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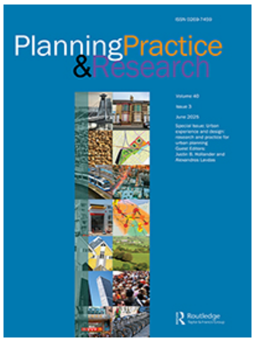

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Towards a successful implementation of the X-minute city vision - the importance of multi- and cross-scale interactions for creating sustainable and resilient cities in an urban planning context

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Towards a successful implementation of the X-minute city vision - the importance of multi- and cross-scale interactions for creating sustainable and resilient cities in an urban planning context

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ABSTRACT
There is a demonstrable usefulness of the focus on the neighbourhood scale promoted in the X-minute city vision, as part of a larger climate change mitigation strategy. However, emphasis on the neighbourhood runs the risk of over-simplifying the processes by which critical urban functions are created. Many urban functions depend on the interplay between spatial scales that needs to be addressed in the X-minute city vision. Here, we provide examples of how multi- and cross-scale interactions play an important role into the generation of three critical urban functions: ensuring food security, adapting to climate change and reviving public life.

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X-minute city; multi- and cross-scale interactions; sustainable urban planning; resilient urban planning; climate change adaptation

Introduction

Cities face multiple challenges, from intense population increase to the many negative impacts of climate change and, hence, governments must work towards improving their sustainability and resilience (United Nations, Department of Economic and Social Affairs, and Population Division, 2019). In this context, CO_2 mitigation strategies have been at the forefront (Pörtner *et al.*, 2022) that, in an urban context, often is about reducing private car mobility because it constitutes a large part of urban greenhouse gas emissions. Multiple visions have been put forward to deal with this challenge, such as the Smart Growth[2]- and the Smart City vision[3] and recently, the X-minute cities vision. The idea is to switch from transport by car to active transport and design urban spaces which enable and promote walking and biking (Frumkin, 2004; Pucher *et al.*, 2010; López-Lambas *et al.*, 2021) by making amenities more accessible (Da Silva *et al.*, 2020; Logan & Guikema, 2020; Graells-Garrido *et al.*, 2021; Moreno *et al.*, 2021), hence, creating cities of proximity (IEA, 2020; Brand *et al.*, 2021). The X- minute city vision, in addition to reducing CO_2 emissions, also claims to generate benefits in the context of health and social cohesion (for an overview, see e.g. (Logan *et al.*, 2022)). Similar to the Smart

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Growth vision, the focus of the X-minute vision leans heavily, if not solely, towards CO_2 mitigation strategies (active) transportation modes and accessibility. The key planning parameter in the Smart Growth vision for improved accessibility is densification, while the focus of the X-minute city vision is proximity. Although densification and proximity arguably constitute different sides of the same coin, the two visions take on quite different approaches on the issue of scale. While the Smart Growth vision extends its focus across multiple scales, ranging from entire urban regions down to the very local neighbourhood scale (see e.g. Gren *et al.*, 2019), the X-minute city vision focuses primarily on the neighbourhood scale. By promoting pedestrian-based proximity, the X-minute city aims to enable inhabitants and city users to access destinations that fulfil most of their daily needs within a short walking distance (Moreno *et al.*, 2021; Shue, 2022). This shift is expected to reduce reliance on motorized traffic and render retail and services viable at a local scale. While such a shift may indeed potentially contribute positively to achieving these goals (see e.g. Logan *et al.*, 2022), there are ample evidence that the study of cause – effect relationships at multiple scales is required to understand and ultimately being able to counteract many pressing environmental problems, often amplified in an urban context, such as climate change, land-use/land-cover change and invasive species (Carpenter & Turner, 2000; Gunderson & Holling, 2003; Soranno *et al.*, 2014; Lindborg *et al.*, 2017; Berghauser Pont *et al.*, 2021). Through its primarily narrow focus on proximity at the neighbourhood scales, we hypothesize that the X-minute city vision runs the risk of failing to manage some of the very benefits it sets out to achieve, as well as failing to address additional benefits essential for sustainable urban development. Also, the one-sided focus on CO_2 *mitigation* strategies in the X-minute city vision, vs also addressing climate change *adaptation* strategies, signals a potential lack of a convincing resilience focus (Pörtner *et al.*, 2022). Similar critique has also been aimed at the Smart Growth and Smart City visions (Colding & Barthel, 2017; Gren *et al.*, 2019).

What we propose to do

In the pursuit of sustainable and resilient cities, we, in this paper, want to contribute to avoiding over-simplifying the implementation of the X-minute vision, by providing examples of how multi- and cross-scale interactions are key to understanding the generation of some critical urban functions. In this paper, we will focus on three distinct but interconnected and critical urban functions: ensuring *food security*, *adapting to climate change*, and *reviving public life*. Before we discuss these critical urban functions, the issue of scale must be addressed properly as the term scale is used in many fields and is often interpreted quite differently in one discipline from another. They have in common that scale is used to measure and compare things such as earthquakes that are measured on the Richter scale. There are also many related concepts like; level, resolution and extent, often used as replacements or synonyms (Gibson *et al.*, 2000). In studies on cities, not least, there is a wide range of references to scale, which also have given rise to a variety of categorizations, such as 'local-global', 'micro-meso-macro', 'neighbourhood-district-city-region'. According to Mike Batty, we by scale basically mean two things: 'the level of resolution at which we observe the city, which is essentially map scale, and the level of functional differentiation that takes place in different sizes of location or city' (Batty, 2005). It is the latter we are interested in here. The simplest way to analyze this is by comparing the size of the individual units, for example by measuring their area. Another approach is to measure size in a systemic way, where one does not compare the size of individual units, such as area of neighbourhoods, but the relative size in terms of their impact or importance in the system (i.e. the city) as a whole. It could, for example, concern the relative distance from the individual unit to all other units, where a short such distance could be argued to represent a strategic location and be interpreted as one way of measuring the individual unit's systemic size. Moreover, such analysis could be conducted within different distance radii of the individual unit, for instance set by metric distance but also time distance, in line with the X-minute city. These radii open for the valuable possibility to compare the individual units' role and function at different scales. While also fractal theory provides important insights into the trans-scalar structure of the urban environment, but it emphasizes the morphological and recursive structure of cities. Our approach focuses instead on systemic and functional differentiation across scales – emphasizing how the roles and positions of urban units shift depending on their contextual relationships rather than their geometric properties.

In what follows, we first present the three critical urban functions: *ensuring food security, adapting to climate change*, and *reviving public life* with the aim to exemplify the importance of trans-scalar interactions among urban systems. After having highlighted the importance of the Issue of Multi- and Cross-Scale Interactions in an Urban Planning and Design Context, in the discussion section, we present several available frameworks and tools to work with trans-scalar interactions effectively. In the concluding section, we bring the work presented back to the X-minute city visions.

Assessing multi- and cross-scale interactions for three critical urban functions

Ensuring food security

Food production, crop pollination and urban green areas

Having land available for growing food for rapidly increasing human population conflicts with current and pending urban expansion (United Nations, Department of Economic and Social Affairs, and Population Division, 2019) that has taken place almost exclusively at the expense of farmland (see e.g. Russell, 2006; Munton, 2009). Furthermore, 75% of the world crops rely on pollination for crop output (Klein *et al.*, 2006). Hence, in the context of safeguarding crop production, an important part of food security, albeit, not the only one (see e.g. Smith, 2021), is the ecosystem service of crop pollination also needs to be addressed (Gren & Andersson, 2018). Although farmland is an important land use type for underpinning crop pollination, e.g. through providing food for pollinators (Westphal *et al.*, 2003), additional land use types, often referred to as semi-natural habitats, are required to meet pollinator needs for food and nesting sites (Holland *et al.*, 2017; Eeraerts & Isaacs, 2023). Here, urban green areas, if properly planned and managed, have been shown to constitute excellent pollinator habitats, to the point of even becoming source areas of the crop pollination service to the surrounding urban agricultural landscape (Andersson *et al.*, 2007; Ahrné *et al.*, 2009). Hence, beneath the apparent direct trade-offs between finding suitable land for projected urban development and preserving enough agricultural land for food production, there is potential for compromises, opportunities and synergies, by better grounding the urban planning process in an ecosystem service and pollination potential reality (Gren & Andersson, 2018). However, this, amongst other things, requires an understanding of the complexity of the issue of scale.

Crop pollination, multi- and cross-scale interactions and connectivity

Crop pollination can be referred to as a population-based ecosystem service (Kremen *et al.*, 2007; Tscharntke *et al.*, 2007; Bengtsson, 2009). Such ecosystem services depend on the population- and community dynamics of the service providing fauna (Jonsson *et al.*, 2014).

The local pollinator community is a collection of species assembled from a larger-scale biogeographic species pool (see e.g. Ricklefs & Schluter, 1994; Leibold *et al.*, 2004; Carstensen *et al.*, 2013), hence, demonstrating the multi-scale nature of the (crop) pollination service. Furthermore, the behaviour of the (crop) pollinators is characterized by interdependencies between processes at the local- and the larger scale, which can be categorized as cross-scale interactions (Soranno *et al.*, 2014).

In the field of landscape ecology, connectivity between green areas has been identified as a key parameter for the (crop) pollination service (Alberti, 2008; Kindlmann & Burel, 2008; Vasiliev & Greenwood, 2023; Graffigna *et al.*, 2024). Through the potential role of urban green areas as pollinator habitats, this connectivity also becomes relevant in an urban planning and design context (Mörtberg *et al.*, 2012). Hence, in the face of ongoing and pending massive urban expansion, where urban green areas are continuously being eroded (Colding *et al.*, 2020), scale relevant planning and design of urban green area connectivity becomes key. Using bumblebees as an example of a crop pollinator group (Kremen *et al.*, 2002), two relevant scales of operation, the day-to-day movement scale and the dispersal and colonization scale, are compared in Figure 1.

Biodiversity, ecological resilience and scale

The underpinning of biodiversity constitutes an essential part of building ecological resilience[4] (Gunderson, 2000; Elmqvist *et al.*, 2003) and requires an understanding of the scale of operation of the various species involved (Peterson *et al.*, 1998). Species that perform different functions, i.e. they belong to different functional groups, can potentially operate at the same spatial scale, provided they do not utilize the same resources (MacArthur, 1955). This type of diversity can be referred to as functional diversity. Species belonging to the same functional group, i.e. they perform the same function, e.g. pollinating a certain type of crop, do not operate at the same scale. This type of diversity, having multiple species performing the same function, is referred to as response diversity. Hence, while there are multi- and cross-scale interaction to consider in relation to managing a single functional group, e.g. bumblebees (Figure 1), there are additional scales to consider if the goal is to promote multiple species within a functional group, i.e. to promote response diversity. For example, two different pollinator groups, solitary bees and bumblebees, belonging to the same functional crop pollinator group, perceive the scale of the landscape matrix differently, due to differences in their day-to-day movement ability. While the range of solitary bees day-to-day movement, based on a study of 16 different solitary bee species (Gathmann & Tscharntke, 2002), is approximately between 150 and 600 m,

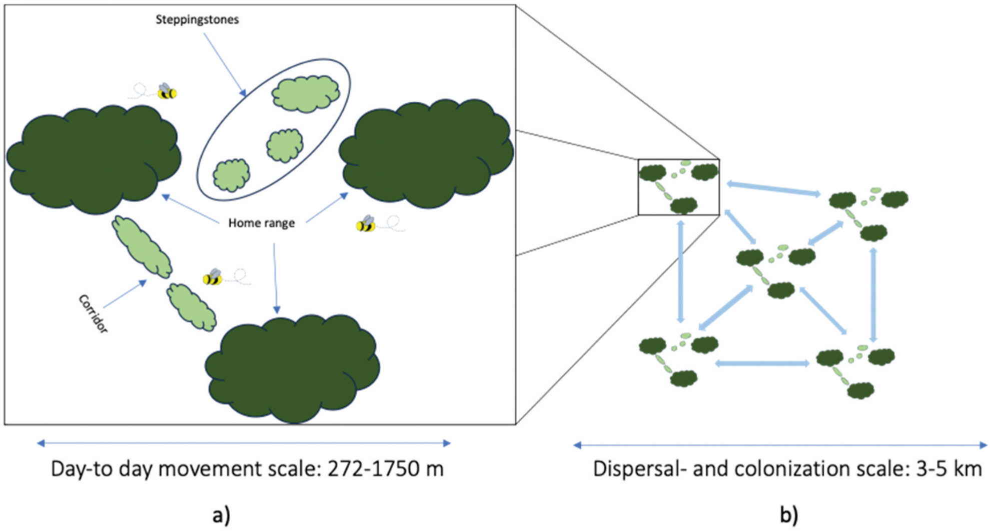

Figure 1. The local bumblebee pollinator community, (a), is a collection of species assembled from a larger-scale biogeographic species pool (b). The scale of operation at the local scale is linked to the day-to-day movement of bumblebees (Dramstad, 1996; Walther-Hellwig & Frankl, 2000; Osborne *et al.*, 2008; Redhead *et al.*, 2016) and the scale of operation at the larger scale is linked to the dispersal- and colonization movement of bumblebees (Lepais *et al.*, 2010). Various green design elements, such as stepping stones and corridors, can be used to build connectivity between home ranges.

the range of the bumblebees day-to-day movement, based on multiple studies (Dramstad, 1996; Walther-Hellwig & Frankl, 2000; Osborne *et al.*, 2008; Redhead *et al.*, 2016), is approximately between 272 and 1750 m. Such scale differences matter in the context of planning and designing (urban) green area connectivity, e.g. with regards to the placement, numbers and sizes of various (urban) green area design elements, such as corridors and stepping stones.

Having multiple members in a crop pollination functional group, i.e. having a high response diversity, contributes to food security by increasing the probability of upholding crop pollination in the face of multiple types of change. For example, a solitary bee species and a bumblebee species, belonging to the same functional group, respond very differently to climate change induced disturbances. While a univoltine species (i.e. a species that only has one brood of offspring per year), such as the solitary bee species *Osmia bicornis*, may struggle to face an extended summer season (Radmacher & Strohm, 2011), a multivoltine species (i.e. a species that can have two or more broods of offspring per year), such as the bumblebee species *B. terrestris*, may, instead, cease on this as an opportunity to start one or more additional generations in the growing season (Robinet & Roques, 2010). Reversely, while the dependence on a few key early flowering plants of many bumblebee species, early in the season, makes them vulnerable to changes in the flowering phenology of these key plants (Kudo *et al.*, 2004; Axelsson Linkowski *et al.*, 2004; Post *et al.*, 2008), the later seasonal emergence of many solitary bees, such as *O. bicornis*, renders them less sensitive to such climate change induced disturbances. Having both these types of pollinators present in the urban agricultural landscape has indeed proven valuable in an ecological resilience and food security context (Engström *et al.*, 2020).

Building urban food security, in the sense of upholding pollinator sustained crop production in the face of (climate) change, hence, requires an understanding of the various multi- and cross-scale interactions related to the species carrying out the ecosystem service at hand.

Adapting to climate change

Urban climate resilience, nature based solutions, ecosystem services and the issue of scale

The potential of green spaces to provide ecosystem services that can enhance urban resilience against adverse effects of climate change, by e.g. implementing various climate change adaptation strategies, is widely acknowledged (Potschin *et al.*, 2016; Kabisch *et al.*, 2016; Sharifi & Yamagata, 2018; Pan *et al.*, 2023; IPCC, 2023). Integrating ecosystem services into urban planning and design through the adoption of so called Nature Based Solutions (NBS) are supported in various EU policies, like the European Green Deal, the Biodiversity Strategy for 2030, and the Green Infrastructure Strategy (EEA, 2021) and the role of NBS for building urban resilience in an urban planning and design context has been highlighted (Frantzeskaki *et al.*, 2022).

The successful implementation of NBS oriented climate change adaptation strategies requires an in depth understanding of the scale of the functions and processes behind the generation of the ecosystem service(s) at hand, which can vary from assessing the potential of a single tree to provide micro-climate regulation and shading in the face of heat waves (Cimburova & Berghauser Pont, 2021), to understanding the multi-scale interactions for climate proofing an entire city against heavy rainfall events (Egegård *et al.*, 2024). Typically, the implementation of NBS-oriented climate change adaptation strategies in an urban planning and design context has been limited to small-scale interventions at the micro-scale of cities, such as the construction of green roofs, rain gardens, permeable and porous pavement, vegetated swales and bioretention. However, climate-proofing larger areas require the implementation of large-scale NBS through appropriate upscaling (see e.g. Vojinovic *et al.*, 2021). Unfortunately, an adequate focus on the issue of scale in implementing NBS is still missing (Odongo *et al.*, 2022).

Implementing a large-scale NBS for climate proofing an entire city – the example of water run-off mitigation

Depending on the ecosystem service at hand, upscaling may not be as straightforward as merely implementing a desired NBS in enough local places for it to matter on a larger scale. For example, in the context of trying to climate proof an entire city against heavy rainfall events, local land use changes, e.g. caused by the implementing of upstream local urban development projects, will affect the water run-off mitigation potential of the sub drainage basin within which the land use changes are taking place and the geographical location of the sub drainage basin within the larger drainage basin context, will, in turn, influence the water volume that ultimately reaches the downstream (urban) areas (Figure 2).

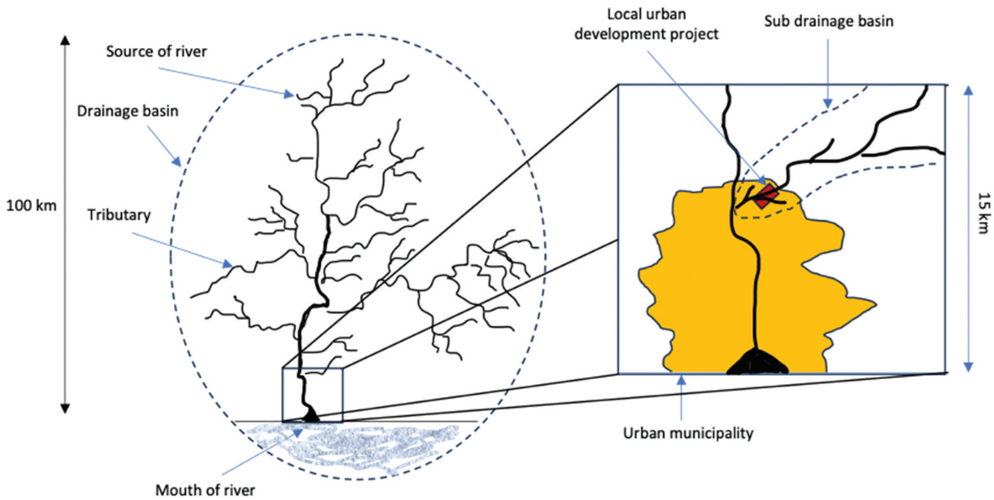

Figure 2. Example of a coastal city and its location within a typical drainage basin (inspired by the Göta river drainage basin in the city of Gothenburg, Sweden). Rain that falls inside the drainage basin will flow downstream through the various tributaries, ending up at the mouth of the river. Changes in land use, e.g. through the implementation of a local upstream urban development project (red rectangle), will influence the water run-off mitigation potential of the sub drainage basin within which the development project is located, affecting the quantity of water that will run through the urban municipality (in orange) and, ultimately, the volume of water that will reach the mouth of the river.

Hence, in the context of climate proofing, an entire city against heavy rainfall events through water run-off mitigation, local scale urban development projects need to be understood in a multi-scale drainage basin context. As an example, in a study of the City of Gothenburg, Sweden, Egegård *et al.* (2024), using the Urban Flood Risk Mitigation (UFRM) model,[1] found that, due to geographical location, soil type- and land use type conditions, the implementation of a planned local urban development project upstream of the city centre, would unproportionally erode the ability to climate proof the entire city against predicted increase in the frequency and intensity of heavy rainfall events.

Reviving public life

Quality and inclusivity of shared urban spaces, often where co-presence happens

Socio-economic segregation is a concern for cities that has been discussed and studied extensively, albeit mostly focusing on residential segregation (Legeby, 2013). Segregation is a subject of concern in urban policy because the concentration of deprived populations in specific neighborhoods can represent a threat to social cohesion, hindering citizen participation, access to the labor market, educational attainment and even lead to urban unrest and riots (Haandrikman *et al.*, 2023).

To combat negative segregation, initiatives often focus on diversifying the types of dwellings in neighbourhoods with the aim to attract residents with other socio-economic profiles. The scale of segregation is here thus measured on the individual unit of a neighbourhood and compared to the other neighbourhoods in the city or the whole country. Living in a diverse neighbourhood is though not a guarantee that one encounters the other, while this is found to be important for the nurturing of desirable societal processes in a city (Legeby, 2013). The sharing of space makes people gain information and knowledge from fellow citizens and participate in processes that negotiate social structures, identities, and acceptable behaviours (ibid). In cities, these encounters take typically place in public spaces such as streets, squares, parks and so on, that frame and support everyday life in the city (Hanson, 2000; Marcus & Legeby, 2012). How many people one encounters (i.e. are co-present) and whom we meet in public spaces is found to be associated with the emergence and distribution of movement flows, which in turn depend on the configurational properties of space, that is, the degree to which a specific place – a street or a square – is related to other places even at great distances away (Hanson & Zako, 2007; Hillier, 2007; Legeby *et al*., 2015). It is demonstrated that these variations are primarily the result of the interrelation between local and city-wide networks of public spaces, meaning that spatial relations at the city level are important for the properties of local spaces. To measure social encounters in public space, we thus need to compare its role and function at different scales using different radii. A local square has typically an important role in the network of public spaces nearby but drops importance at the larger radii. The cities main square typically has an important role at various radii. Here, we can expect to meet people from across the city, while in the local square we can expect to meet locals. A comparative study on co-presence in Gothenburg shows that public squares that are well integrated in the street network of the whole Gothenburg

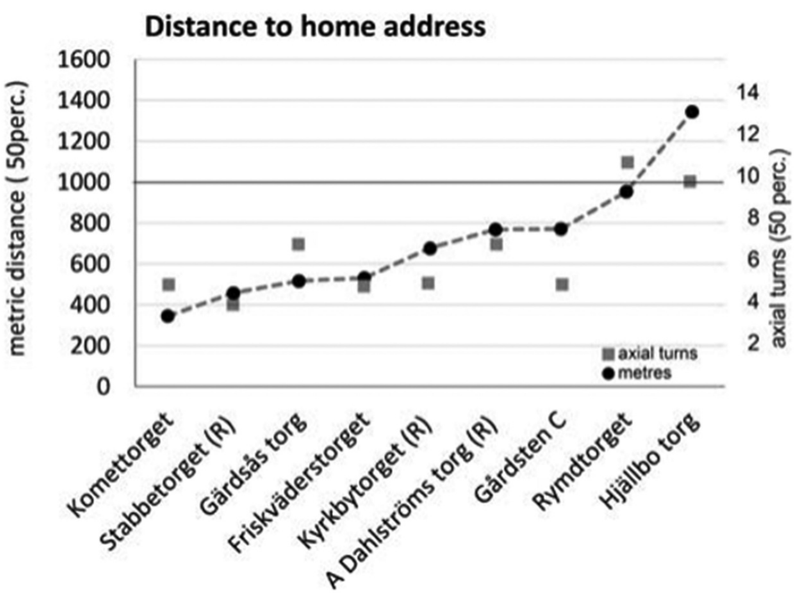

Figure 3. Diagram showing the social catchment of squares in Gothenburg by measuring the distance from the square to the home address of visitors to each square. This reveals who is contributing to the local everyday life at each square, where Komettorget has a more local character, while the potential for citizens from other parts of Gothenburg being present is higher at hjällbo torg. This social pattern has proven to be associated with measures of spatial segregation (Legeby *et al*., 2015). Source: Legeby *et al*. (2015). Permission to reprint this figure has been given.

host visitors from neighbourhoods across Gothenburg, while spatially segregated squares were mainly visited by locals (Legeby *et al.*, 2015). In other words, there is an association between spatial and social segregation (Figure 3).

The informal surveillance of locals and strangers by being co-present in public spaces or by the informal surveillance of residents over public space has also been shown to impact urban safety (Hanson & Zako, 2007). The urban models of modernism with inward-facing housing groups ruptured this spatial interface between inhabitants and passers-by. The separation of local streets from access streets and motorized traffic from pedestrian flows has also contributed to this split.

To combat segregation, initiatives have typically focused on initiatives targeting work, health and education. When spatial aspects are addressed, these have primarily focused on renovation of the housing stock and replacement of the housing stock to diversify the types of housing in the neighbourhood, often combined with densification (Legeby *et al.*, 2015). Both initiatives to reduce segregation or the negative impact of segregation are focusing on the individual neighbourhoods, ignoring the role of the larger urban system to promote co-presence and encounters in public space, although it might be faster and cheaper to get people from neighbouring areas with varying socioeconomic profiles to meet in public space than trying to diversify both these areas. We do not claim that such initiatives should replace the others though. The aim here is to highlight the importance to also include a multi- and cross-scale perspective when trying to mitigate negative segregation in cities.

A network of public spaces to overcome social exclusion

To support day-to-day interaction between people and exchange of information, which in extension may also contribute to the overcoming of social exclusion, we must understand how to support and distribute probabilities of co-presence and encounter. Space syntax has contributed to the understanding of how the distribution of public spaces is correlated with the distribution of pedestrian movement densities, also after controlling for land uses and densities (Hillier & Iida, 2005; Berghauser Pont *et al.*, 2019; Peponis, 2024).

Interestingly, these networks of public space can almost universally be characterized by a clear distinction between a foreground and background network (Hillier, 2002). The foreground network is characterized by streets that are well-integrated to create a grid that traverses and connects the whole city in multiple directions, while the background network represents a large set of shorter infill lines with lower integration at the city scale. These can still be well-integrated on the local scale, supporting local encounters with a smaller group of people. The foreground network typically hosts land uses that require a high flow of pedestrian movement and because of this, attracts more economic activities, especially those that are dependent on a higher flow of people. The background network on the other hand is often dominated by residential functions. The flow of people in these streets is generally much lower. The foreground network is important as well as the interface between the foreground and background network to support encounters between different social groups.

The distribution of retail

The distribution of retail in cities is often explained by a combination of three factors (Scoppa *et al.*, 2009). First, the distribution of population; second, the frequency with which shopping occurs (shopping for food, for example, occurs much more frequently than shopping for furniture); third, the structure of accessibility which determines how far and how fast people can travel to satisfy retail needs. The concentration of retail in centers is thought to produce economies of different kinds, ranging from the ability to satisfy several shopping needs with essentially one trip, to the success of each shop thanks in part to the presence of potential clientele attracted by other shops. Further, centers are organized hierarchically, where small centers respond to more frequent and more local demand. These smaller centers are nested between larger centers responding to less frequent and more global demand.

The distribution of these centers over the area of the city is often thought to be mainly a function of the distribution of population but in many cities, shops are almost ubiquitously distributed, not only in what we would call the center. What varies is the intensity of their presence in different areas or along different streets. It is revealed that the structure of connectivity can theoretically distribute opportunities for retail throughout the urban fabric as a function of accessibility. So, it is not primarily about population density but also about how easily each location can be approached from surrounding locations at varying ranges of distance (i.e. different radii or scales). This is central to Space Syntax as was already described above. Instead of focusing on the street as a place for encounter, do we now focus on the street as a distributor of pedestrian intensities that, moreover, are recognized as an important driver of local markets and economies (e.g. Hillier *et al.*, 1993; Hillier, 2007).

Identifying multi-scalar street types to describe retail potential

In line with the discussion of foreground and background network, we see here that the foreground network highlights streets that are well integrated on the city scale and drive local markets and economies that depend on a higher volume of pedestrians, while the background streets play a more modest role on that level with lower volumes of pedestrians and markets. The street becomes so also a place of encounter between citizens and, as discussed earlier, a place where processed of social integration start. A large pedestrian study conducted in 60 neighbourhoods of different type (from low dense villa areas to dense and central areas) in three main cities in Europe (London, Amsterdam and Stockholm) has shown that the differentiation between foreground and background network plays an important role for the distribution of pedestrian flows. This confirms the importance of a multi-scalar description of streets such as has been developed in more sophisticated descriptions using clustering analysis. This has resulted in methods that allow us to identify street types with different multi-scalar profiles (Serra, 2013; Berghauser Pont *et al.*, 2019) that furthermore can explain the intensity of pedestrian flow, its spatial distribution and fluctuations in time (e.g. rush hour, weekday vs weekend).

Berghauser Pont et al. (ibid), for instance, distinguished four street types (Figure 4). The 'City streets' include streets with increasing centrality at the higher radii. These streets play an important role in the movement at the larger scale across the whole city. The 'Neighbourhood streets' represent streets with consistently high centrality on most scales but dropping clearly

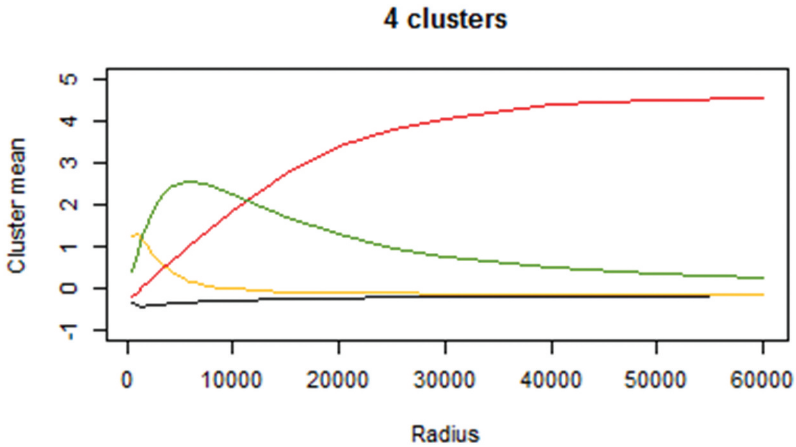

Figure 4. Multi-scalar street types with centrality betweenness on the y-axis and the radii of analysis on the x-axis. City streets (red line) have a general high centrality that growth when the radii of analysis increases. Neighbourhood streets (the green line) have a high centrality at the lower radii that decrease at higher scales. Local streets (yellow line) have only high centrality at the lowest radii, while the background streets (dark blue line) have overall low centrality.

on the lowest and highest scales. These streets have an important function for the movement between neighbourhoods. The 'Local streets' include streets with high centrality only on the very local scale but dropping centrality on all other scales. These streets play an important role in movement within neighbourhoods. The 'Background streets' represent most streets with low centralities at all radii and have generally lower number of people in the street.

Returning now to the distribution of retail, it is not a far stretch to see how these different street types will be fit for certain economic activities. The local street is a good location for the local bakery, while in the city street retail that is dependent on a clientele from the whole city thrives better. This street can more easily be reached from across the city and will thus be an attractive location for other types of activities. Again, this example shows how important it is to go beyond the description of local streets characteristics such as its width and alignment of buildings as well as street furniture. To know what function the street will have in the movement patterns of people and which activities will be successful, an understanding of the role of the street in the street network is crucial as was highlighted already by Jacobs (1961), where she argued for short blocks to increase the number of possible paths to reach all destinations in a neighbourhood. She thus emphasizes the role of movement that is directly linked to the configuration of the street network. To describe the role of the network for movement in cities, Space Syntax uses two centrality measures. First, Closeness centrality that measures the connectivity of each street with all other streets. Higher values indicate that the street is spatially better integrated. This measure shows similarities to other network measures used in walkability studies such as network density (Berghauser Pont and Haupt, 2023) and density of road crossings (Wang *et al.*, 2024). Second, betweenness centrality measures the role of the street when moving between areas. Higher values indicate the importance of that street as a path connecting different parts of the city. Both measures are good indicators for the movement patterns in cities, both in terms of distribution and count.

Discussion

Contending with the issue of multi- and cross-scale interactions in an urban planning and design context

The three urban functions discussed in this paper show how important scale is for a proper understanding of how cities work. For instance, an area detected as relatively homogeneous at one scale may prove to be quite heterogeneous at another. Moreover, it is not least enquiries of overlapping scales, that is, where localities simultaneously perform on different scales and thereby are reinforced or weakened, that prove critical for our understanding of urban phenomena and processes such as segregation. Concerning this critical interplay between scales, Jacobs (1961), for instance, took a critical position to planners' ability to establish self-governing neighbourhoods, given their stubborn focus on the neighbourhood scale and negligence in putting it in relation to the over-all city scale for a proper understanding of the functioning of neighbourhoods. As discussed thoroughly elsewhere, Jacobs was probably the first to argue the need of a consistent systems view of cities,[5] famously answering her own question: What kind of a problem is a city?: 'Cities happen to be problems in organized complexity' (Jacobs, 1961).

To summarize, proper understanding of urban phenomena in most cases necessitate having a multi-scale approach that covers, for instance, micro-, meso- and macro-studies, in order to get the full perspective and especially there is a need to move between scales looking for interrelations and reinforcements or lack thereof. Not least, this is important for policy and concrete interventions in urban planning and design. For instance, urban design is normally understood to concern primarily the local scale but through better knowledge about the interaction between scales, an urban development project on one location in the city can perhaps be proven to indirectly influence also other locations and even the city at large. Conversely, to achieve aims in one neighbourhood, interventions in areas elsewhere or on other scales might be necessary. In this regard, hierarchical analysis covering neighbourhood, district and city scale, suggests itself as critical. Recall here the earlier discussion on scale, where we mean that different radii of analysis (the performance of a location within e.g. 500 m, 1 km and 5 km) open for the valuable possibility to compare the individual projects' role and function at different scales.

Physical planning tools to address multi-scalar effects of interventions in the built environment

Tools that have proven useful for navigating the issue of scale in an urban planning and design context share a view of cities and landscapes as networks, typically being described in network analysis (e.g. Newman, 2010), a field that addresses the relations between things rather than the things themselves. Network analysis has been applied in both urban modelling (Hillier, 2007; Batty, 2013) and landscape ecology (e.g. Pascual-Hortal & Saura, 2006). In network analysis, entities of interlinked parts are typically represented using graph theory, which makes use of a very simple geometric language consisting of only two elements: vertices (or nodes) representing the parts, and edges (or links) representing the links. This, because of rather than despite its simplicity, has proven to be an extremely powerful language of representation.

If we begin with the application of network analysis in landscape ecology, several GIS-based digital tools have been developed, where we can distinguish two groups. The first group uses population models that calculate dispersal rates from Euclidean interpatch distances (Akcakaya *et al*., 2004). Changing the interpatch environment by building more houses or by adding new transport infrastructure will not automatically change the outcome as this kind of environmental changes do not affect the distance between the existing patches. This is unfortunate, because it is known that both these transformations affect dispersal probabilities of many organisms (Vergnes *et al*., 2014). The second group uses the Cost-distance algorithm (Karlson & Mörtberg, 2015; Sahraoui *et al*., 2021) or electrical circuit theory (McRae *et al*., 2008) to model species dispersal. Without going into details, these models include not only Euclidean distance but also information about the impedance the landscape constitutes. The chosen route between patches is thus the one with the least resistance and length, giving a more real-life representation of the built environment. Various tools are available to run these kind of analysis such as Matrixgreen (Zetterberg, 2011) and Habitat connectivity analysis (Kindvall *et al*., 2024).

In the urban planning and design context, network analysis is often associated with accessibility that is always measured as an attribute of pairs of origins and destinations. These can be divided into three main groups. First, measures based on spatial separation, which only uses impedance (typically distance, cost, or travel time) in measuring accessibility (Heyman *et al*., 2018). The second is cumulative opportunity and measures the sum of opportunities that can be reached up to a particular time, distance, or cost. The third group is centrality and measures the level of accessibility in the network itself. This is the way accessibility is measured in Space Syntax studies that we have frequently referred to in this paper. Tools to analyze the first two types of accessibility are common in GIS packages, while centrality is less common, but several tools exist such as PST (Marcus *et al*., 2005) and Depthmap (UCL, 2016).

There are to our knowledge no tools that address these two networks in an integrated manner. However, Kindvall *et al.* (2024, in review) have recently developed a tool where the results of centrality measures are used as input data to calculate the level of barrier effect that then is used to measure habitat connectivity and species dispersal.

Here follows a summary of policy relevant insights and identified useful tools for each of the three urban processes, *ensuring food security*, *adapting to climate change* and *reviving public life*, addressed in this paper (Tables 1–3).

Navigating the problem of fit

Linking social and ecological functions

The various multi- and cross-scale interactions identified in relation to the four urban functions presented in this paper, in addition to confirming the significance of a sophisticated understanding of the issue of scale for a successful

Table 1. Key insights and tools for creating and implementing food security policies in an urban planning context, with a specific focus on pollinator sustained crop production. Insights directly referring to the issue of scale are presented in bold.

Ensuring food security	
Insights for food security policies in an urban planning context	Examples of useful GIS-based digital tools for urban planners
• Upholding pollinator sustained crop production needs to be part of any food security plan • the ES of pollination needs to be integrated into the urban planning and design process. • **Successfully integrating the ES of pollination into urban planning entails an understanding of the various multi- and cross-scale interactions related to the pollinator species carrying out the ecosystem service at hand** • Urban green areas, if properly managed, can act as pollinator habitats • **Scale relevant planning and design of urban green area connectivity is key for the (crop) pollination ES** • Having multiple members in a crop pollination functional group, i.e. having a high response diversity, contributes to food security by building (ecological) resilience	• Cost-distance algorithm Karlson & Mörtberg (2015); Sahraoui *et al*. (2021) • Electrical circuit theory McRae *et al*. (2008) • Matrixgreen Zetterberg (2011) • Habitat connectivity analysis (https://github.com/SMoG-Chalmers/hnat)

Table 2. Key insights and tools for creating and implementing climate change adaptation policies in an urban planning context, with a focus on nature based solutions (NBS) and the specific ecosystem service (ES) of water run-off mitigation. Insights directly referring to the issue of scale are presented in bold.

Adapting to climate change	
Insights for implementing climate change adaptation policies in an urban planning context	Example of a useful GIS based digital tool
• Green spaces have the potential to provide ecosystem services that can enhance urban resilience against adverse effects of climate change, including flooding due to heavy rainfall events • **The successful implementation of NBS* oriented climate change adaptation strategies requires an in depth understanding of the scale of the functions and processes behind the generation of the ecosystem service at hand** • **NBS oriented climate change adaptation strategies are often limited to small-scale interventions** • **Climate-proofing entire cities requires appropriate upscaling of ES** • **Upscaling ES may not be as straightforward as merely implementing a desired NBS in enough local places for it to matter on a larger scale** • **In the context of climate proofing an entire city against flooding, through water run-off mitigation, local scale urban development projects need to be understood in a multi-scale drainage basin context**	• The Urban Flood Risk Mitigation (UFRM) model**

*The European Commission defines the application of NBS as: '. . . the deliberate inclusion of natural system processes within human environments to obtain relevant outcomes in the form of ecosystem services' (Dumitru 2021).

**The UFRM model (https://naturalcapitalproject.stanford.edu/invest/urban-flood-risk-mitigation) is an open source, relatively simple, low data requirement model, which has proven useful for quantify the ecosystem service of water run-off mitigation across scales (see e.g. Egegård *et al*., 2024). It is part of a suite of 18 InVEST open source software models (https://naturalcapitalproject.stanford.edu/software/invest).

implementation of the X-minute city vision, also illustrates the relevance of such an understanding in relation to both social and ecological functions. In fact, the social-ecological nature of many of the identified interactions emphasizes the importance of also understanding the link between social and ecological (urban) functions. This

Table 3. Key insights and tools for creating and implementing public life policies in an urban planning context with a focus on the quality and inclusivity of shared urban spaces, often where co-presence happens. Insights directly referring to the issue of scale are presented in bold.

Reviving public life	
Insights for implementing quality and inclusivity of shared urban spaces, often where co-presence happens policies in an urban planning context	Example of a useful GIS based digital tool
• **Public life quality is deeply influenced by the spatial configuration of public spaces, affecting co-presence and social cohesion.** • Urban segregation limits social encounters, often due to spatial layout more than socio-economic diversity. • **High configurational integration of public spaces promotes wider co-presence, enhancing inclusivity and safety.** • **Multi- and cross-scale spatial analysis is necessary to design inclusive public spaces that function both locally and city-wide.** • **Foreground and background networks define pedestrian movement flows and access to diverse services.** • **Designing for public life includes understanding the role of public spaces in supporting both local familiarity and city-wide diversity.**	• Space Syntax: Analyzes spatial configurations to predict pedestrian flows and co-presence • PST (Place Syntax Tool) and Depthmap: Tools for spatial network analysis and visualization of centrality and movement (https://github.com/SMoG-Chalmers/PST). • Multi-scalar street type classification (e.g. City, Neighbourhood, Local, Background streets): Helps assess spatial role at different urban levels (Berghauser Pont *et al.*, 2019).

challenge has been referred to as *the problem of fit*, highlighting the importance of a proper understanding of the link between ecosystems and socioeconomic-cultural issues in its local, regional, national, continental, and global contexts (Folke *et al.*, 2007). Here follows an example of how the choice of "x" can affect the urban function of food security, via the potential impact on pollination potential. We do this by comparing the spatial range of a 10- and 20-min city, based on movement by bike and walking to the dispersal and colonization scale of a typical bumble bee pollinator (Figure 5).

This type of comparison, albeit based on 'back on the envelope' calculations, provides a good starting point for navigating the problem of fit. For example, in this specific example, it makes it clear that the spatial scales for management of a bumblebee species pool do not fit within the spatial scale of operation of a walking 10- or 20-min city planning focus, i.e. there is a scale mismatch.

Some examples of useful frameworks for navigating the problem of fit

Frameworks that have proven useful for navigating the problem of fit in an urban planning and design context share a view of cities as complex, dynamic, social-ecological systems (Cumming & Collier, 2005; Batty, 2017; Andersson *et al.*, 2021), stressing the necessity to reconnect urban life with the work of nature (Folke *et al.*, 2011). There are multiple ways of implementing such a view of cities towards successfully navigating the problem of fit. Here, we provide three examples of frameworks that share the view of cities as complex, dynamic, social-ecological systems, but use different approaches to navigating the social-ecological links in an urban planning and design context: 1) *Ecological Governance* (Ernstson *et al.*, 2010) specifically address how to navigate scale mismatches between ecological processes and social

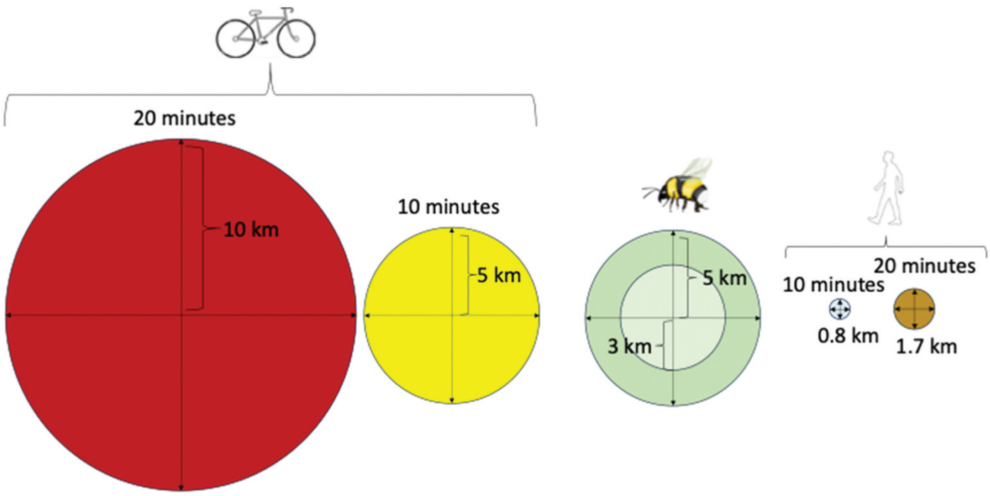

Figure 5. The spatial ranges of a 10- and 20-minute city, based on movement by bike and walking, are shown in comparison to the spatial range required to uphold the 'biogeographic species pool for bumblebees '(light green = low range, darker green = high range). The spatial scale of the '20-minute city by bike' is shown in red, the '10-minute city by bike' is shown in yellow. The spatial scale of the '10-minute city by walking' is shown in light blue and the '20-minute city by walking' is shown in brown. The spatial range of biking is based on an average speed of 30 km/h, which is on the high end, in order not to exaggerate potential scale mismatches. The spatial scale of walking is based on an average walking speed of 5 km/h. The range required to uphold the biogeographic species pool of bumblebees in general are 3–5 km (Lepais *et al*., 2010).

processes of governance by combining ecological scales with social network structure; 2) *Social Ecological Urbanism (SEU)* (Colding *et al*., 2022; Berghauser Pont *et al*., 2022) use institutions (formal and informal norms and rules of society) and urban form (including blue, green and grey infrastructure) as tools for governing various urban processes, offering a broad conception of urban sustainability and resilience by addressing cities on the relevant systems level, combining social, economic and ecological urban systems; 3) *Hybrid Infrastructure Framework* (Andersson *et al*., 2022), which, similar to SEU, promotes the linking of the built environments with landscape-scale biophysical structures and processes and, in addition, highlights the dynamic nature of complex systems, by pointing to the '*... opportunities for ongoing (re)design at the landscape level, where structure and function can be constantly renegotiated and recombined*'.

Conclusions

The three key urban functions addressed in this paper, i.e. ensuring food security, adapting to climate change, and reviving public life, all show that a complex view of the scale issue is a prerequisite for a successful implementation of the X-minute city visions. The examples discussed in the paper supports the insight that the limitation of localized urban development interventions can become a barrier to sustainable and resilient urban development, e.g. in the context of implementing green infrastructure for urban flood management (Li *et al.*, 2020), for integrating the ecosystem service of pollination into urban planning (Gren & Andersson, 2018) and in the context of promoting social cohesion and reviving public life (Legeby *et al.*, 2015).

Further, contending with the problem of fit, the X-minute city needs a social-ecological systems view of the scale issue to support both social and ecological processes. Following this proposition, we see the network of main streets as a provider of proximity locally but also to wider-range mobility options, forming a meshed structure across the urban landscape. Further, this network of streets should develop synergies (and avoid conflicts) with ecological networks that also operate on various scales and have the potential to provide crucial ecosystem services that increase the resilience and ecological integrity of cities, improve the physical and mental health of residents and can strengthen communal cohesion and belonging via a myriad of pathways (Hartig *et al.*, 2014; Braubach *et al.*, 2017; Dizdaroglu, 2022).

While this paper offers a thematic review of the role of scale in urban planning through selected examples, it does not constitute a systematic review; therefore, the selection of sources was not exhaustive and may reflect certain biases in coverage or emphasis.

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Endnotes

1. The UFRM model is one in a series of 18 InVEST open-source software models. The UFRM model is a relatively simple, low data requirement model, which has proven useful for quantify the ecosystem service of water run-off mitigation across scales (Egegård *et al.*, 2024). https://naturalcapitalproject.stanford.edu/invest/urban-flood-risk-mitigation. InVEST constitutes a series of 18 open-source software models. https://naturalcapitalproject.stanford.edu/software/invest
2. Here, Smart Growth is used as an umbrella concept representing the most prevalent planning strategies to combat urban sprawl, advocating for compact, transit-oriented, walkable, and bicycle-friendly land use (Gren *et al.*, 2019).
3. Here, the Smart City vision entails urban management strategies, using technical tools that offer state-of-the-art technologies, to facilitate a transition towards both urban sustainability and resilience (Winkowska *et al.*, 2019).
4. Here we use the definition of *ecological resilience* by Gunderson (2000) as ‘the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks’.

References

Ahrné, K., Bengtsson, J., Elmqvist, T., & Somers, M. (2009) Bumble bees (Bombus Spp) along a gradient of increasing urbanization, *PLOS ONE*, 4(5), p. e5574. doi:10.1371/journal.pone.0005574.

Akcakaya, H. R., Burgman, M., Kindvall, O., Wood, C., Sjögren-Gulve, P., Hatfield, J., & Mccarthy, M. (2004) *Species Conservation and Management: Case Studies* (Oxford University Press). doi:10.1093/oso/9780195166460.001.0001.

Alberti, M. (2008) *Advances in Urban Ecology* (Boston, MA: Springer US). doi:10.1007/978-0-387-75510-6.

Andersson, E., Barthel, S., & Ahrné, K. (2007) Measuring social–ecological dynamics behind the generation of ecosystem services, *Ecological Applications*, 17(5), pp. 1267–1278. doi:10.1890/06-1116.1.

Andersson, E., Grimm, N. B., Lewis, J. A., Redman, C. L., Barthel, S., Colding, J., & Elmqvist, T. (2022) Urban climate resilience through hybrid infrastructure, *Current Opinion in Environmental Sustainability*, 55, pp. 101158. doi:10.1016/j.cosust.2022.101158.

Andersson, E., Haase, D., Anderson, P., Cortinovis, C., Goodness, J., Kendal, D., Lausch, A., McPhearson, T., Sikorska, D., & Wellmann, T. (2021) What are the traits of a social-ecological system: Towards a framework in support of urban sustainability, *Npj Urban Sustainability*, 1(1), pp. 1–8. doi:10.1038/s42949-020-00008-4.

Axelsson Linkowski, W., Björn, C., & Nilsson, L. 2004. *Vildbin Och Fragmentering, Kunskapssammanställning Om Situationen För de Viktigaste Pollinatörerna i Det Svenska Jordbrukslandskapet*.

Batty, M. 2005. Cities and complexity. MIT Press. Available at https://mitpress.mit.edu/9780262524797/cities-and-complexity/ (accessed 23 September 2024).

Batty, M. (2013) *The New Science of Cities* (The MIT Press). doi:10.7551/mitpress/9399.001.0001 .

Batty, M. (2017) *The New Science of Cities*, Reprint ed. (Cambridge, Massachusetts London, England: The MIT Press).

Bengtsson, J. (2009) Chapter 9 applied (meta)community Ecology: Diversity and ecosystem services at the intersection of local and regional processes, In: H. A. Verhoef & P. J. Morin (Eds) *Community Ecology: Processes, Models, and Applications*, pp. 115–129 (Oxford: Oxford University Press). doi:10.1093/acprof:oso/9780199228973.003.0010.

Berghauser Pont, M., Barthel, S., Colding, J., Gren, Å., Legeby, A., & Marcus, L. (2022) Editorial: Social-ecological urbanism: Developing discourse, institutions and urban form for the design of resilient social-ecological systems in cities, *Frontiers in Built Environment*, 8. doi:10.3389/fbuil.2022.982681.

Berghauser Pont, M., & Haupt, P. (2023). *Space Matrix - Space, Density and Urban Form*, 2nd revised edition. nai010 publishers. The book is open access and can be downloaded at TU Delft Open Books. *Space Matrix - Space, Density and Urban Form*.

Berghauser Pont, M., Haupt, P., Berg, P., Alstäde, V., & Heyman, A. (2021) Systematic review and comparison of densification effects and planning motivations, *Buildings & Cities*, 2(1), p. 378. doi:10.5334/bc.125.

Berghauser Pont, M., Stavroulaki, G., & Marcus, L. (2019) Development of urban types based on network centrality, built density and their impact on pedestrian movement, *Environment and Planning B: Urban Analytics and City Science*, 46(8), p. 1549–1564. doi:10.1177/2399808319852632.

Brand, C., Götschi, T., Dons, E., Gerike, R., Anaya-Boig, E., Avila-Palencia, I., de Nazelle, A., Gascon, M., Gaupp-Berghausen, M., Iacorossi, F., Kahlmeier, S., Int Panis, L., Racioppi, F., Rojas-Rueda, D., Standaert, A., Stigell, E., Sulikova, S., Wegener, S., & Nieuwenhuijsen, M. J. (2021) The climate change mitigation impacts of active travel: Evidence from a longitudinal panel study in seven European cities, *Global Environmental Change*, 67, pp. 102224. doi:10.1016/j.gloenvcha.2021.102224.

Braubach, M., Egorov, A., Mudu, P., Wolf, T., Thompson, C. W., & Martuzzi, M. (2017) Effects of urban green space on Environmental Health, equity and resilience, In: N. Kabisch, H. Korn,

J. Stadler, & A. Bonn (Eds) *Nature-Based Solutions to Climate Change Adaptation in Urban Areas: Linkages Between Science, Policy and Practice, Theory and Practice of Urban Sustainability Transitions*, pp. 187–205 (Cham: Springer International Publishing). doi:10.1007/978-3-319-56091-5_11.

Carpenter, S., & Turner, M. (2000) Hares and tortoises: Interactions of fast and slow variables in ecosystems, *Ecosystems*, 3(6), pp. 495–497. doi:10.1007/s100210000043.

Carstensen, D., Lessard, J.-P., Holt, B., Borregaard, M., & Rahbek, C. (2013) Introducing the biogeographic species pool, *Ecography*, 36(12), pp. 1310–1318. doi:10.1111/j.1600-0587.2013.00329.x.

Cimburova, Z., & Berghauser Pont, M. (2021) Location matters. A systematic review of spatial contextual factors mediating ecosystem services of urban trees, *Ecosystem Services*, 50, pp. 101296. doi:10.1016/j.ecoser.2021.101296.

Colding, J., & Barthel, S. (2017) An urban Ecology critique on the "Smart city" model, *Journal of Cleaner Production*, 164, pp. 95–101. doi:10.1016/j.jclepro.2017.06.191.

Colding, J., Gren, Å., & Barthel, S. (2020) The incremental demise of urban green spaces, *The Land*, 9(5), pp. 162. doi:10.3390/land9050162.

Colding, J., Samuelsson, K., Marcus, L., Gren, Å., Legeby, A., Berghauser Pont, M., & Barthel, S. (2022) Frontiers in social–ecological urbanism, *The Land*, 11(6), p. 929. doi:10.3390/land11060929.

Cumming, G. S., & Collier, J. (2005) Change and identity in complex systems, *Ecology and Society*, March 19, 2024, 10(1). doi:10.5751/ES-01252-100129.

Da Silva, C., Denise, D. A. K., & Lemar, S. (2020) Accessibility in Practice: 20-minute city as a sustainability planning goal, *Sustainability*, 12(1), p. 129. doi:10.3390/su12010129.

Dizdaroglu, D. (2022) Developing design criteria for sustainable urban parks, *Journal of Contemporary Urban Affairs*, 6(1), pp. 69–81. doi:10.25034/ijcua.2022.v6n1-7.

Dramstad, W. E. (1996) Do bumblebees (Hymenoptera: Apidae) really forage close to their nests? *Journal of Insect Behavior*, 9(2), pp. 163–182. doi:10.1007/BF02213863.

Dumitru, A. (2021) *Evaluating the Impact of Nature-Based Solutions: A Summary for Policy Makers* (Publication Office oc the European Union: Luxembourg).

EEA. 2021. Nature-based solutions in Europe: Policy, knowledge and Practice for climate change adaptation and disaster risk reduction. European Environment Agency. Available at https://www.eea.europa.eu/publications/nature-based-solutions-in-europe (accessed 23 September 2024).

Eeraerts, M., & Isaacs, R. (2023) Different semi-natural habitat types provide complementary nesting Resources for wild bees, *Journal of Pollination Ecology*, 34, pp. 101–107. doi:10.26786/1920-7603(2023)726.

Egegård, C. H., Lindborg, M., Gren, Å., Marcus, L., Berghauser Pont, M., & Colding, J. (2024) Climate proofing cities by navigating nature-based solutions in a multi-scale, social–ecological urban planning context: A case study of flood protection in the city of Gothenburg, Sweden, *The Land*, 13(2), pp. 143. doi:10.3390/land13020143.

Elmqvist, T., Folke, C., Nyström, M., Peterson, G., Bengtsson, J., Walker, B., & Norberg, J. (2003) Response diversity, ecosystem change, and resilience, *Frontiers in Ecology and the Environment*, 1(9), pp. 488–494. doi:10.1890/1540-9295(2003)001[0488:RDECAR]2.0.CO;2.

Engström, G., Gren, Å., Li, C.-Z., & Krishnamurthy, C. K. B. (2020) Valuing biodiversity and resilience: An application to pollinator diversity in the Stockholm region, *Spatial Economic Analysis*, 15(3), pp. 238–261. doi:10.1080/17421772.2020.1784988.

Ernstson, H., Barthel, S., Andersson, E., & Borgström, S. T. (2010) Scale-crossing brokers and network governance of urban ecosystem services: The case of Stockholm, *Ecology and Society*, March 11, 2024, 15(4). doi:10.5751/ES-03692-150428.

Folke, C., Jansson, Å., Rockström, J., Olsson, P., Carpenter, S. R., Stuart Chapin, F., Crépin, A.-S., Daily, G., Danell, K., Ebbesson, J., Elmqvist, T., Galaz, V., Moberg, F., Nilsson, M., Österblom, H., Ostrom, E., Persson, Å., Peterson, G., Polasky, S., Steffen, W., Walker, B., & Westley, F. (2011) Reconnecting to the biosphere, *AMBIO: A Journal of the Human Environment*, 40(7), pp. 719–738. doi:10.1007/s13280-011-0184-y.

Folke, C., Pritchard, L., Jr, Berkes, F., Colding, J., & Svedin, U. (2007) The problem of fit between ecosystems and institutions: Ten Years Later, *Ecology and Society*, 12(1). doi:10.5751/ES-02064-120130.

Frantzeskaki, N., Israa, H. M., & Eugenio, M. (2022) Nature-based solutions for resilient and thriving cities: Opportunities and challenges for planning future cities, in: I. H. Mahmoud, E. Morello, F. L. de Oliveira, & D. Geneletti (Eds) *Nature-Based Solutions for Sustainable Urban Planning: Greening Cities, Shaping Cities, Contemporary Urban Design Thinking*, pp. 3–17 (Cham: Springer International Publishing). doi:10.1007/978-3-030-89525-9_1.

Frumkin, H. 2004. Urban sprawl and public Health: Designing, planning, and building for healthy communities. Available at https://www.academia.edu/2080701/Urban_sprawl_and_public_health_Designing_planning_and_building_for_healthy_communities (accessed 23 September 2024).

Gathmann, A., & Tscharntke, T. (2002) Foraging ranges of solitary bees, *Journal of Animal Ecology*, 71(5), pp. 757–764. doi:10.1046/j.1365-2656.2002.00641.x.

Gibson, C. C., Ostrom, E., & Ahn, T. K. (2000) The concept of scale and the human dimensions of global change: A survey, *Ecological Economics*, 32(2), pp. 217–239. doi:10.1016/S0921-8009(99)00092-0.

Graells-Garrido, E., Serra-Burriel, F., Rowe, F., Cucchietti, F. M., Reyes, P., & Zhang, W. (2021) A city of cities: Measuring how 15-minutes urban accessibility shapes human mobility in Barcelona, *PLOS ONE*, 16(5), pp. e0250080. doi:10.1371/journal.pone.0250080.

Graffigna, S., González-Vaquero, R. A., Torretta, J. P., & Marrero, H. J. (2024) Importance of urban green areas' connectivity for the conservation of pollinators, *Urban Ecosystems*, 27(2), pp. 417–426. doi:10.1007/s11252-023-01457-2.

Gren, Å., & Andersson, E. (2018) Being efficient and green by rethinking the urban-rural divide—combining urban expansion and food production by integrating an ecosystem service perspective into urban planning, *Sustainable Cities and Society*, 40, pp. 75–82. doi:10.1016/j.scs.2018.02.031.

Gren, Å., Colding, J., Berghauser-Pont, M., & Marcus, L. (2019) How Smart is Smart Growth? Examining the Environmental validation behind city compaction, *AMBIO: A Journal of the Human Environment*, 48(6), pp. 580–589. doi:10.1007/s13280-018-1087-y.

Gunderson, L. (2000) Ecological resilience–in theory and application, *Annual Review of Ecology and Systematics*, 31(1), pp. 425–439. doi:10.1146/annurev.ecolsys.31.1.425.

Gunderson, L., & Holling, C. (2003) Panarchy: Understanding transformations in human and natural systems, *Bibliovault OAI Repository, the University of Chicago Press*, 114(2), pp. 114. doi:10.1016/S0006-3207(03)00041-7.

Haandrikman, K., Costa, R., Malmberg, B., Farner Rogne, A., & Sleutjes, B. (2023) Socio-economic segregation in European cities. A comparative study of Brussels, Copenhagen, Amsterdam, Oslo and Stockholm, *Urban Geography*, 44(1), pp. 1–36. doi:10.1080/02723638.2021.1959778.

Hanson, J. (2000) Urban transformations: A history of design ideas, *URBAN DESIGN International*, 5(2), pp. 97–122. doi:10.1057/palgrave.udi.9000011.

Hanson, J., & Zako, R. 2007. 'Communities of Co-presence and surveillance: How public open space shapes awareness and behaviour in residential developments'. in: *Proceedings of the 6th International Space Syntax Symposium Istanbul*. https://discovery.ucl.ac.uk/id/eprint/3294/ (September 24, 2024).

Hartig, T., Mitchell, R., de Vries, S., & Frumkin, H. (2014) Nature and Health, *Annual Review of Public Health*, 35(1), pp. 207–228. doi:10.1146/annurev-publhealth-032013-182443.

Heyman, A. V., Law, S., & Berghauser Pont, M. (2018) How is location measured in housing valuation? A systematic review of accessibility specifications in hedonic price models, *Urban Science*, 3(1), pp. 3. doi:10.3390/urbansci3010003.

Hillier, B. (2002) A theory of the city as object: Or, how spatial laws mediate the social construction of urban space, *Urban Design International*, 7(3–4), pp. 153–179. doi:10.1057/palgrave.udi.9000082.

Hillier, B. 2007. Space is the Machine: A Configurational Theory of Architecture. London, UK: Space Syntax. https://discovery.ucl.ac.uk/id/eprint/3881/ (accessed September 24 2024).

Hillier, B., & Iida, S. (2005) Network and psychological effects in urban movement, pp. 475–490. doi:10.1007/11556114_30.

Hillier, B., Penn, A., Hanson, J., Grajewski, T., & Xu, J. (1993) Natural movement - or, configuration and attraction in urban pedestrian movement, *Environ Plann B*, 20(1), pp. 29–66. doi:10.1068/b200029.

Holland, J. M., Douma, J. C., Crowley, L., James, L., Kor, L., Stevenson, D. R. W., & Smith, B. M. (2017) Semi-natural habitats support biological control, pollination and soil Conservation in Europe. A review, *Agronomy for Sustainable Development*, 37(4), pp. 31. doi:10.1007/s13593-017-0434-x.

IEA. 2020. 'Energy efficiency 2020 – analysis'. IEA. Available at https://www.iea.org/reports/energy-efficiency-2020 (accessed 23 September 2024).

IPCC. 2023. 'Sixth assessment report - IPCC'. https://www.ipcc.ch/assessment-report/ar6/ (March 15, 2024).

Jacobs, J. (1961) *The Death and Life of Great American Cities*, Reissue ed. (New York: Vintage).

Jonsson, M., Bommarco, R., Ekbom, B., Smith, H. G., Bengtsson, J., Caballero-Lopez, B., Winqvist, C., Olsson, O., & Freckleton, R. (2014) Ecological production functions for biological control services in agricultural landscapes, *Methods in Ecology and Evolution*, 5(3), pp. 243–252. doi:10.1111/2041-210X.12149.

Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, M., Artmann, M. & Haase, D. (2016) Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action, *Ecology and Society*, 21(2), pp. 39. doi:10.5751/ES-08373-210239.

Karlson, M., & Mörtberg, U. (2015) A spatial ecological assessment of fragmentation and disturbance effects of the Swedish road network, *Landscape and Urban Planning*, 134, pp. 53–65. doi:10.1016/j.landurbplan.2014.10.009.

Kindlmann, P., & Burel, F. (2008) Connectivity measures: A review, *Landscape Ecology*, 23, pp. 879–890. doi:10.1007/s10980-008-9245-4.

Kindvall, O., Berghauser Pont, M., Stavroulaki, I., Lanemo, E., Wigren, L., & Levan, M. (2024) Predicting habitat functionality using habitat network models in urban planning, *Environment and Planning B: Urban Analytics and City Science*. doi:10.1177/23998083241299165.

Klein, A.-M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2006) Importance of pollinators in changing landscapes for world crops, *Proceedings of the Royal Society B: Biological Sciences*, 274(1608), pp. 303–313. doi:10.1098/rspb.2006.3721.

Kremen, C., Williams, N. M., Aizen, M. A., Gemmill-Herren, B., LeBuhn, G., Minckley, R., Packer, L., Potts, S. G., Roulston, T., Steffan-Dewenter, I., Vázquez, D. P., Winfree, R., Adams, L., Crone, E. E., Greenleaf, S. S., Keitt, T. H., Klein, A.-M., Regetz, J., & Ricketts, T. H. (2007) Pollination and other ecosystem services produced by mobile organisms: A conceptual framework for the effects of land-use change, *Ecology Letters*, 10(4), pp. 299–314. doi:10.1111/j.1461-0248.2007.01018.x.

Kremen, C., Williams, N. M., & Thorp, R. W. (2002) Crop pollination from native bees at risk from agricultural intensification, *Proceedings of the National Academy of Sciences*, 99(26), pp. 16812–16816. doi:10.1073/pnas.262413599.

Kudo, G., Nishikawa, Y., Kasagi, T., & Kosuge, S. (2004) Does seed production of Spring ephemerals decrease when Spring comes early?, *Ecological Research*, 19(2), pp. 255–259. doi:10.1111/j.1440-1703.2003.00630.x.

Legeby, A. 2013. Patterns of Co-presence: Spatial configuration and social segregation. Available at https://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-133678 (accessed 24 September 2024).

Legeby, A., Berghauser Pont, M., & Marcus, L. 2015. Streets for Co-presence?: Mapping potentials. Space Syntax Laboratory, The Bartlett School of Architecture, University College London. Available at https://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-174038 (accessed 24 September 2024).

Leibold, M. A., Holyoak, M., Mouquet, N., Amarasekare, P., Chase, J. M., Hoopes, M. F., Holt, R. D., Shurin, J. B., Law, R., Tilman, D., Loreau, M., & Gonzalez, A. (2004) The metacommunity concept: A framework for multi-scale community Ecology, *Ecology Letters*, 7 (7), pp. 601–613. doi:10.1111/j.1461-0248.2004.00608.x.

Lepais, O., Darvill, B., O'Connor, S., Osborne, J. L., Sanderson, R. A., Cussans, J., Goffe, L., & Goulson, D. (2010) Estimation of bumblebee Queen dispersal distances using sibship reconstruction method, *Molecular Ecology*, 19(4), pp. 819–831. doi:10.1111/j.1365-294X.2009.04500.x .

Li, L., Collins, A. M., Cheshmehzangi, A., & Ka Shun Chan, F. (2020) Identifying enablers and barriers to the implementation of the green infrastructure for urban flood management: A comparative analysis of the UK and China, *Urban Forestry and Urban Greening*, 54 (126770), pp. 126770. doi:10.1016/j.ufug.2020.126770.

Lindborg, R., Gordon, L. J., Malinga, R., Bengtsson, J., Peterson, G., Bommarco, R., Deutsch, L., Gren, Å., Rundlöf, M., & Smith, H. G. (2017) How spatial scale shapes the generation and management of multiple ecosystem services, *Ecosphere*, 8(4), pp. e01741. doi:10.1002/ecs2.1741.

Logan, T. M., & Guikema, S. D. (2020) Reframing resilience: Equitable access to essential services, *Risk Analysis*, 40(8), pp. 1538–1553. doi:10.1111/risa.13492.

Logan, T. M., Hobbs, M. H., Conrow, L. C., Reid, N. L., Young, R. A., & Anderson, M. J. (2022) The X-Minute city: Measuring the 10, 15, 20-minute city and an evaluation of its use for sustainable urban design, *Cities*, 131, pp. 103924. doi:10.1016/j.cities.2022.103924.

López-Lambas, M. E., Manuel Sánchez, J., & Alonso, A. (2021) The walking Health: A route choice model to analyze the street factors enhancing active mobility, *Journal of Transport & Health*, 22, pp. 101133. doi:10.1016/j.jth.2021.101133.

MacArthur, R. (1955) Fluctuations of animal populations and a measure of community stability, *Ecology*, 36(3), pp. 533–536. doi:10.2307/1929601.

Marcus, L., & Legeby, A. 2012. The need for Co-presence in urban complexity: Measuring social capital using space Syntax. Eigth International Space Syntax Symposium. Available at https://www.diva-portal.org/smash/record.jsf?pid=diva2:470211 (accessed 24 September 2024).

Marcus, L., Ståhle, A., & Fitger, M. 2005. The Place Syntax Tool (PST): Application for GIS MapInfo. Available at https://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-82709 (accessed 24 September 2024).

McRae, B. H., Dickson, B. G., Keitt, T. H., & Shah, V. B. (2008) Using circuit theory to model connectivity in Ecology, evolution, and Conservation, *Ecology*, 89(10), pp. 2712–2724. doi:10.1890/07-1861.1.

Moreno, C., Allam, Z., Chabaud, D., Gall, C., & Pratlong, F. (2021) Introducing the "15-minute city": Sustainability, resilience and place identity in future post-pandemic cities, *Smart Cities*, 4 (1), pp. 93–111. doi:10.3390/smartcities4010006.

Mörtberg, U., Zetterberg, A., & Balfors, B. (2012) Urban landscapes in transition, lessons from integrating biodiversity and habitat modelling in planning, *Journal of Environmental Assessment Policy and Management*, 14(1), pp. 1250002. doi:10.1142/S1464333212500020.

Munton, R. (2009) Rural land ownership in the United Kingdom: Changing patterns and future possibilities for land use, *Land Use Policy*, 26, pp. S54–61. doi:10.1016/j.landusepol.2009.08.012.

Newman, M. (2010) *Networks* (Oxford University Press). doi:10.1093/acprof:oso/9780199206650.001.0001.

Odongo, V. O., Barquet, K., & Green, J. (2022) *Addressing Scale in nature-Based Solutions* (stockholm, Sweden: Stockholm Environment Institute). doi:10.51414/sei2022.043.

Osborne, J. L., Martin, A. P., Carreck, N. L., Swain, J. L., Knight, M. E., Goulson, D., Hale, R. J., & Sanderson, R. A. (2008) Bumblebee flight distances in relation to the forage landscape, *Journal of Animal Ecology*, 77(2), pp. 406–415. doi:10.1111/j.1365-2656.2007.01333.x.

Pan, H., Page, J., Shi, R., Cong, C., Cai, Z., Barthel, S., Thollander, P., Colding, J., & Kalantari, Z. (2023) Contribution of prioritized urban nature-based solutions allocation to carbon neutrality, *Nature Climate Change*, 13(8), pp. 862–870. doi:10.1038/s41558-023-01737-x.

Pascual-Hortal, L., & Saura, S. (2006) Comparison and development of New graph-based landscape connectivity indices: Towards the priorization of habitat patches and corridors for Conservation, *Landscape Ecology*, 21(7), pp. 959–967. doi:10.1007/s10980-006-0013-z.

Peponis, J. (2024) Space Syntax and design, *Environment and Planning B: Urban Analytics and City Science*, 51(5), pp. 1073–1078. doi:10.1177/23998083241246661.

Peterson, G., Allen, C. R., & Holling, C. S. (1998) Original articles: Ecological resilience, biodiversity, and scale, *Ecosystems*, 1(1), pp. 6–18. doi:10.1007/s100219900002.

Pörtner, H.-O., Roberts, D. C., Adams, H., Adelekan, I., Adler, C., Adrian, R., Aldunce, P., Ali, E., Begum, R. A., Bednar-Friedl, B., Kerr, R. B., Biesbroek, R., Birkmann, J., Bowen, K., Caretta, M. A., Carnicer, J., Castellanos, E., Cheong, T. S., Chow, W., Cissé, G., Clayton, S., Constable, A., Cooley, S. R., Costello, M. J., Craig, M., Cramer, W., Dawson, R., Dodman, D., Efitre, J., Garschagen, M., Gilmore, E. A., Glavovic, B. C., Gutzler, D., Haasnoot, M., Harper, S., Hasegawa, T., Hayward, B., Hicke, J. A., Hirabayashi, Y., Huang, C., Kalaba, K., Kiessling, W., Kitoh, A., Lasco, R., Lawrence, J., Lemos, M. F., Lempert, R., Lennard, C., Ley, D., Lissner, T., Liu, Q., Liwenga, E., Lluch-Cota, S., Löschke, S., Lucatello, S., Luo, Y., Mackey, B., Mintenbeck, K., Mirzabaev, A., Möller, V., Vale, M. M., Morecroft, M. D., Mortsch, L., Mukherji, A., Mustonen, T., Mycoo, M., Nalau, J., New, M., Okem, A., Ometto, J. P., O'Neill, B., Pandey, R., Parmesan, C., Pelling, M., Pinho, P. F., Pinnegar, J., Poloczanska, E. S., Prakash, A., Preston, B., Racault, M.-F., Reckien, D., Revi, A., Rose, S. K., Schipper, E. L. F., Schmidt, D. N., Schoeman, D., Shaw, R., Simpson, N. P., Singh, C., Solecki, W., Stringer, L., Totin, E., Trisos, C. H., Trisurat, Y., van Aalst, M., Viner, D., Wairiu, M., Warren, R., Wester, P., Wrathall, D., & Ibrahim, Z. Z. (2022) Technical Summary, In: H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, & A. Okem (Eds) *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 37–118 (Cambridge, UK and New York, NY, USA: Cambridge University Press. doi:10.1017/9781009325844.002.

Post, E., Pedersen, C., Wilmers, C., & Forchhammer, M. (2008) Phenological sequences reveal aggregate life history response to climatic warming, *Ecology*, 89(2), pp. 363–370. doi:10.1890/06-2138.1.

Potschin, M., Haines-Young, R., Fish, R., & Turner, R. K. (eds.) (2016) *Routledge Handbook of Ecosystem Services* (London: Routledge). doi:10.4324/9781315775302.

Pucher, J., Buehler, R., Bassett, D. R., & Dannenberg, A. L. (2010) Walking and cycling to Health: A comparative analysis of city, state, and International data, *American Journal of Public Health*, 100(10), pp. 1986–1992. doi:10.2105/AJPH.2009.189324.

Radmacher, S., & Strohm, E. (2011) Effects of constant and fluctuating temperatures on the development of the solitary bee osmia bicornis (Hymenoptera: Megachilidae), *Apidologie*, 42 (6), pp. 42. doi:10.1007/s13592-011-0078-9.

Redhead, J., Dreier, S., Bourke, A., Heard, M., Jordan, W., Sumner, S., Wang, J., & Carvell, C. (2016) Effects of habitat composition and landscape structure on worker foraging distances of five bumble bee species, *Ecological Applications*, 26(3), pp. 726–739. doi:10.1890/15-0546.

Ricklefs, R. E., & Schluter, D. (eds.) (1994) *Species Diversity in Ecological Communities* (Chicago, IL: University of Chicago Press). https://press.uchicago.edu/ucp/books/book/chicago/S/bo3626513.html. (September 23, 2024)

Robinet, C., & Roques, A. (2010) Direct impacts of recent climate warming on insect populations, *Integrative Zoology*, 5(2), pp. 132–142. doi:10.1111/j.1749-4877.2010.00196.x.

Russell, A. (2006) Urban sprawl: A growing concern for agriculture, *Journal of Natural Resources and Life Sciences Education*, 35(1), pp. 152–154. doi:10.2134/jnrlse2006.0152.

Sahraoui, Y., De Godoy Leski, C., Benot, M.-L., Revers, F., Salles, D., Van Halder, I., Barneix, M., & Carassou, L. (2021) Integrating ecological networks modelling in a participatory approach for assessing impacts of planning scenarios on landscape connectivity, *Landscape and Urban Planning*, 209, pp. 104039. doi:10.1016/j.landurbplan.2021.104039.

Scoppa, M., French, S., & Peponis, J. 2009. 'The effects of street connectivity upon the distribution of local vehicular traffic in Metropolitan Atlanta'. In *Proceedings of the 7th Space Syntax Symposium, Stockholm, Sweden*, 8–11. http://sss7.org/Proceedings/05%20Spatial%20Morphology%20and%20Urban%20Growth/098_Scoppa_French_Peponis.pdf (September 24, 2024).

Serra, M. 2013. 'Anatomy of an emerging metropolitan territory: Towards an integrated analytical framework for metropolitan morphology'.

Sharifi, A., & Yamagata, Y. (2018) Resilience-oriented urban planning, pp. 3–27. doi:10.1007/978-3-319-75798-8_1.

Shue, R. 2022. Highlights report 2022 out Now. EIT Urban Mobility. Available at https://www.eiturbanmobility.eu/highlights-report-2022-out-now/ (accessed 23 September 2024).

Smith, By Esprit Smith, NASA's Earth Science News. 2021. Improving food security through capacity building. Climate Change: Vital Signs of the Planet. Available at https://climate.nasa.gov/news/3113/improving-food-security-through-capacity-building (accessed 7 March 2024).

Soranno, P. A., Cheruvelil, K. S., Bissell, E. G., Bremigan, M. T., Downing, J. A., Fergus, C. E., Filstrup, C. T., Henry, E. N., Lottig, N. R., Stanley, E. H., Stow, C. A., Tan, P.-N., Wagner, T., & Webster, K. E. (2014) Cross-scale interactions: Quantifying multi-scaled cause–effect relationships in macrosystems, *Frontiers in Ecology and the Environment*, 12(1), pp. 65–73. doi:10.1890/120366.

Tscharntke, T., Bommarco, R., Clough, Y., Crist, T. O., Kleijn, D., Rand, T. A., Tylianakis, J. M., Van Nouhuys, S., & Vidal, S. (2007) Conservation biological control and enemy diversity on a landscape scale, *Biological Control*, 43(3), pp. 294–309. doi:10.1016/j.biocontrol.2007.08.006.

UCL. 2016. depthmapX: Visual and spatial network analysis software. The Bartlett School of Architecture. Available at https://www.ucl.ac.uk/bartlett/architecture/research/space-syntax/depthmapx (accessed 24 September 2024).

United Nations, Department of Economic and Social Affairs, and Population Division. 2019. *World urbanization prospects: The 2018 revision.*

Vasiliev, D., & Greenwood, S. (2023) The role of landscape connectivity in maintaining pollinator biodiversity needs reconsideration, *Biodiversity and Conservation*, 32(12), pp. 3765–3790. doi:10.1007/s10531-023-02667-y.

Vergnes, A., Pellissier, V., Lemperiere, G., Rollard, C., & Clergeau, P. (2014) Urban densification causes the decline of ground-dwelling arthropods, *Biodiversity and Conservation*, 23(8), pp. 1859–1877. doi:10.1007/s10531-014-0689-3.

Vojinovic, Z., Alves, A., Patiño Gómez, J., Weesakul, S., Keerakamolchai, W., Meesuk, V., & Sanchez, A. (2021) Effectiveness of small- and large-scale nature-based solutions for flood mitigation: The case of Ayutthaya, Thailand, *Science of the Total Environment*, 789, pp. 147725. doi:10.1016/j.scitotenv.2021.147725.

Walther-Hellwig, K., & Frankl, R. (2000) Foraging habitats and foraging distances of bumblebees, *Bombus* spp. (Hym. Apidae), in an agricultural landscape, *Journal of Applied Entomology*, 124 (7–8), pp. 299–306. doi:10.1046/j.1439-0418.2000.00484.x.

Wang, C., Zhang, X., Guo, Y., & Mou, Y. (2024) Assessing the walkability of high-density neighborhoods: Development and reliability of the high-density environment assessment tool (HEAT), *Journal of Transport & Health*, 38, pp. 101847. doi:10.1016/j.jth.2024.101847.

Westphal, C., Steffan-Dewenter, I., & Tscharntke, T. (2003) Mass flowering crops enhance pollinator densities at a landscape scale, *Ecology Letters*, 6(11), pp. 961–965. doi:10.1046/j.1461-0248.2003.00523.x.

Winkowska, J., Szpilko, D., & Pejić, S. (2019) Smart city concept in the light of the literature review, *Engineering Management in Production and Services*, 11(2), pp. 70–86. doi:10.2478/emj-2019-0012 .

Zetterberg, A. 2011. MatrixGreen. KTH. Available at https://www.kth.se/en/seed/forskning/ovriga-forskningsprojekt/ema/urban-landscapes/finalized-projects/matrixgreen-1.197348 (accessed 24 September 2024).