URBAN GREEN INFRASTRUCTURE FOR SUSTAINABLE LAND USE PLANNING

Martyna Joanna Surma, PhD, University of Reading
https://www.henley.ac.uk/people/person/dr-martyna-joanna-surma
m.j.surma@pgr.reading.ac.uk
Department of Real Estate & Planning
Henley Business School
University of Reading
Whiteknights
Reading
RG6 6UD
United Kingdom

ABSTRACT

The article examines the role of urban green infrastructure for sustainable land use planning, based on the examples of London (UK) and New York City (USA). The urban green infrastructure concept is presented as a cross-cutting solution for many interrelated urban challenges of the 21st Century within human-nature urban ecosystem to ensure environmental quality and liveability of global cities, helping to achieve the Sustainable Development Goals (e.g. making cities inclusive, safe, resilient and sustainable). The paper explores the green infrastructure definition proposed by e.g. the European Commission and the US Environmental Protection Agency. The short study summarizes the current trends in urban green infrastructure environmental planning based on two chosen urban agglomerations, ranging from the city to the site-scale. The article includes debate on the benefits of urban green infrastructure for contemporary challenges (e.g. densification; biodiversity loss; climate change; environmental degradation; human health and wellbeing). Moreover, the study identifies a typology of green infrastructure elements (natural; semi-natural; other) which can support integration, connectivity and multifunctionality of green infrastructure network within city boundaries. Finally, it discusses how the presented green and blue strategies can be integrated for a wider benefits in terms of upgrading future cities' resilience.

INTRODUCTION

The contemporary world is becoming more and more urbanized. Cities face unprecedented and extraordinary challenges due to global trends like rapid urbanization, economic globalization, and climate change (Gill et al., 2007). At the moment, more than a half of the population lives in cities and this number is expected is rise in the coming decades. The cities' growth has put pressure on the capacity of urban systems in terms of transport, environment, sewerage etc. Therefore, The United Nations calls for more integrated city policies, where cross-cutting solutions can ensure better qualities of urban settings and sustainable development pathway (UN, 2015). This is strongly emphasized e.g. in the Sustainable Development Goals (e.g. making cities inclusive, safe, resilient and sustainable). In this context, urban green infrastructure can provide a significant tool, helping to resolve the interconnected urban challenges (e.g. climate change adaptation and mitigation; uncontrolled urbanization process; decreased environmental quality; public health and wellbeing; biodiversity loss). As human-nature relationship can be very complex and underestimated, this short study aims to have a closer look at urban ecosystem, focusing solely on a very dense urban environment, which seems to be the most problematic (challenging?) in terms of future sustainable planning. Hence, addressing key urban challenges (e.g. urban heat island effect; stormwater flooding) by interconnected city policies seems very relevant and up-to-date, if we wish to ensure future prosperity of city environments in the next decades. The urban green infrastructure can possibly help to resolve this issue if properly adapted to local needs (Sandstrom, 2002, Lovell and Taylor, 2013, Schilling and Logan, 2008, Mell, 2016). Although dense urban structure can ensure compact city, efficient transportation and reduced energy demand, a 'good' density should be appropriately balanced (e.g. including green infrastructure). It has been already studied that green city environment has financial benefits for the real estate and planning (Pain, 2018), contributing to resilient, healthy and environmentally friendly cities as an integral component of urban infrastructure, underpinned by place-based ecology, political power and economy (Young et al., 2014). Giving the fact that COVID-19 has added on an additional layer of risk to cities in terms of resilience, an availability of a network of green open space may allow for social distancing for everyone to walk, cycle, play, or just rest, which seems to be an important case when living within dense urban fabrics now and in the future.

Against this background, the short study seeks to bring together the debates on sustainable land use planning in developed economies (based on the green infrastructure concept) on the examples of London (UK) and New York City (USA). The global cities were chosen as case studies to better examine the current trends, taking into consideration both European and American perspectives. Due to the strong urban development processes, the chosen cities need to face many common sustainability challenges, which are in fact observed in other mega cities as well. Hence, the paper looks specifically at how the chosen urban agglomerations adapt the concept of urban green infrastructure to their specific needs and what can be learn from this. More generally, the study explores how the proposed initiatives using green infrastructure approach can better address sustainability challenges, which may have relevance for other cities as well. The study refers to the broader topic of the 'Cross-Cutting Solutions for the Decade of Action' proposed for the 8th International Conference on Sustainable Development at Columbia University in the City of New York (September 21-22, 2020)[1].

[1] https://ic-sd.org/ (10 June 2020)

With this approach the following research question is addressed:

- How urban green infrastructure as a cross-cutting solution can better address sustainable land use planning challenges?

The paper is structured as follows. The first section reflects on the role of urban green infrastructure and its benefits for cities, taking into consideration the definitions proposed by e.g. the European Commission and the US Environmental Protection Agency. Based on this introduction to the topic, the second section looks at the relevant policies dealing with urban green infrastructure on the examples of London and New York City. The third section summarizes the proposed strategies as a mixed green-blue approach. The last section includes conclusions and recommendations for a future research.

URBAN GREEN INFRASTRUCTURE: DEFINITION

The definition of urban green infrastructure various in academic literature and related environmental policies, with the focus on ecosystem services and biodiversity enhancement. This way of understanding of urban green infrastructure is scientifically based on urban ecology studies (Benedict and McMahon, 2012, Ahern, 2007, Benedict and McMahon, 2002). For example, the Town and Country Planning Association (TCPA) in the United Kingdom defined green infrastructure as ‘the sub-regional network of protected sites, nature reserves, greenspaces, and greenway linkages’ (TCPA, 2004), emphasizing an importance of connectivity between natural areas ranging from urban centers to open countryside and its conservation for the support of wildlife corridors (including river corridors), and to ensure a broad spectrum of ecological services (e.g. biodiversity; flood protection; microclimate control) and human recreation and cultural experience. Therefore, it is important to consider green infrastructure in different scales (e.g. from a rain garden to a floodplain) to ensure its connectivity (and impact) across possibly large area (Cameron et al., 2012). A necessity of ‘high-quality’ of these spaces was highlighted later by the Natural England (2009), as a critical factor ensuring good human physical and mental health conditions (Croucher et al., 2007).

An importance of urban green infrastructure was emphasized in many documents on the regional, national and city level. From the European perspective, the relevance of urban green infrastructure for sustainability was highlighted by e.g. the European Commission (*The EU Green Infrastructure Strategy*) and the European Environment Agency. Green infrastructure was defined by the European Commission as ‘a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services’. Therefore, it comprises both green and blue areas, which can be of natural origin (e.g. forest; river) or semi-natural supported by engineered solutions (e.g. green roof). In contrast to the traditional ‘grey’ infrastructure (e.g. sewer system), which serves one single function, the green infrastructure is multifunctional, delivering social, economic and environmental benefits. According to green infrastructure multifunctional approach, the sustainability aspects are much more recognized and valued, significantly contributing to sustainable land use planning as a whole. The European Commission’s *Building a Green Infrastructure for Europe* (2013) stated that: ‘Investing into Green Infrastructure (GI) makes sound economic sense – a single area of land can offer multiple benefits, provided its ecosystems are in a healthy condition. Such healthy ecosystems, which are powered by the diversity of life within them, provide society with a stream of valuable, economically important goods and services such as clean water and air, carbon storage, pollination etc. They also play a central role in fighting climate change impacts by protecting us against floods and other environmental disasters'. As noticed by the European Environment Agency, the multifunctionality of green infrastructure enables it to be fully integrated in different policy domains. Hence, this approach can potentially serve a role of a cross-cutting solution for sustainable land use planning. To fully integrate this concept, it is necessary to implement the network at different special levels (ranging from the site, district and city-level to larger peri-urban and regional scale).

On the American ground, the definition of green infrastructure was extended, including not only semi-natural (e.g. green roofs; trees and tree boxes; rain gardens; vegetated swales; pocket wetlands; infiltration planters; vegetated median strips), but also some other engineered components with 'green' function (e.g. porous and permeable pavements) to better fit with strategies aiming to adapt built environment to unpredictable events as a result of climate change (Foster et al., 2011). This definition focused on built up spaces was proposed by e.g. the Environmental Protection Agency (EPA) in the United States, constituting efforts towards improving sustainable urban stormwater management processes. In this context, green infrastructure aimed to provide a hydrological balance for large areas of impervious surfaces within urban districts (EPA, 2008). This extended approach for green infrastructure - closely tight to built environment – significantly contributed to current understanding of green urban environment, previously limited to green open spaces (e.g. park). In contrast to the approach proposed by the European bodies, where green infrastructure connectivity supports species movement, the American concept ensures the network connectivity through stormwater flow. However, both perspectives put attention to sustainable dynamics of the whole urban ecosystem, which main goal is to mimic the natural processes, contributing to sustainable land use planning. This challenging task - demanding balance between built up and open space - is especially hard to achieve within very dense urban environment where land remains a highly competitive resource. Nevertheless, the multi-functionality of green infrastructure can simultaneously benefit an urban land according to sustainability agenda, linking together social, environmental and economic goals. Moreover, a cross-cutting function of green infrastructure enable it to fit well with different policies in terms of scale (e.g. region; city) and topic (e.g. health; environmental quality; climate change; green economy; biodiversity; food; active transport).

Since the focus of this study is on the urban scale, which seems to be the most challenging to ensure connectivity of the whole green infrastructure network (region-city-neighborhood-site), the next section will look at the examples of global cities with highly dense urban structure and ongoing population growth, namely London and New York City. The general aim is to investigate the current efforts taken by these large urban agglomerations in 'accommodating' sustainability dimensions in the land use planning process. The focus will be put solely on urban green infrastructure as a potential cross-cutting solution to different urban challenges, referring to social, environmental and economic aspects of sustainability (e.g. human health and wellbeing; climate change; air pollution) (Tzoulas et al., 2007).

CONCEPTUALIZING THE NEXUS BETWEEN URBAN GREEN INFRASTRUCTURE AND SUSTAINABLE LAND USE PLANNING: CASE STUDIES

To better examine the actual role of green infrastructure as a cross-cutting solution for different urban sustainability challenges, this section will look at some 'green' initiatives taken by two global metropolis: London and New York City. The aim is to analyze how green infrastructure can be 'fitted' within different urban policies ensuring systematic approach for sustainable land use on the urban level.

Case study: London

City scale

The Greater London Plan was published for the first time in 1944. The main goal of the land use planning policy in the 20th Century regarding green space was to protect major parks, green spaces, areas of natural conservation and the Green Belt surrounding the city. In the 21st Century, the focus shifted towards new challenges facing global cities worldwide, namely climate change and population growth (Massini and Smith, 2018). An importance of green infrastructure (GI) for a future development of London was highlighted several times in the current version of *the London* P*lan* (2016) (the strategic policy framework for London), including the strategic network of green infrastructure (Chapter 2: *London's Places*; pp.81-85), GI as a tool for climate change adaptation (Chapter 5: *London's Response to Climate Change*; pp.197-198; see also *the Climate Change Adaptation Strategy*) and protection guidance for open and natural environment (Chapter 7: *London's Living Spaces and Places*). Since the Greater London Authority is divided into 33 areas with local authority responsibilities, the boroughs are required to translate *London Plan* policy into their own *Local Plans* to provide the basis for local planning decisions (Massini and Smith, 2018).

The green infrastructure remains an integral part of *the London Environment Strategy* (2019). The elements of green infrastructure network range from parks, green spaces, gardens, woodlands, riversides to street trees, green roofs and sustainable drainage. The City aims to achieve more than 50 percent general green cover in 2050 and increase tree canopy cover by 10 percent. To better cope with these challenges, a Greener City Found provides financial support for planting trees, improving green spaces, creating wildflower meadows, establishing community orchards and food-growing areas. An importance of green infrastructure network was also highlighted in the draft *new London Plan* (increased protection of the Green Belt, Metropolitan Open Land, public open space and nature conservation sites) and *the All London Green Grid Supplementary Planning Guidance*. The new version of *the London Plan* will be published in 2020.

The green infrastructure in London's policy is contextualize very broadly, which may refer to its cross-cutting function. The access to green infrastructure data in the city context is GIS-based and available through online resources[2]. *The Green Infrastructure Focus Map* (2018) highlights, for example, an access to public open space, but it is also connected to other environmental characteristics related to green infrastructure distribution within city boundaries (e.g. air quality; surface water flood risk; urban heat island). An interactive web application helps decision makers understand where best to

[2] https://maps.london.gov.uk/green-infrastructure/ (7 June 2020)

make interventions and investments in green infrastructure. These actions aim to promote healthier living, lessen the impacts of climate change, mitigate flooding, improve air quality and water quality, cool the urban environment, encourage walking and cycling, store carbon, improve biodiversity and ecological resilience. The tool is focused on environmental health (water; climate; air quality; biodiversity) and social wellbeing (active transport; noise; health), ensuring green infrastructure is an essential part of the urban fabric. For example, a relevance of green infrastructure for the climate change adaptation policy is presented on Fig.1-2, where the hottest spots overlap with the most built up areas in the city, and the coolest represent the green space location. The research shows that increasing urban green space can help to cool high density areas of the city (Gill et al., 2007, Norton et al., 2015).

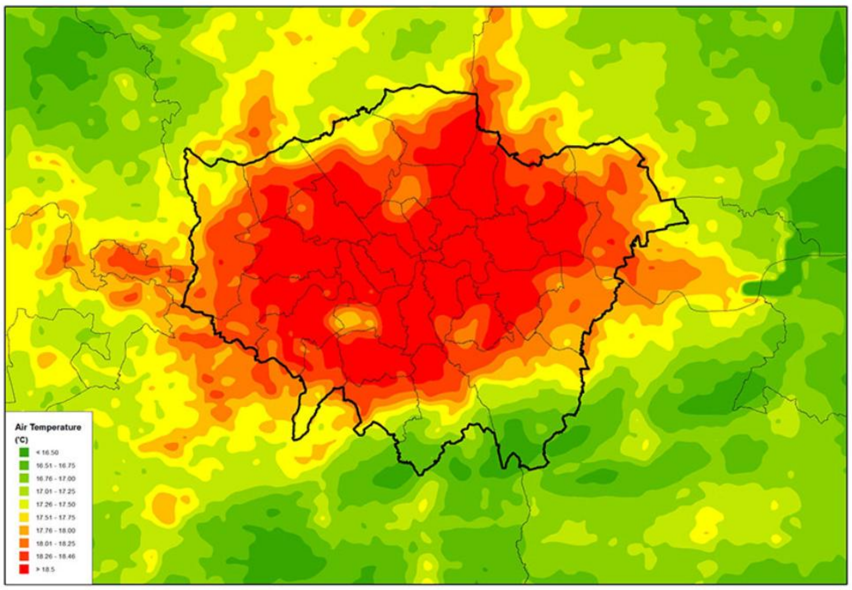


Figure 1. Urban Heat Island Effect in London[3].

Figure 2. London green infrastructure network. Source: Mell (2016).

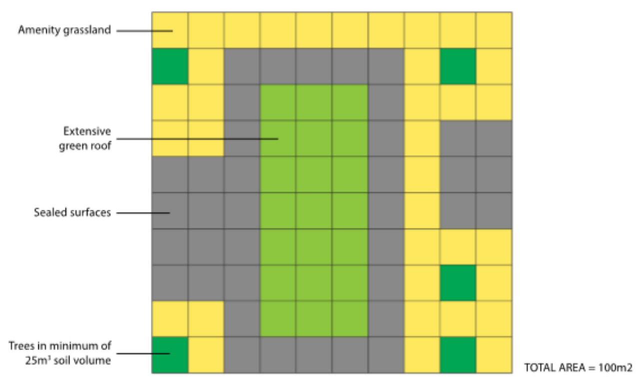
The next section will look at how city expands the existing green infrastructure network on the site-scale through developed Urban Greening Factor.

[3] https://informedinfrastructure.com/5503/satellite-images-reveal-londons-heat-island-effect/ (8 June 2020)

Site scale

The new planning tool – Urban Greening Factor (UGF) (2017) - ensures all new major developments include urban greening (e.g. green roofs and walls; trees; sustainable drainage systems). The aim of this tool is to help to achieve a substantial amount of green space in new development, going beyond the protection of existing green space which has already been well established. The new tool will be added to the new *London Plan* in 2020, referring to Green Space Factors implemented in a number of European and North American Cities (e.g. Berlin; Malmö; Seattle; Washington DC; Helsinki; Southampton). The process of extending green infrastructure network can help to relieve the pressure on existing network, ensuring equal opportunities for all citizens in terms of e.g. physical and mental health benefits. The aim of the proposed Urban Greening Factor is to improve environmental conditions of high-density zones with significant lack of accessible green spaces. The Urban Greening Factor is coordinated with other relevant policies (e.g. green infrastructure and biodiversity strategies; district plans; neighbourhood plans; landscape plans; masterplans; design codes). An example of how it works in practice is presented on Fig.3.

1. Measure site area, measure various surface cover types



2. Table showing areas of each cover type and factor assigned to each:

		Factor	Area (m²)
	Extensive green roof	0.7	21
	Sealed surfaces	0.0	38
	Amenity grassland	0.4	36
	Trees in minimum of 25m³ soil volume	0.8	5
			100

3. Calculation of the overall score for the site

$$\frac{(0.7 \times 21) + (0 \times 38) + (0.4 \times 36) + (0.8 \times 5)}{100}$$

Score = 0.33

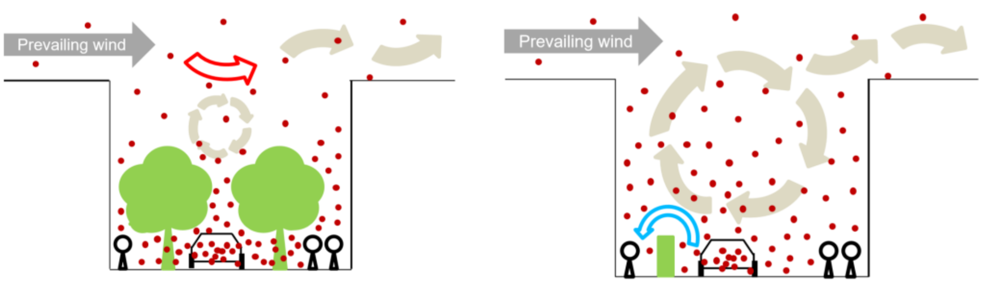
Figure 3. Diagram of simplified theoretical development site to demonstrate how the GSF works[4].

The other identified challenge where green infrastructure can possibly act as a cross-cutting solution on a site scale is air pollution. This is especially visible in urban street canyons which are a dominant urban form of dense core centers (Pugh et al., 2012). As

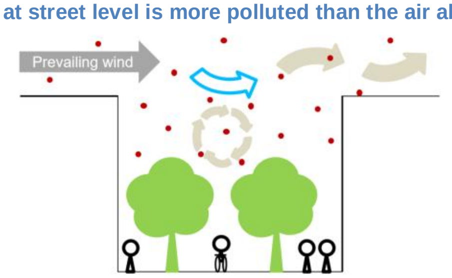
[4] https://greeninfrastructureconsultancy.com/green-infrastructure-factor/ (9 June 2020)

the main source of air pollution in London is the road transport, green infrastructure is included in the guidance for transport strategy (2019). The aim is to reduce citizens' exposure to air pollution produced by vehicles (e.g. exposure to lower levels of nitrogen dioxide and particulate matter and/or exposure for shorter periods of time) by controlling their dispersion at the source. The proposed interventions (based on green infrastructure approach) are aimed at two types of urban road: street canyon (a street with buildings on both sides) and an open road (a road with buildings only on one side or detached, single-storey buildings that are widely spaced and/or set back a long way from the road). In this specific context, green infrastructure within city's streets and nearby areas (e.g. street trees; hedges; parks; green spaces) can deliver significant reductions in exposure and, therefore, improvements in public health. Moreover, the use of green infrastructure encourages 'active travel' (e.g. walking; cycling) through created 'green corridors'. In this way, a connectivity of green infrastructure network supports also a green transportation flow, contributing to public health, reducing the use of vehicles. These goals are in line with *The Transport Strategy* which includes the target that 80 per cent of trips in London are made on foot, by cycle or using public transport by 2041. The examples of green infrastructure interventions are presented on Fig.4 (street canyons) and Fig.5 (open roads).

In street canyons (Fig.4), when air at street level is more polluted than the air above the buildings (a), a dense avenue of trees could trap the pollution emitted from vehicles at street level and prevent it from mixing with cleaner air above. Also, a vegetation barrier (i.e., a hedge) between the road and pedestrians may offer some protection. When air above the buildings is more polluted than the air at street level (b), a dense avenue of trees, forming an almost unbroken canopy, provides a barrier to downward dispersion, reducing the flow of polluted air down to street level where people are exposed to it.



a) Air at street level is more polluted than the air above the buildings

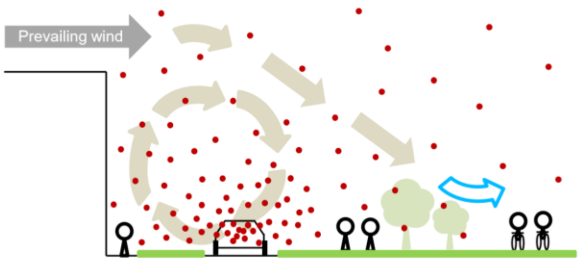


b) Air above the buildings is more polluted than the air at street level

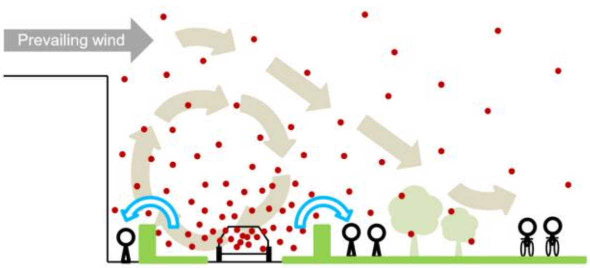
Figure 4. Street canyons[5].

[5] https://www.london.gov.uk/sites/default/files/green_infrastruture_air_pollution_may_19.pdf (10 June 2020)

An open space next to an open road (Fig.5), particularly green open space such as a park, plays a vital role in reducing public exposure to road transport pollution (a). Moreover, hedges can provide effective barriers between cars and pedestrians to protect people close to the side of open roads (b). Also, a dense line of trees, with a hedge or green wall beneath, can provide an effective barrier (c).



a) The value of open space, particularly green open space



b) Protecting people at the site of the road

c) Protecting people further from an open road

Figure 5. Open roads[6].

The next section will look at the example of New York City to examine how the green infrastructure approach is being implemented there and what the main relationships are with general sustainable land use planning on the urban level.

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6 https://www.london.gov.uk/sites/default/files/green_infrastruture_air_pollution_may_19.pdf (10 June 2020)

Case study: New York City

City scale

The urban green infrastructure concept in New York City reflects the definition proposed by the Environmental Protection Agency (EPA) in the United States, emphasizing strong focus on stormwater management processes. According to this approach, the main goal of green infrastructure network is to collect and manage the rain water on site, which helps to avoid combined sewer overflows (CSO) into New York Harbor and improves condition of local waterbodies, at the same time contributing to human health and wellbeing. In the proposed vision, urban green infrastructure ensures different sustainability priorities – ranging from environmental (e.g. increased urban greening; improved water quality; resilience to global warming; urban heat island reduction; more habitat for birds and pollinators around the City) to social (e.g. recreational spaces) and economic factors (e.g. less investments in traditional 'grey' infrastructure; reduced urban flooding). By retrofitting existing transport infrastructure (e.g. streets; sidewalks) and other public/private properties, the Department of Environmental Protection (2018) aims to achieve the goal of reducing combined sewer overflow by 1.67 billion gallons a year. Therefore, the green space management becomes an integral part of sustainable stormwater management practices. Hence, the interconnectivity and multifunctionality of urban green infrastructure helps to ensure wider benefits to the society. The map displaying city-wide distribution of green infrastructure elements (constructed; in construction; final design) is presented on Fig.6.

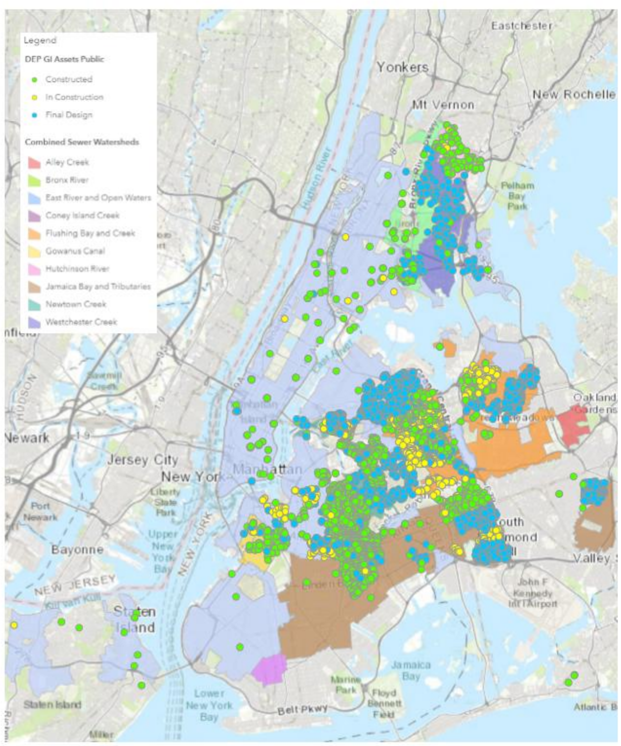

Figure 6. Green infrastructure program map for New York City[7].

[7] https://www1.nyc.gov/assets/dep/downloads/pdf/water/stormwater/green-infrastructure/gi-annual-report-2018.pdf (12 June 2020)

The Green Infrastructure Program (coordinated by the Department of Environmental Protection) aims to incorporate the number of green infrastructure micro-scale elements (e.g. rain gardens; stormwater greenstreets; green roofs; blue roofs; permeable paving; subsurface detention systems; rain barrels and cisterns) across the city locations where they are mostly needed[8]. These small-size investments fit well within dense urban structure, and the large-scale implementation contributes to sustainable land use planning within city boundaries. Although nature-based, not all of the elements comprise a vegetative element as they are primarily engineered solutions (e.g. blue roofs; permeable paving; subsurface detention systems; rain barrels and cisterns). However, the engineered blue spaces are fully integrated with the natural blue spaces. These were highlighted by the European Commission as a vital part of a whole green infrastructure network. Moreover, the stormwater issue is strongly tight to the economic aspect of sustainability, which still remains underestimated and not well recognized. The connection between greenspace and stormwater management helps to visualize the financial benefits of urban green infrastructure more clearly. The urban green infrastructure is also managed by the New York City Department of Parks & Recreations, which reflects interdependency and multifunctionality in terms of planning a green-blue network.

The City provides financial support (e.g. Green infrastructure Grant Program) to enhance private property initiatives. The aim is to straighten public-private partnerships and public engagement in regards to the design, construction and maintenance of green infrastructure on private property throughout New York City (DEP, 2018). The funds are an important part of achieving reductions in stormwater runoff, but public engagement also contributes to wider promotion of green infrastructure among citizens and better results in terms of implementation across the city. Hence, the social dimension of green initiatives becomes an integral part of comprehensive and sustainable green infrastructure policy.

Site scale

In analogy to the Urban Greening Factor (UGF) proposed for London and presented in the previous section, the Department of Environmental Protection (DEP) in New York City uses another type of sustainability metrics for land cover, namely the Greened Acre (GA) (2018). In contrast to London's Urban Greening Factor, which identifies the ratio between the built up and green space cover, as well as a type of green infrastructure used, the Greened Acre aims to calculate a volume of runoff managed by a green infrastructure practice.

The green infrastructure elements considered in the New York's strategy include e.g.: ROW rain garden (multiple types), ROW porous pavement, ROW infiltration basin, rain garden, porous pavement, subsurface retention/detention, turf field with retention, tree trench, green roof and cloudburst rain garden.

The Fig.7 explains how the Green Acre is being calculated. For example, a right-of-way (ROW) rain garden on a sidewalk might hold 250 cubic feet (CF) of runoff. If that volume is spread over an area at 1" deep, its greened acres would be 3,000 square feet (SF), or 0.07 Greened Acres (GA). Therefore, the metrics used by DEP explains, how the water

[8] http://www.arcgis.com/home/webmap/viewer.html?webmap=a3763a30d4ae459199dd01d4521d9939&extent=-74.3899,40.497,-73.3757,40.9523 (5 June 2020)

holding capacity of each green infrastructure practice is related to the equivalent impervious area that would be managed if that volume was spread over an area at 1” depth.

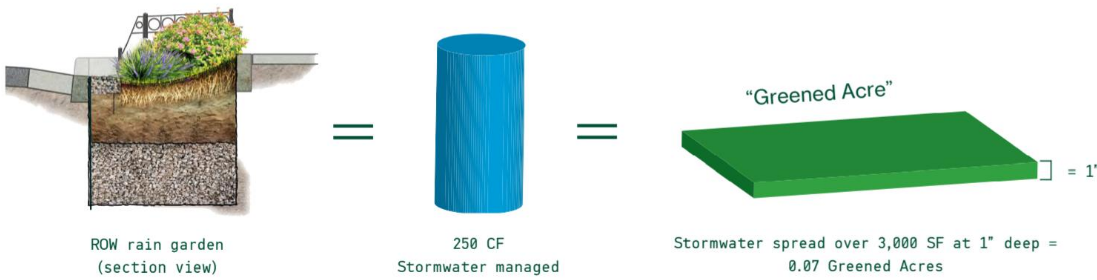

Figure 7. Calculation of the Green Acre[9].

Hence, in contrast to the Urban Greening Factor, which is specifically linked with a wider city’s green infrastructure network, the Green Acre is primarily related to the watershed distribution across the city’s boroughs (Fig. 8).

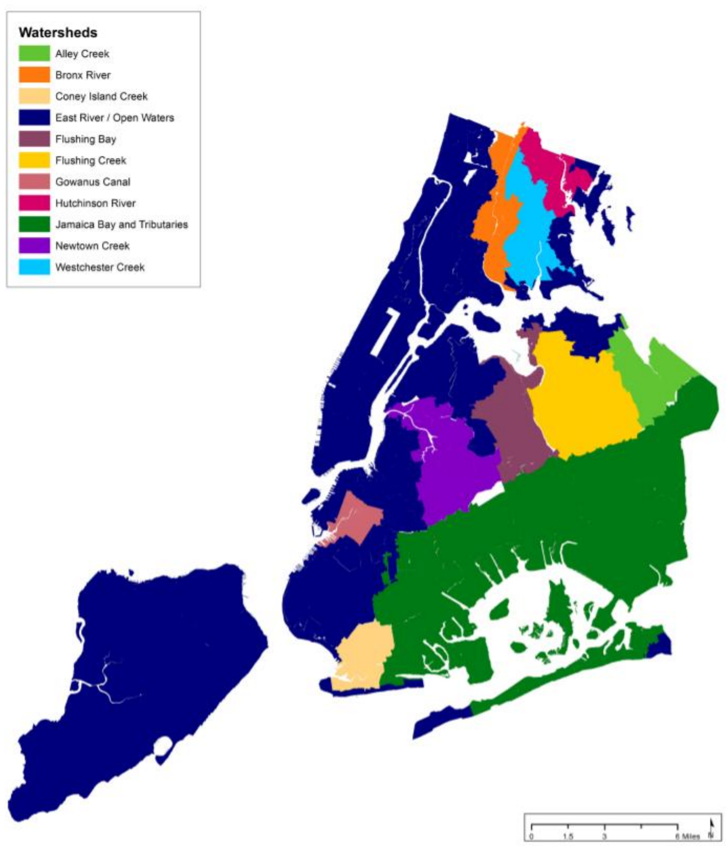

Figure 8. Watershed map for New York City[10].

[9] https://www1.nyc.gov/assets/dep/downloads/pdf/water/stormwater/green-infrastructure/gi-annual-report-2018.pdf (12 June 2020)

Apart from stormwater management, there is also a close connection between green infrastructure and transport infrastructure. For example, a public right-of-way infrastructure (e.g. sidewalks; parking lanes; medians; roadways) consists of approximately 30 percent of the impervious cover in the City and generates stormwater runoff during rain events. This sort of 'grey' infrastructure after retrofitting to 'green' can significantly decrease stromwater runoff, contributing to general environmental performance of the transportation network and increase active transport (e.g. walking; cycling). In contrast to London's example, where green infrastructure aims to reduce public exposure to air pollution (presented in the previous section), in New York City the focus is put solely on improving condition of local waterbodies. However, both strategies aim to improve general health conditions of local citizens and the surrounding environment, which emphasizes multifunctional benefits of green infrastructure and its possible contribution as a 'cross-cutting solution' to sustainable land use planning. Therefore, the next section will look at the introduced green infrastructure strategies as a mixed green-blue approach.

GREEN (BLUE?) APPROACH FOR SUSTAINABLE LAND USE PLANNING

The presented case studies' strategies can be roughly summarized as green (London) and blue (New York City). However, in the light of contemporary challenges, it may be more relevant to consider a mixed green-blue strategy which can potentially better address 'cross-cutting' challenges of sustainable land use. The Table 1 below exemplifies how urban green infrastructure comprising mix of natural, semi-natural and other elements can cut across various interrelated city challenges reflecting social, environmental and economic aspects of sustainability. The goal of this mini-study is to look at the proposed strategies as a mixed green – blue strategy which can potentially better address the future resilience of cities. However, the Table 1 doesn't refer to the traditional triply sustainability approach (environment; society; economy) due to the fact, that many of the sustainability challenges have multiply benefits for sustainability. For example, enhanced sustainable stormwater management has the environmental values (e.g. improved quality of local waterbodies), as well as the social (e.g. recreational spaces along riversides) and the economic (e.g. less cost of investment in traditional 'grey' infrastructure'). The aim is to directly refer to the specific urban policies which can be informed by 'cross-cutting' characteristics of green infrastructure based on the proposed green – blue approach.

[10] https://www1.nyc.gov/assets/dep/downloads/pdf/water/stormwater/green-infrastructure/gi-annual-report-2018.pdf (12 June 2020)

		Provision of recreational space	Reduction of stormwater runoff	Reduction of exposure to air pollution	Mitigation of urban heat island effect	Provision of space for urban farming	Enhancing sustainable transport
City/ district scale	**Natural GI (e.g. park; riverside)**						
Site scale	**Semi-natural GI (e.g. green roof)**						
Site scale	**Other GI (e.g. porous pavement)**						

Table 1. The relevance of green infrastructure for various urban policies (Source: own).

The Table 1 is a summary of the strategies towards green infrastructure. It presents how the relevant green infrastructure components in terms of its origin and scale can enhance specific urban policies linking environmental, economic and social aspects.

Due to predicted cities' expansion (e.g. increased population growth and urban density; housing demand) accompanied by climate change (e.g. heavy rainfalls, higher temperature) and environmental degradation (e.g. higher exposure to air pollution), the capacity of urban areas supported by traditional 'grey' solutions (e.g. conventional sewer systems) may be not enough to sustain city's resilience in terms of future prosperity and growth. Nevertheless, there are many challenges for continuing the green infrastructure network in the urban scale to help cities in the adaptation and mitigation efforts. As green infrastructure network is primarily based on the large-size natural areas (e.g. parks; waterbodies) which are directly connected to the other natural areas in the regional scale, this forms should gain priority protection. This is a core structure for the whole city network (intense green/blue) which performs its various sustainability roles (e.g. biodiversity); the most intensely, so it is the most valued in the green – blue strategy. However, the capacity of the core natural network may be not enough for dense urban fabric of contemporary cities. Therefore, the small-scale semi-natural elements (e.g. green roofs; rain gardens) and other green infrastructure (e.g. porous pavement) can help to intensify green infrastructure benefits, as they can be directly tight to the built environment on different levels (e.g. rooftop; side street) (Ellis, 2013). Although the role of these elements has more narrow impact on general cities' environmental performance than the previous larger-scale units, these site-scale elements (light green/blue) are in fact critical in terms of continuing the network within urban agglomeration. Besides, these elements ensures water connectivity in urban space through its stormwater management function, which significantly helps to straighten the mutifunctional role of green infrastructure and mimic the natural water cycle.

CONCLUSIONS

Referring to the presented case studies, it can be generally concluded that green infrastructure can act as a cross-cutting solution to various sustainability challenges in terms of land use planning. Giving the fact that most of the global highly urbanized areas face similar problems, it is worth to learn from pioneering studies in the field as these may be relevant for other cities worldwide as well. Green infrastructure can be a very flexible tool in dense built environment in terms of e.g. variety of implementation scales (e.g. city; district; site), connectivity and flexibility of interrelated elements (e.g. natural elements; semi-natural elements; other elements) and complementarities with many interlinked urban challenges (e.g. climate change; stormwater management; urban heat island effect; recreational opportunities for the urban society). Therefore, it can support existing planning decision tools and it can be tailored to local needs as well (e.g. protecting and expanding existing green infrastructure network; improving water quality in local waterbodies) (Mell, 2008).

It can be observed that presented green infrastructure case studies reflect the green infrastructure definitions proposed by the relevant bodies on a high political level (e.g. the European Commission; the US Environmental Protection Agency). Moreover, both approaches are interlinked with:

- the general green infrastructure strategies, e.g. to expand an existing green infrastructure network based on natural and semi-natural elements (London) or to increase stormwater capacity through new green infrastructure investments based on semi-natural and other green infrastructure elements (New York City);
- new developments (London) or retrofitting existing urban space in combined sewer areas (New York City);
- both public and private space;
- other city-related policies (e.g. transport infrastructure; air quality; climate change).

Now, when cities need to face an extra challenge related to ensuring social distancing in public space, it is the right time to consider a ratio between open and built up spaces across the city to support social needs of using green space in a safe manner. As it has already been pointed out, a ‘good’ density approach should be rationally planned to ensure a well-balanced urban structure, which has an economic sense for the real estate and planning (Pain, 2018), but also for the local citizens in terms of improved physical and mental health conditions. Hence, green infrastructure as a cross-cutting solution – when properly addressed - can be an effective tool to ensure sustainable land use planning and help to achieve a more holistic approach for the city’s resilience in the next decades (Elmqvist et al., 2013).

A future research may concentrate on new economic linkages between green infrastructure and city development. As environmental and social aspects of investments in green infrastructure seem to be well researched, there is still a lack of sufficient knowledge on financial benefits resulting from green urban environment (Jones and Somper, 2014, Mell et al., 2013). Although sustainable stormwater management practice (based on the natural systems) successfully contributed to the discussion on economic benefits of green infrastructure, a more business-oriented case would encourage its wider implementation to sustain cities’ economic resilience in a future.

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