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Commercial farming within the urban built environment – Taking stock of an evolving field in northern countries

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ABSTRACT

Urban horticulture has historically contributed to the supply of fresh produce to urban dwellers and has been gaining popularity over the last years in the Global North, with growing awareness of environmental and health concerns. Over the past few years, commercial farms have been emerging in major northern cities, promoting a trend of environmentally friendly food, grown in highly efficient installations on top of or in buildings. This paper presents a scoping study, including: (i) a *review* of the scientific literature addressing environmental, economic and social aspects of commercial farming in urban contexts; and (ii) a *consultation exercise* to inform and validate findings from the review, consisting of semi-structured interviews with a few practitioners in the Netherlands. The main findings are: (1) while the recent proliferation of commercial farms in major cities shows that these new modes of urban agricultural production are gaining momentum, establishing their viability as compared to conventional agricultural practices is a challenge when it comes to scalability, resource efficiency, and cost-effectiveness; (2) as it is still a relatively new field, very few studies have been conducted to quantitatively assess the impacts of commercial farming in urban areas; (3) given the complex environmental, economic and social dimensions of urban agriculture, holistic decision support tools could help integrating them in urban areas.

1. Introduction

Global population is projected to reach almost 10 billion by 2050, resulting in a higher demand for food by around 50% compared to 2013 – in a scenario of moderate economic growth; at the same time, income growth in low- and middle-income countries is expected to hasten a dietary transition towards higher consumption of meat, fruits and vegetables, requiring changes in agricultural output and intensifying pressure on natural resources (FAO, 2017). However, while an acceleration in productivity growth is needed, it is also hampered by the fast degradation of natural resources caused by agricultural practices, that have already led to massive land use change in order to meet demand for food, which in turn has amplified the environmental effects.

Agriculture and climate change are interconnected: the former not only contributes to the latter, but is also affected by its manifestations. The effects of agriculture on climate change have been largely demonstrated, mainly through GHG emissions, depletion of underground aquifers, and impacts of tillage, fertilizers and pesticides on soil, air and water quality, and on biodiversity (Clark and Tilman, 2017). Furthermore, the use of fossil fuels, jointly with land degradation such as desertification and deforestation, are the major anthropogenic sources of carbon emissions worldwide (IPCC, 2013). At the same time, rising carbon levels and the effects of global warming on temperatures and precipitations are projected to have impacts on crop yields (Zhang and Cai, 2011). In spite of the uncertainty in defining its net impact on the food system, it is likely that climate change will affect the suitable land area for crops, leading to significant socio-economic costs (Stevanovic et al., 2016).

In a context of climate change and increasing urbanization – over two-thirds of global population are projected to be living in cities by 2050 (United Nations, 2014), while some experts are skeptical about the capacity of the biosphere to produce enough food for the entire human population (Gilland, 2006), interest for local production to contribute to sustainable urban food systems has re-emerged among decision-makers (Baker and de Zeeuw, 2015), and the practice of urban agriculture as a food, income and employment generator is likely to expand (Caputo, 2012). Today, urban cultivation has been widely recognized not only to enhance food security by shortening and thus

Abbreviations: BIA, Building-Integrated Agriculture; CEA, Controlled-Environment Agriculture; GHG, Greenhouse gas; GWP, Global Warming Potential; PF, Plant Factory; RF, Rooftop farming; RG, RTG, Rooftop greenhouse; SC, Shipping Container; UPA, Urban and periurban agriculture; VF, Vertical Farming; VIG, Vertically-Integrated Greenhouse; ZFarming, Zero-Acreage Farming

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improving the resilience of food supply chains, but also to provide economic development opportunities, enhance urban public health (Brown and Jameton, 2000), and contribute to mitigate environmental impacts of the food system by reducing food losses and wastage and cutting transportation distances (Benis and Ferrao, 2016).

However, in spite of the growing awareness of its significant benefits for the environment and for communities, urban agriculture has been largely absent in urban planning strategies and policies (Pothukuchi and Kaufman, 2000; Steel, 2008) until very recently, and establishing its viability as compared to conventional agricultural practices is a challenge when it comes to land accessibility, scalability, resource efficiency, and cost-effectiveness. Over the past decade, hundreds of cities, both in the Global North and South, have developed policies and programs on urban food security, nutrition, and urban agriculture (Baker and de Zeeuw, 2015). At the same time, there has been large debate about defining sustainable cities and urban forms that alleviate pressure on natural resources. Some planners defend that "rurban" areas like the *Oosterworld* in the Dutch city of Almere, which combine housing and farming, can provide great sustainability (Jansma et al., 2014). Others advocate the concept of "green urbanism", which promotes compact resource-efficient urban development with mixed land uses, as a way of preserving agricultural land (Lehmann, 2010).

Whereas livestock, cereals and oilseeds require large areas of land, horticultural crops offer high yields in small areas and can thus be easily grown in urban gardens, backyards, vacant lots, rooftops or even indoors. Worldwide, a study has shown that urban agriculture would require around one third of the total global urban area to meet the global vegetable consumption of urban dwellers (Martellozzo et al., 2014). Other researchers have measured the potential of large North American and European cities for self-reliance in food if they were to use only their currently vacant urban space, estimating that 77–100% of urban vegetable demand can be met, depending on available areas and farming methods to be implemented, which would lead to different yields (Grewal and Grewal, 2012; Haberman et al., 2014; Orsini et al., 2014; Saha and Eckelman, 2017). Such proposals include large-scale implementation of high-yield urban horticultural production within the built environment. One of the commonly used concepts in the literature of such practices, Building-Integrated Agriculture (BIA), was coined in 2007 (Caplow and Nelkin, 2007) and consists of adapting soilless cultivation techniques such as hydroponics or aquaponics, for use on top of or in buildings in a way that exploits synergies between the buildings and the agricultural activities. On-site production through urban BIA cuts transportation distances and avoids land use change while creating urban jobs. Furthermore, when involving Controlled-Environment Agriculture (CEA), advantages of BIA include year-round production, higher yields, enhanced water use efficiency (Gould and Caplow, 2012) and improved building energy efficiency through the creation of symbiotic relations between the farm and its host building (Nadal et al., 2017). BIA systems can be applied: (i) on the building envelope, i.e., on the rooftop or facades, to take advantage of the availability of natural light; or (ii) indoors, in a fully controlled environment. In the literature, the term Zero-acreage Farming (ZFarming) can also be found, describing all types of urban agriculture characterized by the non-use of farmland or open spaces, and rather using otherwise unused spaces in the urban built environment (Specht et al., 2014). In this category, authors usually also include low-tech alternatives such as rooftop open-air on-soil farming.

Fig. 1 shows examples of different forms of farming systems that are currently sprouting within the built environment of major cities worldwide.

Among existing forms of envelope-integrated systems, rooftop farming is the most popular since rooftops represent large unutilized solar exposed urban areas. Rooftop farming is either practiced on intensive green roofs, or in Rooftop Greenhouses (RG) equipped with hydroponic equipment. In the latter, state-of-the-art installations generally include recirculating water systems, waste heat captured from the building's HVAC system, local renewable energy production such as solar PV, rainwater harvesting systems and evaporative cooling (Gould and Caplow, 2012). A few North American and European companies have already proven that significant amounts of local food can be produced year-round for urban dwellers on unutilized rooftops in dense cities where affordable land is rare.

For facades, Vertically-Integrated Greenhouses (VIG) have been developed as a concept and patented (Adams and Caplow, 2012). VIG systems consist of double skin building facades combined with hydroponic systems. However, to the best of our knowledge, there is currently no existing significant example.

Vertical Farming (VF) is another form of high-yield urban food

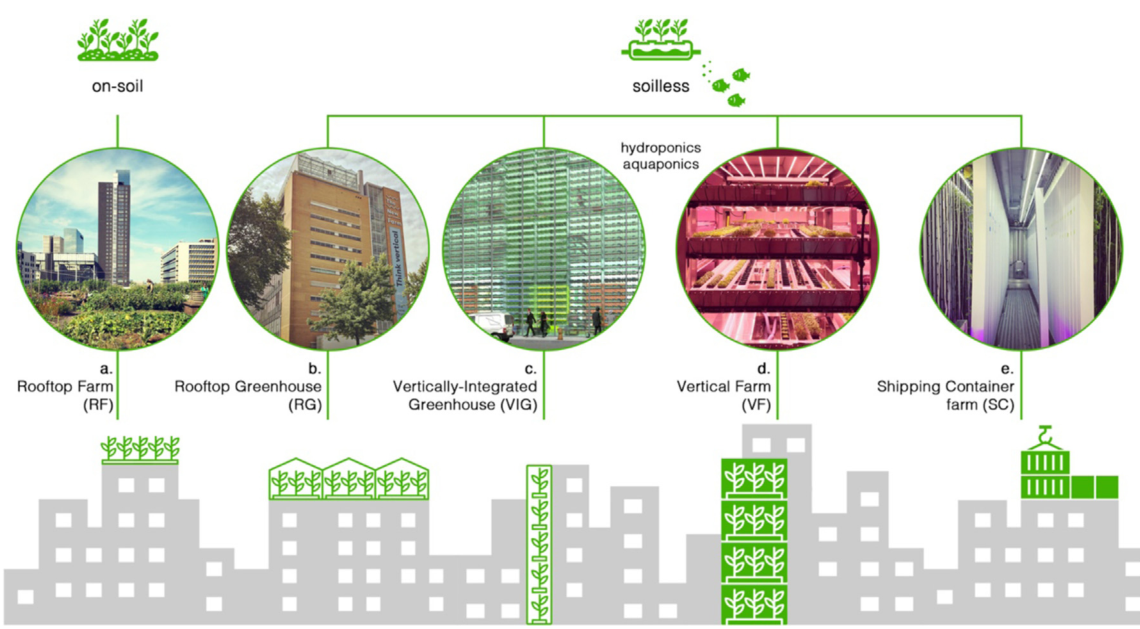

Fig. 1. Typologies of commercial urban farms. a. Dakakkers rooftop farm, Rotterdam; b. Urban Farmers aquaponics rooftop greenhouse, The Hague; c. VIG concept, patented by Adams and Caplow (US 2009/0307973 A1); d. GrowX vertical farm, Amsterdam; e. Freight Farms'Leafy Green Machine, Boston - a, b, d, e: First author's own photographs; c: New York Sun Works.