4 Promoting Blue-Green Infrastructure in Urban Spaces Through Citizen Science Initiatives

Indu K. Murthy and Monowar Alam Khalid

Abstract

The compounded effects of urbanization and climate change are taking a serious toll on rapidly growing urban spaces around the world. Blue-green infrastructure offers a host of opportunities and benefits for addressing the multiple challenges of environment, social well-being and climate change. Cities can mobilize key actors for crosscutting and inclusive action, bringing diverse stakeholders such as national governments, private sector, civil society and common citizens together. This chapter discusses the role of citizen science which is now seen as a tool for educating citizens on scientific research, engaging them where possible and considering views and expectations of different stakeholders. Citizen science can play a role at different stages of development of urban spaces, and they include (i) project demand, (ii) project design, (iii) project implementation and delivery and (iv) project monitoring and maintenance. For facilitating and promoting enhanced participation of citizens through the entire project cycle of blue-green infrastructure, appropriate policy instruments, ranging from legal to market-based to communication to organizational, are needed.

Keywords

Blue-green infrastructure · Urban spaces · Cities · Climate change · Citizen science · Sustainable development

I. K. Murthy (✉)
Center for Study of Science, Technology and Policy, Bangalore, Karnataka, India
e-mail: indukmurthy@cstep.in

M. A. Khalid
Integral University, Lucknow, Uttar Pradesh, India

S. Dhyani et al. (eds.), *Blue-Green Infrastructure Across Asian Countries*,
https://doi.org/10.1007/978-981-16-7128-9_4

4.1 Introduction

Cities present enormous potential to anchor in wealth generation and economies. According to the UN Department of Economic and Social Affairs report, by 2030, there would be 43 megacities globally with more than ten million population each—mostly in the developing regions (United Nations 2018). The world's cities that occupy just 3% of the land account for 60–80% of energy consumption and 75% of the carbon emissions globally.[1] Increasing and rapid urbanization is exacerbating the pressure on freshwater supplies, sewage, the living environment and public health.[2] This is leading to scarcity of resources, lack of basic services, increased congestion and decline in infrastructure. Unplanned sprawl as cities spill beyond formal boundaries threatens developmental planning and attainment of global goals of sustainable development.[3] Shao et al. (2020) analysed the extent and pattern of urban sprawl in Morogoro urban municipality and concluded that urbanization affects the quality of urban life and its sustainable development.

In India, as per the 2011 census, 31% of people live in urban areas, and by 2025, 46% of Indians will live in cities with more than one million people. By 2030, the number of cities with more than one million population will grow from 42 to 68 and is expected to grow to 814 million by 2050 (McKinsey 2010). Oxford Economics Global cities report (2016) estimated that 17 of the 20 fastest-growing cities in the world will be from India during 2019 and 2035. Rapid urbanization poses multiple challenges with regard to liveability. As the cities are expanding in an unplanned manner, they are ill-equipped to deliver basic services of housing, infrastructure, water and sanitation. This is evident from the report of Economist Intelligence Unit's Global Liveability Index 2019 covering 140 cities, which ranks New Delhi and Mumbai in the 118th and 119th position. This index is developed by a city being assigned a rating of relative comfort for over 30 qualitative and quantitative factors across 5 broad categories. These include culture and environment, healthcare, education, stability and infrastructure which are rated as acceptable, tolerable, uncomfortable, undesirable or intolerable. While a rating is awarded based on the judgment of in-house analysts and in-city contributors for qualitative indicators, the rating is calculated based on the relative performance of a number of external data points for quantitative indicators. The scores are then compiled and weighted to provide a score of 1–100, where 1 is considered intolerable and 100 is considered ideal.

The challenges to urban spaces could be overcome through improved resource use such as better water and waste management and by building cities that offer job opportunities and provide access to basic services like energy, housing and transportation. This is because cities can either dissipate energy or help optimize energy use by reducing energy consumption and adopting green energy systems (Kennedy

[1] Cities—United Nations Sustainable Development

[2] Goal 11 targets; UNDP

[3] SDG 11: Sustainable Cities and Communities

et al. 2009). Therefore, building cities that are inclusive and sustainable is not an option but a requirement.

The Government of India through its Smart Cities Mission, the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) and the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) is working to address the challenge of improving urban spaces. However, the challenges of congestion, pollution, housing, sanitation, energy access, transport, unemployment, waste management and poverty remain (Aijaz 2016). Blue-green infrastructure—an approach to building resilience through capitalizing the benefits of working with urban green spaces and naturalized water flows (Lamond and Everett 2019)—offers an opportunity to manage multiple challenges of urbanization such as infrastructure and water demands, waste management, etc., in addition to providing climate change mitigation and adaptation benefits. In this chapter we explore the multiple co-benefits of promoting blue-green infrastructure, and also how citizen science—involving general public—could provide the required impetus to have cities that are sustainable and inclusive.

4.2 Cities, Climate Change and Sustainable Development

Cities are centres of commerce, culture and innovation. The effects of urbanization and climate change consequences are taking a serious toll on the rapidly growing urban pockets across the world (Carter et al. 2015). A growing number of people will continue to face unprecedented negative impacts, both due to climate change and reduced economic growth, quality of life and increased social instability (Hoegh-Guldberg et al. 2018). About 70% of cities are already dealing with the effects of climate change and nearly all are at risk, according to the C40 report.[4] Cities are sources and sinks of emissions (Hoornweg et al. 2011; Lin et al. 2018). According to the C40 report[4], two-thirds of the world's energy is consumed by cities, and they are a source of 75% of global CO_2 emissions, with transport and buildings being the biggest contributors. According to Rosenzweig et al. (2015), "temperatures are already rising in cities around the world due to both climate change and the urban heat island effect." In this study for 100 cities, Rosenzweig et al. (2015) reported the following:

- The mean annual temperature increase in about 39 cities around the world is at a rate of 0.12–0.45 °C per decade during 1961 to 2010.
- The mean annual temperature is projected to increase by 0.7–1.5 °C by the 2020s and 1.3–3.0 °C by the 2050s.
- The mean annual precipitation is projected to change in the range −7 to +10% by the 2020s, and −9 to +15% by the 2050s.
- Sea level is projected to rise in the coastal cities by 4–19 cm by the 2020s and 15–60 cm by the 2050s.

[4] https://www.c40.org/ending-climate-change-begins-in-the-city

The impacts of climate change on urban ecosystems are multiple—both direct and indirect as biodiversity in urban ecosystems and the ecosystem services that they provide for human health and well-being is impacted, making them vulnerable (Emilsson and Ode Sang 2017).

The Goal 11 of the UN Sustainable Development Goals (SDGs) is “sustainable cities and communities.” SDG 11 aims at safe and affordable housing, affordable and sustainable transport systems, inclusive and sustainable urbanization, protecting the world’s cultural and natural heritage, reducing the adverse effects of natural disasters, reducing the environmental impact on cities, providing access to safe and inclusive green and public spaces, strong national and regional development planning, implementing policies for inclusion, resource efficiency and disaster risk reduction and supporting least developed countries in sustainable and resilient building. SDG 11 is thus a transformational element of the 2030 Agenda as it is location-specific at a manageable scale, highlighting the interlinkages and opportunities cities provide across sectors and goals—being microcosms of all the other SDGs.

4.3 Citizen Science and Blue-Green Infrastructure

In this section, we define citizen science and green and blue infrastructure and also discuss the evolution of the concept over time, along with looking at citizen science in conjunction with green and blue infrastructure.

Citizen science: Citizen science is the process of producing scientific knowledge in which non-scientific or non-professional actors, individuals or groups actively and intentionally participate (Francois Houllier Merilhou-Goudard 2016). In other words, citizen science can be defined as the involvement of public or people from non-academia in the process of scientific research. It is also referred to as participatory action research (Pettibone et al. 2016), civic science, amateur science (Finke 2014), community science and crowd-sourced science. There are also certain related concepts such as community-based monitoring (Mark et al. 2017), stakeholders’ engagement, etc. The earliest citizen science programme is believed to be developed in the 1800s by Wells Cooke from the American Ornithologists Union, who looked at the patterns of bird migration under North American Bird Phenology programme, allowing private citizens for the first time to join the government programme. Later, since 1900, the National Audubon Society involved private citizens in their annual Christmas Bird Counts.

Citizen science thus encompasses a diverse range of approaches and, in addition to generation of scientific data, provides engagement benefits and other outcomes such as education, awareness building and action (Kelemen-Finan et al. 2018). Numerous disciplines and research topics are adopting a citizen science approach (see Fig. 4.1), and in addition to researchers, engineers and technicians, a range of actors including individuals as well as groups (associations, companies, regional authorities, etc.) are beginning to engage in citizen science.

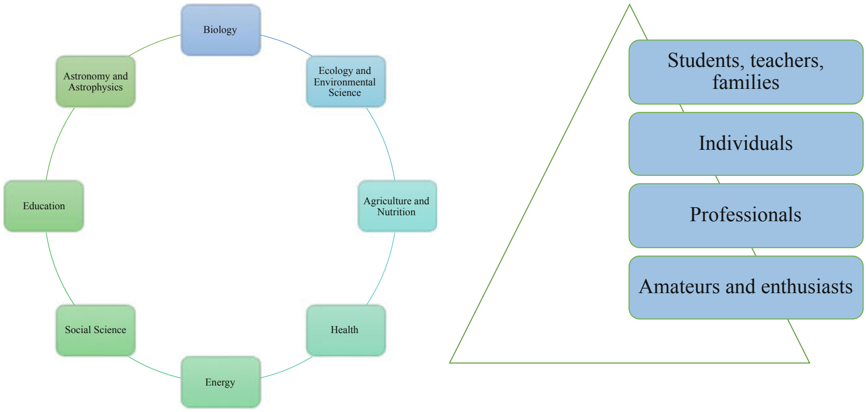

Fig. 4.1 Emerging topics and streams of citizen science engagement and actors

Blue and green infrastructure: Blue infrastructure refers to water elements—rivers, canals, ponds, wetlands, floodplains, water treatment facilities, etc. Green infrastructure refers to trees, lawns, parks, fields, forests, etc. These terms are borrowed from urban planning and land-use planning. Green infrastructure is defined as "the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, storm water harvest and reuse, or landscaping to store, infiltrate, or evapo-transpirate storm water and reduce flows to sewer systems or to surface waters."[5] Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts while providing many community benefits.

4.3.1 Citizen Science and Green Infrastructure

Citizen engagement in green infrastructure is driven by the need for "all groups of society having a say in its planning and implementation to ensure that it meets their requirements" (Wilker et al. 2016). Such a need for varied forms of citizen engagement is also highlighted in literature by Mees et al. (2019), Faehnle et al. (2014) and Lovell and Taylor (2013). Citizen participation in green infrastructural development is focused on the early stages of development, advocating collaborative governance and co-production (Frantzeskaki 2019). However, Wilker et al. (2016) argue that current methods adopted for promoting participation such as stakeholder consultations alone are not sufficient but more interactive participation methods such as involving communities in plan and design of projects need to be adopted in order to achieve meaningful outcomes. However, involvement of citizens at the

[5] https://www.epa.gov/green-infrastructure/what-green-infrastructure

later stages such as at the time of maintenance is reported but under-researched (Jerome et al. 2017).

Despite its promise and increasing use, mixed results of participation of citizens in green infrastructure are reported (Burton and Mustelin 2013), underpinning the need for more elaborate forms of citizen engagement such as those reported by Mees et al. (2019) and Faehnle et al. (2014).

4.3.2 Citizen Science and Blue Infrastructure

Use of a citizen science framework for hydrological studies is complex and limited by cost, technological demands and need for spatially and temporally distributed measurements (Paul et al. 2018). However, in the recent times, technological developments with respect to monitoring equipment and volunteered geographical information have improved the rate and quality of data collection through real-time mapping services that are tagged to a location (Newman et al. 2012). This has led to increased application of citizen science in hydrology (Paul et al. 2018).

Water resource monitoring through citizen science has emerged worldwide leading to development of networks of well-monitored sites created over time, improving the spatial coverage of monitoring (Ochoa-Tocachi et al. 2018). Such monitoring programmes include measurements of precipitation, water quality, soil moisture, groundwater level, etc. The input and use of citizen science data in freshwater science has resulted in improvement in the quality of scientific outputs (Thornhill et al. 2019), which certainly will provide new source of valuable and much needed freshwater data and knowledge through involvement of volunteers.

A number of studies demonstrate that humans enjoy visual and physical proximity to water and these settings deliver immense emotional and therapeutic benefit (DePledge and Bird 2009; Wheeler et al. 2012). To capture on the same benefits and provide awareness through involvement of people, citizen science project "FreshWater Watch" was globally launched in 2012 to monitor the health of lakes, rivers, streams, wetlands and reservoirs as part of the HSBC Water Programme (Earthwatch 2012), which, since then, has reached out to volunteers, research organizations and schools across the world and collected more than 26,461 measurements of freshwater data (https://freshwaterwatch.thewaterhub.org/our-data/explore-our-data). Other programmes like BlueCarbonArmy in partnership with Earthwatch and HSBC aimed at sensitizing and educating community on the values of coastal wetlands and contributing to blue carbon research. Few other prominent citizen science programmes are Project BudBurst, BugGuide, FrogWatch USA, NestWatch, Zooniverse, etc.

The concept of citizen science has thus gained increasing attention and popularity in the recent years although citizen involvement in collection of data and specimens of ecological value is not new (Miller-Rushing et al. 2012). According to Kosmala et al. (2016), the number of peer-reviewed publications on citizen science has increased significantly over the last decade. Further, there is increased acceptance of citizen science in the recent decades (Fritsch-Kosmider 2018), and improved

Fig. 4.2 Forms of citizen science engagement

visibility (Mark et al. 2017; Pocock et al. 2018) unlike in the past, when biodiversity data collection by volunteers was seldom acknowledged in scientific publications. Citizen science is now seen as a tool for educating citizens on scientific research, engaging them where possible and considering views and expectations of different stakeholders (Wittmayer and Janssen 2019). This has been brought about due to increased access to new technologies such as the internet, smartphones, apps, etc., allowing better access and sharing of data (Goudeseune et al. 2020). Innovative technologies becoming available such as reliable and relatively cheap environmental sensors that facilitate data collection and reduce errors in spatial and temporal information associated with the records (Skarlatidou et al. 2019) have made citizen involvement easier. Creation of apps and development of website interfaces and platforms have also enabled easy data hosting, analysis of data or even recruitment of volunteers (e.g. SciStarter). Waller (2018) reports that on the Global Biodiversity Information Facility, 50% of occurrence records are citizen science observations and six of the top ten datasets are citizen science datasets.

Reduced budget, capacity and scope for monitoring by institutions (Carlson and Cohen 2018) coupled with increased awareness, increasing public knowledge and concern of citizens on human impacts on ecosystems (Conrad and Hilchey 2011) have created the needed impetus for citizen involvement in environmental monitoring and decision-making. Several models of citizen science ranging from top-down to bottom-up participatory approaches are increasingly being adopted, depending on the level of engagement (Paul et al. 2018; McKinley et al. 2012).

Bonney et al. (2009) distinguish three main forms of engagement (Fig. 4.2):

- Contributory projects where scientist design and citizens contribute data.
- Collaborative projects—where scientists design and citizens contribute data as well as help refine project design, analyse data and/or disseminate findings.
- Co-created projects—where scientists and citizens co-design projects and a few citizens are actively involved during the entire project cycle from conception to dissemination.

According to Bonney et al. (2009), 73% of the studies reviewed were contributory, 23% were collaborative, and 4% were cocreated—employing a deeper citizen involvement (García and Brown 2009). In the contributory category of studies, scientists designed the programme, trained the citizens and adopted quality control measures to ensure credibility of citizen science generated data. Quality control measures include standardized training programmes, simplified data collection protocols, use of time series analysis and comparison of citizen science datasets with standard methods or expert data—as a validation (Weeser et al. 2018; Jollymore et al. 2017; McGoff et al. 2017; Moffett and Neale 2015).

4.4 Blue-Green Infrastructure for Sustainable Development

There are evidences to show that human contact with green and blue spaces can have significant health and well-being benefits, in addition to carbon sequestration by trees, improvement of air quality, dampening of urban heat island effect, flood prevention, etc.—all needed for sustainable living and development. Conservation and promotion of biodiversity in urban spaces helps tide over adverse climatic conditions such as flooding, and act as natural barriers and filters to air pollution. This is at a time when extreme events under climate change are projected to increase (Seneviratne 2012), and traditional grey infrastructure—such as underground drainage systems—are proving to be inadequate to deal with heavy rainfall and flooding events, and increased heat due to rising temperature (Davis and Naumann 2017).

Blue-green infrastructure thus offers a host of opportunities and benefits. The benefits from blue-green infrastructure are summarized in Table 4.1 and Fig. 4.3.

4.5 Citizen Science for Promoting Blue-Green Infrastructure in Urban Spaces

Cities are hubs of innovation in the past two decades and have been incubators for movements demanding improvement in resilience and sustainability. Worldwide, cities are striving to offer desirable living conditions such as clean air and water, sustainable mass transit, expansive green spaces and safe communities that attract people. As such, cities are a complex nexus of social, political, economic and ecological systems. In recent times, it is widely recognized that the way forwards must be an integrated approach to development and resource management. Additionally, it should also create and enable processes that facilitate participation of local and regional governments, and communities (Childers et al. 2015).

Cities can mobilize key actors for crosscutting and inclusive action. Bringing diverse groups—national governments, the private sector, universities, civil society and common citizens—is a challenge since, traditionally, they work in isolation. However, as urban areas are expanding, local governments and communities have

Table 4.1 Benefits of blue-green infrastructure

Benefits	Evidence	Reference
Cooling	– Use of green walls in the United Kingdom reduced indoor temperatures by 4–6 °C during summer	Ip et al. (2010)
	– Retrofitting of roofs of existing buildings with green roofs at a city scale is reported to reduce surface temperatures on roofs by around 20 °C	Charlesworth (2010)
	– Trees close to buildings have been reported to lower indoor summer temperature by 4 °C and increase winter temperatures by 6 °C, compared to no trees next to buildings—Resulting in reduced energy consumption by up to 26%	Bozovic et al. (2017)
Air quality improvement	– Green infrastructure can improve urban air quality – Green hedges between roads and pedestrians and green walls are win-win air pollution measures	Hewitt et al. (2020)
	– Long-term benefits of trees for improved health due to removal of air pollutants, better cooling and carbon storage benefits are reported to be twice the cost of planting and maintenance	McPherson et al. (1994)
Improved physical and mental health	– Improved attention and emotional state	Tzoulas et al. (2007)
	– Higher survival rates of senior citizens with easy access to walkable green space	Takano et al. (2002)
Water regulation and reduced flooding	– Absorption of 100% of incident rainfall on installation of green roofs	Mentens et al. (2006)
	– Use of green roofs, water gardens, etc., for increased infiltration and slower and gradual flow of rain water into drains, reduces the risk of surface water flooding	Ossa-Moreno et al. (2017)
	– Reduced run-off of storm water per building through use of green roofs	ADAS (2019)
Biodiversity conservation	– Urban spaces are reported to support double the biodiversity potential when the tree cover increases from 33% to 52%	Ibid

gradually assumed more responsibilities related to the provision of basic services within cities. Examples of such creative and resourceful projects in response to complex challenges include the bus rapid transit in Bogotá, Colombia; waste management programme in Curitiba, Brazil; and energy saving in Freiburg, Germany.

A review of the 244 SDG indicators by Fraisl et al. (2020) identified SDG targets and indicators to which citizen science is already contributing to and those to which they can potentially contribute to (Fig. 4.4). The number of indicators to which citizen science "could contribute" is 76 (of the 244). Currently, the contribution to indicators of SDG 3 (good health and well-being), SDG 11 (sustainable cities and communities), SDG 15 (life on land) and SDG 6 (clean water and sanitation) is well utilized. Similarly, Bishop Isabel et al. (2020) have explored the potential of citizen science to deliver SDGs through integration into monitoring schemes. Fritz et al. (2019) have

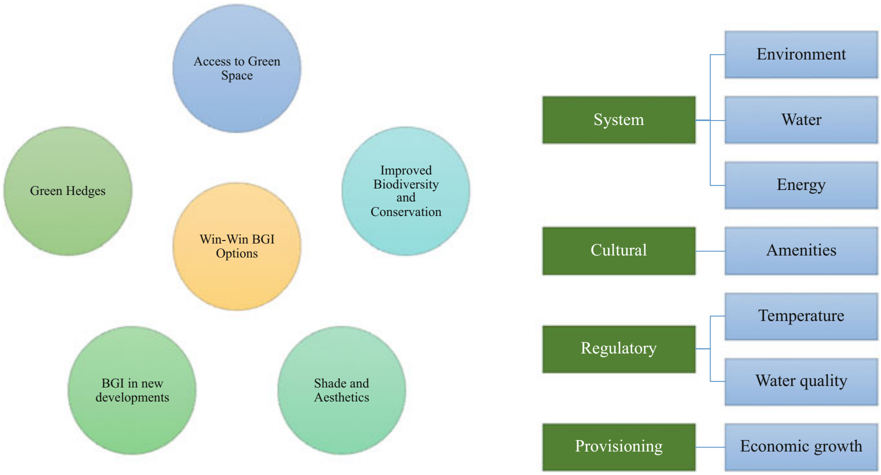

Fig. 4.3 Blue-green infrastructure solutions and likely net benefits. *Created by authors*

created a road map for citizen science and SDG reporting and identified relevant citizen science projects. SDG 11—sustainable cities and communities—is one of them. Thus, the potential of blue-green infrastructure to contribute towards sustainable development and the feasibility of adopting citizen science approaches for promoting them are established.

It is clear from these studies that citizens can play a key role in promoting resilience and sustainability. In particular, the feasibility of adopting a citizen science approach for SDG 11 which relates to sustainable cities (urban spaces) and communities has been demonstrated.

Increasing the level of participation of citizens in blue-green infrastructure has wider societal benefits if all stakeholders in a society have a say in its planning and implementation—ensuring it meets their requirements (Wilker et al. 2016). In literature, involvement of citizens in blue-green infrastructure is largely reported to be focused on the early stages of development. However, what is required is collaborative governance and co-production (Frantzeskaki 2019), in order to ensure legitimate outcomes (Wilker et al. 2016).

The various stages (Fig. 4.5) at which citizen science can play an important role include (i) project demand, (ii) project design, (iii) project implementation and delivery and (iv) project monitoring and maintenance.

4.5.1 Project Demand

Citizen science programmes can play an important role in creating the demand for blue-green infrastructure in cities. Ongoing citizen science programmes on urban tree monitoring, water quality monitoring and air quality monitoring could serve as data sources to understand the issues in urban spaces, and also the potential for

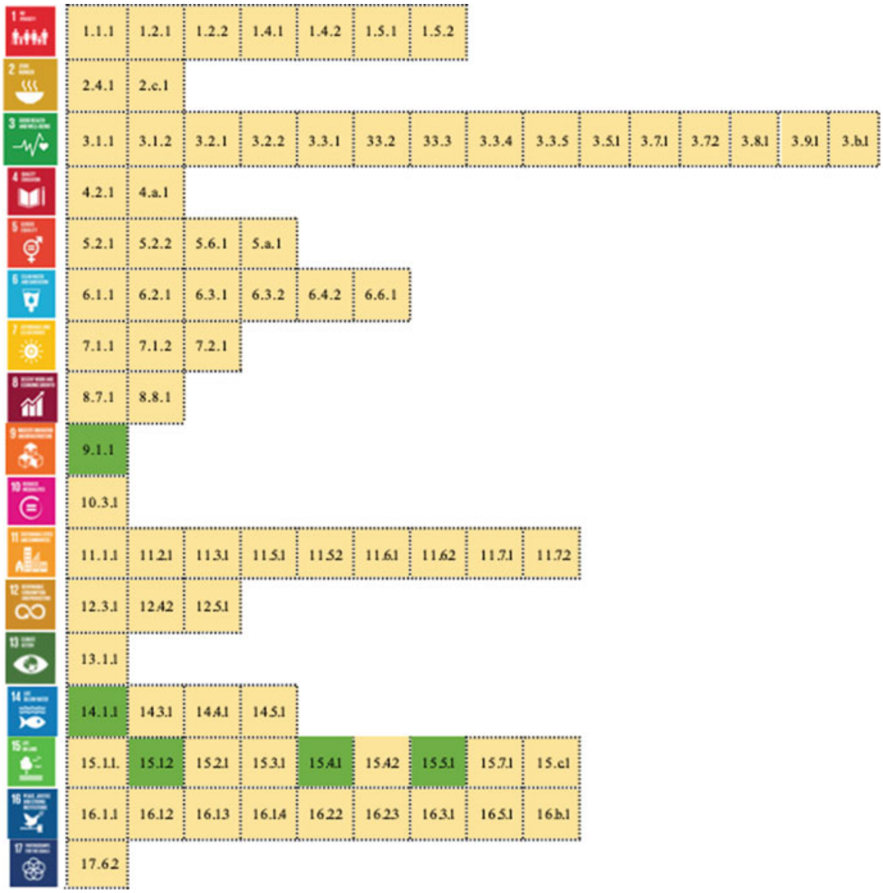

Fig. 4.4 Contribution of citizen science to monitoring of SDGs; "already contributing" (in green), "could contribute" (in yellow). Adapted from Fraisl et al. 2020

creating blue-green infrastructure. This can be derived through documenting existing structures, the issues and also the scope for development of blue-green infrastructure. They could further create awareness which in turn motivates citizens to demand for improved blue-green infrastructure in cities, if research groups coordinating these programmes build consciously a component of imparting information on blue-green infrastructure and its benefits, as well as how cities around the world have successfully integrated this into urban planning.

4.5.2 Project Design

Citizen involvement at the time of design revolves around promoting engagement with the living environment, creating awareness and promoting partnership and

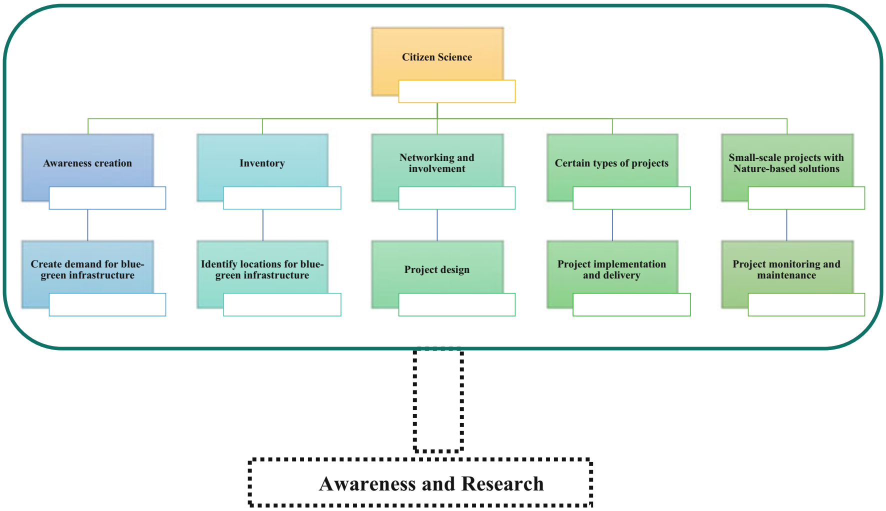

Fig. 4.5 Phases and stages for embracing citizen science in promoting blue-green infrastructure in urban spaces

coalition, so they become involved in project design. Such an example is seen in projects implemented at Gothenburg and Antwerp (van Popering-Verkerk and van Buuren 2017). In Antwerp, the opportunity to create green infrastructure was seen as a means to involve land owners and local residents as it impacts them too, and therefore their involvement in design, maintenance and delivery was sought. Likewise, in Gothenburg where the goal was to transform the Frihamnen area, an uninhabited harbour area, into a residential neighbourhood, local residents were involved in co-designing the project, thereby increasing their awareness of the hitherto uninhabited area (Willems et al. 2020). Yet another example is the city of Dordrecht,[6] wherein investments that were planned for improving the living conditions and sewage systems were combined to create green infrastructure through a comprehensive plan that brought together residents, NGOs and local organizations.

Thus, public participation in spatial planning provides an opportunity to take into consideration local knowledge in decision-making, which otherwise would be lost (Chaffin et al. 2016). Davis and Naumann (2017) also indicated the increasing social inclusion in green infrastructure planning process. Previous studies suggest the importance of involving citizens in the planning process (Anderson et al. 2019), to promote multifunctionality, and more equitable access to green space services (Hansen et al. 2017), and strengthening of green infrastructure resilience (Monteiro et al. 2020).

[6] file:///Users/indukmurthy/Downloads/BGI%20poster%20BEGIN.pdf

4.5.3 Project Implementation and Delivery

The role of citizen science at project delivery phase and the scope for involving citizens in these projects are quite limited, given the need for green skills for implementing and delivering projects. Even in ongoing or recently completed green infrastructure projects such as the one in Bergen and Bradford for providing light rail transport, and in Aberdeen and Hamburg for creating sustainable urban drainage system, and water storage systems, opportunity for citizen involvement was limited to consultations and awareness building as these are predominantly engineering-oriented but focused on creating climate adaptation measures (Willems et al. 2020). However, the Sustainable Urban Drainage Systems in Aberdeen is more nature-based, using ecosystem principles in technical design, and involved creation of rain gardens along streets—with the scope for citizen involvement (Willems et al. 2020).

4.5.4 Project Monitoring and Maintenance

Governance is one of the principles of green infrastructure planning, aimed at effective collaboration between the government actors and citizens. According to Monteiro et al. (2020) "this principle assumes great importance to the development and implementation of green infrastructure because green spaces offer a wide range of recreational functions, focused on people, and their management and maintenance depend directly on the population."

While the project design phase is aimed at building networks and bridging interests of a diverse set of stakeholders, the scope for involvement of citizens in project maintenance is determined by the scale and nature of the blue-green infrastructure. For instance, small-scale infrastructure could be maintained by citizens through regular monitoring. In Kent[7] and Enfield,[8] with rain gardens and wetlands, respectively, co-maintenance by involving local voluntary groups, potentially stimulating social cohesion and lowering of budget for maintenance, has been achieved.

Further, citizen science programmes could provide opportunities for promoting monitoring of tree and air and water quality and infrastructure through involvement of volunteers and scientists, thus providing impetus to research understanding and awareness among citizens for its safeguard and in turn increasing the demand for blue-green infrastructure in urban spaces.

[7] Kent, Interreg VB North Sea Region Programme

[8] https://northsearegion.eu/begin/bgi-pilot-projects/enfield/

4.6 Widening the Niche for Blue-Green Infrastructure in Urban Spaces

Blue-green infrastructure holds promise for adaptation to rapidly changing human and environmental circumstances and therefore needs to be recognized and internalized in the planning process. This has the potential to (i) secure water during the dry season and droughts or filter and enable water drainage during flooding, (ii) create jobs and (iii) mitigate and help to adapt climate change. Given the interconnectedness of natural and anthropocentric systems, and issues in an urban system, well-thought-out interventions such as promotion of blue-green infrastructure would be successful when communities and systems for which these are implemented are sensitized and made aware of the workings and benefits of blue-green infrastructure (Sposito et al. 2014).

Implementing blue-green infrastructure in urban spaces will result in both, local, regional and global benefits. It can help to improve biodiversity, groundwater storage, water quality and water purification. Additionally, through increase in green spaces, it can lead to incremental addition of carbon sequestration, thereby mitigating the impact of climate change. Chen (2015) estimates, based on empirical data, that carbon stored in vegetation of urban green infrastructure of 35 major Chinese cities was 18.7 million tons, with an average carbon density of 21.34 t/ha. Further, Daniel et al. (2020) state that blue-green infrastructure is an environmentally friendly and cost-effective approach to carbon sequestration. Also, these trees will in turn promote biodiversity, both flora and fauna, create habitat niches, improve water holding capacity of soils, reduce erosion and improve the overall flow of ecosystem services. Blue-green infrastructure can also help create spaces for social and recreational activities, thereby contributing to improved physical and mental health, and help people connecting with nature, making the general living conditions of an urban system attractive. There are case studies of dementia-friendly parks contributing to well-being of people with dementia in Canada,[9] Netherlands[10] and Scotland.[11] Further Zeisel et al. (2003) report positive outcomes in behavioural outcome of Alzheimer's special care units and environment. Additionally, Kuo and Sullivan (2001) report lower levels of fear, fewer incivilities and less aggressive and violent behaviour among residents living in green surroundings. If appropriately designed, blue-green infrastructure can be a significant tool for designing resilient urban spaces, with improved flexibility and adaptability.

In order to promote enhanced participation of citizens through the entire project cycle of blue-green infrastructure, there is a need for appropriate policy instruments. These could possibly range from legal to market-based to communication to

[9] https://vancouversun.com/news/local-news/canadas-first-dementia-village-to-open-in-langley-next-year

[10] https://hogeweyk.dementiavillage.com/en/

[11] https://www.pathsforall.org.uk/news-post/scotlands-first-dementia-friendly-park-is-launched-in-stirling

organizational policy instruments deployed at various stages of implementation. Putting in place such policy instruments will facilitate enhanced citizen participation at all stages of blue-green infrastructure implementation, unlike traditional systems which are hierarchical and engineering/design driven.

Acknowledgements Authors sincerely thank the Center for Study of Science, Technology and Policy and the Department of Environmental Sciences, Integral University, for supporting this research.

Conflict of Interest Authors declare no conflict of interest for this publication.

References

ADAS (2019) Committee on climate change: research to provide updated indicators of climate change risk and adaptation in England

Aijaz R (2016) Challenges of making smart cities in India. Asie Visions No. 87 Ifri

Anderson EC, Egerer MH, Fouch N, Clarke M, Davidson MJ (2019) Comparing community garden typologies of Baltimore, Chicago, and New York City (USA) to understand potential implications for socio-ecological services. Urban Ecosyst 22:671–681. https://doi.org/10.1007/s11252-019-00855-9

Bishop Isabel J, Warner S, Toos CGE, van Noordwijk TC, Nyoni FC, Loiselle S (2020) Citizen science monitoring for sustainable development goal indicator 6.3.2 in England and Zambia. Sustainability 12:10271. https://doi.org/10.3390/su122410271

Bonney RH, Ballard R, Jordan E, McCallie T, Phillips J, Shirk CC, Wilderman (2009) Public participation in scientific research: defining the field and assessing its potential for informal science education. A CAISE inquiry group report. Center for Advancement of informal science education (CAISE), Washington, DC

Bozovic R, Maksimovic Č, Mijic A, Smith KM, Suter I, Van Reeuwijk M (2017) Blue green solutions. A systems approach to sustainable, resilient and cost-efficient urban development. https://doi.org/10.13140/RG.2.2.30628.07046

Burton P, Mustelin J (2013) Planning for climate change: is greater public participation the key to success? Urban Policy Res 31(4):399–415

Carlson T, Cohen A (2018) Linking community-based monitoring to water policy: perceptions of citizen scientists. J Environ Manag 219:168–177. https://doi.org/10.1016/j.jenvman.2018.04.077

Carter JG, Cavan G, Connelly A, Guy S, Handley J, Kazmierczak A (2015) Climate change and the city: building capacity for urban adaptation. Prog Plan 95:1–66. ISSN 0305-9006

Chaffin BC, Garmestani AS, Gunderson LH, Benson MH, Angeler DG, Tony CA, Cosens B, Craig RK, Ruhl JB, Allen CR (2016) Transformative environmental governance. Annu Rev Environ Resour:41399–41423. https://doi.org/10.1146/annurev-environ-110615-085817

Charlesworth SM (2010) A review of the adaptation and mitigation of global climate change using sustainable drainage in cities. J Water Clim Change 1(3):165–180. https://doi.org/10.2166/wcc.2010.035

Chen WY (2015) The role of urban green infrastructure in offsetting carbon emissions in 35 major Chinese cities: a nationwide estimate. Cities 44:112–120., ISSN 0264-2751. https://doi.org/10.1016/j.cities.2015.01.005

Childers DL, Cadenasso ML, Morgan Grove J, Marshall V, McGrath B, Pickett STA (2015) An ecology for cities: a transformational nexus of design and ecology to advance climate change resilience and urban sustainability. Sustainability 2015(7):3774–3791. https://doi.org/10.3390/su7043774

Conrad CC, Hilchey KG (2011) A review of citizen science and community-based environmental monitoring: issues and opportunities. Environ Monit Assess 176:273–291. https://doi.org/10.1007/s10661-010-1582-5

Daniel K, Hayley H, Alejandro DCM, Demián R, Rodolfo A (2020) Blue-green infrastructure (BGI) in dense urban watersheds. The case of the Medrano Stream Basin (MSB) in Buenos Aires. Sustainability 12:2163. https://doi.org/10.3390/su12062163

Davis M, Naumann S (2017) Making the case for sustainable urban drainage systems as a nature-based solution to urban flooding. In: Kabisch N, Korn H, Stadler J, Bonn A (eds) Nature-based solutions to climate change adaptation in urban areas. Theory and Practice of Urban Sustainability Transitions. https://doi.org/10.1007/978-3-319-56091-5_8

DePledge M, Bird W (2009) The blue gym: health and wellbeing from our coasts. Mar Pollut Bull 58:947–948

Earthwatch Institute (2012) Fresh Water Watch, a global citizen science project as part of the HSBC Water Programme. https://freshwaterwatch.thewaterhub.org/our-data/explore-our-data

Emilsson T, Ode Sang Å (2017) Impacts of climate change on urban areas and nature-based solutions for adaptation. In: Kabisch N, Korn H, Stadler J, Bonn A (eds) Nature-based solutions to climate change adaptation in urban areas. Theory and Practice of Urban Sustainability Transitions. https://doi.org/10.1007/978-3-319-56091-5_2

Faehnle M, Bäcklund P, Tyrväinen L, Niemelä J, Yli-Pelkonen V (2014) How can residents' experiences inform planning of urban green infrastructure? Case Finland. Landsc Urban Plan 130:171–183

Finke P (2014) Citizen Science: Das unterschätzteWissen der Laien München: oekom Verlag Quoted in Pettibone et al 2016

Fraisl D, Campbell J, See L, When U, Wardlow J, Gold M, Moorthy I, Arias R, Piera J, Oliver JL et al (2020) Mapping citizen science contributions to the UN sustainable development goals. Sustain Sci 15(6):1735–1751

Frantzeskaki N (2019) Seven lessons for planning nature-based solutions in cities. Environ Sci Pol 93:101–111. https://doi.org/10.1016/j.envsci.2018.12.033

Fritsch-Kosmider P (2018) Citizen science is needed to track biodiversity. New Sci 239(3191):52. https://www.newscientist.com/letter/mg23931910-900-citizen-science-is-needed-to-track-biodiversity-1/

Fritz S, See L, Carlson T, Haklay M, Oliver JL, Fraisl D, Mondardini R, Brocklehurts M, Shanley LA, Schade S et al (2019) Citizen science and the United Nations sustainable development goals. Nat Sustain 2:922–930. https://doi.org/10.1038/s41893-019-0390-3

García CER, Brown S (2009) Assessing water use and quality through youth participatory research in a rural Andean watershed. J Environ Manag 90:3040–3047. https://doi.org/10.1016/j.jenvman.2009.04.014

Goudeseune L, Eggermont H, Groom Q, Le Roux X, Paleco C, Roy HE, van Noordwijk CGE (2020) BiodivERsA citizen science toolkit for biodiversity scientists. BiodivERsA Report https://doi.org/10.5281/zenodo.3979343

Hansen R, Rall E, Chapman E, Rolf W, Pauleit S (2017) Urban green infrastructure planning: a guide for practitioners. 88 Hislop M Sc. http://greensurge.eu/working-packages/wp5/. Accessed 1 June 2017

Hewitt CN, Ashworth K, MacKenzie AR (2020) Using green infrastructure to improve urban air quality (GI4AQ). Ambio 49:62–73. https://doi.org/10.1007/s13280-019-01164-3

Hoegh-Guldberg O, Jacob D, Taylor M, Bindi M, Brown S, Camilloni I, Diedhiou A, KL RD, Ebi F, Engelbrecht J, Guiot Y, Hijioka S, Mehrotra A, Payne SI, Seneviratne A, Warren TR, Zhou G (2018) Impacts of 1.5°C Global Warming on Natural and Human Systems. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Cambridge University Press, Cambridge

Hoornweg D, Sugar L, Trejos Gómez CL (2011) Cities and greenhouse gas emissions: moving forward environ. Urban 23:207–227

Ip K, Lam M, Miller A (2010) Shading performance of a vertical deciduous climbing plant canopy. Build Environ 45(1):81–88. https://doi.org/10.1016/j.buildenv.2009.05.003

Jerome G, Mell I, Shaw D (2017) Re-defining the characteristics of environmental volunteering: creating a typology of community-scale green infrastructure. Environ Res 158:399–408

Jollymore MJ, Haines T, Satterfield MSJ (2017) Citizen science for water quality monitoring: data implications of citizen perspectives. J Environ Manag 200(2017):456–467. https://doi.org/10.1016/j.jenvman.2017.05.083

Kelemen-Finan J, Scheuch M, Winter S (2018) Contributions from citizen science to science education: an examination of a biodiversity citizen science project with schools in Central Europe. Int J Sci Educ 40:2078–2098

Kennedy C, Steinberger J, Gasson B, Hansen Y, Hillman T, Havránek M, Pataki D, Phdungsilp A, Ramaswami A, Mendez GV (2009) Greenhouse gas emissions from global cities. Environ Sci Technol 43(19):7297–7302. https://doi.org/10.1021/es900213p

Kosmala M, Wiggins A, Swanson A, Simmons B (2016) Assessing data quality in citizen science. Front Ecol Environ 14(10):551–560. https://doi.org/10.1002/fee.1436

Lamond J, Everett G (2019) Sustainable blue-green infrastructure: a social practice approach to understanding community preferences and stewardship. Landsc Urban Plan 191:103639. ISSN 0169-2046

Lin JC, Mitchell L, Crosman E, Mendoza DL, Buchert M, Bares R, Fasoli B, Bowling DR, Pataki D, Catharine D, Strong C, Gurney KR, Patarasuk R, MunkhbayarBaasandorj AJ, Hoch S, Horel J, Ehleringer J (2018) CO_2 and carbon emissions from cities: linkages to air quality, socioeconomic activity, and stakeholders in the Salt Lake City urban area. Am Meteorol Soc 99(11):2325–2339. https://doi.org/10.1175/BAMS-D-17-0037.1

Lovell ST, Taylor JR (2013) Supplying urban ecosystem services through multifunctional green infrastructure in the United States. Landsc Ecol 28(8):1447–1463

Mark C, See L, Copas K, Bonde AMZ, López BC, Danielsen F, Legind JK, Masinde S, Miller-Rushing AJ, Newman G, Rosemartin A, Turak E (2017) Contribution of citizen science towards international biodiversity monitoring. Biol Conserv 213:280–294

McGoff F, Dunn LM, Cachazo P, Williams J, Biggs P, Nicolet NCE (2017) Finding clean water habitats in urban landscapes: professional researcher vs citizen science approaches. Sci Total Environ 581(2017):105–116. https://doi.org/10.1016/j.scitotenv.2016.11.215

McKinsey Global Institute (2010) India's urban awakening: building inclusive cities, sustaining economic growth

McKinley DC, Briggs RD, Bartuska AM (2012) When peer-reviewed publications are not enough! Delivering science for natural resource management. For Policy Econ 21(2012):1–11. https://doi.org/10.1016/j.forpol.2012.03.007

McPherson EG, Nowak DJ, Rowntree RA (1994) Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project. Gen. Tech. Rep. NE-186 US Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Radnor, Pennsylvania

Mees HL, Uittenbroek CJ, Hegger DL, Driessen PP (2019) From citizen participation to government participation: an exploration of the roles of local governments in community initiatives for climate change adaptation in the Netherlands. Environ Policy Gov 29(3):198–208. https://doi.org/10.1002/eet.1847

Mentens J, Raes D, Hermy M (2006) Green roofs as a tool for solving the rainwater runoff problem in the urbanised 21st century. Landscape Urban Plan 77:217–226. https://doi.org/10.1016/j.landurbplan.2005.02.010

Miller-Rushing A, Primack R, Bonney R (2012) The history of public participation in ecological research. Front Ecol Environ 10(6):285–290. https://doi.org/10.1890/110278

Moffett ER, Neale MW (2015) Volunteer and professional macroinvertebrate monitoring provide concordant assessments of stream health. N Z J Mar Freshw Res 49(2015):366–375. https://doi.org/10.1080/00288330.2015.1018913

Monteiro R, Ferreira J, Antunes P (2020) Green infrastructure planning principles: an integrated literature review. Land 9:525. https://doi.org/10.3390/land9120525
Newman G, Wiggins A, Crall A, Graham E, Newman S, Crowston K (2012) The future of citizen science: emerging technologies and shifting paradigms. Front Ecol Environ 10(6):298–304
Ochoa-Tocachi W, Buytaert J, Antiporta L, Acosta JD, Bardales R, Célleri P, Crespo P, Fuentes J, Gil-Ríos M, Guallpa C, Llerena D, Olaya P, Pardo G, Rojas M, Villacís M, Villazón P, Viñas BD, Bièvre (2018) High-resolution hydrometeorological data from a network of headwater catchments in the tropical Andes. Sci Data 5:Article 180080
Ossa-Moreno J, Smith KM, Mijic A (2017) Economic analysis of wider benefits to facilitate SuDS uptake in London UK. Sustain Cities Soc 28:411–419
Paul JD, Buytaert W, Allen S, Ballesteros-Cánovas JA, Bhusal J, Cieslik K, Clark J, Dugar S, Hannah DM, Stoffel M (2018) Citizen science for hydrological risk reduction and resilience building Wiley. Interdiscip Rev Water 5:e1262
Pettibone L, Vohland K, Bonn A, Richter A, Bauhus W, Behrisch B, Borcherding R, Brandt M, Bry F, Dörler D, Elbertse I, Glöckler F, Göbel C, Hecker S, Heigl F, Herdick M, Kiefer S, Kluttig T, Kühn, et al (2016) Citizen science for all – a guide for citizen science practitioners. BürgerSchaffenWissen (GEWISS) publication. German Centre for integrative biodiversity research (iDiv) Halle-Jena-Leipzig, Helmholtz Centre for Environmental Research (UFZ), Leipzig; Berlin-Brandenburg Institute of Advanced Biodiversity Research (BBIB), Museum fürNaturkunde (MfN) – Leibniz Institute for Evolution and Biodiversity Science: Berlin. www.buergerschaffenwissen.de
Pocock MJO, Chandler M, Bonney R, Thornhill I, Albin A, August T, Bachman S, Brown PMJ, Cunha DGF, Grez A, Jackson C, Peters M, Rabarijaon NR, Roy HE, Zaviezo T, Danielsen F (2018) A vision for global biodiversity monitoring with citizen science. Adv Ecol Res 59:169–223. https://doi.org/10.1016/bs.aecr.2018.06.003
Rosenzweig CW, Solecki P, Romero-Lankao S, Mehrotra S, Dhakal T, Bowman, Ibrahim SA (2015) ARC3.2 summary for city leaders urban climate change research network. Columbia University, New York
Seneviratne SIN, Nicholls D, Easterling CM, Goodess S, Kanae J, Kossin Y, Luo J, Marengo K, McInnes M, Rahimi M, Reichstein A, Sorteberg C, Vera X, Zhang (2012) Changes in climate extremes and their impacts on the natural physical environment. In: Managing the risks of extreme events and disasters to advance climate change adaptation a special report of working groups I and II of the intergovernmental panel on climate change (IPCC). Cambridge University Press, Cambridge/New York, pp 109–230
Shao Z, Sumari NS, AlekseiPortnov FU, Musakwa W, Mandela PJ (2020) Urban sprawl and its impact on sustainable urban development: a combination of remote sensing and social media data. Geo Spatial Inf Sci 24(2):241–255. https://doi.org/10.1080/10095020.2020.1787800
Skarlatidou A, Ponti M, Sprinks J, Nold C, Haklay M, Kanjo E (2019) User experience of digital technologies in citizen science. J Sci Commun 18(01). https://doi.org/10.22323/2.18010501
Sposito V, Faggian R, Diogo V, Romeijn H (2014) Blue-green infrastructure for creating resilient regions, a case study in the Gippsland Region, Victoria, Australia. Technical Report Deakin University
Takano T, Nakamura K, Watanabe M (2002) Urban residential environments and senior citizens' longevity in mega-city areas: the importance of walkable green space. J Epidemiol Community Health 56(12):913–916
Thornhill I, Loiselle S, Clymans W, Van Noordwijk CGE (2019) How citizen scientists can enrich freshwater science as contributors, collaborators, and co-creators. Freshw Sci 38. https://doi.org/10.1086/703378
Tzoulas K, Korpela K, Venn S, Yli-Pelkonen V, Kazmierczak A, Niemela J, James P (2007) Promoting ecosystem and human health in urban areas using green infrastructure: a literature review. Landsc Urban Plan 81:167–178
United Nations, Department of Economic and Social Affairs, Division P (2018) World urbanization prospects: the 2018 revision. Highlights

van Popering-Verkerk J, van Buuren A (2017) Developing collaborative capacity in pilot projects: lessons from three Dutch flood risk management experiments. J Clean Prod 169:225–233
Waller J (2018) Will citizen science take over? GBIF Data Blog. https://data-blog.gbif.org/post/gbif-citizen-science-data/
Weeser J, StenfertKroese SR, Jacobs N, Njue Z, Kemboi A, Ran MC, Rufino L, Breuer (2018) Citizen science pioneers in Kenya – a crowdsourced approach for hydrological monitoring. Sci Total Environ 631–632:1590–1599. https://doi.org/10.1016/j.scitotenv.2018.03.130
Wheeler B et al (2012) Does living by the coast improve health and wellbeing? Health Place 18:1198–1201
Wilker J, Rusche K, Rymsa-Fitschen C (2016) Improving participation in green infrastructure planning. Plan Pract Res 31(3):229–224
Willems JJ, Molenveld A, Voorberg W, Brinkman G (2020) Diverging ambitions and instruments for citizen participation across different stages in green infrastructure projects. Urban Plan 5(1):22–32. https://doi.org/10.17645/up.v5i1.2613. ISSN: 2183–7635
Wittmayer J, Janssen A (2019) Citizen science – towards democratic science and environmental democracy? DRIFT Blog. https://drift.eur.nl/publications/citizen-science-towards-democratic-science-and-environmental-democracy/
Zeisel J, Silverstein NM, Hyde J, Levkoff S, Lawton MP, Holmes W (2003) Environmental correlates to behavioral health outcomes in Alzheimer's special care units. Gerontologist 43:697–711

Indu K. Murthy works as the Sector Head-Climate, Environment and Sustainability at the Center for Study of Science, Technology and Policy (CSTEP), Bengaluru, India.

Monowar Alam Khalid is a Professor and Head, Department of Environmental Science, and Dean, Faculty of Humanities & Social Sciences at Integral University, Lucknow, India.