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Longevity of rain gardens in Minnesota (US) as a stormwater solution: a question of homeowner motivation and satisfaction

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Rain gardens are gardens with a specific purpose. Designed as a shallow depression that captures stormwater runoff from impervious surfaces, rain gardens are planted with deep-rooted, wet/dry-cycle tolerant plants that enable the water to slowly permeate and be filtered by the soil. They are used as stormwater best management practices by municipalities and organizations as part of their overall plans to meet water quality goals as mandated by the United States (US) Clean Water Act. City and watershed administrators are counting on these rain gardens to be durable, effective solutions for managing stormwater runoff. But when the rain gardens are installed in the yards of privately owned homes, control of these solutions lands on the homeowners' shoulders. How effective are the rain gardens years after installation? How do the social factors of motivation and satisfaction relate to the longevity of the rain gardens? The objective of this case study was to determine the perceived performance of residential rain gardens as well as homeowner motivation and satisfaction with them over time. Data was collected via an email survey from homeowners located in the Twin Cities of Minneapolis and St. Paul, MN, US that had installed a rain garden. Key findings include (1) almost all rain gardens performed effectively, though some were not seen as successful, (2) motivations for installing rain gardens differ widely for successful vs. challenged gardens and (3) satisfaction with the rain gardens decreases over time.

KEYWORDS

rain garden, stormwater, incentive, motivation, satisfaction

Introduction

Green infrastructure, as defined by the US Environmental Protection Agency (EPA), consists of landscape elements such as infiltration basins, green roofs, and permeable pavements (US EPA, 2022). These infrastructure elements are designed to absorb and filter stormwater where it lands (Spatari et al., 2011; Nordman et al., 2018; US EPA, 2022). The European Commission defines green infrastructure more broadly as a planned network of green (land) and blue (water) elements that are designed to deliver a wide array of ecosystem services beyond improving water quality such as enhancing biodiversity and improving health and quality of life (EU, 2023). The current study aligns with the US EPA definition. Rain gardens, a popular form of green infrastructure, not only absorb stormwater where it lands, but take this one step further by being designed to capture runoff from nearby impervious surfaces such as roofs, driveways, and sidewalks. These shallow garden

depressions, planted with deep-rooted, wet/dry-cycle-tolerant plants, collect the runoff and allow it to slowly filter down into the soil, thereby preventing it from running straight to storm sewers (Dietz and Clausen, 2005; US EPA, 2021). Stormwater runoff is often polluted with bits of asphalt shingles, engine oil, heavy metals, salt, pesticides, and animal feces and flows directly into nearby water bodies without any treatment (Keeler et al., 2019). Rain gardens are an effective way to redirect stormwater away from storm sewers and filter it directly into the ground (Rouhi and Schwartz, 2007; Shuster et al., 2007; Woodward et al., 2008; Vineyard et al., 2015; Jennings, 2016). They were first conceived in the US in 1990 by a Maryland housing developer who installed the rain gardens as a cost-saving alternative to retention ponds and the gray infrastructure they required including curbs, drains, and culverts (US EPA, 1995; Malaviya et al., 2019). The use of rain gardens in the US grew quickly as cities worked to comply with regulations that were enacted as part of the Clean Water Act in the late 1990's. Rain gardens became one of the strategies used to engage commercial and residential community members in being part of the stormwater solution and, thus, defraying a portion of the cost of upgrading gray infrastructure. They have become one of the most popular stormwater best management practices (BMP) used (Davis et al., 2009). Adopting rain gardens as a means to manage stormwater runoff and to meet new regulations was happening around the world in parallel to that in North America. Rain gardens are one of the tactics described in Australia and New Zealand's Water Sensitive Urban Design, and United Kingdom's Sustainable Urban Drainage System – both developed in the 1990's (Fletcher et al., 2015; Zhang et al., 2019). Asia adopted rain gardens somewhat later; Singapore installed its first bioretention pond in 2008 (Ong et al., 2012) while Japan updated its regulations in 2015 and increased rain garden adoption has followed (Zhang et al., 2019).

US federal and local policy and regulations assume that green infrastructure is a durable solution; one that is maintained and operational over time. Rain gardens, when installed per design guidelines of size, depth, and composition, consistently work as intended; they capture stormwater runoff and drain within days (Jennings, 2016; Zhang et al., 2019). However, homeowner experiences, attitudes, and norms can play an important role in the perceived success or failure of the rain garden. Homeowners may be skeptical about the function of the rain garden citing concerns of standing water providing habitat for mosquitos (Shaw et al., 2011). Rain gardens can be designed or installed improperly, plants can die or become overgrown, weeds can take over, and mulch or sediment can fill the basin – all causing homeowners to have concerns with the rain garden's performance (Shuster et al., 2007; Woodward et al., 2008; Liebsch, 2011; Ishimatsu et al., 2017). Shaw et al. (2011) found that positive outcome expectations such as improving water quality and increasing wildlife habitat were twice as motivating as social norms. Other studies have found that community norms are important, driving homeowners to choose only neat, aesthetically pleasing landscapes (Barnes et al., 2020; Bahrou et al., 2024). Homeowner beliefs about environmental issues such as water quality or loss of pollinator habitat can motivate them to take action (Bahrou et al., 2024). Incentive programs may be attractive to homeowners that, otherwise, would not have installed a garden (Brown et al., 2016). Gardening is a time-consuming, tiresome, and often expensive chore; a fact that homeowners can overlook in their quest to keep up with their neighbor's garden standards (Blaine et al., 2012; Barnes et al., 2020). With these issues in mind, this case study seeks to understand homeowner perceived performance, motivations, and satisfaction of their rain gardens centering on a series of research questions. (1) Do the rain gardens perform as intended and expected? (2) What were the homeowner's motivations for installing the rain garden? (3) Does the homeowner continue to be satisfied with their rain garden over time?

Methods

The study was conducted via an online survey sent to homeowners in greater Minneapolis and St. Paul, Minnesota, US, an area known as the Twin Cities. This area is situated around the confluence of the Mississippi, Minnesota, and St. Croix Rivers with Minneapolis lying largely to the west of the Mississippi River and St. Paul lying largely to the east of the Mississippi River. It has a population of over 3.1 million (Metropolitan Council, 2022) and covers nearly 8,000 km^2. In addition to the three rivers, the 7-county area includes lakes, ponds, marshes, and creeks governed by 14 watershed districts, 16 watershed management offices and 6 county conservation districts.

To reach out to the intended population of local residents with rain gardens, the survey (see Supplementary material) was sent to an email list of Metro Blooms, a local non-governmental organization (NGO) that provides training and rain garden installation services to residents (Metro Blooms, 2022). In May 2022, an email survey was sent to 2,498 recipients who had expressed interest in installing a rain garden and/or had attended a rain garden workshop, followed up by a reminder one week later. The number of survey recipients that had installed a rain garden on their property was unknown. A total of 277 responses were received (11.1% response rate). Twenty respondents stated that they had not installed a rain garden on their property and sixteen survey responses were incomplete; both groups were excluded, leaving a total of 241 responses included in the survey results.

Survey respondents were asked to self-assess their rain gardens on a five-point Likert-type scale ranging from "Highly Successful" to "Highly Challenged." "Successful" rain gardens were defined as those that have a variety of healthy plants, are generally free of weeds, accept stormwater runoff that is channeled to them, and drain within 48 h. "Challenged" rain gardens were defined as those that were abandoned, have dead or distressed plants, overgrown weeds, overflow, or experience ponding. Rain garden performance was self-reported via questions regarding the garden's ability to contain a rainfall event and its time to drain. The survey inquired about the homeowners' motivation for installing their rain gardens via questions pre-populated with typical rain garden benefits as noted in the literature including: "to solve a standing water or runoff problem"; "to protect local water bodies including streams, rivers, ponds, and lakes"; "to provide habitat for pollinators, birds, and small animals"; "to provide an aesthetically pleasing area to my yard"; and "to receive incentives provided by a local organization or municipality" (Schmidt et al., 2007; English and Somers, 2020). The motivation questions also included an open response allowing participants to add more detail in narrative form,

TABLE 1 Self-assessment rating of rain garden performance.

Self-assessment rating	Number of responses	Percentage of total responses
Highly successful	79	32.8%
Successful	94	39.0%
Mixed results	51	21.2%
Challenged	15	6.2%
Highly challenged	2	0.8%
Total	241	100.00%

if desired. Homeowners were asked to report their satisfaction with their rain garden at two timepoints: (1) at the time of installation and (2) today. To determine changes in satisfaction over time, survey respondents were asked to score using the Likert-type scale responses of "Very Satisfied" to "Very Dissatisfied." Scoring of the change in satisfaction was conducted as follows: a drop from the rating "Very Satisfied" (at installation) to the rating "Satisfied" (today) would get a −1 score. Positive satisfaction changes were scored in the same way – an increase in rating from "Neither" to the rating "Satisfied" received a +1 score. These scores were then averaged for the rain gardens grouped by age ranges of 0–3 years, 4–7 years, 8–11 years, 12–15 years and 16+ years.

Results

Rain garden performance self-assessment

A majority of homeowners (71.8%) rated their rain gardens as "Successful" or "Highly Successful" (Table 1). A significant minority of homeowners (28.2%) rated their gardens as "Challenged" or "Highly Challenged" or having "Mixed Results."

When asked what caused their "Highly Successful" and "Successful" rating, the top response was "healthy plants" (98.7 and 83.9%, respectively). For "Highly Successful" rain gardens, the second and third most prevalent responses were "drains within 48 h" (93.7%) and "sightings of pollinators, birds, or small animals" (92.4%). For "Successful" rain gardens, the second and third most prevalent responses were "accepts stormwater runoff" (82.8%) and "drains within 48 h" (76.3%). These rain gardens were not only functioning well as a stormwater runoff BMP, but also provided aesthetics and habitat.

For those gardens rated as having "Mixed Results," the top three responses for what caused that rating were "accepts stormwater runoff" (60.8%), "drains within 48 h" (51.0%) and "dead or distressed plants" (49.0%). Comments from these respondents included the "need to replant," "plants died over time," "took longer than expected to flourish," "some plant varieties becoming aggressive," and "not visually pleasing."

For those gardens rated as having "Challenged" or "Highly Challenged" results, the top responses were dead or distressed plants (66.7 and 100%, respectively), and overgrown weeds (50.0 and 0%, respectively). Comments included "plant selection not conducive to sun," "volunteers invading," and "plants are not coming back."

When asked three questions used as objective measures to self-report their rain garden's performance as a stormwater runoff BMP, 98.2% stated that their rain garden drains in 2 days or less, 83.3% reported that their rain garden had never overflowed, and 87.5% reported that the rain garden had solved their drainage problems.

Homeowner motivation to install rain garden

The survey asked respondents to select the factors that motivated them to install their rain garden. The motivational factors included: "to solve a standing water or runoff problem"; "to protect local water bodies including streams, rivers, ponds, and lakes"; "to provide habitat for pollinators, birds, and small animals"; "to provide and aesthetically pleasing area to my yard"; and "to receive incentives provided by a local organization or municipality." The top three motivational factors for installing a rain garden across all respondents were "to protect local water bodies" (79.6%), "to provide habitat for pollinators, birds, and small animals" (77.5%), and "incentives provided by a local organization or municipality" (65.0%).

When respondents are categorized by their rain garden self-assessment of "Highly Successful" to "Highly Challenged," differences in motivation factors appear (Figure 1). "To protect local water bodies" and "to provide habitat" are most often selected by those with "Successful" (77.7 and 79.8%, respectively) and "Highly Successful" rain gardens (88.6 and 83.5%, respectively), where "incentives" and "to protect local water bodies" are most often selected by respondents with "Challenged" (80.0 and 60.0%, respectively) and "Highly Challenged" rain gardens (100.0 and 50.0%, respectively). "Aesthetics" was a higher motivating factor for those with "Successful" (66.0%) and "Highly Successful" rain gardens (74.7%) than for those with "Mixed Results" (37.3%) or "Challenged" (46.7%) rain gardens. In fact, gardeners with "Highly Challenged" rain gardens were not motivated by "aesthetics" or "habitat" at all (0.0%, 0.0%). Noticeably, "incentives" moved from the fourth most prevalent motivating factor for respondents with "Successful" and "Highly Successful" rain gardens to the most prevalent factor for "Challenged" and "Highly Challenged" rain gardens. These incentives, which were offered by municipalities or other local organizations, took the form of cost-share reimbursements, rebates on utility bills, donated garden designs, volunteer and donated labor and cost-reduced plant material.

Homeowner satisfaction with rain garden

A majority of homeowners were "Satisfied" or "Very Satisfied" both immediately after the installation of their rain garden (93.3%) and today (88.1%). The rain gardens ranged in age from 0 to 17 years (Table 2) with an average age of 5.3 years and a median age of 4.0 years.

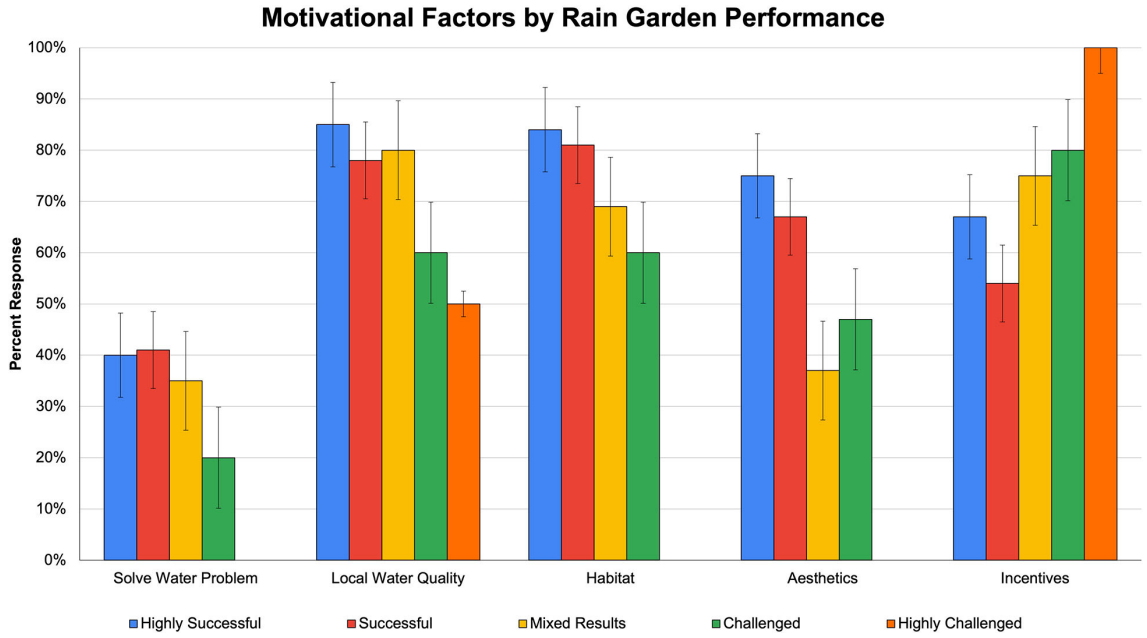

FIGURE 1
Percent response of homeowner motivational factors categorized by perceived rain garden performance. Error bars show standard error.

TABLE 2 Age of rain gardens.

Age (years)	Number of responses	Percentage of total responses	Age (years)	Number of responses	Percentage of total responses
0	5	2%	9	6	3%
1	14	6%	10	9	4%
2	37	17%	11	4	2%
3	49	22%	12	11	5%
4	29	13%	13	3	1%
5	14	6%	14	3	1%
6	6	3%	15	4	2%
7	13	6%	16	5	2%
8	8	4%	17	2	1%
			Total	222	100%

However, the change in satisfaction from the time of installation until today shows a different picture when categorized by the age of the garden (Figure 2). Rain gardens aged 0 to 3 years were the only group that showed improving satisfaction on average. For gardens aged 4 to 7 years, the change in satisfaction turned negative. Gardens aged 8 to 17 years showed decreasing satisfaction trending down at an increasing rate.

Maintenance of the garden was a specific area that showed a negative change over time. Although only 8.3% of survey respondents did not feel equipped to maintain their rain gardens at the time of installation, 20.3% stated that currently the level of maintenance was more or much more than they expected.

Discussion

As part of their compliance to US federal regulations, municipalities strive to educate citizens on stormwater management issues and include them in solving stormwater problems. Rain gardens are an important stormwater management solution that are popular with homeowners (Davis et al., 2009). This research shows some interesting dichotomies. While the rain gardens were overwhelmingly reported to be performing well as stormwater BMPs, this finding didn't completely align with the homeowner's self-assessment of their rain garden's success. Homeowner motivations included altruistic factors of protecting local water bodies and providing habitat but also a less altruistic factor of

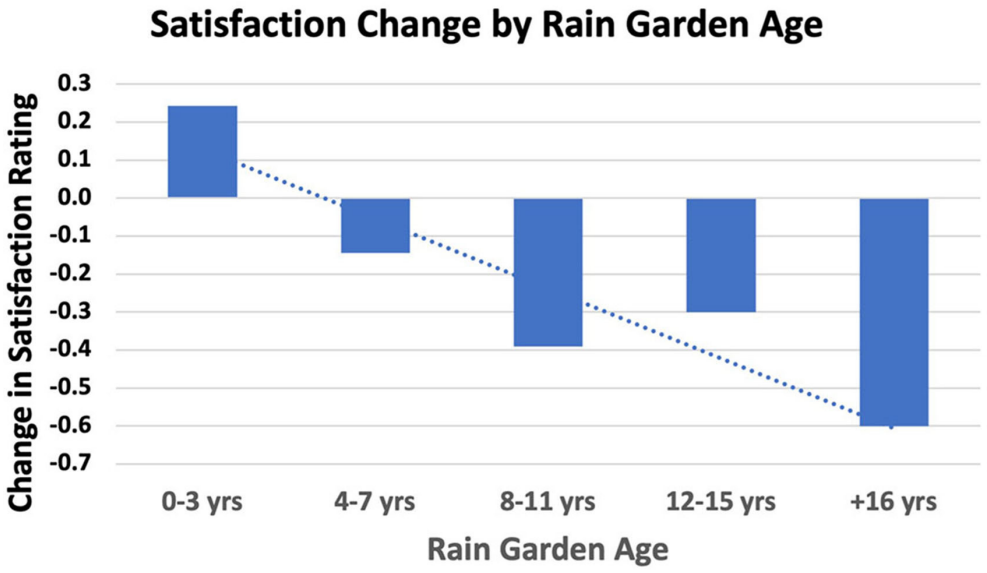

FIGURE 2
Change in satisfaction rating from installation to current categorized by rain garden age.

financial incentives. Most homeowners reported being satisfied with their rain gardens although that satisfaction decreased over time.

Do the rain gardens perform as intended and expected?

As BMPs, the rain gardens performed well to collect the intended runoff and drain quickly with 98.2% of respondents stating that their rain garden drained in 2 days or less, 83.3% reporting that their rain garden had never overflowed, and 87.5% reporting that the rain garden had solved their drainage problems. These rain gardens are working as intended and designed. This is consistent with other studies where rain gardens show excellent performance (Barr Engineering Company, 2006; Schlea et al., 2014). Interesting then, that only 71.8% of these same gardens are rated as "Successful" or above. Clearly homeowners have expectations for their rain gardens beyond the primary purpose as a stormwater runoff BMP. Could other factors such as aesthetics and ease of maintenance be clouding homeowner's perceptions of their rain gardens?

What were the homeowner's motivations for installing the rain garden?

Understanding the motivational factors for installing the rain gardens may help us answer the question. Overall, most gardeners were motivated by protecting local water bodies which aligns with the primary objective of rain gardens. While most "Successful" rain gardeners were also motivated by providing habitat to wildlife and an aesthetically pleasing result, financial incentives were the top motivational factor for those with "Challenged "rain gardens. The promise of a free front-yard garden can be quite compelling to homeowners. Incentive programs described in the survey came in different forms – most of the survey respondents reported upfront programs such as cost-share and waived design and/or labor fees with fewer reporting longer-term utility fee rebates. The data is likely skewed toward design and/or labor fees because the email population comes from an NGO that provides this type of support. Although the grant programs provide a nice incentive to move homeowner behavior in a desired direction, are the programs overselling the beauty and ease of the gardens? Those that reported incentives as a motivational factor experienced a sharper drop in satisfaction over time (-0.22) than those that reported other factors (-0.10). Is the upfront or reimbursement incentive model the best one to use for rain gardens?

The literature is mixed on this point. Larson et al. (2014) found that financial incentives alone had a low potential to motivate a high level of participation in stormwater BMP programs. Seattle's RainWise program experienced low participation rates even though residents were rebated 100% for the cost of their rain gardens (Larson et al., 2014). Brown et al. (2016) found financial incentives to be a key motivator for most residents for a local rain garden and tank installation program. These studies may be missing an important variable that another study dove into – learning how participants are motivated to determine if incentives are effective. Yasué and Kirkpatrick (2020) studied whether program participants were driven by personal beliefs and values or by guilt, reward and/or punishment. They found that those reporting lower levels of pro-environmental values and beliefs were more likely to participate in incentive programs designed to increase pro-environmental behavior. Those same incentive programs had little effect on those reporting high levels of pro-environmental values and beliefs. The design of incentive programs is also important, and many have been tried but

the data on long-term results is lacking. The longevity of rain gardens as a stormwater management solution is critical. Should grant programs be incentivizing the rain garden's installation and/or maintenance over time? Rain garden installation cost can be a major barrier to participation for homeowners (Brown et al., 2016). Although seen less often, one longer term incentive scheme was shown to be effective: the RainScapes program in Montgomery County, MD where after installation of their rain gardens, homeowners were offered a "water quality charge credit" in exchange for a maintenance verification every 3 years (English and Somers, 2020). A shortcoming of the maintenance verification requirement is its ongoing burden on the sponsoring organization. The current study aligns with previous findings related to the limitations of utilizing private land to implement public stormwater solutions (Keeley et al., 2013; Copeland, 2014). Incentives can provide the motivation to implement the solution, but municipalities have less control over the long-term effectiveness of the solution.

Are some residents responding to the incentive and the allure of a free front-yard garden without understanding the maintenance that a garden requires? Recall the increase of homeowners who reported from at time of installation (8.3%) to currently (20.3%) that the maintenance required was more than they expected. Demonstration gardens hosted by residents are one way to acquaint prospective rain gardeners with the amount of maintenance the gardens require (Brown et al., 2016). Demonstration rain gardens installed in their community enabled homeowners, property developers and community leaders to see, learn about and experience the gardens in their community (Obropta et al., 2008). Participation in the construction of Habitat for Humanity homes, commonly known as "sweat equity," has been shown to increase homeowner pride, satisfaction, and maintenance frequency (Zhu, 2007). This "sweat equity" process is noted in one case study where homeowners were engaged in planting their own gardens, supported by a landscape architect and municipal staff, thus ensuring that homeowners had a hands-on investment in their rain gardens and an understanding of the various plant species and requirements (Minnesota Pollution Control Agency, 2005).

Does the homeowner continue to be satisfied with their rain garden?

Many homeowners became dissatisfied with their rain gardens over time. Respondents reported increasing satisfaction at 0 to 3 years of age and then transitioning to decreasing satisfaction for older rain gardens aged 4 to 17 years. Even though 75% of the rain gardens were aged 7 years or less, the drop off in satisfaction can be seen in the 4-to-7-year group. Note: it can be challenging to find homeowners that were the original installers of older rain gardens given the average US homeownership tenure is 5.6 years (ATTOM Data Solutions, 2023). One explanation for the early satisfaction could be that the perennial plants typically planted in rain gardens can take 3 years to mature causing increasing satisfaction as they bloom and fill in the garden space. Then the maintenance activities of the garden start to kick in with pruning, plant replacement, weed removal, mulching, etc. If these maintenance activities are left undone, the garden can become unmanageable and unsightly over time. This reduction in satisfaction over time aligns with the increase in survey respondents that reported, over time, that the required maintenance was more than they expected. Yue et al. (2012) also found a strong preference for landscapes that required reduced maintenance. Satisfaction and maintenance are closely linked; Barnes et al. (2020) found a tradeoff between satisfaction factors of aesthetics, water quality and habitat vs. maintenance.

Survey responses expressed aesthetics as both a motivator and source of dissatisfaction. Locke et al. (2018) found that homeowners were both positively and negatively motivated by neighborhood perceptions of aesthetics; they expressed pride and joy in their gardens but also anxiety and peer pressure to fit in with the neighborhood standard. One of the objections to rain gardens can be their messy appearance particularly when the design emphasizes use of native plants. Hooper et al. (2008) found that native plants are not perceived to be as beautiful as traditional cultivated plants. Native flowers and grasses are adept at filtering due to their deep root systems and are also attractive to native pollinators, so they are frequently recommended for use in rain garden designs (Schmidt et al., 2007; Three Rivers Rain Garden Alliance, 2022). The use of natives may be at odds with local regulations or norms. Homeowners association rules and city regulations often employ a kind of norm enforcement with vague language such as must maintain "a neat, well-kept appearance" (Engebretson et al., 2021). These norms played out in a study where, given the choice, 17 out of 18 (94.4%) homeowners chose cultivated flowers and shrubs over native plants for their rain gardens (Minnesota Pollution Control Agency, 2005). Three-quarters (76%) of the rain gardens in the study were installed in the residential front yards which may have skewed the plant choices to a more manicured, predictable look. Studies show that cultivars and exotics can be as valuable in the rain garden as natives (Laukli, 2022). To achieve wide adoption and longevity of rain gardens as a stormwater runoff BMP, it may be important for program leaders to relax rules regarding required exclusive use of native plants.

Homeowners need to understand that a rain garden is still a garden – one that requires the maintenance tasks of pruning, dividing, weeding, and replacing plants. The good news is that the vast majority of rain gardens in the survey met the definition of a stormwater runoff BMP – they work well. Unfortunately, many of those rain gardens were not seen as successful by the homeowner due to the garden's lack of aesthetics from distressed plants, weeds, or general messy appearance as well as the amount of work needed to maintain the garden. The downside here is that although the rain gardens perform as intended, they run the risk of being returned to turfgrass lawns and their primary purpose lost. Programs need to be structured to mitigate this fall-off in satisfaction as well as address the fact that the homeowners are likely to change over time. Perhaps incentives could be devised such that part of the incentive is awarded after a follow-up visit in three to five years and beyond. Additional education regarding care and maintenance as well as ongoing support could also be useful.

One limitation of the study was the low survey response rate (11.1%). Previous reviews have found response rates between

20.5 and 42.5% depending on reminder emails, deliverability, and incentives offered (Manfreda et al., 2008; Millar and Dillman, 2011). The low response rate in the current survey could be due to the inclusion of only a single follow-up email as well as lack of an incentive for participation. This subsequently could impact the relative representativeness of the gathered sample. Future work should broaden the population surveyed via inclusion of other organizations who install rain gardens, including additional follow-up emails, and providing an incentive to encourage participation. Another limitation of the study was that it didn't delineate motivational trade-offs. This knowledge could be useful to environmental policy and program developers for tailoring future program marketing and funding. With thousands of rain gardens installed in the greater Twin Cities area and millions of gallons of stormwater runoff directed away from storm sewers, these programs must be considered a resounding success. Additional research and application of lessons learned can enhance the programs even further in their quest to protect local water quality long term.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

LJ: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing—original draft, Writing—review & editing. MB: Methodology, Supervision, Writing—review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsc.2023.1277066/full#supplementary-material

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