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Promoting Green Transformations through Smart Engagement: An Assessment of 100 Citizen-Led Urban Greening Projects

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Abstract: In the face of challenges like heatwaves, flooding, other extreme events, as well as increasing pollution and declining quality of life in cities, there is a growing demand for the preservation and expansion of urban green spaces, often driven by citizen-led transformations. This paper examines 100 urban greening projects initiated or supported by citizens globally, categorizing them according to the type of greenery, the stakeholders involved, the mode of implementation, and the use of smart technologies incorporated. We notice variations in green endeavors based on the stakeholders orchestrating them; most of the entirely citizen-led initiatives being aimed at the creation of urban farms and food growing, demonstrating the pressing need to secure food and self-determination in communities. More than half of the assessed initiatives that managed to scale up and multiply had public authorities providing a framework or a type of support for their development or an NGO or other organization providing expertise and mobilizing citizens at various stages. In terms of technological use, we mostly found that websites and social media platforms ease participatory endeavors and knowledge sharing of best practices, accelerating scaling efforts, while there is low integration of more advanced digital technologies, which, if used, could enable real-time monitoring of green spaces, inform evidence-based decision-making, and streamline processes in scaling up green initiatives.

Keywords: urban greening initiatives; civic action; smart technologies; green transition; climate change; urban transformation; green city; smart city planning

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1. Introduction

Urbanization has led to unprecedented challenges for urban environments, including the loss of green spaces, increased pollution, and rising temperatures. Urban life is becoming increasingly challenging: heat waves, health, and environmental risks are only expected to increase [1]. In this context, urban greening is considered crucial in improving life in cities and in climate mitigation and adaptation since it can improve well-being, health, biodiversity, water quality, the microclimate, and overall sustainability [2,3]. At the same time, urban green spaces fulfill a range of social, economic, and ecological functions, encompassing therapeutic advantages, the facilitation of social cohesion, and the potential for community development [4]. The urban green area per capita is positively associated with mental health [5,6], as the presence of nature in cities can enhance well-being [7]. The recent COVID-19 sanitary crisis brought changes in the lifestyle and behavior of citizens, which was perceived by many municipalities as an opportunity to promote sustainable development practices through open spaces, parks, and alternative models of urban mobility [8].

The importance of urban greening has been recognized by assessment frameworks like LEED [9], BREEAM [10], and Green Star [11], which incentivize the integration of outdoor areas and sustainable landscaping into new building projects [3,12]. To meet green targets

in existing overly populated cities, interventions should take place on existing facades and roofs, sealed pavements, and roads [13,14].

Today, green infrastructure initiatives are mostly top-down, yet citizen-led efforts can contribute to the greening of cities, complementing and enriching institutionalized efforts [15]. Engaging citizens in urban greening projects can foster stronger public support and generate interest in democratizing the planning, management, and oversight of public urban areas [16]. This also addresses the exclusionary dynamics of green gentrification and ensures that minority and low-income communities take part in molding fair, diverse, and sustainable urban green spaces [17]. Citizen participation can also lead to increased satisfaction with planning results, prolong project sustainability, and create avenues for increased public interest and civic involvement [18]. Research on public perceptions of urban nature and green spaces has revealed a broader (than that of the traditional top-down) spectrum of services that the public values, including social interaction opportunities, educational experiences, recreational activities, and sources of inspiration [17].

Existing research has focused on the measurement of the public's sentiments and motives behind citizen participation in urban green spaces and perspectives on urban expansion, quality of life, community conservation, and forestry while delving into intricate social nuances and the dynamics of citizen attitudes [19–22]. However, there has been less emphasis on the study of community efforts, which often consist of small-scale endeavors that cannot easily be monitored, assessed, or scaled up. When it comes to assessing those initiatives, it becomes challenging to quantify the dedication and efforts of individuals or businesses in promoting urban greening.

In this paper, we collect 100 citizen-led initiatives for urban greening from around the world. We focus on initiatives where the contribution of citizens was the enabling factor with the aim to shed more light on such efforts. By shedding light on these often smaller-scale interventions and understanding the modes of their implementation and the actors' involvement, this research endeavors to offer valuable insights that can guide the implementation of effective green initiatives within communities. Strengthening citizen ownership of green transformations can be achieved by gaining a better understanding of citizen-led urban greening initiatives. The collected data support evidence-based policy decisions and targeted scaled-up interventions for greening projects. This involves examining various strategies and approaches that can empower individuals and communities to take an active role in the planning, development, monitoring, and maintenance of environmentally sustainable urban greening projects.

The next section provides a literature review covering the role of bottom-up urban greening initiatives in community empowerment (Section 2.1), an overview of existing measurement tools and mechanisms, such as indices for assessing urban greening (Section 2.2) and delineates the various types of smart technologies that would support digitally enabled participatory urban greening and community engagement (Section 2.3). In Section 3, we introduce our methodologies and data collection approach, which involved assessing 100 citizen-led initiatives. Section 4 categorizes the collected initiatives based on infrastructure typology, implementation mode, and the integration of smart technologies. Finally, Section 5 concludes with a summary of the various synergies enabling participatory initiatives and the opportunities for the adoption of advanced smart technologies.

2. Literature Review

2.1. Grassroots Initiatives for Urban Greening

The relevance and importance of urban greening are high in the context of the climate crisis. Studies show that in urban areas, there is frequently an unequal distribution of parks, green spaces, and trees, resulting in limited access for low-income and minority communities [23]. In a study conducted in Montreal, residents of immigrant background were found to be 52% more possible to inhabit neighborhoods characterized by greater impervious surfaces and diminished tree coverage [23]. Embracing nature-based solutions within urban greening initiatives presents an opportunity to enhance resilience and si-

multaneously tackle multifaceted urban challenges [24]. Integrating these solutions into urban planning holds the promise of fostering more fair and sustainable development and improving the overall quality of urban life.

Several cities have embarked on radical transformations in response to climate change. These efforts, often driven or supported by grassroots activism, aim at creating fair and livable communities from the ground up, including reclaiming their streets from cars, restoring watersheds, growing forests, and adapting shorelines to improve people's lives while addressing our changing climate [15]. For example, advocacy groups in Washington, DC, are expanding the urban tree canopy and offering job training in urban forestry. In San Francisco, community activists are creating shoreline parks while addressing historic environmental injustice. We found several such advocates, non-profit organizations, community-based groups, and government officials who built alliances to support and embolden the urban greening vision together [15]. There are also programs initiated by cities aimed at preserving local parks, encouraging residents to take on the responsibility of caring for these green spaces, and seeking volunteers to assist the parks department. In some instances, the appeals for community involvement were prompted by insufficient funding allocated to public green areas [25].

By transforming concrete landscapes into vibrant green spaces, these initiatives create communal hubs that encourage social interaction, recreational activities, and shared experiences. Pocket parks, community gardens, and green corridors enhance the esthetic appeal of urban areas and serve as focal points for gatherings, events, community-driven activities, and even urban farming. Multiple past analyses have shown that urban agriculture fosters community bonds, nurtures trust among residents, promotes civic participation, enhances well-being, and potentially mitigates socio-economic disparities [26–29]. The involvement of residents in the planning, maintenance, and use of these green spaces instills a sense of pride and responsibility, nurturing a shared commitment to the well-being and sustainability of their neighborhood and promoting their social cohesion, sense of belonging, social capital, and critical health behaviors that might enhance psychological health and well-being [7,30,31]. Examining the contributions of significant contemporary urban theorists, Gehl argued for designing cities that promote the emotional and psychological well-being of their residents [32,33], while Jacobs also supported grassroots, community-driven approach to urban planning, as bonds between neighbors foster a sense of unity and collective ownership [34]. Happy cities are characterized by a sense of social trust, which can be achieved through a mix of public and green spaces for communal activities [35].

Urban green spaces including pocket parks were particularly appreciated by residents during the different COVID-19 lockdowns and restrictions. Being the principal place for interaction and exercise, urban green spaces were key for both the physical and mental health of people during that period [8,36,37]. Pocket parks can enhance public health and foster social cohesion among residents, particularly in densely populated neighborhoods that are often underserved. The importance of pocket parks in offering accessible green spaces to urban populations was recognized even before the onset of the coronavirus pandemic; however, their role has now become even more critical, serving as essential lifelines for improving the health and well-being of urban residents in both ordinary and challenging times [38].

2.2. Urban Greening Policies and Measurement Toolkits

The concept of urban nature is gaining traction as a potential solution for promoting sustainability in urban planning and development [39,40]. Cities can play a key role in meeting the targets outlined in the Paris Agreement on climate change. The engagement of cities and urban stakeholders is also supported by the New Urban Agenda and the 2030 SDGs [41]. Overall, at different levels (international, regional, local) urban greening policies and strategies are supported through different means. At the international level, the UN issue toolkits and guidance documents, set international fora for peer learning, offer international visibility (positive reputation of the city) through platforms and communication

channels for the best performing cities and initiatives. In some instances, tailored advisories and capacity-building support are provided to local authorities.

On a regional scale, we observe policies such as those supported by the European Union, which offer similar means and tools, with the important addition of significant funds given to authorities and partnerships that foster bottom-up and multistakeholder urban greening initiatives. Evidence-based policy and monitoring are informed by the European Environmental Agency (EEA), which studies and issues recommendations on urban greening. The EEA mainly measures urban greening with two indicators: urban tree cover and urban green space. Other indicators of air pollution and urban heat correlate to assessments of urban green spaces. They also raise awareness of the potential of green spaces to boost health and well-being, which is increasingly recognized, both in science and policy [42,43]. The European Union has committed to the European Green Deal and to becoming the first climate-neutral continent [44]. In addition, a biodiversity strategy is set with 2030 as the horizon [39]. It is recognized that green spaces often lose out in the competition for land as the share of the population living in urban areas continues to rise. Guidance and toolkits are made available to municipalities, proposing collaborative processes for developing urban greening plans. It is highlighted that municipalities need to work with citizens and other stakeholders and aim for cross-departmental work and integration of greening plans with other aspects of urban development, from mobility and health, air and water, to energy and climate adaptation. Overall, this is indicative of many policy frameworks and measures deployed at the EU level as part of the European Green Deal, which relies on citizen participation and activation [44]. The "New European Bauhaus" initiative, in the same line, awarded a citizen-led initiative in Spain, where citizens claimed unused space for the creation of a community park [45].

At the local level, authorities are the ones to ultimately set their political priorities and decide to stream funds and resources towards green interventions. Authorities can decide on the degree of citizen involvement in policy and strategy making (e.g., through voting, participatory budgets, workshops), as well as the interventions themselves, their monitoring, and scaling up. When it comes to citizen-led initiatives, local authorities can decide on their level of tolerance or support for them. In the examples analyzed in the scope of this paper, we find several cases of citizen-led occupations of unused and gray spaces and their transformation to green public spaces. There, the role of the local authorities is to tolerate, legalize, or support such initiatives in the longer term through funds and resources.

Apart from the minimum number of green spaces per capita, a key aim pursued by many municipal leaders is to ensure that open spaces are conveniently accessible within a ten-minute walking radius. For instance, looking at the data in the US, merely 22% of the population in Phoenix enjoys such proximity to a park, while 99% of Washington, DC, residents live in proximity to a park. The median city of the 100 most populous U.S. cities scores 74%, while for the median city considering all urban cities and towns in the U.S., the percentage drops to 55% [46]. We see that San Francisco has achieved the commendable milestone of providing a 10 min walk access to parks for all its residents in 2017, whereas other cities in California are still working towards this goal [47].

Implementing a network of small-scale open spaces, pocket parks, and plazas dispersed throughout neighborhoods can significantly encourage pedestrian activity, ease social engagement, and contribute to an improved state of well-being. These spaces may serve as tranquil retreats for relaxation or dynamic venues for activities such as exercise, jogging, work, and more. "Smart Urban Growth","Transit-Oriented Development", and "New Urbanism" form a conceptual and planning model for environmentally sustainable communities and cities, promoting both the understanding of cities as living ecosystems as well as principles for the preservation of natural resources and ecosystems [48]. Local authorities can also influence the international urban development agenda through their participation in networks.

Networks and city associations, such as C40, ICLEI (Local Governments for Sustainability), or the Global Covenant of Mayors (GCoM), also support urban greening initiatives by issuing guidance and easing peer learning [40,49–51]. Data4Cities, an initiative by the Global Covenant of Mayors, measures and manages the climate ambition and progress of cities and local governments. GCoM cities commit to the use of Environmental Insights Explorer ("Google Environmental Insights Explorer—Make Informed Decisions", n.d.), launched in collaboration with Google for data access, and the Data Portal for Cities (designed by GCoM and the World Resources Institute) for community-specific activity data and emission factors for the development of greenhouse gas emissions inventories and fact-based climate action planning [51].

2.3. Smart Technologies for Engagement and Participation in Urban Greening Initiatives

Upon evaluating the bibliography on the technological aspects of urban greening initiatives, a discernible trajectory appears, outlining the incorporation of smart technologies that can empower citizens to actively engage in urban greening initiatives. For example, residents could compete in tree-planting contests or take part in scavenger hunts to identify plant species in local parks. Mobile applications and online platforms enable citizens to contribute data, report issues, and take part in tree planting activities and participatory budget spending, as in the example of Lisbon analyzed as one of the 100 initiatives. Citizen-contributed data enhance public awareness, foster a sense of ownership, and create a feedback loop between the community and urban planners. Mobile applications play a pivotal role by actively involving citizens in data collection efforts [52]. These apps empower users to upload images, pinpoint locations, and provide vital feedback on the state of green spaces. This approach not only fosters a stronger sense of community engagement but also significantly amplifies the volume of data collected. Furthermore, specialized apps designed for citizen science projects enable residents to take an active role in monitoring green spaces, allowing them to report on various aspects such as plant health and wildlife sightings and even participate in tree inventories [53,54].

Social media platforms, such as Facebook, Twitter, Instagram, and online forums have been helpful in mobilizing and organizing community events, disseminating progress updates, and building a sense of unity around urban greening endeavors [55]. Additionally, digital surveys and feedback forms as well as data visualization tools serve as invaluable tools to gather input from residents on their preferences for green space design, desired amenities, and suggestions for improvement that help citizens understand current needs and trends.

Furthermore, through IoT, cities are not only transforming urban landscapes but are also fostering a stronger sense of community ownership and participation in greening efforts. IoT applications can make agricultural and farming industry processes more efficient by reducing human intervention through automation [56]. Previous studies have demonstrated that remote sensing imagery provides powerful tools for master planning and analysis regarding green urban area expansion; yet measures of urban greening and sustainability cannot be solely based on indicators obtained from 2D geographical information. In fact, 2D urban indicators should be complemented by 3D modeling of geographic data [57].

The incorporation of VR and AR applications allows citizens to immerse themselves in interactive experiences, visualize and engage with proposed greening projects. Implementing gamification and challenges related to urban greening further encourages participation [58,59]. This hands-on approach provides a clearer understanding of the potential impact and instills a sense of ownership in the community. Geographic Information Systems (GIS) and mapping tools play a vital role in planning workshops, where they can be used to visualize data and ease discussions about urban greening plans. This enables citizens to actively take part in the decision-making process and contribute valuable insights [60]. A sustainable, dynamic, and participative solution includes land cover and land-use mapping using remote sensing and GIS [61].

The transformative impact of AI, machine learning, and big data has been proven effective in addressing research gaps within this field. These innovative technologies have offered unprecedented insights into ecosystem dynamics and their associated services, facilitating a deeper comprehension of intricate ecological processes [62]. Machine learning algorithms have become indispensable tools for analyzing extensive datasets. By discerning patterns and relationships, these algorithms offer a more refined understanding of urban greening initiatives [63,64]. Data suggest that knowledge and practice are biased toward the Global North, under-representing key CBS (climate–biodiversity–society) challenges in the Global South, particularly in terms of climate hazards and urban ecosystems involved [63]. The integration of big data and technology in the research and practice of urban greening transcends mere data analysis [62]. These innovative tools have become invaluable resources for decision-makers and urban planners alike. The proposal of a geospatial model for nature-based recreation in Paris underscores the empowerment of a data-driven approach to conservation and urban development [64]. By providing a systematic and informed framework, these technologies ease the seamless integration of sustainable practices into urban development strategies and initiatives.

3. Geographical Scope and Methods and Limitations

To compile a diverse set of 100 urban greening initiatives, we conducted systematic internet searches with a global scope, verified repeatedly in different languages (English, French, Spanish, Portuguese, German, and Greek), including the following keywords: citizen-led urban greening, urban green, community greening, community gardens, community parks, and civic urban action. By conducting these web and literature searches, we acquired an initial 60 initiatives.

Through a simultaneous literature review, we became aware that citizen-led initiatives, especially those without involvement from any authority or other stakeholder steering, are often poorly or not at all represented in the literature and online platforms. This is also confirmed in the findings of this study, with many initiatives not even having a dedicated website.

To complement the list and reach a representative sample, we conducted a specialized workshop during Placemaking Europe Week 2023 [65]. The workshop was attended by 40 researchers, architects, placemakers, and elected municipal representatives. The participants were requested to share additional citizen-led urban greening initiatives, research, and the platforms that show them. As a result, another 40 initiatives were collected (see Figure 1), affecting our sample and adding more gravity to examples from Europe (see Appendix A).

However, we recognize and highlight in our literature review that the power of urban greening as a social movement is demonstrated across the world. According to research conducted with examples from the USA and Australia, urban greening was proved to be an instrument for disadvantaged communities in promoting greater resilience, health, and well-being [66]. In cities with limited history of community-driven urban greening, like Shanghai's community garden projects, there has been notable progress over the last decade. This shift shows a move away from external interventions to initiatives driven by the community. This progress is facilitated by partnerships between communities and universities, along with a comprehensive approach that includes building community capacity and providing professional support [67].

We organized and analyzed these initiatives based on the type of actors involved, the type of green infrastructure they promote, their mode of implementation, and the technologies they incorporate. First, for each of the above-mentioned characteristics, we grouped initiatives based on the type of actors involved: (i) initiatives with only the participation of citizens, (ii) initiatives that were developed through the collaboration of local authorities and citizens, (iii) initiatives developed with the participation of NGOs and citizens, (iv) joint efforts between businesses and citizens, (v) initiatives stemming

from public institutions such as schools/universities and their communities, and finally, (vi) more complex efforts arising from multistakeholder partnerships.

Figure 1. Geographical spread of analyzed initiatives.

To better understand urban green interventions, it was important to define the types of interventions we assessed for this study. Green infrastructure refers to the connective matrices of greenspaces that can be found in and around urban and urban fringe landscapes and provide a great number of complimentary benefits to the ecological, economic, and social space of the city [68]. Urban green infrastructure is characterized by more distinctive features than its rural counterparts. A typology classification is officially acknowledged by the European Commission and will be our basis for categorizing the initiatives in terms of the type of greening [69,70].

While the following list of elements (see Table 1) is not exhaustive, it aims to provide an overview of some of the most common elements within a specifically urban and peri-urban setting, as well as illustrative examples. This typology, as used by the European Commission, includes "Blue areas" and "Green areas for water management" as two distinct categories. However, in the context of this research, we have decided to merge them. Blue and water management cases are already very few compared to other categories, especially with our scope being citizen-led initiatives in urban centers. In most cases, water management generally requires calculated infrastructure works and institutionalized interventions. Analyzing citizen-led initiatives based on the type of greening can help show the priorities and needs of citizens. Civic initiatives require the investment of time and effort and aim at addressing needs citizens consider important.

In our analysis of incorporating green technologies, we relied on the technologies outlined in the bibliography (Section 2.3) pertaining to citizen participation as our foundational framework (see Table 2). This approach ensured that our exploration of smart technologies was grounded in established research and methodologies, enhancing the credibility of our analysis. By leveraging these identified technologies, we aimed to foster greater engagement and collaboration among citizens in the implementation and adoption of environmentally sustainable solutions such as urban greening initiatives.

Table 1. Types of green infrastructure as identified by the European Commission.

Typology of Green Infrastructure	Types of Greening Included
Building greens	Green balcony, ground-based green wall, facade-bound green wall, extensive green roof, intensive green roof, atrium, green pavement and green parking pavement, green fence, and noise barrier.
Urban green areas connected to gray infrastructure	Tree alley and street tree/hedge, street green and green verge, house garden, railroad bank, green playground/school ground, green parking lot, riverbank green.
Parks and (semi)natural urban green areas, including urban forests	Large urban park, historical park/garden, pocket park/parklet, botanical garden/arboreta, zoological garden, neighborhood green space, institutional green space, cemetery and churchyard, green sports facility, forest, shrubland, abandoned and derelict area with patches of wilderness.
Allotments and community gardens	Allotment, community garden, horticulture.
Agricultural land	Arable land, grassland, tree meadow/orchard, biofuel production/agroforestry, horticulture.
Blue areas/ Green areas for water management	Rain garden or sustainable urban drainage system (SUDS), rain garden, swales/filter strip. Lake/pond, river/stream, dry riverbed, canal, estuary, delta, seacoast, wetland/bog/fen/marsh.

Table 2. Types of technologies as identified in bibliography.

Type of Technologies	Use of Technology
Web Platforms and Mobile Applications	Web and smartphone apps that enable citizens to report issues, participate in surveys, and access information conveniently.
Social Media Platforms	Platforms like Twitter, Facebook, and Instagram used for engaging citizens, sharing information, and gathering feedback.
Crowdsourcing Platforms	Online platforms such as Crowdsourced Mapping and OpenStreetMap that allow citizens to contribute data and insights.
Internet of Things (IoT) Devices	Connected devices like smart sensors and meters that collect data on environmental parameters or infrastructure usage.
Geographic Information Systems (GIS)	Systems for mapping and analyzing spatial data, enabling citizens to visualize and understand local issues better.
Online Forums and Discussion Boards	Web-based forums and discussion boards where citizens can engage in debates, share ideas, and propose solutions.
Virtual Reality (VR) Platforms, Augmented Reality (AR) Application	Immersive platforms that allow citizens to experience simulations of proposed urban developments or environmental changes and applications overlaying digital information onto the physical world, providing citizens with real-time data and contextual information.
Blockchain Technology	Distributed ledgers ensuring transparency and security in citizen-led initiatives such as voting or crowdfunding projects.
Data Visualization Tools	Tools like Tableau or D3.js used to create interactive visualizations that help citizens understand complex datasets and trends.

4. Research Findings

4.1. Analysis Based on Enabling Actors

Urban greening initiatives can involve a diverse array of actors and stakeholders, each contributing unique expertise and perspectives to enhance the vitality of urban landscapes. Municipal authorities play a pivotal role, providing the regulatory framework, funding, and strategic planning necessary to initiate and sustain green transformations. NGOs and community-based organizations actively engage with residents, advocating for green spaces, providing expertise, organizing volunteer efforts, and fostering community participation. Private sector entities, including developers and businesses, often collaborate to integrate green elements into urban infrastructure, promoting sustainability while enhancing commercial spaces. Academia and research institutions contribute scientific

knowledge and innovation by conducting pilots and informing evidence-based practices on the ecological and societal benefits of urban greenery [71]. Collectively, citizens and other stakeholders mentioned can create collaborative networks, which can drive urban greening initiatives towards holistic, sustainable outcomes that benefit both the environment and communities. Assessing the 100 initiatives, it gets clear that these synergies vary based on cultural, societal, and legal frameworks (see Table 3).

Table 3. Types of partnerships and actors leading and implementing the 100 initiatives.

Implementing Partners and Partnerships of the 100 Citizen-Led Initiatives Analyzed	
Citizens (solely in own capacities)	28
Local authority and citizens	28
NGO and citizens	20
Multistakeholder partnership (public or public–private, including citizens, authorities, NGOs, and others)	13
School/University and their communities (professors, students, parents)	9
Businesses and citizens	2

4.1.1. Citizen-Led Initiatives: Nonprofits and Community Groups

Of the studied initiatives, 48 are entirely led by citizens (including partnerships between NGOs and citizens). Out of these initiatives, 61.7% are dedicated to urban farms and food growing, also showing the pressing need to secure food and self-determination in cities. We observe in some cases that after the creation of the green space takes place, the community sets up non-profit organizations and/or a decision-making mechanism that can be as simple as community meetings (e.g., Navarinou Park in Athens) [72]. Such cases show the role of urban greening in creating bonds within the community and social cohesion. In relevant research, eight case studies of community-led urban farms were analyzed and showed that neighborhood-bound gardens and gardens with communal plots attract gardeners interested in the social aspects of gardening, while non-neighborhood-bound gardens and gardens with individual plots attract gardeners interested in harvesting and cultivation [30].

Twenty (20) of the one hundred (100) cases consist of an NGO or another type of non-profit structure playing a key role in providing expertise and guiding citizens or other citizen organizations. Interesting examples are urban forests in France, Luxembourg, and Belgium, which mention the Akira Miyawaki method [73] of fast-growing diverse urban forests and other methods following similar principles. In certain cases, we see non-profits offering training and opportunities to encourage the civic action of interested citizens and citizen groups. Lastly, we observe other initiatives where citizens act in a capacity, such as parents or teachers. A few of the collected initiatives (e.g., in Greece, France, Poland, Canada, the Netherlands) consist of actions taken for the greening of schoolyards through gardens, small allotments, and other interventions to depave. Green schoolyards can facilitate diverse behaviors and activities, provide sensory and embodied nature experiences, provide a restorative environment, support biodiversity, and provide a resilient environment that supports climate resilience and mitigates environmental nuisances [71]. The Grenoble Schoolyard Initiative is a notable urban development project focused on transforming schoolyards in the city of Grenoble, France [71]. The project aims to reimagine schoolyards as multifunctional spaces that not only cater to educational needs but also serve as vibrant community hubs. It involves comprehensive redesigns that prioritize elements such as greenery and recreational facilities. By integrating sustainable features and fostering a sense of community ownership, the Grenoble Schoolyard Initiative exemplifies a forward-thinking approach to urban development, one that prioritizes the well-being and development of both students and the broader population. This project has

served as an inspiring model for cities worldwide looking to create inclusive, dynamic, and environmentally conscious spaces within their urban landscapes.

4.1.2. Citizen and Authorities' Initiatives

Out of the 100 initiatives, 28 are implemented in collaboration between local authorities and citizens. This collaboration materializes in different ways, which we could group under two categories:

- The municipality creates a framework for citizen action (23 initiatives). This materialized with the municipality/local authority giving permits to citizens who wish to intervene in the public space by greening. In such cases, the citizens decide on the space and intervention. The authority could also describe a set of urban greening activities eligible for a grant. In one case, the local authority creates employment opportunities for artists and gardeners to intervene in public spaces.
- The municipality is guided by citizens to decide on urban greening actions (5 initiatives). As such, we group cases of citizens pushing for green interventions through participatory budgets or putting pressure on authorities to reutilize abandoned spaces or change plans for parking spaces or buildings to create common green spaces.
- We find that the partnership of citizens and authorities is a very successful one in terms of time, impact, and geographical range and the longevity of the initiatives. One of the oldest initiatives we mapped is the New York City Green Thumb Program, which dates back to 1978 and has supported 550 gardens to date [74].

4.1.3. Private Sector Involvement

Out of the 100 initiatives collected, 11 include the involvement of the private sector and, notably, local businesses. Two of them are in London and follow the Business Improvement District (BID) model [75,76]. A BID is a designated area within a city or town where local businesses collaborate to enhance the economic and physical environment. It operates through a self-imposed tax or fee collected from businesses within the district, which is then reinvested back into the community. The primary goal of a BID is to foster economic development, improve the overall attractiveness and vitality of the area, and address specific concerns shared by local businesses and property owners. This may include initiatives such as streetscape enhancements, marketing campaigns for green initiatives, security measures to protect green/public spaces, and events designed to increase vibrancy. By pooling resources and working collectively, BIDs play a pivotal role in revitalizing commercial areas, fostering a sense of community, and ultimately driving sustained growth in the local economy. They serve as a powerful model for public–private partnerships, illustrating the potential for businesses to proactively shape and improve the environments in which they operate.

Other isolated cases among the 100 include funds given to the public for greening purposes as part of corporate responsibility strategies and the involvement of small businesses in the rehabilitation of brownfields and abandoned areas.

4.2. Types of Urban Greening

Out of the 100 initiatives, 44 interventions referred to the creation of allotments, community gardens, and agricultural land (see Table 4). This finding is interesting as it connects the need for green spaces with the primary need for access to food. Three initiatives consist of the creation of green spaces connected to gray infrastructure.

Out of the 49 initiatives entirely led by citizens with NGO involvement, 31 are allotments, community gardens, or agricultural land (see Table 5). It becomes clear that when citizens lead interventions to add green into the public space, they are also driven by the need to secure access to food. Five out of the eleven initiatives that are driven by schools or universities and their students and professors are allotments, community gardens, or agricultural land (see Table 6). When the private sector is involved (11 initiatives), we

see a slightly different breakdown, with more initiatives connected to gray infrastructure (see Table 7).

Table 4. Types of greening associated with stakeholders leading the 100 initiatives.

100 Citizen-Led Initiatives Analyzed per Type of Greening	**100**
Allotments and community gardens	44
Urban green areas connected to gray infrastructure	34
Parks and (semi)natural urban green areas, including urban forests	15
Building greens	4
Blue areas/green areas for water management	2
Agricultural land	1

Table 5. Types of initiatives involving NGOs.

Initiatives Led or Supported by NGOs Analyzed per Type of Greening	**49**
Allotments and community gardens	31
Urban green areas connected to gray infrastructure	10
Parks and (semi)natural urban green areas, including urban forests	8
Agricultural land	-
Blue areas/green areas for water management	-
Building greens	-

Table 6. Types of initiatives involving schools and universities.

Initiatives Implemented by Schools/Universities and Their Communities Analyzed per Type of Greening	**11**
Allotments and community gardens	5
Urban green areas connected to gray infrastructure	4
Parks and (semi)natural urban green areas, including urban forests	1
Building greens	1
Agricultural land	-
Blue areas/green areas for water management	-

Table 7. Types of initiatives involving private sector.

Initiatives that Were Realized with Private Sector Involvement Analyzed per Type of Greening	**11**
Urban green areas connected to gray infrastructure	4
Parks and (semi)natural urban green areas, including urban forests	3
Allotments and community gardens	3
Agricultural land	-
Building greens	-

4.3. Modes of Implementation and the Role of Authorities

The initiatives in which municipalities and public authorities are involved are highlighted with an asterisk in Table 8. The role of the authorities can be interpreted as follows:

- Providing funding;
- Providing a framework for action for citizens and small businesses (e.g., allowing citizens to intervene in the public space);

- Legalizing citizen action (e.g., by accepting green spaces that are a result of occupation, protests, or other);
- Transferring part of their power to citizens (e.g., by making part of their budget participatory).

Table 8. Modes of implementation of the citizen-led initiatives. Modes involving public authorities are highlighted with an asterisk *.

Mode of Implementation of the Citizen-Led Initiatives	
(Solely) Civic action	40
* Municipality creates framework for citizen initiative	20
NGO-coordinated action	10
* Citizens decide/mobilize public interventions (including participatory funding)	7
* Public funding for community greening initiatives	4
* Municipality, NGO, citizen collaboration	3
Research pilot	2
Business Improvement District (BID)	2
* National fund to municipalities, communities, and stakeholders	1
* Municipality encourages green initiatives led by small businesses	1
Private funds, NGO coordination, citizens volunteering	1
Citizen-business common action	1

4.4. Categorization Based on the Incorporation of Smart Technologies

Upon evaluating the technological landscape adopted by these initiatives, we see that 46 out of 100 initiatives, a notable portion of the analyzed initiatives, have integrated smart technologies. Of those 46 initiatives, more than 36 have created a web-based platform, with 5 featuring a user-friendly and interactive map interface. Furthermore, a considerable proportion of these initiatives have embraced social media channels as a means of communication. Table 9 consists of technologies integrated by the initiatives, encompassing only a subset of the technologies examined in Section 3.

Table 9. Types of smart technologies incorporated by the initiatives studied.

Integration of Smart Technologies in the 100 Analyzed Initiatives	
No technology detected	54
Web Platform or. Application (only)	35
Social Media Platforms (only)	5
Social media and Website	4
Internet of Things (IoT) Devices (tracking) and Website	2

Specifically, thirteen of the initiatives have an interactive map, ten of the initiatives actively use these platforms for outreach and engagement purposes as they provide the users with the option to register as a volunteer or partner, while eight of the initiatives' websites include a calendar with past actions. Another seven initiatives allow their users to submit ideas for new actions (see Figure 2).

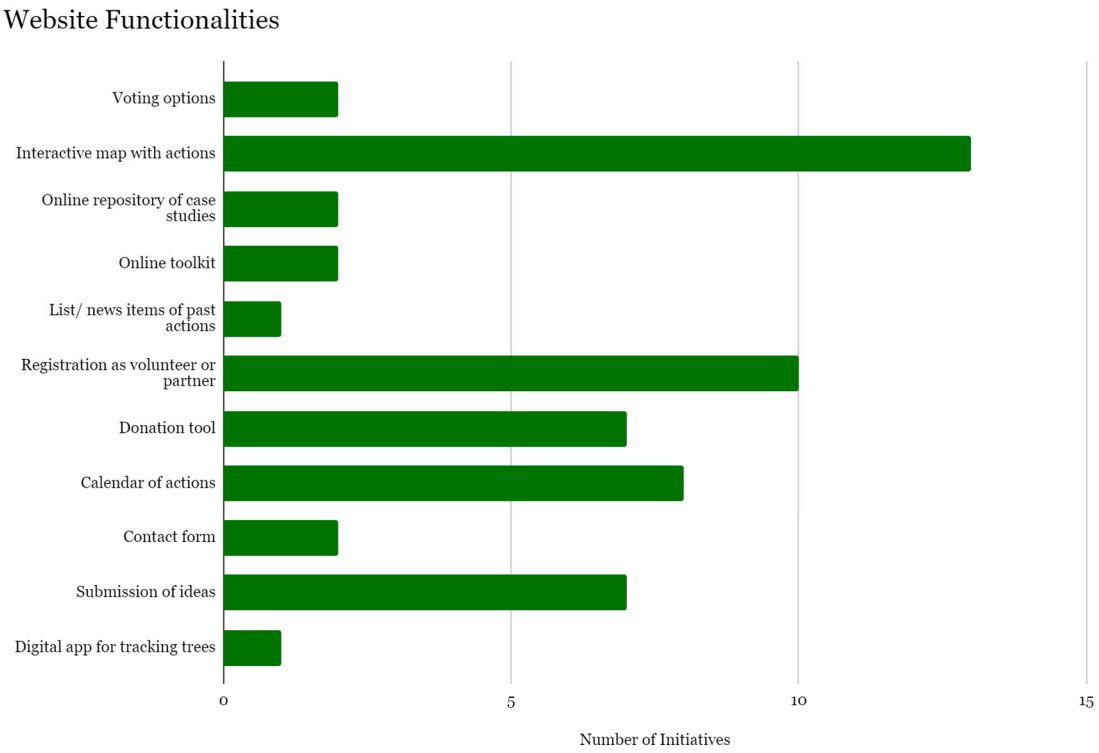

Figure 2. Functionalities of urban greening web platforms.

We have observed a restricted adoption of the Internet of Things (IoT). There is much opportunity for neighborhoods and communities that adopt IoT devices to obtain the capacity to oversee their initiatives and promptly address the ongoing requirements of the green space. Through the strategic application of these technologies, citizens and community organizers will become empowered to monitor small-scale urban green areas in their neighborhoods, fostering a profound sense of ownership and pride in their local environment. In contrast to the environmental logic of New Urbanism and LEED-ND, which tries to improve the physical environment of cities, IoT-based environmental sustainability focuses on user behavior. We can describe the entire process as a sequence that starts from (a) the deployment of sensors and smart meters across city ecosystems, districts, neighborhoods, and utilities, which collect information from city activities, people, and supply chains; (b) information processing, analytics, knowledge extraction, and dissemination to users and authorities; (c) users becoming aware and motivated to develop sustainable behavior by realizing they have a direct gain, a long-term environmental benefit, or some kind of reward; (d) public authorities obtaining information to design more sustainable policies; and (e) the impact, which is monitored, measured, documented, and disseminated [48].

The Cityscape Lab Berlin is a proper example of this type of initiative, which originated within the framework of the Berlin-Brandenburg Institute of Advanced Biodiversity Research (BBIB), a collective of both university and non-university research institutions dedicated to biodiversity studies in Berlin and Potsdam. Its real-world implementation began in 2016, supported by funding from the German Federal Ministry of Education and Research (BMBF) under the collaborative initiative "Bridging in Biodiversity Science—BIBS", spearheaded by Berlin's Technical University. The major aim of the Cityscape Lab Berlin is to provide a flexible research platform for exploring the effects of urbanization and rapid transitions in urban land-use patterns on biodiversity and ecosystem functioning at different spatial and temporal scales [77].

5. Conclusions, Challenges, and Future Outlook

The analysis of citizen-led initiatives showed the actual users' needs. Citizen-led initiatives address the very real and often urgent needs of communities, while institutional-

ized and top-level planning is guided often by other objectives. These grassroots efforts, fueled by local insight and passion, target immediate challenges faced by residents, ranging from food insecurity and access to green spaces to environmental conservation. These initiatives leverage the collective expertise, creativity, and resourcefulness of individuals to devise practical solutions. Whether through neighborhood urban farming, urban greening programs, or advocacy addressed towards authorities for better or bigger green community infrastructure, these endeavors express the urgent needs on the ground. They show the remarkable impact that citizen-driven action can have on effecting positive change within communities.

We observe that most of the entirely citizen-led initiatives aimed at the creation of urban farms and food growing, demonstrating the pressing need to secure food and self-determination in communities. Initiatives also have better chances to scale up and multiply when public authorities provide a framework or a type of support for their development or when an NGO or other organization is available to provide expertise and mobilize citizens at various stages. Scaling up green initiatives involves navigating a range of factors to ensure their successful expansion and impact. From this study, we see that clear frameworks, incentives, and regulations that promote sustainability encourage the adoption and expansion of green initiatives. In addition, engaging stakeholders, garnering local support, and fostering a sense of ownership are vital for assuring the continuation and the scale up of these initiatives. Knowledge sharing of best practices and lessons learned ensures that successful strategies can be replicated or adapted in other contexts, accelerating scaling efforts.

Most of the initiatives that receive any type of support from a larger organization, be it the municipality or a nonprofit with relevant expertise, are digitally documented through interactive maps, while most calls for further action and support are addressed through online platforms and social media. Integration of more advanced digital technologies in the future could enable accurate and real-time assessments of green spaces, facilitate community engagement, provide robust monitoring and evaluation mechanisms, and inform evidence-based decision-making.

Through this study, we investigated the ways that citizens participate in and lead urban greening initiatives, as well as the digital means they use. However, we recognize that the responsibility for advancing further digitization initiatives, monitoring, and scaling up greening at urban and larger levels lies with the public authorities. This pivotal role involves not just observing the ongoing technological landscape but also orchestrating strategies for widespread adoption and expansion. In addition, authorities bear the crucial task of ensuring that digitization efforts align with broader organizational goals, fostering seamless integration and maximizing the potential benefits of technological advancements across the spectrum. Collaborations among urban planners, technologists, researchers, and policy makers are crucial for designing effective monitoring systems. As cities continue to grow, the use of smart technologies can contribute to creating sustainable, resilient, and livable urban environments that prioritize the health and well-being of residents and ecosystems alike.

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Appendix A

Table A1. Locations and names of the studied initiatives.

Location (City, Country)	Name of Initiative
Lisbon, Portugal	Participatory Budget
Alberta, Canada	Guerilla gardeners
Amsterdam, the Netherlands	"De Ruigi Hof" nature association
Amsterdam, the Netherlands	Bio-receptive concrete as green wall
Melbourne, Australia	Green your laneway
Amsterdam, the Hague Netherlands	Green Schoolyards
Athens, Greece	Adopt your city, Pocket parks
Athens, Greece	City interventions ("Παρεμβάσεις στην Πόλη")
Athens, Greece	Navarinou Park
Athens, Greece	Urban Farmers (Αγρότες στην Πόλη)
San Sebastian, Spain	Ulia Garden
Berlin, Germany	Nomadisch Grün
Berlin, Germany	Prinzessinnengarten
Berlin, Germany	Tempelhofer Feld
Berlin, Germany	CitiScapeLab
Berlin, Germany	Volkspark Lichtenrade
Bristol, UK	Avon Wildlife Trust
Brussels, Belgium	Asiat Park
Buenos Aires, Argentina	Huerta Luna garden
Buenos Aires, Argentina	Vivera Organica in Rodrigo Bueno green and social housing development
Canada	Eco-urban gardens
Canada, USA	TD Bank's Green Streets Program
Cape Town, South Africa	Abalimi Bezekhaya
Cape Town, South Africa	Oranjezicht City Farm
Greece	Green schoolyards
Chicago, USA	NeighborSpace
Copenhagen, Denmark	Bioteket
Copenhagen, Denmark	Byhaven
Copenhagen, Denmark	Garden in a night
New York, USA	High Line
San Francisco, USA	Hayes Valley Farm
Durban, South Africa	Local communities improve river flow
Edinburgh, UK	Duddingston Field Group
France, Belgium, Luxembourg	Urban forests
São Paulo, Brazil	Parque Augusta
Glasgow, Scotland	Glasgow Community Gardens
Grenoble, France	Greening of the street in front of the schools
Melbourne, Australia	Pocket Parks

Table A1. *Cont.*

Location (City, Country)	Name of Initiative
Mumbai, India	Urban Leaves
New York, USA	It's My Park Day
London, UK	Community Garden
London, UK	Curve Garden
London, UK	Drummond BID
London, UK	Green interventions through Business Improvement District—Waterloo
London, UK	Guerrilla gardening
London, UK	London's DIY Streets
London, UK	Paper Garden
London, UK	Skip Garden
London, UK	The Edible Bus Stop
London, UK	Capital Growth
Los Angeles, California, USA	Guerrilla gardening
Los Angeles, USA	Los Angeles Community Garden Council
New York, USA	MillionTreesNYC, USA
Los Angeles, USA	Los Angeles TreePeople
Ixelles, Belgium	Planting permit
Manchester, UK	Leaf Street Community Garden
Amsterdam, the Netherlands	ROEF—green roof festival
Melbourne, Australia	3000 Acres
Melbourne, Australia	CERES Community Environment Park
Barcelona, Spain	Guide for green roofs to citizens
Milan, Italy	Boscoincittà
Montreal, Canada	Loyola Farm
Montreal, Canada	NDG Food Depot
Montreal, Canada	P.A.U.S.E—Urban Garden network in the university campus
Montreal, Canada	Santropol Roulant
Netherlands	Tiny forests
Curitiba, Brazil	100,000 trees for Curitiba
Detroit, USA	Detroit Future City's Field Guide to Working with Lots
Ilam, East Nepal	Greening of urban commercial center
Madrid, Spain	Huertos Urbanos
San Francisco, USA	San Francisco's Pavement to Parks
Paris, France	Greening of the street in front of the schools
Paris, France	Greening Roofs
Philadelphia, USA	Orchard Project
Paris, France	Planting permit
Seattle, USA	Seattle P-Patch Program
Philadelphia, USA	Gibbsboro Community Garden

Table A1. *Cont.*

Location (City, Country)	Name of Initiative
Portland, USA	Depave
Portland, USA	Portland Neighborhood Greening Projects
Singapore	Singapore's Community in Bloom
Rotterdam, the Netherlands	Voedseltuin Rotterdam
Rotterdam, the Netherlands	Educational Gardens
San Francisco, USA	Alemany Farm
Philadelphia, USA	Tree Tenders Program
Philadelphia, USA	Philadelphia LandCare Program
San Francisco, USA	San Francisco's Friends of the Urban Forest
Los Angeles, USA	Los Angeles Green Alleys
Freetown, Sierra Leone	The TreeTown campaign
Seattle, USA	Seattle's Neighborhood Street Fund
Seattle, USA	Beacon Food Forest
New York, USA	NYC GreenThumb
Reggio Emilia, Italy	Regulation for citizenship labs
San Francisco Bay Area, USA	The Jean Sweeney Open Space Park and Community Garden
Stockholm, Sweden	Stockholm's Inner-City Gardens
Tampere, Finland	Meadow planting in the city
Toronto, Canada	Depave Paradise
Toronto, Canada	Toronto Green Community
Trento, Italy	Comun'Orto
Vancouver, Canada	CityStudio Greenest City Projects
Warsaw, Poland	Green schoolyards

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