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Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure

M. Demuzere [a], K. Orru [b c], O. Heidrich [d], E. Olazabal [e j], D. Geneletti [f], H. Orru [g h], A.G. Bhave [i], N. Mittal [i], E. Feliu [e], M. Faehnle [j k]

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Abstract

In order to develop climate resilient urban areas and reduce emissions, several opportunities exist starting from conscious planning and design of green (and blue) spaces in these landscapes. Green urban infrastructure has been regarded as beneficial, e.g. by balancing water flows, providing thermal comfort. This article explores the existing evidence on the contribution of green spaces to climate change mitigation and adaptation services. We suggest a framework of ecosystem services for systematizing the evidence on the provision of bio-physical benefits (e.g. CO_2 sequestration) as well as social and psychological benefits (e.g. improved health) that enable coping with (adaptation) or reducing the adverse effects (mitigation) of climate change. The multi-functional and multi-scale nature of green urban infrastructure complicates the categorization of services and benefits, since in reality the interactions between various benefits are manifold and appear on different scales. We will show the relevance of the benefits from green urban infrastructures on three spatial scales (i.e. city, neighborhood and site specific scales). We will further report on co-benefits and trade-offs between the various services indicating that a benefit could in turn be detrimental in relation to other functions. The manuscript identifies avenues for further research on the role of green urban infrastructure, in different types of cities, climates and social contexts. Our systematic understanding of the bio-physical and social processes defining various services allows targeting stressors that may hamper the provision of green urban infrastructure services in individual behavior as well as in wider planning and environmental management in urban areas.

Introduction

Urban areas are facing increasing challenges from climate change, for example, floods, droughts, heat waves and other threats to human comfort and environmental justice. In addressing ways to deal with these challenges, growing attention has been paid to the potential role of green and blue spaces, often approached with the concept of green (and blue) infrastructure (GUI). Green urban infrastructure can be interpreted as a hybrid infrastructure of green spaces and built systems, e.g. forests, wetlands, parks, green roofs and walls that together can contribute to ecosystem resilience and human benefits through ecosystem services (Naumann et al., 2010, Pauleit et al., 2011, EEA, 2012). Although GUI cannot fully replace natural areas, it is regarded as beneficial, e.g. as it can provide habitats for diverse biota and thereby help protect terrestrial and aquatic ecosystems (Ignatieva et al., 2011). However, a more integrated approach highlights the need for a holistic view of functions from nature conservation to social benefits, including benefits for coping with climate change, for citizens from regional to city (neighborhood) and site specific scales (Naumann et al., 2010, Niemelä et al., 2010, Pauleit et al., 2011).

Green urban infrastructure has been indicated as promising for reducing the adverse effects of climate change in urban areas, for example, by balancing water flows to alleviate flooding, providing thermal comfort by shading vegetation, and supporting coping capacities by providing people with opportunities to grow food for themselves (e.g. Krasny and Tidball, 2009, Cameron et al., 2012, Farrugia et al., 2013). Green urban infrastructure has also gained attention as a resource for mitigating climate change, e.g. its biomass can function as carbon storage (e.g. Davies et al., 2011). In scientific debates on climate change mitigation and adaptation, green urban infrastructure has often been described in terms of policy and governance (Naumann et al., 2010), but less holistically based on empirical evidence of benefits and trade-offs. The services and benefits of green urban infrastructure to climate change mitigation and adaptation have been studied (Gill et al., 2007, Lafortezza et al., 2009), and conceptual frameworks have been developed for addressing services and benefits in multi-scalar contexts (Faehnle et al., 2014, Scholes et al., 2013). Improved knowledge on the scales at which these services function and the benefits are delivered can link these processes to the appropriate level of decision-making, municipal or state authorities or individual level (Sternlieb et al., 2013, Wyborn and Pixler, 2013).

This review synthesizes empirical evidence on the contribution of green urban infrastructure to climate change mitigation and adaptation services and benefits. For this purpose, we propose a framework of ecosystem services and identify a set of green urban infrastructure services and benefits reported in the literature. We will address the production of the services, benefits, and potential co-benefits as well as elaborate on trade-offs at various spatial scales. The article concludes with identifying knowledge gaps worth exploring in future research.

Section snippets

Evidence on services and benefits provided by GUI

In order to draw together the empirical evidence on the contribution of green urban infrastructure from a climate change mitigation and adaptation perspective, we have developed a framework for the analysis of the benefits (Fig. 1). Ecosystem services can be defined as the contribution of ecosystems to human well-being, based on ecological phenomena (Fisher et al., 2009). Services are the production of benefits that are of value to the people (Chan et al., 2012). For example, carbon storage and …

Dealing with complexity by identification of relevant spatial scales

Planning and managing green urban infrastructure and climate change mitigation and adaptation needs to be approached holistically, taking into account diverse spatial-temporal dynamics including the interactions between services (Fisher et al., 2009). One way to deal with these complexities is to analyze the benefits in relation to different spatial scales. The scalar differentiation can help in identifying the particular biophysical characteristics that matter in the benefit production and…

Conclusion

This article demonstrated that an increasing body of knowledge related to the estimation of the benefits provided by green urban infrastructure to climate change mitigation and adaptation is available. The topic is clearly gaining momentum and many studies provide empirical evidence that can be used to design green infrastructure to decrease the vulnerability of urban areas to climate change. However, the analysis also showed that it remains difficult to draw unambiguous conclusions regarding…

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