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Green Infrastructure Solutions to Health Impacts of Climate Change: Perspectives of Affected Residents in Detroit, Michigan, USA

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Abstract: Cities worldwide are incorporating green infrastructure to mitigate climate change and achieve health cobenefits. However, green infrastructure projects are often distributed inequitably based on race and class. Residents' perspectives are necessary to develop and enact effective and equitable 'green' strategies to address climate change and its health impacts. This study reports findings from interviews and ethnographic observations with diverse residents of Detroit, Michigan, USA, who have experience with both green infrastructure projects and intense weather events (flooding). Residents expressed widespread support for green infrastructure solutions, while also sharing concerns about unintended health consequences from unsatisfactory governance of green spaces and climate change itself. Residents also held differing perspectives regarding their responsibility for, and capacity to enact, these solutions compared to businesses, city government, and nonprofit organizations. These findings illuminate key factors that city governments and partnering institutions should incorporate into planning processes with residents to achieve greater environmental justice through green infrastructure strategies to mitigate climate change and related health impacts.

1. Introduction

Cities worldwide are incorporating green infrastructure to mitigate climate change, and its associated human health impacts. Street trees, woodlands and other vegetation store greenhouse gas emissions, keep neighborhoods cooler on high heat days, and filter stormwater from increasingly frequent heavy rainfall events [1,2]. Green infrastructure can even limit damage from tropical storms and hurricanes by reducing the force of winds and absorbing excess floodwaters [3,4]. However, trees and vegetation can also suffer damage during storms that can increase risk of injury or other harm to nearby human populations [5]. Furthermore, climate change facilitates the spread of some invasive insects and diseases to trees and other vegetation in urban areas, including emerald ash borer (EAB) which began its decimation of ash trees in Detroit, Michigan, and has since spread to several states [6]. These circumstances undermine the ability of green infrastructure to mitigate climate change and improve the health of city residents.

The term "green infrastructure" is open to some debate, and constitutes a variety of practices within the umbrella of "nature-based solutions." For this study, we utilize the definition offered by

the U.S. Environmental Protection Agency: "Green infrastructure uses vegetation, soils, and other elements and practices to restore some of the natural processes required to manage water and create healthier urban environments" [7]. This includes downspout disconnection, rainwater harvesting (e.g., rain barrels), rain gardens, planter boxes, bioswales, permeable pavements, green streets and alleys, green parking, green roofs, urban tree canopy, and land conservation [7]. Our study focuses on this definition because of its emphasis on green infrastructure as a mitigation strategy for stormwater management—a growing issue in urban communities like Detroit, Michigan.

There are considerable environmental justice implications embedded in the design and implementation of green infrastructure solutions to climate change. For example, many cities or foundations working within cities offer grant funding or other financial incentives to businesses and individuals who engage in green infrastructure solutions, such as installation of rain gardens and green roofs to capture and filter stormwater during heavy rain events. However, such funding can perpetuate environmental injustices if grants are awarded only to those with resources to secure grants, leaving out those with limited grant writing experience or capacities, economic resources, or those who do not meet prerequisite criteria [8]. Physical abilities and technical skills are also required to plant and maintain trees, rain gardens, or other green infrastructure solutions. Furthermore, "green infrastructure" does not produce health benefits for everyone, all of the time. For instance, tree cover is associated with both positive and negative effects on respiratory illness, asthma, and allergies [9]. Governance regimes and climate change itself interact with green infrastructure to cause an array of outcomes, which can include negative outcomes to health, though these are understudied barriers to green infrastructure implementation. Attention to these details can lead to more equitable distribution of costs and benefits, greater inclusion of groups traditionally marginalized from decision-making processes that impact their local environment, and more sustainable green infrastructure strategies.

Issues of climate justice at the city scale are receiving a growing amount of scholarly attention [8]. Urban heat—measured through land surface temperatures—is significantly greater in census tracts with more residents from racial/ethnic minorities and higher poverty rates in several U.S. cities [10,11]. Urban tree cover, which mediates temperatures as well as stormwater runoff, is also disproportionately lower in neighborhoods with higher percentages of non-white residents and lower income residents [12,13]. In response to these distributional inequities, several U.S. cities have taken steps to increase urban green space in neighborhoods that currently experience a dearth of such resources [14]. However, this goal raises concerns about "ecological gentrification," or displacement of lower income residents that occurs when neighborhoods become more "green," thereby increasing property values and taxes [15]. Additionally, residents in Detroit, Michigan, have expressed resistance to particular green infrastructure approaches (i.e., street tree-planting programs) when they feel they lack meaningful inclusion in decision-making about species to plant and long-term maintenance responsibilities [16,17]. These findings align with other studies of social resistance to urban greening that have used an urban political ecology lens to identify how governance of urban forests within capitalist economic contexts has prioritized commodification of trees and their instrumental value for maximizing financial profits (i.e., by attracting wealthier residents and businesses to cities), rather than inclusion of marginalized residents to achieve holistic and equitable well-being of all residents [18]. These sociopolitical dimensions of urban forestry and green space management present another threat to climate justice within cities, and signal the importance of understanding the perceptions and experiences of city residents in regards to green infrastructure to move towards more just and sustainable cities [19].

Abundant scholarship identifies some dimensions of the physical and mental health benefits of green infrastructure in urban environments (for reviews see [20,21]). However, studies of health and green infrastructure are limited in scope. For example, in a recent systematic review of research, scholars found no studies that connected mental and physical health outcomes to green infrastructure specifically designed for stormwater and flood management [22]. Additionally, such research often omits discussion of how to ensure equitable distribution of the costs and benefits of green infrastructure

projects within current social and political environments in cities. While research on the execution of such "green solutions" has acknowledged the potential for injustices to occur, engagement with diverse populations of residents who are vulnerable to climate change impacts has been limited. As such, there is a critical need to understand the experiences of diverse, vulnerable populations with green infrastructure solutions that have been implemented by city governments, foundations, and other formal institutions. This is an urgent area for future research in the city of Detroit, Michigan [23].

Perspectives of residents who are vulnerable to health impacts of climate change, yet often marginalized from decision-making processes based on income, race, and/or class, provide necessary insights to gauge the environmental justice and overall efficacy of green infrastructure solutions at neighborhood and city scales. These perspectives are also needed to achieve holistic health, defined as: " . . . not just the physical well-being of an individual but the social, emotional, and cultural well-being of the whole Community in which each individual is able to achieve their full potential as a human being thereby bringing about the total well-being of their Community" [24].

The study reported here sought to understand how residents who are vulnerable to health impacts of climate change—based on their geographic location and/or income, race, and other demographic characteristics—responded to green infrastructure solutions presented in policies and outreach materials from the city government and its nongovernmental partners. In particular, we investigated two research questions: (1) What are the benefits of green infrastructure from the perspective of city residents vulnerable to climate change impacts? (2) What barriers do city residents face to implementing green infrastructure? Our findings highlight how local residents experience and perceive green infrastructure deployed in the current social, political, and environmental landscape. Residents' perspectives provide helpful guidance that can be used to revise existing governance approaches at the city scale to maximize the holistic health benefits of green infrastructure in an era of climate change.

2. Materials and Methods

2.1. Study Site

We collected data for this study between March and April 2018 in the city of Detroit, Michigan (population 672,795 in 2016), located in the Midwest U.S. The city experienced federal disaster-designated flooding in August 2014 (partly as a result of a historically heavy rainfall event), which was followed by another major flooding event in certain parts of the city in September 2016. Observed and predicted increases in heavy rainfall events, in addition to existing sewage infrastructure degradation and ongoing recovery from bankruptcy declared in 2014, have prompted several city government policy changes intended to promote the use of green infrastructure by residents and business owners as a mitigation strategy. However, some of these policies have been criticized by residents as an inequitable burden on low-income residents [25].

2.2. Data Collection and Analysis

Data were collected in three ways: One-on-one scheduled interviews with residents, observation of dialogue among stakeholders at local community meetings, and field notes from conversations with residents at community meetings. The first author conducted structured, audio-recorded interviews with 21 residents, which lasted 30 min to 1 h. Approval for the data collection methods was provided by the researchers' University Research Protections Office (CHRBSS code #: 18-0231). Interviews were transcribed by a third party, then coded and further analyzed by the authors using a directed content analysis approach within Microsoft Excel software [26]. This approach to data analysis entails reading through interview transcripts to identify themes related to the research questions (i.e., benefits of, and barriers to, green infrastructure implementation), and then developing subcodes within those themes (i.e., specific types of benefits or barriers). We utilized Microsoft Excel to organize interview responses according to themes and subthemes, as well as to track interviewee demographics that were associated with each theme.

Participants were asked to review a list of 10 health impacts of climate change identified by scientists and indicate which they were concerned about impacting their local community. Participants were then asked the following questions:

1. What do you think are potential solutions to the issues you are most concerned about?
2. How does your local community engage with those solutions, or other solutions?
3. What do you think are some barriers to dealing with these issues in this community?

Subsequently, participants were given two fact sheets to review from the Detroit Climate Action Collaborative, outlining health impacts of increasing high temperatures and heavy rainfall events, as well as some strategies to mitigate and adapt to these conditions [27,28]. At this point, residents were asked:

1. What parts of these information sheets do you find useful?
2. What else could the state or city be doing to help address the weather-related health issues that most concern you?
3. What else would you like to share with me that I didn't think to ask?

In response to these questions about the fact sheets and green infrastructure solutions proposed within them, many residents shared their perspectives on the benefits of specific green infrastructure approaches. At the conclusion of each interview, participants were asked to complete a demographic questionnaire.

Field notes recorded during observation of six community meetings between 14 March and 8 April 2018, as well as conversations with residents at these meetings in the study sites, provided an additional source of data which were compared with interview findings to see how broadly applicable themes were among the larger community [29]. These events were forums where participants discussed the impacts of flooding and ways to address this issue in the future, including: two different neighborhood community group meetings focused on discussing current issues faced and resources for neighborhood residents, a housing resource fair hosted by a third neighborhood community group (and attended by city government agencies), a "Land and Water Works Forum" co-hosted by the Detroit Water and Sewerage Department and at least six other local environmental organizations (e.g., Friends of the Rouge River, Detroit Future City), and a neighborhood revitalization planning meeting for one of the study neighborhoods organized by the city government. Residents received invitations to attend by email or mail from the organizers of each forum, or saw flyers and online advertisements for the forums posted by organizers, and self-selected to attend.

2.3. Interviewee Sampling

We selected study participants in three neighborhoods in southeast Detroit which have a history of flooding issues reported by residents and scholars working in the area (Figures 1 and 2). These neighborhoods are located near the Detroit River and the city's sewage treatment facility. To identify participants, the first author contacted leaders of local neighborhood groups and city government employees who provided suggestions on local events at which to meet residents and invite them to participate, and in some cases provided connections to specific residents to invite. This method of purposive sampling through the use of community gatekeepers helps to create trust and rapport between researchers and participants, leading to results and interpretations considered credible to the local participants [29].

We stratified our sample based on: (1) income (both above and below the median income, which between 2012 and 2016 was $58,411 annually for Detroit metropolitan area) to ensure a diversity of socioeconomic perspectives; and (2) length of residence, because these two factors could affect perceptions of newly instituted green infrastructure policies, as well as the distribution of costs and benefits of green infrastructure solutions. The interviewer asked participants how long they had lived in their neighborhood (and the city in general) at the start of the interviews. At the end of the

interviews, participants were asked to check a box to indicate their income category (ranging from less than $15,000 a year to more than $200,000 a year), provided on a demographic questionnaire. In total, 21 residents from a range of income levels, ages, gender identity, lengths of residence, and race completed interviews (Table 1).
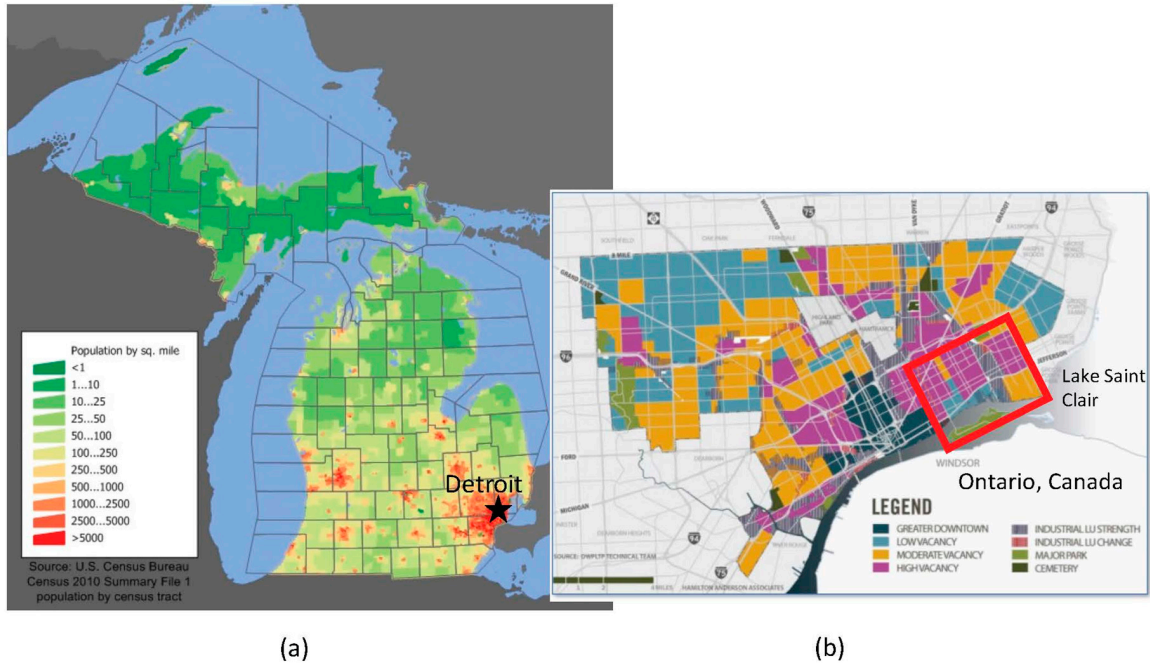

(a) (b)

Figure 1. (**a**) State of Michigan population density map [30]; (**b**) City of Detroit boundary indicating degree of property vacancy [31]. Neighborhoods selected for this study are outlined in a red box.

Figure 2. Flooding reported by residents in one of the study neighborhoods at a local meeting organized by the city government on March 27, 2018. Red dots indicate areas of heavy flooding seen, and green dots indicate mild flooding.

Table 1. Demographic characteristics (gender identity, age group, race, ethnicity, income category, and length of residence) of Detroit residents interviewed (n = 21).

Demographic Characteristic	Categories	Number of Respondents
Gender identity	Female	13
	Male	8
	Gender variant/nonconforming	0
	Not listed (space to write provided)	0
Age (years)	25–34	2
	35–44	4
	45–54	3
	55–64	7
	65–74	3
	75 or older	1
Race	Black or African American	10
	Caucasian or White	9
	Asian or Pacific Islander	1
	Other	1
Ethnicity	Hispanic or Latino/Latina	1
	Not Hispanic or Latino/Latina	12
	No answer provided	8
Income Category	Below Median (<$58,411 annually for Detroit metropolitan area *)	8
	Above median (>$58,411 annually)	10
	Not disclosed	3
Length of residence	0–4 years	4
	5–19 years	2
	20–39 years	5
	40 years or more	10

* Source: U.S. Census, 2017 American Community Census 2017, for Detroit–Warren–Dearborn Statistical Metropolitan Area. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?fpt=table.

3. Results

Nearly half of the residents interviewed identified benefits that could accrue to multiple levels of stakeholders (i.e., individuals, neighborhoods, jurisdictions) and to multiple domains (e.g., health, economy, environment) from a range of green infrastructure practices, such as the installation of rain gardens (Section 3.1; Table 2). However, three main barriers to implementation of green infrastructure emerged: (1) unintended health consequences, (2) limited capacity among residents and within city government, and (3) limited awareness of the health threats of climate change and how green infrastructure addresses those specific threats (Section 3.2; Figure 3). Respondents identified two contributors to these barriers: (1) past and current governance of urban green spaces, and (2) climate change impacts. Concerns about the rights and responsibilities of various urban actors to institute "green" solutions also emerged, with several interviewees pointing out differential access to resources to implement green infrastructure practices based on race, property ownership, and length of residence. These themes are described in detail below, followed by a discussion of how government actors and their partners can integrate residents' perspectives into more equitable and effective green infrastructure strategies. Interviewee numbers are provided with each participant quote (e.g., 1D = first Detroit participant).

Table 2. Benefits of green infrastructure identified by Detroit residents interviewed (n = 21).

Perceived Benefits of Green Infrastructure (Number of Respondents)	Perceived Domain of Benefit	Example Quotes
Decrease usage of city water (3)	Economic	"I've got a rain barrel myself. I love it. That much less I have to pay to the city for water. When you get your water bill, one-third of that bill is for actual water use. Two-thirds of it is the cleaning, and the processing, and everything else. That's what makes the water bill so high...It just means I don't have to use the city water. I can use that to water my garden, water my flowers." (14D)
Absorb stormwater runoff (3)	Ecological, Economic	"I know some of the algae blooms that occurred in Lake Erie has affected the city policy on stormwater and stormwater drainage and I know that's affected us knowing that we'd rather naturally filter a lot of the water that's fallen from the sky, naturally filter it through the soil rather than put it into the drainage systems. And they can also save money doing that with anticipated drainage fees that are coming from the city." (15D)
"Green" alleys could be more usable and safe than existing alleys (2)	Social, Health, Ecological	Green alleys "take what is a pretty beat up piece of infrastructure and clean it up and make it much more usable, friendly, and safe for people … And also the environmental gains, if you can show development that helps the environment then that's a wonderful thing." (15D)
Regulate outdoor temperatures (2)	Ecological, Economic	"All of the benefits that natural foliage does for cleaning air, and moderating temperatures, and taking carbon out of the atmosphere … I planted a liberty elm, one of the disease-resistant ones. And now, it's almost to the third story and so I don't run the air conditioner anywhere near as much because it's shady. Definitely because of the cost of energy, people are paying more attention to home efficiency, insulation, all that good stuff." (8D)
Habitat restoration (1)	Health, Ecological	"I think it's five million dollars to do habitat restoration in that neighborhood, specifically around the canals and the parks. I think that sort of thing will probably help with these two issues [increased bacteria and/or algae in drinking and/or swimming waters, mosquito and tick-borne illness]. I think finding a natural, healthy ecosystem balance will probably help with some of that. It'll probably help with other things like erosion...I'm not an environmental expert. I'm just excited for money to come into the neighborhood, frankly." (10D)
Increased engagement in gardening (4)	Ecological	"I see a lot of folks are using rain barrels. And also they're using them to work like little gardens and stuff. A lot of folks were doing that. Yeah, it's helpful." (5D) "I just try to do my little part. I try to do my gardening so I can have food … And I'll have bees for pollination. I'll have birds." (4D)

3.1. Benefits of Green Infrastructure

Fifteen of 21 residents interviewed (71%) named at least one benefit of green infrastructure when describing solutions to mitigate heavy precipitation events. In total, residents identified six major benefits of various green infrastructure practices: decreased usage of city water, increased stormwater runoff absorption, more usable and "friendly" alleys, regulating outdoor temperatures, habitat restoration, and increased engagement in gardening (Table 2). Perceived benefits extended beyond the realm of direct health outcomes (e.g., reduction in waterborne and vectorborne diseases) to include improved social and economic conditions, both of which also affect health.
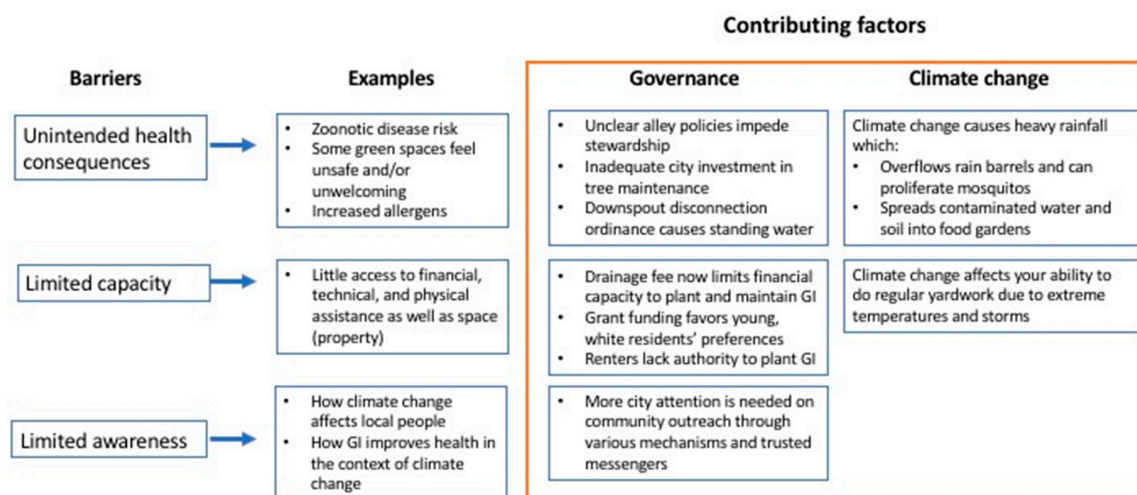
Contributing factors

Barriers	Examples	Governance	Climate change
Unintended health consequences	• Zoonotic disease risk • Some green spaces feel unsafe and/or unwelcoming • Increased allergens	• Unclear alley policies impede stewardship • Inadequate city investment in tree maintenance • Downspout disconnection ordinance causes standing water	Climate change causes heavy rainfall which: • Overflows rain barrels and can proliferate mosquitos • Spreads contaminated water and soil into food gardens
Limited capacity	• Little access to financial, technical, and physical assistance as well as space (property)	• Drainage fee now limits financial capacity to plant and maintain GI • Grant funding favors young, white residents' preferences • Renters lack authority to plant GI	Climate change affects your ability to do regular yardwork due to extreme temperatures and storms
Limited awareness	• How climate change affects local people • How GI improves health in the context of climate change	• More city attention is needed on community outreach through various mechanisms and trusted messengers	

Figure 3. Barriers to green infrastructure (GI) implementation identified by Detroit residents (n = 21).

3.2. Barriers to Green Infrastructure Implementation

3.2.1. Unintended Health Consequences

In addition to these benefits of green infrastructure, nine of 21 interviewees mentioned concerns about potential unintended consequences of implementing various green infrastructure. Concerns included increases in zoonotic disease threats from lack of stewardship in the current unclear governance of green space in the city. As one resident said of alleys that run behind homes:

> When the city closed the alleys, I don't think that they [city government] properly prepared people, or explained to people, that once the alley was closed that it extended their property line back to that alley. And as a result of that people lost their backyards because it's so overgrown, it becomes spooky … the children can't safely play back there because now they're worried about vermin, and wild animals, and things like that. Rats, you know rats can build habitats in those thick alleys. Add to that some abandoned furniture and all of the debris, and you have health-related issues. Because rodent feces is dangerous. (1D)

Another resident, who secured a grant as leader of a block club to implement a "green alley" project, also remarked on governance hurdles:

> We are trying to work with Detroit Water and Sewerage Department on how to install those sorts of structures that filter water. And there's some confusion around that, there's no set policy at this point from the city. I think they're getting close to it but it's been a difficult process for us. So we've tried to respond by showing a good example of ecologically friendly water, filtration and water drainage with this green alley project. (15D)

Maintenance of green space is a long-standing challenge in Detroit which some felt was slowly improving. As one 20-year resident remarked regarding street trees:

The city used to maintain trees. And during the last gasp of the old regime, they weren't even cutting down the ones that died. The street parkway trees. The city, it's gotten better, but up until fairly recently, you got anything done in spite of the city. (8D)

A lifelong resident similarly commented on the city's challenges with managing vacant lands:

There was a time not too long ago that the city had a lot of abandoned buildings and/or property. And so an individual could get a citation for not taking care of their building or property, but then the city had hundreds of them. . . . But it's being turned around. It's being addressed. There's been some change. There's been lots of change. (4D)

A city ordinance requires residents to disconnect the downspouts that drain roof runoff from homes into the combined city sewage system. This ordinance evoked concern about what to do with the water to avoid damage to homes (Figure 4), as one resident remarked:

People buying houses here are going to have to deal with all the problems with the foundations [of their homes] that are created from not having any drainage plan for a very long time . . . We've got ponds all over the place now because of this ordinance. What do we do? (7D)

Figure 4. A resident showing her downspout disconnected from the city sewage system, in compliance with an ordinance which some residents felt created standing water and health issues.

Regarding rain gardens designed to capture stormwater and therefore mitigate flooding, some residents worried about the potential for increased mosquitos and safety hazards. For example, one resident noted the importance of 'blue and green infrastructure' in "preparing for the more extreme storms that are coming our way by planting more trees and just really trying to prevent runoff" but went on to say, "People have talked about this idea of using basements in these demolished houses as rain gardens. I mean that's a hazard for children or whatever. And then just having a pond for water sounds like a big mosquito trap" (7D). Another resident similarly remarked, "Like with the rain garden, how do you not just end up with a giant puddle in your backyard?" (10D).

Rain barrels presented the same concern to these residents in the context of increasing heavy rainfall events from climate change: "A rain barrel fills up pretty much as soon as you have one rain

and they overflow . . . and then it's pouring near the foundation. We tried and it didn't really work out that well" (7D). Two other residents at a community meeting also commented that they did not feel rain barrels would help since the city pipes needed to be replaced.

Increased heavy rainfall events due to climate change created other health concerns specifically related to green infrastructure, including the spread of allergen-triggering pollen: "And the pollen from the trees or plants floating around in excessive moisture that creates more pollen, and ragweed, and mold, and mulch and so forth and so on. So people like myself and my children with allergies, that does not feel good" (19D). Another resident said, "My young daughter, she has this little rash, itchy rash, around her face. I said, 'it's the season.' As soon as the trees bud and the grass turn back green, we can smell it. Yeah the trees are budding, it's that season now" (13D). One resident noted new issues, "For me, as I have gotten older, I've developed allergies that I never had growing up" (14D).

A few residents also worried about contaminated water from heavy rainfall impacting food gardens: " . . . any type of virus or bacteria that's circulating around in the air or the water will contaminate the food in your house, the food in your stores . . . there's a lot of community gardens around too, and that could affect it as well . . . the diseased water" (19D). Others voiced concerns about implementing food gardens in an industrialized environment: "What good would it do people, say to do a garden, if where they're planting the soil is contaminated?" (1D).

3.2.2. Limited Capacity to Implement Green Infrastructure

One-third of residents interviewed noted limited access to the financial resources, technical knowledge, physical ability, and property ownership to implement green infrastructure, even if they wanted to do so. Regarding financial resources, one resident noted this challenge in the context of a revised drainage fee program instituted by the city, which now charges people for water treatment based on the proportion of impervious surface on their property, rather than the previous flat fee:

> And I honestly think that if people have gardens, they got to give them jugs and things to catch the rainwater. They need to give them to people . . . I'm talking about the city, or the country, or the government. They're charging people here for runoff, off of their lots. And so their getting a secondary bill...you don't have living wage jobs...and then it's fee upon fee upon fee. (1D)

At a 2018 community meeting facilitated by the city government to discuss priority issues to address in one of the study neighborhoods, a small group of residents wrote on a piece of flip chart paper their number-one issue: "Flooding and resources for residents without disposable income to remedy flooding." Another lifelong African American resident of a different neighborhood included in this study felt that grants available to implement green infrastructure "more often are awarded to young, white professionals and favor what they want to see in the city" (4D). She went on to explain:

> when [a neighborhood pie shop] came in—not just them, but along this whole strip where they did this commercial business and everything—they had talked about doing a green space where the people in the neighborhood could come, and sit down, and chitchat, and everything. That sounded good, but that has not happened. And these businesses that have been here for about two years. What they've done, they have come up with a grant so that a green space can go behind these buildings, but that only benefits these businesses. It doesn't benefit the community as a whole.

One resident said she needed, "Physical help. Because I like gardening" (6D), while another noted this would be useful "if you're elderly and just don't know how to do it" (8D). One renter also noted current limitations to installing a rain garden, stating, "Once we have our own place, we'll be able to do a little more" (10D). These barriers primarily relate to existing governance of green space (i.e., drainage fee systems, ordinances, and laws governing renters' ability to modify green space where they reside).

However, one resident also shared a climate change-related barrier that affected capacity to implement green infrastructure practices: "of course, when it's colder, people aren't outside as much . . . same thing if it's overwhelmingly hot, people tend to stay home and try to chill out. And then it's harder in both scenarios to do any yard work, or curb appeal, or see people more, or stuff like that" (17D).

3.2.3. Limited Awareness of How Green Infrastructure Affects Local People

The third barrier to implementing green infrastructure related to perceived lack of awareness among many urban residents of how these practices would be beneficial to people's health, particularly in the context of climate change. As one resident said, "A lot of times people in the communities, I mean global warming, it's not a thought to them, in terms of impact on the conditions that goes on in their community" (11D). Regarding rain gardens another resident said, "I like gardening. Yeah. Yeah. But as far as introducing something like that to a neighborhood of people that don't—what's the difference? How's it really going to affect me? That's just what you hear. And they don't realize how it's going to affect them" (6D). Another resident concurred: "I think it would help people to understand why certain things need to be done and should be done . . . It has to be shown to them in a very easy to understand way, what the benefits are to them and why it is to their benefit to be a part of it" (3D).

One resident expressed that such information was helpful after asking the researcher conducting the interview to explain why certain strategies either contributed to or mitigated climate change: "I think just information would help because just by sitting here, talking to you these past 20 min or so, I mean, I've learned a lot. I didn't know you could disconnect a downspout. I didn't know that when you're driving your car that it had something to do with the reason why it's so hot, that there's a limit of trees" (12D).

An African-American resident went on to note the importance of the mechanism, as well as the messenger, used to communicate these messages: "Some things [flyers] are already massively dealt out to the homes because if I get them, I know they get them, too . . . but I think if it's verbally heard-can I say?-from another black person that lives in the area, maybe it would make more impact on these younger people" (6D). A face-to-face mechanism for communicating with someone who lives in the area was also considered beneficial in cases where residents may not use online platforms:

> And just for me, a lot of times just awareness for people seems to help a lot. Like just being more aware of our neighbors and those who might be more in need of all of this. I think it would be really helpful. Because chances are good they may not be on the email servers, if they're older and they don't know. And so how do we reach those people?" (18D)

Another resident felt media could help reach a larger audience with key messages: "It would be something maybe on the news or something like that, or on the radio, or all the channels that people listen to, 'We're on a water advisory at the moment.' And maybe they can explain what that means over the news. I mean, that would be handy" (7D).

4. Discussion

Cities and their nongovernmental partners often promote green infrastructure as an effective solution to climate change and its related health impacts. In Detroit, however, the city's implementation of "green" initiatives did not adequately integrate the perspectives and concerns of lower income and/or nonwhite residents. As the study reported here shows, "green" initiatives in Detroit (such as credits on drainage fee bills for residents who implement green infrastructure practices) are happening within the context of legacies of stewardship (or lack thereof), conflicting narratives about rights and responsibility for stewardship, existing inequalities, and broken trust between some residents and the city government. For example, some residents described inadequate communication from city government when alleys were closed and became the responsibility of residents to steward. As a result of unclear stewardship roles and responsibilities, some residents said alleys posed a health threat with overgrown vegetation that attracts wildlife and insects that could transmit diseases, and making the

area appear unsafe and unwelcoming. Even for leaders of neighborhood groups that sought to create "green" alleys to improve aesthetics and walkability (as well as social interaction), they perceived a dearth of city policies to guide alley management and use.

Such issues fall under the realm of governance, which involves "efforts to coordinate [or direct] human actions toward [common] goals" [32] (p. 35). While many Detroit residents interviewed for this study identified benefits of green infrastructure (e.g., decreased use of city water and drainage fee bills), several residents also felt that unintended health consequences resulted from a lack of clear city government policies as well as inadequate communication and coordination between stakeholders related to green space management. Understanding residents' experience with green infrastructure governance up to this point can help government actors and their partners to proactively explore possible unintended consequences of green infrastructure programs that arise from insufficient communication or coordination with residents.

Understanding residents' experiences should not be a one-time event (as in the case of this research, which is merely a starting point), but a long-term commitment on the part of government and others with decision-making power to coordinate with and support residents, who are not just users of green infrastructure but also active producers of it. As one public administration scholar contends "What is needed is a new public service ethos or compact in which the central role of professionals is to support, encourage, and coordinate the coproduction capabilities of service users and the communities in which they live" [33] (p. 858). As it relates to this study's findings, such an ethos would entail proactive negotiation of green infrastructure coproduction responsibilities between municipal governments, local neighborhoods groups, and individual citizens, and ongoing coordination and adaptation.

In addition to these governance challenges, green infrastructure is being deployed in places increasingly feeling the effects of climate change, including more frequent and severe heat waves and heavy rainfall events. All of these issues create barriers to successful implementation (and sustainability) of green infrastructure, as Detroit residents interviewed for this study described. For instance, residents worried that heavy rainfall events would create standing water even with green infrastructure practices, due to overflowing rain barrels and inadequate green space to absorb water from disconnected downspouts. Further, these residents feared that this standing water would proliferate mosquitos, a perception that has been uncovered in Portland, Oregon, as well [34].

In the case of Detroit, success of green infrastructure solutions to climate change and its attendant health impacts depends upon understanding where there are areas for improved collaboration and communication between those with more power to set the rules (i.e., city government and its non-governmental and business partners) and those who currently hold less power (i.e., lower-income and African-American residents). Building cooperative relationships within the city of Detroit (and possibly other cities facing similar challenges) will require revisions to current power dynamics that will account for the barriers faced by residents interested in supporting and implementing green infrastructure initiatives. Such revisions are not only useful to the success of green projects, but necessary since residents represent the largest group (proportionally) of land managers in many cities. A key question for future research and urban actors to consider is: How can government actors and their partners integrate residents' perspectives and power-in-numbers into more equitable and effective green infrastructure strategies?

Our study provides foundational insights to build upon in future research, particularly in other geographic, political, and socioecological contexts. The findings presented here are limited to the city of Detroit, and the perspectives shared during 21 interviews and dialogue at five community meetings. Further research is needed in diverse locations and from a range of actors to understand governance experiences that either help or hinder green infrastructure implementation by residents. Future research should also compare residents' perspectives to those within groups or government agencies implementing and funding green infrastructure projects. Research questions in future studies could include: How have agencies and their partners tried to work within local communities to implement green infrastructure? What barriers do agencies face when trying to work within

local communities on green infrastructure? How do agencies and nongovernmental organizations measure successful outreach with residents related to green infrastructure? What governance strategies have generated mutually beneficial partnerships between government agencies, nongovernmental organizations, and residents in relation to green infrastructure projects?

Our findings suggest a need to not just inform Detroit residents about green infrastructure and its benefits, but also to develop clear and effective governance approaches that bolster the capacity of residents to engage in green infrastructure projects. Although residents identified that a barrier to green infrastructure implementation was a lack of knowledge regarding the benefits of green infrastructure to individual and community well-being, several also emphasized a lack of capacity to implement such projects in current governance arrangements. This finding concurs with public health scholars who maintain: "Information is a necessary but not sufficient ingredient for community capacity" [35] (p. 125). In fact, communities that have experienced significant demographic change (like Detroit) can have lower capacities to address environmental burdens than other communities [35]. Capacity building in this context should be informed by the needs expressed by local residents, including the need for financial, physical, and/or technical assistance. These findings also support calls for governance structures that facilitate inclusion of residents' voices in the codesign and coproduction of green spaces [23,36].

Just as industrialization has resulted in both benefits and costs to human society, Detroit residents in this study perceived both benefits and costs (economic and health) to implementing green infrastructure within current systems of governance. As our findings suggest, green infrastructure should not simply be promoted and enacted as an inevitable "good" without digging deeper to uncover the governance dynamics that can either hinder or promote the equitable and sustainable integration of green spaces into cities.

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