Green Urban Infrastructure: Assessing Potential Ecosystem Services in Urban Cities

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Introduction

Cities all over the world are currently experiencing climate change caused by rapidly increasing atmospheric greenhouse gases (GHGs). Fortunately, cities may mitigate GHG concentrations by incorporating vegetation into green urban infrastructure (GUI) to develop parks, green roofs, waterways, and other structures. For example, plants sequester carbon (C) by removing atmospheric CO_2 and incorporating it into their tissues through photosynthesis, behaving as carbon sinks[1]. GUI may also remove urban air pollutants, such as particulate matter (PM_{10}) or black carbon, further contributing to climate change mitigation[2]. The societal benefits provided by GUI are defined as 'ecosystem services'[3].

The role of GUI in reducing GHG emissions and reducing air pollution have been observed in cities within the United States, Asia, and Canada, as described in previously published studies. However, additional empirical data and research is required to accurately quantify GUI's contribution to mitigating GHG and air pollution, due to a variety of factors and/or uncertainties that must be considered. For example, factors such as the age of vegetation, meteorological conditions, and soil moisture availability may influence urban vegetation's ability to remove atmospheric GHG/CO_2 concentrations and air pollutants[1,4]. Moreover, as observed in some literature, GUI may not contribute significantly towards mitigating GHG emissions and air pollution in cities, and thus, may not be an ideal strategy for cities ambitious about significantly reducing local GHG emissions and pollutants. However, it is important to note that implementing GUI in cities may also offer an alternative array of ecosystem services beyond decreasing GHGs or air pollutants, such as purifying air/storm water, storing, balancing water flows, and regulating climates[2]. Consequently, GUI may also promote human well-being by creating recreational spaces to encourage active lifestyles or to promote community engagement practices[3]. Figure 1 depicts four categories of ecosystem services as described by the Millennium Ecosystem Assessment report (2005).

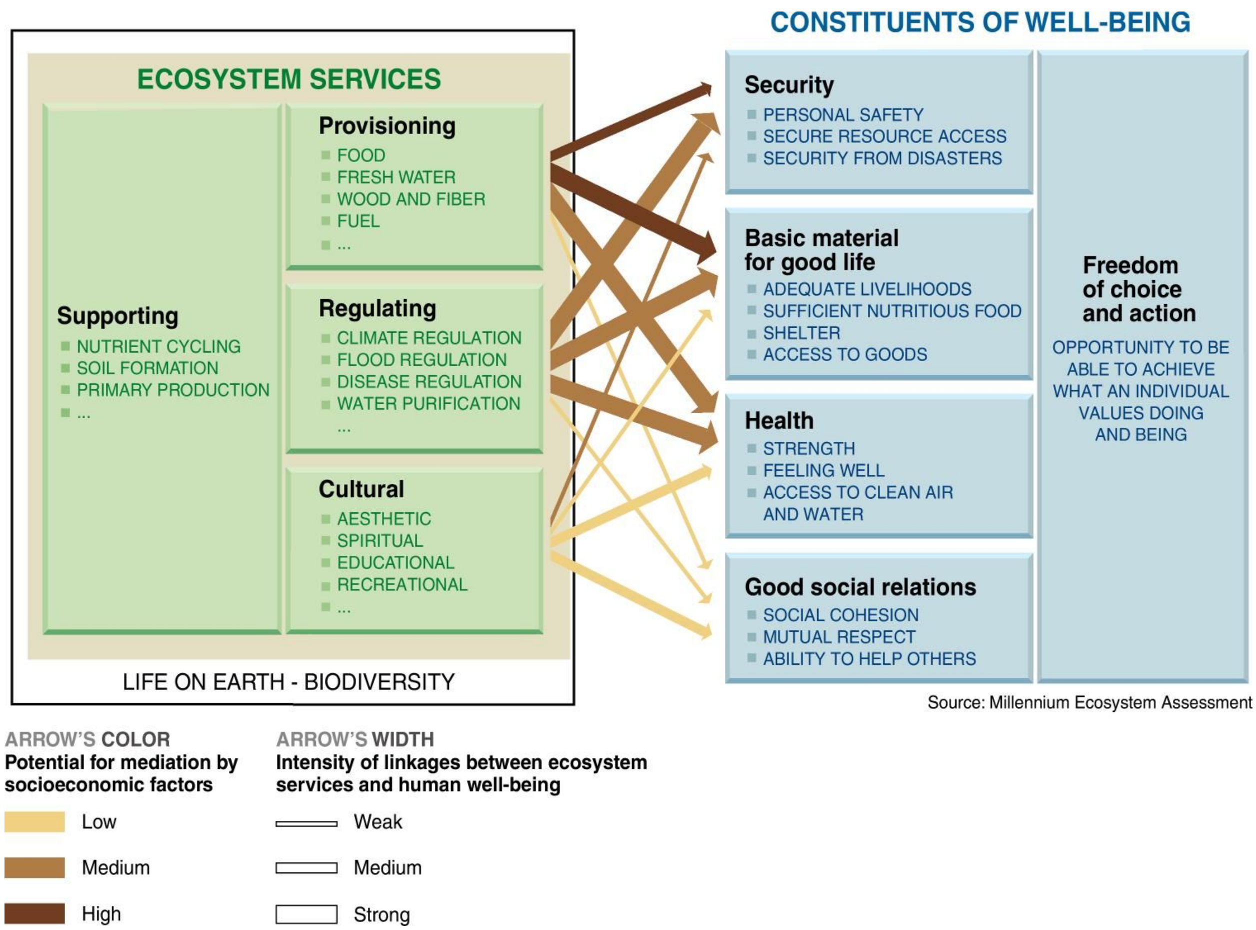

Figure 1. Figure depicting four categories of ecosystem services and their relations to common constituents of human well-being, as described by the Millennium Ecosystem Assessment report (2005). As depicted in this figure, socioeconomic factors which influence these relationships will not be discussed in this report. *Credit: Millennium Ecosystem Assessment, millenniumassessment.org.*

In this report, we argue that despite the studies which suggest that GUI modestly (almost negligibly) reduces GHG emissions and air pollution, it may still be an effective strategy to mitigate climate change in the city, due to the alternative benefits it may provide. However, we outline specific considerations that policymakers should take into account before developing GUI-oriented strategies to combat climate change in cities.

Is GUI Development the Best Approach to Mitigating GHG Emissions in Cities?

We observed two previously published studies to determine the viability of GUI development as a strategy to mitigate climate change via reducing GHG emissions and C sequestration. In the first study, Baró et al. (2014) investigated the urban forests' contribution towards urban air purification and mitigating GHG emissions in Barcelona, Spain, determining the forests' mitigation rates of CO_2, nitrogen dioxide (NO_2), carbon monoxide (CO), sulfur dioxide (SO_2) ozone (O_3), and particulate matter (PM_{10}; a non-GHG that is a major contributor to Barcelona's air pollution, alongside NO_2) for 2008. It was observed that Barcelona's urban forests experienced the highest, most significant removal rate of PM_{10} compared to the removal rates of NO_2, CO_2, CO, SO_2, and O_3. Moreover, the results indicated that Barcelona's urban forest modestly contributed 0.47% of climate change mitigation relative to the city's annual GHG emissions via net C sequestration, but can be significantly higher (22.55%) if all other activities except those managed directly by Barcelona's City Council is considered for the study. Overall, the results suggested that the contribution of urban forests was insignificant in regards to air purification and mitigating GHG emissions [4]. In the second study, Chen (2015) investigated the C sequestration potential of GUI from 35 major cities in China for 2010, which collectively consumed 40% of China's produced energy. Chen (2015) also investigated how these GUI may have contributed to mitigating the cities' CO_2 emissions from fossil fuels. Firstly, it was determined that GUI of the 35 cities sequestered approximately 1.895 million tons of C, which contributed to 1.3% of China's total C uptake by terrestrial vegetation. Specifically, the results depicted that each of the cities possessed different C sequestration capabilities (with values ranging from 374.5×10^3 tons to 2.76×10^3 tons of C), as a result of different climatic factors, vegetation size and density, growing conditions, and growing seasons. Secondly, it was observed that the GUI of the 35 cities could only collectively offset 0.33% of CO_2 emissions from fossil fuel combustion. The study's results suggested that the GUI of 35 cities in China did not significantly sequester C or offset CO_2 emissions from fossil fuel. Similarly, the results of the studies were consistent with previous research which suggested that GUI in cities modestly contributed to climate change mitigation, such as those located in Asia, the United States, and Canada[1,4]. For example, similar to the previously described studies, Pataki et al. (2009) estimated that the GUI in Utah's Salt Lake Valley will only reduce 0.2% of the city's CO_2 emissions from 2005 to 2030[5]. Overall, the studies previously described suggested that the contribution of GUI to mitigating GHG emissions, especially CO_2 (or CO_2-equivalent) concentrations, in the cities of Barcelona and China are insignificant and negligible.

Moreover, GUI may also present negative societal consequences or tradeoffs, known as ecosystem disservices. Tradeoffs may include reduced solar radiation and thermal comfort due to extensive tree shade, increased population density due to extensive developed green areas, and potential attractions of disease-carrying animals or insects due to urban vegetation development[2]. Additionally, GUI and urban vegetation may behave as CO_2 emitters if extensive fossil fuel usage is required to maintain them[4]. For example, approximately 70% of annual CO_2 emissions from Shanghai's urban forest maintenance originates from irrigation practices[1]. Maintenance of developed urban forests, lawns, and turfgrass are also capable of emitting non-CO_2 GHG gases including nitrous oxides and methane (CH_4)[3].

In hindsight, it may seem like a poor investment for cities to develop GUI strategies in an attempt to offset GHG and/or CO_2 emissions due to their negligible contributions. However, published literature has suggested that GUI offer alternative ecosystem services and benefits that may interest policy makers and cities.

Integrating GUI Strategies in a City's Plan to Mitigate Climate Change

Developed GUI may offer cities additional ecosystem services, and in some cases, with minimal monetary cost. In Baró et al.'s (2014) study, Barcelona's urban forests demonstrated significant removal rates of particulate matter, which was a health concern in the city. It has accordingly been suggested that developing urban forests in Barcelona to eliminate air pollution caused by particulate matter is an ideal strategy, since it is cheap and would improve the city's health substantially.[4] Alternatively, in warm climates, urban vegetation situated near building infrastructures may provide local cooling effects through shading or transpiration, decreasing the use of air conditioners, while possibly decreasing GHG emissions associated with energy generation. GUI in the form of woody debris or urban streams provide coarse, channel beds that are capable of removing pollutants from stormwater runoff, thereby improving municipal water quality[3]. GUI and urban vegetation also provide a city's population with spaces for recreation, leisure, physical activity, and community functions. These amenities are capable of promoting a comfortable, healthy, and active lifestyle within the city [2]. It is important to consider that GUI can still modestly contribute to a city's climate change mitigation strategy through C sequestration and GHGs reduction. However, because of its insignificant (almost negligible) contribution, policy makers focusing on mitigating climate change in the city should not solely develop GUI-oriented strategies.

Firstly, alternative strategies that are focused on reducing GHG and CO_2 emissions should be developed to complement GUI strategies that provide alternative ecosystem services and benefits. Baró et al. (2014) suggested that the cities similar to Barcelona should consider implementing GUI with alternative strategies that will effectively mitigate air pollution and GHG emissions. Baró et al. (2014) suggested that Barcelona's transportation sector may be a more significant contributor to removing NO_2 emissions to satisfy future policy targets, compared to GUI development. Reducing road traffic, implementing fuels that are less polluting, and promoting public transportation and cycling are various referenced examples that the city's transportation sector can implement to promote NO_2 removal and reduction[4]. Meanwhile, Chen (2015) suggested that developing GUI in China's cities can be incorporated into a national agenda to mitigate climate change impacts through sustainable development initiatives. Possible policies that could be developed may include green spaces, zoning control of natural environments, and planting rapidly-maturing plants to optimize carbon sequestration [1].

Secondly, policy makers must remember that cities possess diverse geo- and biophysical characteristics, and thus, may produce different types benefits or ecosystem services from GUI. Cities possess diverse vegetation species, which may impact the capacity of GUI to provide ecosystem services, even related to mitigating urban GHG emissions. For instance, urban vegetation's capacity to mitigate air pollution in a city is dependent on overall tree health, soil moisture availability, meteorology, physiology of the vegetation, and the area's pollution concentration.[4] The 35 Chinese cities studied by Chen (2015) experienced varying growing seasons, where cities (i.e. Beijing) with long growing seasons possessed urban vegetation with large C sequestration rates, compared to cities (i.e. Hohot) with short growing seasons. Policy makers must be cautious to examine a city's regional characteristics, even identifying unique characteristics and differences in neighbourhoods or districts within the city[1]. It is also important to remember that GUI presents a variety of ecosystem services (benefits), as well as ecosystem disservices (trade-offs). Pataki et al. (2011) suggests conducting a cost-benefit analysis of the city's region, to ensure that GUI provides more ecosystem services than disservices. For example, additional research is required to properly explore the economic cost of developing GUI as a strategy to decrease energy use (i.e. air conditioning use), due to a variety of factors that can impact this phenomenon (i.e. vegetation species and distribution)[3].

Conclusion

The literature reviewed in this report suggests that GUI has only modestly contributed to reducing CO_2, CO_2-equivalent, and GHG emissions in the cities of China and Barcelona[1,4]. Therefore, cities that are focused on mitigating climate change by reducing CO_2 and/or GHG emissions should not solely rely on developing GUI-oriented strategies. Instead, cities should create alternative strategies that complement GUI development, such as improving local transportation. As seen in the reviewed literature, GUI offer cities alternative ecosystem services which can complement strategies that can significantly mitigate GHG emissions, creating an effective municipal agenda towards fighting climate change and the consequences as a result of it.

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