IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Deconstructing water sensitivity: experiences from global cities

To cite this article: G Mishra *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **592** 012012

Deconstructing water sensitivity: experiences from global cities

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Abstract. Cities around the world today are facing common issues of rapid urbanization, varying climatic conditions, and challenging economies, which are known to impact the environment and quality of life. In response, multiple concepts have emerged related to water management practices over the past few decades. One such recently discussed concept is of Water Sensitive Cities, which envisions a place that judiciously uses its existing resources, building resilience for tomorrow by simultaneously ensuring community participation for sustainability. Synonymous with this notion, there exist other overlapping concepts such as Water Sensitive Urban Design, Low Impact Development, Best Management Practices, Green Infrastructure, and the like. This research intends to deconstruct these concepts and their practices through a review of 120 case studies located across different agro-climatic and water-stressed regions globally. These cases were analyzed for their inclination to three thematic components: society, water sensitive urbanism, and technologies. The evidence suggests that there is not a single water sensitive city in the world today. This paper discusses the utopian nature of this notion and identifies relevant pathways to explore to reach the destined vision of Water Sensitive Cities.

1. Introduction

The term "Water Sensitive Cities" was first coined by Cooperative Research Centre for Water Sensitive Cities (CRCWSC), established in July 2012. It was a consequence of water crisis in the region where bulk of the water supply came from various desalination plants installed. While most Australian cities have witnessed drought in the past, a major contributing factor in their water crisis was surplus supply of water, which was a result of lifestyle pattern. The Australians have mere preference for suburban detached dwellings, which they were willing to pay higher prices, with its own set of hydrological constraints. Along with this, the increased dependency on desalination caused tremendous amount of cost and carbon emissions. These cultural water issues were posed upon with more threshold due to – (a) rapidly growing population with changing lifestyles; (b) changing and highly variable climate and; (c) a challenging economic environment [1, 2]. However, it is revealed that rather than advanced technology that highly depends on elevated energy consumptions, simple solutions like water pricing and education campaigns are more effective. Water Sensitive Cities envisions cities which are sustainable, resilient, productive, and livable. Interestingly, these issues stand true for all fast-growing urban areas in the world and therefore, the concept cannot be restricted to Australian cities alone [1, 2]

2. Conceptualizing Water Sensitive Cities

According to CRCWSC [2], a water sensitive city is envisioned as a place that (a) serves as a potential water catchment, providing different water sources at a range of different scales for a variety of uses; (b) provides ecosystem services and a healthy natural environment to offer various social, ecological, and economic benefits and; (c) involves water sensitive communities where citizens have the knowledge and desire to make wise choices about water and are actively engaged in decision making and demonstrate positive behaviors such as conserving water at home and not tipping down chemicals in the drain [2]. Thus, to summarize, the concept encourages making the most out of current resources, building resilience to provide for tomorrow and community involvement for a sense of belonging.

The stepping stones of Water Sensitive Cities are – (a) researching to address industry challenges through multi-disciplinary research and active learning; (b) synthesizing the translation of the knowledge across disciplines into relevant guidance and tools and; (c) influencing by working together to create an on-ground change founded on science and understanding. The work is focused on three thematic programs namely Program A – Society; Program B – Water Sensitive Urbanism and; Program C – Future Technologies, together forming the adoption pathways to implement research and innovation [2]. Program A includes socio-economic impact and participatory approach of involving communities such as analyzing the increase in real estate prices due to the addition of blue-green infrastructure, influencing behavioral changes in communities, collaborative engagement of stakeholders in governance models, sensitizing organizations about new innovations among other such line of work. Program B focuses on all water sensitive design interventions revolving around water sensitive design such as urban metabolism framework for urban, peri-urban, and rural landscapes, stormwater management, urban microclimate management, flood resilience and statutory planning for the same. Program C includes line of work around all innovative practices for stormwater and wastewater treatment, finding balance between centralized and decentralized and performance assessment systems for optimization [2].

The concept is envisioned in order to reverse the alteration of natural landscapes resulting in urban climates, which is different than natural environments, due to replacement of vegetation and soil with hard impervious surfaces for urban development. This has posed extra pressure on water infrastructure that resulted in floods, heatwaves, bush fires, droughts, intense storms and cyclones, air pollution, and modified rainfall patterns. The path of achieving water sensitivity within cities is through interacting with water cycle and respecting the natural flow of water in the landscape. The goal of water sensitive cities is to make the cities livable, resilient, sustainable, and productive, which will help in creating coping capacities and carrying capacities within respective urban areas. To reach this aim, the objectives would include – (a) providing water security for economic prosperity through judicious use of available resources; (b) enhancing and protecting the health of waterway and wetlands, river basins surrounding them, as well coasts and bays; (c) mitigating flood risk and damage and; (d) creating public spaces that collect, clean, and recycle water. Essentially, a city is expected to provide sufficiently, integrate natural water flow, incorporate water resilience, and possess a water collection system [2, 3].

In various ways, water sensitive practices differ from traditional water services. Traditional water services comprise bulk water supply, water manufacturing, water treatment, water distribution, retail services, as well as wastewater collection, treatment, recycling, and discharge. Meanwhile, water sensitive practices include integrating various water sources, combining centralized and decentralized systems, delivering wide range of community services and integrating into urban design mainly through blue-green infrastructure for flood and drainage mitigation, extreme heat mitigation, and climate responsive design. The water sensitive approach, however, also recognizes the broader definitions of urban water services such that it offers enhanced livability outcomes [4].

Water sensitive cities highly advocate respecting the natural landscape and water flow of an area, which is closely linked to how we spatially plan our cities. It is incredible to realize the interlinkages of water sensitivity with various domains in an area; having a water sensitive city can bring values of protection, equity, rehabilitation, and sustainability with essential water services, including supply security, flood control, and public health, but also additional benefits such as food security, energy savings, amenity and resilience of cities to climate change [5]. Hence, it is extremely essential to consider the flows of water resources into, through, and out of urban settlements, where the concept of Urban Metabolism actually emerges. According to Renouf, et al [6], Urban Metabolism is defined as, "the process of resources flowing through and being transformed and consumed in urban areas to sustain all the technical and socio-economic processes that occur within in it". This definition could be crucial and much relevant for taking informed decisions regarding urban and regional planning.

Urban metabolism forms the umbrella term which refers to the amount and flows of water, energy, and materials entering and leaving an administrative boundary, and constitutes the other two terms i.e., urban water metabolism and water mass balance. Urban water metabolism can be defined as the trajectories and magnitudes of flows of energy and nutrients that are created in the process of water treatment or pumping, whereas water mass balance can be defined as only stocks and flows of water, excluding any energy or nutrient efficiency considerations. These concepts take into account natural flows (precipitation, evapotranspiration, groundwater infiltration, and stormwater runoff) along with anthropogenic flows (centralized water supplies, decentralized water supplies, and wastewater discharged or recycled). This foundational conceptualization forms the Urban Metabolism Evaluation Framework which essentially quantifies and tracks the flows to understand the impacts of implementation of water sensitive practices. The evaluation informs about the status of local water supplies and their vulnerability extent to external and internal stresses [6]. However, water sensitive city is actually a stage which a city acquires based on its service delivery functions and possibly a result of certain quantification and evaluation. Typically for this, a city goes through the following stages, which includes, water supply city when cities have access to water supply and security, sewered city when cities have public health protection, drained city when cities have flood protection system, waterways city when cities treat water as a social amenity and for environmental protection, water cycle city when cities limit its dependency of natural resources, and ultimately water sensitive city when cities have intergenerational equity and resilience to climate change. This is not necessarily a linear process and various stages of it can be achieved through leapfrogging with proper formulation of plans. The linearity or leapfrogging function highly depends on the status of a country; the functionality differs majorly in developing and developed countries, which will be further discussed [5, 7].

Concepts Synonymous to Water Sensitive Cities

Although pitched forward as an ideal city, the first time when 'Water Sensitive Cities' as a concept was introduced, it did not seem very alien. There have been various terminologies similar to water sensitive cities, especially relating to urban drainage. Today, cities facing major challenges of climate change and growing population due to industrialization and urbanization require stakeholder coordination, institutional support, and community engagement. This, as a result has given rise to various evolving paradigms which encourage integrated management of water resources in water systems, not only technically but also institutionally and socially. Various paradigms have emerged and evolved, having a common vision to deal with complex urban water challenges, without disturbing the existing habitats. Some of the common identified stresses faced by urban areas, which gave way to emergence of these paradigms include, climate change, growing demand and urbanization, aged infrastructure, depleted polluted resources, and increased frequency of disruptive events. As a consequence, major challenges increased vulnerability of water systems to uncertainty. Various innovative concepts to combat these causes started emerging in the late 19th century and have been evolving ever since. Chronologically, the concepts of Modern Infrastructural Ideal (MII), Integrated Water Resource Management (IRWM), Integrated Urban Water Management (IUWM), Water Sensitive Urban Design (WSUD) including Sustainable Urban Drainage System (SUDS), Green Infrastructure (GI), Low Impact Development (LID), Best Management Practices (BMP), Water Sensitive Cities, Water Wise Cities are the merging concepts that have emerged in the past few decades [8, 9].

There has been a shift from traditional systems which only prioritized public provision and safety to a more multifunctional wastewater management which integrates with the water cycle. The former systems lead to climate change due to increased energy and resource consumption, while the latter is attempting to mitigate along with urban heat island, water quality, and recreation. The old systems also lead to pollution by urban runoff, loss of nutrients, high maintenance costs, and low flexibility. This forms the baseline rationale for these emerging concepts essentially related to urban drainage. However, there are various concepts which have come and have similar approaches, but have used different terminologies. This is because these jargons have developed rather informally driven by local and contextual understandings at different timelines and hence differ in different parts of the world. It has also been often observed that despite the emergence of a concept with a particular terminology in a particular part of the world, when applied to a different region changes, its contextual understanding and application fit the local context [8, 9].

A major difference is observed in global north and global south cities. For developing countries, these new systems are a way to tackle their survivability concerns, whereas for developed countries, it is a way to tackle their environmental concerns. As the alternatives discussing integration of decentralized systems into existing centralized systems have emerged in the north, it becomes important for the global south cities to adapt to local context by bottom up approach. In the various phases of cities as mentioned earlier, the northern cities have already achieved the status of water supply city, sewered city, and drained city. Therefore, for them, a linear procession is a possible scenario. Meanwhile, the southern cities are still struggling with the status of water supply city and sewered city, which is the most basic provision of infrastructure services. Thus, for these cities, a systematic leapfrogging approach could be a more preferred scenario. These concepts have emerged in the global north, where the first three stages of city have already been procured. At the same time, for the global south cities, these concepts form a pillar towards sustainable systems which cannot be achieved by following the conventional systems of the industrialized world [8].

The challenges that these two parts of the world face are also different than one another. The developing countries come across multiple barriers pertaining to social, institutional, technological, and economic contexts. These essentially include resistance to change, poverty and marginalization, fragmented responsibilities, lack of institutional capacity and legislative mandate, insufficient engineering standards and guidelines, uncertainties in performance and cost of potential solutions, and lack of funding and effective market incentives. So, in such a scenario, the developing countries could reflect on the mistakes done by developed countries in the past and directly opt for more sustainable and efficient technological innovations [5, 8].

As mentioned previously, these integrated practices bloomed essentially in the late 19th century. These concepts have been popularized under the terminologies IUWM, WSUD, LID, BMP, GI, SUDS and others, which have similar understanding on a broader scale, but differ in terms of its focus and place of origin. For instance, the term Low Impact Development (LID) emerged in North America and New Zealand in 1977 with an original intent of having natural hydrology through site layout plan and integrated control measures characterized by minimization of impervious services. However, in late 1990s, the focus shifted to stormwater treatment practices and later to stormwater management. Also, the term sheds more focus on 'low impact' and does not contain 'water', which allows for further interpretation from a multi-disciplinary approach. Water Sensitive Urban Design which originated in Australia in 1990s focused on managing water balance, enhancing water quality, encouraging water conservation and water related recreation. It was a rather philosophical approach to urban planning and design. Further, stormwater management was posed to be a subset of WSUD in its practices with its focus swiftly shifting to stormwater. WSUD is now widely used synonymous to water sensitive cities and has observed increased applications in New Zealand and UK. IUWM when first commonly used in 1990s focused mainly on urban drainage management, which now is being closely linked to WSUD and LID, beyond drainage management. Sustainable Urban Drainage Systems (SUDs) which originated in UK around 1980s focusses on controlling urban runoff, which further added its focus on natural pre-development site drainage and also improving water quality. The Best Management Practices (BMPs) which originated in North America around 1970s focuses on restoring more favorable plant cover and soil structure through non-structural measures which further evolved to reduction in pollution prevention in stormwater discharge. Green Infrastructure (GI) originated in the USA around 1990s had it original focus of network of green spaces but further tapped into its potential of ecological services of stormwater management such green roofs, permeable pavement, raingardens etc. [9].

The important question arises: where does Water Sensitive Cities fit in each of these concepts? The essential difference here is, a water sensitive city is the destination intended to reach through these processes under various jargons for integrated water management. They form the essential building blocks of water sensitive cities, exhibiting values of environmental protection, equity, rehabilitation and sustainability with essential water services, including supply security, flood control, and public health, but also additional benefits such as food security, energy savings, amenity and resilience of cities to climate change [5]. The focus here is on the practices that bring the concept of "fit-for-purpose" water systems forth, where water from various sources is treated based on the quality required at end use, incorporating "non-traditional" (or alternative) sources of water. The ultimate goal is to integrate alternative, decentralized systems into the existing centralized infrastructural solutions, reducing the sole dependence on large, capital-intensive network infrastructure while allowing for added flexibility [8, 9].

Water Sensitive Practices for Sustainable Water Management

Water sensitive practices are a combination of an overlap between governance, design and technology. After establishing a conceptual understanding of water sensitive cities by closely linking it to integrated water management innovations, it is essential to know what implementation solution helps us to achieve the respective objectives. None of these methods give us the best solution, rather the contextual combination of them would enable the cities to arrive at the stage of water sensitivity city. It is crucial that selection of each of these methods for implementation is done in response to the local set up or else could be met with various resistances of the local barriers.

To breakdown these practices, they have been categorized into Society and Governance; and Design and Technology. Society and Governance mainly identifies roles of various stakeholders in the system which includes regulations to keep the system in place. Following are some of the identified ways in which could be achieved through function of policy norms, participatory planning and design, monitoring systems, and creation of public spaces. The basic idea is to involve various stakeholders and generate a sense of ownership and belonging among people. Meanwhile, Technology and Design identifies various sustainable design and innovative technologies which primarily intends to move towards more natural hydrology and landscapes. They could further be categorized into Stormwater: Treatment, Storage, and Use; and Wastewater: Treatment and Re-use. Under Stormwater: Treatment, Storage, and Use, the practices comprise rainwater harvesting, bio-retention, biotopes, sand-gravel filter, rooftop retention, permeable paving, infiltration trenches, geo cellular systems, swales, detention ponds, and evapotranspiration mechanisms. For Wastewater: Treatment and Re-use, decentralized wastewater management is often considered more sustainable due to its longevity, resilience, and reduction in cost and resources for implementation and maintenance. These are usually characterized by on-site systems where it gets treated on site and returns back to the ecosystem. However, there are limitations in terms of soil percolating capacities which varies from site to site. There are various sustainable options of centralized and combination of centralized and decentralized, although they are accompanied by a set of limitations. The decentralized systems include DEWATS, constructed wetlands, soil bio technology, soil scape filter technology, eco sanitation, fecal sludge management, and various others. Variations of aforementioned technologies can be used with different components which can be used for breaking down of organic and inorganic components in wastewater such as bio sanitizer, green bridge technology, bio remediation to name a few.

The combination of Centralized and Decentralized Systems is highly advocated by water sensitive cities and depends on the priority of use. A densely populated region prefers a centralized system due its high purification and less cumbersome operation. On the other hand, decentralized systems are preferred for its environmental and expenditure concerns with reduction in cost and resources. In some cases, however, a combination of these approaches offers an optimal solution. It is eventually a balancing act between engineering and environmental solutions. Some of these solutions include Septic

Tank Effluent Pumping Systems, Advanced Onsite Wastewater Treatment Systems (AOWTS), and the like.

Evaluating Water Sensitivity

Since water sensitive city is a state that a city arrives at, it is essential to evaluate the progress of implementation strategies practiced by respective cities. This could be done either qualitatively or quantitatively, or both simultaneously. One such official way is through water sensitive index, which intends to benchmark and rank cities, in terms of performance, targets and management responses for policy makers, service providers, and intercity learning. It emerged by citing issues and shortcomings of the existing monitoring systems which had narrow focus of indicators, failed to address needs of policy and decision makers, had spatial mismatch between administrative boundaries and flow of resources, limited data availability and disconnect between data collection and reporting. Water Sensitive Index attempts to provide a communication tool for describing key attributes of a water sensitive city; articulates and shares set of goals or benchmarks of a WSC for evaluating its performance, measuring the progress, assisting decision makers and accountability. This includes 7 thematic goals constituting 34 indicators distributed across sustainability, urban design, vulnerability, and governance. Each of the indicators is then scored qualitatively and quantitatively on a 5-point scale [10]. However, this requires detailed information of each of the project and also requires performance monitoring post-project implementation.

For a broader understanding, the projects could be analyzed qualitatively which would provide a fair idea of project performance. One way of doing it could be through rating the project based on how many objectives it is fulfilling with respect to a constant set of objectives. This would give a comparative idea of which projects fulfilled maximum number of objectives, and which objectives are fulfilled the most and to what extent. Other way of evaluating could be in terms of overlaying contextual geographical information with the location of projects, and understanding if the projects are catering to its local conditions or not. Other qualitative ways of evaluation could be in terms of its scalability by looking at the scale of implementation and hence scale of impact. There are other ways of evaluating a project in terms of its efficiency in its project management timeline or even its project finance approach. This, however, doesn't stand relevant while talking about the performance of project pertaining to water sensitivity. These are some simplified ways in which water sensitivity of a place could be evaluated in terms of project implementation.

3. Methodology

Despite the initial evolution of concepts revolving around water sensitive practices since late 19th century, there is not one single example of a 'water sensitive city' in the world. This makes us question the whole concept and its utopian nature, as they call it the ideal city. The conceptual literature paints a scenario of a city which largely respects the natural landscape of a pre-developed area and its natural hydrology, and plans its spatial development in a manner that enhances its original state. This poses a direct credibility in land use and regional planning domain; yet when we look at the practices or indicators, they are largely focusing on small scale interventions. Consequently, it is crucial to look at the current status of project implementations happening all around the world: Which theme is it catering to the most? What is the scale of implementation? How is it catering to the climatic and social context of the place? These are some relevant enquiries to know its status right from the birth of these concepts, to today.

The three thematic programs, Program A – Society, Program B – Water Sensitive Urbanism, and Program C – Future Technologies, have been considered within a base framework to assess different case studies of water sensitive practices. A sample of 120 global case studies (Appendix A) catering to different water sensitive approaches was reviewed. These cases were marked on a Likert scale (0 or 1) under each of the three thematic programs and their respective sub-themes. This type of marking enables quantifying the inclination of various case studies towards the thematic areas of water sensitive practices. The locations of these respective cases were further mapped spatially with respect to their agro-climatic zones and water stress zones, giving a broader idea of water availability in various regions. These cases have been evaluated in terms of its scale of implementation and impacts at city level.

4. Results

After mapping the case studies spatially and with the matrix of thematic programs (Figure 4), analysis emerged on various fronts. The analysis was done for: i) sub-thematic zones which they were catered to the most, ii) the predominant scale of implementation iii) scale of implementation with respect to predominant thematic programs iv) spatial locations of the cases with respect to agro-ecological zones and water stress zones.

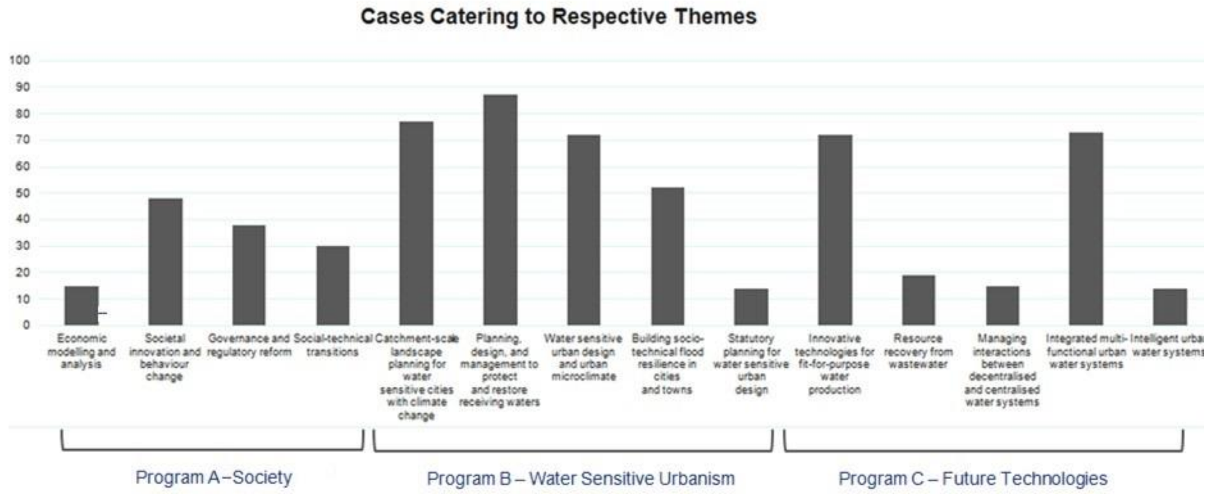


Figure 1 Graph showing sub-themes the most catered to by projects

Figure 1 was fetched from the mapping of case studies in the matrix against themes and sub-themes (Appendix A). Out of the sample of 120 global cases, it was observed that the Program B focusing on water sensitive urbanism has been catered the most. This infers that most of the projects focus on implementation of water sensitive design practices. Relatively, there has been less focus on Program A, and from the projects catering to it the focus has mainly been generating a sense of belonging within people through participatory project implementation or generation of public spaces for people. Within Program C, the focus is mainly on providing water based on end user and creating multi-functional water sources. However, there is limited focus on monitoring system, wastewater re-use, and integration of centralized and decentralized water systems. Overall, it is evident that the limelight has mostly been on stormwater management, and the potential of wastewater management hasn't been tapped enough.

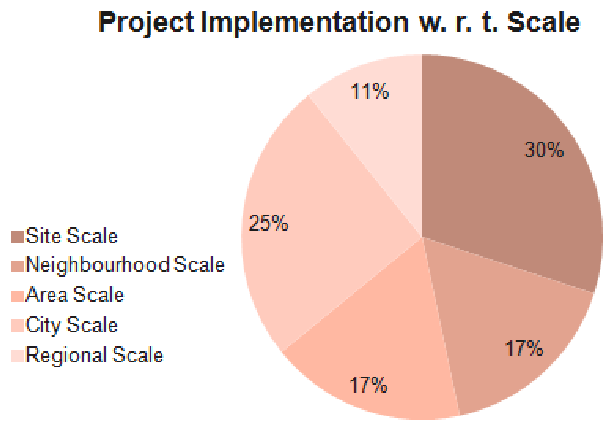


Figure 2 Graph showing predominant scale of project implementation

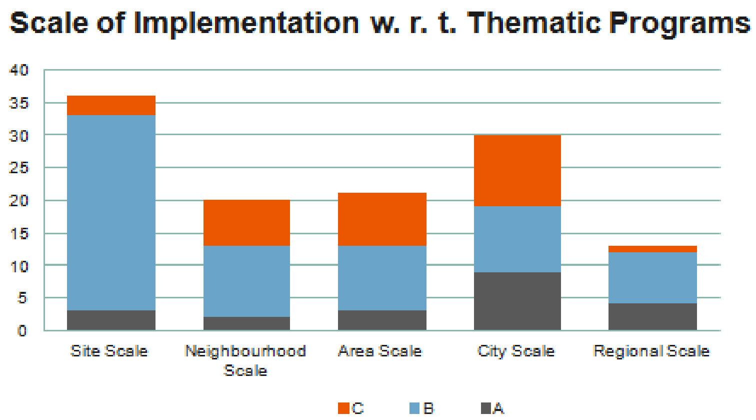
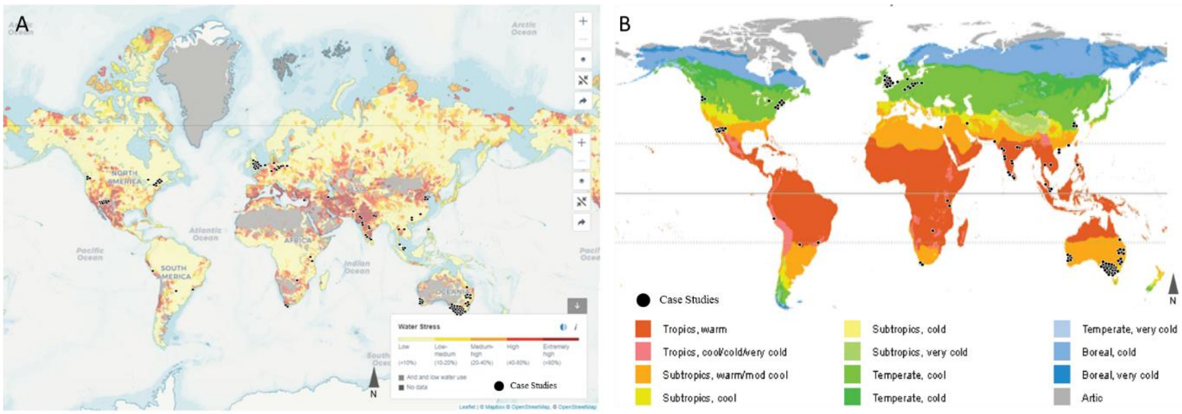


Figure 3 Thematic programs and scale of implementation of cases

The evidence shows that most of the projects have been implemented at small scale at either site or neighborhood or area level (Figure 2). The site scale has been the predominant scale of projects, constituting 30% of the cases. This has been followed by the neighborhood and area level projects which together comprise of 64% of the cases, and hence, could be generally referred to as the small scale projects. Furthermore, about 25% of the cases fall in the category of city scale projects, while the remaining 11% of the cases were found to be implemented at the regional scale. A correlation of each of the project scales with thematic programs was done (Figure 3). In the small-scale project covered in site scale, neighborhood scale, and area scale, the predominant theme is Program B, characterized by design projects for stormwater management. Followed by this is Program A, mainly including practices of participation of various stakeholders and creation of spaces for people to have a sense of belonging in the community. In the city scale, we see that most of the projects fall under Program A and C which focus on participation of various stakeholder, governance initiatives, provision of fit-for-purpose water, and wastewater management. In terms of catering to environmental sustainability and innovative design practices, only a few projects have taken some initiatives. At regional level, there are limited projects that would predominantly fall under the Program B essentially through the provision of blue-green infrastructure initiatives.



(a) (b)

Figure 4 Location of 120 case studies with regards to different water stress zones (a) and Agro-Ecological Zones (B) of the world.

Furthermore, on mapping these case studies spatially, it can be said that a majority of these projects are clustered in Australia, North America, and UK in Europe (Figure 4). Overall, all of the projects fall under agro-ecological zones of Tropics warm, Subtropical warm/moderate cool, and Temperate cool (Figure 4b) which are mostly the high water stressed regions (Figure 4a).

5. Discussions and Conclusion

The evidence of 120 global case studies shows that the primary focus of projects has mostly been implementing small-scale water sensitive design practices. Therefore, this study reflects on the fact that the conceptual literature paints a scenario of a city which largely respects the natural landscape, posing a direct credibility on land use and regional planning domain. However, the practices or indicators are largely limited to the small-scale interventions only. In such cases, the question of scalability and city-wide impact remains unaddressed. Are we really moving towards water sensitive “cities” (cities being the operative word here) without any pan city interventions?

It is also crucial to understand the real intention of these practices. The theories essentially try to propagate the idea of planning as a way of life, which is difficult to achieve through the site specific or neighborhood level interventions. Water sensitive planning theories provide an opportunistic platform to combat climate change. However, it is not possible unless we really make use of literature on urban metabolism and integrate it with urban and regional planning tools. The theories essentially discuss how replacement of natural landscapes has posed immense pressure on water infrastructure and yet, there were very site-specific evidences that have promoted permeable surfaces.

There is also limited focus on other important concepts of water sensitivity such as integration of centralized and decentralized water systems. Aspects of wastewater management and re-use of treated wastewater were given less emphasis in comparison to the stormwater management, thus, losing out on a crucial type of water resource.

Furthermore, interesting inferences can be drawn from the spatial location of the evidence case studies with regards to the genesis of concepts related to water sensitivity (Figure 4). It can be inferred that the clustered locations of most of these cases in Australia, North America, and UK are essentially due to the emergence of notions of WSUD, LID, and SUDS in these regions respectively. These concepts are also found to be implemented in South America, Asia, Africa, and Europe based on the suitability of agro-ecological regions and local conditions. Spatially, all of the global cases reviewed fall under high water stressed zones or arid regions. This conveys that certain regions have adopted these practices as the most pressing solutions for sustenance. On the other hand, it is also essential to understand that other regions of the world were empowered in advance, to adopt the water sensitive practices.

Practices in the global north are predominantly design-based stormwater management (Program B). This is because these countries have already arrived at the stage of drained city, and therefore, their primary focus now is environment conservation. At the same time in global south, initiatives are inclined towards the technology-based service provision (Program C) to improve access, as these countries are still not at par as a water supply city. Consequently, the current focus remains towards providing basic services while learning from the global north by adopting sustainable approaches.

Lastly, since the evidence shows that there is not a single water sensitive city on earth today, the question that needs to be discussed further is about the whole notion of water sensitive cities in general, which is rather utopic in nature. How can we tweak these concepts so as to encourage bigger impacts? At what stage of accomplishment does a city really become water sensitive? Perhaps, more empirical studies are required for different regions to appropriately assess the gaps in implementing water sensitive practices at pan-city levels. Thus, this study poses a way forward for such deeper empirical assessments to precisely identify the gaps and suggest contextual learnings for different regions of the world.

Appendix A List of 120 Global Case Studies catering to different themes

Sr. No.	Project	Place	Scale	Predominant Theme
1	The South Bank Rain Bank - Urban Stormwater Irrigating Brisbane's Iconic Parkland	West End / South Brisbane, Australia	Area level	Program B – Water Sensitive Urbanism
2	Small Creek Naturalisation	Ipswich, Queensland, Australia	City level	Program B – Water Sensitive Urbanism
3	Josh's House	Fremantle, Australia	Neighbourhood level	Program B – Water Sensitive Urbanism
4	Angus Creek Stormwater Harvesting and Reuse Scheme	Rooty Hill, NSW, Australia	Area level	Program B – Water Sensitive Urbanism
5	Dobsons Creek Disconnection Project	Melbourne, Australia	Area level (Over 180 Properties, 1900 Bioretention Systems, 11.5ha Portion of The Dobsons Creek)	Program A – Society
6	Enhancing Our Dandenong Creek Program	Melbourne, Australia	Neighbourhood level	Program A – Society
7	Park Orchards Community Sewerage Trial	Park Orchards and Ringwood North, Australia	Neighbourhood level	Program C – Future Technologies
8	Warrnambool Roof Water Harvesting Project	Warrnambool, VIC	Area level	Program B – Water Sensitive Urbanism
9	Bannister Creek Living Stream	Perth, Australia	Area level	Program A – Society
10	Kalamunda Managed Aquifer Recharge Project	Kalamunda, Australia	Site level	Program C – Future Technologies
11	Kalkallo Stormwater Harvesting And Reuse	Kalkallo, Australia	Neighbourhood level	Program C – Future Technologies
12	Waterproofing the West	West Adelaide, SA	Regional level	Program B – Water Sensitive Urbanism
13	Sydney Water Bank Naturalisation	Sydney, NSW	City level	Program B – Water Sensitive Urbanism
14	Randolph Avenue Streetscape Upgrade	Adelaide, SA	Neighbourhood level	Program B – Water Sensitive Urbanism
15	Adelaide Airport Irrigation Trial	Adelaide, SA	Site level	Program B – Water Sensitive Urbanism
16	Greening The Pipeline - Williams Landing Pilot Park	Melbourne, Australia	Site level	Program A – Society
17	Currumbin Ecovillage Rainwater Harvesting	Currumbin Valley, Australia	Neighbourhood level	Program C – Future Technologies
18	Currumbin Ecovillage Wastewater Management	Currumbin Valley, Australia	Neighbourhood level	Program C – Future Technologies
19	Gladstone East Shores Precinct	Gladstone, Australia	Area level	Program C – Future Technologies
20	Kings Square Raingardens	Perth, Australia	Area level	Program B – Water Sensitive Urbanism
21	Waterwise Council Program	Australia	Regional level	Program A – Society
22	A New Community at Officer	Melbourne, Victoria	Area level	Program B – Water Sensitive Urbanism

Sr. No.	Project	Place	Scale	Predominant Theme
23	Orange Stormwater to Potable	Australia	Regional level	Program B – Water Sensitive Urbanism
24	Aquarevo	Lyndhurst, USA	Neighbourhood level	Program B – Water Sensitive Urbanism
25	White Gum Valley	Fremantle In Western Australia	Neighbourhood level	Program B – Water Sensitive Urbanism
26	Salisbury Alternative Water Scheme	Salisbury, Australia	City level	Program C – Future Technologies
27	Water Sensitive Elwood	Melbourne, Australia	Site level	Program B – Water Sensitive Urbanism
28	Elizabeth Street Catchment	Melbourne, Australia	Area level	Program B – Water Sensitive Urbanism
29	The City of Moonee Valley Local Planning Scheme	Melbourne, Australia	City level	Program A – Society
30	Forest Park Ecological Wetland	Kunshan, Jiangsu, China	Site level	Program B – Water Sensitive Urbanism
31	Sponge City Innovation Park	Kunshan, Jiangsu, China	Site level	Program B – Water Sensitive Urbanism
32	Central Park Recycled Water Scheme	Sydney, Australia	Neighbourhood level	Program C – Future Technologies
33	One Central Park Green Walls	Sydney, Australia	Site level	Program A – Society
34	Dubbo Urban Heat Island Amelioration Project	New South Wales, Australia	Regional level	Program B – Water Sensitive Urbanism
35	Kunshan Ring Road Case Study	Kunshan, Jiangsu Province, China	Regional level	Program B – Water Sensitive Urbanism
36	City Of Gold Coast Water Sensitive City Transition Strategy	Gold Coast, Queensland	Regional level	Program A – Society
37	Moonee Valley Water Sensitive Cities Benchmarking Case Study	Melbourne, Australia	Area level	Program A – Society
38	Resource Recovery from Wastewater	Brisbane, Australia	Site level	Program C – Future Technologies
39	Collaborative Planning for The Fishermans Bend Urban Redevelopment	Melbourne, Victoria	Area level	Program C – Future Technologies
40	Green Infrastructure Implementation Case Study In Asia Monsoon Climate	Singapore	City level	Program B – Water Sensitive Urbanism
41		Bangkok, Thailand	City level	Program A – Society
42		Colombo, Sri Lanka	City level	Program C – Future Technologies
43		Jamshedpur, India	City level	Program C – Future Technologies
44	Every Drop Counts: Learning from Good Practices In Eight Asian Cities (ADB And Institute Of Water Policy)	Kuala Lumpur, Malaysia	City level	Program A – Society
45		Manila, Philippines	City level	Program C – Future Technologies
46		Phnom Penh, Cambodia	City level	Program A – Society
47		Shenzhen, People's Republic of China	City level	Program A – Society
48		Singapore	City level	Program C – Future Technologies

Sr. No.	Project	Place	Scale	Predominant Theme
49	From Grey to Green | Large Scale	Portland, Oregon, USA	City level	Program C – Future Technologies
50	Waterplan 2 | Large Scale	Rotterdam, Netherlands	City level	Program B – Water Sensitive Urbanism
51	Blue-Green Network | Large Scale	City of Lodz, Poland	City level	Program B – Water Sensitive Urbanism
52	Tanner Springs Park | Medium Scale	Portland, Oregon, USA	Regional level	Program B – Water Sensitive Urbanism
53	Trabrennbahn Farmsen	Hamburg, Germany	Regional level	Program B – Water Sensitive Urbanism
54	Hohlgrabenäcker | Medium Scale	Stuttgart, Germany	Regional level	Program B – Water Sensitive Urbanism
55	Potsdamer Platz	Berlin, Germany	Regional level	Program B – Water Sensitive Urbanism
56	10th@Hoyt Apartments	Portland (Oregon, USA)	Site level	Program B – Water Sensitive Urbanism
57	Prisma Nürnberg	Nürnberg, Germany	Site level	Program B – Water Sensitive Urbanism
58	Sustainable Urban Water Management	Amravati, India	City level	Program C – Future Technologies
59	Alma Road Rain Gardens, London	Alma Road, London Borough Of Enfield	Site level	Program B – Water Sensitive Urbanism
60	Access Road, Chelmsfor	Jehovah's Witnesses Britain Headquarters	Site level	Program B – Water Sensitive Urbanism
61	Aztec West Business Park, South Gloucestershire	Aztec West Business Park, Waterside Dr, Almondsbury, Bristol, South Gloucestershire	Site level	Program B – Water Sensitive Urbanism
62	Bath Road, London	Bath Road, London, W4 1LW	Site level	Program B – Water Sensitive Urbanism
63	Derbyshire Street Pocket Park, London	Derbyshire Street Pocket Park, Derbyshire Street, London Borough of Tower Hamlets, London	Site level	Program B – Water Sensitive Urbanism
64	Woodberry Down Regeneration, London	Woodberry Down, Hackney	Neighbourhood level	Program B – Water Sensitive Urbanism
65	Sustainable Drainage Estates, Hammersmith And Fulham	London Borough of Hammersmith and Fulham	Neighbourhood level	Program C – Future Technologies
66	Norwood Greening Streets, Residential Retrofit, London	Lambeth, London	Neighbourhood level	Program B – Water Sensitive Urbanism
67	Dunfermline Eastern Expansion, Residential Suds Scheme, Dunfermline	Dunfermline, Scotland	Site level	Program B – Water Sensitive Urbanism
68	Emersons Green Development, Gloucestershire	Emersons Green, Bristol, Gloucestershire	Site level	Program B – Water Sensitive Urbanism

Sr. No.	Project	Place	Scale	Predominant Theme
69	Firs Farm Wetlands, London	Firs Farm Wetlands, Whinchmore Hill, Enfield	Site level	Program B – Water Sensitive Urbanism
70	Manor Ponds, Sheffiel	The Manor Estate, Manor Lane, Sheffield, South Yorkshire	Site level	Program B – Water Sensitive Urbanism
71	Silver Lake Beach LID Retrofit	Wilmington, MA,	Site level	Program B – Water Sensitive Urbanism
72	Silver Lake Neighbourhood LID Retrofit	Silver Lake in Wilmington	Site level	Program B – Water Sensitive Urbanism
73	Monitoring Low Impact Development at Elm Drive Demonstration Site	Mississauga, Canada	Site level	Program B – Water Sensitive Urbanism
74	UA Lester Street Landscaping	Tucson, AZ, USA	Neighbourhood level	Program B – Water Sensitive Urbanism
75	Scott Avenue Revitalisation	Tucson, AZ, USA	Neighbourhood level	Program B – Water Sensitive Urbanism
76	Cambio Grande Streetscape Enhancement	Tucson, AZ, USA	Neighbourhood level	Program B – Water Sensitive Urbanism
77	Blue Moon Community Garden (Tucson House)	Tucson, AZ, USA	Neighbourhood level	Program B – Water Sensitive Urbanism
78	Nature Conservancy	Tucson, AZ, USA	Neighbourhood level	Program C – Future Technologies
79	Lid Retrofit: Unh Parking Lot Bioretention	New Hampshire, USA	Site level	Program B – Water Sensitive Urbanism
80	Greenland Meadows	New Hampshire, USA	Site level	Program B – Water Sensitive Urbanism
81	Making Urban Water Management More Sustainable: Achievements in Berlin	Berlin, Germany	City level	Program C – Future Technologies
82	Case Study Brief – The Restoration of The River Cheonggyecheon	Cheonggyecheon, Seoul	City level	Program B – Water Sensitive Urbanism
83	The Emscher Region - The Opportunities of Economic Transition for Leapfrogging Urban Water Management	Emscher Region, Germany	Regional level	Program A – Society
84	Implementation of The Blue-Green Network	Lodz, Poland	City level	Program B – Water Sensitive Urbanism
85	Boneo Recycled Water Scheme	Boneo, Victoria, Australia	Area Level	Program C – Future Technologies
86	Coburg Stormwater Harvesting Project	Coburg, Germany	Neighbourhood level	Program C – Future Technologies
87	Doncaster Hill Recycled Water Project	Doncaster Hill, Victoria, Australia	Neighbourhood level	Program C – Future Technologies
88	Kalkallo Stormwater Harvesting Project	Kalkallo, Victoria, Australia	Regional Scale	Program C – Future Technologies
89	Coldstream Recycled Water Project	Melbourne, Australia	City level	Program C – Future Technologies
90	Fitzroy Gardens Stormwater Harvesting Scheme	Melbourne, Australia	Neighbourhood level	Program B – Water Sensitive Urbanism
91	Toolern Stormwater Harvesting Scheme	Toolern, Australia	Area level	Program C – Future Technologies

Sr. No.	Project	Place	Scale	Predominant Theme
92	Swan Lake Drive Development, Delaware County	Concord, PA	Neighbourhood level	Program B – Water Sensitive Urbanism
93	Lebanon Valley Agricultural Center, Lebanon County	Lebanon, PA	Site Level	Program B – Water Sensitive Urbanism
94	Commerce Plaza III, Lehigh County	Lehigh County, PA	Neighbourhood level	Program B – Water Sensitive Urbanism
95	Urban Decentralised Wastewater Management	Badlapur, India	Neighbourhood level	Program C – Future Technologies
96	Natural Wetland in The Musi River Micro-Watershed	Telangana, India	Site Level	Program B – Water Sensitive Urbanism
97	U Of A Capla	Tucson, AZ, USA	Site Level	Program B – Water Sensitive Urbanism
98	Highland Vista	Tucson, AZ, USA	Park Scale	Program B – Water Sensitive Urbanism
99	Kolb Detention Basin Retrofit	Tucson, AZ, USA	Site Level	Program B – Water Sensitive Urbanism
100	LANCASTER RESIDENCE And RIGHT-OF-WAY	Tucson, AZ, USA	Site Level	Program B – Water Sensitive Urbanism
101	Madurai: Action Plan For Blue-Green Infrastructure	Madurai, India	City level	Program B – Water Sensitive Urbanism
102	Surat: Flood Action Plan	Surat, India	City level	Program B – Water Sensitive Urbanism
103	Sao Paulo: Improving Water Services Access and Security	Sao Paulo, Brazil	City level	Program B – Water Sensitive Urbanism
104	Jodhpur: Rainwater Harvesting	Jodhpur, India	City level	Program B – Water Sensitive Urbanism
105	Jamshedpur: Privatisation of Public Sector	Jamshedpur, India	City level	Program A – Society
106	Columbo: Integration of Water Systems	Columbo, Sri Lanka	City level	Program C – Future Technologies
107	Kenya: Mara River Basin Water Management Plan	Kenya, Africa	City level	Program B – Water Sensitive Urbanism
108	Capetown: Water Management Plan	Capetown, South Africa	City level	Program B – Water Sensitive Urbanism
109	Mazhapolima: Ensuring Water Security Through Participatory Well Recharge in Kerala	Thrissur, Kerala	Regional level	Program A – Society
110	Groundwater Conservation: Sustainable Water Supply In Ajmer Dargah Premises	Ajmer, India	Site Level	Program A – Society
111	Urmia Lake Restoration, Azerbaijan, Iran	Azerbaijan, Iran	Site Level	Program C – Future Technologies
112	Lusaka, Zambia: Approaches to Peri-Urban Water Supply	Lusaka, Zambia	City level	Program B – Water Sensitive Urbanism
113	Lima, Peru: Fog Water Harvesting	Lima, Peru	City level	Program B – Water Sensitive Urbanism
114	Dar Essalem, Tanzania: Tabata community Water System	Dar Essalem, Tanzania	Neighbourhood level	Program A – Society
115	Israel: Mitigation Through Technology	Israel	City level	Program C – Future Technologies
116	Buenos Aires: Privatisation To Re-Nationalisation	Argentina	City level	Program A – Society
117	Johannesburg: Corporation Model	South Africa	City level	Program A – Society

Sr. No.	Project	Place	Scale	Predominant Theme
118	Karachi, Pakistan: Orangipilot Mission	Karachi, Pakistan	City level	Program A – Society
119	Bishan Ang Mo Kio Park	Singapore	Neighbourhood level	Program B – Water Sensitive Urbanism
120	K-Water	Republic of Korea	City level	Program C – Future Technologies

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