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Procedia Environmental Sciences 38 (2017) 595 – 602

Procedia Environmental Sciences

International Conference on Sustainable Synergies from Buildings to the Urban Scale, SBE16

Life Cycle Assessment of Land Use in Neighborhoods

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Abstract

Urban sprawl and the increase of the built-up area have a major impact on land use. Buildings are responsible for two types of land use interventions: primary land use, i.e. the building footprint and secondary land use, associated with the resource extraction, production, transport and end-of-life treatment of construction products. However the environmental impact related to the primary land use is mostly not considered in current Life Cycle Assessment (LCA) studies of the built environment.

The purpose of this paper is to assess the environmental impact of primary land use in neighbourhoods, considering not only the footprint of buildings but also the footprint of infrastructure and open spaces. Impacts related to land occupation and transformation are evaluated based on the impact assessment methods soil organic matter (SOM) (i.e. impact on soil quality) and Eco-indicator 99 (i.e. impact on biodiversity).

An LCA study of neighbourhood models with diverse built densities, i.e. consisting of detached houses, semi-detached houses, terraced houses to compact apartment blocks, is performed. Moreover, buildings are simulated using combinations of building elements, from solid to timber frame structure.

The results reveal the high contribution of primary land use to the neighbourhood life cycle environmental impacts, especially in low built density neighbourhoods. Furthermore, the environmental impact of primary land use is in most cases higher than secondary land use. Based on this analysis, it is recommended to include the assessment of primary land use in neighbourhood LCA, especially in studies comparing different built densities.

Peer-review under responsibility of the organizing committee of SBE16.

Keywords: Built density; Neighbourhood layout; Primary land use; Secondary land use; Land occupation; Land transformation

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Peer-review under responsibility of the organizing committee of SBE16.
doi:10.1016/j.proenv.2017.03.133

1. Introduction

Urban sprawl and the increase of the built-up area have a major impact on land use. Between 1980 and 2000, the built-up area in Europe increased by about 20% [1]. Buildings are responsible for two types of land use interventions: primary land use, i.e. the building footprint and secondary land use, associated with the resource extraction, production, transport and end-of-life treatment of construction products [2]. However, the environmental impact related to the primary land use is mostly not considered in current Life Cycle Assessment (LCA) studies of the built environment. In Allacker et al. (2014) [2], the primary land use of a detached house in Belgium is evaluated, using different land use impact assessment models. This study reveals the importance of including primary land use in a building LCA, as the impact of primary and secondary land use are of the same order of magnitude.

The purpose of this paper is to assess the environmental impact of primary land use in neighbourhoods, considering not only the footprint of buildings but also the footprint of infrastructure and open spaces. Based on the analysis of neighbourhood models with diverse built densities, the contribution of primary land use to the neighbourhood life cycle environmental impacts is evaluated. Furthermore, the impact of the neighbourhood primary land use is compared to the secondary land use resulting from the construction products.

In the subsequent section, the methodology is presented, including a description of the LCA method, the assessment of primary land use in neighbourhoods and the analysed case studies. In section 3 the LCA results of the neighbourhood models are described. Conclusions and recommendations are formulated in the final section.

2. Materials and methods

2.1. Life Cycle Assessment (LCA)

The environmental impact assessment used in this paper is based on the LCA method developed within the MMG ("Environmental profile of building elements") research project, commissioned by the Public Waste Agency of Flanders (OVAM)[3][4]. Within this project an evaluation method for the environmental performance of building elements is developed, specific for the Belgian context. In a recent research [5], the MMG method was extended to the neighbourhood scale level, by evaluating building clusters, in combination with the required road infrastructure.

Regarding the selected environmental indicators (Table 1), the impact categories in the MMG method include the ones defined by the EN 15804 standard [6], which are further referred to as CEN indicators. In addition, seven more impact categories are considered based on the International Reference Life Cycle Data System (ILCD) Handbook [7]. The additional impact categories are further referred to as CEN+ indicators. Concerning land use, two types of interventions are considered: land occupation and land transformation. Land occupation occurs when a specific land use type is maintained over a period of time, leading to a delay in the recovery of land to its potential natural state, while land transformation refers to a change in the land use type [2]. Within the MMG method, impacts related to land occupation and transformation are evaluated based on a combination of two impact assessment methods, such as recommended by Allacker et al. (2014) [2]: soil organic matter (SOM) of Milà i Canals [8] for the impacts on soil quality and Eco-indicator 99 [9] for the impacts on biodiversity.

Table 1. Overview of the environmental impact indicators used in the MMG LCA method [4]. A distinction is made between the CEN and CEN+ impact categories.

CEN indicators	**CEN+ indicators**
Global warming	Human toxicity (cancer and non-cancer effects)
Depletion of the stratospheric ozone layer	Particulate matter
Acidification of land and water sources	Ionising radiation (human health and ecotoxicity)
Eutrophication	Ecotoxicity (freshwater)
Formation of tropospheric ozone photochemical oxidants	Water scarcity
Abiotic depletion of non-fossil resources	Land use occupation (soil organic matter and biodiversity)