Urban Climate 8 (2014) 100–125

Contents lists available at ScienceDirect

Urban Climate

journal homepage: www.elsevier.com/locate/uclim

A review of the current progress in quantifying the potential of urban forests to mitigate urban CO_2 emissions

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ARTICLE INFO

Article history:
Received 15 May 2013
Revised 7 September 2013
Accepted 1 January 2014

Keywords:
Urban forest
Climate change mitigation
Carbon pools
CO_2 fluxes
Urban ecology

ABSTRACT

Urban areas generally emit large amounts of anthropogenic carbon dioxide (CO_2). However, studies that quantified the temporal and spatial variability of mean atmospheric CO_2 concentrations and fluxes have suggested that dense vegetation may act as a local sink within cities. Consequently, urban greening programmes now form an important part of many urban climate change mitigation policies. Knowledge about the direct impact of urban vegetation and soils (collectively known as urban forests) on atmospheric CO_2 concentrations is still limited and comprehensive measurement programmes are scarce. This article examines the methods currently used to quantify carbon (C) pools and CO_2 fluxes of urban forests, and compiles currently available results. Whilst vegetation did not offset CO_2 emissions on an annual basis in studies from mid-latitude cities, vegetative CO_2 uptake contributed to the significantly lower atmospheric CO_2 fluxes in summer. However, the currently available results are related to a large degree of uncertainty due to the limitations of the applied methods, the limited number of urban areas studied and the temporal/spatial resolution of the measurements. This article demonstrates that in order to effectively quantify CO_2 fluxes from urban forests, future research needs to integrate data from a combination of methodologies collected at a range of scales.

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http://dx.doi.org/10.1016/j.uclim.2014.01.002
2212-0955/© 2014 Published by Elsevier B.V.

Contents

1. Introduction

Over half the world's population lives in cities and the number of people that live in urban areas is constantly increasing (United Nations, 2011). The conversion of rural land surfaces into urban areas leads to a loss and modification of vegetation and soils, which in turn alters the local and regional carbon (C) cycle (Svirejeva-Hopkins et al., 2004). At the same time, cities are a major source of anthropogenic carbon dioxide (CO_2) emissions owing to the high consumption of fossil fuel for transport and heating purposes as well as for manufacturing and industrial activities (Mills, 2007; Velasco and Roth, 2010). Nevertheless, studies that quantified atmospheric concentrations and fluxes of CO_2 have shown marked intra- and inter-urban temporal and spatial variability and demonstrated that heavily vegetated parts of urban areas may act as a local sink of CO_2 (Grimmond et al., 2002). Urban vegetation and soils, commonly referred to as urban forest, including "all urban trees, shrubs, lawns, and pervious soils ... located in highly altered and extremely complex ecosystems where humans are the main drivers of their types, amounts and distribution" (Escobedo et al., 2011: 2078) as well as green roofs, have the potential to mitigate local CO_2 emissions in two ways. Urban trees, lawns and green roofs reduce atmospheric CO_2 directly through photosynthetic uptake during daytime and through the storage of carbon in the form of stems, branches or roots (Velasco and Roth, 2010). Similarly, urban soils store organic C (Fig. 1, Liu and Li, 2012). Indirectly, urban trees also reduce heating and cooling demands of buildings, thus reducing CO_2 emissions related to the production of electric power (Akbari et al., 2001; Escobedo et al., 2010; McPherson and Simpson, 1999). However, urban forests may also act as a CO_2 source as ecosystem respiration, including above- and belowground heterotrophic and autotrophic respiration, can lead to an increase of atmospheric CO_2 concentrations (Fig. 1, Escobedo et al., 2010). Moreover, urban forests require regular maintenance, which may result in further emissions of CO_2 from vehicles, chain saws or chippers (Nowak et al., 2002).

Due to the potential of urban forests to mitigate CO_2 emissions directly and indirectly, interest in urban greening has been growing continuously in the past years. The establishment of new urban parks and urban tree planting initiatives are incorporated into many urban climate change mitigation and adaptation strategies (Jo and McPherson, 1995; Pincetl et al., 2012). Although such measures are already implemented in many cities, the net CO_2 reduction potential of urban forests is still poorly supported by scientific evidence. Indeed, information about the temporal and spatial variability of CO_2 fluxes across cities and between cities is still limited and little research has been undertaken to investigate the influence of urban forests in determining the magnitude and direction of these fluxes. Current knowledge on the potential of urban forests to mitigate CO_2 emissions is mainly based on biomass estimates by allometry and growth rate prediction equations (Fig. 2) and information about