Building natural resource networks: urban agriculture and the circular economy

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1 Introduction

The year 2007 represented a landmark in history of humankind, witnessing for the very first time the urban population outmatching the rural population (World Bank, 2018). Never before had cities hosted more humans than rural regions. This unprecedented trend has brought humanity into a new landscape characterised by a critical relationship between urban and rural areas, their inhabitants, and natural resources (Woods, 2009; Wiskerke and Viljoen, 2012; Lopez-Goyburu and García-Montero, 2018). In this chapter I argue that the process leading to this new landscape is inherently connected with how growth and development have been conceptualised and implemented in socio-economic and political agendas during the last few decades. These agendas have been dominated by the principles of the so-called linear industrial economy (Pascucci and Duncan, 2017; Stahel, 2019).

In a linear economy cities and urban regions are centres of agglomeration, the 'space' in which resources are distributed, accumulated, used, and eventually disposed in order to satisfy the demand of a growing population (Masuda and

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Garvin, 2008). In this type of 'take-make-dispose' economy, capital, land, labour, energy, water, and waste, are all key resources contributing to the growth of urban regions, often at the expense of rural areas (Wiskerke, 2015; Ellen MacArthur Foundation, 2019). This perspective is particularly relevant if we focus on the food landscape in a linear economy. Food provisioning is organised such that resources are first extracted and used to make food products, and then used and disposed, thus contributing to design food networks that do not ensure urban self-sufficiency or resilience (Pascucci and Duncan, 2017; Ellen MacArthur Foundation, 2019). In a linear approach to designing food provisioning, cities become dependent on activities located in rural areas, while forms of agriculture and food production are substantially 'ejected' from the core of metropolitan areas (Marsden and Sonnino, 2012; Lopez-Goyburu and García-Montero, 2018).

Together with the increased dependencies on inputs from agricultural and rural areas, cities have also become 'food deserts', where finding fresh or locally-produced food is challenging if not impossible (Crush and Battersby, 2016; Opitz et al., 2016). Large retailing networks and restaurants are the main (and often only) food providers in cities. Interactions between food producers (e.g. farmers) and final consumers become limited if not completely absent, and more and more mediated by large corporate retailers (Opitz et al., 2016). This increasing degree of separation between 'places of production' (i.e. rural areas) and 'places of consumption' (i.e. urban areas) is affecting the way food provisioning is handled, including food waste management (Seto and Ramankutty, 2016). Cities contribute to the production of a huge amount of food and organic waste that no longer goes back into biological cycles, for example to feed livestock or to be used as fertilisers for farming activities (Wiskerke, 2015; Ellen MacArthur Foundation, 2019). Instead, these flows of urban organic and food waste become a costly waste disposal problem, contributing to the deterioration of precious natural resources and planetary sinks, as well as polluting air, soil and water (Ellen MacArthur Foundation, 2019). Moreover, food products have become part of a plastics and metals economy since, in the processing and distribution stage, packaging has to be added to store, preserve and/or transport food products.

Industrialised food systems have also become increasingly energy intensive. At the agricultural production stage, increased use of fertilisers, machinery and groundwater pumping have increased dependency on energy from fossil fuels (Ringler et al., 2013). Post-harvest processing, storage and transportation are all very energy-intensive processes. At the consumption stage the shift to more processed food products purchased in supermarkets, as well as the increase of globally traded food products, also contribute to resource and energy-intensive food systems.

Overall, cities operate as dysfunctional ecosystems and networks of natural resources. It is not surprising then to find cities around the world at the core of

the global socio-ecological crisis. In my view this crisis is inherently connected to the linear industrial economy. Its origins lie partly in the increasing disequilibrium between urban and rural areas and their 'metabolisms'. In the pre-industrialization era cities and countryside were connected through flows of natural resources that could be virtuously exchanged through various networks. However, during the different stages of industrialization, this connection has been progressively disrupted and eroded (Seto and Ramankutty, 2016; Lopez-Goyburu and García-Montero, 2018; Stahel, 2019). In my view, the disruption of these flows and networks, and the disappearance of agricultural activities from urban areas, is part of this process. It is the outcome of an industrial economy designed to separate places of production from places of consumption (and waste production) (Wiskerke, 2009; Wiskerke and Viljoen, 2012).

Given this background, a few issues seem to be worth exploring: how can we design regenerative urban metabolisms overcoming the detrimental outcomes of the industrial linear economy? How can agriculture and food provisioning regain space in the core of cities and urban regions? And ultimately, how can cities regain socio-ecological resilience through (re-)building of functional networks of natural resources?

I argue that urban agriculture and food provisioning define a 'novel space' to re-think socio-ecological functions for urban areas in an economy inspired by the principles of circular and regenerative practices. Food systems can be designed in urban areas in order to facilitate the emergence of networks of natural resources aligned with the regenerative cycles of a circular economy. In fact, although agriculture has substantially disappeared from the inner core of several urban regions, their rapid expansion has means the persistence of agricultural activities in the new 'peripheries'. The process of intensive urbanization has created new peri-urban areas in which agricultural activities can still survive and even thrive (Lopez-Goyburu and García-Montero, 2018). These areas are particularly interesting since they combine traits of urbanity with features of rurality (Heimlich and Brooks, 1989). In these areas, natural resources (e.g. water, carbon, critical nutrients like phosphorus or nitrogen) are still functionally connected through regenerative cycles (Ellen MacArthur Foundation, 2019). Farming activities are economically and socially still vital, offering the opportunity to build local networks of food and ecosystem-service provisioning, enhancing the self-sufficiency and resilience of the city (Gren and Andersson, 2018). Together with ecologically functional peri-urban areas, cities are also witnessing the emergence of food communities and social movements challenging the assumption of the 'take-make-dispose' food economy, and creating a new idea of a place-based food economy in the very core of urban areas. Peri-urban agriculture and food communities represent the frontier between a food desert, on the one hand and, on the other, a placed-based food economy founded on a still ecologically functioning (urban) territory.

However in order to preserve the functionalities of these areas and to re-build a healthier relationship between rural and urban areas, I argue that a new approach to re-design the current industrial economy, and the urban expansion and sprawl associated with it, needs to be put in place and to become the dominant sociopolitical agenda for all those involved. The roots of the crisis must to be identified in the way urban agriculture and food provisioning activities have been designed and implemented within in a linear economy. This is the first step I make in this chapter.

2 Rethinking urban agriculture and food provisioning beyond a linear economy

I propose to start rethinking urban agriculture and food provisioning by acknowledging the link between the socio-ecological crisis of urban areas and the linear design of industrial agri-food systems. These systems are typically organised in value chains in which resources are extracted, used/transformed and eventually disposed of. In such linearly designed system, natural resources are extracted, made into products (food, feed or fibre), used or consumed, and disposed of, often generating waste as in detrimental emissions and pollution (Braungart et al., 2007). While linearly-designed systems can be highly resource efficient, the drive to standardise and simplify leads to overreliance on a few productive varieties and an over-dependency on external inputs, including biological materials. The industrial linear approach also results in the creation of waste. This makes it a net contributor to the ecological challenges faced by the planet, including greenhouse-gas emissions and contribution to global warming, loss of diversity, depletion of vital nutrient cycles like phosphorus and nitrogen (Pascucci and Duncan, 2017). Industrialised agricultural systems are leading drivers of deforestation and forest degradation globally, a process that accounts for 17% of global carbon emissions. Furthermore, 19–29% of global greenhouse gas emissions are directly attributed to agriculture (Vermeulen et al., 2012).

The dominant logic in designing linear industrial agri-food system is to achieve economies of scale, through standardization and specialization, and by commodifying natural resources through food production. This approach leads to the separation between places of consumption and places of production, making urban areas places of consumption rather than production (Wiskerke, 2015). In fact, during the last few decades we have witnessed a rapid and intense urbanization (Crush and Battersby, 2016), in which agglomeration of consumption has led to the disconnection of urban and rural areas, and the disappearance of food production from the inner core of the cities (Woods, 2009). This has profoundly changed the relation between rural and urban areas and has completely reshaped the networks and cycles of natural resources, for

example of water, air, carbon, nitrogen phosphorus, among others, that have traditionally connected these places.

At the same time, while rapid and disruptive, the contemporary urbanization of rural areas has also defined new contexts: peri-urban areas in which urbanity and rurality co-exist. These areas have witnessed increased population growth, pressure on land use and profound socio-demographic transformations. However, in these areas a network of functioning farms is still operating, and food supply chains are still vital and active (Heimlich and Anderson, 2001). Peri-urban areas are, in my view, a new place to start re-thinking conditions to re-establish and enhance interconnections between urban and rural areas. These are areas where social innovations seem to take place and inspire the emergence of new socio-economic dynamics, in which the role of agricultural activities and relations between farmers and non-farmers, has assumed multi-faceted connotations (Libby and Sharp, 2003; Wiskerke, 2009). For example, in some areas the condition 'peri-urbanity' has become structurally dominant with respect to the 'extreme conditions' of urbanity and rurality, to the point that some authors have introduced the concept of a urban-rural agro-ecosystem or rural-urban bioregion (Lopez-Goyburu and García-Montero, 2018). All these authors highlight a novel structural interconnection between rural and urban areas which occurs through peri-urban territories (Council for Agricultural Science and Technology, 2002).

In per-urban areas elements of the rural system have been quickly embedded in, or mixed with, an emerging urban system. Examples include: green belts of farmland, in between buildings and industrial areas, which are still in place and offering agro-ecological services; farming activities preserving agricultural land use which offer open space for recreational purposes, clean water and air (Gren and Andersson, 2018); flourishing short supply chains and community-based agriculture, connecting producers and consumers in novel relationships (Jarosz, 2008; Aubry and Kebir, 2013). All these socio-ecological contexts define peri-urban areas, with agricultural activities located in these areas described as urban or peri-urban agriculture (Heimlich and Barnard, 1997; Council for Agricultural Science and Technology, 2002). There is a convergent view in identifying a 'continuum' between rural and urban areas rather than the traditional urban/rural dichotomy or divide (Sonnino, 2016). The interest in the emergence and stabilisation of periurban areas within processes of intense urbanization goes beyond considerations around rural-urban relations (Sharp and Smith, 2003).

These 'novel' socio-ecological spaces offer the opportunity to re-think how agricultural and food provisioning activities can be used to define patterns of sustainable development in an increasingly urbanised world. Although the persistence of a vital agriculture and rural community can contribute to mitigating the disruptive impact of urbanization on socio-ecological processes,

there is mounting evidence that urban and peri-urban agriculture risk following existing processes of further resource-use intensification, potentially exacerbating rather than mitigating socio-ecological tensions in the cities (Gren and Andersson, 2018). In fact, urban and peri-urban agriculture can be shaped by the same principles and practices of the industrialised agriculture taking place in rural areas. The presence of agriculture and food provisioning in the peri-urban landscape does not guarantee, per se, an increase of cities' resilience, food security, health and sustainability Lang, 2003; Stuckler and Nestle, 2012; Booth and Coveney, 2015). Most likely, it might be the opposite.

So, how do we re-design urban agri-food systems without a negative impact on health and ecosystems? How do we re-establish functional and regenerative networks of natural resources between rural areas and cities? What can be the role of peri-urban areas in this process?

I propose to address these questions by looking into solutions that can be found in the cyclical metabolisms proposed by the circular economy (Ellen McArthur Foundation, 2019). In what follows I first introduce the guiding principles of the circular economy, then discuss how these principles can help in re-imagining industrialised agri-food systems and, finally, how they can be used to contribute to build regenerative networks of natural resources between rural and urban areas, highlighting the role of 'peri-urbanity' in this process.

3 Designing regenerative urban agri-food systems through a circular economy approach

A circular economy approach seeks to tackle the limitations of linearly designed systems. In circular food systems the aim is to counter the 'taken, used and disposed of' tradition of industrialised food production, by designing approaches where natural resources can be used, reused and/or safely returned back to the ecosystem (Oliver et al., 2015). Circular food systems can be designed following the logic of closing nutrient loops and fostering regenerative approaches as well as enhancing sharing and optimising use of resources (Kalmykova et al., 2012). Moreover, following agro-ecological practices in circular food systems, social and ecological diversity is preferred to simplification and specialization (Ellen MacArthur Foundation, 2015, 2019). Often this approach draws on, and fits within, localised systems and mimics natural systems (Ellen MacArthur Foundation, 2013; Ghisellini et al., 2016).

Closing loops and using regenerative approaches is perhaps the most known principle of circular economy design. By following this principle, production, distribution and consumption processes are designed around the use of renewable energy and materials based on working with ecosystems. The aim is to design processes capable of returning biological nutrients safely back into natural cycles (Ellen MacArthur Foundation, 2015). In this way a regenerative

food system is able to produce and distribute food by minimising reliance on fossil fuels. Following this principle, food systems need to be designed eco-effectively; that is, in such a way that the use of hazardous and toxic materials is eliminated. In this way, products promote a positive synergistic relationship between ecological and social systems, on the one hand, and economic growth, on the other (Tukker, 2013; van Weelden et al., 2016; Smol et al., 2015).

One of the main challenges facing linear food systems is the use of key elements, such as phosphorus, nitrogen and water, as non-renewable resources. Regenerative food system use resources renewably since the design includes strategies to recover nutrients such as phosphorus, nitrogen or water, or include agricultural practices that avoid the use of synthetic chemicals, as in the case of organic agriculture and permaculture. Closing cycles in urban and peri-urban areas is part of this approach, which can also lead to reconnecting these areas with agricultural activities practiced in rural area too. For example, one strategy is to recover nutrients after feed or food consumption in the city, by extracting phosphorus, nitrogen and water from urine and sewage, and use these nutrients as fertilisers in food production (Kalmykova et al., 2012; Wiskerke, 2015).

Closing loops means addressing the re-utilization of materials. Inspired by industrial ecology, food products in a circular economy are designed to be used and consumed in a way that means their biological and non-biological components (i.e. packaging) are not mixed. Avoiding the mix of biological and technical materials means designing food products, and managing materials during the process, in ways that facilitate easy separation and re-use. Issues related to how residual outputs (i.e. packaging or wastewater) will be used by another actor/participant in the cycle after usage/consumption are incorporated in the design of the product. In a circular economy (CE) it is not only products that are being designed, but also 'streams' of nutrients, including the social and technical infrastructures for recycling and upcycling waste (Pascucci and Duncan, 2017). In practice, this means that the design of a food product will include the use of biodegradable or compostable packaging, or any packaging, which can be upcycled as a technical nutrient in a given metabolism (e.g., paper, glass, plastics). Key to the design process is avoiding the use of materials that mix biological and non-biological nutrients. This results in a waste product that cannot easily be returned to the system (Braungart and McDonough, 2002).

Strategies to close loops also place emphasis on trying to produce more renewable energy as needed by the specific production unit and to share it. In this way a CE aims to inspire transition towards a post-carbon/post-fossil-fuelled society, and it demands a re-think of the way we associate energy production and consumption to food. In this respect, a regeneratively-designed food system uses renewable energy, from farming to food consumption. It therefore

inspires a re-think of the type of energy used in food production and distribution processes (Ellen MacArthur Foundation, 2019). In fulfilling renewable energy principles, farmers, food processors, distributors and consumers can become part of a functional network of energy production and sharing. This can contribute to urban planning and policy which aims to create and adopt new technologies, and to source renewable energy locally.

Another principle in a CE design thinking is sharing and optimizing. This principle relates to the idea that there is a tension to be tackled between streamlining and seeking efficiency, and collaborating, networking and sharing key resources. For instance, in linearly designed food systems this tension is reflected in a trade-off between resource efficiency and resilience (Pascucci and Duncan, 2017). While resilience calls for an interconnection and diversification of food systems, such that perturbations can be absorbed by and dealt with by the different components (actors) of the system, efficiency is oriented to streamline production processes and celebrate standardization in isolation. Diversified systems prove to be more resilient and adaptive, but are not always efficient in the short run. Vice versa, highly specialised systems may gain efficiency in terms of resource use in the short run. However, because they rely on resource-intensive and standardised, processes which make them over-dependent on external inputs, they lose adaptability to change, thus being highly inefficient in the long-run.

A food system designed around sharing resources aims at reconciling efficiency and resilience through adaptive optimization processes. This requires a system-thinking approach and flexibility in terms of technology, practices and capabilities used. At farm level, sharing and optimizing stimulate the adoption of technology towards, for example, a more selective use of fertilisers and water (e.g. precision farming), to adopt a crop rotation, reduce the tillage (or eliminate it), and adopt permaculture and/or agro-ecological practices. Sharing and optimizing along the supply-chain also aims at prolonging the life span of key materials, for example, re-using and upcycling packaging. At the distribution level, it also deals with eliminating food waste, for example by improving the use of big data and IT-based platforms to better organise operations and inventories in the retailing space (e.g. optimizing the storage capacities of retailers). Optimisation also involves reducing the use of materials and energy for packaging as a resource-intense component of current food systems. The design and implementation of alternative systems to deliver food products to consumers, as well as inputs along the food supply chains, for example through the enhanced use of virtual and IT-based platforms, can be seen as a way of combining the idea of optimising and sharing. Virtual and online value chains and communities and platforms are currently the leading practices moving us towards the combination of new technologies and dematerialised delivery systems (Pascucci and Duncan,

2017). Technologies such as precision agriculture, IT and big data are technologies capable of supporting resource efficiency and recovery in food production processes (Ellen MacArthur Foundation and McKinsey Center for Business and Environment, 2015). This is potentially changing the landscape of both urban food production. For example, vertical farming, based on precision agriculture practices combined with industrial symbiosis, seems to be a promising endeavour to place food production back in to the core of cities and urban areas.

In more general terms, the CE applied to urban agriculture and food provisioning can be seen as an emerging community of practitioners and scholars all engaged at various levels in changing and transforming current linear industrial systems. It often navigates in between practices that are neglected or separated in linear industrialised food systems. For example, it combines IT solutions with agro-ecological practice to regenerate soil and protect soil health. Celebrating various forms of diversity is the common ground of this emerging approach. In fact, rather than promoting a food system, or a type of urban agriculture, the CE invites us to design multiple and diverse systems and networks. A CE approach is not just about a more integrated way to deal with (food) waste or resource recovery, but inviting actors involved in the food system to think about local communities, food cultures, social justice, as well as collaboratively design rules and decision-making mechanisms to govern food systems. To a certain extent, the call to celebrate social and ecological diversity is meant to encourage people to (re-)think how to foster collaboration and democratise food systems in the city as well as in the countryside.

4 Strategies for building natural resource networks in circular urban agriculture

Several approaches have already been proposed and/or implemented to stimulate the transition to a CE in urban contexts (Circle Economy, 2016; Ellen MacArthur Foundation, 2019). These approaches can be seen as revolving around three key lines of action:

- closing loops in bio-based systems, particularly focusing on streams of organic waste, including food waste.
- encouraging the emergence and diffusion of 'food communities' in the cities in order to reconnect places of production and places of consumption and, therefore, to trigger a different relationship between food producers and consumers.
- by fostering creativity and innovation when designing new food products and processes, thus creating new food landscapes in cities. These innovative processes enable the implementation of circular solutions

in organic waste streams, allowing novel bio-waste-based products to replace plastics and other materials.

All these strategies entail different engagement with networks of natural resources, as well as reliance on diverse socio-ecological and technological relations. While solutions to close loops and tackle the problem of re-using organic waste streams are mostly addressing 'end of the pipe' problems using technology-driven solutions, community-based and innovative strategies relate more directly with social innovations. In the latter case, there is an intention of 'localising' urban food provisioning, on one hand, and, on the other, extending food production and process design to collectives and groups of consumers to enhance access to food in urban areas. In what follows, we present and discuss these three approaches and their implications in terms of building networks of natural resources.

4.1 Building natural resource networks in bio-based metabolisms

Arguably the most widespread approach to foster the transition to circular urban agriculture and food systems is related to re-using and recycling organic waste streams. Organic waste presents the potential for being easily re-used as well as having the greatest impacts on raw material substitution (Ellen MacArthur Foundation, 2019). This approach is based on an extension of the principles of industrial ecology to how streams and flows of resources are managed in cities. In this approach, urban areas become networks of resources embedded in close-loop systems. The central resource in these networks is often food or organic waste (Ellen MacArthur Foundation, 2019). For example food waste streams can be used to produce bio-composted products that can safely return into agricultural bio-cycles as fertilisers. In this way, industrial symbioses are created by connecting urban and rural areas through the establishment of new networks of natural resources. These loops can be closed locally to support agricultural activity in the peri-urban areas.

It is not surprising to observe that several projects have developed ways to close loops of nutrients in relation to food waste related to urban and peri-urban farming. The European Union has supported many of these projects in order to tackle food waste through circular solutions.[1] For instance, according to Circle Economy, a social enterprise and think tank based in Amsterdam, closing loops of organic and food waste is an absolute priority to accelerate circular transitions in urban regions and to enhance cities' sustainability and resilience (Circle Economy, 2016). In the 'Cities and Circular Economy for Food' report the Ellen MacArthur Foundation (2019) has indicated the need to improve

1 http://ec.europa.eu/environment/circular-economy/index_en.htm

cities' capacity to manage food waste streams as one of the priorities in the CE agenda worldwide.[2] Several practices related to interconnecting closing loops of nutrients with valorisation of food waste are presented in this report, showing how this issue has become central in the circular agenda of many cities and regional authorities worldwide (Ellen MacArthur Foundation, 2019).

Sometimes the valorisation of food and organic waste streams through closed loops is achieved by the development of agro-industrial parks in urban and peri-urban areas. Agri-industrial parks are inspired by industrial symbiosis principles by which networks of resources, including waste, water and energy, are embedded in industrial clusters with a well-defined physical location. Agro-industrial parks have been implemented for closing material loops particularly to produce bio-based materials (e.g. bio-plastics) and energy (Nuhoff-Isakhanyan et al., 2017). These parks are set-up and managed in order to create an integrated system in which ties between companies are created based on shared materials (i.e. waste industrial streams), water and energy (Zwier et al., 2015). Composters and anaerobic digesters are often the key technologies underpinning the cluster. These agro-industrial clusters have emerged particularly in Europe and North America, and lately spread out all over the world, particularly in emerging economies such as China, Brazil and India, and more recently in Africa (Nuhoff-Isakhanyan et al., 2017). Recently this approach is finding novel applications, for example by varying the scale of the 'metabolism' and by allowing the actors operating in the symbiosis to be located in different regions. An interesting approach in this sense is offered by a public-private partnership project called AgroCycle. This is a Horizon 2020 research and innovation project addressing the recycling and valorisation of waste from the agri-food sector.[3] The project takes a holistic approach to understanding and addressing how to make best use of the full range of waste streams associated with the agri-food industry, including: bio-fuels, high value-added biopolymers, energy and microbial fuel cells.

4.2 Building natural resource networks through local communities for food provisioning

A second typology of networks of natural resources established in urban circular food systems refers to strategies practiced by collectives, associations of consumers, NGOs, social enterprises, charities and public-private partnerships. All these initiatives are based on the idea to use social innovations and to build or engage with local communities to address issues related to food waste management in the cities. Sometimes food waste is associated and

2 https://www.ellenmacarthurfoundation.org/assets/downloads/Cities-and-Circular-Economy-for-Food_280119.pdf
3 http://www.agrocycle.eu/#project

coupled with issues of food security and health, particularly to ensure access to healthy food products for a wider set of urban citizens. An emblematic example in this area is Zero Waste Europe. This is among the largest network organisation that connects and supports a vibrant network of 29 national and local NGOs promoting the so-called 'Zero Waste' strategy as a way to make Europe more sustainable. Local groups are responsible for promoting the strategy, managing and monitoring the network of Zero Waste municipalities, and engaging with companies and decision-makers.[4] The Waste and Resources Action Programme (WRAP) in the UK provides another example of how CE has been directly applied to find solutions to food waste issues in urban contexts.[5] Several initiatives on regenerative agriculture are rapidly emerging at the interface of the agribusiness corporate domain and social enterprises and grassroots movements. For example, 'FoodTank' is a non-profit organization which actively connects projects and initiatives around regenerative agriculture and sustainable food production systems, promoting actions to reduce food waste and recovery materials along the food supply-chain.[6]

Some of these initiatives are connecting with existing food communities and collectives already operating in urban and peri-urban areas with the attempt to shorten food supply chains and to develop alternative food networks (Jarosz, 2008; Goodman et al., 2012; Pascucci et al., 2016). What seems to be emerging is a landscape of communities operating at local level to identify joint solutions to key problems of linear food systems, such as access to affordable and healthy food products on one hand, and valorise waste streams and support regenerative agricultural practices, on the other hand. This is also creating an opportunity to reconnect places of production with places of productions through novel networks of natural resources embedded in local communities. The UK-based GrowUP start-up,[7] for example, combines principles of closing loops with community engagement in order to foster social innovation, particularly when it comes to food and water waste, access to nutritious food products and application of technology solutions to food production in urban contexts. Imperfect is an US-based start-up that collects fruit and vegetables from farmers when they are non-selected by buyers due their appearance and cosmetics.[8] This produce is delivered to customers through a veggie-box scheme, instead of ending up in a landfill. Similar projects can be found in several cities and have assumed various forms, from projects run by food banks to campaigns against food waste. EndFoodWaste.org, for example, is

4 https://zerowasteeurope.eu/
5 http://www.wrap.org.uk/
6 https://foodtank.com/
7 http://growup.org.uk
8 https://www.imperfectproduce.com/

the website of a social movement which was born around the Ugly Fruit and Veg campaign.[9]

4.3 Building natural resource networks in innovative food designs

Another set of approaches and practices deals with creative and explicitly design-oriented actions to transition into an urban circular food economy. Although they are very different in terms of scope, type of principles used, and stage of the food system they operate, these practices all share similar features such as: fostering technical, product and process innovation; introducing social and environmental goals through new business models; stimulating creativity and new forms of engagement between and among actors of the food system, for example through the creation of innovation ecosystems (Pascucci and Duncan, 2017). In this space many small and medium food enterprises, micro-enterprises and start-ups have been experimenting with using alternative sources of nutrients or by investing in bio-based technologies to enable more efficient energy-recovery from biological waste streams.

As an example, during the last decade a network of new businesses has born around the idea of using food waste as feed for insects which eventually are used to produce feed for animals and proteins. The International Platform of Insects for Food and Feed (IPIFF) is an EU non-profit organisation, which represents the interests of the insect production sector.[10] Originally created in 2012, the association is today composed of 50 members. Most IPIFF members are European small and medium size enterprises who produce insects for the European market[20]. The association also welcomes insect producing companies located outside Europe, research institutes and other actors along the food supply-chain. Other examples in this sector include Agriprotein,[11] Ynsect,[12] and Protix BV.[13] The use of insects is potentially impacting not only the way food waste is managed and recycled, but effectively offering a way to upcycle it by creating large scale protein production. Although the introduction of proteins from insects in western diets has proven problematic, its application to feedstock, and particularly to aquaculture and poultry, seems successful and potentially disruptive for these sectors.

Another area of very intense experimentation is around novel food ingredients based on re-engineering, re-use and upcycling of biological waste streams. Planetarians, for instance, is using defatted seeds and solid food waste streams to produce high-protein and fibre ingredients.[14] At the same

9 http://www.endfoodwaste.org/ugly-fruit---veg.html
10 http://ipiff.org/about-ipiff/
11 https://agriprotein.com/
12 http://www.ynsect.com/en/
13 https://protix.eu/
14 https://www.planetarians.com/

time companies are testing technologies to turn organic waste streams from large scale agricultural production into new fibres and biomaterials. Pinetex is a successful example of upcycling waste streams from pineapple production (https://www.ananas-anam.com/). Ricehouse uses rice production waste streams and designs and engineers novel biomaterials for the construction sector.[15] In general both the textile and building industries are becoming areas in which businesses are developing novel approaches to upcycle waste streams from agricultural production or food waste.

Initiatives revolving around the concept of vertical farming are another example of projects oriented to design new food systems by using innovation and technological development to create closed loops of materials and energy. Vertical farming is considered among the most promising technologies to tackle food provisioning and security for urban areas. A well-known example of this type of approach is offered by the Philips–City farming solutions project.[16] The Association for Vertical Varming (AVF) openly endorses CE and closed loop thinking as a key strategy to develop the sector in the future.[17] The US company 'AeroFarms' has been highlighted as having one of the most disruptive vertical farming business models in food production, and is inspired by close-loop thinking.[18] As these examples show, the number of innovative projects claiming to use principles of circularity to design novel food products, processes and systems is growing and reshaping the urban food landscape quite substantially.

5 Key bottlenecks to transition into circular urban agriculture and food provisioning

There is evidence that cities struggle to implement a full transition to circular systems. There are least three overarching types of bottlenecks hindering systemic implementation of a CE in urban and peri-urban areas, which affect urban agriculture and food provisioning systems. These bottlenecks can be identified as (Borrello et al., 2016):

1. institutional barriers (e.g. lack of definition of property rights relating to materials within biological flows)
2. governance issues in managing bio-based systems (e.g. tensions between competitive, collaborative, public or private approaches)
3. behavioural barriers (e.g. users' perception of waste as resource, lack of participation in recycling scheme, weak incentives to re-use bio-based materials)

15 https://www.ricehouse.it/eng-home
16 http://www.lighting.philips.com/main/products/horticulture/press-releases/Philips-commercializing-city-farming-solutions-based-on-LED-light-recipes.html
17 https://vertical-farming.net/
18 https://aerofarms.com

These bottlenecks are common in all three types of networks presented in the previous section. Together they represent a key limitation to further transition to circular urban economies that include urban agriculture and food provisioning (Pascucci and Duncan, 2017).

Institutional barriers are particularly relevant in relation to the definition of property rights in networks of resources established in closed loops. Property rights relating to food waste and organic waste in general follow the principles of the linear economy. While food products are produced and exchanged through a principle of private ownership, thus following a chain of transactions from producers to consumers, food and organic waste often remains in grey area between ownership by consumers and public authorities. The question is: who has the ownership of food and organic waste and who is in charge (and is liable) to manage it? In order to enhance closing loops strategies, definition of property rights relating to food and organic waste is the key. Defining ownership of these resources is essential for individuals and organisations engaging in work to close loops work to upcycle nutrients and optimise at maximum value (Ellen MacArthur Foundation and McKinsey Center for Business and Environment, 2015).

Strictly related to the problem of gaps in the institutional setting of waste management, there is evidence of bottlenecks to transition due to lack or gaps in the governance of circular bio-based systems. In fact, if property rights are not well-defined, both in relation to the food or the organic waste streams and the nutrients extracted and used in bio-based metabolisms, it is also challenging to devise governance mechanisms. There is a tension between treating food products and processes as a private good while food waste and nutrients extracted in circular bio-based metabolisms are often seen as semi-public or common goods. I have presented examples in which public authorities are often the initiators of agri-parks, urban food communities or closed loops projects. However private actors, NGOs, social entrepreneurs are often co-founders and/or managers of the project. While this would often call for a public-private partnership approach, in practice it is challenging to define and maintain this governance arrangements without clear goals, incentives and definition of responsibilities. Often initiatives promoting circular solutions remain limited to the timespan of the public funding and experience challenges if arranged in partnership with private investors and donors.

Besides institutional and governance barriers, the development of circular solutions in urban agriculture and food provisioning face the challenge of behavioural issues. These issues often relate to the final users or consumers and their engagement in the project. As an example, stimulating and incentivizing practices to upcycle food waste in urban areas has proven difficult (Borrello et al., 2017). The engagement of consumers in local food communities has grown during the last decade. However, it is still confined to particular groups.

The convergence of food communities and circular practices is still at its infancy, with promising results but limited evidence. Small-scale projects have tried so far to combine IT-based solutions with wider participation of consumers to close loops of nutrients, particularly engaging with food waste. Whether they can be scaled out or up is difficult to say. Finally, retailers have been largely reluctant to be involved in circular economy-inspired projects where food products, food waste and recycling are concerned. Since food retailers are a very influential player in urban food systems, particularly when consumer behaviours are concerned, their engagement can be a potential game changer in the transition. However, with few exceptions, circular solutions have generally been designed and implemented without engaging systematically with retailers or with final consumers (Borrello et al., 2017).

6 Conclusions

In this chapter I have presented and discussed ideas and cases to argue that urban agriculture and food provisioning define a 'novel space' to re-think socio-ecological functions for urban areas in an economy inspired by the principles of circular and regenerative practices. Circular food systems can emerge in urban areas based on new or re-established networks of natural resources aligned with the regenerative cycles of a CE. Urban and peri-urban areas can become again 'places of food production' and contribute to sustainability and resilience through revitalising use and re-use of natural resources (e.g. water, carbon, critical nutrients like phosphorus or nitrogen), situated in functionally connected and regeneratively designed food production and consumption cycles (Ellen MacArthur Foundation, 2019). Through these approaches, farming activities in the urban and peri-urban areas can still be economically and socially vital, offering the opportunity to build local networks of food and ecosystem-service provisioning, enhancing self-sufficiency of the city (Gren and Andersson, 2018). Moreover we have seen how circular food systems in cities can be coupled with the emergence of food communities and social movements challenging the assumption of the 'take-make-dispose' food economy, and creating a new idea of a place-based food economy in the very core of urban areas. From this perspective, urban agriculture and food communities represent an opportunity to define new placed-based food economies, communities and systems. In this process the engagement of food producers and consumers with new or re-established networks of natural resources has proven to be a key element for a successful transition from linear to circular urban agriculture and food provisioning.

However, we have also discussed current challenges and bottlenecks that require further attention by scholars and practitioners. In fact designing circular food systems, communities and systems requires tackling structural and

fundamental questions in society such as the nature of food provisioning and therefore food security, the definition of property rights of resources connected to food provisioning and security, the governance mechanisms that actors may need to use in circular food provisioning and their behavioural responses. All these challenges suggest the definition of an exciting research and practice-oriented agenda.

7 References

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