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OPPORTUNITIES AND CHALLENGES OF URBAN AGRICULTURE FOR SUSTAINABLE CITY DEVELOPMENT

Abstract. Urban Agriculture (UA) has gained popularity in cities all over the world. In this paper, we explore the concept of UA and discuss it along various locational and strategic dimensions. The article aims to provide insights into the chances and challenges of UA for sustainable city development. By making use of case examples from cities worldwide we show that UA can contribute to the social, environmental, and economics pillars of sustainable city development. However, there are limitations which should be taken into account for cities that want to invest in urban agriculture.
Keywords: urban agriculture, sustainability, cities, case examples.

1. INTRODUCTION

Driven by major developments, such as rapid urbanisation, climate change, lifestyle changes, and fast technological developments, cities all over the world invest in UA initiatives (Steel, 2008; Cockrall-King, 2012; Morgan, 2009). They do this with a variety of rationales and policies. In developing countries, UA is

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particularly used to feed the rapidly growing population, while in developed countries, UA usually is associated with lifestyle, health, community development, and innovation (Tornaghi, 2014). Despite this large diversity in motivations for UA, the underlying discourse is not so different (McClintock, 2010). The rising interest in UA can be regarded as a reaction to a crisis in the industrial food system, giving rise to 'food justice movements', 'alternative food systems' (i.e. Agymann, 2014), 'the new food equitation' (Morgan, 2009) or the 'food as a commodity versus food as a commons approach'. In a nutshell, it is stressed that food should not be perceived as a tradable product in a system mainly based on low costs, but as a human right, cultural determinant, renewable resource, essential for humans or public good in an alternative food system (Vivero-Pol, 2017). This would suggest a shift from an economic approach to a more social orientation in which UA is a key instrument in developing a more sustainable food system.

In the planning literature, the role of UA and (potential) changes in the food system have been discussed in studies dealing with urban food security strategies (Steel, 2008; Morgan, 2009; Van der Valk, 2012; Cockrall-King, 2012). Other studies focus on the role of UA at the rural-urban interface (Yang *et al.*, 2010; Torreggiani *et al*., 2012) or provide a spatial analysis of urban farms and other types of UA (Rogus & Dimitri, 2015; Pulighe & Lupia, 2016). There are also UA studies that deal with emerging technologies, such as 'vertical farming', providing new opportunities for architecture, business, innovation, and economic development (Thomaier *et al.*, 2015; Pfeifer *et al.*, 2015). Moreover, UA could play a role in ecological development by countering the negative effects of climate change and increasing bio-diversity in cities (Dubbeling, 2014).

All in all, it could be argued that UA offers opportunities for sustainable city development (Thomaier *et al.*, 2015; Pearson *et al.*, 2010). The concept of sustainable city development has been explored in many studies, with Haughton & Hunter (1994), Jenks & Johnes (2009), and Camagni *et al.* (1998) as just a few examples. Our analysis is restricted to the UA literature, and following Pearson *et al.* (2010), we explore the potential of UA for three dimensions of sustainable development: ecological, economic, and social development. The paper addresses two sets of questions: i) What UA is and what types of UA exist, and ii) What the chances and challenges of UA for sustainable city development are. To approach these questions, we make use of case examples of cities worldwide based on a desktop research strategy. We review the growing international academic literature related to UA, professional magazines, and other relevant (internet) sources. We make use of case examples worldwide rather than focussing on a single region. That seems sensible because UA is a global phenomenon, while exchanges of ideas and experiences take place between developing and developed countries (McClintock, 2010).

The remainder of this paper is structured as follows. Section 2 discusses dimensions and types of UA. Section 3 explores the benefits of UA for the various pillars of sustainable development and the challenges lying ahead. The last section concludes with a summary, and some policy advice.

2. UA: TYPES, LOCATIONS AND STRATEGIC FOCUS

The concept of UA has been widely discussed in the literature covering a wide range of disciplines. For example, in urban planning food security strategies are studied (e.g. Morgan, 2009), legal scientists deal with issues like food justice (Turner *et al.*, 2011), economists focus on themes like innovation and new business models (Opitz *et al.*, 2016), and engineers explore new farming technologies (Whittinghil & Bradley Rowe, 2011). Various studies provide detailed reviews of the UA literature, such as McClintock (2010) who has theorized the concept of UA in order to explain the rising interest of UA. Guitart *et al.* (2012) provide a detailed overview of the literature on urban community gardens, while Tornaghi (2014) reviews UA in the interdisciplinary literature in order to build a research agenda for the field of human geography.

From these reviews it has become clear that UA is a broad concept without a commonly agreed definition. The concept refers to the production of food within cities and around them. It includes commercial and non-commercial activities, and covers food processing as well as other activities in the food value chain (Van Oorschot, 2013; Rogus & Dmitri, 2015). Moreover, UA has many different purposes, appears in many locations, and takes many forms (Dimitri *et al.*, 2015). To give a general view of the different types of UA,[1] Tab. 1 – adapted from Pulighe & Lupia (2016) – provides an overview and description. In it, we have excluded 'residential gardens' that are normally limited to food production for household consumption and/or hobby purposes. However, we included a number of new types of energy efficient cultivation concepts and types of UAs – Vertical Farming, Zero-Acreage Farming (ZFarming), Plant Factories with Artificial Lighting (PFAL), Agro-parks and Agro-tourism – that are a result of rapid technological development and convergence of different technologies, including IT, energy, and biology. Not every type of UA fits in a single category, and overlaps between the types exist (McClintock, 2014). Combinations are also possible. For instance, community gardens on roofs of buildings can make use of ZFarming technologies.

[1] Various types of UA also exist in rural areas. We classify the types as UA when those take place in urban or peri-urban locations.

Several researchers (McClintock, 2014; Thomaier *et al*., 2015; Pulighe & Lupia, 2016) indicate that the various types of UA differ in terms of, among others, the scale and location of production, management, and organisation (for instance, public vs private), strategic focus, and the market dimension (i.e. commercial vs non-commercial). Thus, UA is a multi-dimensional concept (Rogus & Dmitri, 2015). The various dimensions can be divided into two main categories, i.e. the 'locational dimension' and the 'strategic focus' (see Fig. 1). The locational dimension deals with locations of UA in cities, while the strategic focus refers to various purposes of UA, market orientation, and the products it generates. We use the two dimensions to further explore what UA involves.

Table 1. Different types of UA

Type	Description	Reference(s)
Community gardens	Broad term covering various types of gardens, including demonstration gardens, horticultural therapy gardens, job-training gardens, neighbourhood gardens, inter-cultural, etc. Those diverse gardens can play a role for various purposes, such as promoting urban health, social inclusion, and active civic participation.	Turner *et al.,* 2011 Guitart, *et al*., 2012
Institutional gardens	Food production management by institutes, such as schools, hospitals, prisons, and other non-profit organisations.	Pulighe & Lupia, 2016
Guerrilla gardening	Gardening public space with or without permission, in the latter case also known as 'illegal gardening'.	Tracey, 2013
Urban farm	Commercial food production by professional farmers using intense and advanced growing systems.	Pulighe & Lupia, 2016
Vertical farming	Indoor farming based on hydroponic and aquaponic technologies.	Despommier, 2010
Plant factories with artificial lighting	Indoor farming combined with resource utilisation efficiency and closed plant production system.	Kozai, 2013
Zero-Acreage Farming	Specific forms of food production that are characterised by the non-use of land, covering various forms and technologies.	Thomaier *et al.*, 2014
Agro-park	Clusters of agro-activities in which various links of the food chain are located in one place. The concept has been developed to apply industrial ecology in the agro-sector.	Smeets, 2009 Metze & Van Zuydam, 2013
Agro-tourism	Farming in agro-recreational parks in peri-urban locations combined with the provision of facilities and services for urban tourists (e.g. food, accommodation, guided tours, and horse riding).	Yang *et al.*, 2010

Source: own work.

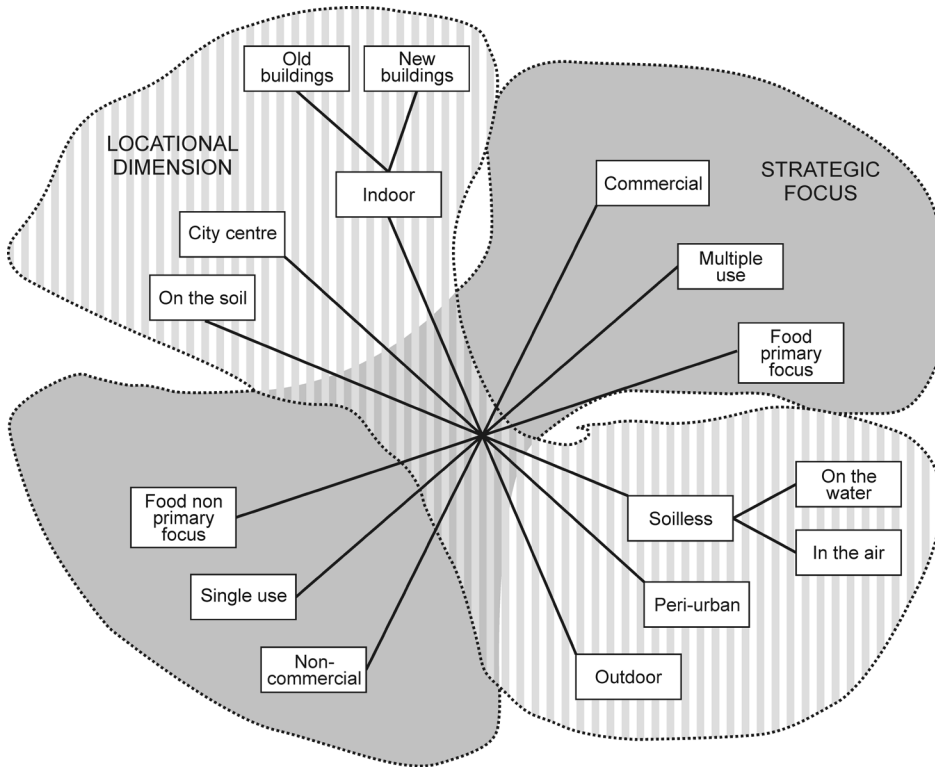

Fig. 1. Urban agriculture as a multi-dimensional concept

Source: own work.

2.1. The locational dimension of UA

City centre versus peri-urban

UA can take place at several spatial levels, ranging from small yards on the neighbourhood level providing food for individuals to large commercial urban farms producing food for various communities (Pearson *et al*., 2010; McClintock, 2014). UA refers to agricultural activities in 'urban' and in 'peri-urban' areas (i.e. Van Oorschot, 2013). In other words, UA covers large urban regions, such as Greater Paris, the city-state of Singapore, and the New York metropolitan area (including New Jersey and Connecticut). It also includes urban and peri-urban parts of polycentric metropolitan regions, such as the German Ruhr Area and the Dutch Randstad Area.

Within metropolitan areas, UA can take place in various places, and in different forms. UA can be found in central districts or downtown areas, such as New York

Gotham Greens' rooftop farm on top of a supermarket in Brooklyn.[2] Another example is the Pasona O2 urban farm which is an indoor office farm in the financial district of Tokyo (Feng, 2013). There are several types of urban gardening initiatives on empty plots in city centres, as well as in non-central urban districts. For instance, youngsters have started gardening in the trendy urban neighbourhood of Berlin Kreuzberg. Similarly, the so-called 'inter-cultural gardens' have been set up at the site of the former Berlin-Tempelhof Airport in order to bring people with different cultural backgrounds together (Müller, 2014).

UA can also be found outside core cities, in peri-urban areas, in places that are strategic from a logistical point of view, e.g. close to highways, ports or airports. Those so-called 'agro-parks' are concentrations of agriculture and related activities. Different parts of the food value chain are combined there to create synergies, like re-using energy sources and reducing transport movements (Smeets, 2009; Metze & Van Zuydam, 2013). An interesting example in that respect is Bio-Park Terneuzen in the Netherlands, where the company WarmCO2 produces vegetables in glasshouses using the heat and CO2 from industrial companies next door at the same industrial site (Biopark Terneuzen, n.d.). Similarly, UA in peri-urban locations can be found in the so called 'agro-tourism enterprises', where agriculture is combined with tourism (Yang *et al.*, 2010).

Empty spots on vacant land are also fruitful places for UA. Those include small-scale 'guerrilla gardening' initiatives (Tracey, 2013), as well as larger strategic initiatives on industrial brownfields. For instance, in Detroit, many urban agricultural initiatives take place at former industrial locations. Those cover both social projects in order to generate work for a large group of the unemployed, as well as commercial initiatives aimed at using UA as a new way to generate income (Cockrall-King, 2012).

Farming on the soil versus soilless farming

A second locational dimension of UA is 'farming on soil' versus 'soilless farming'. Traditionally, agriculture is a soil-based activity with 'land' being a key production factor. However, due to technological developments and driven by increasing scarcity of suitable agricultural land, it is possible to produce food 'in the air' and 'on the water'. Firstly, it is possible to produce food on, in, and around buildings. This refers to relatively simple soil-based food production on balconies and in rooftop gardens. Examples include 'Brooklyn Grange' – the world's largest rooftop garden in New York (Miller, 2014) – and 'Dakpark' in Rotterdam, a vegetable garden, restaurant and park on top of a shopping centre.[3] In addition, thanks to new cultivation technologies and energy efficient growing concepts, such as 'aeroponics' (soilless growing where roots are misted in nutrient-dense water),

[2] http://gothamgreens.com (26.02.2018).

[3] http://www.dakparkrotterdam.nl (26.02.2018).

'hydroponics' (growing plants in nutrient-rich water) and 'aquaponics' (indoor fish farming), it is possible to produce food without the use of land. An example of this 'Zero-Acreage Farming' (Thomaier *et al*., 2015) is the 'UF001 LokDepot', a commercial aquaponics rooftop farm on an old locomotive depot in the Swiss city of Basel (Junge, 2014).

A specific type of Zero-Acreage Farming is the vertical farming concept developed by Despommier (2010). The concept refers to high-tech indoor farming based on modern agricultural and environmental technologies. It can be regarded as a synthesis of architecture, technology, gardens, and agriculture (Torreggiani *et al.*, 2012). Vertical farm projects are rapidly taking off in various places of the world (Despommier, 2010). An example is the Sky Green vertical farm in Singapore that consists of more than 750 towers with about 2,600 plants in each tower. Those 'farm skyscrapers' are a response to Singapore's chronic lack of food security caused by high population density with limited space to grow fresh food (Ng, 2014). Floating technologies are also used to develop new urban agricultural concepts. One example is a floating greenhouse in the Westland area (the Netherlands) that was fulfilled as a demonstration project on the site of Flora Holland, an auction hall for fresh flowers, in 2005.[4] Likewise, a floating urban dairy farm in Rotterdam (planned to be opened in 2018) has been set up as a 'creative living lab for UA built on water', combining floating technologies and modern cultivation technologies, aiming to produce local fresh food in dense urban surroundings (Verhoeven, 2017).

Outdoor versus indoor farming

Outdoor versus indoor farming is another locational dimension of UA. In addition to traditional outdoor farming and food production in dedicated greenhouses, modern technologies enable agricultural activities also inside common buildings. Concepts like 'vertical farming' and Plant Factory with Artificial Lighting ('PFAL') (Kozai, 2013) deal with modern installations and equipment based on artificial lighting (mainly LED light) and other high-tech systems enabling the cultivation of crops inside buildings.

A further distinction can be made between UA in new and old buildings. On the one hand, we can find various examples of indoor farming in new buildings, such as Sky Green (Singapore) and the Suwon vertical farm (South-Korea). On the other hand, UA can be a creative way to re-use old buildings (Pfeiffer *et al*., 2015). Examples of that are RotterZwam, a mushroom grower and coffee bar in a former swimming pool in Rotterdam (Cox & Slegers, 2014), and Nuvege in Kyoto that houses a vertical farm in an old aircraft hangar (Marks, 2014).

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[4] http://www.urbangreenbluegrids.com/projects/floating-greenhouse-naaldwijk-the-netherlands/?s=floating%20 (26.02.2018).

2.2. Strategic focus, inputs and outputs of UA

Apart from differences in terms of location, UA differs in terms of its strategic focus (see Fig. 1). The focus, or main purpose, differs according to the type of UA and ranges from urban gardening projects for community construction, education and/or leisure purposes to professional, often high-tech, farming activities for commercial purposes (McClintock, 2014; Thomaier *et al.*, 2015). Many combinations are possible with all kinds of side activities, like food markets and restaurants in addition to gardening opportunities. To further investigate the activities and products that can be observed in practice, we make a distinction between inputs and outputs of UA (see Fig. 2).

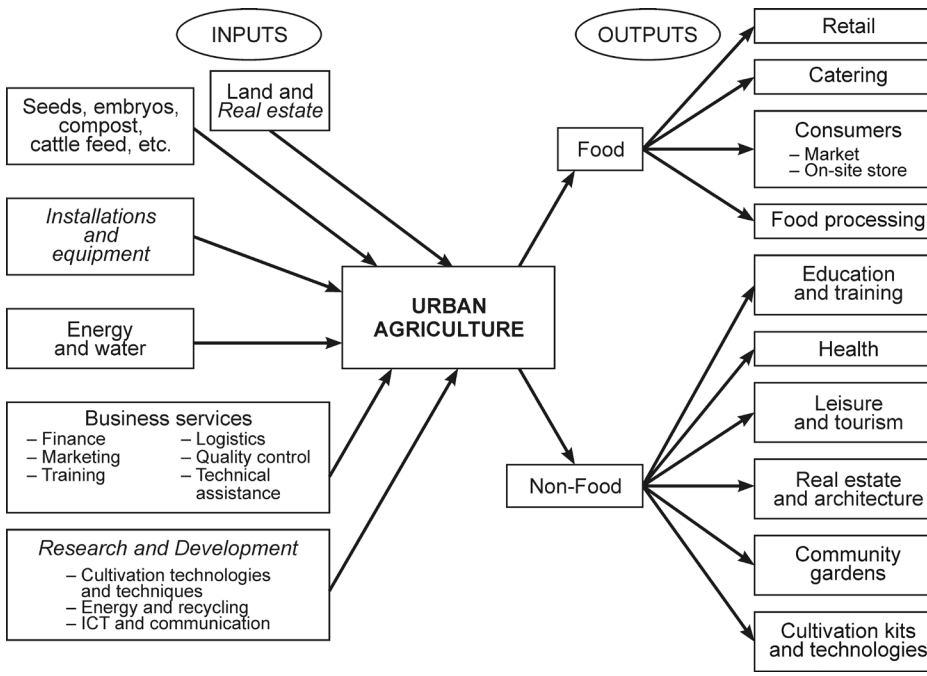

Fig. 2. Urban agriculture in the value chain
Source: own work.

Inputs of UA

The left-hand side of Fig. 2 shows the upper part of the value chain: all inputs needed for food production, including common inputs for traditional agriculture, as well as new inputs for modern high-tech UA (italicised). Traditional inputs include (natural) resources, such as land, cattle feed, seeds, embryos, and energy. Additionally, there are all kinds of supporting services, like financing, logistics, marketing, quality control, training, and technical assistance. For modern UA, new inputs may be used, like real estate, needed for indoor farming and rooftop

farming. Thus, new players are included in agricultural activities, such as property owners, architects, and planners (Thomaier *et al.*, 2015).

Another type of new input are the installations and equipment for UA, i.e. new farming systems and technologies, such as grow kits and plant towers. In that respect, knowledge institutes can also play a role. In Switzerland, for example, UrbanFarmers AG is a spin-off from the University of Applied Sciences in Wädenswil, and runs the UF001 LokDepot rooftop farm in Basel, while in the city of Dresden, the concept of Brickborn Farming has been developed by researchers from the University of Applied Sciences Dresden (Junge, 2014).

Urban farming systems vary from high-tech to low-tech, and are sold to professional farmers as well as to consumers and users in other industries. An example of a relatively simple product is offered by RotterZwam that does not only sell mushrooms, but also 'mushroom grow kits' for household applications (Cox & Slegers, 2014). Developers of more advanced systems include Mirai Co. Inc. (Japan)[5] and PlantLab (The Netherlands). PlantLab has developed the so-called 'Plant Production Units' that can be applied in producing a wide product range, such as vegetables, flowers, and ingredients for medicines and cosmetics.[6]

Outputs of UA

The right-hand side of Fig. 2 indicates the outputs of UA, or the lower part of the value chain. UA consists of a 'food' and a 'non-food' part, leading to a wide variety of business and funding models (Thomaier *et al.*, 2015). In many cases, food production is often only a secondary goal following from other social or economic goals (Pfeiffer *et al.*, 2015; Cockrall-King, 2012). Many UA projects, especially those initiated by NGOs, are devised for social purposes, like increasing social cohesion (e.g. in inter-cultural gardens) (Müller, 2014), educational and learning purposes (like kids visiting urban farms), and health care (e.g. fresh food for low-income neighbourhoods). In addition, UA projects can have environmental goals, such as 'greening cities' and 'climate protection' (Dubbeling, 2014).

The development of new business models around UA means that food production can be combined with other economic activities, such as restaurants, processing industries, leisure and tourism, real estate, and architecture. For example, the Plant in Chicago combines UA with a bakery and a brewery, and the project is used as an innovative strategy of re-using old buildings (Cockrall-King, 2012). In China, there are various agro-tourism enterprises combining high-tech agriculture with tourism and leisure in the form of fishing, gardening, hotels, and restaurants (Yang *et al.*, 2010). More generally, developers may invest in UA as a regeneration strategy to increase property values. Finally, food production can be combined with R&D leading to technological development and new (export)

[5] http://miraigroup.jp/en/ (26.02.2018).

[6] http://www.plantlab.nl (26.02.2018).

products. Companies like Sky Green not only sell fresh vegetables to retailers or consumers directly, but they also sell new grow concepts and plant towers to other farms (NG, 2014).

To sum up, in its simplest form, UA refers to food production in and around cities for commercial and non-commercial purposes. It may take place in metropolitan areas, covering urban and peri-urban places, as well as in and around buildings. In addition, UA has a food dimension, as well as non-food dimensions. As such, the concept is clearly different from traditional agriculture in rural areas and industrial food production. UA is regarded as a multi-functional concept (McClintock, 2010), and has particular social, economic, and environmental aspects.

3. OPPORTUNITIES AND CHALLENGES OF UA

In this section, the potential of UA for sustainable city development is first discussed. After that, the challenges of UA that also should be taken into account are identified.

3.1. Potential benefits of UA

UA can be beneficial for all pillars of sustainable development, be it social, ecological/environmental or economic. This sub-section lists the reasons for that.

Social development

UA may contribute to social development in at least three (related) ways. Firstly, UA is an important element of food security strategies. In developing countries, cities use food security strategies to 'feed citizens', and to fight chronic hunger. Examples include the Brazilian city of Belo Horizonte – 'the city that ended hunger' – and the African cities of Kampala (Uganda) and Dar es Salaam (Tanzania) that have integrated UA in their planning strategies to increase food security (Morgan, 2009). In developed countries, cities use UA to give citizens access to healthy and fresh food. Frontrunners include New York, Chicago, Vancouver, and Toronto in North-America, while Amsterdam and London could be regarded as pioneers in Western Europe (Morgan, 2009; Cockrall-King, 2012; Johnson Coffin & Young, 2017). In some of those, UA is an important tool for countering 'food deserts', i.e. low-income neighbourhoods that are devoid of grocery stores or markets. In those areas people have little or no access to healthy and fresh food because grocery stores have been relocated to suburbs, following more affluent customers (Cockrall-King, 2012).

Secondly, UA can be used for community development. This refers particularly to urban gardening as an activity to increase social cohesion between different groups in the society, to provide work and training experience for unemployed workers, and as a tool for crime prevention. Many examples could be offered, such as inter-cultural gardens in Berlin (Müller, 2014), Growing Power Inc. as a training centre for youths (Cockrall-King, 2012), the Recovery Park in Detroit as a large social programme to generate jobs, and the Refugee Empowerment Agricultural Programme in Cleveland where urban gardening is used as a strategy to help former prisoners return to the society (Masi *et al.*, 2014).

Thirdly, UA is used in cities for educational purposes. Through workshops, courses, and tours, urban farmers increase the awareness among citizens about the origin and production of food (e.g. 'milk comes from a cow and not from the supermarket'). Examples include the Science Barge in New York (Ehrenberg, 2008), Pasona O2 in Tokyo (Feng, 2013) and the Floating Urban Diary Farm (Rotterdam). Another example is 'Uit je eigen stad' ('From your own city'), an urban farm in Rotterdam that offers courses, workshops, and internships to the youth (Van den Broek, 2013).

Environmental development

UA has various benefits for environmental development, such as increasing biodiversity, and the reduction of pollution. Cities use UA also for climate change mitigation, and adaptation (Masi *et al.*, 2014). For instance, New York promotes green infrastructure and UA in its storm water management strategy, just like Durban where UA is also used for increasing biodiversity and producing food to feed the local population (Dubbeling, 2014). Furthermore, UA can be employed for the 'greening of cities'. For example, the Pasona O2 office farm 'greens' Tokyo's urban jungle by bringing some nature to the sterile downtown office environment (Feng, 2013).

Modern high-tech urban farming is also applied to create closed-loop energy systems between different types of agriculture (e.g. between fish farming and crop production) and between agriculture and other activities. Important examples with such closed-loop systems on urban farms are The Plant in Detroit and Growing Power Inc. (Cockrall-King, 2012). Similarly, energy reduction and resource efficiency have been fulfilled by linking agriculture with the manufacturing industries at the same site, which is one of the major aims of 'agro-parks' (Smeets, 2009). On a larger scale, in Rotterdam, the so-called 'heat-roundabout' project links industrial firms in the port with large scale agricultural production in the greenhouses of the Westland area (Duursma, 2017).

Economic development

UA offers economic benefits for cities in various ways. Firstly, it can be regarded as a new way for generating income. There are already various firms that use UA for commercial purposes. Some of the examples include Panasonic Factory

Solutions Asia Pacific (Singapore) that designs and develops indoor agricultural solutions for the business market,[7] Lufa Farms in Montreal (Canada) that operates large scale commercial hydroponic rooftop farms,[8] and the already-mentioned RotterZwam (Cox & Slegers, 2014). UA is also important for entrepreneurship and new firm formation. For instance, The Plant in Chicago offers specific incubator spaces and services to help start-ups in the food processing business (Cockrall-King, 2012).

Secondly, UA is important for innovation, research, and knowledge development. Many high-tech urban farms function as pilots for new (indoor) vertical growing technologies and closed loop systems. Therefore, various urban farms have R&D labs on site – such has the Science Barge in New York (Ehrenberg, 2008), and the Sky Green (NG, 2014) – or they are linked with knowledge institutes, like UrbanFarmers AG in Basel (Junge, 2014).

As a result of such R&D strategies, UA may lead to the development of new products and markets. For instance, UrbanFarmers AG expanded its activities to the Netherlands in 2016, where it opened in the Hague Europe's largest commercial urban farm. On the roof of a former office building, UrbanFarmers AG is now producing vegetables and fish on a commercial basis (Van der Heijden, 2015). That does not only refer to fresh food sold against premium prices, but also to other products, including new growing technologies and closed loop systems. Therefore, it is no coincidence that various urban farms sell not only vegetables, but also high-tech farming technologies, e.g. AeroFarms (Newark),[9] and Future Growing LCC (San Francisco).[10] PlantLab ('s-Hertogenbosch),[11] and Plantagon International (Stockholm/Linköping)[12] have set up 'vertical farms' as 'demonstration plants' to promote new technologies. Other companies sell vegetables and 'simple' household grow kits to consumers, with Top Sprouts (Boston)[13] being an example.

Thirdly, UA may offer potential for recreational, tourist and marketing purposes. Many urban farms are open for the public, and organise tours, and as such, they could be compared to other tourist attractions. Moreover, working on a farm is a trendy way of spending free time, and escaping stressful daily life, especially for workers with a high income. This refers also to 'crop mobbing' in which participants pay to work on a farm. For instance, various rooftop farms in Queens or Brooklyn offer the possibility to do agricultural work while enjoying a fascinating view on Manhattan (Van der Valk, 2012). A more extreme form are agro-tourism enterprises where agriculture is combined with tourism facilities, like the Xiedao

[7] http://www.pfsap.panasonic.com.sg (26.02.2018).
[8] http://corpo.lufa.com/en/index.html (26.02.2018).
[9] http://aerofarms.com (26.02.2018).
[10] http://www.futuregrowing.com (26.02.2018).
[11] http://www.plantlab.nl (26.02.2018).
[12] http://www.plantagon.com (26.02.2018).
[13] http://www.topsprouts.com (26.02.2018).

Green Resort in Beijing (Yang *et al.*, 2010). Finally, in the real estate sector, UA is sometimes seen as a promotion and marketing tool to increase property values, and create shared values with local stakeholders. For instance, in Amsterdam, a real estate developer has invested in a large rooftop garden on a former department store to be used for recreation and food-production. The aim is to add more economic value to the building, while also contributing to social development (Oskam *et al.*, 2013).

All in all, UA offers various bases of economic potential. However, the degree of commercial success (or for non-profit companies: not making losses) depends on many factors, including the 'mix of activities'. Success depends on what is defined as the core business and what part(s) of the value chain is/are covered. Other success factors include the 'mix of products' – e.g. the balance between high value crops and other products – and the degree to which subsidies are possible, such as grant money for research or brownfield clean-up (Cockrall-King, 2012). However, in many cases, the focus of UA is not on food production and commercial purposes, but on social and/or ecological development (Pfeiffer *et al.*, 2015).

3.2. Challenges of UA

Despite its potential for sustainable city development, there are several weak points concerning UA. To start with, UA is not as new as it seems (Steel, 2008; McClintock, 2010). Agricultural activities were common practice in cities in developed countries in the past. For example, one sixth of the total surface area of Paris in 1890 was used for agriculture, generating over 1,000,000 tonnes of vegetables per year (Cockrall-King, 2012). In general, allotment gardens were widely used as a food security strategy during industrial times in order to feed the low-class industrial and mining workers. Furthemore, more advanced types of UA are not new. For instance, the first commercial PFAL was developed by General Electric in the USA in the 1970s, but was discontinued at the beginning of the 1980s due to a lack of sufficient market demand (Kozai, 2013). Similarly, modern cultivation techniques and closed loop systems have already been widely used in 'normal' agriculture, such as in greenhouses of the high-tech horticulture cluster of the Westland area in the peri-urban zone between the Dutch cities of Rotterdam and the Hague.

Next, it can be argued that UA is not as healthy and fresh as expected. Vaneker (2014) even noted that due to (air) pollution in cities, there are health risks concerning 'urban vegetables' that may contain high concentrations of heavy metals. Similarly, it has been argued that new soilless growing technologies lead to 'artificial food' that lacks sufficient natural nutrients.

Furthermore, UA may lead to conflicts with other urban functions, such as living and working. There can be a lack of sufficient and suitable land for agricultural

activities in cities, and whenever space is found for it, UA may cause negative externalities, such as air pollution (e.g. odour from livestock), or overcharging the city's energy grid (Lawson, 2016). Environmentalists may also protest against farming in cities, particularly referring to (animal) husbandry. For instance, in Rotterdam, environmentalists have (unsuccessfully) protested against a pilot project dealing with pig farming in rooftop gardens which is said to go at the cost of the wellbeing of pigs (AD, 2015).

Moreover, and related to the previous point, UA may be hindered by legal constraints and governance conflicts. Zoning policies and certification have an impact on all aspects of UA, including siting, production, infrastructure, marketing, and access to inputs (Pfeiffer *et al.*, 2015). In general, certification is seen as an important constraint for farming in cities, which explains why many urban farmers focus on the social dimension of UA rather than producing for the market (Thomaier *et al.*, 2015).

Finally, UA requires large investments to cover high operational costs, including the costs of the infrastructure, energy, and management (Van der Valk, 2012). Therefore, it may be hard for beginner urban farmers to generate sufficient income (Dimitri *et al.*, 2016). Vertical farming in buildings in particular leads to high energy costs, making it difficult to compete with traditional outdoor farming in regions with a better climate. However, technology has developed rapidly. For example, Philips has demonstrated that new LEDs reach 68 per cent efficiency – compared to normal LEDs with about 28 per cent efficiency. That could cut lighting costs considerably (Marks, 2014). Moreover, due to a high concentration of different activities in cities (e.g. living, leisure, and different economic activities) it is easier to develop closed loop systems, and to increase energy efficiency.

All in all, the success of UA is far from guaranteed. There are limitations to the concept creating challenges for cities that intend to invest in it. UA is hindered by a variety of economic, spatial, functional, organisational, and institutional challenges. These challenges might be hard to overcome, especially when cities strive for an integrated approach towards UA.

4. CONCLUSIONS

In this paper, various dimensions and types of UA have been explored in order to provide insights into its opportunities and challenges for sustainable city development. If anything, it can be concluded that UA is a multi-dimensional (Rogus & Dimitri, 2015) and multifunctional (McClintock, 2010) concept. Starting with the locational dimension, UA takes place in urban as well as in peri-urban locations of metropolitan areas, as well as in around buildings. Regarding the strategic focus and resulting projects and products, we have seen that UA clearly differs from

traditional farming in rural areas and from industrial food production. The concept covers activities in different industries, and may involve a variety of stakeholders, including farmers, citizens, planners, architects, policy makers, entrepreneurs, and educational and research institutes. Besides food, many urban farms offer a whole range of non-food related products and services, such as education and training, cultivation kits and installations, and tourism and leisure services.

In Fig. 3, we have plotted the potential contributions of UA to the different pillars of sustainable city development. UA can be beneficial for social development in the form of urban food security (to prevent hunger as well as to provide access to fresh and healthy food), community development (e.g. to increase social cohesion and crime prevention) and for educational purposes. Regarding environmental development, UA can be used for the greening of cities, climate mitigation and adaptation, increasing bio-diversity, and for pollution reduction. UA also has the potential to apply new closed-loop systems with other urban activities. From an economic standpoint, UA offers potential for the generation of new income, entrepreneurship, knowledge development and innovation, and for new export products. However, we need to stress that 'success' of UA in a city is far from guaranteed, as clearly indicated by the limitations to the concept and challenges ahead, like legal barriers, high costs, a lack of space, conflicts with other urban functions, and health risks regarding food produced on urban farms.

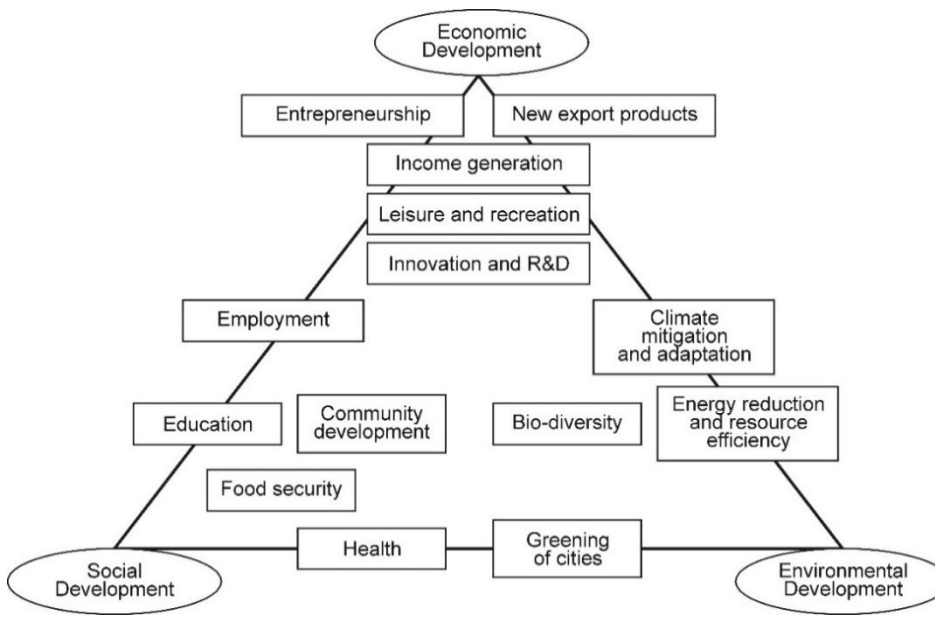

Fig. 3. Urban agriculture and the potential for sustainable city development

Source: own work.

From a policy perspective, UA affects many domains of city administration, suggesting the need to integrate UA in wider urban planning, or even broader sustainability strategies (Pearson *et al*., 2010). As a concept, it could be used to foster social, economic, and environmental aspects of sustainable city development. However, just like sustainable development in general, in practice it will be difficult to balance the various pillars of sustainable city development by means of UA. Therefore, it makes sense to invest in UA to counter the most urgent challenges in the city (e.g. fighting hunger, upgrading old industries, or social integration). At the same time, UA is just one of the many tools of sustainable city development. It is certainly not a 'panacea for urban ills' (McClintock, 2010; 2014). From that perspective, cities should invest in the right type of UA at the right place and for the right reasons, while being realistic about its potential. To note an example, it makes no sense to invest in expensive high-tech indoor farming in a part of a city with sufficient outdoor place. Nor does it make sense to set up large UA projects in an area with options to import fresh food at low prices from bordering places. Therefore, following the approach of Pulighe & Lupia (2016), we encourage policy makers to map various types of UA initiatives in their cities. Such a database could be used as a valuable planning tool to increase the contribution of UA for sustainable city development.

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