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Conference report

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Nurturing cities: pathways towards a circular urban agriculture

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Abstract
The recent Covid-19 pandemic has shown how world crises manifest themselves in a more disruptive way in urban communities. Urban areas were hit harder by the virus, and the images of empty shelves and endless queues in front of the supermarkets are the emblems of a western society that started to fear for its food security. Today, soils are under a lot of pressure to feed an increasingly urban population (80% of food will be consumed in cities by 2050), and if a future pandemic would hit grain or wheat or soy seeds instead of humans, there is a good chance that our food-system would be disrupted. In this scenario cities are the epicenter of the new challenges for the future, having the means, the technologies, and the assets to spark the transition towards a circular economy of food that replicates natural systems of regeneration, eliminating wastes, using them as inputs for the next production cycles. Hence, farming the cities emerged as a possible solution to feed an increasingly urbanized world, reducing the impact of our food system on agricultural soils, while providing citizens with local, freshly-produced food. This paper aims to illustrate how circular urban agriculture can be achieved by finding new farming spaces in cities, removing the constraints of the soil, and thus integrating off-soil production systems within buildings and urban districts, developing new synergies between the built environment and agriculture practices.

Keywords: Urban Agriculture; Circular Economy; Sustainable Cities; Hydroponics; Food Production

1. Introduction
The recent Co-vid19 pandemic crisis has shown some of the contradictions of the way we live in urban areas. On a global scale, cities use about 3% of the land area [1], and yet, 90% of all Covid cases happened in cities [2]. This is because cities have rapidly become our 'natural habitat, with the first urbanization processes taking place no more than 200 years ago [3]. Today, the majority of the world's population already live in cities and the urbanization trends confirm the increasing curve over the next 30 years with about 85% of people expected to live in European urban areas by the year 2050. However, due to their dimensions, cities are not able to be self-sufficient. Indeed, they rely on large and complex global supply chains and have large ecological footprints, drawing on 'distant elsewhere' for food, fuel, and carbon sinks. In this sense, the urge for new planning policies to make cities more sustainable is justified by the recent reports of the Intergovernmental Panel for Climate Change (IPCC), which have estimated that urban areas account for 67-76 percent of global energy use and 71-76 percent of global energy-related carbon dioxide (CO_2) emissions [3]. Furthermore, a 2017 report from UNFCCC [4], reported that 20% of the worldwide anthropogenic GHG emissions come from urban infrastructure such as buildings and transportation (of which buildings and construction account for about 70% and transportation for about 30%). In this scenario, the rapid expansion of the urban population equals mass expansions of urban infrastructure. This will increase the dependence of very large concentrations of urban populations on long international supply chains for food, fuels, and consumer goods, making cities vulnerable to disasters in locations that supply these or buy their products, as well as to rising fuel prices [5]. A taste of what such a crisis may look like was provided during the first months of the pandemic crisis: the severe international lockdowns and the fear for what it could have come next, disconnected for a short while cities from their supply chains. In this context, supermarkets were assaulted by fearing crowds that left nothing but empty shelves and few non-

survival-related needs like it already happened during the wartime crisis. The images of endless queues in front of the supermarkets are the emblems of a western society that started to fear for its food security and stopped taking its food for granted. In this scenario, it emerged clearly that cities will have to consider the issue of food security, including strategies on how to develop more localized food production systems. European cities make great efforts to feed themselves, and the environmental costs of food systems are becoming more and more unsustainable. If we take London as an example, it has been calculated that it needs around 150 times its footprint just to feed itself [6]. Unfortunately, our food system, from which cities so much depend, is put in crisis by the same urbanization and increase in global population. Today, there is a deep paradox in our industrialized agro-system, where nurturing us means consuming the earth. Thanks to the technological advancements and their widespread use in agriculture, agricultural production has more than tripled between 1960 and 2015 [7]. This caused a significant expansion in the use of land, water, and other natural resources for agricultural purposes [7], followed by the constant lengthening of the food supply chain, which dramatically increased the physical distance from farm to plate. Thus, the expansion of the food production system and its consecutive economic growth have had a heavy impact on the natural environment: almost one-half of the forests that once covered the Earth are gone leaving the place to monocultural agriculture fields; groundwater sources are being depleted rapidly; biodiversity has been deeply eroded; agriculture CO2 emissions rose year after year, contributing to global warming and climate change [7]. The way we produce food now is an actual threat to our possibility of producing enough food in the future for a growing population. Indeed, even small changes in the climate such as shifts in annual rainfall or seasonal precipitation patterns can severely affect productivity. Hence, with an overcrowded future at the clear sight and the renovated fear of new pandemics bursting out of nowhere, the core question is how modern industrialized agriculture can meet the needs of a global population that is projected to reach more than 9 billion by mid-century and may peak at more than 11 billion by the end of the century [7]. The depletion of soils together with the scarcity of land and a reduced capacity of freshwater reservoirs mark the necessity for a transition towards more sustainable and fair production systems. If it is a consensus opinion that the modern agro-business will be able to produce enough food for a growing population (it already produced food for 10 billion inhabitants [8]), it is also acknowledged that it won’t be able to do so inclusively and sustainably [7]. In this scenario, several solutions have emerged that promote a shift towards more sustainable food production practices, often complementary to each other. Strategies vary from investing in a renovated organic agriculture [9], going from commercial monocultural farms to diversified farming, to proposing the transitions towards plant-based foods as the main source of proteins, to dramatically reduce the meat’s consumption [10]. In this context, a strategy that is catching on is to implement food production systems within cities and large urban environments [11]. The recent fortune of this practice, known as Urban Agriculture (UA), is connected to its capacity to target both urban and agricultural issues, proposing solutions that promote both the sustainable transition of urban food systems and new healthy urban lifestyles. Thus, UA should not be considered just as a food-related practice, but instead, as a tool for planners and practitioners to boost cities’ sustainable development by implementing new urban green infrastructures, as well as new sustainable solutions for food productions. In this context, horizontal and vertical surfaces in the city, such as rooftops, facades, squares, and interior spaces, as well as urban vacant and residual spaces, can host a large-scale urban food production, taking off pressure from agricultural land [12]. Cities have resources like infrastructures, labor, energy, water, and a ready-made market for food production [13], therefore, it makes sense to produce in urban areas where citizens are not only the final users but also the producers.

1.2 Brief history of food production inside the city

Historically there has always been a link between the development of organized agriculture and the process of urbanization [6]. Indeed, cultivating crops in urban areas is an old practice, dating back to the beginning of civilization. In Palestine, archeologists found the remains of what was probably one of the very first settlements in human history: Jericho. Founded around the 9.500 b.C., excavations showed that by the early 8.000 b.C. Jericho was hosting around 2-3 thousand inhabitants, organized into a proper community able to build walls and produce art. In 1.500 years, that very small settlement became a town, which could grow and develop for another 5000 years, thanks to the development of the very first agricultural techniques: complex irrigation systems and trace of grains and wheat were found in the archeological site. Eventually, even Jericho had to fall, the increasing population, greed, needs, war, drought, and famine finally destroyed it after six thousand years of existence [14].

Throughout history, cities have been in a codependent relationship with their countryside, and their survival strictly depended on the capacity of the land to produce food: food transportation was extremely complicated and that limited the capacity for cities to expand. The very basic laws of geometry can explain that as the larger the city grew, the smaller the size of its hinterland became with the inevitable consequence that the latter could no longer feed the former. For instance, in the 15th century, Bologna was one of the biggest cities of its time with a population of 75.000 people, famine was most certainly much known by its inhabitants until the black plague decimated its population partially resulting in easier food access for those that survived [14]. The cultivation of plants and crops in villages and towns was an established practice during middle age in the form of *hortus* [15]. The *hortus* pattern recurred through gardens that complete the village's general geometry and feed the local community [15]. They were usually positioned at the borders of towns, adjacent to the defensive walls, enabling food security in times of siege (Fig. 1). During the same time, horticulture was also developed in monasteries where food production and processing were established under the Rule of Saint Benedict [15]. Until the 19th-century food had strongly determined where and how cities were built. However, during the industrial revolution, the appearance of new infrastructures that were able to connect cities at high speed suddenly changed this paradigm: once the first railways started to be built in Europe it was clear that they represented an unprecedented opportunity to distribute food all around cities and countries. The boundaries of the urban environment and rural hinterland started to fade and the city sprawl was then unstoppable. Still, some forms of urban agriculture persisted: during the industrial revolution gardens were found within the fringes of industrial towns, contributing to the food security of the migrant workers, and during the two great world wars of the 20th-century war or "victory" gardens were promoted by governments to feed the urban population [16]. It is right in this period, at the beginning of the 20th century, that the first form of modern UA was developed by an English architect with regard to urban planning. Just over a century ago in England occurred the first significant phenomena of great urbanization, with massive migrations from the countryside to the industrial city. During the Second Industrial Revolution, for the first time, a book called Garden Cities of Tomorrow (1902) by Ebenezer Howard theorized the return to a city in harmony with nature. According to Howard, one of the biggest mistakes of the time was considering industry and agriculture as two different elements separated by a clear demarcation line. Unfortunately, albeit fascinating, Ebenezer Howard's theories did not have good success in practice. Some New Towns were built but never became really self-sufficient, on the contrary, since they were dependent on the main cities, they ended up merging with them, determining one of the first phenomena of urban sprawl [17]. With respect to these experiences, today, it is legitimate to wonder whether it is appropriate to overturn the paradigm of the city moving into nature, maybe it should be nature itself to colonize the city in a salvific way with green spaces and agricultural areas. Today, this is possible thanks to the technical advancements in the construction sector and in the food production technologies. Indeed, new off-soil, hydroponic technologies provide have high yields in very narrow spaces, opening to new frontiers on how to integrate these systems within the urban environment. In this scenario, modern Urban Agriculture can be considered a relatively new approach by which planners, engineers, architects, and agronomists are trying to shape the cities of the future enhancing circularity, promoting more resilient urban spaces.

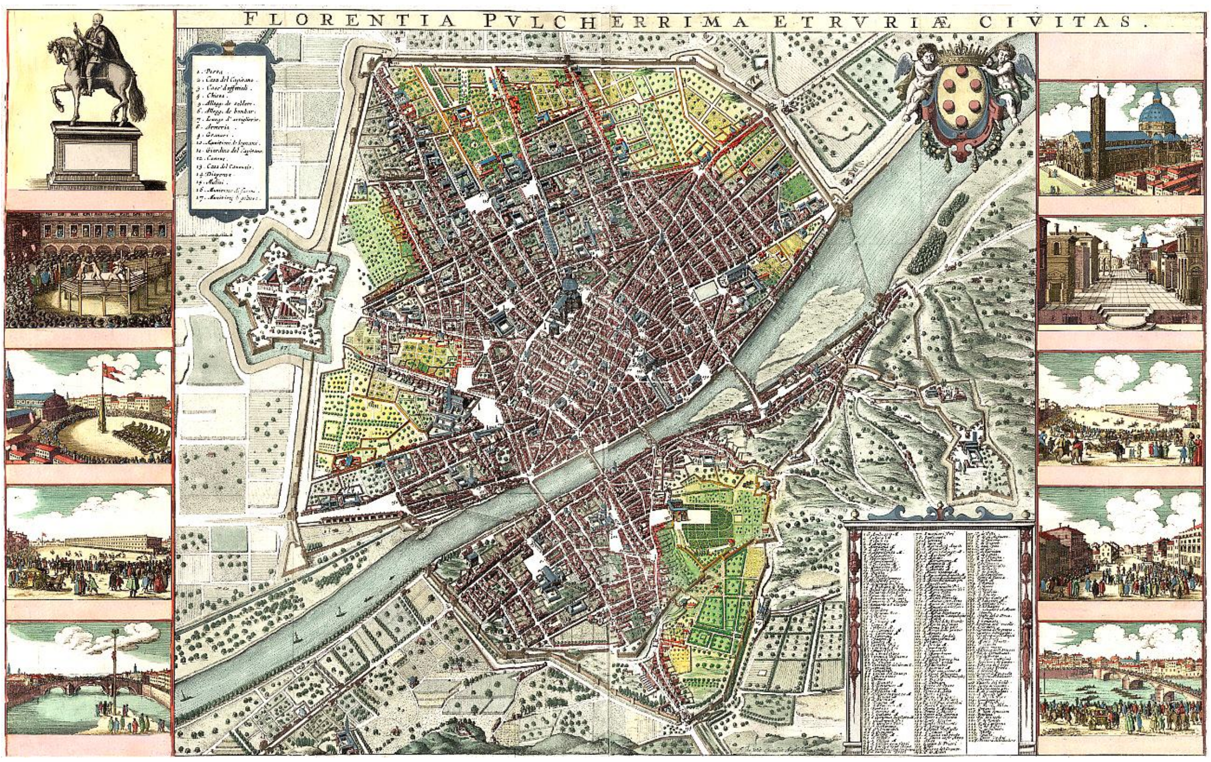

Fig. 1: Historic map of Florence. P. Van der Aa, 1728
Credits: *SANDERUS, antique maps and books*
Urban hortus and gardens are clearly visible in this map and willingly highlighted with a higher saturation. From this historic map, it is possible to appreciate the location of the urban hortus, right next to the borders walls

2. UA fields of application

Urban Agriculture can be defined as the activity of planting food and breeding animals within and around cities. In the past 20 years, the evolution of urban agriculture resulted in different definitions and conceptual developments. The United Nations Development Program (UNPD) adopted the definition of Smit et al. (1996) [18] which defines urban agriculture as an industry that produces, processes, and markets food, largely in response to the daily demand of consumers within a town, city, or metropolis, on land and water dispersed throughout urban and peri-urban areas. Mougeot (2000) [19] submitted a revised definition, where urban agriculture is defined as an industry located within (intraurban) or on the fringe (periurban) of a town, city, or metropolis, which grows or raises, processes, and distributes a diversity of food and non-food products, (re-)using largely human and material resources, products, and services found in and around that urban area. Nonetheless, the board applications of UA on different scales and with different focus make it harder to adopt a commonly agreed definition [20]. For this reason, it is important to understand UA aims, location, and cultural/climatic context before approaching new UA activities. The variety of UA forms can be classified in various ways, depending on its actors, purpose, land use, scale, location, property, technology, and production system [21]. The concept refers to the production of food crops within cities and around them. It includes commercial and non-commercial activities and covers food processing as well as other activities in the food value chain. That makes UA a multi-dimensional concept that can deeply vary from project to project. An analysis made by Tujil et al. [20] identified several applications of UA projects and categorized them into nine macro typologies depending on the location, the dimension, and the strategic focus (Fig. 2): i) Community Garden; ii) Institutional Garden; iii) Guerrilla gardening; iv) Urban Farms; v) Vertical Farming; vi) Plant Factories with artificial lighting (PFAL); vii) Zero-Acreage Farming (ZFarming); viii) Agropark; ix) Agro-tourism.

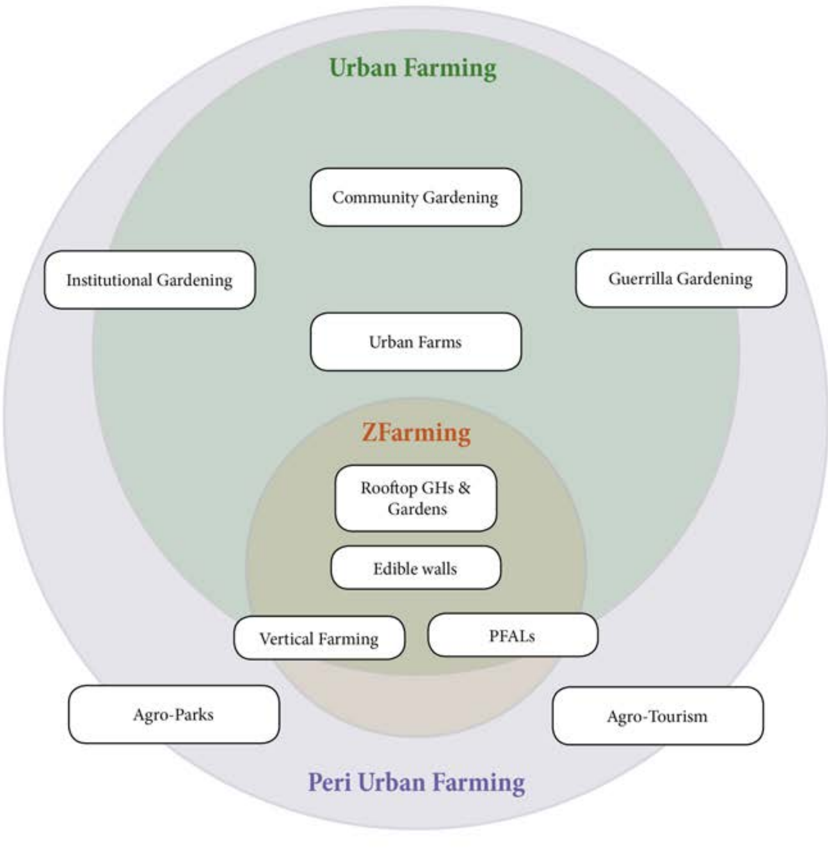

Fig. 2: Broad applications of UA and PUA
Source: *Own work*

Not every type of UA fits in a single category and overlaps between the types exist and are easily found in UA projects. Often, different categories can complement each other, for instance, rooftop gardens can be community gardens and also fall into the category of ZFarming. However, a great difference between those categories can be identified linked to two macro-dimensions of food production: use of land and food technologies. Whereas the common purpose is to shift towards sustainable intensification of urban crop production [22], in highly constructed urban areas land availability is a great limit for production. Therefore, in densely built-up areas, where the availability of space often limits the size of the production unit, the use of soil-less technologies represents new opportunities to increase urban crop yields [23]. In this regard, ZFarming (including Vertical Farming ad PFAL concepts) is the best solution to achieve high yields in very limited urban spaces [23].

2.2 Farming in and on buildings: potential impact

To integrate agricultural activities within buildings in a highly dense urban environment, ZFarming offers the best solution to achieve intense production while minimizing the use of land. The term was introduced to describe all types of urban agriculture characterized by the non-use of farmland or open space, thereby differentiating building-related forms of urban agriculture from those in parks, gardens, and urban wastelands [23]. Hence, ZFarming differs from ground-based UA, of which it can be considered as a subtype. It can be considered as a complementary practice of ground-based UF, that offers opportunities for resource-efficiency synergies between buildings and farming [24]. Implementing ZFarming models within cities requires new regulation frameworks and advanced technical knowledge of ZFarmers, which have limited today the expansion of these types of UF in respect to ground-based practices. The strategic objectives of ZFarming projects, as well as its peculiar characteristics of producing food without using land space, make this special subtype of UF particularly interesting for professionals involved in sustainable urban construction and planning. Architects, planners, and engineers recently developed an increasing interest in ZFarming methods to implement green buildings design, trying to connect aesthetic, functional, and ecological principles. The need to reduce cities' resource consumption, create sustainable infrastructure and plan more inclusive cities while reducing the food chain make ZFarming a powerful tool to implement new green urban designs. This might be particularly true for Building-Integrated Agriculture (BIA), a specific subtype of ZFarming which is defined as the practice of locating high-performance off-soil greenhouse systems, such as hydroponic, aeroponic, and aquaponic, on and in mixed-use buildings to exploit the synergies between the building environment and agriculture-like energy and nutrient flows [23]. BIA is considered to be highly compatible with sustainable bioclimatic design principles [25]. However, today the synergies between buildings and farming are yet not fully exploited. Nonetheless, ZFarming and BIA are powerful tools for the retrofitting of abandoned buildings and old industrial sites. Integrating food production in vacant urban plots is an opportunity to bring back to life post-modern ruins, creating new mixed-use buildings that can generate revenues and implement local living quality improving the urban landscape [26]. Therefore, ZFarming and Building-Integrated Agriculture should be considered as new design tools to foster cities' sustainable development. In this regard, new planning strategies, as well as new legislation and regulations must be adopted to facilitate the retrofitting and the new construction of mixed-use buildings where food production and other living and social activities are interconnected.

2.3 Off-soil production and cities' development

Finding new spaces for agriculture in urban environments drove scientists and researchers to develop new technologies that can maximize yields in limited spaces removing the constraints of the soil using other media to grow plants. In this scenario, ZFarming experiences rose as a subtype of already existing urban farming concepts taking advantage of vertical spaces in cities to increase urban food production. The advantages of ZFarming projects and the integration of agricultural systems within buildings are not only connected to the possibility of producing food without occupying urban grounds, but also in the way they could implement synergies between buildings and agriculture [23]. In this regard, the application of advanced farming systems within the constructed environment represents a new opportunity for planners, architects, and engineers to use integrated UF projects to implement circular flows of resources in cities. Cities are in-fact the hubs where circular strategies can be experimented and implemented: here, the confluence of government actors, business, and citizens "[…] creates live innovation labs for addressing the complex challenges of linear economic models" [27]. Furthermore, local municipalities can act faster than national governments, making it more agile for cities to transition towards circular policies [28]. Transitioning to a circular economy requires rethinking market strategies and models that encourage the responsible consumption of natural resources, educating consumers, proposing new sustainable behaviors [27].

In this context, implementing ZFarming and BIA projects is coherent with cities' circular development goals where closed-loop agricultural ecosystems can treat waste as a resource. In metabolic synergies between buildings and farming, the waste of one part of the system can become the nutrients for the other. Thus, a closed-loop system recycles and reuses nearly every element of the farming process, from dirty water to nutrients. Furthermore, food waste can also be converted into organic matter and used either as compost for other agricultural practices or as burning bio-fuel in bio-gas plants. Ideally, in closed-loop systems, everything remains in the system, leading to a zero-waste outcome.

3. Circular Urban Agriculture for circular cities

Implementing newly sustainable, environmental and people-friendly urban food production is directly connected to the transition towards a circular food economy. This is because when an urban food system goes circular it supports more resource-efficient and regenerative agricultural practices like precision and organic farming, and low and high tech protected cultivations. Here, the use of all by-products and waste streams along the whole food supply chain is recirculated and wastes and inputs collide, limiting the use and exhaustion of resources like soil, energy and fertilizer. Furthermore, in ZFarming projects, circular food strategies are connected with the built environment and the principles of circular construction, thus promoting sustainable design principles such as modular construction and the use of building materials within high value closed loops for efficient assembly/disassembly techniques. Hence, adopting circular urban horticulture within the built environment is seen ad an opportunity to connect different spheres of urban living, implementing the sustainable growth of the modern metropolises. In this regard, cities may shape their vision of the city of the future in the connection of circular construction and circular horticulture, defining circular economy as an economic system that replaces the 'end-of-life' concept with restoration [29], shifting towards renewable energies, and eliminating waste. In this context, circular horticulture is intended as a circular economy of food that consciously emulates natural systems of regeneration so that waste does not exist, but instead works as input for another cycle [30]. Today, thanks to soil-less protected cultivation techniques, it is possible to fully integrate greenhouses and plant factories in buildings, generating new synergistic relationships between the two entities. The target in protected cultivation systems should always be to save resources and energy and to develop zero emission. Nonetheless, the degree of circularity and sustainability depends on the quality of the inputs [29]. For instance, in off-soil production, the quality and quantity of water flowing through the system is fundamental to determine and design the circular production system. In this scenario, recovering resources from buildings is, in fact, at the core of the circular development of integrating food in buildings (Fig. 3a & 3b).

Fig. 3a: Circular processes in ZFarming
Source: *Own work*

Fig. 3b: Example of integrated rooftop greenhouse
Credits: *Michele D'Ostuni, UrbanFarmers in Den Haag*

Buildings are, in fact, hot spots for nutrients and water recovery, fundamental resources to produce food in urban areas. Soilless cultivation systems and especially closed or re-circulating hydroponic systems can significantly reduce fertilizer runoff but not eliminate it [29], for this reason integrating them in buildings can benefit both entities developing water and nutrients closed-loops, eliminating dangerous runoffs. Nonetheless, even though high-tech greenhouses may present a high level of circularity, they need high investment cost, greater installation and running costs, and a high degree of automation and technical skill [29], which limit their applications in those areas in Europe where technologies and know-how are already known. In this sense, municipalities play a crucial role in the development of ZFarming and building-integrated agriculture. Today, cities have the opportunity to spark a transformation towards a circular economy for food, given that most of all food is expected to be consumed in cities by 2050. Cities have the assets, the technology, and a dense networks of highly skilled workers that represent the ideal conditions for innovation in the food system. Citizens, retailers, and service providers are all in close proximity, making new types of business models possible where producers are directly connected with the consumers [30]. This combination of factors means that governments and municipalities have the means to implement a circular economy for food.

Connecting high tech production systems with the construction sectors, providing incentives also to developers and constructors, will foster a diffuse planning of ZFarming projects in cities, weakening the limitations represented by the initial investment costs and creating the business conditions for new urban food enterprises to thrive. Cities have, in fact, tremendous demand power as a great volume of food is eaten within them [30]. Furthermore, cities accumulate a large amount of food by-products and waste, that can be re-used directly in urban areas. In this context, new technologies and innovations in the food production sectors may be the key factors to minimize resource consumption while producing enough food to contribute in feeding growing urban communities. For this reason, the production systems that will be integrated in city planning must have nearly zero environmental impact [29]. In circular protected horticulture plants grow in closed systems, where water and nutrients are recirculated and reused. These systems, like hydroponic or aquaponic greenhouses and indoor plant factories, require adequate management, and a deep knowledge of irrigation and fertigation techniques. For this reason, investment in research programs and in the education of the operators are crucial in urban areas to achieve high yields with maximum efficiency of the use of natural resources.

3.1 Strategies for the integration of off-soil systems within buildings

It is possible to see different approaches of integrating agriculture within architectural buildings, ranging from passive systems, such as container growing, to technological systems such as rooftop greenhouses, vertical facades and various types of indoor growing facilities. Each system has its way to implement the overall sustainability of the building, from mitigating roofs heat absorption, to adding extra green insulating layers to existing facades. In particular, high-tech greenhouses and plant factories are the most used systems in building-integrated agriculture, as they present the great advantage of maximizing production yields, making them more suitable for the integration in mixed-use buildings, allowing them to host multiple functions other than just food production. The main difference between these two systems is the way they interact with the exterior climate. One one hand, greenhouses are transparent structures that interact with the exterior climates and let the solar radiation pass through the enclosure surface allowing plants to start the photosynthetic process. On the other hand, plant factories are air-tight structures that don't interact with the exterior climates and exclusively rely on artificial light and indoor climate control devices to cultivate plants. Thus, the integration of these two systems in buildings highly depend on the location of each ZFarming/BIA initiative. In this regard, rooftops and south facing facades are the most commonly used spaces for active building integration with high-tech greenhouses. Here, these greenhouses operate resource efficient methods, using closed hydroponic systems, recovering rainwater, and exchanging heat with the building. For instance, the heat absorbed by the building and transferred to the greenhouse is an efficient way to lower the production's energy demand, resulting in a win-win symbiotic relationship between the two systems.. All this considering, it is possible to determine strategic design solutions to optimize the integration of high-tech greenhouses in buildings. Thanks to new growing methods and technologies it is possible to see the production spaces as new components of the architectural project. In this regard, it is possible to recognize three main integration concepts (Fig. 4):

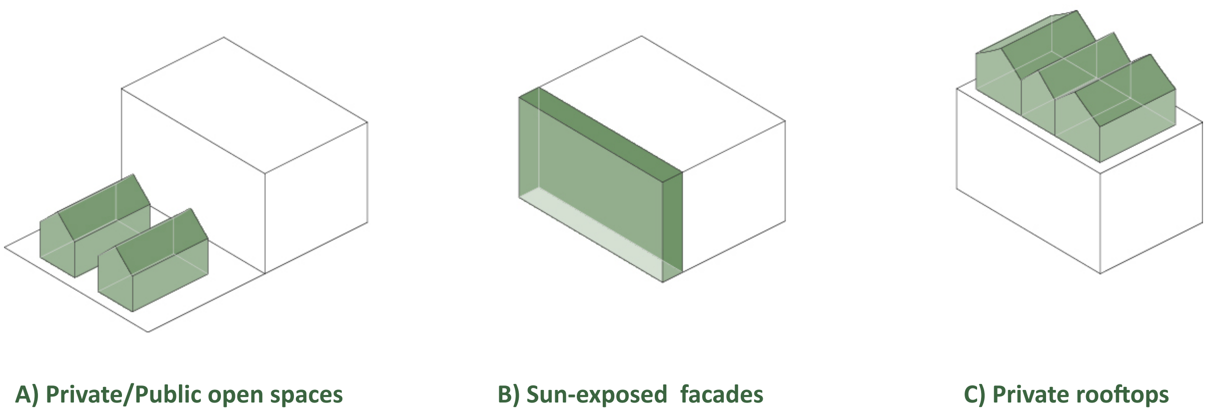

Fig. 4: High-tech Greenhouse integration in buildings
Source: *Own work*

While integrating high-tech greenhouses in architectural projects must take into consideration the exterior conditions, maximizing their exposure to solar radiations, indoor growing spaces rely exclusively on artificial light for plant production, opening a whole new other world of possibilities for their integration in buildings. Indoor growing spaces must have better insulation than greenhouses using different opaque envelope materials. As reported by Graamans et al. (2018) [31] this typology is better suited to extreme climates, where temperature swings are of larger concern than lighting (Graamans et al. 2018). However, these systems are also suitable for the integration of this typology into the darkest spaces of buildings, creating new design opportunities. Taking this in mind, it is possible to define three main integration concepts in buildings. (Fig. 5)

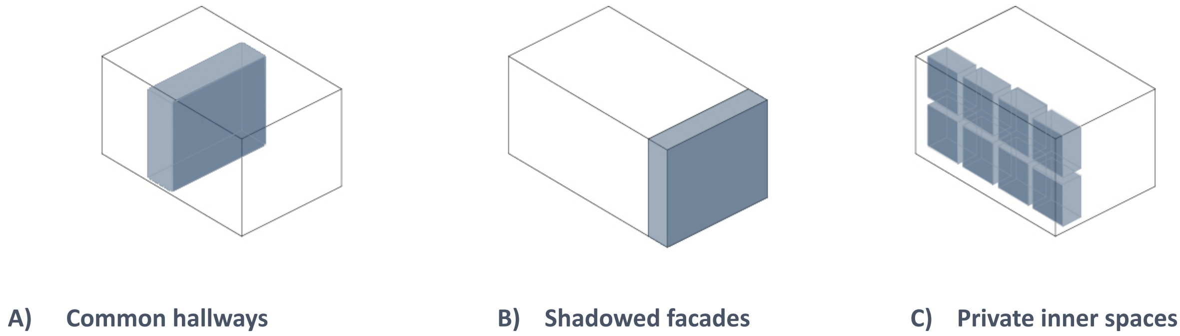

Fig. 5: Indoor farming integration in buildings
Source: Own work

3.2 Limitations to the development of circular agriculture in cities

Including urban agriculture in the city's spacial planning is a key strategy for the transition towards a diverse and resilient food system, reconnecting people with food, and delivering a range of societal and environmental benefits [30]. To do so, it is important to acknowledge that single, spot UF initiatives cannot contribute significantly to satisfy urban food demand and needs, especially in cities where population growth is constant. However, even indoor urban farming methods won't be able to cover all the food needs within cities, and also when coupled with open-field Urban Agriculture, it is unlikely that they could provide for more than one third (by weight) of all the food needed for urban consumption [30]. Furthermore, planning strategies are effective only if they can overcome three main challenges of UF:

1. **Competition for land:** to be effective UF initiatives must be diffused over a territory. Finding farming spaces within the city can prove challenging due to zoning laws, technical feasibility and competition for other revenue-generating uses. Of course ZFarming help avoiding the need of physical land, but it must face local regulations and the skepticism of local developers and farmers to invest in such projects. Single virtuous initiatives cannot be the answer to deeply routed problems in current urban food system, and the implementation of advanced building-integrated agriculture requires vision, planning and fundings both from the private and the public sectors.
2. **Limited crops type:** Crops that are typically produced in indoor greenhouses and vertical farms are sill limited to leafy greens, herbs, other vegetables, and selected fruit, such as strawberries and tomatoes. Even if a city produced all the required volumes of these food types in indoor urban farms, it would still depend on food from peri-urban and rural areas for other food types. Nonetheless, the advancements in greenhouse design and production technologies are increasing the number of crops that can be produced indoor with high yields. Tests and experimentations are leading the way for a growing offer of food crops that can be sold in urban areas. However, local regulations might limit the commercialization of this newly indoor produced crops, limiting for the moment their commercial development. In this scenario, research and development is fundamental to achieve maximum variety in urban crops production, as both costs and production data are needed to assess the economic feasibility of cultivating more variety of crops within the urban boundaries.
3. **Difficulties in becoming circular:** Finally, indoor urban farm types (multi-story soil-less hydroponic or aeroponic, greenhouse, aquaponics greenhouse, and hydroponic greenhouse) face challenges to becoming entirely circular. High-tech soil-less farming methods require tailored nutrient solutions, where water pH and mineral nutrients concentration is manually or automatically controlled. Nutrients used in high-tech hydroponic greenhouses are mostly nitrogen, phosphorus, and potassium coming from unsustainable sources, and, if not recirculated into the production system, they may cause environmentally dangerous runoffs. Furthermore, reaching high yields in indoor facilities require high energy inputs for lighting and heating/cooling, which at the moment are generally reliant on fossil fuels [31]. However, technological innovation, as well as infrastructure planning strategies can help overcome these challenges as high-tech closed production systems have high potential in becoming completely circular.

4. Final discussion

In conclusion, the expressed potential for circularity in integrated high-tech protected agriculture in urban areas highly depends on the technical knowledge of the production systems. More technology and more control may lead to improved circular performances, but that requires high investments and a specific set of expertise that may not be easy to find in urban areas and in certain countries. Furthermore, optimal solutions for circularity have not been developed for all regions in Europe or the Mediterranean [33]. For instance, the closed or semi-closed greenhouse concept, fundamental for the circularity of the indoor food system, has been developed and is already applied by some Dutch greenhouses and cannot be directly transferred to the Mediterranean regions. That's because closed and semi-closed greenhouses in the Mediterranean climates require a lot of energy for cooling. Reconnecting people with food, educating them to healthy diets, bringing production visible and tangible within the city boundaries, is considered crucial if cities want to change the way citizens see food, creating a ripple effect that may partially or drastically change modern food system. In this context, marketing strategies are fundamental for the acceptance of a new type of food grown without the constraints of the soil and integrated in buildings. In particular, ZFarming initiatives can involve the participation of a great part of population, as they operate right there where people live and work. They can shape new architectural forms, and urban look, making food visible and livable for every citizen. Furthermore, in comparison with soil-based urban farming, ZFarming projects can directly connect food and architecture, exploring and developing those interconnected relationships where the two entities can exchange food, knowledge and resources. In this sense, integrating food production in urban areas, especially in buildings where people live or work could increase the perception of food security in period of crisis. Furthermore, like our ancestors, we just re-discovered how important can be to have reserves of food in time of sieges. The recent Covid pandemic has forced us in our homes, and we are barely seeing the end of it. In this scenario, taking care of our food, reconnecting with it, can be an important coping mechanism to face the future urban challenges of contemporary overcrowded cities.

Bibliographical References

[1] Referring Web Pages Web: **http://www.newgeography.com/content/001689-how-much-world-covered-cities**

[2] Referring Web Pages Web: **https://sdgs.un.org/goals/goal11**

[3] Referring Web Pages Web: **https://www.ellenmacarthurfoundation.org/publications/circular-economy-in-cities-project-guide**

[4] United Nations Framework Convention on Climate Change. 'Urban environment related mitigation benefits and co-benefits of policies, practices and actions for enhancing mitigation ambition and options for supporting their implementation', The Secretariat Paper Report, 2017.

[5] DESPOMMIER, Dickson. The Vertical Farm: Feeding the World in the 21st Century, New York: Picador, 2010. ISBN

[6] KEEFFE, Greg. Hardware software interface – A strategy for the design of urban agriculture in R. ROGGEMA, Rob. Sustainable urban agriculture and food planning. Routledge, 2016. p.

[7] FAO, 2018. *The future of food and agriculture – Alternative pathways to 2050*. Rome. 224 pp. Licence: CC BY-NC-SA 3.0 IGO.

[8] HOLT-GIMÉNEZ, Eric. *"Can we feed the world without destroying it?".* London: Polity Press, 2018.

[9] HOLT-GIMÉNEZ, Eric, SHATTUCK, Annie, ALTIERI, Miguel, HERREN, Hans, GLIESSMAN, Steve. We Already Grow Enough Food for 10 Billion People... and Still Can't End Hunger. 2012. *Journal of Sustainable Agriculture*, 36 (6), pp. 595-598.

[10] LEA, Emma, CRAWFORD, D. WORSLEY, Anthony. Public views of the benefits and barriers to the consumption of a plant-based diet. *Eur J Clin Nutr* **60,** 828–837, 2006. https://doi.org/10.1038/sj.ejcn.1602387.

[11] LIPINSKI, Brian. HANSON, Craig. LOMAX James. KITINOJA, Lisa. WAITE Richard. Reducing food loss and waste. World Resources Institute Working Paper, 2013.

[12] FAO, IFAD, UNICEF, WFP and WHO. The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security. Rome, 2017. FAO.

[13] FAO. The state of food insecurity in the world. Rome, Italy. 2009, Economic and Social Development Department Food and Agriculture Organization of the United Nations.

[14] D'OSTUNI, Michele. TROMBADORE, Antonella. *Cities shaped by food - A new architectonic avant-guard*, in UrbanFarm 2019 - Book Finale challenge, Bologna 2019 - UniBo pp. 60-61.

[15] ORSINI, Francesco. PENNISI, Giuseppina. MICHELON, Nicola. MINELLI, Alberto. BAZZOCCHI, Giovanni. SANYÉ-MENGUAL, Esther. GIANQUINTO, Giorgio. Features and Functions of Multifunctional Urban Agriculture in the Global North: A Review. 2020, Frontiers in Sustainable Food Systems. 4. 562513. 10.3389/fsufs.2020.562513.

[16] PARTALIDOU, Maria, ANTHOPOULOU, Theodosia. Urban allotment gardens during precarious times: from motives to lived experiences. 2017, Sociol. Rural. 57, 211–228. doi: 10.1111/soru.12117.

[17] ZAFFI, Leonardo. D'OSTUNI, Michele. Metabolic cities of the future. Between Agriculture and Architecture, *AGATHÓN | International Journal of Architecture, Art and Design*, 8(online). 2020, pp. 82-93. doi: 10.19229/2464-9309/882020.

[18] SMIT, Jac. NASR, Joe. RATTA, Annu. Urban agriculture: Food, jobs and sustainable cities. New York: UNDP, 1996.

[19] MOUGEOT, Luc J.A. Urban agriculture: Definition, presence, potentials and risks, and policy challenges. Cities Feeding People Series Report 31, Ottawa: International Development Research Centre, 2000.

[20] TUIJL, Erwin. HOSPERS, Gert-Jan. VAN DEN BERG, Leo. Opportunities and Challenges of Urban Agriculture for Sustainable City Development. 2018, *European Spatial Research and Policy.* 25. 5-22. 10.18778/1231-1952.25.2.01.

[21] NADAL FUENTES, Ana. Urban Agriculture in the Framework of Sustainable Urbanism. *Temes de Disseny*, [online], 2015, Num. 31, pp. 92-103, https://www.raco.cat/index.php/Temes/article/view/299595.

[22] ORSINI, Francesco. KAHANE, Remi. NONO-WOMDIM, Remi. GIANQUINTO, Giorgio. *Urban agriculture in the developing world: a review*. Agronomy for Sustainable Development, Springer Verlag/EDP Sci- ences/INRA, 2013, 33 (4), pp.695-720.

[23] SPECHT, Kathrin. SIEBERT, Rosemarie. OPITZ, Ina. FREISINGER, Ulf. SAWICKA, Magdalena. WERNER, Armin. THOMAIER, Susanne. HENCKEL, Dietrich. WALK, Heike. DIERICH, Axel. Urban agriculture of the future: An overview of sustainability aspects of food production in and on buildings. 2014, Agriculture and Human Values. 31. 10.1007/s10460-013-9448-4.

[24] THOMAIER, Susanne. SPECHT, Kathrin. HENCKEL, Dietrich. DIERICH, Axel. SIEBERT, Rosemarie. FREISINGER, Ulf. SAWICKA, Magdalena. (2014). Farming in and on urban buildings: Present practice and specific novelties of Zero-Acreage Farming (ZFarming). Renewable Agriculture and Food Systems. 30. 1-12. 10.1017/S1742170514000143.

[25] PURI, Viraj. and CAPLOW, Ted. How to grow food in the 100% renewable city: Building-integrated agriculture. In P. DROEGE (ed.). *100% Renewable: Energy Autonomy in Action*. Earthscan, London, UK. 2009, p. 229–241.

[26] ORSINI Francesco. Bringing interdisciplinary knowledge for sustainable urban landscapes: results from the international student competition UrbanFarm2019 - Bangokok 2019, Acta Horticulturae.

[27] WEF World Economic Forum Circular. *Economy in Cities Evolving the model for a sustainable urban future white paper.* Published: 8 March 2018.

[28] Ellen MacArthur Foundation, 2015. *Towards a Circular Economy: Business Rationale for an Accelerated Transition*.

[29] European Commission, EIP-AGRI Focus Group on Circular horticulture: *Final report*, 2019.

[30] Ellen MacArthur Foundation. *Cities and circular economy for food,* 2019.

[31] GRAAMANS, Luuk. BAEZA, Esteban, VAN DEN DOBBELSTEEN, Andy. TSAFARAS, Ilias. STANGHELLINI, Cecilia. Plant factories versus greenhouses: Comparison of resource use efficiency, Agricultural Systems, Volume 160, 2018, Pages 31-43, https://doi.org/10.1016/j.agsy.2017.11.003.

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