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Carbon sequestration through urban ecosystem services A case study from Finland

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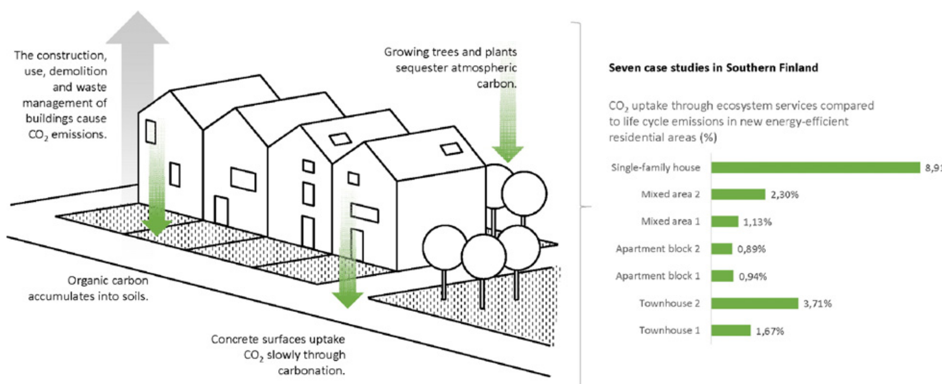
HIGHLIGHTS

- The CO_2 emissions of buildings may be regulated by the uptake of carbon in plants.
- The sequestration compensates for less than 10% of emissions over the full life cycle.
- Up to 85% of emissions may be compensated for in the production phase.
- Site efficiency and the number of trees set the potential for emission compensation.
- Several knowledge gaps were found in the quantification of the compensation potential.

GRAPHICAL ABSTRACT



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ABSTRACT

Plants and soil are natural regulators of atmospheric CO_2. Whereas plants sequester atmospheric carbon, soils deposit it for decades. As cities become increasingly more densely built, the available land area for such ecosystem services may decrease. We studied seven different housing areas in the Finnish city of Espoo to ascertain the extent to which site efficiency affects to the ecosystem services if the full life-cycle GHG emissions of these areas are taken into account. The results show that the impact of CO_2 uptake through carbon sinks in growing plants and the uptake of soil organic carbon vary greatly. Its share of all emissions varied from a marginal value of 1.2% to a more considerable value of 11.9%. The highest potential was calculated for a detached house located on a large site, while the weakest was calculated for compact apartment blocks. The study revealed that in order to quantify this potential more accurately, several knowledge gaps must first be addressed. These include impartial growth algorithms for Nordic wood species, missing accumulation factors for soil organic carbon in cold climates and statistical maintenance scenarios for gardens.

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1. Introduction

1.1. The challenges in mitigating urban greenhouse gas emissions

Urban areas continue to expand globally. By 2050, the urban population is estimated to increase by 2.5–3 billion (Seto et al., 2014). Today cities and urban areas are accountable for 71–76% of all greenhouse gas (GHG) emissions and 67–76% of all primary energy (PE) demand (Seto et al., 2014). Urbanisation cannot continue with such consumption and emission rates if we wish to prevent the costly consequences (Stern, 2006; World Bank, 2013) and extreme risks (Hansen et al., 2013) of climate change and reach the possible co-benefits of transition into a low-carbon economy (Nelson et al., 2014).

A common solution for reducing urban GHG emissions and PE demand has been compacting cities and limiting urban sprawl (Edenhofer et al., 2014; The Global Commission on the Economy and Climate, 2014). As urban areas get denser, the amount of parks, natural forests and other green spaces within the same area decreases. Such development decreases the potential benefits of the "regulating" ecosystem services in the area of climate change mitigation. As there are less trees and soil that regulate the amount of atmospheric carbon dioxide (CO_2) by sequestering it into their biomass through photosynthesis, the lost climate change regulation will have to be met in other ways. There are possibly significant benefits from the densification of cities as well: less embodied energy and emissions from infrastructure construction and maintenance (IPCC, 2014), and denser residential areas may be more resource, energy and material efficient (Takano et al., 2014a).

However, the construction of dense and energy-efficient areas have been found to cause a peak in GHG emissions and energy demand (Heinonen et al., 2012). This peak may be large and it may take several decades before it is amortized. The payback time of these consequential GHG peaks is greatly influenced by the amount of energy that can be saved through the improved energy and carbon efficiency of buildings and areas.

1.2. The potential of ecosystem services in regulating greenhouse gas emissions

Plants and soil are natural regulators of atmospheric CO_2. Plants sequester atmospheric carbon in photosynthesis and convert it into sugar that they store in their biomass. This biomass is beneficial for humans as food or raw-material. In addition, plants grown from atmospheric carbon may provide shade and shelter from the sun, rain, wind, noise and pollution. Soil organic carbon (SOC) is a depository of the slowly decaying carbohydrate remains of plants, animals and microbes. This carbon stock is significant and vital for the regulation of a liveable climate on our planet: nearly 80% of terrestrial carbon resides in soils (Ontl and Schulte, 2012).

Urban environments also hold potential for ecosystem services. There is a growing interest in quantifying the climate benefits of ecosystem services in cities across the world. Recent scientific findings are encouraging. In Leicester, UK, it was found out that the SOC in urban areas can be much higher than in agricultural areas (Edmondson et al., 2012) and that the soils are actually the largest repository of organic carbon (OC) in urban areas, totalling 82% of all OC. Interestingly the study also showed that there is a high amount of OC lying under impervious surfaces (13%). In Leicester only 18% of urban OC was found stored in vegetation. In addition it has been found (Edmondson et al., 2013; Davies et al., 2011) that trees that grow in domestic yards greatly increase the amount of SOC. These "backyard carbon storages" should be protected to prevent the release of CO_2 into the atmosphere.

1.3. The assessment of the regulation of climate change through ecosystem services in standards

International and regional standards guide the assessment of the environmental performance of the built environment. Interestingly, no discussion about the role of ecosystem services in the environmental calculations has been found from the current versions of the international standards (ISO 14040, 14,044, 14,067) or European EN standards (EN 15643 series, EN 15978, EN 15804) for the assessment of the environmental performance of the built environment.

EN 15978 (CEN, 2011a) states that in the environmental assessment of buildings, the whole site and its full life cycle are to be included. However, there is no guidance on the inclusion or exclusion of green infrastructure within this system boundary.

The technical specification ISO/TS 14067 (ISO, 2013) briefly discusses the calculation of soil carbon change but seemingly in the context of land-use change (Section 6.4.9.5, pp. 26). The specification further mentions that "there is ongoing research to develop methodology and models, and provide data for the inclusion of soil carbon change in GHG reporting" (pp. 26). The uptake and release of GHGs in SOC, however, are not mentioned.

Standards EN 15643-1 (CEN, 2010), EN 15643-2 (CEN, 2011b) and EN 15804 (CEN, 2013) do not discuss issues that would directly relate to including the regulation of GHGs through ecosystem services into the environmental assessment of the built environment.

An overview of the current standard versions leads to the conclusion that – as there is no direct guidance for either including or excluding GHG regulation, sequestration or delayed release through ecosystem services – the environmental assessor has to make a decision on the subject based on the definition of the scope and goal of the study. This may, however, lead to biased results if the results of a life cycle assessment (LCA) are used for finding solutions to, for example, low carbon construction. The built environment in almost all cases also consists of vegetation, be it natural, cultivated, barren land or decorative gardens.

As there is no standardised method or guidance, the role of ecosystem services in the mitigation of urban GHG emissions is yet to be investigated in greater detail. We do not know how much the densification of residential areas mitigates climate change through decreasing urban emissions when compared to the lost potential of sequestering carbon in plants and soil. We do not know where the optimum between denser cities and ecosystem services lies. We lack an understanding of how to design and run a resilient city from both energy efficiency and ecosystem service viewpoints.

2. Materials and methods

2.1. Scope and objective

The aim was to investigate the potential of carbon uptake in urban yards through the processes of photosynthesis in vegetation, the accumulation of SOC and the carbonation of concrete surfaces. In addition this potential is compared to the overall GHG emissions of each building's life cycle, including the production of materials, construction work, operative energy use and at its end-of-life stage. The study period is 50 years.

The data are collected from seven residential areas in the city of Espoo, southern Finland. Choosing a Nordic example provides insight into the carbon sequestration potential of boreal urban gardens.

The study is made according to the system boundaries that are defined in the standard EN 15978 (CEN, 2011a). Thus the object of assessment is "the building, including its foundations and external works within the curtilage of the building's site, over its life cycle."(CEN, 2011a, pp.16). However, we wish to study the role of the green infrastructure if it is taken into account in the standard-based sustainability assessment of buildings. Therefore the system boundary of EN 15978 is used.