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Rethinking "future nature" through a transatlantic research collaboration: Climate-adapted urban green infrastructure for human wellbeing and biodiversity.

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Abstract:

With climate change arguably the greatest threat facing our planet, we are witnessing unprecedented losses of biodiversity and growing human health challenges. The need to prioritise urban green infrastructure (UGI) has never been so great. As two researchers from the UK and Brazil, we draw on recent research evidence and contrasting examples from the UK, Brazil and Italy, demonstrating how enlightened approaches to UGI planning, design and delivery can mitigate and adapt to climate change, support human health and wellbeing and enhance biodiversity. We highlight the need to make decisions across scales and the value of partnership working across sectors. We emphasise the need to identify synergies and trade-offs between climate-resilience, biodiversity and human wellbeing objectives. Synergies generate positive opportunities to provide multiple benefits, whereas trade-offs require prioritisation. These case studies provide transferable precedent learning for planners, designers and managers of multifunctional "future nature" in urban areas throughout the world.

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1. Introduction

By 2050 almost 70% of the global population will live in urban areas (United Nations, 2018). With near universal awareness of the acute and urgent need to address the Climate Crisis (Grundmann, 2016), and growing mental and physical health challenges (Vigo, Thornicroft & Atun, 2016), particularly in urban areas (Dye, 2008), the need to prioritise urban green infrastructure has never been so great. Networks of multifunctional parks, green and blue spaces and features such as green roofs and walls, urban green infrastructure (UGI) can provide Nature-Based Solutions (NBS) to mitigate and adapt to climate change (Demuzere, Orru, Heidrich et al. 2014), whilst at the same time improving aesthetics (Hoyle, Hitchmough & Jorgensen, 2017a); and recreational opportunities (Fischer, Honold, Botzat et al. 2018a) supportive of human health and well-being (Hartig, Mitchell, de Vries & Frumkin, 2014). Biodiversity conservation and enhancement are realistic co-benefits (Hoyle, Norton, Dunnett et al. 2018; Norton, Bending, Clark et al. 2019). In some places, enlightened approaches to UGI planning, design and delivery have achieved a win-win-win for climate change, human happiness and biodiversity (Southon, Jorgensen, Dunnett et al. 2016; Schwarz, Moretti, Bugalho et al. 2017) yet in others, the delivery of UGI has resulted in 'green' with scant consideration for prioritising characteristics which produce clear and measurable benefits in terms of climate adaptation, human well-being and plant and animal diversity. One example is the high proportion of urban greenspace in cities throughout the world designed and maintained as short mown amenity grassland (25% in the UK (Evans, Newson & Gaston, 2009); 23% in the USA (Robbins & Birkenholtz, 2003; Norton et al. 2019). Managed for recreational use, this requires frequent mowing (Hoyle, Jorgensen, Warren et al. 2017), high inputs of fertiliser (Alumai, Salminen, Richmond et al. 2009), an increasing need for irrigation under climate change (Bijoor, Pataki, Haver & Famiglietti, 2014) and supports reduced plant and invertebrate diversity in comparison to more structurally complex meadows and grasslands (Norton et al. 2019).

Here we draw on recent research evidence and present contrasting examples from the UK, Brazil and Italy to demonstrate the opportunities and challenges (Hoyle et al. 2017) associated with planning, designing and delivering specific UGI interventions to prioritise climate change, human happiness and biodiversity. We provide positive examples of sustainable urban drainage and climate-adapted planting offering aesthetic benefits and invertebrate value (UK); innovative urban parklands prioritising both people and biodiversity (Milan, Italy) and the challenges of UGI retrofitting in a modern, planned UNESCO World Heritage Site (Brasilia, Brazil). Together with recent research findings, these practical case studies provide valuable and transferable precedent learning for planners, designers and managers of multifunctional "future nature" in urban areas throughout the world.

2. A climate in crisis

Climate change is arguably the most severe challenge facing our planet, with taking 'action to combat climate change and its impacts' prioritised as Goal 13 of the United Nations (2015) 2030 Agenda for Sustainable Development. Specific effects of climate change on urban populations include high temperatures, particularly because urban areas already experience a 'heat island effect'; higher temperatures than surrounding rural areas due to anthropogenically generated heat, built surfaces with low reflectivity, a lack of cooling vegetation and enhanced pollution (Emmanuel & Loconsole, 2015). Flooding and drought (Demuzere et al. 2014) are additional hazards, with susceptibility depending on broad climatic conditions and specific locational context determining weather conditions and the percentage of impermeable surfaces which promote flooding. This is being exacerbated by the continuing loss of 'natural' surfaces as urban residents pave over gardens and driveways. Termed 'urban creep' a study by the UK Water Industry, (2010) revealed this loss of 'natural' surfaces was occurring at the rate of 0.4 sq m – 1.1 sq m/house/year, with the impact on flooding estimated to be equal to the effects of climate change itself. Climate change also highlights environmental injustice, as its effects are experienced most severely by vulnerable elderly or very young urban residents living in socially disadvantaged areas with low household incomes. Here the provision of green spaces may be lacking and existing health challenges (such as obesity and mental illness) exacerbate the effects (Bi, Williams, Loughnan et al. 2011; Norton, Coutts, Livesley et al. 2015).

The Intergovernmental Panel on Climate Change (IPCC, 2019) calls for appropriately designed policies, institutions and governance systems to enable both climate change mitigation and adaptation measures to be realised. Mitigation refers to reducing the impact of climate change, whereas adaptation involves developing coping mechanisms, adjusting to present or expected future climates. The introduction of appropriate 'fit-for place' (Norton et al. 2015) UGI provides the possibility of both mitigating and adapting to the challenges of climate change. To mitigate high temperatures in urban landscapes, Norton et al. (2015) present a 5-stage framework to prioritise appropriate green infrastructure interventions. They propose working at three main scales; firstly the neighbourhood, then street scale incorporating the 'canyon' or space between the street and flanking buildings and finally at the microscale, considering prioritisation of the most appropriate UGI features for specific locations within the street. Potential UGI features include street trees, green open spaces (providing 'islands' of cool in hot areas), green roofs and vertical greening. Street trees and urban woodlands have the greatest potential as agents of cooling, providing the multiple benefits of surface shading, human shading, enhanced solar reflectivity and evapo-transpirative cooling.

Street trees and urban woodlands provide additional climate-change mitigation via enhanced carbon sequestration, interception and infiltration, thereby reducing and slowing surface water runoff and flooding. Selecting and specifying urban street trees has always been a balancing act. Environmental factors (climatic and local habitat) are weighed along with social and cultural considerations (aesthetics, functions and disservices such as leaf litter) and the economics of planting and maintaining trees (Miller, 1997). A 5-step model can be used to inform the choice of species (after Hitchmough, 2019) (Fig. 1).

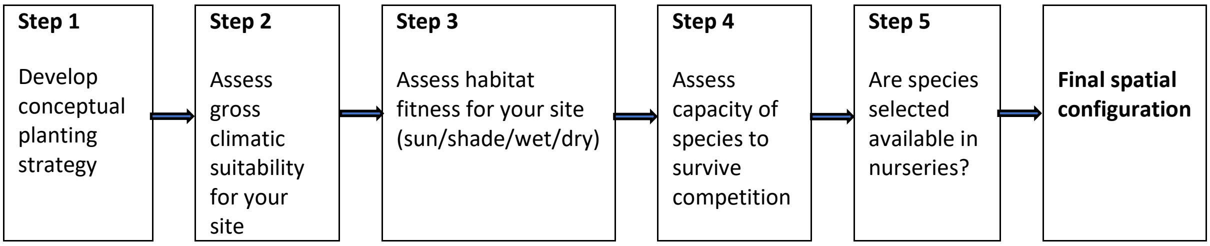

Figure 1. Five-step model of species selection in urban areas (also applies in urban edge and rural situations) after Hitchmough (2019).

Nevertheless, urban woodlands and street trees are themselves vulnerable to climate-change: the stressors of extreme heat; droughts; extreme winds and pests (McPherson, Berry & van Doorn, 2018). Building resilience into urban trees necessitates selecting and specifying climate-adapted species ready for future climates. This often involves sourcing seed stock in parts of the world currently experiencing the temperatures and annual rainfall predicted in the future by climatic modelling. Research (Watkins and Hitchmough, 2019) has generated techniques to sample species ranges and analyse their fit with current and future climate scenarios. Modelling the suitability of two oak species (*Quercus robur* and *Quercus cerris*) using current (2019) climatic (temperature and precipitation) conditions in the UK and those for 2050 suggests that whereas *Quercus robur* is best suited to the 2019 climate, by 2050, *Quercus cerris*, currently dominating Greece and other parts of SE Europe, is likely to be better adapted to the warmer, drier conditions predicted. In North America researchers are taking a similar approach, using a 5-step approach to prioritising a diverse mix of 'climate-ready' tree species (McPherson, et al. 2018): (i) Climate evaluation and modelling along with; (ii) identification of likely 'promising' species by experts; (iii) scoring the long list of potential species on the basis of habitat suitability: physiological tolerance, biological interactions, uncertainty and availability (paralleling the 5-step model suggested by Hitchmough, Fig. 1) to select 'finalists'. These finalists are then planted and monitored prior to evaluation (iv). The results of monitoring and evaluation are then disseminated widely to stakeholders via reports, publications and digital channels (v), facilitating ongoing best practice in future-proofing urban forests, which could be viewed as a further sixth stage (Fig. 2).

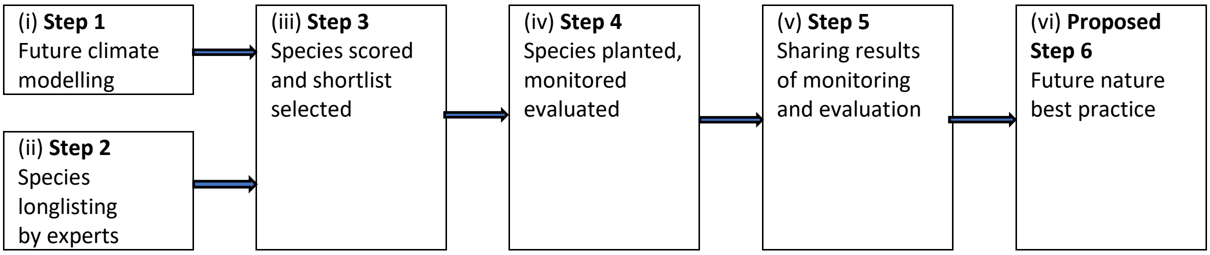

Figure 2. Selecting climate-ready tree species for future best practice (adapted from McPherson et al., 2018).

Considering cultural responses to the introduction of so-called 'non-native' planting, recent UK research (Hoyle, Hitchmough & Jorgensen, 2017b) indicated that over 75% of participants (n=1411) were positive about introducing 'climate-adapted' non-native species in public parks and gardens if they were better-adapted to future climate than the species currently used. (Fig. 3). The main driver of public acceptance was the need to adapt to changing climate, reducing the need for irrigation of public planting. Participants also gauged non-natives significantly more attractive and interesting than native planting.


Figure 3. Over 75% research participants (n = 1411) were positive about introducing non-native planting such as *Eucaluptus* woodland and Mediterranean herbaceous planting in UK parks and gardens if it was better adapted to changing climate than species currently used (Hoyle et al., 2017b).

3. Human happiness and well-being: What do we need?

The third goal of the United Nations' 2030 Agenda for Sustainable Development is to 'ensure healthy lives and promote wellbeing for all at all ages' (United Nations, 2015). Urban populations worldwide gain myriad health and wellbeing benefits from spending time in natural environments. Recent UK research estimates the human well-being value associated with frequent use of local parks and green spaces to be worth £34.2bn/yr, with the NHS saving £111m/yr based solely on reduction in GP visits (Fields in Trust, 2018). Parks and green spaces support physical activity and related cardio-vascular benefits (White, Elliot, Taylor et al. 2016), yet there has also been an exponential growth in evidence for the life-enhancing impact of nature contact on human mental health and well-being (Frumkin, Bratman, Breslow et al. 2017). This is particularly significant because research has shown an association between living in a high-density urban environment remote from nature (Cox, Hudson, Shanahan et al. 2017) and depression (Bratman, Hamilton, Hahn et al. 2015). The proportion of global burden of disease attributable to mental illness has been shown to be comparable to that of cardiovascular and circulatory diseases (Vigo, Thornicroft & Atun, 2016) (32% of total years lived with disability (YLD) and 13% disability-adjusted life years (DALYs)). In 2015 mental ill-health cost the UK economy an estimated £94bn (Organisation for Economic Co-operation and Development, 2018), whereas in Australia costs reached $60bn ($4,000 per person) in 2016 (Parliament of Australia, 2019). Existing research has identified two psychological pathways between natural environments and positive mental wellbeing. Attention Restoration Theory (ART) (Kaplan and Kaplan, 1989), focuses on the potential for nature to relieve mental fatigue induced by living and working high intensity urban environment, and Stress Recovery Theory (SRT) (Ulrich, 1986), which highlights the potential for natural environments to reduce physiological stress.

“We need more beauty, not more green!” Piet Oudolf, designer of the High Line in New York, declared (2012). Early evidence linking ‘green’ natural environments and human wellbeing tended to treat all natural environments as homogenous, contrasting these with built hardscapes (Clark, Lovell, Wheeler et al. 2014), yet recent research in the field has been much more nuanced in approach, showing that different types of natural environment (Wheeler, Lovell, Higgins, et al. 2015) with varying aesthetics may have differential impacts on human mental wellbeing for different groups or individuals (Hoyle et al. 2017a). This UK study showed that planting with a flower cover of 27% and above was considered significantly more attractive than that with a lower percentage flower cover. Whereas bright flowering planting was stimulating and exciting, green planting induced feelings of calm and relaxation. Reactions to natural environments have also been related to socio-cultural characteristics, such as gender (Hoyle at al. 2017a), nature-connectedness (Hoyle, Jorgensen and Hitchmough, 2019) and having a migration background (Fischer, Honold, Cvejićd, et al. 2018b). This recent European research also provided convincing evidence for a positive relationship between mental wellbeing and exposure to increased biodiversity.

Contrasting research (Rooke, Lowry & Raison, 2013) has suggested that the risk of psychiatric conditions related to brain development, cognition and mood may be heightened in an urban area compared to rural area as a result of reduced exposure to immunoregulation-inducing macro-and microorganisms and microbiota, that might in turn affect the human biome, and that biodiverse green spaces and other green infrastructure features may have considerable potential for prevention, providing ‘a prescription for global urban health’ (Flies, Skelly, Negi et al. 2017).

4. Our duty to biodiversity

Biodiversity refers to both the abundance and variety of living plant and animal species on the planet. Globally, biodiversity is prioritised in Sustainable Development Goals 14 (maritime biodiversity) and 15 (terrestrial biodiversity) (United Nations, 2015). At the European level, policy strives to 'halt the loss of biodiversity and ecosystem services in the EU, and help stop global biodiversity loss by 2020' (European Union, 2010), yet the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019) reported ongoing global deterioration in nature and its contributions to people. Human actions themselves were seen to be threatening more species with extinction than ever before with an acceleration in decline over the last 50 years. At the national level, in the UK, all public authorities have a duty to conserve biodiversity and consider it in all aspects of decision making (Natural Environment and Rural Communities Act, 2006). The importance of conserving biodiversity was reinforced by the government's 25-year plan (2018), and revisions to the National Planning Policy Framework (2019) which emphasise the need to deliver Biodiversity Net Gain through 'creating and enhancing habitats' associated with development. The impact of this policy may be most effective in urban areas, where development is concentrated. Here opportunities to enhance biodiversity exist through the introduction of urban meadows (Norton et al. 2019) and sustainable urban drainage systems (Demuzere et al. 2014) whereas the loss of biodiversity resulting from arable monocultures outside cities has been extreme (Burns, Eaton, Barlow et al. 2016). The second theme of Italy's biodiversity strategy explicitly recognises the significance of 'Biodiversity and Climate Change', with the other themes addressing ecosystem services and economic policies (Italian National Biodiversity Strategy, 2010). In Brazil, significant biodiversity loss has occurred in the Cerrado (savanna) ecoregion due to the introduction of intensive agro-pastoral systems (Brannstrom, Jepson, Filippi et al. 2008). Originally covering 1.8 million km^2 south and east of the Amazon rainforest, an increasing percentage of this land in now under pressure from agricultural expansion.

Climate change has been identified as a 'direct driver' of global biodiversity loss, intensifying the effects of other drivers (IPBES, 2019). Indeed, climate change has already resulted in entire biomes shifting polewards and to higher elevations with rising temperatures (Scheffers, De Meester, Bridge et al. 2016). An emphasis on conservation and ecological restoration using indigenous native species as specified in policy guidance such as the EU Biodiversity Strategy to 2020 may be ineffective. As explained, plant species typically used in UGI design at one latitude (such as *Quercus robur* in the UK) are increasingly less fit for purpose, and there is a need to look to other climatic zones such as Greece and other parts of SE Europe to source species such as *Quercus cerris*, to design a resilient future nature (Hoyle et al. 2017b). The UK National Planning Policy Framework (2019) revision acknowledges the need to provide opportunities for species to migrate to more suitable habitats via networks of multifunctional UGI.

5. Urban green infrastructure in practice

Over the last ten years, the exponential growth in research evidence for the human wellbeing benefits of nature contact has had a significant impact on built environment and public health professionals (e.g. Greater London Authority, 2015). Policy makers and practitioners are now acutely aware of the considerable scope for UGI interventions to deliver enhanced mental wellbeing concurrently with climate resilience and biodiversity conservation. During this period, significant UGI interventions have been implemented in diverse contexts around the world, ranging from high profile city centre locations (e.g. Bosco Verticale and Biblioteca degli Alberi, Milan) to greenspaces in residential areas of smaller towns and cities (such as Bedford and Luton in the UK) where land managers have modified management practices. Interventions are at contrasting scales, ranging from the 250-hectare Queen Elizabeth Olympic Park, originally developed for the London 2012 Olympics, to smaller developments such as the 'Grey to Green' project in Sheffield, which is transforming a 1.2 km section of redundant 'grey' impermeable carriageway in the city centre into an effective, aesthetically pleasing sustainable drainage system supportive of biodiversity. Some of the most successful schemes have involved the retrofitting of existing urban areas (such as the 'Grey to Green') and have used brownfield sites (such as E London, prior to the development of the London 2012 Olympic Park). The most successful schemes are effective because they prioritise synergies between multiple benefits, and deliver multifunctionality, arguably easier at scale, where zoning can deliver some areas for recreation, others as biodiversity hot spots and others where aesthetics and display are prioritised. In the City of Lyon, France, the Green Space Division manages sites across the city as: 'Nature spaces', prioritising biodiversity and restricting public access; 'Living spaces', prioritising public use and recreation and 'Flowered spaces', where managers strive to generate 'the wow factor' (Hoyle et al. 2017a) through vibrant colourful planting.

a. Greening grey Britain: The Queen Elizabeth Olympic Park on a former brownfield site

London's 2012 Olympic Park, now the Queen Elizabeth Olympic Park, was developed on a 250-hectare site in East London comprising former industrial/commercial brownfield land largely contaminated by industrial waste, and the Lea Valley Park. Five strategic watercourses crossed the site, necessitating consideration of flood mitigation and facilitating the introduction of a considerable sustainable urban drainage system (SuDS) (Susdrain, 2019). The development housed significant Olympic venues, most of which have been retained for legacy use by London residents and visiting users. Current facilities include the prominent (Olympic) Stadium, London Aquatics

Centre, Lee Valley Velo Park (Olympic Velodrome), Copper Box Arena and Lee Valley Hockey and Tennis Centre. Prior to the London 2012 Olympics, the priority was to deliver a spectacular visual 'wow factor' (Hoyle et al. 2017a) to delight the public at the time of the Opening Ceremony on 27th July 2012. The vision for the Park was one of two zones. The culturally-informed South Park (Fig. 4 (b)) enveloped the Stadium. Here there was more hard surfacing, and open spaces to allow people to gather. Planting included the spectacular 1km long Olympic Gardens and 10 ha vibrant annual wildflower meadows. This vibrancy of colour was achieved through the inclusion of non-native plant species such as the *Coreopsis tinctoria* (Plains coreopsis), which extended flowering beyond that of native species, providing a celebratory golden colour into September when the Paralympic Games took place (Fig 4 (b)). Subsequent research (Salisbury, Armitage, Bostock et al. 2015; Hoyle et al. 2018) has also revealed the value of such late flowering non-native plant species to native invertebrates; these plants continue to provide nectar and pollen after indigenous UK species have finished flowering. The North Park (Fig. 4 (a)) was more naturalistically-informed and ecologically-oriented, with 8 ha native wildflower meadows, extensive SuDS component and a woodland understorey. Two different meadow mixes were designed in response to varying habitat; one for dry sunny sites (including species such as *Echium vulgare* (Viper's bugloss)) and the other for shady, damp conditions (including species such as *Malva moschata* (Musk mallow)). Some common species such as *Linaria vulgaris* (Common toadflax) were included in both mixes. SuDS were incorporated throughout the Park, with porous asphalt strips used through the extensive pedestrian concourse in the South Park. In the North Park an extensive wetlands area was incorporated including swales, filter strips/drains and small volume balancing ponds and rainwater harvesting was installed at two permanent venues: the Velodrome (now Lee Valley Velo Park) and Copper Box Arena. As well as providing sports venues through to legacy, the Park now provides extensive landscaped green spaces supportive of recreation, quiet reflection and human wellbeing. There are natural play spaces and water features attracting children, especially in summer. This is combined with ongoing biodiversity enhancement and the management of extreme flood events taking account the impacts of climate change.

The development of the Olympic Park and its transformation through legacy to the Queen Elizabeth Olympic Park provide an example of challenging yet successful partnership working involving multiple stakeholders across sectors (Susdrain, 2019). These included the London Organising Committee for the Olympic Games (LOCOG), the Olympic Delivery Authority (ODA), the Olympic Park Legacy Company, designers LDA Hargreaves with planting design expertise, academics from the University of Sheffield, the Environment Agency, British Waterways, Thames Water, London Boroughs and many contractors.

(a) The North Park (b) The South Park

Figure 4. The London 2012 Olympic Park in summer 2012. Native perennial meadows were sown in the North Park (a), whereas more vibrant annuals were used around the Olympic Stadium (b). These included the late-flowering *Coreopsis tinctoria* (Plains coreopsis) which continued to flower into the paralympic games.

b. Greening grey Britain: Introducing urban meadows in Bedfordshire

The University of Sheffield subsequently collaborated with local authority land managers in Bedfordshire to introduce native perennial meadows in ordinary public spaces previously managed as short-mown amenity grassland. Co-produced as an urban meadows experiment (2013-15), this was designed to gauge public and invertebrate response to 9 different meadow mixes of varying height and floristic composition in contrasting locational contexts across Luton and Bedford (Fig. 5). Many of the same species used in the London 2012 perennial meadows were incorporated (*Echium vulgare* (Viper's bugloss), *Leucanthenum vulgare* (Ox-eye daisy), *Lotus corniculatus* (Bird's foot trefoil)), and different meadow heights were achieved through species selection and varied cutting regimes. The locational context included one urban park, one green space adjacent to commercial land uses, a 'green' in front of housing and a large sloping swath of greenspace behind one area of housing and separated from house frontages by a raised bank and a road.

Figure 5. Tall meadows including *Leucanthenum vulgare* (ox-eye daisies) flowering outside residents' homes in Bedford.

Research with the public during the meadows experiment (Southon et al. 2016) revealed that site users perceived an improvement to the quality of greenspace overall on meadow introduction. Users preferred the medium height meadows with the highest level of floristic diversity. They were also increasingly prepared to accept the appearance of brown plant stems after flowering, when informed of the value of these for wildlife. Related research conducted with land managers (Hoyle et al. 2017) revealed clear messages from the public about the preferred locational context for perennial meadows. Although some residents liked to see flowering meadows directly outside their homes (Fig. 5), others preferred a tidier aesthetic here, considering meadows more appropriate in spaces behind housing, or along woodland edges. Further research with annual meadows (including non-natives such as *Coreopsis tinctoria* (Plains coreopsis) as shown in Fig. 4 (b)) confirmed public preference for meadows of high colour diversity. Species diversity per se was unrelated to preference, and people used colour diversity as a cue to estimating species diversity. Invertebrate response to native perennial meadows indicated a positive change with increasing meadow height and floral diversity (Norton et al. 2019). This research showed that as well as improving site users' satisfaction and aesthetic enjoyment, compared with short mown grassland, the introduction of native meadows can generate real biodiversity benefits: biologically diverse grasslands supporting more diverse and abundant invertebrate communities, and restructured soil microbial communities.

c. Greening grey Britain: Sheffield's 'Grey to Green'

Sheffield's 'Grey to Green' sustainable urban drainage system (SuDS) is the most successful retrofitted SuDS scheme in the UK. The overall project is expected to transform 1.2km of now redundant impermeable grey road carriageway into a SuDS incorporating swales and rain gardens, perennial meadow-style planting and enhanced public realm incorporating totems and street art (Ceequal, 2016). This will link the city centre to the Riverside Business District and residential areas of Sheffield adjacent to the River Don, which were flooded badly in 2007. Phase 1, the 0.5km section of the scheme running past the Law and Family Courts towards Riverside, has now been completed at a cost of £3.4M. Funded by the European Regional Development Fund (ERDF), Sheffield City Region Investment Fund (SCRIF) and Sheffield City Council (SCC), the project began on site in February 2015, and was completed by spring 2016.

In 2008 South Yorkshire Forest's 'Creating a Setting for Investment' project highlighted the role of high-quality public realm via landscaping in supporting employee wellbeing and a positive corporate image, thereby boosting economic investment. The planting is a key element of the scheme's overall success. The new scheme incorporated 40 new additional trees, 45,000 bulbs, 665 evergreen plants and 26,000 herbaceous plants, with the inclusion of species such as *Knifofia, Verbena* and *Rudbeckia*, designed to deliver year-round interest and colour as well as 'green'. Since completion in spring 2016, the quality of the environment has continued to improve, as the new planting has established. The author visited in October 2019 and was impressed to see *Verbena* and *Rudbeckia* still in flower and offering resources to invertebrates (Fig. 6).

The innovative project is another example of partnership working between the client Sheffield City Council (Landscape design team), Robert Bray Associates (advice on SuDS elements and hydrological modelling), Yorkshire Water, Amey (Highway and Lighting engineers) and the University of Sheffield. The scheme is also a success by measure of its multifunctionality and seamless delivery of multiple benefits. It fulfils the primary function of flood mitigation, yet also a positive aesthetic experience for people living, working or passing through the area. The perennial planting enhances plant and invertebrate biodiversity and is also low maintenance. The growing medium (crushed sandstone aggregate, recycled glass sand, composted green waste and sandy silty loam) minimises weed growth and the planting needs only a once a year cut in the autumn. Although the longer vegetation may collect some litter, this is a small price to pay for the other benefits in a central urban area.

Figure 6. Sheffield's Grey to green scheme with planting still flowering in late October.

d. Innovative practice in Milan: The Biblioteca degli Alberi and Bosco Verticale

In October 2018 an innovative urban park with truly multifunctional aspirations opened at the foot of the Bosco Verticale in central Milan (Fig. 7). Developed on a brownfield site with a varied past, in the Porta Nuova District of Milan, adjacent to Garibaldi Station, the Bibilioteca degli Alberi (Library of Trees) welcomes the public, making bold claims for the park as an 'urban connector, cultural campus and botanical garden', and a 'place of leisure, sports, learning and of beauty' (Blaise, 2019). Land values are very high in Porta Nuova, yet the park aspires towards inclusivity; 'everyone is invited to act and interact, meet, enjoy and educate themselves.' The Bibiliteca degli Alberi was designed by Petra Blaisse and the Dutch studio Inside Out, with significant input from the planting designer Piet Oudolf. Development of the park began in 2003. At 10 ha in size, and with over 135,000 plants of

100 different species (including 500 trees of 21 species), it cost 14 million euros to develop. It certainly supports biodiversity (hence the name) and encourages human contact and connection with nature. The ‘educational’ dimension is subliminal although maybe not subtle, with the names of plant species such as “*Acer rubrum* ‘October glory’” emblazoned across the surface of the paths as design features (Fig. 7). The park encompasses a 5km network of bike and pedestrian paths facilitating open access to all and links with the surrounding area including transport hubs such as Garibaldi Station. The authors visited the site in July 2019. The design plays with geometry and perspective, with diagonal cross-cutting paths framing irregular ‘fields’ or greenspaces, some mown, others sown with colourful flowering annual meadows. These are interspersed by circular ‘forests’ or groves of trees forming enclosed ‘rooms’ fostering a sense of security and belonging. Here we saw children playing and older residents prostrate on purpose-built loungers. We witnessed first-hand an inclusive space where local residents, workers, tourists of varying age, gender and ethnicity enjoyed different experiences: sitting, drawing, talking, (dog) walking, sunbathing, reading and playing within a park offering a celebration of light and life: aesthetically bold geometry and the vivid colours of flowering planting providing the ‘wow factor’ (Hoyle et al. 2017a).

Figure 7. The geometric lines of the ‘Biblioteca degli Alberi’ (Library of trees) frame the iconic ‘Bosco Verticale’ (Vertical forest). Bike and foot paths are boldly signed with species names such as *Acer rubrum* ‘October glory’ (below).

The Biblioteca degli Alberi frames the iconic Bosco Verticale (Vertical Forest). The redevelopment of the Porta Nuova District of Milan celebrates the synergies between climate resilience, biodiversity and human wellbeing benefits, providing an exemplar in innovative multifunctional UGI. Proposed in 2008 and completed in 2014, the iconic Bosco Verticale design has been adopted in cities throughout the world: Barcelona, Utrecht, Chicago, Sao Paulo, Mexico, Cairo, Mumbai, Shanghai and Beijing amongst others. The precedent in Milan consists of two residential towers at 112 and 80 metres high (27 floors above ground, 3 below and 148 parking spaces) incorporating a living green façade, where traditional cladding materials have been replaced by screens of vegetation (Boeri, 2019). The stoneware finish of the buildings is dark brown, deliberately evoking bark. Staggered and overhanging balconies are designed to accommodate external planters for vegetation and the towers house a total of 800 trees, 5,000 shrubs and 15,000 perennials and ground cover plants, the equivalent to 2 ha woodland and undergrowth. This plant diversity has promoted the colonisation of birds and invertebrates enhancing their species richness in a central urban area. In terms of climate resilience, this vegetation mitigates the heat island effect and sequesters carbon, as well as filtering air and reducing noise pollution. Maintenance of the vegetation is done at the level of the whole development, with arborist-climbers abseiling in to prune vegetation and irrigation is also done centrally, recycling grey water from residential apartments. The concept of the Bosco Verticale is rooted in the aspiration to foster synergies between human residents and nature (birds and trees) yet although the Biblioteca degli Alberi may stake a claim to inclusivity, in the case of the Bosco Verticale the well-being benefits of this direct nature contact are most accessible to affluent residents.

e. The challenge of retrofitting Brasilia: The Drenar-DF urban drainage management project

Brasília, the city planned to be Brazil’s new capital by urban planner Lúcio Costa, architect Oscar Niemeyer and landscape architect Burle Marx in 1956, was first conceived by President Juscelino Kubitschek to bring economic growth to the Midwest interior region of the country. Built rapidly in three years, the city was inaugurated as Brazil’s new capital in 1960, and by 1987 it was awarded UNESCO World Heritage status. A photograph from 1957 reveals the original blank canvas of natural ‘cerrado’ or savannah landscape, with the point where the two main axes of the city would cross marked out clearly on the ground. Costa devised ‘The Pilot Plan’ in the form of an aeroplane, with the fuselage the main or ‘monumental axis’ along which significant government, civic and religious functions were to be located: the iconic towers of the Ministerial Buildings, Catedral Metropolitana Nossa Senhora Aperecida (Metropolitan Cathedral), Teatro Nacional Claudio Santoro (National Theatre) and dome-shaped Museum of the Republic. The city is still an exemplar in monofunctional zoning, with residential neighbourhoods, retail and hotel areas laid out with little attention to existing sense of place, ecological functioning or topography. Although Niemayer aimed for sensual curves, there is little to soften the landscape in the harsh light. The white concrete structures of Niemayer's architecture catch the sun, but there is little softening green vegetation.

Some 'green' areas are incorporated within zoned areas without due consideration for the characteristics of the biodiversity or aesthetics of the native Cerrado landscape. This has been translated into lawns, squares, extensive wooded areas, gardens, and the shores of the artificial Paranoá lake, used for recreation, leisure and preservation. The city looks its 'greenest' along the Monumental Axis of the Pilot Plan, where foot and cycleways have been retrofitted, yet here the Cerrado landscape is especially fragmented and the topography contributes to the city's greatest challenge, flooding (Fig. 8). The Axis is aligned along a slope, and with a high percentage of impermeable surfaces and compacted soils, rainfall flows rapidly overground towards the Lake Paranoa to the east of the city. The replacement of most of the native Cerrado vegetation with short grass limits infiltration and further contributes to flooding and the sedimentation of Lake Paranoa. Traditional grey engineered solutions to flood mitigation, characteristic of the 1960s when they were conceived, are a further problem. Unable to accommodate the volume of water needed, they speed up the flow to Lake Paranoa.

Figure 8. The planned city of Brasilia. Impermeable surfaces and short mown grass have replaced the biodiverse *Cerrado*vegetation leading to rapid surface runoff and heightened flood risk.

Brasilia's UNESCO world heritage status is itself a major barrier to the retrofitting of appropriate UGI to address these challenges, as any addition to or alteration of Niemayer's minimalistic designs is forbidden. Yet Brasilia's built environment professionals are aware of the urgent need to retrofit the green areas of the city with water-sensitive urban design (WSUD). The Drenar-DF project aims to do this by enhancing the rainwater storage within drainage basins in the urban landscape of the Pilot Plan. It proposes sustainable alternative solutions to the treatment of water capture with landscape and ecological bias, integrating these areas into the system of urban green areas as a provider of environmental and social (aesthetic and recreational) services. Focus is also placed on promoting the habitat for biodiversity. In this context, a square International Peace Park has been proposed connecting the entire open space system in the Northern Embassy sector, with a water capture basin of approximately 4.8 ha (Figs. 9 &10). The project which promotes biodiversity with the use of native Cerrado species, such as *Vochysia pyramidalis* (Gomeira), *Calocasia* (Orelha de elefante), G*unnera manicata* (Ruibarbo gigante), *Philodendron uliginosum*, *Philodendron Brasiliense* (Filodendro) and *Lobelia brasiliensis* (Lobella).

Figure 9. Arial image showing Brasilia's Pilot plan with the proposed triangular Drenar-DF International Peace Park shown in green (Source: Google maps).

1. Implications for future policy, practice and research opportunities

Planning, designing, delivering and maintaining UGI to futureproof our cities necessitates decision making and prioritisation across a range of scales (Fig. 11). At the local authority or city scale planners must aim for multifunctionality, interconnectedness, and inclusivity. Climate-ready UGI must be prioritised or vegetation will not be adapted to changing conditions. This is especially important yet challenging in the context of austerity politics operating across the UK, Europe and N. America, where withdrawal of funding for public services has resulted in significant cuts to GI funding (Mell, 2020). The value of partnership working across sectors must be recognised, potentially as a source of innovative funding opportunities (Mell, 2018), and planners and landscape architects need to be mindful of possible synergies and trade-offs between human wellbeing, biodiversity and climate change mitigation objectives. The synergies provide opportunities to deliver multifunctionality at the site scale. Examples of this include the Grey to Green Scheme in Sheffield (UK) where flood mitigation, biodiversity enhancement and dramatic improvements to the aesthetics of the public realm are all positive outcomes. Introducing urban meadows in different contexts has similar synergistic benefits: improvements in wellbeing amongst site users, enhanced invertebrate habitat and resource provision, as well as possible reductions in future maintenance costs. Milan's Biblioteca degli Alberi and Bosco Verticale provide synergistic benefits too: enhanced biodiversity, human recreational and aesthetic value as well as localised cooling and heat island mitigation. In the case where trade-offs occur, for example between biodiversity conservation and human recreation, priorities can be identified for specific sites, for example, in Lyon, where the Greenspace Division manage the city's UGI as 'Nature' 'Living' and 'Flowered' spaces. Localised site-scale design must also prioritise the habitat fitness and competitive qualities of planting incorporated. Plants are not concrete; they grow, change and need maintenance under conditions of austerity. Future research priorities include closer examination of the synergies and trade-offs between prioritising climate change resilience, biodiversity and human wellbeing at different scales. A focus on the translation of research evidence into practical advice for the Landscape profession is also a priority, especially in the face of the grand challenge of the climate crisis.

Figure 10. Visuals of the proposed International Peace Park which will connect the entire open space system in the Northern Embassy sector, with a water capture basin of approximately 48,000 m^3 (source: DIEP—DIRETORIA DE PARQUES E ESPAÇOS LIVRES).

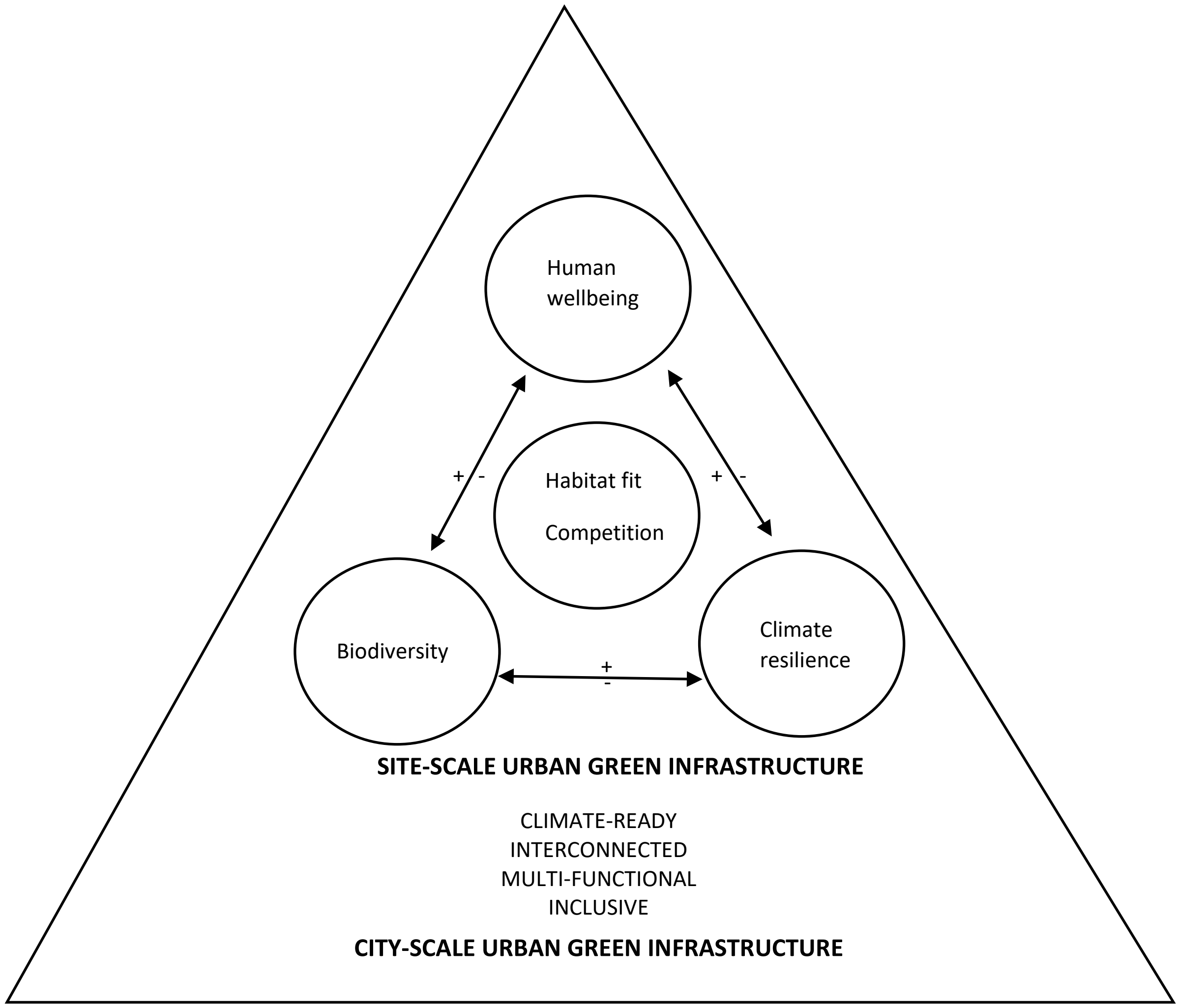

Figure 11. Priorities, synergies (+) and trade-offs (-) for urban green infrastructure (UGI) at the city and site scale.

References

Alumai, A., Salminen, O. S., Richmond, D. S., Cardina, J., & Grewal, P. S., (2009). Comparative evaluation of aesthetic, biological, and economic effectiveness of different lawn management programs. Urban Ecosystems 12:127–144.

Bi, P., Williams, S., Loughnan, M., Lloyd, G., Hansen, A., Kjellstrom, T., Dear K. and Saniotis, A., (2011). The effects of extreme heat on human mortality and morbidity in Australia: Implications for public health Asia-Pacific Journal of Public Health, 23 (2 suppl), pp. 27S-36S

Bijoor, N., D. Pataki, D. Haver, and J. Famiglietti. 2014. A comparative study of the water budgets of lawns under three management scenarios. Urban Ecosystems 17:1095–1117.

Blaise, P. (2019) Biblioteca degli Alberi, Milan. https://www.insideoutside.nl/Biblioteca-degli-Alberi-Milan [accessed 13th October 2019]

Boeri, S. (2019) Vertical Forest. https://www.stefanoboeriarchitetti.net/en/project/vertical-forest/ [accessed 12th October 2019]

Brannstrom, C., Jepson, W., Filippi, A.M., Redo, D., Xu, Z. & Ganesh, S. (2008). Land change in the Brazilian Savanna (Cerrado), 1986–2002: Comparative analysis and implications for land-use policy Land Use Policy 25(4): 579-595

Bratman, G.N., Hamilton, J.P., Hahn, K. S., Daily, G.C., & Gross, J.J., (2015). Nature experience reduces rumination and subgenual prefrontal cortex activation PNAS 112 (28) 8567-8572

Burns, F., Eaton, M.A., Barlow, K.E., Beckmann, B.C., Brereton, T., Brooks, D.R., et al. (2016) Agricultural Management and Climatic Change Are the Major Drivers of Biodiversity Change in the UK. *PLoS ONE* 11(3): e0151595.

Ceequal, (2016). Grey to Green Phase 1: Case Study https://www.ceequal.com/case-studies/grey-to-green-phase-1/ [accessed 12th September 2018].

Clark, N.E., Lovell, R., Wheeler, B.W., Higgins, S.L., Depledge, M.H., & Norris, K. (2014). Biodiversity, cultural pathways, and human health: a framework. *Trends in Ecology and Evolution,* 29(4), 198 – 204.

Cox, D.T.C., Hudson., H.L., Shanahan, D.F., Fuller, R.A. & Gaston, K.J., (2017). The rarity of direct experiences of nature in an urban population. Landscape and Urban Planning 160, 79-84

Dye, C. (2008) Health and urban living. Sci 319:766-769

Demuzere, M., Orru, H., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Bhave, A.G., Mittal, N., Feliu, E. & Faehnle, M. (2014). Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure Journal of Environmental Management 146:107-115

Emmanuel, R. & Loconsole, A. (2015). Green infrastructure as an adaptation approach to tackling urban overheating in the Glasgow Clyde Valley Region, UK. Landscape and Urban Planning 138: 71-86

European Union, (2010). EU Biodiversity Strategy to 2020 http://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm [accessed 4th November 2016]

Evans, K. L., Newson, S.E. & Gaston, K.J., (2009). Habitat influences on urban avian assemblages. Ibis 151:19–39.

Fields in Trust (2018). Revaluing Parks and Green Spaces Report http://www.fieldsintrust.org/Upload/file/research/Revaluing-Parks-and-Green-Spaces-Report.pdf [accessed 11th November 2019].

Fischer, L.K. & Honold, J. & Botzat, A. & Brinkmeyer, D. & CvejiÄ‡, R. & Delshammar, T. & Elands, B. & Haase, D. & Kabisch, N. & Karle, S.J. & Lafortezza, R. & Nastran, M. & Nielsen, A.B. & van der Ja, (2018a). "Recreational ecosystem services in European cities: Sociocultural and geographical contexts matter for park use," Ecosystem Services, 31: 455-467.

Fischer, L.K., Honold,J., Cvejićd, R., Delshammare, T., Hilbert,S., Lafortezzah,R., Nastrand, M., Nielsenj, A.B., Pintard,M. van der Jagt, A.P.N., Kowarika,I., (2018b). Beyond green: Broad support for biodiversity in multicultural European Cities. *Global Environmental Change* 49 35-45

Flies, E., J., Skelly, C., Negi, S., Singh, P., Poornima; L., Qiyong; L., Goldizen, F. C., Lease, C. & Weinstein, P. (2017). Biodiverse green spaces: a prescription for global urban health. Frontiers in Ecology and the Environment 15 (9): 510-516.

Frumkin, H., Bratman, G. N., Breslow, S. J., Cochran, B., Kahn, P. H., Lawler, J. J., Levin, P. S., Tandon, Pooja S; Varanasi, Usha; Wolf, Kathleen L; Wood, Spencer A (2017). Nature contact and human health: A research agenda. Environmental Health Perspectives 125 (7)

Greater London Authority, (2015). Natural Capital: Investing in a Green Infrastructure for a future London. https://www.london.gov.uk/sites/default/files/gitaskforcereport.hyperlink.pdf [accessed 19th January 2020]

Grundmann, (2016) Climate change as a wicked social problem. Nature Geoscience 9, 562-563.

Hartig, T., Mitchell, R., de Vries, S. & Frumkin, H. (2014). Nature and Health. Annu. Rev. Public Health, 35, 207–28

Hitchmough, J.D. (2019) Unpublished lecture slides, Department of Landscape, University of Sheffield.

HM Government (2018). A Green Future: Our 25 Year Plan to Improve the Environment. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf [accessed 25th October 2019]

Hoyle, H., Hitchmough, J.D., & Jorgensen, A. (2017a). All about the 'wow factor'? The relationships between aesthetics, restorative effect and perceived biodiversity in designed urban planting. *Landscape and Urban Planning,* 164, 109-123

Hoyle, H., Hitchmough, J.D., & Jorgensen, A. (2017b). Attractive, climate-adapted and sustainable? Public perception of non-native planting in the designed urban landscape. *Landscape and Urban Planning,* 164, 49-63

Hoyle, H., Jorgensen, A., Hitchmough, J.D. (2019). What determines how we see nature? Perceptions of naturalness in designed urban green spaces. People Nat. 00: 1–14.

Hoyle, H., Jorgensen, A., Warren, P., Dunnett, N. & Evans, K. (2017). "Not in their front yard" The opportunities and challenges of introducing perennial urban meadows: A local authority stakeholder perspective. *Urban Forestry & Urban Greening,* 25, 139-149.

Hoyle, H., Norton, B., Dunnett, N., Richards, P., Russell, J. & Warren, P. (2018) Plant species or flower colour diversity? Identifying the drivers of public and invertebrate response to designed annual meadows. *Landscape and Urban Planning* 180 pp. 103-113

Intergovernmental Panel on Climate Change (2019) IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse gas fluxes in Terrestrial Ecosystems Summary for Policymakers Approved Draft. https://www.ipcc.ch/site/assets/uploads/2019/08/3.-Summary-of-Headline-Statements.pdf [accessed 4th November 2019]

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2019) IPBES Global Assessment Summary for Policymakers. https://ipbes.net/news/ipbes-global-assessment-summary-policymakers-pdf [accessed 26th November 2019]

Italian National Biodiversity Strategy, (2010) https://www.minambiente.it/pagina/strategia-nazionale-la-biodiversita [accessed 19th January 2020]

Kaplan & Kaplan, (1989). *The Experience of Nature: A psychological Perspective*. Cambridge, UK, Cambridge University Press.

McPherson, E.G., Berry, A.M., & van Doorn, N.S. (2018). Performance testing to identify climate-ready trees Urban Forestry & Urban Greening 29: 28–39

Mell, I., (2018) Financing the future of green infrastructure planning: alternatives and opportunities in the UK. Landscape Research, 43:6, 751-768.

Mell, I. (2020) The impact of austerity on funding green infrastructure: A DPSIR evaluation of the Liverpool Green & Open Space Review (LG&OSR), UK. Land Use Policy 91, 104284

Miller, R.W., (1997). Urban Forestry: Planning and Managing Urban Greenspaces, 2nd ed. Prentice-Hall, Upper Saddle River.

National Planning Policy Framework (2019) https://www.gov.uk/guidance/natural-environment#biodiversity-geodiversity-and-ecosystems [accessed 12th October 2019]

Norton, B.A., Coutts, A.M., Livesley, S.J., Harris, R., J., Hunter, A.M. & Williams, N.S.G. (2015). Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. Landscape and Urban Planning 134: 127-138.

Norton, B. A., Bending, G. D., Clark, R., Corstanje, R., Dunnett, N., Evans, K. L., Grafius, D.R., Gravestock, E., Grice, S.M., Harris, J.A., Hilton, S., Hoyle, H., Lim, E., Mercer, T.G., Pawlett, M., Pescott, O.L., Richards, J.P., Southon, G. E., Warren, P. H. (2019). Urban meadows as an alternative to short mown grassland: Effects of composition and height on biodiversity. Ecological Applications 00(00):e01946. 10.1002/eap.1946

Organisation for Economic Co-operation and Development (2018) Factsheet on promoting mental health. http://www.oecd.org/els/health-systems/OECD-Factsheet-Mental-Health-Health-at-a-Glance-Europe-2018.pdf [accessed 19th March, 2019]

Parliament of Australia, (2019). Mental Health in Australia: a quick guide. https://parlinfo.aph.gov.au/parlInfo/download/library/prspub/6497249/upload_binary/6497249.pdf [accessed 11th November 2019].

Robbins, P., & T. Birkenholtz. (2003). Turfgrass revolution: measuring the expansion of the American lawn. Land Use Policy 20:181–194.

Rooke, G.A.W., Lowry, C.A. & Raison, C.L. (2013) Microbial 'Old Friends', immunoregulation and stress resilience. Evolution Medicine, and Public Health:1: 46–64

Salisbury, A., Armitage, J., Bostock, H., Perry, J., Tatchell, M., & Thompson, K., (2015). Enhancing gardens as habitats for flower-visiting aerial insects (pollinators): should we plant native or exotic species? *Journal of Applied Ecology,* 52, 1156–1164.

Scheffers, B. R; De Meester, L., Bridge, T. C. L., Hoffmann, A. A., Pandolfi, J. M., Corlett, R. T., Butchart, S. H. M., Pearce-Kelly, P., Kovacs, K. M., Dudgeon, D., Pacifici, M., Rondinini, C., Foden, W. B., Martin, T. G., Mora, C., Bickford, D. & Watson, J. E. M. (2016).
The broad footprint of climate change from genes to biomes to people. Science 354 (6313) aaf7671

Schwarz, N., Moretti, M., Bugalho, M. N., Davies, Z.G., Haase, D., Hack, J., Hof, A., Melero, Y., Pett, T. J. & Knapp, S. (2017). Understanding biodiversity-ecosystem service relationships in urban areas: a comprehensive literature review. Ecosystem Services 27:161–171.

Southon, G., Jorgensen, A., Dunnett, N., Hoyle, H. & Evans, K. (2016). Biodiverse perennial meadows have aesthetic value and increase residents' perceptions of site quality in urban green-space. *Landscape and Urban Planning*. 158 pp.105-118.

Susdrain, (2019) Olympic Park, London: Case Study
https://www.susdrain.org/case-studies/pdfs/olympic_park_london_final_v2.pdf
[accessed 8th October 2019]

UK Water Industry (2010). Report on the Impact of Urban Creep on Sewerage Systems
https://www.ukwir.org/reports/10-WM-07-14/66915/Impact-of-Urban-Creep-on-Sewerage-Systems
[accessed 11th November 2019]

Ulrich, (1986). Human responses to vegetation and landscapes. *Landscape and Urban Planning* 13, 29 – 44.

United Nations (2015). The 2030 Agenda for Sustainable Development: Sustainable Development Goals https://sustainabledevelopment.un.org/sdgs [accessed 12th October 2019]

United Nations (2018) Revision of world urbanisation prospects https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html [accessed 14 Feb 2019]

Vigo, D.M.D., Thornicroft, G., Atun, R. (2016) Estimating the true global burden of mental illness. Lancet Psychiatry 3, 171–178

Watkins, H & Hitchmough J.D. (2019). Findings from unpublished PhD research, Department of Landscape, University of Sheffield.

Wheeler, B.W., Lovell, R, Higgins, S.L., White, M.P. Alcock, I., Osborne, N.J., Husk, K., Sabel, C.E. & Depledge, M.H. (2015).Beyond greenspace: an ecological study of population general health and indicators of natural environment type and quality. International Journal of Health Geographics (2015) 14:17

White, M.P., Elliot, L. R., Taylor, T. Wheeler, B.W., Spencer, A., Bone, A., Depledge, M.H. & Fleming, L.E. (2016). Recreational physical activity in natural environments and implications for health: A population based cross-sectional study in England. *Preventive Medicine* 91, pp.383-388.