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WATER SENSITIVE URBAN OPEN SPACES: COMPARING NORTH AMERICAN BEST MANAGEMENT PRACTICES

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HIGHLIGHTS

- Sustainable Water Management Criteria.
- Glossary of technical solutions for BMP application.
- Comparison between climatic data and adopted solutions.

ABSTRACT

The paper reports about the opportunity to apply the principles of sustainable stormwater management in urban open spaces, as realized in some countries all over the world. Focusing on the design criteria of green streets and emphasizing their multiple benefits, the main technical solutions of best management practices are presented in a glossary proposal. Having selected nine North American mayor cities, to study possible connections between facilities typologies and geographical positions, their climatic features are associated with the technical solutions suggested in the related stormwaters sustainable design manuals and toolkits. The discussion of presented comparisons indicates directions of development for critical reflections and research on the subject, useful for cities still lacking in these technical indications.

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1. INTRODUCTION

The consequences of increasing consumption and soil impermeability, in addition to the discontinuities and macroscopicity of weather events due to climate change, have driven the environmental project to advanced research on strategies for the sustainable management of meteoric waters during last decades. More and more often, in various geographic areas, devastating alluvial phenomena have been recorded in urban and peri-urban zones, due to the overloading of sewers, undersized for the latest peak flows and 50-year return times. In such cases there is severe environmental damage caused by spills in natural water bodies of waste water not treated by purification processes, in addition to damages caused by the amount of water and sediment of flash floods.

Around the world, design criteria to avoid this have been named in different ways: Low Impact Development (LID) and Best Management Practices (BMP) in the United States and Canada, Water Sensitive Urban Design (WSUD) in Australia, or Sustainable Urban Drainage Systems (SUDS) in the UK. Main principles are the maximization of green areas and permeable surfaces, the protection of groundwater, the evapotranspiration, the collection, reuse, detention, filtration, treatment and infiltration of rainwater on site.

The water sensitive approach therefore also includes considerations about vegetation, air quality, viability and safety of open spaces, requiring local governments to make work together the departments of planning, transportation, sewers, environment, parks, health, disadvantaged social groups and technological innovation. These topics are now widespread at the global scale among scholars and environmental designers, although experiencing strong differences in awareness and preparation. The disparities in the application of such systems are even greater, as the shared convictions among researchers do not correspond to the spread of operational practices.

In the redesign of urban roads and open spaces, the concept of "green streets" has developed, connecting areas with storm water management principles on-site, through a specific type of best management practices. These generate multi-beneficial effects, as improving stormwater quality, augmenting water supply, providing for flood management, harvesting rainwater, securing a reliable local water supply source also by infiltrating underground water bed, providing for open space, habitat and recreational benefits, building pedestrian friendly green connections within the community, reducing Heat Island Effects, improving air quality (City of Los Angeles, 2009). The beneficial effects also relate to the thermo-hygrometric equilibrium given by the increase in the vegetation area in urban areas, the increase in the value of the building stock for the qualification of the surrounding environment and the impulse towards civic awareness on environmental management topics, given by showing the facilities on the street surface.

This environmental design approach has spread from Germany in the 1990s with the experiences of the recovery of the Ruhr region and later of the Potszdamer Platz areas in Berlin. At the same time, in 1992, in the United States, the Clean Water Act prescribed at federal level that cities had to clean their storm waters (Valente R., Mozingo L.A., 2015). This activated the experiences led by the local wise administrations of the cities of Portland, San Francisco, New York, Seattle, Philadelphia, Boston, to mention just the principal. Already in 2009 (Kurtz, 2009) in the city of Portland 500 facilities were already operating. Great impetus has also been on research in the subject in Australia, where it is very active The Cooperative Research Centre for Water Sensitive Cities, established in July 2012 “to help change the way we design, build and manage our cities and towns by valuing the contribution water makes to economic development and growth, our quality of life, and the ecosystems of which cities are a part” (CRCWSC, 2012).

In Italy among the few similar experiences in local governments there are those of the Region Lombardia (Gibelli, 2015), of the Provincia di Bolzano (Kompatscher, 2008) and the ones in the municipalities of Reggio Emilia (Comune di Reggio Emilia, 2014), Firenze (Comune di Firenze, 2011), Imperia, Rimini. No experiences are still reported in Southern Italian regions.
As it is common in environmental design, this topic is spread across multiple project scales. At the upper level, the water catchment area of the site is considered together with the coexistence of mixed and interdependent uses and the relationship with different contiguous urban contexts, often characterized with different ownerships and hence different management regimes. On the other side at the small scale, the systems of detail constructive elements are defined and developed.
The climatic question transversally affects any scale, with the trends of ongoing transformations (tropicalization, groundwater rise, rainfall extremization) to be understood to adapt technical solutions to predictable situations.

2. NOTES FOR A GLOSSARY

Each North American local government oriented towards sustainable management strategies of urban rainwater has produced manuals, both divulgative on the general criteria, and operational for the application of specific techniques. The comparison of such materials shows as not all technical solutions are common to each case under consideration, both for different geographic-physical and climatic conditions, and for different denominations of details, though very similar. A basic glossary attempt is reported below, derived by author from the comparison of the most common definitions.

- Stormwater Planter: “specialized, landscaped planter installed in the sidewalk area and designed to manage stormwater runoff. Runoff is routed to the planter by setting the top of the planting media in the planter lower than the street’s gutter elevation and connecting the planter to one or more inlets.” (City of Philadelphia, 2014) (Figure 1)
- Permeable Pavement: “hard pavement surface consisting of materials that allow water to pass freely through the surface, thereby eliminating or reducing runoff compared to impervious paving. Permeable pavement surfaces typically include a storage media such as stone beneath the permeable surface.” (City of Philadelphia, 2014)
- Stormwater bumpout: “landscaped curb extension that extends the existing curb line into the cartway. It is designed to manage stormwater runoff by setting the top of the planting media in the bump-out lower than the street’s gutter elevation and connecting the bump-out to one or more inlets, which allows stormwater runoff from the street to flow into the bump-outs” (City of Philadelphia, 2014) (Figure 2)
- Stormwater Tree: “specialized tree pit installed in the sidewalk area. It is designed to manage stormwater runoff by placing the top of the planting media in the tree pit lower than the street’s gutter elevation and connecting the tree pit to an inlet, which allows stormwater runoff from the street into the tree pit.” (City of Philadelphia, 2014) (Figure 3)
- Stormwater Tree Trench: “subsurface trench installed in the sidewalk area that includes a series of street trees along a section or the total length of the subsurface trench. It is designed to manage stormwater runoff by connecting the subsurface trench to one or more inlets.” (City of Philadelphia, 2014) (Figure 4)
- Green Gutter: “narrow and shallow landscaped strip along a street’s curb line. It is designed to manage stormwater runoff by placing the top of the planting media lower than the street’s gutter elevation allowing stormwater runoff from both the street and sidewalk to flow directly

into the green gutter." (City of Philadelphia, 2014) (Figure 5)

- Bioswales: "typically long, narrow, gently sloping landscaped depressions that collect and convey stormwater runoff. (…) As the stormwater flows along the length of the swale, the vegetation and check dams slow the stormwater down, filter it, and allow it to infiltrate into the ground." (City of Portland, 2016) (Figure 6)
- Rain Garden or Basin: "method of stormwater management that directs roof and/or paved area runoff to a shallow, flat, vegetated landscape depression amended with compost to allow for onsite infiltration." (City of Portland, 2016)
- Pond: "*Wet ponds* are constructed with a permanent pool of water. Stormwater enters the pond at one end and displaces water from the permanent pool. Pollutants are removed from stormwater through gravitational settling and biological processes. (…) *Extended wet ponds* are also constructed with a permanent pool of water, but have additional storage above that fills during storm events and releases water slowly over a number of hours. (…) *Dry detention ponds* are designed to fill during storm events and slowly release the water over a number of hours. (City of Portland, 2016)
- Constructed Wetland: manmade facilities that collect, store, and filter water also providing a habitat for wildlife.
- Green Roof: "impervious area reduction technique which decreases stormwater management requirements on the project site. (It) is a lightweight vegetated system consisting of waterproofing material, a growing medium, and low growing, drought tolerant plants." (City of Portland, 2016)
- Drainage well: "designed to manage stormwater runoff by receiving stormwater from upstream collection and pretreatment systems and then discharging the stormwater into the surrounding soils through perforations in the manhole." (City of Philadelphia, 2014)
- Stormwater Barrel and cisterns: technical solutions useful to collect rainwater and use it for irrigation and outdoor surfaces cleaning.

Figure 1: Three-dimensional view of a Stormwater Planter. *Source: City of Philadelphia Green Streets Design Manual, 2014*

Figure 2: Three-dimensional view of a Stormwater bump-out. *Source: City of Philadelphia Green Streets Design Manual, 2014*

Figure 3: Three-dimensional view of a Stormwater Tree. *Source: City of Philadelphia Green Streets Design Manual, 2014*

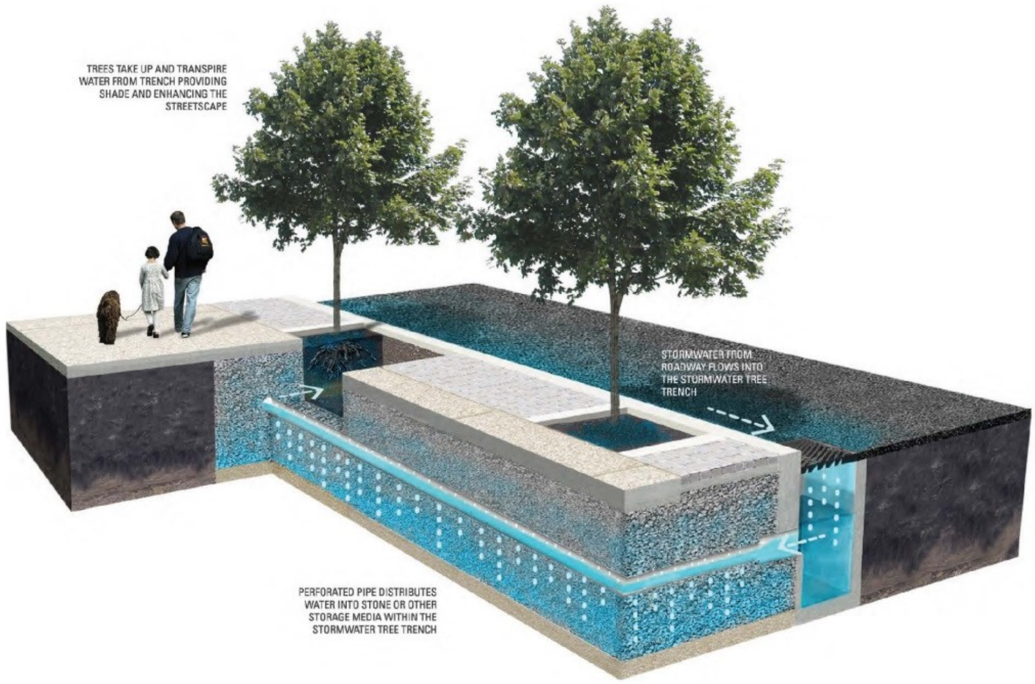


Figure 4: Three-dimensional view of a Stormwater Tree Trench. *Source: City of Philadelphia Green Streets Design Manual, 2014*

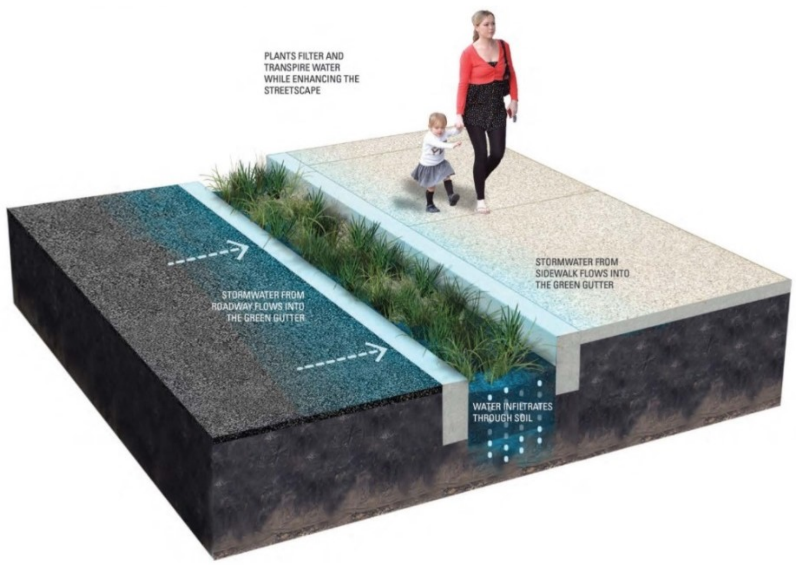


Figure 5: Three-dimensional view of a Green Gutter. *Source: City of Philadelphia Green Streets Design Manual, 2014*

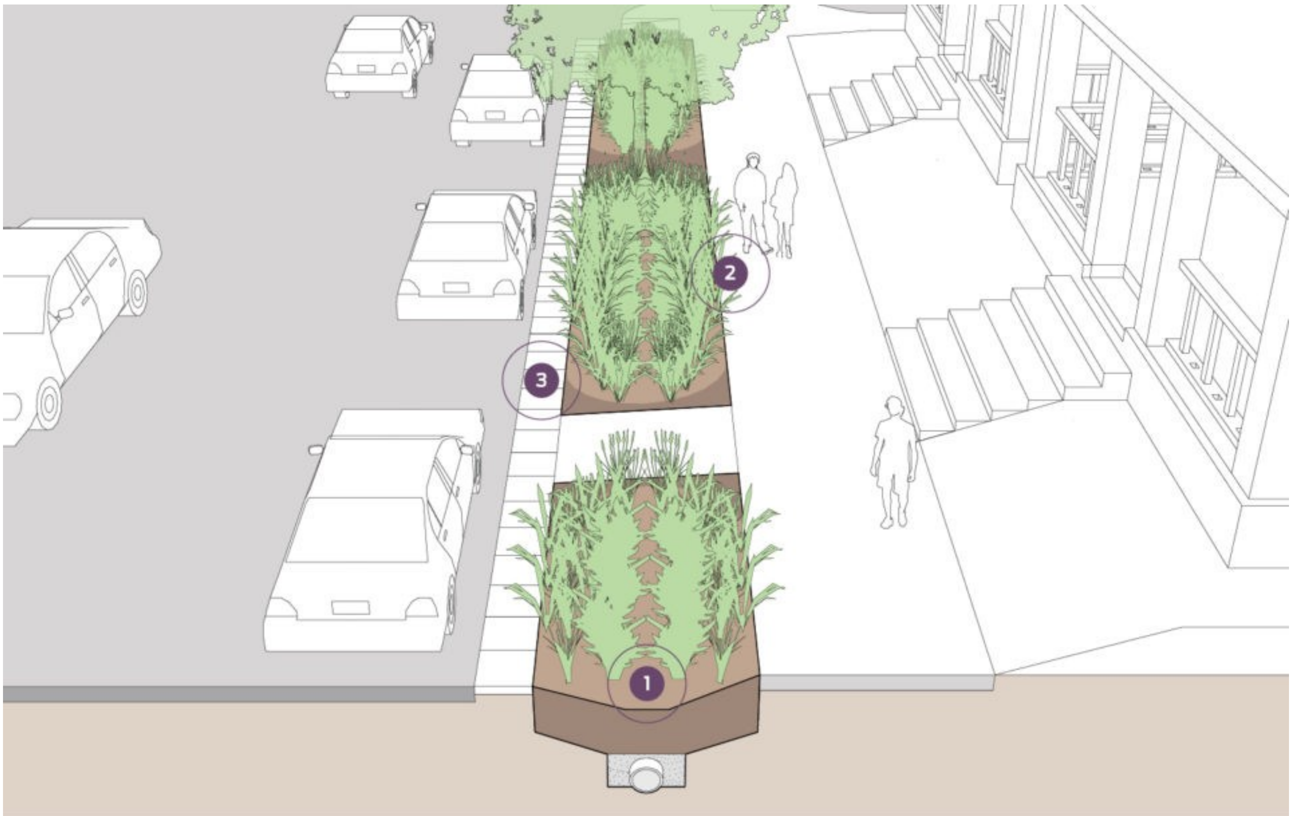


Figure 6: Bioretention Swale **1**. The bottom area of a bioretention cell along with the side slopes; 2. Areas where pedestrians may step off the sidewalk 3. Areas with significant on-street parking turnover *Source: Urban Street Stormwater Guide, National Association of City Transportation Officials, US*

3. COMPARISON CRITERIA

The amount of North American technical regulations, the variety of technical solutions proposed and tested in different experiences, are assets for the study of these best practices. Various may be the comparison criteria, also overlapping for an integrated analysis.
A first consideration concerns the different climates of the examined cities, chosen for the advanced level of practice. Table 1 shows temperatures, average annual rainfall and climatic classification *sensu* Köppen (1937) and James (1966) (Dfa/b, cold climates with wet winter with an average temperature of the hottest month upper or less than 22°C; Cfa/b, mild humid climate with an average temperature of the hottest month upper or less than 22°C; Csa/b, warm and temperate climate; Csc, warm climate with dry summer from 1 to 3 months above 10°C). Table 2 and Figure 7 show the rainfall in the various months of the year and the difference between the major and minor, made more explicit by the next graph. Similar considerations are in Table 3 and Figure 8 for the city of Naples, in Southern Italy.
In Figure 9, having grouped the cities in three classes of climate (Df, Cf, Cs) and three of rainfall (low 500-800mm, medium 801-1001mm, high 1002-1122mm) the BMP technical solutions described from urban regulations are indicated, to look for compatibility reports. The separate sewer systems percentage is also indicated.

Table 1: Climate data year average for considered North American cities. (Dfa/b, cold climates with wet winter with an average temperature of the hottest month upper or less than 22°C; Cfa/b, mild humid climate with an average temperature of the hottest month upper or less than 22°C; Csa/b, warm and temperate climate; Csc, warm climate with dry summer from 1 to 3 months above 10°C)

city	Climate type (*sensu* Köppen)	Average temperature (°C)	Average rainfall (mm)
Chicago	Dfa	10,0	918
Toronto	Dfb	8,3	785
Seattle	Csb	10,9	969
Washington	Cfa	13,3	1023
Philadelphia	Cfa	12,5	1113
Boston	Cfa	9,8	1122
Portland	Csb	11,9	1001
San Francisco	Csc	14,1	537
Los Angeles	Csa	18,2	396

Data Source: it.climate-data.org (2017), elaboration by author

Table 2: Rain fall monthly average (mm) for considered North American cities

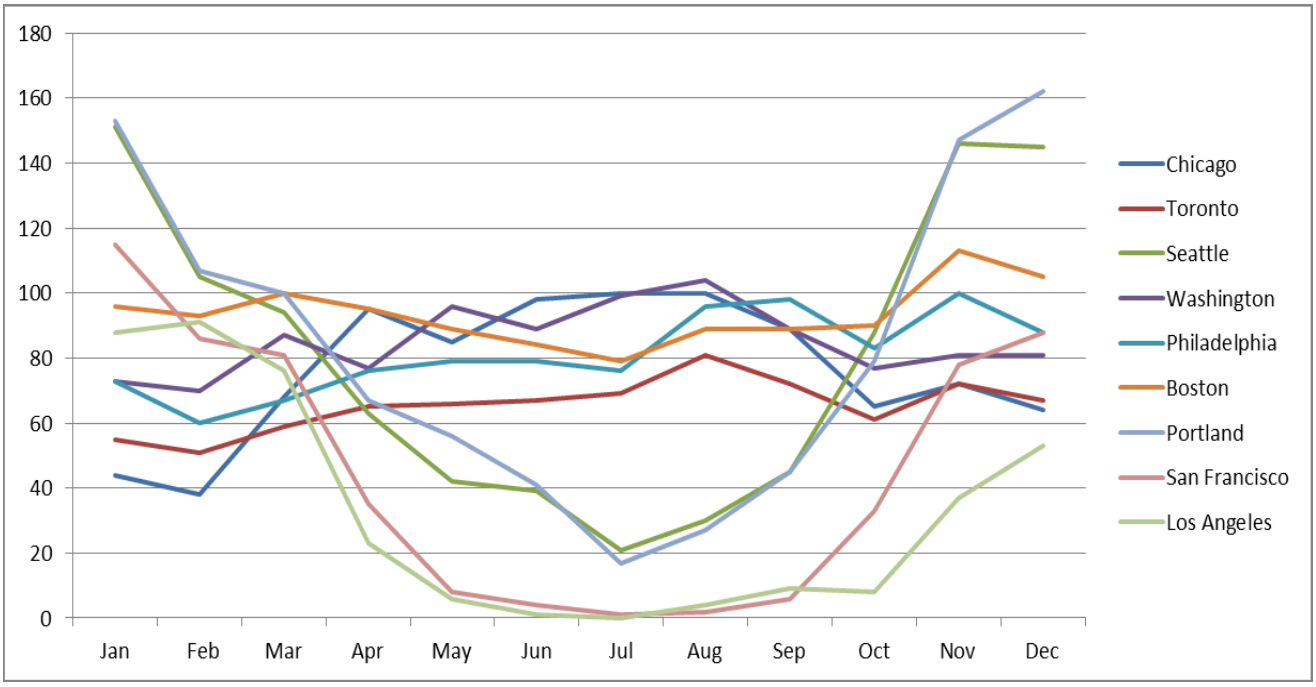
city	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	gradient
Chicago	44	38	68	95	85	98	100	100	89	65	72	64	**62**
Toronto	55	51	59	65	66	67	69	81	72	61	72	67	**30**
Seattle	151	105	94	63	42	39	21	30	45	88	146	145	**130**
Washington	73	70	87	77	96	89	99	104	89	77	81	81	**34**
Philadelphia	73	60	67	76	79	79	76	96	98	83	100	88	**40**
Boston	96	93	100	95	89	84	79	89	89	90	113	105	**34**
Portland	153	107	100	67	56	41	17	27	45	79	147	162	**145**
San Francisco	115	86	81	35	8	4	1	2	6	33	78	88	**114**
Los Angeles	88	91	76	23	6	1	0	4	9	8	37	53	**91**

Data Source: it.climate-data.org (2017), elaboration by author

Table 3: Climate data year average and Rain fall monthly average (mm) for Naples, Italy

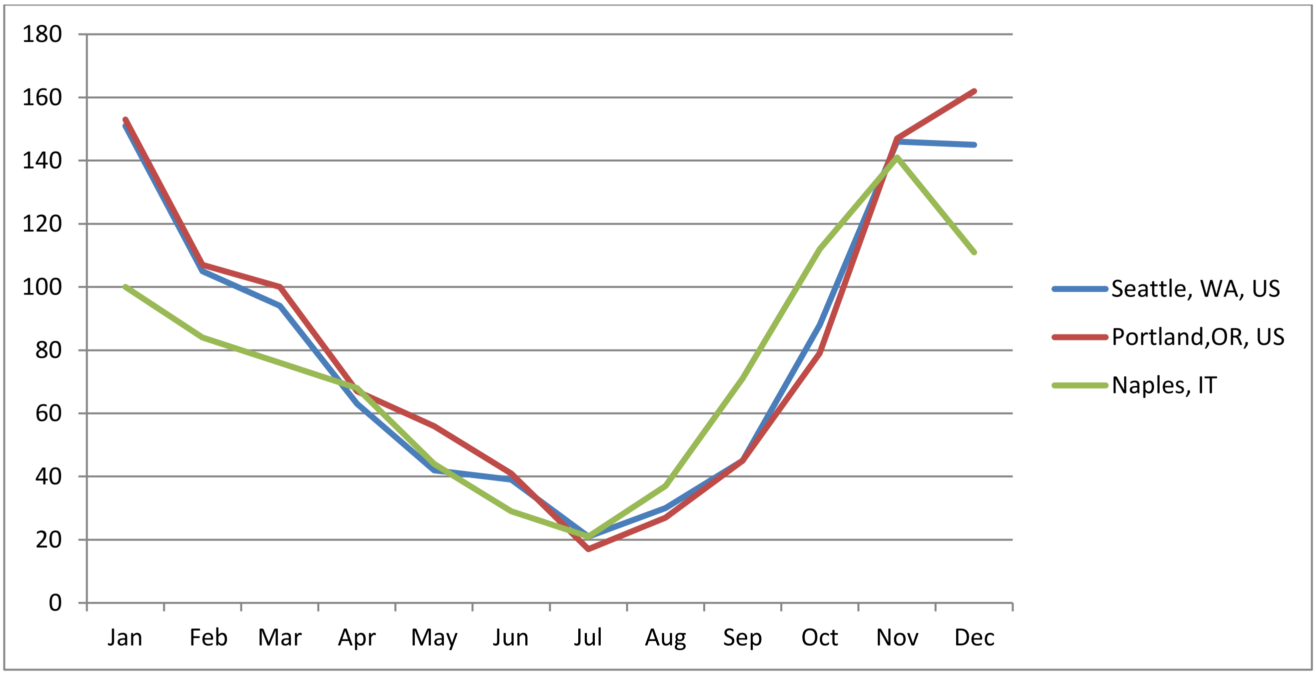
city	Climate type (*sensu* Köppen)	Average temperature (°C)	Average rainfall (mm)
Naples, IT	Csa	15,7	894

city	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	gradient
Naples, IT	100	84	76	68	44	29	21	37	71	112	141	111	**120**



Data Source: it.climate-data.org (2017), elaboration by author

Figure 7: Graph derived from Table 2



Data Source: it.climate-data.org (2017), elaboration by author

Figure 8: Graph derived from Table 3

	Los Angeles, CA	Portland, OR	S. Francisco, CA	Boston, MA	Philadelphia, PA	Washington, DC	Seattle, WA	Toronto, Canada	Chicago, IL
% of separate sewer	100	60	0	0	33	66	33	77	0
Stormwater Planter	○ Inf/Flow Thr.	○	○ Bioretention Pl.	○ Planter Box	○	○		○	
Permeable Pavement	○	○	○	○	○	○	○	○	○
Stormwater Bumpout	○ Curb Extension	○ Curb Extension	○ B. Pl. Curb Cut		○	○ Roadside Bior.	○ Roadside Bior.	○	
Green Gutter		○ Filter Strips	○	○ Veg. Filter Str.	○			○	
Stormwater Tree	○ Canopy Tree	○ Tree Credits	○	○ Tree Box filter	○	○	○	○	
Stormwater Tree Trench	○ Curb Inlet				○	○ Bior. Step Out		○	
Bioswale	○	○	○	○ Dry W. Qual. S.		○	○ Biofiltration	○	
Rain Garden	○ Infil. Trench	○	○	○ Bior. Areas		○ Bior. Areas	○	○	○
Pond		○							○
Constructed Wetland			○	○					
Green Roof		○	○	○			○		○
Drainage well		○	○	○	○			○	
Stormwater Barrel/cistern		○ RW Harvest.	○	○			○	○	○
Downspout discharges		○	○						○
Urban Forest Canopy								○	
Ecopassages								○	
Green Walls								○	

Climate: Dfa/Dfb; Cfa; Csa/Csb/Csc

Rain: 537/785 mm; 918/1001 mm; 1002/1122 mm

Figure 9: Comparison between climate conditions and BMP technical solutions in considered case studies.

4. DISCUSSION

The presented relationships show as the cities along the North American West coastline have discontinuous rainfall, comparable to each other during the year, even though with different climates.
Along the East coast, with colder climates, the meteoric contribution is constant. These considerations are helpful to orient still lacking cities guidelines, particularly in the Southern Italian areas, similar to some of the investigated cases. For the first time here it is noted that the data of the city of Naples, Italy, are comparable to those of the cities of Seattle and Portland (with even more balanced values during the year). As there are no examples of operational technical regulation on stormwater management in South Italy, the lack of active experiences stimulates research in this area, which is densely of positive potential application impacts. To this end, the Unit at the University of Campania Luigi Vanvitelli, led by the author - within the Italian Research Projects of Relevant National Interest 2015 "Adaptive Design and Technological Innovations for Resilient Regeneration of Urban Districts in Climate Change" coordinated by Mario Losasso - chose to focus on the study of the application of BMPs in the Mediterranean environment of Southern Italy.
To this end, the first considerations in Figure 9 relate to the distribution of BMP solutions, indicating the ones that are mainly used, according to repeated choices that do not depend on climate diversity and show the possibility of varying only botanical solutions.
Compared to the different sewage systems, different percentages of separate water disposal systems are noticed, with values ranging from 0% to San Francisco, Boston and Chicago to 100% in Los Angeles. Green street facilities are useful both in the case of separate disposal systems, but also in order to counteract the damaging phenomenon of overflow in the combined sewer systems.
Another interesting comparison from the North American technical manuals is the appropriateness of the various solutions studied by each city for its different internal conditions of settlement. Philadelphia offers an interesting matrix of equipment's suitability for different types of streets (City of Philadelphia, 2014), while San Francisco reports those suitable for seven different types of settlement, from residential, to industrial, to new parcels, to the piers on the water (City of San Francisco, 2016).
The diversity of city-published guidelines is also reflected each time in the departments editing them: in Boston as part of the full street plan, in Philadelphia's green street plan, in Portland and San Francisco in the plans of stormwater management, but each time as the fruit of virtuous collaborations.
Finally, the comparative considerations of BMP application cases also relate to the rather high performance evaluations (Kurtz, 2009), but there are some scholars doubting the possibility of extending current experiences to different contexts with concentrated rainfall regimens (Page, 2016). “So, how can Green Streets projects be more effective in ecoregions with shorter, high-intensity storms? More storage for runoff is need – both above and below the ground surface. This can be achieved with hybrid infiltration and detention systems, longer linear infiltration zones, or subsurface detention and treatment like a suspended pavement system.” (Page, 2016). In some areas of the United States, there were results improvements coming “only” from 50% down to a minimum of 25% reduced flow, fewer than those achieved along the West coast with an average of 80% of Portland's in the most existing facilities (Page et al., 2015). The solution found in particular cases is the use of larger surfaces and capturing volumes, but these may be inactive for a long time of the year.
However, relying on the described many benefits of sustainable stormwater management, it should be underlined to evaluate its contribution considering the totality of the ecosystem services offered and the specific technical performance, not only in relation to the obtained runoff reductions.
On the basis of all these reflections, the research of the University of Campania unit for the first time aims at the design of highly performative technical solutions in Mediterranean areas, carrying out

more tasks than the sustainable management of the meteoric waters. On this last aspect we develop research to imagine facilities with varied use, depending on meteorological conditions and different seasons, as well as to enhance the quality of the urban landscape through a systemic reorganization of the public space. The ability to catalyze BMP solutions for service equipment offers the opportunity to update and specialize the performance of components and systems themselves. Meanwhile, the interest of the field of production in this market has already been manifested, for example with patents for tree roots containers (Filterra and Treepad among the best known). The research process is still ongoing towards reported directions and further reports will follow.

5. Conclusion

The remarkable number of existing international examples testifies to both the goodness of adaptive solutions adopted in practice and how their comparison is useful and stimulating. The replicability of the solutions is wider than expected, while deployment through dedicated research can extend the application of experience to different geographic, physical and climatic environments, as well as to investigate possible outcomes of technical and performance evolution.
The balance between the basic technical literature and the sito-specific solicitations each time considered will give rise to qualified urban spaces for each city that wants to improve its public realm.
Research is ongoing to specialize solutions and multiply positive effects, dealing with different context.

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