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Features and Functions of Multifunctional Urban Agriculture in the Global North: A Review

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In recent years, urban agriculture (UA) projects have bloomed throughout the world, finding large applications also in the developed economies of the so-called Global North. As compared to projects in developing countries, where research has mainly targeted the contribution to food security, UA in the Global North has a stronger multifunctional connotation, and results in multiple combinations of farming purposes and business models pursued. The present review paper explores the contribution and role that UA plays in cities from the Global North, defining its functionalities toward ecosystem services (ES) provisioning and analyzing the factors that hinders and promote its regional diffusion and uptake. The manuscript integrates a description of UA growing systems, as well opportunities for crop diversification in the urban environment, and a comprehensive classification of UA business models. The distinctive features in terms of business models, farming purposes and farm size are then applied over an inventory of 470 UA projects in the Global North, allowing for a characterization and comparative analysis of distribution frequency of the different project typologies.

Keywords: urban horticulture, green infrastructure (GI), vertical farm, rooftop agriculture, ecosystem service, ecology, business models, circular cities

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INTRODUCTION

First, it was hunting for food and caves to live in. Then, settled agriculture came, in the form of horticulture, primarily practiced by women, to complement the game that men brought home (Hansen et al., 2015). Homes that were built to provide shelter to the family, with horticulture that along the ages would become the first formal organization of nature, following strictly defined structural patterns. While geometry naturally occurs within ecological systems, human mind requires regular forms; therefore, gardens were created following geometrical patterns already in ancient Egypt. Integration of agriculture within the anthropic landscape also emerged in Babylon's hanging gardens (**Figure 1**) or in the so-called *sacred lands* devoted to food production in Greek cities in the classical era (Isager and Skydsgaard, 2013). In *Roman* gardens, exotic species could be found, as emerged in the buried gardens of Pompeii. The practice of plant cultivation in villages and towns further became established in the middle ages in the form of *hortus,* where applications of relationships, dimensions and figures evolved from the Pythagoreans (Steenbergen and Reh, 2003). The *hortus* pattern recurred through gardens that complete the village's general geometry and feed the local community. They were often placed between the town defensive walls, enabling food security in times of wars. Horticulture also developed in monasteries where food production and processing were established under the Rule of Saint Benedict (Aben and de Wit, 1999). *Arabic*

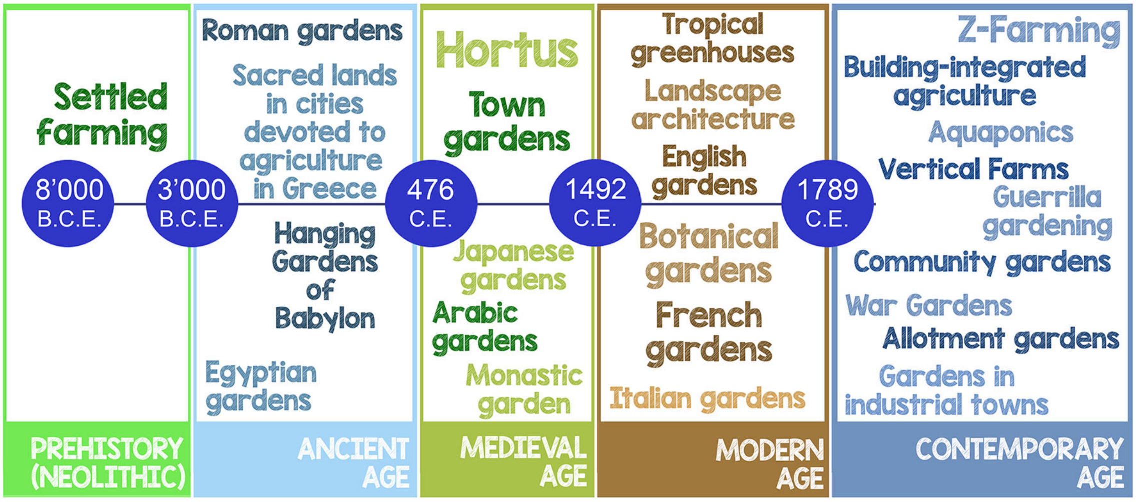

FIGURE 1 | Timeline of relevant keywords along the history of Urban Agriculture.

gardens combined beauty and sensorial experiences, building on the beneficial effects that plants can bring to humans (**Figure 1**).

In the modern age, and along the Renaissance, whole farms were conceived following the *hortus* design, until the Romanticism and toward the time of affirmed urbanism, where a re-unification of the rural-urban continuum occurred. Exotic plant species were grown in tropical glasshouses in private villas of the wealthier or in urban botanical parks. English, Italian and French gardening schools were born, paving the way for modern landscape architecture principles. In the contemporary age, and from the industrial revolution, gardens were found within the fringes of industrial towns, contributing to the food security of the migrant workers (Partalidou and Anthopoulou, 2017). Allotment gardens were established and became formally recognized. During the world conflicts of the twentieth century, war or "victory" gardens were promoted by governments to feed the urban population, while starting from the post-war period, urban horticulture has become a social structure, an economically fundamental element, a source of ecosystem services (ES) for sustainable cities (Keshavarz and Bell, 2016). It assumed the form of political activism, as for the case of community gardens and guerrilla gardening initiatives. In these same years, however, the rapid economic growth of cities was associated with a general decentralization of functions (e.g., with agriculture being moved out from the city, where it was assumed to be healthier thanks to the lower air pollution), and the increased urbanization resulted in severe fragmentation of urban and peri-urban farmed plots (Mok et al., 2014). Nevertheless, from the beginning of the twenty first century, the rapid evolution of agricultural technologies has brought new forms of plant cultivation, allowing for multiple productions and circularity (e.g., in aquaponics systems), but also through the creation of common metabolisms in urban buildings, as for the growing examples of vertical farming and rooftop agriculture projects (**Figure 1**) (La Rosa et al., 2014).

While fresh horticultural goods represent its main products, urban farming today also explores new crops and novel food products and services. A set of innovative business models takes form, and a plethora of experiences emerge at global level. Meanwhile, a clear differentiation emerges between urban agriculture (UA) specifically aimed at tackling food insecurity and the forms it may take when occurring in wealthier world regions, where the associated ES may even become more relevant than food production *per se*, at least until the SARS-CoV-2 outbreak (Lal, 2020). Indeed, while the role and functions of UA in developing countries have been addressed in several review papers (Bryld, 2003; de Bon et al., 2010; de Zeeuw et al., 2011; Gallaher et al., 2013; Orsini et al., 2013; Hamilton et al., 2014; Poulsen et al., 2015), a more limited body of literature (e.g., Mok et al., 2014; Lin et al., 2015) considered to date the role and forms it may play within stronger economies of the so-called Global North (e.g., UN classified "developed countries, United Nations, 2020).

In the coming sections, this review paper brings together a comprehensive state of the art of all the above-listed features of agriculture in cities in the Global North, including a classification and inventory of urban farming projects. While the research does not target the comparative analysis of UA in the Global North vs. Global South, it actually builds on data from Global North in order to answer the following research questions:

1) *Which are the main ES of UA in the Global North?*
2) *Which factors affect the development and diffusion of UA projects?*
3) *Which are the most represented farming systems for UA in the Global North?*
4) *What is the average farm size in UA projects?*
5) *How can business models in UA be classified and which business models are more common in the different regions of the Global North?*

6) *Which are the most relevant farming purposes of UA?*

In order to answer the research questions, the research methodology combined an extensive literature review on ES provided, functions, enabling factors, cropping system typologies and associated business models observed in UA projects in the Global North, altogether with the implementation and classification of a database of regional case studies. The literature review was performed using scientific journal databases, including Google Scholar® and SCOPUS®. Search strings were compiled by integrating selected keywords including "urban farming," "urban and periurban agriculture AND/OR horticulture," "urban food security," "urban food safety," "horticultural therapy," "multifunctional agriculture," "ecosystem services," "social function," "urban regeneration," "urban planning," "urban land," "vacant land," "eco-efficiency assessment," "life cycle assessment (LCA)," "social-life cycle assessment (S-LCA)," "social justice," "urban green infrastructures," "life cycle costing (LCC)," "urban ecology," "urban biodiversity," "food contaminants," "urban pollution," "urban heat island," "allotment gardens," "community gardens," "rooftop agriculture AND/OR farming AND/OR garden AND/OR greenhouse," "hydroponics," "plant factories with artificial lighting (PFAL)," "vertical farms," "urban beekeeping," "urban peasant," "business model," "farming purpose," "entrepreneurial urban agriculture." Within each combined search, selected articles from first 50 results for each keyword search were used for the study, altogether with snowball sampling (e.g., from references and citations included in already identified documents) additional articles already familiar to the authors and those suggested during the review process. The inventory of regional case studies in the Global North was implemented using internet search (through Google®), of selected keywords (including multiple combined searches for words "urban farming," "urban agriculture," "community supported agriculture," "vertical farm," "indoor farm," "rooftop garden," "community garden," "rooftop greenhouse," "allotment garden," "periurban farm," "solidarity buying group," "farmers market," "workshop"), eventually translated in national languages through online translators. Among identified projects, those with available information (e.g., online or responding to contact e-mails) were integrated in the study, accounting for a total of 470 projects, out of which, 417 declared their cultivated area (m^2). The results emerged from both the literature survey and the implemented case study database are discussed in the following sections. Classes for cultivated area were then created, diversifying projects based on area below 500 m^2, between 501 and 1,000 m^2, between 1,001 and 5,000 m^2, between 5,001 and 25,000 m^2, between 25,001 and 100,000 m^2 and those above 100,000 m^2 (10 ha). Contingency tables were used to analyze the relationships among class of projects dimension and business model typologies ($n = 447$), farming purposes ($n = 470$), city typology ($n = 470$), city density ($n = 470$), or city climate ($n = 470$). According to Magrefi et al. (2018), business models were classified in cost-reduction, differentiation, diversification, share economy, experience and experimental. Farming purposes were classified in commercial, image, innovation, social and educational and urban living quality (Thomaier et al., 2015). Cities were classified according to urban population in six categories (Dijkstra and Poelman, 2012): Small (S) for cities with a population ≤100,000 inhabitants; Medium (M) for cities with a population ranging 100,001 to 250,000 inhabitants; Large (L) for cities with a population ranging 250,001 to 500,000 inhabitants; Extra-large (XL) for cities with a population ranging 500,001 to 1,000,000 inhabitants; Megacity (XXL) for cities with a population ranging 1,000,001 to 5,000,000; (Global city) for cities with a population ≥ 5,000,0001 inhabitants. Cities were also classified according to city density in three categories (Saldivar-Sali, 2010): "LOW density" for cities with a population density ≤ 5,000 inhabitants km^{-2}; "MEDIUM" density for cities with a population density ranging 5,001 to 15,000 inhabitants km^{-2}; "HIGH density" for cities with a population density ≥ 15,001 inhabitants km^{-2}. Finally, city climate was classified according to Koppen's classification in tropical, temperate and continental.

Chi-square test was used to assess the null hypothesis (i.e., the independence of the two categorical descriptors) comparing observed and expected frequencies. When Chi-square test resulted significant, a standardized Pearson residuals analysis as a measure of the strength of the difference between observed and expected values was performed (Agresti, 2003). Standardized residuals are useful as they enhance the detection of the cells that mainly contribute to the value. Additionally, a Bonferroni adjustment was applied by dividing the significance level by the number of cells in the contingency table in order to compensate for potential type 1 family wide errors (Garcia-Perez and Nunez-Anton, 2003).

DEFINING URBAN AGRICULTURE (UA)

UA has been defined by the Food and Agriculture Organization of the United Nations as the "plant cultivation and animal rearing (including aquaculture) within cities and towns and in their immediate surroundings" (Drechsel and Kunze, 2001). While providing for both food and non-food products for household consumption as well as income generation, UA also includes all related activities (production and sale of agricultural inputs and processing and marketing of products) (Mougeot, 2000). Being a complementary activity to the dominant agricultural production taking place in the countryside, UA overall increases the efficiency of the food system. UA allows for producing several typologies of crops (cereals, roots and vegetables, fruits, herbs, ornamentals, trees) and livestock (poultry, rabbits, goats, sheep, cattle, pigs, guinea pigs, fish) or animal-based products (meat, eggs, milk). However, in most cases it is represented by horticultural crops (vegetables, aromatic and medicinal plants, flowers and ornamentals, fruit and wood trees) grown in small fields or gardens (Orsini et al., 2013). Within a recent debate on how to define UA in developed economies, definitions building on its main features were elaborated, including *where* it is conducted (spatial dimension), *what* it produces (functional dimension), *why* it takes place (motivational dimension), *where* its produce *is consumed* (market dimension), *how* it generates (origin dimension), or *by whom* it is performed (actor dimension) (Vejre et al., 2016). Furthermore, as within UA projects in the Global North, externalities and non-food products may take over the primary driver of farming, their classification may either rely on the adopted business strategy (Pölling et al., 2015) or the main farming purpose (Thomaier et al., 2015), as further detailed in the following sections.

ECOSYSTEM SERVICES (ES) ASSOCIATED WITH UA

As farming takes place closer to cities or even inside them, several differences from conventional agriculture arise, translating into both advantages and limitations (**Table 1**), whose perception among societal groups and initiatives may largely vary (Sanyé-Mengual et al., in review). It appears that, according to Sanyé-Mengual et al. (2019), in order to be viable among the three sustainability dimensions (social, economic and environmental) and overcome the constraints related to the urban environment, the development of UA needs to combine both social and technological innovations. As a result, urban farming must bring together the existing knowledge and advances from the traditional agricultural sector with a set of new skills, technologies, tools and strategies allowing to target a diversified set of ES, falling into four main categories (TEEB, 2010):

(a) *provisioning services*: services that describe the material or energy output from ecosystems, including food, raw materials, water and medicinal plants (Pourias et al., 2015).
(b) *regulating services*: services that ecosystems provide by acting as regulators (e.g., regulating the quality of air and soil, storing greenhouse gases, or providing flood and disease control, Camps-Calvet et al., 2016).
(c) *habitat services*: services that ecosystems provide by the maintenance of genetic biodiversity and offering habitat for species (Lin et al., 2015).
(d) *cultural services*: services which represent the non-material flow of benefits from ecosystems to humans, including recreation, mental and physic health, tourism, spiritual experiences, amenity or social inclusion (Camps-Calvet et al., 2016).

All of them are strictly connected with and contribute to the functionality and environmental sustainability of the city. Moreover, since UA experiences primarily target specific ES, a classification based on the *farming purpose* has been recently elaborated (Thomaier et al., 2015), which distinguishes UA projects in five main categories (image, commercial, urban living quality, innovation, or social-education).

Urban Food and Nutrition Security

Among *provisioning services* supplied by UA, the most acknowledged is associated with food production and supply. Indeed, while estimates for the potential UA contribution to food security (Orsini et al., 2013) and sovereignty (García-Sempere et al., 2019) are available for several cities in developing countries, a lower number of studies addressed the quantification of urban food production in cities from richer economies, where aims of UA are mainly associated with environmental and social functionalities. Nonetheless, food production potential of UA in the Global North has raised interest in response to economic crises (e.g., after 2007, Colasanti et al., 2012) or as a tool to mitigate the effects of food deserts on the health status of the poorest strata of the population (Meenar and Hoover, 2012; McClintock et al., 2013). The emergent phenomenon of new peasantry as a response to growing urban poverty has also lead to new forms of UA, where innovation takes place in both businesses and land-use models, as occurred for instance in Detroit, Michigan (USA) (Draus et al., 2014), Berlin (Germany) (Clausen, 2015) and Yokohama (Japan) (Ikejima, 2016). Accordingly, several studies targeted in the last couple of decades the quantification of potential food production of UA in cities of North America, Europe, Asia and Oceania (**Table 2**), although estimates most often built on scenarios rather than actually measured data.

Health

Horticulture is a discipline that has great therapeutic potential, and its role in human well-being was well-explained by Diane Relf in her "Human Issues in Horticulture," which examined "the other side of horticulture" (Relf, 1992). Since then, horticulture's therapeutic roles were increasingly studied and debated, and the definitions and methodologies that use horticulture as support in therapeutic processes of physical and/or mental rehabilitation were elaborated (Relf and Dorn, 1995; Burls, 2008). A distinction was made between *Horticultural Therapy* and *Therapeutic Horticulture*. *Horticultural Therapy* is defined as a process through which plants, gardening activities and the simple contact with nature are used as tools in therapy and rehabilitation programs conducted by a therapist. It is an active process in which horticulture is used as support for other rehabilitation interventions. *Therapeutic Horticulture* is instead defined as a process that uses plants and the relationship with them to create or improve people's physical, psychological and social well-being. It is a process in which the plant plays a central role but in which specific therapeutic objectives are not pursued (Shoemaker and Diehl, 2010).

The therapeutic role of horticulture is based on the general positive psychological and physiological actions promoted by all sensations and emotions that arise from contact with nature, especially in those contexts (e.g., a walk in a park, taking care of a vegetable garden, the presence and sight of plants and flowers) in which the relationship between man and nature does not have the character of a working commitment (Ulrich, 1984; Ulrich et al., 1991; Kaplan, 1995; Thwaites et al., 2005; Mattson, 2010). Although scientific evidence of the positive effects of gardening on blood pressure, body temperature, brain activity, immune system response and psychological sphere are only recent (Coleman and Mattson, 1995; Liu et al., 2004; Park et al., 2004; Sugimoto et al., 2006; Gonzalez et al., 2009; Park and Mattson, 2009; Kam and Siu, 2010), the intuitions about the beneficial effects of horticulture on human health are much older. More than 2,000 years ago the Chinese Taoists built gardens in the belief that the environment had beneficial effects on health.

TABLE 1 | PROs and CONs of Urban Agriculture.

Category	Experimental evidence	References
ADVANTAGES (PROs)		
Food security and ecosystem service provision	Contribute to the city food security	Orsini et al., 2014
	Improve food system sustainability, reduces food miles and post-harvest handling	Sanyé-Mengual et al., 2013; Pascale et al., 2015; Dimitri et al., 2016
	Landscape management	Donadieu, 2006
	Biodiversity promotion	Halaj et al., 2000; Colding et al., 2006; Andersson et al., 2007; Baker and Harris, 2007; Breuste et al., 2008; Loram et al., 2008; Matteson et al., 2008; Ricketts et al., 2008; Sperling and Lortie, 2010; Shrewsbury and Leather, 2012; Burkman and Gardiner, 2014; Lin et al., 2015; Pölling et al., 2016a; Bazzocchi et al., 2017; Lanner et al., 2019; Tresch et al., 2019; Bazzocchi, 2020
	Social inclusion	Armstrong, 2000; Saldivar-Tanaka and Krasny, 2004; Wakefield et al., 2007; Teig et al., 2009; Anguelovski, 2013; Taylor and Taylor Lovell, 2014; Camps-Calvet et al., 2015; Marchetti et al., 2015; Gasperi et al., 2016; Reynolds and Cohen, 2016; Calvet-Mir and March, 2017; Specht et al., 2017; Sanyé-Mengual et al., 2019
	Job creation and creation of business opportunities	Yang et al., 2010; Draus et al., 2014; Clausen, 2015; Ikejima, 2016; Pölling et al., 2016a
	Therapeutic and recreational activities	Coleman and Mattson, 1995; Liu et al., 2004; Park et al., 2004; Sugimoto et al., 2006; Gonzalez et al., 2009; Park and Mattson, 2009; Kam and Siu, 2010; Meneghello et al., 2016; Righetto et al., 2016
	Increase liveability and improves the value of nearby buildings	Vitiello and Wolf-Powers, 2014; Colle et al., 2017; Poulsen, 2017
Resource use efficiency	Use of rainwater or regenerated greywater for irrigation	Mok et al., 2014; Opher et al., 2018; Mason et al., 2019; Rufí-Salís et al., 2020
	Improved energy use efficiency	Nadal et al., 2017
	Use composted urban organic waste	Cofie et al., 2006; Dorr et al., 2017
Climatic resilience	Reduction of flood risk	Zasada, 2011
	Reduction of heat waves	Depietri et al., 2012; Dubbeling, 2014
	Improves air quality	Lin et al., 2015
Awareness creation	Engage citizens in the food system and linking them to local farmers	Sanyé-Mengual et al., 2019
	Improving dietary habits and health	Gerster-Bentaya, 2013
	Increasing awareness and providing educational and training opportunities	Magrefi et al., 2018
CONSTRAINTS (CONs)		
Land access	High land costs as compared to the generally limited profits associated with agricultural production	Cohen and Reynolds, 2015
	UA may ultimately foster gentrification and increased costs of living in the neighborhood	Anguelovski, 2015; Cohen and Reynolds, 2015; Reynolds and Cohen, 2016
	Extreme fragmentation results in small farmed plots and lower economy of scale	Mok et al., 2014
	Long term sustainability and investments may be compromised by the limited duration of space concession agreements	Tornaghi, 2017
Legal and policy framework	Land-use is mainly devoted to building purposes	Masson-Minock and Stockmann, 2010
	Agricultural production in cities is not regulated	Bell et al., 2016
	Food marketing schemes used in rural agriculture are not applicable	Opitz et al., 2016
	Taxation regimes are different from conventional agriculture	Heckler, 2012
	Absence of marketing infrastructure limits marketing to informal scheme (farmers market, solidarity buying groups	Brown and Miller, 2008
Water use	Inefficient water use due to limited knowledge	McDougall et al., 2019
	Competition for water availability may occur	Molle and Berkoff, 2009

(Continued)

TABLE 1 | Continued

Category	Experimental evidence	References
	Elevate use of tap water	Deelstra and Girardet, 2000
Health and safety	Risk associated with urban atmospheric and soil contamination	Mancarella et al., 2016, 2017
	Risk of mosquito outbreak	Winkler et al., 2010
	Limited farmer skills may result in overuse of pesticides	Ochoa et al., 2019

TABLE 2 | Estimated and potential contribution of UA to food security in world cities.

Continent	Country	City	Estimated contribution to food security	References
Asia	China	Shanghai	About 2,000,000 t year^{-1} of cereals, 100% of milk and 90% of eggs	Yi-Zhang and Zhangen, 2000
	Japan	Yokohama	UA could alleviate food insecurity of 25,000 local residents	Ikejima, 2016
Europe	France	Paris	Around 600 t year^{-1} are produced within 10 hectares of community gardens	Pourias et al., 2015
	Italy	Bologna	Up to 12,500 t year^{-1} of vegetables (77% of the city requirements) if the 82 ha of vacant rooftop spaces would be transformed in gardens	Orsini et al., 2014
	Spain	Barcelona	15% of the vegetables circulating in the wholesale vegetable market is locally produced	Paül and McKenzie, 2013
	Spain	Barcelona	Tomato production with rooftop greenhouses in the Zona Franca logistics park could satisfy from around 130,000 to 1,100,000 inhabitants (from short-term to long-term scenarios)	Sanyé-Mengual et al., 2015c
North America	Canada	Toronto	Up to 4,000 t year^{-1} from 65 ha of greened rooftops	Peck, 2003
	CA, USA	Oakland	UA produces 30% of the city food needs	McClintock et al., 2013
	MA, USA	Boston	UA implementation in Boston could satisfy from 10 to 75% of the USDA dietary guidelines of different groups of vegetables	Goldstein et al., 2017
	OH, USA	Cleveland	When devoting to UA urban vacant lots, industrial and commercial rooftops and limited up to 100% of the city requirements could be satisfied	Grewal and Grewal, 2012
	PA, USA	Philadelphia	About 8,500 t year^{-1} are donated from urban gardens to food cupboards	Meenar and Hoover, 2012
Oceania	Australia	Adelaide	Up to 98% of the cauliflowers consumed within the state are urban grown	Mok et al., 2014
	Australia	Melbourne	About 97% of the strawberry consumed are grown within the city	Mok et al., 2014
	Australia	Sydney	The city already produces 99% of the Asian Vegetable consumed and about 12% of the total agricultural production of the state. It may potentially cover up to 15% of the food requirements	Mok et al., 2014; McDougall et al., 2020

In Europe, therapeutic activities related to horticulture have been documented as beneficial already in the seventeenth century in Spanish psychiatric hospitals, whilst in America Benjamin Rush mentioned the practice of horticulture and gardening as a remedy for anxiety or phobic disorders or, more generally, against depression, in the eighteenth century (Smith, 1998). Nowadays, all over the world, horticulture is a consolidated and recognized practice for the treatment of a wide range of disorders in therapeutic programs. Furthermore, it is integrated in the aims and fields of activities of numerous associations such as the American Horticultural Therapy Association founded in 1973 (www.ahta.org), the Thrive founded in 1978 in England (www.thrive.org.uk), the Canadian Horticultural Therapy Association founded in 1987 (www.chta.ca), the Japanese Horticultural Therapy Society founded in 1996 (www.jhts.jp), the German Association for Horticulture and Therapy founded in 2001 (www.ggut.org), the Horticultural Therapy Swiss association established in 2004 (www.horticulturaltherapy.ch), and the Therapeutic Horticulture Australia (www.tha.org.au).

Social Inclusion and Justice

Within the sustainability rhetoric of UA (Tornaghi, 2014), social inclusion and justice have been commonly linked to UA initiatives. As a matter of fact, some initiatives have started as a reaction to urban policies, the marginality of neighborhoods or to economic crises (Anguelovski, 2013; Camps-Calvet et al., 2015; Gasperi et al., 2016; Reynolds and Cohen, 2016; Calvet-Mir and March, 2017). Accordingly, the regeneration of unused urban spaces and the creation of community networks to manage and access food production resources are seen as an opposition to the capitalistic framework of conventional food production (McClintock, 2010). Gardens can be a place where "collective efficacy" flourishes (Teig et al., 2009), where citizens can create community and empower themselves toward conflicts resolution and rights claiming. Such characteristics support the UA contribution to community improvement, including social inclusion and empowerment (Armstrong, 2000; Saldivar-Tanaka and Krasny, 2004; Wakefield et al., 2007; Teig et al., 2009; Taylor and Taylor Lovell, 2014; Camps-Calvet et al., 2015).

Notwithstanding the potential social benefits, society's impact mainly relies on the typology of initiative, as already reported for rooftop agriculture (Specht et al., 2017). Sanyé-Mengual et al. (2019) observed that socially innovative UA activities contributed to a larger diversity of social benefits than technologically-innovative ones. UA grassroots initiatives (e.g., community gardens, squatting gardening) commonly focus on enhancing social inclusion and justice, such as improving food access for low-income citizens, thereby creating socially inclusive spaces. On the contrary, within commercial initiatives, economic profit stands as main driver, while specific social aspects are usually sidelined (Poulsen, 2017).

Nonetheless, UA initiatives can also generate negative social impacts. Some bottom-up initiatives claiming social inclusion and justice have become places of injustice and exclusion, where elites can displace low-income and culturally-diverse citizens (Anguelovski, 2015). Access to UA programs can be imbalanced, accentuating social exclusion and injustice among the community instead of closing the gap between citizens with different economic and cultural backgrounds (Cohen and Reynolds, 2015; Reynolds and Cohen, 2016). On the other hand, when UA experiences are implemented by local governments in a purely top-down process without including the citizens through participatory approaches, ineffective and unsuccessful projects can appear, negatively affecting the local community (Gasperi et al., 2016). As an emerging new urban space typology, urban gardens can also ultimately contribute to urban green gentrification, as observed in Barcelona (Anguelovski et al., 2018).

Ecological Aspects

UA is strongly related to some *regulating* and *habitat* ES. Genetic agro-biodiversity is strictly linked to food security (Thrupp, 2000; Frison et al., 2011). In a survey on UA projects in 10 European countries (Pölling et al., 2016a), it was observed that about half of the considered cases promoted biodiversity preservation, by cultivating more than thirty crop types and varieties. Alternatively, limited biodiversity was only observed within intensive monocultural farms, including vine growers or greenhouses. UA also intrinsically foster biodiversity: more than 1,000 plant species were recorded in 267 private gardens in London (Loram et al., 2008) and 440 different species have been found in a single 400 m^2 allotment garden in Stockholm (Colding et al., 2006). Small and widely diversified urban crop systems also increase the vegetative complexity of the cities and can have positive effects on animal biodiversity, providing suitable habitats for the microbiological fauna (Tresch et al., 2019), invertebrates (Halaj et al., 2000; Sperling and Lortie, 2010), birds (Andersson et al., 2007), and mammals (Baker and Harris, 2007).

UA systems can have a relevant impact on the provision of arthropod mediated *regulating* ES, such as natural pest control and pollination (Shrewsbury and Leather, 2012; Lin et al., 2015; Bazzocchi, 2020). Allotment gardens often exhibit a rich abundance of flowering plants, supporting urban pollinators for long periods: at least a quarter of all known bee species in Vienna are hosted by communal gardens (Lanner et al., 2019) and 54 species (13% of the recorded New York State bee fauna) were found in few community gardens located in heavily developed neighborhoods in New York City (Matteson et al., 2008). Importance of increased floral resource availability and plant structural diversity of urban agro-systems has been demonstrated to maintain and promote presence of ladybugs (Bazzocchi et al., 2017), main agents of natural pest control.

In addition to habitat quality, habitat connectivity is a key factor. Some studies suggest that proximity to natural habitat can increase bees abundance and pollination success for a wide range of crop species (Ricketts et al., 2008). Agro-ecological corridors, exploiting a network of small, natural habitat fragments and cultivated patches across urban areas may affect the ability of beneficial insects (both pollinators and pest natural enemies) to persist in the urban landscape (Breuste et al., 2008; Burkman and Gardiner, 2014; Bazzocchi, 2020). On the other hand, potential disservices might come from UA and must be considered. Intensive UA, which can be characterized by pesticide application, extensive pruning, and frequent mowing, would presumably have a negative impact on biodiversity and ES. Moreover, not all biodiversity is necessarily "desired": some pests and pathogens are polyphagous and can benefit from vegetational diversification, and potentially dangerous mosquitos can proliferate due to the presence of stagnant water for irrigation (Winkler et al., 2010).

Economic and Environmental Sustainability

In recent years, research studies aimed at evaluating the environmental impact of UA initiatives have flourished, with a number of reference studies being released, with a main focus on Mediterranean Europe, including Spain (e.g., Sanyé-Mengual et al., 2015a) and Italy (e.g., Sanyé-Mengual et al., 2015b), also thanks to associated European (e.g., SustUrbanFoods, FewMeter, UrbanGreenTrain, and FoodE projects) and National (e.g., FertileCity project) fundings on the topic. Literature on impact assessment of UA systems often refer to innovative solutions and technologies, including aquaponics (e.g., Forchino et al., 2018), mushroom cultivation (Aubry and Daniel, 2017), rooftop farms and greenhouses (Sanyé-Mengual et al., 2015a,b; Grard et al., 2018; Sanjuan-Delmás et al., 2018), indoor and vertical farms (Liaros et al., 2016; Martin and Molin, 2019; Martin et al., 2019; Pennisi et al., 2019a,b), or resource use efficiency including energy (Nadal et al., 2017), organic waste (Dorr et al., 2017), or water (Opher et al., 2018). Nevertheless, applied studies on more traditional systems also exists, as for the case of urban gardens in Italy (Sanyé-Mengual et al., 2018a), USA (Algert et al., 2014) and Canada (CoDyre et al., 2015), or periurban commercial farms in The Netherlands (Benis and Ferrão, 2018). Besides evaluating existing strategies, some of these studies also indicate alternative management scenarios, including crop input and management, resource origin and management structures (Sanyé-Mengual et al., 2015b; Martin and Molin, 2019; Pennisi et al., 2019c). Nevertheless, each study's peculiarities and uniqueness (which relate to both the UA project itself and the specificities of the city where it takes place), often limit the possibility to drive general conclusions and implement widely applicable policy tools (Sanyé-Mengual et al., 2019). Indeed, by combining the available body of evidences, it emerges that environmental sustainability shall be specifically targeted by a series of actions, which can be summarized as follows:

- Cradle-To-Grave studies are very limited in number. Mostly, available literature concentrated to certain production stages and often excluded initial investments or infrastructural elements. More comprehensive research is needed to compare sustainability among urban and rural agriculture, with adequate emphasis on all stages associated with food production, transformation and distribution (Sanyé-Mengual et al., 2013). Such life cycle approach has been highlighted in the recently published Farm to Fork Strategy (EC, 2020).
- Available evidence is limited to specific case studies, often experimental or small-scale, and geographical areas, preventing the existing literature's capacity to draft conclusions on the actual contribution of UA in sustainability terms (Sanyé-Mengual et al., 2018c). Such aspect limits the capacity to define how UA can be framed in policy-making.
- The economic sphere and sustainability of newly born UA projects in the Global North still needs to be confirmed. Further studies should specifically target the identification of economic viability of innovative experiences, also through adequate valorisation of the ecosystem and environmental services they supply to the urban fabric (Sanyé-Mengual et al., 2018b). On the other hand, in order to elaborate viable strategies for UA in the Global North it becomes crucial that labor costs are included in the overall economic balance even when information are limited (Love et al., 2015) or associated costs could pose a risk on the financial viability of the experience (Algert et al., 2014).
- Cross sectorial studies are needed. Impact assessment needs to be comprehensive and shall not disregard any element within the three sustainability spheres (economic, environmental and social). Integrated tools—e.g., combining Life Cycle Analysis (LCA) with Life Cycle Costing (LCC) or Social Life Cycle Analysis (S-LCA)—are needed in order to compile a comprehensive and reliable vision on UA experiences. Economic analysis should also make use of financial tools including determination of Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period (PP). S-LCA may allow to better identify which variables—especially when economic figures associated to mere food production and marketing are non-sufficient to ensure viability—should also be accounted for in the evaluation of services provided by UA experiences (Sanyé-Mengual et al., 2018b).
- Environmental studies may provide functional tools to UA entrepreneurs and local policy makers through the creation of alternative scenarios (Martin and Molin, 2019). They allow to identify how local resources availability (including raw materials, energy or labor) may affect a certain project's sustainability, or how alternative management strategies may result in avoided impact. Overall, scenarios allow to widen the applicability of the study and offer adequate policy tools.

FACTORS THAT AFFECT DEVELOPMENT AND DIFFUSION OF UA

Growth and diffusion of UA may be hindered by factors that range from regulatory frameworks, access to land and its potential contamination, the local climatic conditions and resource availability. Each of these hindering factors will be targeted and discussed in the following sub-sections.

Laws and Regulations

Western World cities are densely populated and Europe is one of the most densely urbanized continents in the World, where, between 2012 and 2018, 539 km^2 of land is yearly transformed into housing, industries, roads or recreational uses (EEA, 2019). At the same time, the amount of green space per city dweller for many European cities remains below the minimum standard suggested by the World Health Organization (EEA, 2012). The percentage of green space in the cities of EU varies from 3 to 4 m^2 per person (Reggio Calabria, Italy) to more than 300 m^2 per person (e.g., Liège, Belgium, Oulu, Finland, and Valenciennes, France) (Fuller and Gaston, 2009). In this context, within the EU, strategies that aim at reusing and regenerating the so-called vacant land (Gasperi et al., 2016) have become key elements for territorial development and urban planning (EEA, 2015). They foster the sustainable use of the land by providing green habitats and peaceful places to promote respect for urban heritage (EC, 2010). These policies are geared toward a more sustainable and efficient use of resources, recognizing that land is a limited and declining resource, subject to competing pressures from urbanization, infrastructure, increased food, fiber and fuel production and supply of key ES (Gasperi et al., 2016).

While policies tend to promote green spaces and UA in the city carried out for ecological-environmental, aesthetic-recreational, and social-educational purposes (urban farming as a tool for social inclusion, intercultural dialogue and job creation such as in Bologna, Oslo, Barcelona or Paris), the same cannot be said for UA oriented toward food production. Apparently, while cross-sectoral innovation blooms, taking the form of new technologies (e.g., vertical farms, rooftop greenhouses), production and management models (e.g., community-based agriculture) or supply chain (e.g., solidarity buying groups, farmers markets), the integration of UA within the food system is slowed down by the lack of National and European policies and strategic frameworks (Fox-Kämper et al., 2018). Meanwhile, food consumption becomes accounted for as main driver of EU citizens' environmental impact (Sala et al., 2019), and, within the EU Green Deal, the improvement of the sustainability of the food system paves the way for the upcoming Farm to Fork strategy (EC, 2020), where UA may find appropriate ground for evolution.

Notwithstanding that more than 200 World Cities signed the Milan Food Policy Pact in 2015 (Filippini et al., 2019), a general and consistent uptake at global level is still lacking. A legislative and regulatory environment enabling to ease the establishment and management of small-scale and citizen-driven UA initiatives is needed, overarching the economic, environmental and social functions that sustainable food systems may play. Policies often underestimate the ES associated with multifunctional UA, overall resulting in a limited support to initiatives that in turn, as previously described, would provide climate change prevention and resilience, job creation and social inclusion. Furthermore, given that UA initiatives' long-term success is hindered by both the lack of training and the difficulties in formal community engagement (Ochoa et al., 2019), appropriate policies for awareness creation should be fostered. Accordingly, in recent years, some municipalities have integrated support policies for UA, as in the case of Paris (Colle et al., 2017) or Barcelona (Giacchè et al., 2016) as further described in the coming sections.

Land Access

Today, in developed countries about 20% of the global irrigated cropland is located in cities or within 20 km from the urban centers, where also 44% of the global rainfed agriculture occurs (Thebo et al., 2014). In urban settings, cropping intensity (expressing the amount of crops cultivated within a year in a specific plot) was also found to be higher in urban areas (1.48) (Thebo et al., 2014) than in rural areas (1.12) (Portmann et al., 2010), suggesting more intense rotations in the former, a phenomenon that has also been associated with higher population density (Ellis et al., 2013). In general, agricultural activities' success is correlated with the farm size (Hansson, 2007), given the reduced costs of production that can be achieved when economy of scale can take place (Bertoni and Cavicchioli, 2016). In cities, however, a major constraint limiting the development of UA projects is associated with land access, given that generally any other activity has a greater and faster return of investment (Wästfelt and Zhang, 2016), and the fact that UA still struggles to have a recognized economic role (Specht et al., 2016). Consistently, in USA, grassroot UA initiatives were shown to occur in districts with highest land value, a phenomenon that was linked with smaller plot size (Rogus and Dimitri, 2015) and therefore limited income perspectives (Centrone Stefani et al., 2018).

On the other hand, as cities grow, the phenomenon of urban sprawl is generally observed, with periurban areas characterized by dispersed, scarcely planned and low-density settings (Jaeger et al., 2010), where several unused or empty lots are usually found and named as *vacant lands* (Gasperi et al., 2016). In response to the economic and financial crisis started in 2007 (Heath, 2001), further voids in the urban fabric have emerged, including abandoned industrial districts, but also public buildings (e.g., dismissed army barracks, hospitals and schools) (Frumkin, 2003). In many cities, UA explores potential new uses for these *vacant lands* (Gasperi et al., 2016), by colonizing brownfields, empty rooftops or taking place within abandoned buildings. Municipal plans that foster urban regeneration through UA are also issued, providing land use rights to urban gardeners as for the case of the Green Thumb agency in New York (USA) (Smith and Kurtz, 2003), the Pla Buits in Barcelona (Spain) (Giacchè et al., 2016) or the Parisculteurs initiative in Paris (France) (Colle et al., 2017). Although UA projects are consequently sprouting in marginal urban lands, their long-term sustainability is posed at risk by factors that include small plot size (Ernwein, 2014), limited time concessions for land-use (Tornaghi, 2012), potential contamination risks (Vittori Antisari et al., 2015), space accessibility (Tornaghi, 2017) and distance from potential consumers (Ancion et al., 2019).

Environmental Contamination

When plants are grown within cities' highly anthropogenic environment, questions may arise on the potential contamination risks associated (Hursthouse and Leitão, 2016). While most commonly experienced contaminants are heavy metals or metalloids (B, As, Cd, Cr, Cu, Mo, Mn, Pb, Zn, Hg), a growing concern is also linked to specific localized components (e.g., selenium, or radioactive isotopes) and organic compounds (e.g., polycyclic aromatic hydrocarbons, poly-chloro-biphenyls, pesticides, dioxins and furans) (Megson et al., 2011; Mitchell et al., 2014). In the last couple of decades, the comprehension of how contamination originates and the possible strategies to tackle associated human health hazards was targeted by a relevant body of research activities (**Table 3**). It emerges that, within urban environments, contamination hazard generally varies according to the location where horticulture takes place, being higher in proximity of pollution sources (e.g., main roads, or within former industrial districts) (Hursthouse and Leitão, 2016) or as a consequence of the background geology of the site (Jean-Soro et al., 2014). Heavy metal deposition from nearby roads was however shown to decrease through distancing (e.g., by 25 m, Reinirkens, 1996), elevation (e.g., in rooftop gardens) or inclusion of vegetated barriers (Vittori Antisari et al., 2015). Conduction of accurate soil analyses and quantification of hazard risk (e.g., through application of contamination indexes) is generally recommended before starting the cultivation (Hough et al., 2004). Whenever contamination risk is confirmed, however, strategies may be set in place in order to limit the hazard, including integration of soil amendments or adoption of agronomic practices to reduce plant uptake of the contaminants (**Table 3**). Whenever UA takes place in potentially contaminated sites, the integration of peat or potting soil may also be an option to overtake contamination (Pennisi et al., 2016, 2017), although at the expenses of increased associated environmental impacts (Dahlin et al., 2019), which on a large-scale could pose at risk the overall sustainability of UA (Meharg, 2016). Alternatives to commercial/potting soils should therefore be considered, these including among others composted urban waste (Shrestha et al., 2020), spent coffee grounds (Cervera-Mata et al., 2019) or biochar (Song et al., 2020), assuming they do not contain further contaminants and are suitable for plant cultivation (Beniston and Lal, 2012; Hardgrove and Livesley, 2016).

Climatic Conditions

UA is playing a crucial function on the city environmental sustainability. Based on Koppel's climate classification, world

TABLE 3 | Strategies for reduced contamination risk in urban grown vegetables.

Prevention strategy		Contamination source	Experimental evidence	References
Location	Distance from roads	Air	Main contamination from road is limited within 25 m	García and Millán, 1994; Reinirkens, 1996; Charlesworth et al., 2011; Vittori Antisari et al., 2015
	Rooftop cultivation	Air, soil	Reduced contamination risk in rooftop grown vegetables due to height and distance from roads	Vittori Antisari et al., 2015; Liu et al., 2016
	Adoption of hazard indexes	Air, soil, water	Importance of site-specific risk assessment to reduce the risk of contamination	Hough et al., 2004
	Adoption of tree barriers	Air	Vegetated barriers between roads and gardens allowed to reduce contamination	Vittori Antisari et al., 2015
	Identification of past land use	Soil	Contamination is higher in areas that hosted refineries, petrochemical processing, timber and textile processing or mining sites	El Hamiani et al., 2010; Hursthouse and Leitão, 2016
	Background geology	Soil	Heavy metal contamination may also result from paedogenesis (e.g., As, Pb)	Jean-Soro et al., 2014
Genotype	Crop selection	Air, soil, water	Breeding and cultivar/species selection reduce risks posed by heavy metal contamination	Grant et al., 2008; Ghosh et al., 2012; Ding et al., 2013
	Crop genetic engineering	Air, soil, water	Plants can be genetically engineered to increase tolerance to heavy metals	Edelstein and Ben-Hur, 2018
Agricultural practices	Grafting	Soil, water	Herbaceous grafting can enhance tolerance to heavy metals in vegetables	Edelstein and Ben-Hur, 2018
	Bioremediation	Soil	Use of plants with elevate accumulation capacity allow to clean-up target contaminants in soils	Cunningham et al., 1995; Austruy et al., 2014
	Soilless cultivation	Soil	Reduced contamination when soilless system is used as compared to soil	Pennisi et al., 2016, 2017
	Agrochemicals management	Soil	Overuse of fertilizers or pesticides may result in heavy metal contamination	Hursthouse and Leitão, 2016; Pennisi et al., 2016
	Irrigation	Water, soil	Water quality and both its distribution strategy and applied volumes may modify contaminant presence in soil	Hursthouse and Kowalczyk, 2009
Soil amendments	Manure and compost	Soil	Modify heavy metal phyto-availability and their immobilization	Janoš et al., 2010; Pérez-Esteban et al., 2014
	Zeolites	Soil	Allow to remediate plant uptake of heavy metal in highly contaminated soil	Li H. et al., 2009
	Biochar	Soil, water	Can increase soil pH and contribute to immobilization of heavy metals (Cd, Cu, Pb)	Tang et al., 2013; Zhang et al., 2013
	Soil liming material	Soil, water	Allow to increase pH decreasing heavy metal availability	Abd El-Azeem et al., 2013
	Ashes	Soil	Fly ash increase phyto-stabilization of heavy metal-contaminated agricultural lands	Ukwattage et al., 2013
	Mycorrhizae inoculation	Soil, water	May influence heavy metal availability and uptake by plants in the rhizosphere	Edelstein and Ben-Hur, 2018

global north areas are mainly located within two main climate groups (temperate, C, and continental, D) based on seasonal precipitation and temperature patterns. The temperate climate (C) is characterized by coldest month averaging temperature between 0 and 18°C, with at least 1 month averaging above 10°C. Continental (D) climate displays at least 1 month averaging below 0°C and at least 1 month averaging higher than 10°C (Kottek et al., 2006). Most updated climate models foresee that extreme heatwaves will become more frequent and more intensive also in the Global North due to climate change (Huttner et al., 2009). The development of green spaces and infrastructures reduces urban heat island effects, mitigates rainwater impacts, and improves urban climatic metabolism (Ackerman et al., 2014). Indeed, functionality of green infrastructures is highly connected to plant vegetation status and management. A study carried out in Freiburg (Germany) (Huttner et al., 2009) reported that when natural soils in the urban and periurban areas are not covered with vegetation or not wetted by irrigation or rainfall during heatwaves, their effects on the microclimate are comparable to those from asphalted roads, leading to higher radiative temperatures.

Urban climate is also affected by the city size and the population density. Urban environments in the Global North are today experiencing growing population trends. In Europe, more than 70% of the population is living in urban areas today, and according to updated predictions, this number is likely to increase above 80% by 2050 (Kabisch and Haase, 2011). Intensified urbanization combined with the highest frequency of heavy rainfall are the leading causes of amplified peak flows and increased flood risk in the cities worldwide (Chang and Franczyk, 2008). Major cities in Europe are characterized by elevated (50–75% or even higher) fractions of impervious surfaces (such as roads, buildings, parking lots etc.), which translate into reduced water drainage and elevated risk of pluvial flooding (Du et al., 2015). Urban vegetation and well-planned UA spaces (including green roofs and parks) can significantly improve stormwater management decreasing the impact on the surface of heavy rain and providing run-off regulation and cooling through evapotranspiration (Orsini et al., 2014; Langemeyer and Latkowska, 2016).

Urban Resources

UA may substantially contribute to fostering sustainable resource use within the city metabolism, particularly with reference to water, mineral nutrients and energy fluxes. In cities, water for irrigation generally comes from municipal supply systems, leading to environmental and agronomic concerns (Wortman and Lovell, 2013). Indeed, alternative sources may include both rainwater harvesting and greywater or wastewater regeneration. In a GIS-based study it was recently estimated that if rainfall would be harvested from rooftops of nearby buildings and conveyed toward vegetable gardens in Rome, water saving could be in measure of 20 to 40% (Lupia et al., 2017). Theoretical scenarios of implementing rooftop greenhouses on retail parks roofs in different world cities (including Barcelona, Lisbon, Utrecht, and Rotterdam) indicated that crop water requirements could be satisfied by rainwater harvesting from the greenhouse roof (Sanyé-Mengual et al., 2018d).

The use of regenerated greywater may also significantly reduce the water footprint of UA, although concerns associated with pH or salinity may arise (Li F. et al., 2009), altogether with non-balanced mineral contents or microbiological load (Hanjra et al., 2012). With reference to the mineral nutrition of crops, the integration of composting of the organic waste and pruning residues was shown to markedly contribute to the urban horticultural production, although sanitary aspects shall be carefully considered in order to avoid risks associated with both microbiological load and heavy metal contamination (Brown and Jameton, 2000). Studies have demonstrated the viability of employing urban compost in substrate mixtures for UA (Grard et al., 2018). Moreover, as ambient CO_2 concentrations can be up to 80 ppm greater in urban areas relative to adjacent rural areas due to the combustion of fossil fuels, increased photosynthetic rates may also be experienced in UA (Ziska and Bunce, 2007). With reference to the urban energy balance, the distribution and presence of green infrastructures throughout the urban fabric may significantly reduce the so-called urban heat island effect, both resulting in improved city liveability and reduced heat associated mortality during warmer seasons (Qiu et al., 2013). On a smaller scale, when building-integrated agriculture takes place (e.g., in rooftop greenhouses), an integrated building metabolism was shown to improve water, energy and carbon fluxes, while also supplying a range of ES (Piezer et al., 2019).

MAIN TYPOLOGIES OF UA SYSTEMS

In recent years, also in northern global areas, UA has been considered a strategy to contribute to food security and city environmental sustainability (Taylor and Taylor Lovell, 2014). Within the coming sections, established typologies of UA systems popular in Global North are described (**Table 4**), mainly focussing on allotment gardens, extensive periurban farms and community gardens. Furthermore, this section will introduce some innovative growing systems specifically developed for the urban environment. These range from building-integrated agriculture systems, taking place on building rooftops (e.g., rooftop gardens and greenhouses) or even inside them (e.g., indoor or vertical farms with artificial lighting). Furthermore, the section also explores new crops that are increasingly adopted in UA, thanks to the market opportunities provided by the urban environment and the proximity to consumers.

Allotment Gardens

Private and public urban gardens for vegetables production are widespread all over the world. Historically, allotment gardens were set up with the primary goal to mitigate poverty by providing fresh food among factory workers during the industrial revolution or later during wars and depression times (Barthel et al., 2013). Their relevance was dramatically increased during the first half of the twentieth century, during the two World Wars, when agricultural products could not easily reach the city markets and were sold at elevated prices or on the black market. Consequently, foodstuffs' production, especially fruit and vegetables, became essential for the survival of cities' inhabitants. Urban gardening was then considered as a patriotic act, enabling to feed citizen and the army, while governmental propaganda called for action in the so-called "war gardens" or "victory gardens" (Miller, 2003; Lawson, 2004). As a result, in those years, the number of vegetable gardens rose dramatically in almost all cities touched by the war where not only family and urban gardens but also public parks and roadways' edges were cultivated. During the conflict, areas destroyed by bombing were also used for growing crops. After the war, reconstruction activities began: jobs, industries, cities were growing, the price of building land dramatically raised and the phenomenon of allotments gardens significantly decreased. But the gardens did not disappear; they moved from the city center to the suburbs and frequently reappeared as squatting. They were commonly associated with the concurrent migration process experienced from the rural areas to the city's outer skirts (Tei et al., 2009). Then, since the 1980s, a "renaissance" of UA has been noticed. Urban gardens originally aimed at ensuring food security evolved, addressing other key roles (ecological-environmental, aesthetic-recreational, social-educational, therapeutic) in relation to the changed economic and socio-cultural conditions (Crouch, 2000; Wells, 2000; Hynes and Howe, 2004; Tei et al., 2009; Meneghello et al., 2016; Righetto et al., 2016).

During the last 50 years, the local municipalities promoted the establishment of urban gardens by providing the land, establishing a water system, and eventually fencing the area. In most cases, urban allotment gardens are organized in associations

TABLE 4 | Main UA system typologies in the Global North.

UA system	Typology	Products	Technology level	User type
Allotment gardens	Traditional	Vegetables	Low level	Society
Extensive periurban farms	Traditional	Vegetables, processed products, animal products	Low to medium level	Farmers
Urban community gardens	Traditional	Vegetables	Low level	Society
Rooftop farms	Innovative	Vegetables	Medium to high level	Farmers, society
Vertical farms with artificial lighting	Innovative	Vegetables	High level	Farmers
Microgreens	Alternative	Vegetables	Low to high level	Farmers, society
Food-forestry	Alternative	Fruits	Low level	Society
Aquaponics	Alternative	Fish, vegetables	High level	Farmers
Urban beekeeping	Alternative	Bee products	Low level	Farmers, society

or committees for decision making (Bell et al., 2016). Sometimes, they also appear to be integrated within urban agricultural parks, as for the cities of Rome and Barcelona (Colantoni et al., 2017). Allotment gardeners are generally requested to pay a small rent for the plot and attend specific association duties. Production is intended exclusively for self-consumption or limited to donation, as in most cases the sale is not allowed by municipal regulations (Barthel et al., 2013). Today food production is not anymore the only primary purpose but also other functionalities are acknowledged, including aesthetic-recreational and educational (Wells, 2000), social (Tei et al., 2009), or therapeutic (Crouch, 2000). Also in Italy these types of gardens have evolved in their form in the last decades (La Malfa et al., 2009), mainly under the framework of the Italian association for recreation, culture and gardens (*Associazione Nazionale dei Centri Sociali Ricreativi Culturali ed Orti—ANCeSCAO*), that provides gardeners with administrative and insurance support (Gasperi et al., 2012) and today accounts for more than 360,000 members, and manages 1,400 social centers and 22,000 vegetable gardens. Similar organizations are found in Germany such us *Kleingaerten and Schrebergaerten* (Drescher, 2001), *Real Food Wythenshawe* in UK (Bell et al., 2016), *Gezonde Gronden* in The Netherlands (van der Schans, 2010), *Pispala allotment* in Finland (Bell et al., 2016), and *ROD Obroncow Pokoju* in Poland (Bell et al., 2016) and have proven to be a useful means for learning democratic rules as well (Gasperi et al., 2012).

Extensive Periurban Farms

In recent years, the relevance of urban and periurban farming in terms of food production in cities and their contribution to food security has been a matter of extensive research. Whether or not to include periurban farms as a part of UA has been discussed in several ways, with most authors suggesting their inclusion and adopting the more general definition of Urban and Periurban Agriculture (UPA) (van der Schans and Wiskerke, 2012; Mok et al., 2014) or metropolitan agriculture (Heimlich, 1989), both synonyms of the more general concept of UA adopted in the present manuscript. While UA's primary purpose is still meeting food needs mainly at the household level (Petts, 2005), extensive periurban agriculture can provide more substantial quantities and has broader distribution pathways, allowing for significant contributions in terms of food supply at city level in the Global North. Extensive periurban agriculture farms nowadays provide goods and services both for the local and global markets (Opitz et al., 2016). These farms emerge within the "transition area" between urban and rural environments, characterized by lower population density with lesser infrastructures and buildings, whilst concurrently featuring a more limited land availability for agriculture use as compared to rural areas (Allen, 2003; Piorr et al., 2011).

In extensive periurban farms, multifunctionality at the farm level appears, with farms providing not only agricultural goods and food, but also services to the community as well as public functionalities (Le and Dung, 2018). Representative case studies of periurban farms are found within metropolitan areas in several cities of the Global North. In Bologna (Italy), *Spazio Battirame* (https://www.etabeta.coop/spaziobattirame/), is a place of socio-recreational and educational activities created and developed as an urban regeneration project by the social cooperative Eta Beta (Gasperi et al., 2016). In *Spazio Battirame*, cultural events, handcraft laboratories and concerts are organized, while organic vegetables are produced over 4 hectares of open-fields and marketed through solidarity buying groups and participation in weekly farmer's markets. A professional kitchen serves a bar-restaurant and hosts cooking courses and food-related activities. The project has a strong social connotation, and functions include inclusive job creation, education and training, urban regeneration and sustainable growth (Cavallo and Rainieri, 2018). In the fringes of the city of Angers (France), proximity agriculture takes place at *Le jardin de l'avenir* (The future garden, https://www.jardindelavenir.fr/). The farm, extended over almost 9 hectares, operates on a pick-your-own scheme, where local residents may access the farm and harvest fruits and vegetables based on their needs and then weight and pay them at the counter. The farm is managed following principles of organic farming and permaculture, while environmental sustainability is also targeted through the co-generation of electricity for the farm needs and the local energy supplier. A similar scheme is adopted by the farm *Hof Mertin* (Germany), placed in the densely urbanized and industrial region of the Ruhr (Pölling et al., 2017). The farm (https://hof-mertin.de/) extends over around 120 hectares, out of which 40 are devoted to strawberry cultivation and integrated in a pick-your-own scheme or used for educational or socio-recreational workshops. In Ontario (Canada), a survey involving 21 periurban farmers highlighted that, while proximity to city may open up new marketing opportunities, the overall sustainability of the sector strongly depends on the existence of infrastructural and policy measures to link UPA with the local market (Akimowicz et al., 2016). It appears that while periurban farmers may benefit from the nearly rural conditions of their environment, a set of diversified and adaptive strategies must be integrated in order to attract local citizens and involve them into alternative food networks, as also evidenced in a recent study in the city of Barcelona (Spain) (Paül and McKenzie, 2013).

Urban Community Gardens

The term "community garden" refers to "open spaces which are managed and operated by members of the local community where food or flowers are cultivated" (Holland, 2004; Pudup, 2008). Nowadays, community gardens are growing in popularity in response to the shift toward cooperative forms of spatial design and land-use, and reflect the shift from government to governance including changing roles, responsibilities and impact of government agencies and local citizens (Rosol, 2010). They can involve a wide range of groups such as schools, prisons, youth, the elderly, hospitals, and neighborhood residents (Pudup, 2008; Teig et al., 2009). Different studies emphasized that community gardens are not only a source of food but provide other benefits, such as community building, education, and promoting health (Turner, 2011). Indeed, the most common motivation to take part of a community garden by citizens are: to consume fresh foods, social development or cohesion such as community building and culture exchange, to improve health among members and to make or save money by eating from the garden or selling the produce (Guitart et al., 2012). It was recently estimated that 86% of community gardens in USA were used to grow food, flowers and native vegetation. The same study also revealed that 82% of community gardens were operated by non-profit organizations, including cultural and neighborhood groups (Guitart et al., 2012). Further research studies confirm that community garden members are rather heterogeneous in terms of education, age, gender and financial aspect and usually lack previous gardening experience (Bell et al., 2016).

Community gardens can also be classified based on their own government structures (Fox-Kämper et al., 2018). Nettle (2016) observed that community gardens can be classified as either top-down or bottom-up governance structures depending on who initiated them. McGlone et al. (1999) noted the difference between gardens that were managed by external professionals (top-down) and those that were managed by community members including professionals (bottom-up). Top-down community gardens are implemented with the help of enabling legislation passed by local or central government (Nettle, 2016) and external/private officials carry out the management of the garden in order to meet government-set outcomes (McGlone et al., 1999). On the other hand, bottom-up community gardens build upon a direct involvement of the local community. Indeed, in the latter case, the community garden is planned and devised through collaboration by community groups (Okvat and Zautra, 2014) as well as the implementation with the help of enabling legislation passed by local or central governments (Nettle, 2016). The community also collaborates to devise a management scheme for the garden (McGlone et al., 1999). Among the most famous cases of community gardening in the Global North may be found several initiatives in the city of Berlin (Germany), including *Allmende Kontor* (https://www.allmende-kontor.de/) in the former Tempelhof airport, *Ton Steine Garten* (http://gaerten-am-mariannenplatz.blogspot.com/) in the Kreuzberg area or experiences of community entrepreneurship found in both Prinzessinengarten (https://prinzessinnengarten.net/) and Himmelbeet (https://himmelbeet.de/) (Wunder, 2013; Bradley and Hedrén, 2014).

Rooftop Farms

Within cities, plant cultivation on the rooftops of buildings has been recently gaining global attention (Orsini et al., 2017). It may take place both in protected (rooftop greenhouse) and non-protected (open-air rooftop farm) conditions (Sanyé-Mengual et al., 2015b). Among growing technologies, soil-based (e.g., soil-filled containers) or soil-less (e.g., hydroponics, aquaponics) systems are commonly adopted (Nasr et al., 2017). Due to the peculiar specificities of the environment where it takes place, rooftop agriculture may be constrained by the rooftop structural loading capacity, its accessibility to people and to agricultural input and tools, and the elevate solar radiation and temperature ranges (Caputo et al., 2017). On the other hand, benefits may be associated with rooftop gardening, including potential energy saving up to 15% thanks to the thermal insulation provided by the green cover (Wong et al., 2003). Besides, when a rooftop greenhouse is present, further advantages may be associated with its integration within the building metabolism (e.g., in terms of energetic fluxes and both water and carbon recirculation) (Sanyé-Mengual et al., 2015b).

The majority of rooftop agriculture projects is represented by open-air rooftop farms or gardens that use low-tech systems such as raised beds filled with soil (Thomaier et al., 2015). While the absence of physical barriers may be associated with higher exposure to the atmospheric pollutants' deposition, the higher elevation and the adoption of hydroponics were shown to generally limit the contamination risk in rooftop farms (see section Environmental Contamination, Vittori Antisari et al., 2015). On the other hand, rooftop greenhouses are generally associated with sophisticated technologies, targeting both increased production capacity and resource use efficiency (Sanyé-Mengual et al., 2015b). While open-air rooftop agriculture is widely adopted in the Global South, high tech commercial rooftop farms generally take place in North America, Asia and Europe in the form of business-oriented start-ups with economic profitability as the first aim (Specht et al., 2015). However, rooftop farms are also often associated with non-profit aims, e.g., the amelioration of urban living quality or communities' involvement in social, recreational and educational activities (Thomaier et al., 2015). Furthermore, rooftop cultivation can also represent a marketing action for hotels and restaurants, which offering fresh and self-produced products to customers can ameliorate their image and gain preference among the public (Thomaier et al., 2015).

Rooftop farms may either be located in existing buildings or integrated in new constructions (Buehler and Junge, 2016). In the former case, higher costs for refitting, less rational use of the rooftop space and a limited range of applicable cultivating techniques are commonly experienced (Caputo et al., 2017). Nevertheless, due to a slow uptake of rooftop farming technologies among estate operators and building companies, adaptation of existing buildings still represents the majority of rooftop farming projects (Thomaier et al., 2015).

Vertical Farms With Artificial Lighting

One of the most technologically oriented growing solution for cities is the use of plant factories with artificial lighting (PFALs). PFALs are cultivation systems where the environmental factors (e.g., air temperature and humidity, light, CO_2 concentration) are controlled by minimizing exchanges between indoor and outdoor environments, thanks to the adoption of insulated cultivation room where a minimum amount of air and heat is exchanged with the outside (Kozai and Niu, 2016). The enclosed system also enables the farm to achieve resilience to extreme events and easier control of pest and pathogens as compared to more traditional cultivation systems (Kozai, 2019). Nevertheless, it has also been suggested that when pest outbreaks take place in PFALs, their impact may be dramatic, due to the combined effects of the relative proximity of plants (both in vertical and horizontal dimensions), as well as the intense air circulation fluxes needed to guarantee environmental uniformity (Roberts et al., 2020).

Among the advantages of PFALs, one extremely relevant in the urban environment is the reduced pressure on land, obtained by exploring the vertical direction through multilayers cultivation systems fed by artificial lighting devices (Beacham et al., 2019). Besides, the benefits associated with hydroponics and possible de-humidification and water recovery from the internal atmosphere allow for elevated water use efficiency (Pennisi et al., 2020a), in the range of 30–50-folds the measured values in greenhouses and open-field cultivation (Kozai, 2013). On the other hand, the elevated energetic requirements (mainly due to electricity consumption associated with artificial lighting, Paucek et al., 2020) are still hindering the large-scale applicability of these systems (Kozai, 2019). Indeed, while technology is rapidly evolving, strategies for reducing the environmental burdens associated with PFALs are also being identified (Son et al., 2016; Martin and Molin, 2019; Pennisi et al., 2019c, 2020c; Orsini et al., 2020) and will likely foster the large-scale application of these technologies in the near future. To date, the most common plant species grown in PFALs are leafy vegetables (e.g., lettuce, basil, microgreens), medicinal plants (e.g., cannabis or other crops used in the preparation of pharmaceutical, herbal or cosmetic products), small fruit (e.g., berries), edible flowers and seedlings (e.g., grafted vegetable) (Kozai, 2013).

Beyond Vegetables: Alternative Farm Products in Urban Environments

UA takes many forms and involves a diversity of actors and products. Among new forms of UA, *microgreens* cultivation is gaining relevance and popularity in the Global North. Initiated in the early 80s in California, microgreens are tiny edible greens harvested just after the first set of true leaves, known for their high rate of antioxidants and micronutrients. Because of their limited space needs and their elevated water use efficiency (Durham, 2017), microgreens are well-adapted to UA and, as a matter of fact, many worldwide urban PFALs and vertical farms are dedicated to or include microgreens cultivation (Kozai, 2018; Butturini and Marcelis, 2020). Furthermore, their post-harvest storage requirements may be substantially reduced when they are grown in proximity to consumers, an important feature given their limited shelf-life (Durham, 2017). Alternatives to the conventional purchasing and large-scale retail trade are the sale to-order (e.g., *Brooklyn Grange* rooftop garden in New York City) and the "in-store farming" through modular automated incubators that can be placed in a variety of customer-facing city locations (Butturini and Marcelis, 2020). Homemade self-production is also greatly increasing. Similarly to microgreens, *edible flowers* are also gaining relevance in UA projects, where they find commercial uses thanks the growing interest from chefs and top-class restaurants, their elevated nutritional properties and their limited shelf-life (Mlcek and Rop, 2011).

Another growing strategy in UA is associated with *food-forestry* (crop and animal farming coupled with cultivation of woody perennial plants). Strategic combination of fruit- and nut-producing trees and herbaceous crops meets a multifunctional role of UA contributing to *provisioning* (food production) and *regulating* ES (carbon storage, runoff management, air quality improvement, soil erosion control, climate mitigation) (Clark and Nicholas, 2013). Urban food-forestry projects have been described for at least 37 cities in USA (Clark and Nicholas, 2013), 47 municipalities in Canada (Konijnendijk and Park, 2020) and a growing number of cities in Europe (Park et al., 2019). Related to urban forestry is the concept of *urban foraging*. The renewed interest for the harvesting of forest and rural edible wild species is also becoming popular in many worldwide urban contexts of developed countries (Shackleton et al., 2017; Konijnendijk and Park, 2020).

Aquaponics combines fish farming in smart water environment (aquaculture) and soilless plant production systems (hydroponics). The system is based on a closed water cycle in which fish dejections become inputs for plants development thanks to nitrifying bacteria's action, whereas plants act as filter to clean the water, which can be re-circulated back to the fish tank. Economic and ecological (primarily because the decrease in freshwater availability) sustainability of aquaponics is under investigation (Quagrainie et al., 2018). Interestingly, aquaponic systems can be combined with building-integrated wastewater management in cities (Steglich et al., 2020). An important pilot case is the *Berlin Roof Water Farm* (RWF) in which gray water, treated and mixed with rainwater, is used to irrigate the rooftop aquaponics system, and black water (rich in nutrients) is processed into a liquid fertilizer for UA purpose (Steglich et al., 2020).

A systemic and multifunctional approach is also at the base of the integration of *microalgae* production systems into innovative urban infrastructures. Production of microalgae as food for humans and feeds for animal and fish (e.g., Spirulina) or as energy-based biomass, can outperform other renewable resources with their potential to absorb CO_2, recycle wastewater, and release O_2 (Peruccio and Vrenna, 2019).

Urban bee keeping has been established in ancient times within the Mediterranean basin (Mavrofridis, 2015). Bees (both wild and reared) easily adapt to the urban environment thanks to the warmer temperatures, a wider variety of plants for pollination and foraging, and lower level of pesticide pollution in comparison with agricultural landscapes (Blum, 2017; Hall et al., 2017). Born as an activity linked to urban ecology and the decline of pollinators and honeybees' populations (Lebuhn et al., 2013), urban beekeeping has recently boomed in popularity. Beehives can be found in many cities of the Global North (e.g., New York City, London, Berlin), including in private (e.g., hotels) and public (e.g., operas) buildings, mainly motivated by the cultural and experimental interests of city dwellers (McCallum and Benjamin, 2012). Although, there is a substantial lack of quantitative data on the production and marketing of honey and other beehive products (e.g., wax, propolis, venom) coming from urban beekeeping, economic value of urban apiculture is rising, also in relation to educational and recreational side activities. Some concerns have however been raised on the possible negative effects that domesticated beekeeping could have on the native urban bee fauna, mainly related to competition for flora and disease spreading (Mallinger et al., 2017).

THE UA ECONOMIC DIMENSION: TOWARD A CLASSIFICATION OF BUSINESS MODELS (BMs)

The narrative of economic development in cities from the Global North has recently started to associate UA to key sustainability indicators. The definition of economic viability of UA experiences is however a complex and multifaceted exercise. Financial performances of UA are often benefitting from both external funding and availability of unpaid/voluntary workforce, which often follow alternative, non-capitalist economic logics, as recently analyzed in UA projects in Boston (Massachusetts, USA) (Biewener, 2016). Consistently, a comparative study integrating qualitative and quantitative data from self-harvesting, intercultural and community gardens in Germany revealed that participants are often more concerned on benefits than costs and that sharing and self-governance are predominant ambitions over economic viability (Krikser et al., 2019). Economic indicators and employment opportunities are also highly variable among UA projects (mainly due to the economy of scale and mechanization), as observed in Denver (Colorado, USA) (Fisher and Karunanithi, 2014). Nevertheless, and despite the potential role UA may play toward social and economic justice, policies and financial support often tend to concentrate on UA economic competitiveness, perceived as indicator of enduring and sustainable urban planning (Walker, 2016). Accordingly, and as UA assume growing economic relevance, several attempts have also been made to classify its emerging business models (BMs) (van der Schans, 2010; Liu, 2015; Pölling et al., 2016b; van der Schans et al., 2016). While some models are recurring within all existing literature (e.g., *cost-reduction* BM, *differentiation* BM, and *diversification* BM), emerging strategies are also being integrated as they become commonly adopted. This include the so-called innovative operations (Liu, 2015, now more commonly referred to as *experimental* BM), but also "the commons" (van der Schans et al., 2016, hereby referred to as *share economy* BM) and the *experience* BM (van der Schans et al., 2016).

In the present paper, reference will be made to the more recent classification of BMs in urban farming projects resulting from the EU project Urban Green Train (Urban Green Education for Enterprising Agricultural Innovation) (Magrefi et al., 2018) (**Table 5**).

Cost-Reduction BM

Cost-reduction BM includes farms that build their success on reducing costs associated with crop production. As for traditional agriculture, reducing costs and increasing profit through efficient economy of scale may also prove viable in urban environments (Zasada, 2011). For instance, it is the case of greenhouse farms in the periurban fringes that benefit from the increased market opportunities provided by the proximity of the consumers (Péron and Geoffriau, 2007). The economic viability of proximity farms may also benefit from in-farm shops, participation in farmers market, or integration in consumer delivery schemes, as for the cases of the so-called solidarity buying groups (Opitz et al., 2016), where direct delivery at distribution points within the city is practiced. In this last option, users often purchase a fixed amount of fruits and vegetables, whose composition will reflect the seasonal availability of locally produced goods (Vogl et al., 2003). *Cost-reduction* farms often evolve toward other business models in order to take benefit from the existing and multiple marketing offer (e.g., services associated with food distribution and marketing, as for the following BM categories) that the city can provide (Gasperi et al., 2016). Benefits associated with the proximity from consumers can be associated with reductions in requirements for transport, packaging (Sanyé-Mengual et al., 2013), as well as reducing food losses (Dimitri et al., 2016).

Diversification BM

Diversification BM includes farms that produce a diversified variety of products and services. There are two main categories of diversified urban farms, depending on their original core business. The first typology encompasses those cases where farmers may decide to integrate additional products and services to their main agricultural production. These may be urban peasants that integrate their food production and marketing with services (Dixon et al., 2007). Alternatively, there may be the case of the so-called "new farmers," represented by entrepreneurs, private companies or non-for-profit bodies that have their core business in other sectors and start to explore agriculture in the urban settings. Under this category often fall socially involved

TABLE 5 | Main business models associate with UA systems in the Global North.

BM type	Strategy	Examples
Cost-Reduction	Building success on reducing costs associated with crop production, toward economy of scale	Periurban greenhouse farms benefitting from the increased market opportunities provided by the proximity of the consumers
Diversification	Production of diversified variety of products and services	Socially-involved institutions, horse-riding farms, agro-tourism and educational farms
Differentiation	Differentiation from competitors for the uniqueness of their specific product or production protocol	Organic and biodynamic certifications
Share-Economy	Collective management, where production risks are shared within a community	Grassroots experiences (e.g., cooperatives)
Experience	Revenues mainly associated to the marketing of a specific experience rather than a farm product *per-se*	Cooking experiences, learning experiences (e.g., workshops)
Experimental	Exploration of high levels of innovation, generally linked to new food producing technologies or adaptation of existing solutions to the urban environment	Indoor vertical farms, rooftop greenhouses or aquaponics

institutions (including those providing job opportunities to disadvantaged users, Gasperi et al., 2016), which initially started in other sectors (e.g., handcrafting, catering) and more recently also engaged in agricultural activities thanks to the grown public awareness of sustainable food systems (Sanyé-Mengual et al., 2018b). A further classification is adopted to identify whether the *diversification* stands on a business-to-business (B2B) scheme (e.g., when electricity is produced through solar panels installed in the farm premises and energy is sold to the local energy supplier, Nelkin and Caplow, 2007, or when local compost plants that process urban bio-waste supply the organic matter that is then used for plant cultivation, Deelstra and Girardet, 2000), or on a business-to-consumer (B2C) scheme (e.g., when additional services are provided to the final users, including horse-riding farms, agro-tourism and educational farms, Pölling et al., 2017).

Differentiation BM

Differentiation BM includes farms that differentiate themselves from the competitors for the uniqueness of their specific product or production protocol. Urban farms that operate into the *differentiation* BM may concentrate on a specific niche product (e.g., an ancient tomato cultivar, van der Schans, 2010), or a special production factor specifically available in the city (e.g., rainwater collected from neighboring buildings and used for plant irrigation), a special strategy to target the consumer (e.g., pick-your-own fields, Vogl et al., 2003, or rent-a-field schemes, Pölling et al., 2016b) or determinate standards for food production (e.g., an organic or biodynamics certification scheme, Beauchesne and Bryant, 1999). Interestingly, when vertical integration is set in place (e.g., by implementing transparent, reliable and personal relationships between producers and consumers), differentiated farms may benefit from important market opportunities. These may reflect in more traditional B2C schemes, but also in B2B commercial agreements, where restaurants, canteens or food festivals are engaged in promoting locally-produced food (Pölling et al., 2016a).

Share-Economy BM

Share-economy BM includes collectively managed projects where the production risks are shared within a community. From an economic dimension, the *share-economy* BM entails for the highest level of innovation. They originate from the concept of "commons," bringing together communities into collaborative efforts toward the achievement of a shared objective. In France known as AMAP (Tang et al., 2019), elsewhere generally referred to as Community Supported Agriculture (CSA) schemes (van der Schans et al., 2016), they generally originate and grow from grassroots experiences of groups of activists and environmentally concerned citizens. In these experiences, citizens move from consumer's concept and become so-called prosumers, capable of influencing the structure and overall sustainability of their food systems. A crucial element (that constitutes the main evolution from the previously described farmers markets or solidarity buying groups) stands in the recognition that agriculture plays a main functional role in the society and that responsibility of food systems sustainability shall be distributed. Accordingly, the production risk (which is also being exacerbated by price fluctuations in a global market and uncertainty of production in response to climate change) is distributed among the different food stakeholders rather than placed only on farmers (Pölling et al., 2016a). Beside CSA schemes, citizens are also engaging in collective actions in the Global North, including the establishment of so-called Food Policy Councils, where active citizenships results in modifying public procurement schemes (e.g., in schools and prisons), as occurred in the city of Berlin, where the establishment of the local Ernahrungsrat (Food Policy Council) in 2015, significantly contributed to the creation of a food strategy and a dedicated municipal office (Berlin Isst so—Unsere Ernahrungsstrategie) devoted to improve sustainability of the food system (Braun et al., 2018).

Experience BM

Experience BM includes projects where the revenues are mainly associated with marketing a specific experience rather than a farm product *per-se* (Pölling et al., 2015). The BM targets the growing necessity in urban citizens to reconnect with nature and experience traditional cooking recipes (e.g., recovering traditional ways to process a tomato sauce, or hand-making of pasta) or learn gardening skills (e.g., recognizing wild edible species, or acquiring synergistic or permacultural cropping techniques) (Pölling et al., 2017). Experience may take place in the form of intensive workshops (as for the "kill-your-own chicken" workshops organized at *Nettle Farm*, Rhode Island, USA, *La Bibioteca*, Fermo, Italy, or *Uit Je Eigen Stad* in Rotterdam, The Netherlands, Gustafsson and Olsson, 2016), but also as non-organized activities that are made accessible within the farm (e.g., sensorial paths or pick-your-own fields, Yoshida et al., 2019).

Experimental BM

Experimental BM includes projects that retain a high level of innovation, generally linked to new food producing technologies or adaptation of existing solutions to the urban environment. Innovation may fall within the production technology (e.g., indoor vertical farms, rooftop greenhouses or aquaponics, Calone et al., 2019), but also in the processing stage (e.g., through integration of urban waste flows or the set-up of circular schemes, Pulighe and Lupia, 2019) or in the functions (e.g., regeneration of abandoned districts or brownfields revitalisation, Gasperi et al., 2016). In these systems, technology is often at beta stage, and the project sustainability often benefits from available public or private funding for research and innovation activities (O'Sullivan et al., 2019).

BUILDING AN INVENTORY OF UA PROJECTS IN THE GLOBAL NORTH

To date, a comprehensive census of UA projects and initiatives in the Global North has not yet been compiled, although some attempts of building local inventories exist, mainly in the framework of national and international projects. Entrepreneurial UA projects in Europe were recently listed in two highly comprehensive inventories in the framework of both the COST project TD1106 Urban Agriculture Europe (http://www.urban-agriculture-europe.org, Pölling et al., 2016b) and the Eramus+ project Urban Green Train (https://site.unibo.it/urbangreentrain/en/, Renting et al., 2016), altogether with classifications based on adopted business models. Similarly, a list of urban municipal gardens was compiled in the framework of the COST project TU1201 Allotment Gardens in European Cities (https://www.urbanallotments.eu/, Bell et al., 2016). Educational school gardens were also analyzed within the Erasmus+ project GardensToGrow (http://www.gardenstogrow.eu/, Pennisi et al., 2020b). The sustainability assessment of UA projects was mainly targeted within the H2020 MSCA project SustUrbanFoods (https://susturbanfoods.com/, Sanyé-Mengual et al., 2019) and the ClimateKIC action UrbaClim (http://www2.agroparistech.fr/Projet-URBACLIM.html, Lelièvre and Clérino, 2018). Similar research is also conducted within the JPI Urban Europe project FEW-Meter (http://www.fewmeter.org/en/home/), which targets assessment of resource use in UA projects in both Europe and North America (Ponizy et al., 2018). Moving to North America, among the mostly acknowledged projects, CarrotCity (https://www.ryerson.ca/carrotcity/), evolved from a book that aimed to compile a comprehensive database of UA experiences (Nasr and Komisar, 2014) and allowed for the creation of a mobile exhibition of featured case studies, which between 2009 and 2015 was displayed in cities across North America, Europe, Africa and Asia. Within the present manuscript a comprehensive inventory of UA projects built on all abovementioned databases was compiled (**Supplementary Table 1**), comprising all projects established in countries with developed economies (United Nations, 2020). The search provided no queries associated with some countries within the list, namely Finland, Luxemburg, Croatia, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Romania and New Zealand. Nevertheless, a total inventory of 470 UA projects (respectively, 288 in Europe, 97 in North America, 5 in Asia, and 80 in Oceania) was compiled, whose main features (including area, farming purpose and business models adopted) are hereby summarized (**Figure 2**). For comparative purposes, the main farming purpose and main business model were reported for each project, although these can be combined with other farming purposes and business models. The database shall be considered as updated at May 2020. Out of the 470 cases considered, surface data on the cultivated area was provided by 417 cases.

Statistically significant association [X^2 (25) = 92.568, $p < 0.000$] between projects dimension class and business model typologies was observed (**Figure 3A**, $n = 399$). Share-economy business model is highly (>49% of the total) diffuse in small projects with a surface area lower than 5,000 m^2, while in general experience and experimental business models are less frequent for all the considered projects dimension class. From the standardized residual analyses, it emerged that diversification business model was more common (38.7%) for projects with a surface area ranging 25,001 to 100,000 m^2 (see **Supplementary Table 2**) as compared to the other projects dimension classes, while differentiation business model resulted more represented in the biggest project dimensions category (surface area > 100,000 m^2), where, on the other hand, share-economy business model resulted statistically underrepresented.

A statistically significant association [X^2 (20) = 137.519, $p < 0.000$] between class of projects dimension and farming purposes was observed (**Figure 3B**, $n = 407$). In general, it was observed that social and educational purpose is highly represented (>54% of the total) in small projects with a surface area lower than 5,000 m^2, while for the biggest project category purpose is more common (80% of the total). From the standardized residual analyses, it resulted that projects with commercial purpose were underrepresented in small project category (surface area ≤1,000 m^2), but more common in projects belonging to the highest projects dimension class, trend which resulted completely inversed for social and educational projects (see **Supplementary Table 3**). Furthermore, also projects with image purpose resulted overrepresented in the smallest project dimension class.

Contrarily, chi-square test did not show a statistically significant relation between class of projects dimension and cities

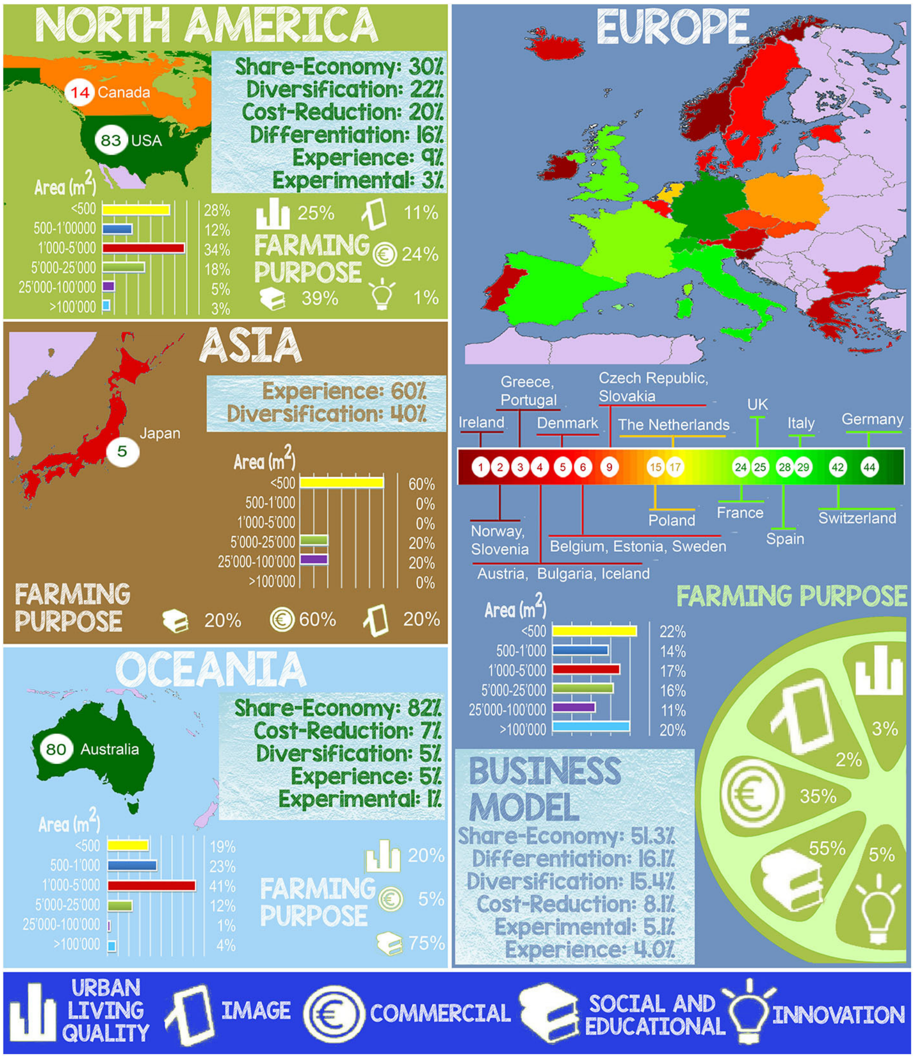

FIGURE 2 | Infographics on the inventory of UA projects in the Global North countries. In white circles the number of cases per country, also reflected within country color over the heatmap (e.g., red 0–10 projects per country, orange-yellow 10–20 projects per country, green more than 20 projects per country). In each World Region, figures on farm area, business model and farming purpose are integrated. Area charts represent the distribution frequency in the different size classes. Business models are classified according to Pölling et al. (2015) in the six categories: cost reduction, diversification, differentiation, share economy, experience, and experimental and placed in order of frequency. Farming purposes are classified accordingly to Thomaier et al. (2015) in five categories: urban living quality, image, commercial, social and educational, innovation. Sample composed of 417 UA projects.

population [X^2 (25) = 41.639, p = 0.05, n = 417], between class of projects dimension and category of city density [X^2 (10) = 12.157, p = 0.275, n = 386] and between class of projects dimension and city climate [X^2 (115) = 20.543, p = 0.152, n = 417] (data not shown).

CONCLUSIONS

Within the present review paper, 470 UA projects distributed across different world regions of the so-called Global North are identified and classified, according to their main business models, farming purposes and surface covered (**Figure 2**). UA's *main ecosystems services* in the Global North span from food provision to health functions, social inclusion and justice and contribution to ecological and environmental sustainability. Main *factors that affect UA development and diffusion* include the existing legal framework, land access, contamination risks, local climatic conditions and resource availability. A diversified number of *typologies of farming systems* were observed, including allotment gardens, extensive periurban farms, urban community gardens, rooftop farms and indoor vertical farms, as well as specific systems associated with the production of niche food products (e.g., microgreens, aquaponics, urban honey). With reference to *farm size*, in all world regions considered, a large share of UA projects operate on small surface (<1,000 m^2). Larger farms

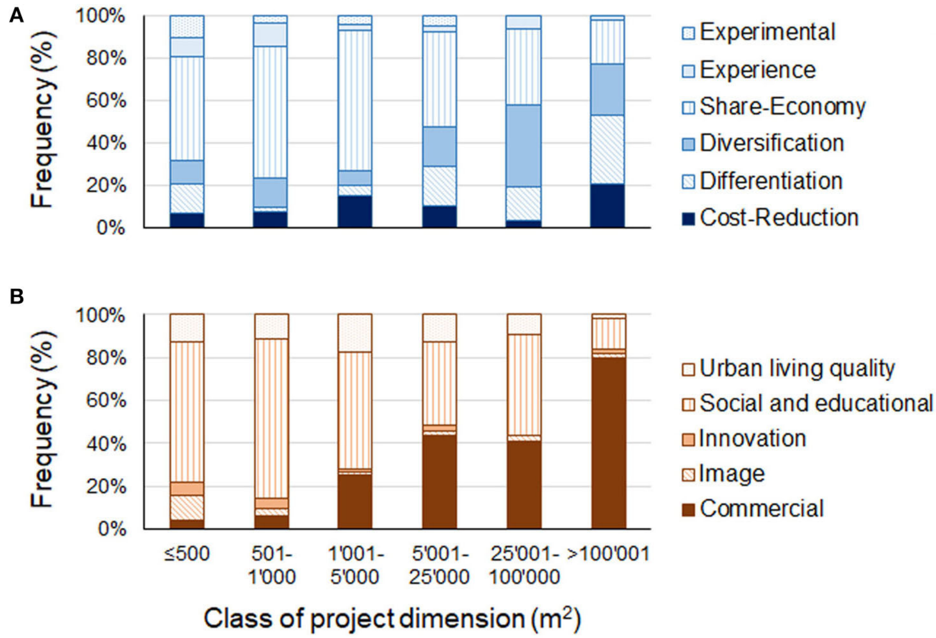

FIGURE 3 | Relative distribution frequency (%) of business models (**A**, Pölling et al., 2015, $n = 399$) and farming purposes (**B**, Thomaier et al., 2015, $n = 407$) with respect to the class of project dimension among the case studies included in the database.

(e.g., above 10 ha), represent a fifth of the cases in Europe, whereas about 3–4% in both America and Oceania. Among *business model strategies*, in Europe, North America and Oceania, the largest share of UA projects followed share-economy BM, but diversification and experience business models were also found in all world regions. Specifically, share-economy business model resulted to be diffuse in projects with small surface area (<5,000 m^2), while differentiation and diversification were the predominant business models in the biggest project dimensions category (e.g., above 10 ha) (**Figure 3A**). Among *farming purposes*, social and educational farming were the most frequent cases in Europe, Oceania and North America, while commercial projects were indeed predominant within the few cases reported in Japan. Considering farming purposes in relation to project surface areas, it emerged that commercial projects were underrepresented in small project category (≤1,000 m^2) but the most common among largest projects, contrarily to social and educational projects which resulted more common in small projects but quite rare for big (above 10 ha) projects (**Figure 3B**). Looking at city population, city density and city climate, no statistically significant relations were highlighted with project surface area categories. The collected data may allow for further design and implementation of successful UA experiences, while also fostering cross-pollination among initiatives and enabling the environment for sustainable urban farming. It overall emerges that, although with smaller figures in terms of food production capacity as compared with rural agriculture, the UA sector has a clear potential in fostering food security in time of emergency (e.g., in response to pandemics or extreme climate events), as well as promoting the overall city sustainability (with the associated benefits in terms of reduced environmental footprint, social justice, ecology and microclimate). However, further research effort is needed to substantiate the estimated potential with actual figures at city scale and enable the environment for the implementation of appropriate legal frameworks and guidelines toward large-scale diffusion of sustainable UA initiatives. Moreover, the application of the hereby adopted methodologies and classifications to UA projects from the Global South could also allow for comparative assessment of successful strategies.

AUTHOR CONTRIBUTIONS

FO drafted the paper and coordinated the preparation of the manuscript and data visualization. GP, NM, and ES-M created the inventory of case studies and contributed to sections Ecosystem Services (ES) Associated with UA, Factors That Affect Development and Diffusion of UA, and Main Typologies of UA Systems. GB contributed to section Ecological Aspects and Building an Inventory of UA Projects in the Global North. AM contributed to section Introduction. GG contributed to sections Introduction, Defining Urban Agriculture (UA), Health, Laws and Regulations, and Main Typologies of UA Systems. All authors critically revised the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2020.562513/full#supplementary-material

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