicitly examine the distribution of GI and its associated benefits.

CONSIDERING EQUITY IN GI PLANNING

Heckert and Rosan (2016), Meerow and Newell (2017), and Dagenais et al. (2017) have all proposed means of identifying target locations for GI investment based on combining community indicators that quantify need for some of the ancillary social and environmental benefits of GI to identify the areas that stand to benefit most from GI implementation. While there are differences between the three approaches, our interest is not in promoting one over the others but in suggesting future directions that could apply to all three. Each method represents a move in the direction of a more inclusive planning process that considers community needs and attempts to efficiently site GI to ensure the most effective and equitable use of GI. Perhaps more importantly, each provides a flexible framework that enables stakeholders to weight various community conditions, allowing the people closest to the planning process to decide which factors are most important in their local context rather than assuming that all considerations are equally important.

This paper builds off of the first of these studies, a Green Infrastructure Equity Index published in 2016 (Heckert and Rosan). The GI Equity Index is a prototype of a Geographic Information Systems (GIS) planning tool that can be used by stakeholders at the city or neighborhood level to start a conversation about the way that GI can be distributed across the city to meet community needs. The index currently includes geographic layers of 14 indicators of environmental and sociodemographic conditions, chosen for their relationships to the potential ancillary benefits of GI and connection to environmental justice concerns, which can be interactively weighted and combined to identify the areas of the greatest composite need for GI implementation (**Figure 1**). Using the index, we can identify areas of the city that may have the greatest need for GI investment and help target investment to places where GI investment is not currently being made. The index can also be used to assess the extent to which existing or proposed distributions of GI are serving high-need areas.

We developed the GI Equity Index with the goal of using it to inform a larger multi-objective decision making model known as StormWISE that was developed by Arthur McGarity and is being incorporated into a larger EPA STAR research project. The StormWISE model allows users to choose desired outcomes for stormwater management then uses cost-benefit analysis to determine the most cost effective allocation of resources in terms of both GI types and sites to achieve the stated goals (McGarity, 2010). The initial model included only direct environmental benefits such as reductions in stormwater volume and pollutant loads, while the current project seeks to expand the range of benefits that can be assessed. As a part of this project, we have worked with a group of advisers from the community and government as a part of our GreenPhilly Community Advisory Research Board (GCARB) in an effort to develop a series of protocols, which could be used to evaluate the ways in which different communities assess their needs and what role they see GI practices playing in addressing those needs. These meetings raised a series of concerns that must also be incorporated into GI planning processes to ensure equitability. The primary concerns that we propose must additionally be included are: (1) that understanding of GI varies considerably within the population and education must be part of the process; (2) that even with a common understanding of what GI is, community

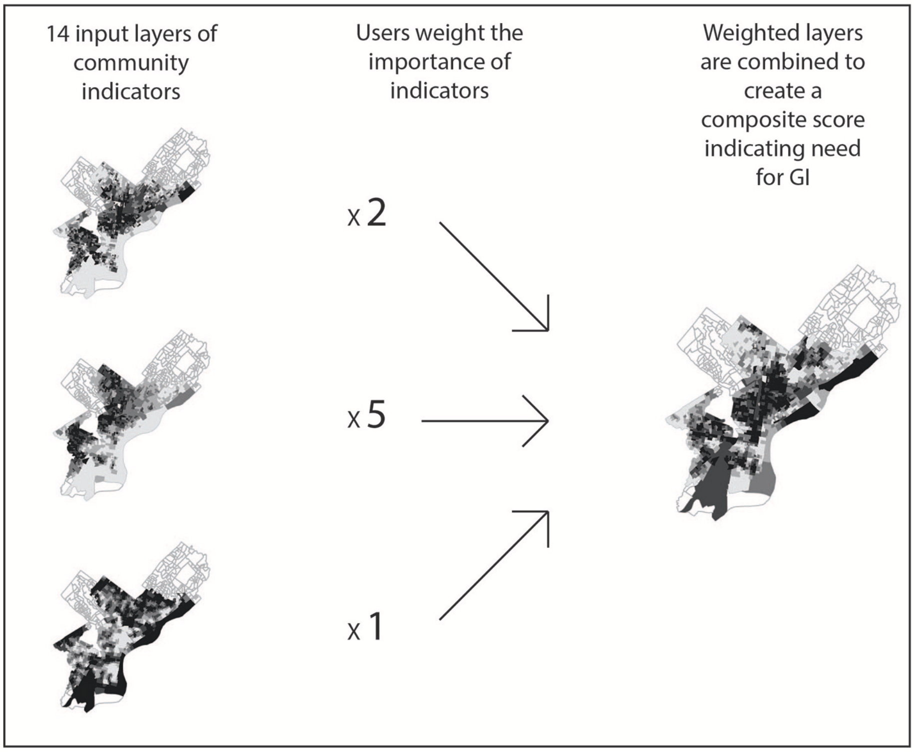

FIGURE 1 | Schematic of the Equity Index in its current form. The original fourteen indicators included: 1) impervious surfaces; 2) particulate matter; 3) traffic; 4) ozone; 5) playground density; 6) parks access; 7) tree canopy cover; 8) percent non-white; 9) percent low-income; 10) percent low educational attainment; 11) percent under 5; 12) percent over 64; 13) percent owner-occupied housing; and 14) vacant land density. The framework is flexible, allowing for different indicators to be used as desired.

members may differ in their perceptions of the benefits (both positive and negative) GI offers; (3) that GI benefits may vary considerably based on the context of the neighborhoods within which they are implemented; and (4) that GI implementation must be considered along with other community pressures like gentrification.

This prioritization of GI investments requires a certain level of environmental education and a more visual approach that engages stakeholders. In one research team meeting with our GCARB, we asked advisory members to give us their feedback on a prototype of a "game" where they were first exposed to various GI techniques and asked to rate the ways in which they felt each GI practice offered socio-economic and community benefits. After they assessed each GI practice, they were placed in groups and asked to spend $100 K in their communities on GI investment. In this scenario, they saw a map of the neighborhood and pictures of the various types of GI practices such as rain gardens, tree trenches, and pervious pavers, with associated costs. It is important to note that while GCARB members generally agreed about the overall potential benefits of GI, they did not agree on the level of importance of these benefits or the extent to which specific GI practices offered them, nor did any two groups create similar plans for spending their hypothetical $100 K. This was particularly true for consideration of more subjective types of benefits, such as creation of community amenities or improved esthetics. It is precisely this kind of variation that must additionally be considered.

Our GCARB members suggested that the visuals were helpful to them because they made GI practices more tangible. This was a very simplistic game; however, we think this approach could be incorporated into an app where citizens could first be asked to assess their community needs using the GI Equity Index, then given an opportunity to learn about how GI might help them meet their needs, and then offered an opportunity to make hypothetical "investment decisions" as a means of assessing which type of GI practice they felt would be the most efficient and effective in their neighborhoods (**Figure 2**). This hands on, more visual approach that includes pictures and some initial explanation of what GI is and how it works, may help citizens understand ways in which GI installation can help improve their communities (McGarity et al., 2015; Hung et al., 2016).

Anecdotal evidence in Philadelphia (based on both observations by the authors during participation at Water Department outreach events and comments by members of GCARB) suggests that many citizens are not even aware of the *Green City, Clean Waters* program and when they do become aware of it, it is because of what they perceive to be potential negative impacts such as trapping litter in planters, a "weedy"

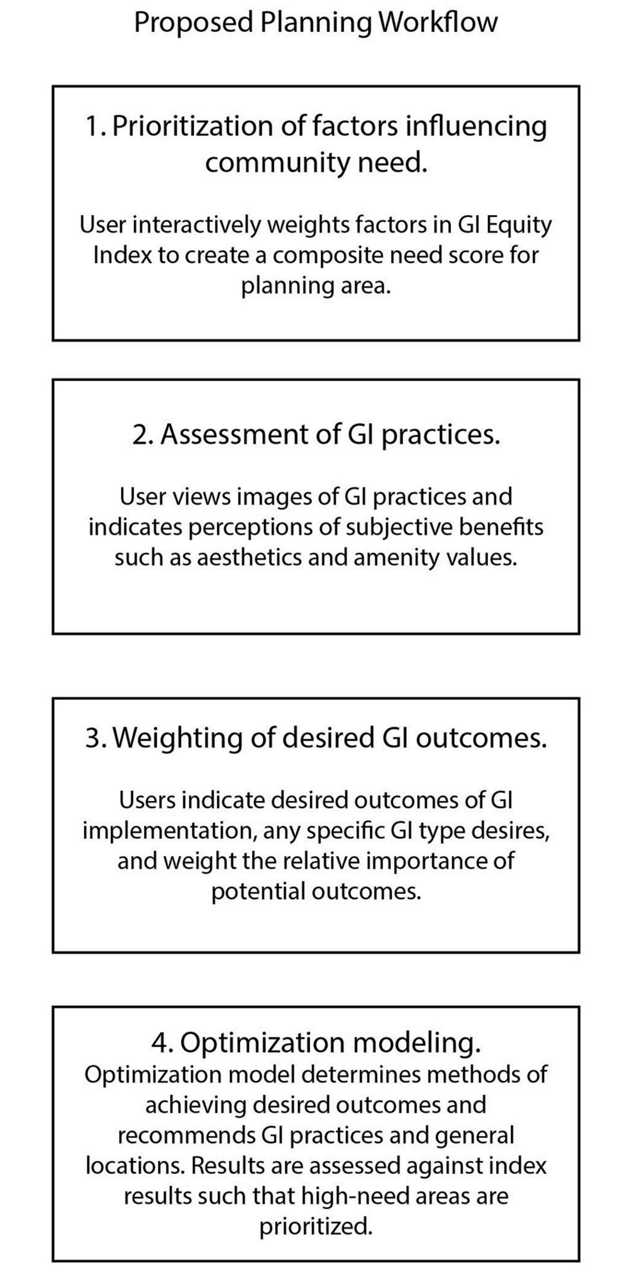

FIGURE 2 | Schematic of proposed planning tool incorporating equity index and additional planning concerns.

look to some rain gardens, or the potential for tree roots to cause damage.

While the nuisance value of GI and other greening initiatives is often at the front of conversations about GI, helping citizens make the direct connection between neighborhood improvement and GI investment is more challenging, particularly in a city with extreme rates of poverty and a host of other more urgent socio-economic and environmental challenges. In addition, in a city where certain lower-income neighborhoods are rapidly gentrifying, we see cases where residents identify investment in GI as a precursor to being pushed out of the neighborhood as property values increase, what is often termed "green gentrification" (Pearsall, 2010; Checker, 2011). Travaline et al. (2015) noted distrust both among residents and between residents and government as challenges to GI implementation in one Philadelphia neighborhood, at least partially due to concerns over possible future redevelopment. As lower-income residents begin to feel threatened by GI practices because they are associated with neighborhood change, we need to engage residents in a conversation about GI investment and increasingly we also need to recognize GI investment as a part of a larger set of place-making tools. These tools need to be incorporated into a larger conversation about neighborhood change and gentrification. The GI Equity Index and other planning tools can be adapted so that they help identify parts of the city that are "threatened" by gentrification and other parts of the city where there is little investment. In addition, as planners, we need to combine place-making efforts with place-staying efforts using financial tools such as community land trusts, promotion of affordable housing, or property tax relief for low-income homeowners. This will require Philadelphia Water to coordinate with other agencies to more adequately assess the impact of GI installation in neighborhoods and take steps to mitigate any harmful impacts such as resident displacement.

The development of the GI Equity Index came out of an interest in thinking more strategically about how to make the best GI investments in communities. Since PW is spending money to install GI, particularly through public/private partnerships, and working to incentivize GI installation, we are interested in developing a tool that allows stakeholders to think more systematically about what an equitable distribution of GI might look like that could both address stormwater and also provide a host of ancillary community benefits.

We recognize a need for a more nuanced typology of GI that can be used to better examine the way that GI connects to the physical built environment as well as the way that it is perceived by residents from different socio-economic and cultural groups. These planning processes need a set of flexible assessment tools that can be used not only to identify the need for green infrastructure but also to provide a toolkit that will help stakeholders assess which GI installations might be the most effective at meeting their particular needs.

AUTHOR CONTRIBUTIONS

MH and CR have both participated in all aspects of the broad research project discussed here. MH completed the GIS portion of building the index and CR organized and ran the community advisory research board meetings.

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