EPiC Series in Built Environment
Volume 7, 2026, Pages 455–464
Proceedings of Associated Schools of Construction 62nd Annual International Conference

Can You See It? Is Green Infrastructure Invisible?

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Green Infrastructure (GI) is increasingly adopted in urban environments as a sustainable stormwater management strategy to reduce flooding risk, enhance resilience, and improve ecological performance. However, the continued adoption of GI also depends on public awareness, recognition, and engagement, particularly in shared community environments such as university campuses. Universities are uniquely positioned to adopt and advance GI technologies. Therefore, this ongoing study assessed levels of awareness, spatial knowledge, interaction, and perception with GI features among students at a large public research university in the southern US using a three-phase online survey. Complete survey responses from 85 participants (undergraduate and graduate students) were analyzed to evaluate familiarity with GI, recognition of three existing campus GI installations (an above-ground cistern, a bioswale, and a sand filtration basin), and interest in learning more about GI functions. Preliminary results indicate that while many respondents spend substantial time on the campus, GI features remain largely under-recognized, particularly lower-visibility systems. However, a strong interest in learning more suggests that awareness barriers are informational rather than attitudinal. The findings highlight opportunities to enhance campus flood resilience and sustainability literacy by improving GI visibility, adding interpretive signage, integrating curricula, and implementing campus engagement strategies.

Keywords: Urban Flooding, Green Infrastructure (GI), Above-Ground Cistern, Bioswales, Sand Filtration Basin

Introduction and Background

Increasing urbanization and its contribution to impervious-surface development have intensified stormwater runoff volumes and increased urban flood risk across many regions (Konrad, 2003; Li et al., 2023), a trend exacerbated by the increasing frequency and intensity of natural disasters (NOAA, 2024). To address these challenges, Green Infrastructure (GI) has emerged as a sustainable approach mimicking natural hydrologic processes by promoting infiltration, evapotranspiration, and decentralized stormwater management (Ahiablame et al., 2012; Baptiste et al., 2015; CWAA, 2011). The Clean Water Act defines Green Infrastructure as "*the range of measures that uses plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspiration stormwater and reduce flows to sewer systems or to surface waters*" (CWAA, 2011; U.S. EPA, 2020). GI strategies, including bioswales, rain gardens, cisterns, permeable pavements, and filtration basins, are designed to reduce peak runoff while providing ecological and aesthetic benefits and recharging the groundwater table, which is vital for areas significantly impacted by prolonged droughts. As cities and institutions strive to enhance climate resilience, GI plays a crucial role in managing increasing rainfall variability, mitigating localized flooding, and enhancing water quality (Benedict & McMahon, 2006). The adoption of such technologies and strategies by institutional stakeholders have been identified within the US (Langar & Pearce, 2017), along with barriers to the adoption of green buildings and technologies on academic campuses (Hopkins, 2016).

Academic campuses (colleges and universities) are essential sites for implementing GIs because they function as micro-urban environments with large populations of academic stakeholders, such as students, staff, and residents from surrounding neighborhoods, with diverse land uses, and extensive built surfaces (Speake et al., 2013). GI implementation on academic campuses presents a unique opportunity to address these environmental challenges while fulfilling broader pedagogical and community engagement missions (Ribeiro et al., 2021). When deployed on campuses, GI can serve a dual purpose: supporting resilience and providing opportunities for environmental education and awareness-building among academic stakeholders. Thereby offers an opportunity for the campuses to operate as living laboratories, where infrastructure also contributes to experiential learning. However, GI's ability to function in this capacity depends heavily on stakeholder's familiarity, visibility, and interpretive accessibility so that learning is independent. If GI features are not recognized or understood by the campus community, their educational value remains unrealized, and their significance for sustainability may remain invisible (Ge et al., 2024; Speake et al., 2013).

Like many growing urban university campuses, the university selected for this study, a large public research university in the southern US, faces increased stormwater management demands due to ongoing development, the expansion of built surfaces, and the region's hydrologic characteristics. To enhance resilience, the university has incorporated several GI features across the main campus, including bioswales, above-ground cisterns, and sand filtration basins, which can be transposed on a gradient of visibility/observability (high to low). The bioswales are recognizable by their form, plantings, and prominent project signage. They are termed *highly visible/observable*, followed by the cistern, which is intentionally elevated and distinct (*medium visibility/observable*). Then, the sand filtration basin, with the *least visibility/observability,* blends more subtly into the surrounding landscapes. This gradient provides a valuable context for studying how visibility/observability influences recognition and awareness.

Understanding campus stakeholder awareness of these GI features is crucial because public familiarity influences environmental support, stewardship, and long-term maintenance acceptance (Church, 2015; Ge et al., 2024). When individuals recognize GI as functional infrastructure rather than ornamental landscaping, they are more likely to value its role in reducing flooding and supporting sustainability goals (Baptiste et al., 2015; Jones et al., 2022). Conversely, low recognition contributes to what scholars describe as "*infrastructural invisibility*," in which essential environmental systems operate in the background and remain unnoticed unless a failure occurs (Benson, 2015; Deitz & Meehan, 2019). This invisibility limits the perceived importance of GI and reduces opportunities for engagement and educational integration. Furthermore, the visibility of GI may influence its future adoption among academic stakeholders. This aligns with Rogers' Diffusion of Innovations theory, which highlights observability as one of the key attributes of innovation and an essential factor in encouraging adoption (Rogers, 2003)

Despite the presence of GI on the university's main campus, anecdotal observation suggested that many campus stakeholders may be unaware of these systems or their stormwater management function. The extent to which academic stakeholders recognize GI features, understand their purpose, and know where they are located has not been well assessed before this study, and this limitation warrants further exploration. Therefore, the article evaluates awareness, recognition, knowledge, and interaction with GI among campus stakeholders (specifically students). The study also assesses interest in learning more about these features and identifies opportunities to enhance visibility and engagement. By examining the relationship between GI visibility and public awareness in a campus context, the study contributes to broader discussions on resilient campus planning, environmental literacy, and the communication of sustainable infrastructure. The research is ongoing, with data still being collected.

Methodology

The research employed a three-phase online survey design (Figure 1) to evaluate familiarity with GI, recognition of three existing campus GI installations (an above- ground cistern, a bioswale, and a sand filtration basin), and interest in learning more about GI functions. The survey design methodology was selected because it enabled the identification of trends, including perceptions and awareness, at a specific point in time (Akhter et al., 2022). *The first phase* involved developing study parameters, including instrument type, study population, and instrument development. An online survey method was selected for its ability to generate value for the research team by enabling broader reach and for the team's experience with the tool. The online instrument developed on Qualtrics had five sections, which included: 1) Demographics; 2) Awareness about GI; 3) Knowledge about GI; 4) Respondent Perceptions; 5) Challenges. For this study, partial results from two sections, demographic and sections 2 & 3, are presented as they address the identified research question. Most questions in the developed instrument were closed-ended and categorical. In addition, the developed instrument incorporated numerous strategies identified in the literature to enhance response rate. First, given that significant literature links survey length to response rate (Kost & Correa da Rosa, 2018), the survey was intentionally designed to be concise and could be completed in approximately 10–15 minutes. Second, financial incentives have been associated with improved response rates (Kost & Correa da Rosa, 2018). Therefore, participants were offered the opportunity to enter a drawing for five $50 gift cards in exchange for completing the survey. The study population comprised all academic stakeholders, including students, faculty, administrators, and staff. The research instrument included hyperlinks to general information on key terms such as GI, bioswales, above-ground cisterns, and sand filtration basins to mitigate ambiguity and reduce potential bias arising from unfamiliarity with the terminology. The hyperlinks provided potential respondents with brief descriptions, examples, and illustrative figures for each GI feature. This approach was intended to ensure that respondents could accurately interpret the questions and provide informed responses even when they were unfamiliar with the technical names of the assessed systems.

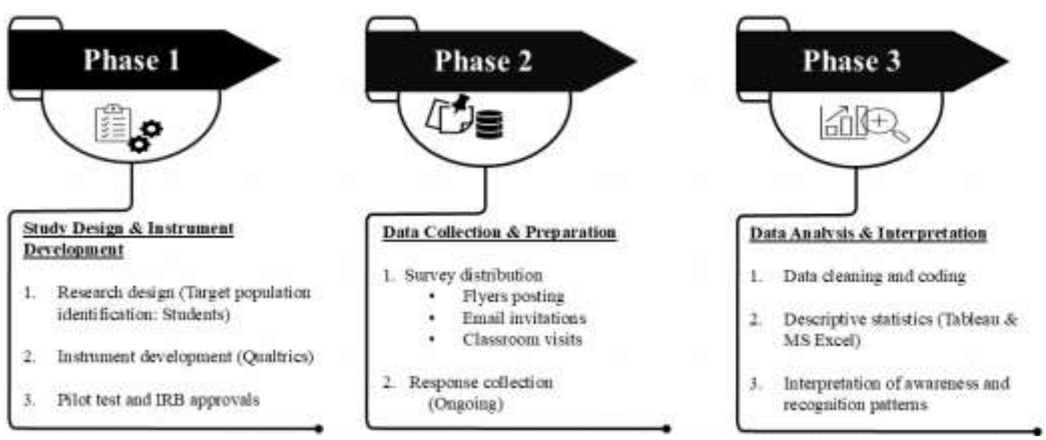

Figure 1. Research Method

Drawing on the authors' prior experience in this research area and in survey design, the instrument was refined through multiple internal discussions to ensure clarity and relevance. In addition, the developed survey instrument was pilot tested, and feedback from pilot test respondents regarding question ambiguity, survey length, redundancy, and ease of understanding was incorporated into the final version. Finally, necessary institutional approvals were sought before launching the second phase.

The second phase involved data collection, which is ongoing. The online survey is distributed across the university's campuses using a combination of physical and digital strategies to ensure broad visibility and participation among academic stakeholders. Printed handouts containing brief study information and a QR code linking to the survey were posted in multiple high-traffic locations, including cafeterias, the university library, departmental notice boards, hallway bulletin boards, and other common areas frequently accessed by students, faculty, administrators, and staff. In addition, members of the research team visited various classrooms across different colleges within the university and delivered brief research information sessions to explain the study's purpose and encourage voluntary participation. As data collection continues, the findings reported in this study are limited to the scope of this study (specifically, undergraduate and graduate students) who completed the survey at the time of analysis. This reporting approach is consistent with domain-based research that presents results as a snapshot of respondents' perceptions at a particular point in time. Currently, 85 student responses have been fully completed, and 32 additional responses have been initiated but remain incomplete.

The third phase involved downloading the data collected to date and interpreting it. For this phase, 85 completed student responses were downloaded, as they fell within the scope of this paper. The downloaded data were coded for analysis, and descriptive statistics were performed in Tableau and MS Excel. The preliminary results were also interpreted for patterns that might emerge.

Results

A total of 85 completed survey responses were included in the analysis. Most respondents identified as male (56.47%), followed by female (42.35%), with 1.18% preferring not to disclose (Figure 2). The sample was primarily composed of younger adults, with 75.29% aged 18–24 years and 15.29% aged 25–34 years; all other age groups accounted for less than 6% (Figure 3).

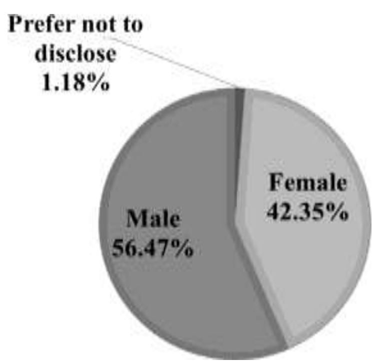

Figure 2. Gender distribution of the survey participants (n= 85)

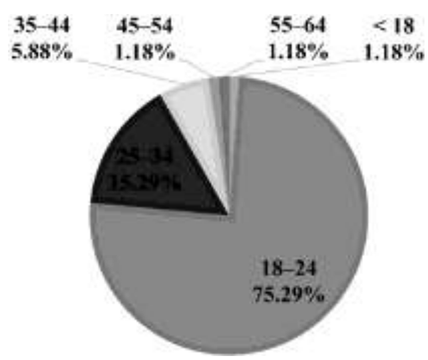

Figure 3. Age distribution of the survey participants in years (n= 85)

In terms of academic status, the most significant proportion of respondents were juniors (31.76%) and seniors (25.88%), followed by doctoral students (15.29%), sophomores (12.94%), and freshmen (10.59%), with 3.53% identifying as master's students (Figure 4). Campus presence varied: the most common category was 8–16 hours per week (35.29%), followed by 25–40 hours per week (20%) and 17–24 hours (18.82%), indicating that most respondents spend a meaningful portion of their time physically on campus (Figure 5).

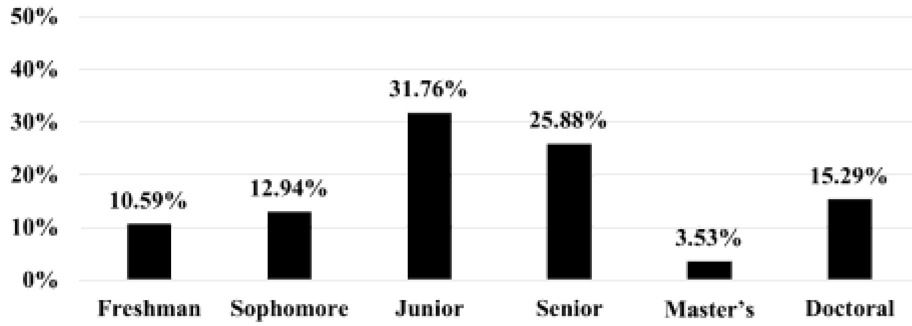

Figure 4. Respondent academic level (n = 85)

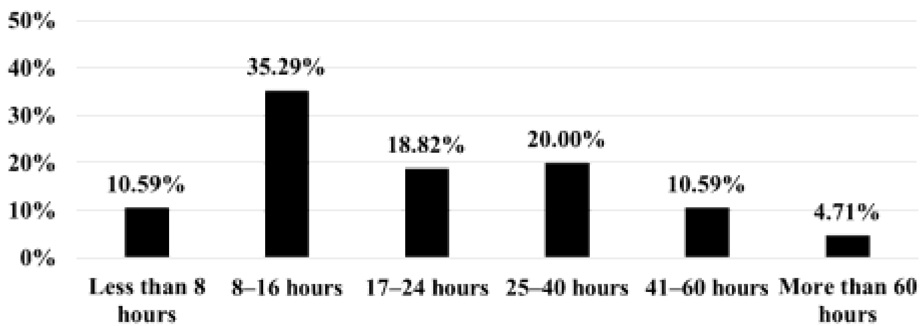

Figure 5. Weekly time spent on main campus (n = 85)

Awareness and Familiarity with Green Infrastructure

Participants demonstrated limited awareness of GI. Nearly one-quarter each reported that they had "*never heard of GIs*" (24.71%) or "*had heard of them but did not know what they were*" (24.71%), indicating that nearly half of the respondents lacked a proper understanding of GIs and their importance in the built environment (Figure 6). The largest group (31.76%) reported a basic understanding, while 14.12% reported a good understanding, and 4.71% reported being very familiar and able to explain GIs to others (Figure 6).

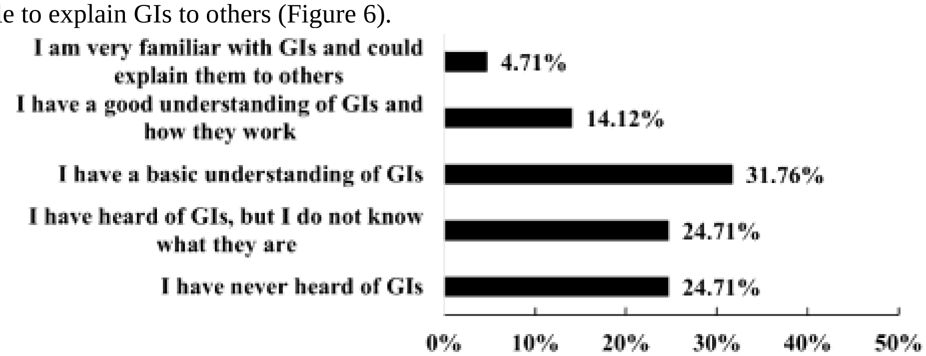

Figure 6. Familiarity with Green Infrastructure (GI) (n = 85)

When asked to compare GI awareness with other sustainability practices (e.g., recycling, renewable energy), most respondents reported being less aware of GI. Specifically, 34.12% reported being "*somewhat less aware,*" and 30.59% reported being "*much less aware*" than for other sustainability practices, while only a small proportion reported being more aware (Figure 7). This suggests that, within campus sustainability messaging, GIs remain less recognized.

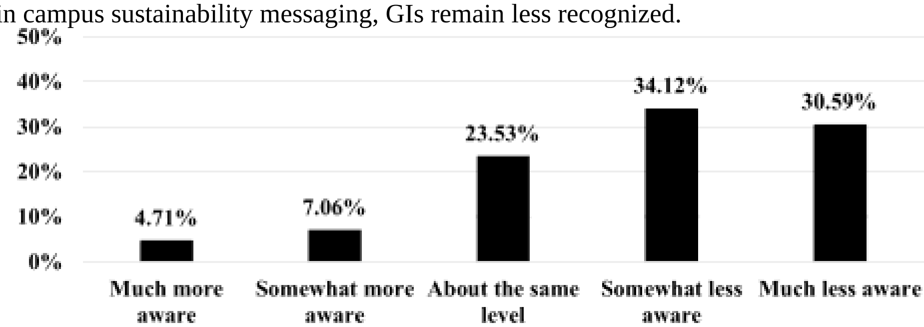

Figure 7. Awareness of Green Infrastructure compared to other sustainability practices (n = 85)

Green Infrastructure Recognition

Respondents (students) were asked whether they could visually recognize GI features on campus; 42.35% reported they "*did not recognize any GI types,*" suggesting limited visual or spatial awareness, even among individuals who spend significant time on campus. Another 24.71% could identify a few GI types, with smaller proportions recognizing some (14.12%), most (11.76%), or all (7.06%) features (Figure 8).

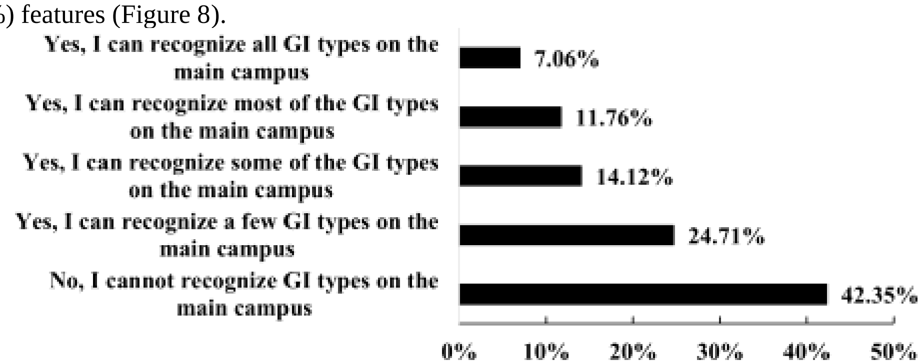

Figure 8. Ability to recognize GI features (n = 85)

The researchers also sought to determine the recognition of the analyzed GI features, which followed a specific visibility pattern: the bioswale (highest visibility) had the highest correct identification, followed by the above-ground cistern (medium visibility), while the sand filtration basin (lowest visibility) was recognized least (Figure 9). Even though these results confirm that greater on-campus visibility is associated with better recognition, whereas subsurface or less visually prominent systems remain largely unnoticed and spatially "*invisible*." However, concerns remain about significantly lower correct response rates for recognizing GI types, with ranges of 27.06% for bioswales, 15.29% for above-ground cisterns, and 8.24% for sand filtration basins (Figure 9). Moreover, the high proportion of "*don't know*" responses across all three features highlights a concerning lack of student awareness of existing campus infrastructure. This is notable given that students are direct users of the campus environment and, as future professionals, will be responsible for designing and implementing sustainable stormwater management solutions. Limited familiarity with these systems at the campus level may reduce their ability to recognize and apply such strategies in future practice, underscoring the need for greater exposure to and education about on-campus green infrastructure.

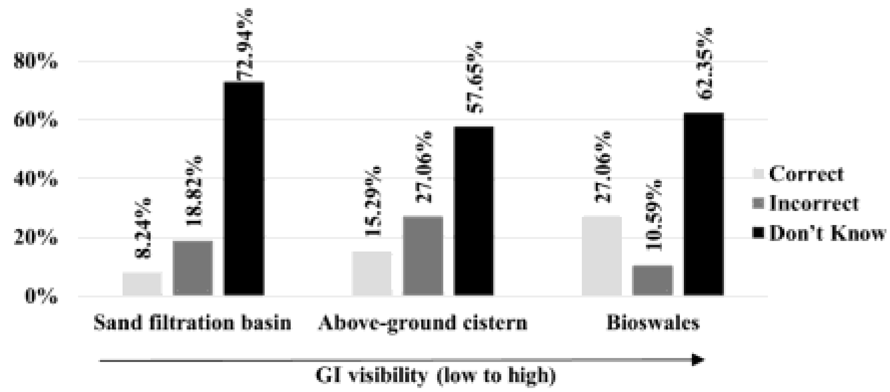

Figure 9. Recognition of the location of the bioswale, above-ground cistern, and sand filtration basin on campus (n = 85)

Exposure and Interaction

When asked how often they walk by GI features, responses varied, but the largest group (40%) selected "*cannot answer,*" indicating uncertainty about GI locations (Figure 10). Among those expressing awareness, the most common response was "*sometimes*" (21.18%), followed by "*rarely*" (18.82%), suggesting incidental rather than intentional exposure. Direct interaction was even more limited. 35.29% selected "*cannot answer*," 27.06% reported never interacting, and 22.35% interacted rarely, with only 4.71% interacting often, while none reported *"always"* (Figure 10). Thus, GI features appear to function primarily as background infrastructure rather than engaged sustainability assets.

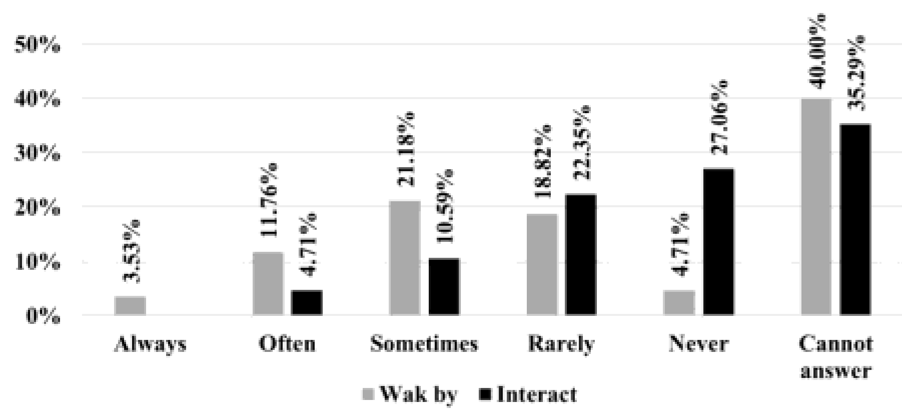

Figure 10. Frequency of walking by and interacting directly with Green Infrastructure features on campus (n = 85).

Future Intentions and Interest in Learning

Despite limited familiarity and recognition, respondents demonstrated a strong interest in learning more about GI, with 77.65% indicating they would like to learn more about the GI features on campus (Figure 11). Further, 70.59% of respondents expressed interest in learning about how GIs help manage stormwater runoff (Figure 12). This indicates a readiness for engagement, suggesting that barriers to awareness are not attitudinal but informational and visibility-based.

Overall, findings show that while many stakeholders spend substantial time on campus, awareness, recognition, and interaction with GI remain low, particularly for less-visible systems such as the sand filtration basin. However, the strong expressed interest in learning more indicates meaningful potential for improvement through signage, guided tours, sustainability campaigns, course integration, or community engagement events.

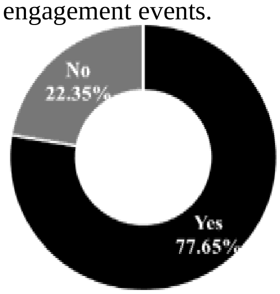

Figure 11. Interest in learning more about Green Infrastructure (GI) (n = 85)

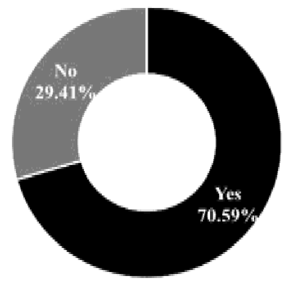

Figure 12. Interest in learning about the GI role in stormwater management (n = 85)

Conclusion

The ongoing research evaluates awareness, recognition, knowledge, and interaction with GI among campus stakeholders (specifically students) at a large public research university in the southern US using an online survey. Initial responses indicate that GI on the main campus currently functions primarily as unrecognized stormwater management infrastructure rather than as a visible sustainability asset. Although respondents in this study demonstrated moderate conceptual awareness of GI as a general environmental practice, their recognition of specific GI installations on campus was strongly tied to physical visibility, visual distinctiveness, and contextual cues. *Higher-visibility/observable GI systems* (above-ground cistern and bioswale), due to their structure, placement, planting configuration, and/or project signage, were identified more frequently than the sand filtration basin, which is less visible/observable and resembles an ordinary landscape or infrastructure component. This pattern is consistent with research showing that low-profile or naturalized GI features often blend into surrounding environments and go unnoticed unless paired with interpretive cues, consistent signage, or distinctive design elements that signal their purpose (Church, 2015; Speake et al., 2013). In the absence of such cues, functioning infrastructure can remain socially and visually invisible.

The high proportion of participants selecting "*cannot answer as I am unsure about the GI location on the main campus*" when asked whether they walk by or interact with GI suggests that respondents may be physically passing or standing near GI without realizing the infrastructure and its inherent importance. This reflects a broader phenomenon of infrastructural invisibility, in which systems that manage water, energy, or waste become part of the everyday background, recognized only when they fail or are disrupted (Deitz & Meehan, 2019). In the case of the university studied in this research, GI appears to be operating successfully in managing stormwater, which may unintentionally contribute to its lack of visibility as a designed resilience feature. However, this lack of recognition should not be interpreted as a lack of interest. Respondents expressed a strong interest in learning more about GI features and their role in reducing flooding and managing runoff, indicating that awareness barriers are informational and interpretive rather than motivational. Prior work has shown that public engagement and stewardship increase when GI is presented as a visible and meaningful element of shared environmental responsibility (Keniger et al., 2013).

Because GI supports infiltration, detention, peak-flow reduction, and resilience during intense rainfall events, building campus awareness is directly tied to long-term support for GI expansion, maintenance, and integration into the university's climate adaptation strategy (Baptiste et al., 2015; U.S. EPA, 2020). To further enhance the visibility and student engagement of GI across campus, numerous synergetic activities could be considered, which include: (1) expanding interpretive signage and QR-linked maps to clearly communicate GI functions, locations, and benefits to students from all academic disciplines, (2) broadening the integration of GI into coursework and student research across diverse fields beyond engineering and environmental programs, and (3) increasing the inclusion of GI features in campus tours, orientation, and sustainability events to normalize GI as a visible and intentional component of campus life. Together, these strategies could elevate GI from background infrastructure to a more recognizable and meaningful system, supporting the university's broader goals related to sustainability, climate resilience, and environmental literacy.

Limitations and Future Research

The ongoing data collection process is a limitation of the article, as the results reflect only those who had completed the survey at the time the study was reported. The preliminary results presented in the paper are based on the subset of completed responses (students). There is a likelihood that later respondents may differ from early respondents, which could affect the overall findings. Furthermore, the findings present only perceptions, awareness, and knowledge levels at a single university, and it is unknown whether the identified trends reflect the educational ecosystem in the US. Future studies could be conducted across academic campuses in the US to assess the generalizability of the findings and determine whether similar patterns exist and whether harmonious activities are needed to enhance GI knowledge, awareness, and impact on the built environment as we continue to observe the increasing impacts of climate change.

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Appendix A

Section	**Construct Measured**	**Example Question**
Awareness	GI familiarity	"Would you be able to recognize Green Infrastructure (GI) such as an above-ground cistern, bioswales, and sand filtration basin if you saw them on the Main Campus?"
Knowledge	Functional understanding	"Which of the following are the benefits of Green Infrastructures (GI)? (Please select all that apply)."
Experience	Exposure	"How often do you directly interact with Green Infrastructures (GI) (such as above-ground cisterns, bioswales, and sand filtration basins) on the Main Campus?"
Perception	Attitudes	"Would you be interested in learning more about the Green Infrastructures (GI) that are on the Main Campus?"