

OPINION ARTICLE

Reconnecting with nature: Developing urban spaces in the age of climate change [version 1; peer review: 2 approved]

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Abstract

Climate change is occurring around us and impacting on our daily lives, meaning that we have to deal with our cities in a different way. There is also increasing awareness of the need for daily contact with green spaces and the natural environment in order to live a happy, productive and meaningful life.

This reflective essay tells the narrative of how urbanisation has been disconnecting humans from nature. Non-sustainable, non-resilient patterns of urbanisation, along with the neglect of inner-city areas, have resulted in fragmentation and urban decline, led to a loss of biodiversity, and caused the deterioration of ecosystems and their services. Urban regeneration projects allow us to 'repair' and restore some of this damage whilst enhancing urban resilience. Connecting existing and enhanced ecosystems, and re-establishing ecosystems both within cities and at the peri-urban fringe is vital for strengthening ecosystem resilience and building adaptive capacity for coping with the effects of climate change.

Cities worldwide need to look for suitable solutions to increase the resilience of their urban spaces in the face of climate change. This essay explores how this can be achieved through the integration of nature-based solutions, the re-greening of neighbourhoods and by correctly attributing value to natural capital. Transforming existing cities and neighbourhoods in this way will enable ecosystems to contribute their services towards healthier and more liveable cities.

Keywords





Climate change; urbanisation; urban regeneration; natural capital; nature based solutions; resource efficiency; healthy cities



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The seriousness and urgency caused by global warming

With global warming and the impacts of climate change, we will need to seriously rethink how our cities should evolve to become more resilient and resource-efficient. A group of leading scientists have warned of grim prospects if we keep abusing the planet, and that the commitment of the Paris Agreement (2016) to keep warming at two degrees Celsius above pre-industrial levels may not be enough to 'park' the planet's climate trajectory at a stable temperature (IPCC, 2018; Nature, 2018; UNEP, 2017).

Jonathan Watts described the 'domino-effect of climate events' that could shift the Earth into a hothouse state, arguing that prominent scientists have warned that crossing such a threshold would make efforts to reduce emissions increasingly futile (Watts, 2018). The loss of the Greenland ice sheet could disrupt the Gulf Stream, in turn raising sea levels and accelerating Antarctic ice loss, triggering a cascade of melting ice, warmer seas, shifting currents, dying forests and the release of methane trapped in Siberian permafrost that could tilt the Earth into a 'hothouse' state (4°C warmer than the pre-industrial era) beyond which human efforts to lower emissions will be increasingly impossible. In 'Losing Earth', Nathaniel Rich writes (2018, p. 2):

"If by some miracle we are able to limit global warming to two degrees Celsius, we will only have to negotiate the extinction of the world's tropical reefs, sea-level rise of several meters and the abandonment of the Persian Gulf. The climate scientist James Hansen has called two-degree warming "a prescription for long-term disaster." Long-term disaster is now the best-case scenario. Three-degree warming is a prescription for short-term disaster: forests in the Arctic and the loss of most coastal cities. Robert Watson, a former director of the United Nations Intergovernmental Panel on Climate Change, has argued that three-degree warming is the realistic minimum. Four degrees: Europe in permanent drought; vast areas of China, India and Bangladesh claimed by desert; Polynesia swallowed by the sea; the Colorado River thinned to a trickle; the American Southwest largely uninhabitable."

Climate change is not something in a faraway future but is already around us and impacting on our daily lives. All this has created an urgency that means we will have to deal with our cities in a different way.

Our disconnect from nature

Within a very short time, humans have experienced transition from a life predominantly spent outside towards a very different life inside buildings. We have changed how we live, and a fundamental change in our relationship with nature has been the result. Over 80% of the UK's population currently live in urban areas, and a large portion are estranged from nature (Office for National Statistics, 2016). Today 90% of our lives is spent indoors, in controlled interior environments (ASHRAE, 2010); with increasing 'screen-time' spent online.

Everything about how we define ourselves today, our cities, industries and our technologies, have only been on Earth for a relatively short period. The earth began to develop around

4.5 billion years ago. Although *Homo sapiens* emerged some 200,000 years ago, the human impact only really began with the impact of agriculture; for instance, the Australian aborigines used fire to assist hunting before that (they also avoided burning certain areas to retain food sources in drought years). We are a comparatively young species, and all the while we have been constantly pulling back from nature. Although we have seen ourselves increasingly as separate from and superior to nature, our impact upon nature has been immense. Biodiversity evolves as different species share the same ecosystem where relationships between the species develop. In this balanced system, the planet's biodiversity has grown to include 30 million different species. Each species is necessary for keeping something in balance in the natural world, yet we have not respected or maintained this delicate balance. Since the time of the dinosaurs 65 million years ago, there has not been this level of sustained destruction on our planet. The current rapid loss of biodiversity is quite possibly the biggest disaster ever.

In the big picture of Earth's evolution, *Homo sapiens* has only been around for a very short time, and it is likely that the Earth will still be around for a long time even after we have destroyed ourselves as a species (the reason why Martin Seligman argues that we have been misnamed as *Homo sapiens*, and are not a 'wise' species at all).

But today, a new awareness is emerging that is driving the regeneration and re-greening of our cities. Humans are able to and have a desire to participate in the community of life and in nature, interacting with all of the species on this planet, without necessarily destroying any of it, let alone destroying all of it. Aboriginal Australians are living proof of how we can take a different approach to nature. They represent over 50,000 years of uninterrupted living culture, based on the 'touching the Earth lightly' concept, meaning that you only take from nature what you really need at that particular moment. Yet over the last 35,000 years we have gradually changed our relationship with nature. Around this time we see the first cave paintings and simple tools being developed, followed around 10,000 years ago by the shift to agriculture, drawing on an awareness of the cycles and seasons of nature. This has been a process of empowering ourselves, taming the natural world and taking control of our own lives and our own destiny. We are not at the mercy of nature; we can farm the land, build dwellings that resist nature's forces, and we can harness what agriculture offers.

Everything changed again with scientific discovery, technology and the Industrial Revolution. Over the last 300 years we saw that we could manipulate nature through the emergence of science. Humankind started to believe that it had dominion over the Earth; and that the Earth and nature have to serve us in our own evolution. Just think of the discoveries of philosophers and scientists like Copernicus, Galileo, Descartes and Newton. Their understanding was that nature was meaningless and purposeless, and its only function was to 'serve humans in their evolution'. Descartes for instance believed that animals had no feelings. His belief was: 'Man is at the top and Earth is here for us to use, to exploit' (see: Figure 1). The seminal book 'The limits to growth' (Meadows *et al.*, 1972) displayed the limits of finite resources and noted that the whole Industrial Revolution was about taking

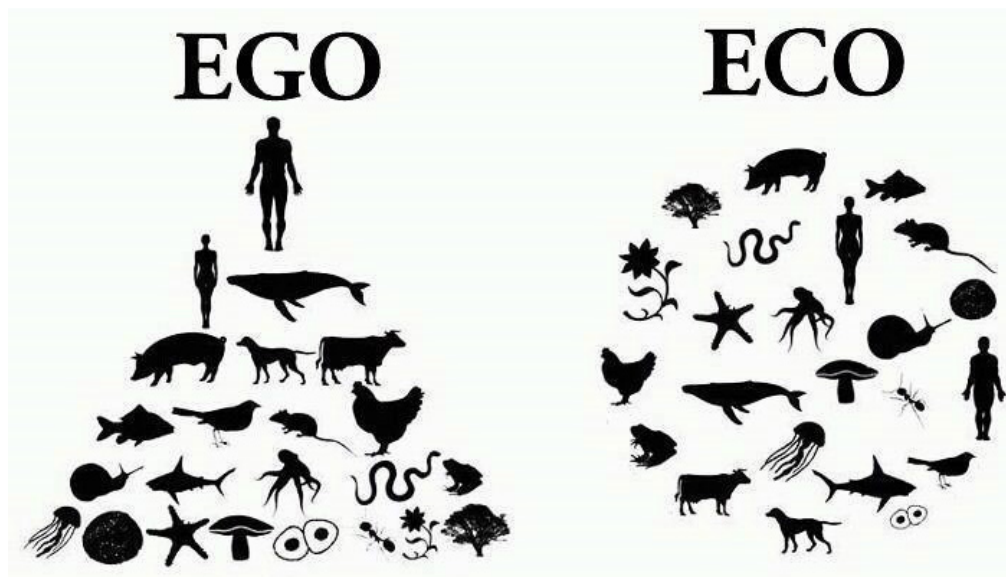


Figure 1. Diagram 'Ego-Eco' – Humankind is part of the ecosystem, not apart from or above it. This diagram depicts this simple fact clearly (diagram: S. Lehmann, 2010).

and extracting minerals and resources, and disposing of waste, with a complete disregard for the environment (see: [Figure 2](#)).

Climate change is caused by humans, through the production of heat-trapping greenhouse gases caused by carbon-dioxide. We have changed the whole dynamics of the planet in a very short time, and we have disrupted billions of years of evolution. Earth was always able to regulate itself, self-regulating the temperature and weather system - fragile systems which have now fallen out of balance. The complex interactive, self-regulating system of biosphere, geosphere and atmosphere has become messed up by global warming and the dangerous effects of climate change. We have been destroying billions of years of creativity and evolution that enabled all of the vitality on Earth to co-exist side-by-side. However, we are just awakening to this mistake; the Earth and nature are not things to dominate and exploit, but a community we are to be part of, to enjoy and participate in.

Understanding and enjoying nature within the city

The study of ecology allows for an understanding of the Earth as a single living system that is in balance. Within this system, cities evolve as the greatest creation of humankind and yet cities are also a source of overload and environmental stress. Cities can possess degrading conditions - just think of windowless work environments, over-crowded housing, air pollution and noise. They are not obvious places to connect with the natural environment.

[Cronon \(1995\)](#) asserts that urban inhabitants have created a wholly artificial view of what nature and wilderness are, based on ideas of open space and grandeur that do not correspond to the lived reality of the people who inhabit rural spaces. The view of nature as a pristine and uninhabited space makes it difficult

to see nature on a smaller, less imposing scale, and to appreciate for instance that a tree in an urban back garden can equate to a tree growing in a forest; that the two trees are identical despite the different setting. The forest tree somehow has a greater perceived natural value and nature is seen as being something that does not belong within the city ([Cronon, 1995](#)).

[Rautio & colleagues \(2017\)](#) argue that this does not have to be the case. In working with children in Finland they have found that urban inhabitants are not disconnected from nature; there is plenty of nature present in urban environments for them to explore. To imply that urban children are disconnected is to disregard the ways in which nature is present in and encroaches on their lives. Their focus is on how children's relationships with nature emerge based upon the setting which they are in. The children's understanding of nature in the urban environment is an assemblage, and may not always be positive as shown in one child's description of an urban gull on a landfill site. The author argues that what is significant here is that nature should not be viewed as something that exists beyond the city, but instead, *“environmental education research and practice could and should intensely focus on the everyday materialisations of complex historical, societal, political and cultural conditions that give rise to environmental phenomena, human attitudes and relations included.”*

[Hand & colleagues \(2017\)](#) explored how children living in urban environments respond to different natural environments. They noted that urban back gardens represented the main source of interaction with biodiversity for these children, and that children were not spending less time in nature due to the lack of natural environments in urban areas, but rather that lifestyle factors, including parental limits and the attraction of electronic



Figure 2. Diagram: The linear extraction process of resources is unsustainable (diagram: S. Lehmann, 2012).

media over natural play spaces, were the cause of the children's increasing disconnect with nature. A behavioural shift is needed to reattribute value and importance to time that is spent outdoors in a biodiverse environment. Although Rautio *et al.* (2017) argue that the urban population is not necessarily disconnected from nature, it is fair to say that the time spent connecting with nature is decreasing for certain groups within society. The penetration of technology into our everyday lives has led to the development of a 'heads-down' generation who spend more 'screen-time' indoors and less time on outdoor activities, and who do not necessarily place the same value on natural encounters.

Connecting with nature makes people come alive and nourishes the senses. Today, we are at a turning point. We understand that cities need to be built on regenerative principles, as we start to grasp how everything in life and the environment is connected. We are revisiting the wisdom of nature to inform our organisational structures (e.g. local food production) and realise that nature has a profound positive influence on our health and well-being. We have arrived at a new understanding, that we are merely participants in the natural world. We rediscover indigenous traditions and the interdependence of all things in nature, things which coexist together. The inter-connectedness of things - it means that we are not in a privileged position to exploit or destroy the ecosystem. In fact the opposite is true. We have a position of stewardship, where we must lead in a respectful and responsible relationship to the natural world. We are not 'above' nature.

The quality of our social, professional and ecological relationships is at the core of what makes us feel alive, happy and safe. Part of this are walkable neighbourhoods on a human scale and the ability to enjoy nature within the city. Urban designers worldwide aim to bring nature back into the city, to compensate for a lack of parks, gardens and green spaces in cities. Today, we talk about the concept of 'Urban Metabolism', a model which understands cities as a living organism. Urban metabolism analyses the flows of energy, resources, food, people and materials in cities (as if the city were an ecosystem) and provides a framework for the study of the interactions of natural and human systems, using the metaphor of the city as a living organism. Ecologist Arthur George Tansley (1871–1955) expanded the term in 1935 to encompass the material and energetic streams (Tansley, 1935). Seminal texts by different authors

offer further ecological wisdom on the architect's relationship with landscapes and their ecosystems (Carson, 1962; Girardet, 2008; McDonough & Braungart, 2002; McHarg, 1969; Register, 1987).

A new deep understanding of nature has emerged that sees the commonality of all of life as part of the same ecosystem, and it influences our thinking of cities as living organisms (one of these approaches is 'urban metabolism'). The concept that the Earth is a self-correcting organism, the so-called *Gaia hypothesis*, was developed by James E. Lovelock in 1975 and published in 1979 (Lovelock, 1979). It states that the Earth is a vulnerable system in balance, and that the temperature of the planet and its atmosphere are produced and maintained by the sum of living organisms. The Gaia hypothesis is based on the idea that all life on earth functions as a single system. This system both defines and maintains the conditions necessary for its survival. Lovelock argues that the earth's living matter – including the atmosphere, oceans and land areas – combine to create a complex system with the ability to keep our planet a place fit for life.

The Gaia hypothesis has fundamentally altered the way scientists view evolution and the environment, but not all agree. Contrary to the Gaia hypothesis, which suggests the Earth has a self-righting tendency, Johan Rockstrom, Director of the Stockholm Resilience Centre (2018) and numerous other leading scientists say that the feedbacks of global warming could push the planet to a more extreme state. In the face of this scenario what we need are strategies to mitigate the effects of climate change (greening up cities will not make a difference unless there is a sharp reduction in the use of fossil fuels).

From garden cities to Biophilia: healthy and resilient cities

One important characteristic of complex urban systems is their resilience. Urban resilience of cities means the ability to maintain human and ecosystem functions simultaneously over the long-term (Alberti & Marzluff, 2004). Urban resilience, also called *adaptive capacity*, refers to a city's ability to cope with and recover quickly from hardship or crisis. A resilient city is typically one that is prepared and well-equipped to contend with and mitigate the multiple effects of climate change, such as urban heat islands, heatwaves, urban flooding, energy blackouts and potential

disasters. A resilient city has a robust infrastructural system and can even turn a crisis into a positive development (Meerow *et al.*, 2016; Mitchell & Harris, 2012).

Redefining cities in the age of global warming goes right to the core of our ability to adapt, and underpins our complicated relationship with nature, technology and place. For some time now humankind has been out of touch with nature and has lost its connection to the natural world. There is a need for us to renew our connection with nature since this is key to both good health and resilience. Related to this is the importance of re-greening cities and introducing nature-based solutions through urban regeneration projects (such as the examples shown at Figure 3).

A *healthy city* is conscious of health of its residents and striving to improve it. Thus, a healthy city has a strong commitment to health and wellbeing, and a process to achieve it. The WHO report (2014) refers to the need for sufficient green spaces in cities and defines what a *Healthy City* is: “A healthy city is one that continually creates and improves its physical and social environments and expands the community resources that enable people to mutually support each other in performing all the functions of life and developing to their maximum potential.” This approach puts health high on the political and social agenda of cities and builds a strong movement for public health at the local level. It strongly emphasizes equity, participatory governance and solidarity, inter-sectoral collaboration and action to address the determinants of urban health. The concept of Healthy Cities was inspired and supported by the WHO *European Health for All* strategy and the Health21

targets and is aligned with the UN’s 2030 Agenda for Sustainable Development.

As predicted by Rachel Carson in ‘Silent Spring’ in 1962, we are now in the process of redefining our relationship with nature, and how our lives depend upon it. This new understanding is not about giving up technology, but rather developing the most advanced technologies to date, for instance through the biological revolution and nanotechnology. We have to use that rich and available knowledge to find new and better solutions, employing ideas of ‘biomimicry’ (Benyus, 2002; Neves & Francke, 2012).

The emulation of nature’s genius is a promising path for our urban systems, processing and neighbourhood designs. It goes beyond just emulating natural form, involving systems’ thinking and asking: how does it fit into the wider ecosystem? Nature has 3.8 billion years of R&D behind it, which we can learn from. Learning from nature also means that the principles of a Circular Economy have become part of this learning process. The Ellen McArthur Foundation (EMF) argues that ‘a circular economy is one that is restorative and regenerative by design’ (Ellen MacArthur Foundation, 2017). Part of the circular economy includes designing out waste and rebuilding natural capital and resilience. In order to support this, the EMF has published a series of key texts on the circular economy that are freely available online.

What does this all mean for the urban regeneration of our cities? How can we create public spaces, infrastructure, buildings, neighbourhoods and products without destroying nature and the ecosystem?



Figure 3. Left: There are numerous ways greenery and vegetation can be integrated in buildings, for instance, such as this hanging garden in Singapore. Right: Green space and the urban are no contradiction, but can co-exist side by side, as here in Rotterdam (photos: S. Lehmann, 2010)

There is significant potential for a new technological era inspired by nature. There is enough solar energy every day to power all of our cities (Afanador *et al.*, 2015; Weissman *et al.*, 2018). We can improve the cooling of buildings by looking at the natural world for solutions, for instance we can harness the process of photosynthesis. Solar power, CO₂ and water create – in the process of photosynthesis – energy and oxygen. This is relevant, as we have to ask: could we pull CO₂ out of the atmosphere in this way, for example by planting more urban forests in all cities? All regenerative city thinking is also relevant for human health, by providing clean air, clean water, and vibrant local foods from the natural environment around us (UN-Habitat, 2016; Woo *et al.*, 2014). Instead, it is tragic what is happening to our forests and oceans. For instance, it is well documented that plastic waste leads to toxins entering our bodies through the food chain (Murphy *et al.*, 2017; Wright & Kelly, 2017).

There is also increasing evidence of the health benefits from re-greening our cities: for instance, a faster healing process from illness (Grinde & Patil, 2009). If we have hospitals with a window view into a garden, this enables faster recovery from surgery. It relates to the concept of ‘Biophilia’, nature’s restorative, regenerative capacity. This includes the benefits for children of being in nature on a daily basis. (Kellert, 2011; Wilson, 1984). The ‘Biophilia hypothesis’ has first been introduced by Edward O. Wilson in 1984, suggesting that ‘humans possess an innate tendency to seek connections with nature and other forms of life’. Biophilia explores the various ways of greening and re-naturing cities to strengthen the calming and cooling effect of nature, and the improvement of air quality and microclimate.

This is timely, as a recent survey (BBC News, 2018, reporting on a WHO study) has revealed that 47 UK towns and cities exceed air pollution limits and have an unhealthy environment to live in. The WHO study found that 30 areas in the UK had fine-particle air pollution levels in excess of 10 micrograms per cubic metre; a further 17 cities had fine-particle air pollution levels that were on this limit. Areas that exceeded the level included London, Manchester, Swansea, Leeds, Leicester, Liverpool, Nottingham, Plymouth and Sheffield (beside others). Fine-particle air pollution is particularly dangerous for human health as it penetrates deep into the lungs and cardiovascular system, in doing so contributing directly to diseases including stroke, heart disease, lung cancer and respiratory problems. But if the outside air has become so polluted, the ‘open the window’ cooling option is less viable and resolution is sought from air-conditioning systems, this creates further energy needs, generating more heat, emissions and pollution.

In today’s fast-paced, over-loaded and distracting built environment, places of refuge, escape and relaxation are much needed within the city (with easy access) to separate ourselves from the external world. Children are masters in identifying and enjoying such ‘secret places’, and in finding joyous moments in pocket spaces and intimate gardens, but must be given the opportunity to spend time outdoors and to appreciate nature as they encounter it, without preconceptions or prejudice (Hand *et al.*, 2017; Rautio *et al.*, 2017).

In the urban regeneration process, ideally we want to increase the density of cities and increase access to urban green space. Increasing the amount of urban greenery and facilitating access to urban green space while at the same time increasing urban density is not a contradiction, but a smart strategy that is feasible, as currently demonstrated by a number of large regeneration projects, from Barcelona to Singapore. Malmö in Sweden has positively branded itself as the ‘City of Parks’, and Singapore calls itself the ‘City in a Garden’. Of course regeneration must be done sensitively, both for the environment and the local community. The New York High Line development has attracted much praise and attention, but has also drawn criticism for its failure to address existing social problems and for its gentrifying effect on the local area (Lang & Rothenberg, 2017; Littke *et al.*, 2016).

Biodiversity loss and ecosystem degradation – what can urban planners and landscape designers do?

Our cities are facing a wide range of challenges, with unsustainable urbanisation (frequently at too low density) in turn being linked to human health problems, the degradation and loss of natural capital and its corresponding ecosystem services (clean air, soil and water), climate change and a worrying increase in the risk of natural disasters. Urban expansion is leading to changes in the countryside, shifting green space to ‘artificial surfaces’. An aerial survey of the UK in 2015 revealed that over 22,000 hectares of green space was converted to artificial surfaces between 2006 and 2012. Over 7,000 hectares of this were previously forest, and over 14,000 hectares were previously agricultural areas and farmland. Over 1,000 hectares were changed from wetlands to artificial surfaces in order to provide more space for households. Completion of urban construction sites comprised nearly 3,000 hectares and completed new industrial and commercial developments slightly over 1,000 hectares (University of Leicester, 2015).

More research is needed to clearly define the factors in our current urbanisation models that hinder the reconnection with nature in the urban system. These factors are partially economic, social, technical and environmental. Governments are increasingly trying to quickly fix the issue of housing affordability by boosting supply and approving unacceptable housing developments on precious greenfield land. However, far too many homes are being planned and built on greenfield sites that were formerly protected green-belt land. There are sufficient brownfield sites for an extra million homes in England alone, and there is no excuse for further encroaching into precious greenfield land that is necessary for recreation, biodiversity, forestry and food supply (CPRE, 2018). The redevelopment of brownfield land and infill densification is still not prioritised enough by the government, developers and policy makers.

Obviously trees and their canopies are a critical piece of the life support system on this planet and are vital for any future project. Urban forest projects, constructed wetlands and the urban farming movement are all good ways to re-integrate nature into an urban setting (see: Figure 4). Natural elements such as street trees, gardens and planting have been a feature of cities for hundreds of years. The most effective urban green space is not a lawn, but a garden with tree coverage from different types of trees

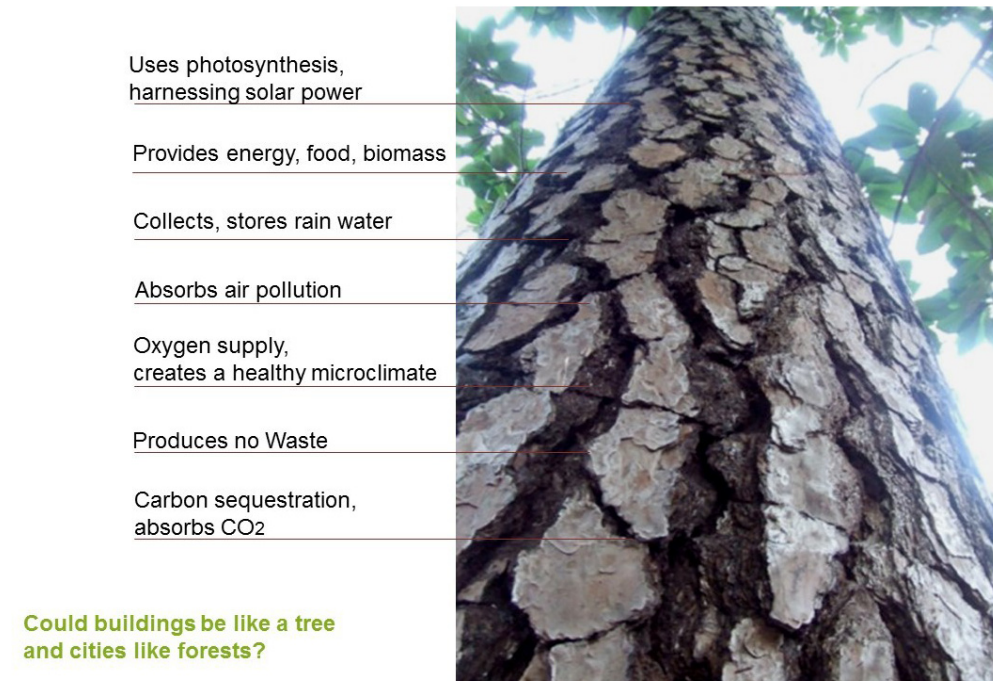


Figure 4. A tree knows no waste, but provides a large range of ecosystem services (image: S. Lehmann, 2010).

and bushes. As far back as his 1722 book (Fairchild, 1722), ‘The City Gardener’, the English botanist Thomas Fairchild (1667–1729) noted that city residents feel more relaxed and healthy when they can enjoy gardens and greenery. He suggested to improve air pollution and improve the urban micro-climate in London by creating parks and gardens, and he also realised that numerous small gardens with trees and bushes are more effective rather than just a large park with a lawn. Almost three hundred years later, the research on the urban heat island (UHI) effect confirms Fairchild’s observation (Bowler *et al.*, 2010; Doick *et al.*, 2014).

The dangerous UHI effect leads to significantly warmer urban areas compared to surrounding rural areas, and this temperature difference is usually larger at night than during the day. The UHI effect occurs because the dense, dark surfaces (such as bitumen on roads and concrete on building roofs) absorb and store heat during the day and then release it at night. Urban greenery can help reduce this heat gain and the impact on human health (Lehmann, 2015; Sailor, 2014). The main cause of the UHI effect is from the modification of land surfaces and material, for instance concrete roofs that store and trap solar heat during the day. It can best be counteracted by green roofs (and facades) with planting and vegetation, white or light-coloured surfaces (using the albedo effect to reflect solar radiation) and the use of materials that absorb less heat (Note: from 2012 to 2014, the author was principal investigator of ‘Urban Climate Research’, the largest study of the UHI effect in Australian cities). It is only a question of time until green roofs will become mandatory for new buildings in the UK.

Understanding the many benefits of urban greening, municipalities are now looking at how urban areas can adapt their

landscapes to better cope with increasing heat stress and the UHI effect. There is growing understanding and appreciation that re-naturing cities can help provide viable solutions for urban engineering, using and exploiting the properties of natural ecosystems and the services that they provide. Ecosystem services that city vegetation delivers, through avenues, gardens, parks, wetlands, urban forests, green roofs and living walls are much celebrated. These ‘nature-based solutions’ (NBS) can provide practical, sustainable, cost-effective and adaptive alternatives for various urban planning objectives; by working with nature, rather than against it, it is possible to take further steps towards a more competitive, resource efficient and greener economy (often termed ‘green growth’). It can also help to enhance natural capital rather than depleting it.

The term ‘nature-based solutions’ refers to the use of nature for tackling environmental and societal challenges while increasing biodiversity. A definition offered by the European Union Commission, who has been funding some of our research in NBS, states that these solutions ‘inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience (...) and bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions’ (EU-Commission, 2015 and EU-Commission, 2017).

For instance, green roofs or walls can be used to reduce the impact of high temperatures, collect storm water, reduce pollution and fine dust, and act as carbon sinks, all whilst simultaneously enhancing biodiversity. Similarly, the collection and storage of rain water in constructed wetlands, or the protection of

mangrove forests along coastlines utilise a nature-based solution to achieve several objectives, including disaster risk reduction. Urban flood control is regulated in a natural way, with mangroves alleviating the impact of wind and waves on coastal settlements or cities whilst also capturing CO₂. Additionally, the mangrove forests can provide safe nurseries for marine life and help control coastal erosion resulting from a rise in sea-levels, mitigating potentially harmful effects on the environment and on human health and society (Kabisch *et al.*, 2016; Lennon & Scott, 2014; Maes & Jacobs, 2017).

New urban design concepts should form a model for incorporating and re-introducing greenery and biodiversity into the urban built environment. Maintaining biodiversity in the face of urbanisation, habitat loss, environmental deterioration and climate change is one of the most extreme challenges of the present day. The inclusion of trees, shrubs and other plant matter into green spaces and gardens within the city is of paramount importance in helping to keep the urban landscape cool, mitigating against buildings and pavements which increase heat absorption and heat storage, causing the UHI effect.

Numerous studies have been conducted on the role of green canopies in urban life, with the result that tree coverage differs widely between cities (Pauleit *et al.*, 2005; Schwarz *et al.*, 2015). One of these, the 2018 MIT Senseable City Lab study, established the *Green View Index* (GVI) that represents the total percentage of a city covered by trees. The study found that Paris has a very high population density but only a GVI of 8.7 percent, compared to London (12.7 percent), Amsterdam (20.6) or Oslo (28.8 percent) (MIT Senseable City Lab, 2018).

The urban neighbourhoods of the future will have to offer new forms of green space. These will serve a dual purpose, existing both as areas for recreation whilst acting at the same time to mitigate the warmer urban microclimate. Tomorrow's neighbourhoods will also need to generate at least 50% of their own power themselves (Lehmann, 2015). Integrated development which concentrates on energy and water management, green infrastructure and the urban microclimate will take a leading role in urban regeneration. A good example for this trend is *Barangaroo* waterfront development at East Darling Harbour in Sydney, Australia's largest urban renewal project. Here all of the roofscapes are green roofs, which provide rainwater storage and contribute to a reduction in the UHI. Open public space forms 40% of the site, which is already setting new standards for the renewal of Australian inner-city precincts. Similar to *HafenCity* in Hamburg, the developers use landscaping to deal with flood protection (see: Figure 5 and Figure 6).

Measuring the value of nature: Natural Capital

'Natural capital' is the world's stock of natural resources, including soil, rocks and minerals, air, water and all living things. Humans are able to derive a wide range of 'ecosystem services' from this stock of natural capital, indeed these services are what makes life possible, and include water supply, food and biomass supply, clean air supply, energy supply, carbon storage and sequestration, flood control, natural medicines, and so on.

There are also several less visible ecosystem services including climate regulation, the pollination of crops by insects, and natural flood defences provided by mangrove forests, not to mention the inspiration and well-being we take from the natural environment (Hawken *et al.*, 1999) (see: Figure 7).

The World Forum on Natural Capital explains why our natural capital debt is an issue: "*With natural capital, when we draw down too much stock from our natural environment we also run up a debt which needs to be paid back, for example by replanting clear-cut forests, or allowing aquifers to replenish themselves after we have abstracted water. If we keep drawing down stocks of natural capital without allowing or encouraging nature to recover, we run the risk of local, regional or even global ecosystem collapse*" (The World Forum on Natural Capital, 2018).

Understandably, all of these essential services cannot be valueless or priceless, but also have a significant value in monetary, financial terms. For example, a recent report calculated that by providing atmospheric regulation and flood prevention, California's street trees provide over US\$1 billion per year in ecosystem services, and by offering services as diverse as storm protection, fisheries support and ecotourism, Mexico's mangrove forests contribute an annual US\$70 billion to the economy (Rizvi *et al.*, 2015; TEEB for Business Coalition, 2013). The study calculated for the first time the financial risk in real monetary terms of unpriced natural capital inputs to production across different sectors on a regional scale. By using an environmentally extended input-output model (EEIO), it also estimated, holistically and at a high level, how these may flow through global supply chains to producers of consumer goods. Interestingly, the study demonstrated that some business activities do not generate sufficient profit to cover their natural resource use and pollution costs (e.g. coal mining activities continuously ignore indirect costs to health) (Shanahan *et al.*, 2015).

There is a real economy from natural capital that we are not discovering, or accounting for. We are getting the benefits but not recording the value. However, if natural capital were to be lost we would feel it immediately, not least in economic terms. An accurate cost-benefit analysis is needed to find out what is the real cost of not doing the things we need to do for sustainability? Investment can then be made wisely.

Revaluing Parks and Green Spaces is a study published in 2018 conducted in line with HM Treasury's best practice in valuing non-market goods. It measures the contribution of parks and green spaces in UK cities towards individual wellbeing, both in financial and social terms. It provides a robust economic valuation of parks and green spaces in the UK, quantifying the improvements in health and wellbeing associated with their frequent use. It is the first study on parks and green spaces to apply a welfare weighting methodology, allowing for more informed evidence-based policy decisions. The study by UK charity Fields in Trust estimates that the country's parks and green spaces save the UK Government more than £111 million (US\$200 million) in visits to the doctor each year (Fields in Trust, 2018).



Figure 5. Barangaroo in Sydney is Australia's largest urban regeneration project (image: courtesy of Lendlease).

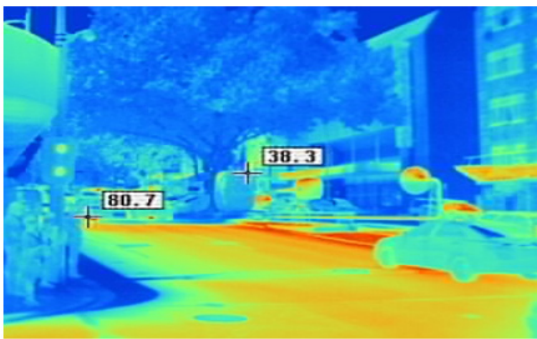


Figure 6. Vegetation and greenery keeps city temperatures cooler during summer, reducing the urban heat island effect. Left: Special cameras reveal urban heat islands. Right: The informal green spaces of university campuses contribute positively to the city (Images, urban heat island effect and campus in Munich: courtesy S. Lehmann).

Nature-based solutions Ecosystem Services

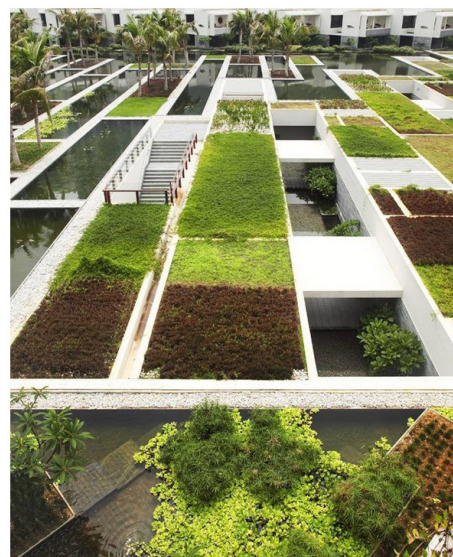
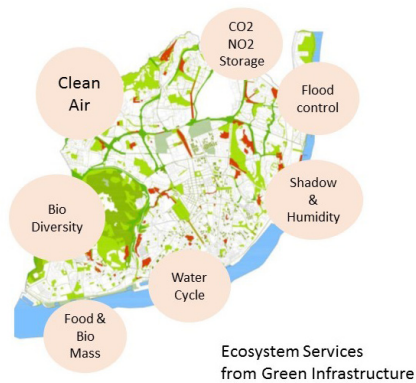


Figure 7. Eco-system services include numerous essential services provided by nature, such as water management and supply, biodiversity, food and biomass, clean air supply and humidity control, energy, carbon storage and sequestration, and flood control (image: S. Lehmann, 2016).

At the individual level, the study found that the Total Economic Value of using parks and green spaces breaks down annually to £30.24 of benefits per person. In addition, the *wellbeing value* associated with the frequent use of local parks and green spaces is estimated to be worth an incredible £34.2 billion (US\$62.23 billion) per year to the UK adult population as a whole (see the research here: www.fieldsintrust.org/research). These findings are compelling figures to consider when discussing the business case for governments and stakeholders investing in more urban green spaces.

Giving ‘ecosystem services’ a monetary value allows for new measures of progress, which are not measured by simplistic GDP growth or other common economic measures. Based on these concepts, ‘environmental justice’ has emerged as a new term, meaning a focus on the fair distribution of the environmental benefits and burdens, increasingly informing environmental policy. Ideally, every person on the globe should ‘enjoy the same equal access to a healthy environment in which to live, learn and work’ (U.S. EPA, 2012; in this context, also refer to the SITES rating system managed by GBCI).

We need more greenery and gardens in our cities, green roofs (planted areas combined with white-coloured roofscapes) and water features, like ponds and small lakes. Merging nature with the urban, the *Urban Manifesto* (Lehmann, 2019) proposes an ecological network with a value system based on an economy of prosperity (not turnover) that also values our natural capital, so we can be citizens, not just merely consumers. It is essential that every urban regeneration project comes with new public green space, small gardens and parks in a wide range of sizes. There are, of course, very different conceptions of what an urban park might be. For instance, Hyde Park in London has been open to the public since 1635 and demonstrates the value of a large (240 hectare in size) park in the city. Frederick Law Olmsted who designed New York’s Central Park in the 1860s, conceived it as a large urban park (340 hectare in size) and a place to escape from the city, as a place in contrast to the surrounding city. Olmsted was committed to egalitarian ideals and was of the belief that common green space should be equally accessible to all citizens at all times, and defended against private intrusion. This is now a fundamental principle behind the idea of a ‘public park’, but was it was previously not assumed to be necessary. Over a hundred years later, Bernard Tschumi, who designed *Parc de la Villette* in Paris (1982), viewed the park as a continuation of the city, with irregular non-hierarchical pathways that lead to nowhere in particular. Another example is the *High Line Park*, an elevated linear park in Manhattan (2009) designed by James Corner Field Operations. Today, a public park for the 21st century is seen as a vital space for cooling cities, cross-cultural neighbourhood contact and social encounters, and as a spatial connector in an increasingly digital and segregated city.

Lessons learnt: Knowing where to begin

Every city is unique. Cities not only differ in their size, density and population distribution, but also in their location and in

the ways in which they are vulnerable to climate change. When it comes to strategies to increase resilience, what works in one city may not work in another. Urban regeneration projects allow to ‘repair’ and restore some of the damage caused to ecosystems whilst enhancing urban resilience. Even when change is acknowledged as necessary, it can be a daunting prospect. Facing the need for change on a large scale it can be helpful to remember that cities are never finished; cities are constantly undergoing transformation. What is needed now is to nudge that transformation in the direction of sustainable and resilient solutions, making the most of opportunities for re-greening, using resources efficiently and acknowledging the value of natural capital.

A good example for such a project is the international research project the author is currently working on: Crunch – the Food-Water-Energy Nexus explores these issues in greater depth using integrated methods (see: www.fwe-nexus.eu).

It may require a paradigm shift in thinking. By beginning to place a value on natural capital, and assessing our vital systems as a whole and not as separate parts, we can begin to make efficiency savings that previously would not have been apparent. In doing so, we not only benefit financially through saving valuable resources and mitigating against environmental risks resulting from climate change, but also contribute towards the repair and renewal of our ecosystem, conserving resources that are finite and helping to prevent further global temperature rise (Lehmann, 2017).

Getting approval for change is not always easy. However, the sooner we can begin to transform our cities into greener, more efficient, climate resilient places to live, the sooner we begin to mitigate against the problems which require this transformation in the first place. By acting quickly we can work to prevent the Earth entering into a ‘hothouse’ state, beyond which human efforts to reduce emissions will be increasingly impossible. This, if nothing else, should provide the impetus necessary to take the first brave steps towards change.

Data availability

No data is associated with this article.

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The opinion article addresses a timely question across research and practice, as for whether and how cities can play a substantial role in moving the Earth System away from a current potential “Hothouse” pathway¹, through implementation of climate change mitigation and adaptation strategies. Within the broad palette of conceptual and operational strategies discussed in literature nowadays, the article concentrates on nature-based solutions, the re-greening of neighbourhoods, and advanced valuation systems for the natural capital.

The discussion provides two complementary yet intertwined contributions to the current flourishing debate on city’s responsibilities and opportunities “in the age of climate change”. I detail both contributions below, focussing on areas where greater specification could help enhance the argument.

The first merit of the opinion articles lies in connecting and, to some extent, bridging “urban sustainability” concepts and methods that originated in distinct disciplinary fields and hence often disconnected or, at least, not synergistically used or combined throughout the literature. The discussion generously engages with a great wealth of urban sustainability concepts, ranging from Urban Metabolism, Circular Economy, Nature-based Solutions, Biophilia, Ecosystem Services, up to Environmental Justice. On this basis, the article surely represents a bold attempt to demonstrate the added value of addressing complementary conceptual and analytical frameworks transversally, a key challenge broadly acknowledged across social and environmental science research advocating the need for more interdisciplinarity and system-thinking. As often observed with sustainability-related prospective essays, the downside of such ambitious efforts lies in some inevitable simplifications and, in some cases, limited discussion (due to space limitations) of the added value of using different concepts within the same knowledge framework. Clearer identification of pathways for cross-fertilization would help clarifying (to both layman and specialist readers) how these concepts are linked or could be linked in a sustainable built-environment prospective.

When introducing the Urban Metabolism approach, the argument will increase in clarity if the

“organism” and “ecosystem” concepts (both used here to refer to the city) were not conflated. It should be noted that, until at least a few years ago, there was a recurring tendency in urban metabolism studies to use these two terms nearly interchangeably^{2,3}. Better integration and more interdisciplinary work across the industrial ecology and urban ecology communities^{4,5} have favoured substantial progress across the urban metabolism approach to increase clarity and consensus on the fact that, rather than organisms, cities *are* ecosystems and not *analogous* to them^{6,7}. This definition is grounded in an understanding of urban ecosystems as human-dominated (and, as such, different from “natural” and said “wild” ecosystems) and characterised by interrelations and feedback loops among material cycles and energy flows (rather than linear input-output dynamics), where regulating and governing mechanisms such as policy and planning play a crucial role in shaping social and ecological processes⁵. Differentiating between the “organism” and “ecosystem” levels when referring to cities in an urban metabolism perspective is not simply a question of semantics. Confining urban metabolism within the limits of the organismal analogy can limit the effective use of scientific principles and frameworks in analysing how cities function and their relationship with the surrounding environment, as well as hamper the consolidation of a common knowledge basis for more transdisciplinary work². Additionally, the use of the urban ecosystem concept and of urban ecology frameworks to understand and analyze the human socio-ecological systems⁸ is particularly critical when aiming at questioning the role of the natural capital in cities and the contribution of properly planned, designed and managed nature-based solutions to improve cities’ resilience to climate change (one of the foci of this article). It is indeed the incorporation of an “urban ecosystem” perspective that can allow urban metabolism studies to properly assess the abiotic/biotic interactions occurring heterogeneously within cities⁹, and (when coupled with economic models) support meaningful attempts to value the natural capital stocks in urban environments (as subsequently emphasised in the article). In this sense, the author’s mention to Tansley’s¹⁰ pioneering text is of clear interest, since the ecologist coined the term “ecosystem” in order to describe the constant interchange among organic and inorganic components, i.e. between the living organisms (individual plants and animals) and between these and all the inorganic factors that compose the environment of a biome. Although Tansley did not attempt to translate these interchanges into energy and material flows (which was done by Lindemann¹¹, with the metabolism idea applied to ecosystems subsequently emphasised by Odum¹²), nor he referred to human-dominated or “urban ecosystems” in particular (in the sense of an Urban Ecological Science¹³), his contribution has the clear merit to have opened the discussion on which level is appropriate to study a city’s degree of heterotrophy through proper consideration of the relationship with its environment and among its biotic/abiotic components².

This point leads to a second suggestion on how to better emphasise the meaningfulness of an urban metabolism approach for the climate change adaptation and mitigation strategies discussed in the article. It is nowadays widely acknowledged in the literature that the reference to the “urban metabolism” concept is of great interest when discussing analytical tools that can support an understanding of the material and energy requirements of cities, in the perspective of optimizing such requirements, reducing their carbon emissions and, consequently, mitigating cities’ impact on climate change^{14,15}. However more insights (based on the author’s experience) into how the “urban metabolism” concept can help advance the discussion on nature-based solutions and their potential to improve cities’ resilience to climate change would strengthen the author’s whole argument. This may, for example, include indications on how urban metabolism analytical frameworks can support effective management of natural capital contributing towards more “circular” urban resource flows (at least when it comes to resource accounting methods,

such Material Flow Analysis, that are increasingly used in research and, to some limited extent, also in decision making and planning practice). Enhancing the use of material and energy flow analysis to advance the planning and design of green infrastructure in cities may be seen as a new frontier in urban metabolism research^{9,16}. On this basis, disclosing the author's own view of such emerging interdisciplinary questions (e.g. through investigation into the cities' food-energy-water nexus) would fuel the debate on the reasons why it is worth discussing urban metabolism approaches as a way forward to "bring nature back into the city".

The second level of contribution to knowledge the article provides lies in questioning the role of urban planners and landscape designers in implementing any kind of climate-sensitive strategy at the city or neighbourhood scale. The author presents and, in some cases, illustrates a range of evidence-based approaches that are well documented in literature but still randomly integrated into practice, triggering thereby an underlining question as for why these approaches are not yet "mainstream". The author's call for identifying the "[economic, social, technical and environmental] factors in our current urbanisation models that hinder the reconnection with nature" becomes even more compelling when addressed to those whose daily work involves "providing more space for households", constantly juggling between quantity and quality parameters. Particularly valuable is the reference to the need for revisiting the "wisdom of nature" to inform new (and probably less resource-intensive and more climate-resilient) organisational structures. How can designers help urban communities to move forward in this direction? How can urban spaces for local sourcing and production (food, energy, water storage) be planned and designed to make a clear (and perhaps measurable) difference in the way resources flows and stocks are managed within urban ecosystems – i.e. to become an integral and functional part of the city's metabolism? Beyond designers' growing enthusiasm for "the fluidity of metabolic processes"¹⁷, can the "wisdom of design" be invoked in the search for new perspectives and the "agency of design" mobilized (again and for good) in the formulation of possible answers to these challenges? The author does mention and illustrate a few built projects in Singapore, Rotterdam and Sydney, which, in his view, represent good examples of integrated energy and water management systems, in which recreational and microclimatic benefits provided by green infrastructure come into play. But, in what exactly do these nature-based solutions provide a valid answer to the overarching climate crisis? More insights into the author's view of potential gains "through designing" would be of great value for this discussion, provided that the author righteously warns the readers against the "tradeoffs" and (environmental and social) "disservices" that nature-based solutions can cause to urban populations, e.g. neighbourhood gentrification due to increased property value, as mentioned for the New York High Line case (or pushing this line of reasoning even further, the carbon emissions associated with the energy demand of the services provided by an urban park¹⁸). The call for more research to connect findings to outcomes across scientific fields and to translate them into actionable knowledge for policy and practice is a much-needed nudge (and, in general, can never be overemphasized).

Finally, the article conclusions provide the opportunity to bring forward questions of stewardship and, to some extent, governance systems, which are essential when it comes to implementing the discussed necessary "change" (both in design strategies and mindsets). The author emphasises that "getting approval for change is not always easy", and that the sooner concrete actions will be undertaken in cities across the world, the more likely scientists' and practitioners' efforts will be to generate successful outcomes. Hence, a final question the article might raise among its readers is: How can we all set the conditions for the change to happen and reasonably "quickly"? In other words, how can effective local to planetary stewardship strategies for urban ecosystems and the

biosphere be “co-designed” within and across communities (of knowledge, practice, and citizenship)?

I wish to thank the author for his thought-provoking contribution.

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Is the topic of the opinion article discussed accurately in the context of the current literature?

Yes

Are all factual statements correct and adequately supported by citations?

Partly

Are arguments sufficiently supported by evidence from the published literature?

Yes

Are the conclusions drawn balanced and justified on the basis of the presented arguments?

Yes

Is the argument information presented in such a way that it can be understood by a non-academic audience?

Yes

Does the piece present solutions to actual real world challenges?

Yes

Is real-world evidence provided to support any conclusions made?

Yes

Could any solutions being offered be effectively implemented in practice?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Urban Metabolism, Green Infrastructure, Ecosystem Services.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 07 March 2019

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Alessandro Premier 

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This opinion article addresses an important issue for the development of contemporary and future urban spaces: the re-connection between man and nature within the built environment. The author proposes a cultural dissertation on how human beings have been gradually disconnected from nature. Scientific discoveries and the Industrial Revolution demonstrated that man could

manipulate nature through the power of technology and – over the centuries – this has led to the current global situation in which we are facing dramatic climate changes. The author argues that, in order to “repair and restore” some of this damage, ample urban regeneration projects are needed. These projects must enhance urban resilience, and the adoption of nature-based strategies like the re-greening of neighborhoods could be the key point for a quantum leap. The article is general well written, and very timely. However, I would like to suggest four minor improvements – hoping that the author will assume them as constructive suggestions.

1. The sentence “Descartes for instance believed that animals had no feelings. His belief was: “Man is at the top and Earth is here for us to use, to exploit”” should be accompanied from adequate quotation from the original author. Descartes developed this topic in the book “Discourse on the Method”.
2. The sentence “Climate change is caused by humans, through the production of heat-trapping greenhouse gases caused by carbon-dioxide”, should be supported by an introduction like this: as stated by the European Commission¹ and several studies, climate change...
3. When mentioning “garden cities” (in the title of a paragraph) a very brief reflection on the garden city movement, the ideas of Ebenezer Howard (expressed in the book “Garden Cities of To-morrow”) and subsequent developments should be added.
4. At page 11 there seems to be a typo: “[...] but was it was previously not assumed to be necessary”.

I really hope the author find my reflections useful and I wish him all the best in his research.

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Is real-world evidence provided to support any conclusions made?

Yes

Could any solutions being offered be effectively implemented in practice?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Technology of Architecture and Sustainable Design

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Comments on this article

Version 1

Author Response 20 Mar 2019

Steffen Lehmann, University of Nevada, Las Vegas, Las Vegas, United States

Thank you to both reviewers for the most thoughtful and valuable feedback, this will improve the quality of the article. Best regards, Dr. Steffen Lehmann

Competing Interests: No competing interests were disclosed.
