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Urban Agriculture 5.0: An Exploratory Approach to the Food System in a Super Smart Society

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Abstract
Society 5.0 aims to promote quality of life and well-being of citizens, reducing inequalities and promoting sustainability with the support of technologies 4.0. Therefore, redesigning value chains to bring social, economic, and environmental gains becomes of particular interest in alignment with a new model of a people-centric super-smart society. This paper aimed to outline a conceptual design of urban agriculture (UA) 5.0 by applying a three-phase methodology supported by data triangulation. A relationship between Industry 4.0, food system, and sustainable society was identified, encompassing many points of convergence between UA and Industry 4.0 (35) as well as Society 5.0 (43). As a result, this paper proposed UA 5.0 as a multifaceted concept that brings a new paradigm for systemic agriculture integrated in cities, considering six key dimensions for its development (spatial, social, technological, economic, sustainability, and systems integration). This exploratory study contributes to in-depth discussions, and new strategies among policy makers for building a more resilient urban food system as an embedded solution in smart cities. The results discussed also outline a basis for developing super smart food system industries by exploring each of the dimensions proposed in this paper.

Keywords- Food systems, Smart city, Urban agriculture, Industry 4.0, Society 5.0.

1. Introduction

The world population is estimated to reach 9.7 billion people by 2050, impacting directly on urban growth, as cities are expected to absorb much of this population increase. Moreover, this outlook implies challenges, especially in building sustainable, resilient, and inclusive cities (United Nations, Department of Economic and Social Affairs, Population Division [UN DESA], 2019). In fact, population growth in urban centers, which tends to get worse and worse, raises a number of concerns about long-term sustainability, as it implies increasing demands for essential resources such as food, energy, and drinking water. Greater urban densification is also associated with increased air pollution, soil degradation, water contamination, and loss of natural environments in urban centers (de Amorim et al., 2019; Grêt-Regamey et al., 2020; Kim et al., 2018).

On the other hand, cities are economic centers and favorable systems for technological development, given the greater availability of infrastructure, resources and qualified human capital (Ribeiro et al., 2018).

Therefore, digitalization and technological innovation find a supportive environment for research and development of solutions for a wide range of sectors, transforming urban areas into more resilient and self-sufficient territories (de Amorim et al., 2019).

Food distribution systems in urban areas are highly dependent on products from outside their borders, not only on a regional, but also on a national and even international scale (Maye, 2019a). This dependence on external actors is shown as a threat to the resilience of urban centers, as it also puts at risk the food security of their populations especially in emerging countries (Filippini et al., 2019).

The transition of cities to a new smart model must integrate the dimensions of governance, environment, technology, economy and society, developing an innovation ecosystem with impact on urban infrastructure and services (Camboim et al., 2019). Traditional agriculture will also have to be reinvented and rely on new technologies and production methods to achieve the productivity and sustainability needed to ensure food security without worsening the environmental impacts resulting from the increase in intensive plantation areas. Accordingly, the application of technological innovations to this sector has the potential to ensure the economic and environmental sustainability of production, increasing productivity and food quality (Reed & Keech, 2019).

One redesign possibility refers to food production and its value chains. The implementation of Urban Agriculture (UA) infrastructure could, for example, bring significant benefits to quality of life and human health through access to healthier food and the provision of other social and environmental services (Riolo, 2019). These services range from mitigating the effects of greenhouse gas emissions to strengthening relationships within urban communities (Coelho et al., 2018). Actually, UA can be seen as a solution incorporated directly into smart cities, having the potential to become a primary source of food production (Weidner et al., 2019).

Different components of urban food systems relate to how food is produced, processed, distributed, and consumed in cities (Kasper et al., 2017; Weidner et al., 2019). These are complex systems, composed of several food production subsystems, ranging from large-scale industrially produced foods (whether imported or not) with heavy reliance on production in rural areas, to those produced locally or regionally through urban and peri-urban agriculture initiatives (Maye, 2019b).

The transition from the current model to a sustainable & resilient society can be enabled through the implementation of Industry 4.0 and digital technologies in association with an approach driven by the people-centric super-smart society philosophy. In this new model, the integration and digitalization of the systems that make up society will be responsible for the well-being of citizens, the economic and environmental sustainability, and the resilience of society as a whole. In addition, Sarker, Bornman, and Marinova (2019) state that a well-structured UA system plays a key role in the development of smarter and more functional cities, and promotes citizens' well-being and sustainability. Moreover, such systems have cultural and ecological contributions, which diversify the functionality of the urban fabric.

Literature discussions on Society 5.0 have only recently begun to develop outside Japan. Many of the papers consulted for this study show the application of Society 5.0 principles and digital technologies to food systems, but few are effectively targeted at the urban environment and furthermore many papers use a single approach, commonly discussing only one aspect of the food system such as the use of IoT in food production or the social and economic benefits of creating urban farms. Therefore, there is a gap in the literature about studies that apply a holistic approach to design and explore the concept of UA 5.0, systemically relating urban food systems, 4.0 technologies, and the principles of a people-centric super-smart society.

As a result, this paper aimed to conduct an exploratory study to provide a deeper comprehension of how the relationships between technology, sustainable & resilient society and urban food systems have been discussed, pointing out a conceptual delineation of perspectives and trends in modern agriculture based on a three-phase methodology that performed data triangulation.

2. Methodology

The working methodology sought to explore the structure of the problem, that is, to identify points of convergence between Industry 4.0, Society 5.0 and UA. The conceptual construction process encompassed three phases, being observation, categorization and association (Hevner & Chatterjee, 2010; Prasetyo & Arman, 2017; Valamede & Akkari, 2020). The observation stage followed with a search of the available scientific literature, conducted through a systematic literature review. The categorization stage organized the observations made previously from the reading and literature study, highlighting possible relationships between the attributes and the intended goals of the study (Hevner & Chatterjee, 2010).

Relations among the observed attributes were defined and evaluated using two-dimensional matrices (Wagner et al., 2017; Zhang & Muñoz Ramírez, 2019). The degree of correlation between pairs of components was identified by symbols: □ identifies a strong correlation, ◊ a medium correlation, and ○ a weak correlation. Defining the degree of relationship was essential to define which aspects should be treated as priorities in building future initiatives and decision-making processes.

The systematic literature review followed the recommendations of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Moher et al., 2009) as a general guideline (Buer et al., 2018; De Paula Ferreira et al., 2020; Samoggia et al., 2021). The searches were conducted on two topics: 1) relationships between Industry 4.0 technologies and UA practices, 2) the role of UA in a Super-smart Society.

Articles published between 2017 and 2020 and in English were considered, excluding books and book chapters, editorials, and introductory texts. 2017 was selected because it is the first recorded year of the term "Society 5.0," coined by the Japanese government (Shiroishi et al., 2018). The selected papers for the first main topic explored the relationship between urban and/or peri-urban agriculture and the digital technologies of Industry 4.0. For the second main topic, the studies related agriculture and its deployment in the urban territory, covering topics such as food security, urban resilience and integrative approaches between cities and food systems. Studies that address urban or peri-urban agriculture in a broad context of a system that promotes food security in urban centers along with traditional agriculture in rural areas were also included.

The searches were performed in three databases, being IEEE Xplore, Scopus and Web of Science using the advanced search tools. 17 search terms were defined, 9 for Axis 1 and 8 for Axis 2 (Table 1). A total of 3,931 articles were returned, of which 1,090 were duplicates.

The analysis of the results obtained was carried out in three stages: checking the titles, checking the abstracts, and reading the full text. After checking the titles, 1,557 papers were removed. Then, after reading the abstracts, 1,136 papers were also removed, leaving 148 papers for evaluation of the full text. Of this total, 35 were excluded for not dealing specifically with UA or technology implementation topics. At the end of the process, 113 articles were included in the systematic literature review (Figure 1).

Table 1. Search terms related to each axis considered.

	#	Search term
Axis 1	1	(("urban agriculture") AND ("smart food system" OR "smart food"))
	2	(("urban agriculture") AND ("industry 4.0" OR "4th industrial revolution" OR “fourth industrial revolution”))
	3	(("urban agriculture") AND ("internet of things" OR "internet of services" OR “big data” OR “cyber-physical systems”))
	4	(("urban agriculture") AND ("agriculture 4.0" OR "farm 4.0" OR “agriculture 5.0” OR “farm 5.0”))
	5	(("urban agriculture") AND ("smart agriculture”))
	6	(("urban agriculture") AND ("cyber-physical systems” OR "internet of things"))
	7	(("urban agriculture") AND (“digitization” OR “big data” OR “integrated system”))
	8	(("urban food" OR "food system*") AND ("cyber-physical systems” OR "internet of things"))
	9	(("urban food" OR "food system*") AND ("digitization" OR "big data" OR "integrated system"))
Axis 2	10	(("smart city" OR "smart society") AND ("food security" OR "food system"))
	11	((“Society 5.0”) AND (“food system” OR “food security” OR “food”))
	12	((“super smart society”) AND (“food system” OR “food security” OR “food”))
	13	(("smart city" OR "smart society") AND ("urban agriculture" OR "periurban agriculture"))
	14	(("smart city" OR "smart society") AND ("agriculture"))
	15	((“Society 5.0”) AND ("urban agriculture" OR "urban farm"))
	16	((“super smart society”) AND ("urban agriculture" OR "urban farm"))
	17	(("urban agriculture" OR "periurban agriculture") AND ("urban resilience" OR "system resilience"))

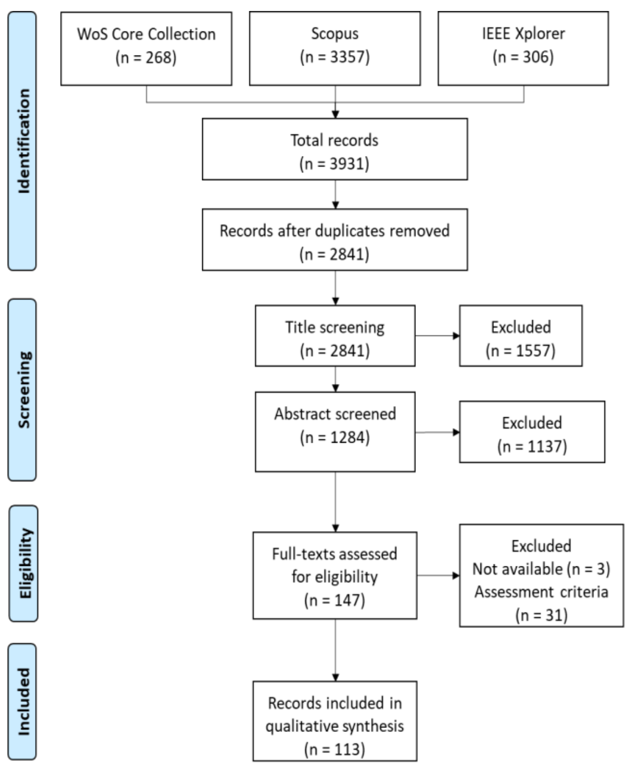

Figure 1. Flow diagram identifying the number of records identified according to the systematic literature review - PRISMA protocol.

A meta-analysis of the publications was performed, evaluating the recurrence of journals and congresses, the number of publications per year and the frequency of keywords through the construction of a word cloud. A second classification of the selected papers was made to simplify the process of evaluation and analysis of the results according to the existing relations between UA, Industry 4.0 and Society 5.0. Following this second categorization, a qualitative evaluation of the results was performed, applying the content analysis method to construct two-dimensional relationship matrices.

3. Results and Discussion

3.1 Observation and Categorization of the Literature

Following the international PRISMA protocol, 113 articles were identified in major databases exploring Industry 4.0, Society 5.0 and UA. Among the studies selected in the systematic literature review, 64% (n = 72) were published in journals and 36% (n = 41) in conference proceedings. The papers covered a diversity of 39 conferences and 46 journals, highlighting *Sustainability* (n = 16), *Journal of Cleaner Production* (n = 4) and *Sustainable Cities and Society* (n = 4). Proceedings included those promoted by the IEEE in information science, computing and automation fields.

The terms *urban agriculture*, IoT, *smart cities*, and *sustainability* stood out (Figure 2), pointing out that there is indeed a relationship between Industry 4.0, urban food system and sustainable society. It can be observed that the articles do not explicitly address the term *Society 5.0*, but the concepts of sustainable development and improved quality of life and urban resilience.

Figure 2. Word cloud for all keywords of the selected papers included in the systematic review sorted by frequency. Source: Authors (2021).

Although these topics are strongly linked to what is expected to develop with the implementation of Society 5.0, the interconnection of all these concepts for building a super intelligent society concerned with economic, environmental, and social sustainability is not much explored.

The selected articles were categorized according to their degree of affinity with the themes explored in this research, where 45 papers were aligned with the concept of Industry 4.0, 57 were in the field of Society 5.0, and only 11 papers were related to both concepts. Seven domains were identified (Table 2), highlighting technological innovation as an enabler of UA advancement with a focus on sustainability.

Regarding innovation applied to UA, it was observed that many papers focus on solutions for agriculture in small spaces, and in the urban context, dealing with automated systems that rely on sensors and actuators for the management and maintenance of crops, from flower beds installed in apartments to gardens grown in relatively large areas. Carrión-Vivar et al., 2019; Veloo et al., 2019). Growing methods are distributed between hydroponics, aquaponics, and traditional soil planting (Ahmed et al., 2019; Jai et al., 2018; Modu et al., 2020).

Table 2. Categorization according to the systematic literature review.

Categories	Description
Innovation (n = 32)	Implementation of IT, digitalization and automation in food production, and other elements of urban food systems. Technologies such as IoT, use of sensors to acquire data about the soil and environment, and connection to actuators that perform maintenance and management of planting conditions are the most common applications.
Sustainability (n = 23)	Environmental benefits (such as reduction in the average temperature of the environment, and protection of the soil), social benefits (such as increased interaction among community members, and availability of food for vulnerable populations), and economic benefits (employment opportunities, and development of new business models) are often cited in the literature as a motivation for UA.
Social and governmental factors (n = 14)	Social and governmental factors can either facilitate or inhibit the implementation of UA activities in a given context. The differences between social efforts, where a community initiates an urban agriculture project, and government-sponsored projects, where there is planning and zoning provided by the management to motivate urban agriculture, are mainly addressed.
System integration (n = 13)	Integration of the UA system with other systems through digitalization, as well as integration of energy and matter flows that can be reused by the UA.
Food production, and food safety (n = 12)	Food production, amount of food produced per planting area, and population potentially benefiting from the consumption of such food.
Technology & resources (n = 11)	Main technologies, planting methods and resources (physical and technological) that can be applied to implement UA. Planting methods that stand out are aquaponics, hydroponics and aeroponics. Use of IT in the automation of these systems.
Software & modeling (n = 8)	Application of technology in a more indirect way, without directly involving the planting and maintenance of the UA. Development of software or systems capable of modeling and predicting suitable areas for planting, space optimization, and project definition.

Source: Authors (2021).

A conceptual IoT architecture for urban farms and precision agriculture can meet all the requirements of a smart city, such as interoperability, real-time monitoring, mobility, and integrated management (Ordoñez-García et al., 2017). In this sense, some strategies have been studied, such as implementation models where a public food network is installed vertically in a modular way, being financed and managed by the local government, enabling citizens to have free access to food (Dokic et al., 2019). A more social view on the implementation of IoT and smart city concepts uses participatory design techniques and proposes the development of a locally grown seed library (Heitlinger et al., 2018; Heitlinger et al., 2019).

A different proposal seeks to use building facades to improve quality of life, as well as the creation of green areas, and food production through autonomous greenhouse-like systems attached to building windows with embedded smart technologies. Such systems aim to reduce water consumption and rely solely on solar energy (Hung & Peng, 2017).

Environmental, economic, and social benefits are often cited in the literature as a motivation for practicing UA. The most commonly mentioned sustainability gains relate to temperature reduction, and microclimate regulation (Dennis & James, 2018; Khalil & Wahhab, 2020; Langemeyer et al., 2018; Singh et al., 2017), biodiversity enhancement, air pollution mitigation (Artmann et al., 2020), food production (Artmann et al., 2020; De Filippi et al., 2019; Dennis & James, 2018; Langemeyer et al., 2018), aesthetic and landscape improvement, recreation and leisure, improved social relationships, and learning networks (Langemeyer et al., 2018; Panagopoulos et al., 2018; Zasada et al., 2020). Actually, vertical agriculture, for example, can contribute to a reduction of between 1 and 1.4 degrees Celsius in outdoor temperature, and a reduction of 2 degrees in average radiation temperature when applied to the facade of just two buildings (Gómez et al., 2019; Khalil & Wahhab, 2020). In addition, data collected from urban agriculture implementation demonstrates the relationships between practice and energy saving through the reuse of water, heat fluxes, and CO_2 emissions as inputs to UA systems.

Concerning social and governmental issues, there is much discussion about the most effective way to implement urban agriculture projects. Some authors claim that the real change comes from community initiative, which ultimately puts pressure on the state to legislate the practice (Heitlinger et al., 2018; Heitlinger et al., 2019; Mancebo, 2018; Nemoto & Biazoti, 2017), while others argue that the role of governments cannot be dismissed (Panagopoulos et al., 2018; van der Jagt et al., 2017). In any case, UA plays a key role in sustainable urban development and constitutes a tool for community empowerment, urban innovation, and articulation between the various spaces and functions of the urban tissue (Amato-Lourenço et al., 2020; Elisei et al., 2018; Jelenski, 2019; Mattsson et al., 2018).

Public policy does play a central role in promoting UA. The city of Melbourne (Australia), for example, has developed the Future Melbourne Plan, which estimates that 30% of all food consumed in the city comes from within a 50 km radius, mainly from the ecosystem of NGOs and non-profit ventures focused on UA (Amato-Lourenço et al., 2020). However, in Sao Paulo (Brazil), governmental initiatives for the development of urban and peri urban agriculture are relatively recent. In 2004, municipal and federal laws to encourage UA as a source of income and social inclusion came into effect (Amato-Lourenço et al., 2020).

It was observed that the role of green infrastructure in smart city planning is still little explored, as well as the integration between systems. However, technologies such as augmented reality, big data, and automation can maximize the social benefits of green areas. This can be done through increased monitoring and data collection to facilitate management and diagnosis of interference in the systems (Nitoslawski et al., 2019). Some elements are essential in integrating this type of infrastructure, such as regionalization of the system to municipal or metropolitan levels, focus on connectivity and distribution among UA initiatives (Jelenski, 2019; Sturiale & Scuderi, 2018), administrative and political organization, circular metabolism, and focus on recycling and reuse of resources, besides social practices as a form of innovation and learning (Kasper et al., 2017; Maye, 2019).

A potency pointed out by the literature refers to the fact that UA is an opportunity to promote food security and citizens' well-being through more conscious and nutritious food choices (Cvijanovic et al., 2018; Martin & Vold, 2018; Skog et al., 2018; Uhlmann et al., 2018). Although they take many different forms, many of these initiatives are distinguished by growing traditional or unconventional foods, and are important for maintaining food diversity (Amato-Lourenço et al., 2020). They also serve as an example for isolated communities with restricted access to fresh foods (Martin & Vold, 2018). Accordingly, many studies have assessed the food production capacity and UA collaboration in meeting daily consumption needs of fruits and vegetables in different parts of the world (Aragon et al., 2019; Salvador et al., 2019).

The technologies and resources available for the implementation and development of UA can be divided between those directly related to the practice of UA and those that address adjacent needs such as fertilization, knowledge of soil type, water availability, training, and other necessary resources (Da Cruz et. al., 2018). Big data and cloud computing can be implemented in the development of specific diets for consumers or in targeted and optimized food production. IoT-connected systems can identify vulnerabilities and issue alerts about process and logistics failures, preventing unfit food from reaching the final consumer (de Amorim et al., 2019).

However, a weakness identified is that the implementation of urban agriculture lacks the tools to define the best technology to be applied depending on the characteristics of each region. Variables such as available space, environmental parameters, and production goals can be used to choose among a selection of farming methods. In this sense, a method using fuzzy logic and the EDAS method (Evaluation Based on Distance to Average Solution) can be selected among three different vertical farming alternatives, for example (Tolga et al., 2020).

Finally, seeking to investigate some specific aspects of UA that may typically be limiting to the expansion of the practice, some papers evaluate modeling and prediction systems. These systems can help decide which plants to grow (Contractor et al., 2020; Wei et al., 2017), management of the urban food system (Ghandar et al., 2019; Ghandar et al., 2018), feasibility of implementing UA on land or rooftops (Contractor et al., 2020; Khan et al., 2018; Xu et al., 2020), in addition to projection of the amount of food produced (Contractor et al., 2020).

In a global view, the systematic review also pointed out that there is a knowledge gap when it comes to the implementation of large-scale UA within cities, and what can be done so that the entire value chain of food production is integrated in a way that meets the needs of the population, while also perpetrating other benefits for cities. Much is discussed about technology and systems development from an IT perspective, but not about how a food system can be implemented and integrated within a city as a whole. In this respect, it is important to assess such concerns and the ways to be explored to enable this model, taking into account the production of food within cities, using the best of the available technology, focusing on the wellbeing, and meeting the nutritional needs of all citizens by modeling intelligent relationships between food production sites, consumer profiles, and optimizing energy, water, and mass flow.

3.2 Association: Conceptual Design of Urban Agriculture 5.0

To outline a conceptual approach and infer the domains associated with Urban Agriculture 5.0 based on data triangulation, relationship matrices were built. First, the main attributes of UA identified in the observation and categorization phases were defined, as presented in Table 3. Likewise, the key technologies of Industry 4.0 (Table 4) and main attributes of Society 5.0 (Table 5) were mapped.

The first matrix assessed the connections between UA and the technologies proposed by Industry 4.0 (Figure 3a), and a total of 35 points of convergence were identified, pointing out that this type of practice has great potential to be driven by a technological approach in order to achieve better results. The second matrix evaluated the convergence between urban agriculture and the principles of Society 5.0 (Figure 3b). Although the concept of a people-centric super-smart society is more recent than the philosophy of Industry 4.0, the social focus of Society 5.0 and food systems have resulted in 43 points of convergence, showing that urban agriculture is associated with the construction of a sustainable and resilient society with a concern for the well-being of the urban population.

Strong convergence was observed between technologies 4.0, notably IoT, and the operationalization of UA systems. The use of simulation, big data, and augmented reality are reported less frequently, but still with high potential for the transformation of urban food systems and gains not only in production, but also in quality of life and community well-being. Data security was not addressed as a major issue in UA scope, but this does not mean that it is not important. As it is an area of knowledge still in an early stage of investigation, certain data security concerns tend to be discussed later. Similarly, additive manufacturing did not appear in any study, demonstrating that, in food systems, its application may not be so clear.

Table 3. Attributes of Urban Agriculture and main related papers identified by the systematic literature review. The corresponding codes were used in the relationship matrices.

Ref.	Attributes	Main papers
A1	Automation of irrigation system, fertilization and environmental adjustments	Mackensen et al. (2019); Karimah et al. (2019); Samonte et al. (2019b); Stevens & Shaikh (2018); Jai et al. (2018); Mahkeswaran & Ng (2020); Penzenstadler et al. (2018); Ambrosio et al. (2019); Yang et al. (2017).
A2	Control and acquisition of soil and environment data	Mackensen et al. (2019); Karimah et al. (2019); Stevens & Shaikh (2018); Ali et al. (2020); Mahkeswaran & Ng (2020); Penzenstadler et al. (2018); Yang et al. (2017); Manju et al. (2017).
A3	Use of applications for control and monitoring	Veloo et al. (2019b); Gunawan et al. (2019); Stevens & Shaikh (2018); Ali et al. (2020b); Mahkeswaran & Ng (2020); Penzenstadler et al. (2018); Manju et al. (2017).
A4	Planting handling and management	Mackensen et al. (2019); Ambrosio et al. (2019); Penzenstadler et al. (2018); Hu et al. (2018); Manju et al. (2017); Munandar et al. (2018); Carríon et al. (2018a).
A5	Identification of suitable places for planting	Wei et al. (2017); Contractor & Mritika (2020); Xu et al. (2020); Khan et al., (2018); Salvador et al. (2019); Aragon et al. (2019).
A6	Planting area optimization, and suitability	Dokic et al. (2019); Mahkeswaran & Ng (2020); Hu et al. (2018); Duarte et al. (2019); Mason et al. (2019); Wei et al. (2017); Contractor & Mritika (2020); Zeng et al. (2019); Tolga et al. (2020); Gwynn-Jones et al. (2018); Chaudhry & Mishra, (2019).
A7	Environmental, social and economic gains	Albright-Borden et al. (2019); Yang et al. (2017); Hung and Peng (2017); Araiza et al. (2019); Heitlinger, Bryan-Kinns & Comber (2018, 2019); Dennis & James (2018); Artmann & Sartison (2018); Petrescu et al. (2020); Gómez et al. (2019); Heard et al. (2017).
A8	Improving food distribution	Ambrosio et al. (2019); Hu et al. (2018); Albright-Borden et al. (2019); Yang et al. (2017); Dokic et al. (2019); Artmann & Sartison (2018); Russo et al. (2017); Mancebo (2018); Chaudhry & Mishra, (2019); Skog et al. (2018); Hara et al. (2018).
A9	Community, well-being and quality of life	Mackensen et al. (2019); Ambrosio et al. (2019); Albright-Borden et al. (2019); Yang et al. (2017); Dokic et al. (2019; Hung and Peng (2017); Heitlinger et al. (2018, 2019); Dezio & Marino (2018); Zasada et al. (2020); Artmann & Sartison (2018); Skog et al. (2018).

Source: Authors (2021).

Table 4. Key technologies of Industry 4.0 and main related papers identified by the systematic literature review. The corresponding codes were used in the relationship matrices.

Ref.	Component	Main papers
I1	IoT	Samonte et al. (2019); Stevens & Shaikh (2018); Ali et al. (2020b); Mahkeswaran & Ng (2020); Ambrosio et al. (2019); Penzenstadler et al. (2018); Albright-Borden et al. (2019); Ordoñez-García et al. (2017); Ordonez-Garcia et al. (2019); Heitlinger et al. (2018, 2019); Jai et al. (2018); Yang et al. (2017); Manju et al. (2017b); Carríon et al. (2018); He et al. (2018); Duarte et al. (2019).
I2	Integrated systems	Mackensen et al. (2019); Karimah et al. (2019); Nitoslawski et al., (2019); Akhmedova & Zhogoleva, (2017); He et al. (2018); Md Ibharim & Salim, (2020); Mishbah et al. (2018).
I3	Autonomous robots	Veloo et al. (2019); Gunawan et al. (2019b); Ambrosio et al. (2019); Araiza et al. (2019).
I4	Simulation	Veloo et al. (2019); Contractor et al. (2020); Wei et al. (2017); Ghandar et al. (2019); Khan et al. (2018); Xu et al., (2020); Tolga et al. (2020).
I5	Cloud computing	Carrión et al., (2018b); Munandar (2018); Lopez-Iturri (2018).
I6	Cybersecutirty	Carrión et al., (2018b); Munandar (2018); Lopez-Iturri (2018).
I7	Additive manufacturing	Carrión et al., (2018b); Munandar (2018); Lopez-Iturri (2018).
I8	Augmented reality	Colding et al., (2020)
I9	Big data and analytics	Veloo et al. (2019); Hu et al. (2018); Carrión et al. (2018); Dokic et al. (2019).
I10	Modularity and customization	Satoh (2018); Mackensen et al. (2019); Karimah et al., (2019); Ambrosio et al., (2019); Penzenstadler et al., (2018); Yang et al., (2017).

Source: Authors (2021).

Table 5. Attributes of Society 5.0 and main related articles identified by the systematic literature review. The corresponding codes were used in the relationship matrices.

Ref.	Component	Main articles
S1	Well-being, and quality of life	Heitlinger et al. (2018, 2019); Dezio & Marino (2018); Saporito (2017a); Singh et al. (2017); Khalil & Wahhab (2020); Russo et al. (2017); Lin & Egerer (2020); Aragon et al. ,(2019b); Salvador et al. (2019); Sioen et al. (2018); De Filippi et al. (2019).
S2	Matter and energy flow efficiency	Mason et al. (2019); Dennis & James (2018); Petrescu et al. (2020); Mohareb et al. (2017); Gómez et al. (2019); Heard et al. (2017); Benis & Ferrão (2017); Fassio & Minotti (2019); Krzemińska et al. (2019); Gondhalekar & Ramsauer (2017); Mohareb et al. (2017); Aragon et al. (2019).
S3	Regional revitalization	Heitlinger et al. (2018, 2019); Araiza et al. (2019); Dezio & Marino (2018); Saporito, (2017a); Langemeyer et al. (2018); Panagopoulos et al. (2018); Zasada et al., (2020); Singh et al. (2017); Petrescu et al. (2020); Amato-Lourenço et al. (2020).
S4	Environmental protection	Araiza et al. (2019); Singh et al. (2017); Dennis & James (2018); Khalil & Wahhab, (2020); Langemeyer et al. (2018); Russo et al. (2017); Benis & Ferrão (2017); Aragon et al. (2019).
S5	Resilience	Saporito (2017a); Petrescu et al. (2020); Grădinaru et al. (2018); Russo et al. (2017); Lin & Egerer (2020); Benis & Ferrão (2017); Dezio & Marino (2018); Sturiale & Scuderi (2019); Aragon et al (2019b); Salvador et al. (2019); De Filippi et al. (2019).
S6	Individual rights	Pinto et al. (2020); Artmann & Sartison (2018); De Filippi et al. (2019); Dennis & James, (2018); Langemeyer et al. (2018); Grădinaru et al. (2018); Amato-Lourenço et al. (2020); Sioen et al. (2018); Aragon et al. (2019).
S7	System integration	Heitlinger et al. (2018, 2019); Petrescu et al. (2020); Jelenski (2019); Nitoslawski et al., (2019).
S8	Social inclusion	Heitlinger et al. (2018, 2019); Araiza et al. (2019); Saporito (2017a); Petrescu et al. (2020); , Azunre et al. (2019); Grădinaru et al. (2018); Lin & Egerer (2020); Sturiale & Scuderi (2019); Amato-Lourenço et al. (2020); De Filippi et al. (2019).
S9	Sustainable development	Heitlinger et al. (2018, 2019); Araiza et al. (2019); Singh et al. (2017); Khalil & Wahhab (2020); Petrescu et al. (2020); Azunre et al. (2019); Benis & Ferrão (2017); Cvijanovic et al. (2018); Martin & Vold (2018); Uhlmann et al. (2018); Sioen et al. (2018); Aragon et al. (2019).

Source: Authors (2021).

Control and acquisition of data as well as use of applications for control and monitoring were the most related UA attributes to Industry 4.0, especially to IoT, system integration as well as modularity and customization. On the other hand, planting handling and management as well as planting area optimization were the UA attributes with the lowest relation to technologies 4.0, suggesting that there is a technological gap that may constitute a bottleneck in the path to improved UA gains.

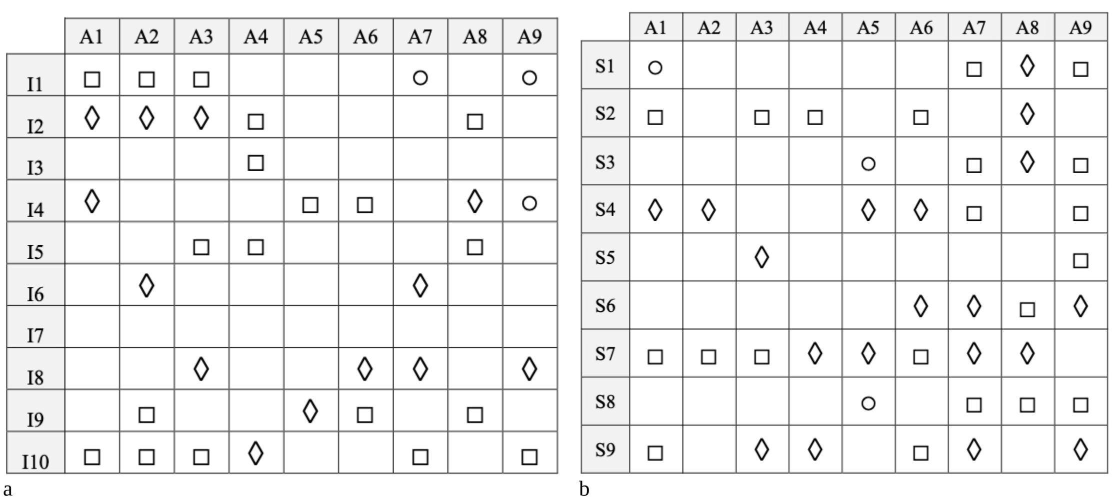

Figure 3. Two-dimensional relationship matrix that points to the convergence between Urban Agriculture and (a) Industry 4.0, as well as (b) Society 5.0. Source: Authors (2021).

Regarding Society 5.0 and UA, it highlights not only the possibility of food production, which contributes directly to the quality of life and urban resilience, but also the integration between the UA systems and the other flows of matter and energy, bringing points in synergy with the principles of flow efficiency and integration between systems. Some authors even discuss the role of food consumption data in meeting individual needs by suggesting balanced diets, and the use of UA as a way to revitalize neighborhoods and communities.

Environmental, social, and economic gains; improving food distribution; and community, well-being, and quality of life were the UA attributes with the most convergence with the Super Smart Society principles. However, control and acquisition of data as well as planting handling and management were the UA attributes with the least relation to the pillars of Society 5.0, possibly because they are dimensions with a more objective and quantitative nature, linked to a technological perspective.

In summary, Urban Agriculture 5.0 (UA 5.0) can be understood as a fusion of science, technology and society where the is no overvaluation of one aspect over another. In order to achieve its goals, UA 5.0 relies and depends on technology and the implementation of new forms of food production - more intelligent and integrated with the processes and flows that surround it - but it remains firmly grounded in meeting the social and economic demands of a society, becoming part of the city's metabolism.

This new form of food production brings a new paradigm for agriculture, integrated to the systemics of cities, considering important dimensions for its development and success, being such dimensions

the spatial, social, technological, and economic dimensions, and also the dimensions of sustainability and systems integration (Figure 4).

All these dimensions must be considered during the development of projects and policies that consider UA as an integral and essential part of cities, while also acting as a framework for the development of new agricultural industries. Accordingly, keeping these dimensions in focus during the design of a new system ensures that the main objectives of UA 5.0 are achieved. Moreover, understanding the points of convergence between urban agriculture, society 5.0 and industry 4.0, as well as working in the domains of these systems facilitates and optimizes the developer's work, bringing more assertiveness and agility in the implementation phase.

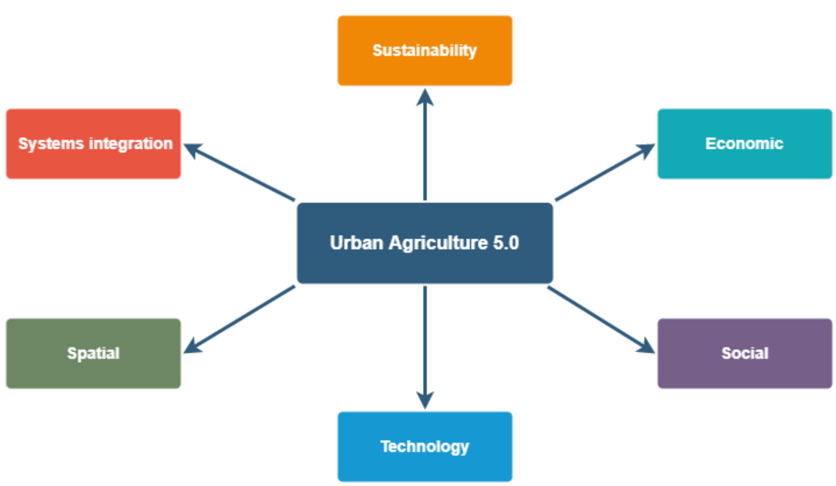

Figure 4. Urban agriculture 5.0 dimensions. source: authors (2021).

Each of these dimensions spells out an important aspect that should be considered during UA-focused urban food system studies and projects, especially because of the various implementation possibilities. The economic and social dimensions, for example, consider parameters such as cost of land use, technology-intensive use, and system operation on food production, in addition to assessing social inclusion, social engagement, and longevity of the project within the community.

The technological dimension, in turn, deals with the solutions available for process and planting optimization and their suitability for a given UA model, which in turn is considered in the spatial dimension of UA 5.0. System integration and sustainability dimensions consider the capacity of a UA system to take advantage of energy, mass and data flows from existing urban systems, being deeply related to each other, although issues such as contaminated soil and waste treatment may be addressed on the sustainability dimension.

4. Conclusion

This paper outlined the relationships between UA, Industry 4.0, and Society 5.0 through data triangulation based on a three-phase methodological approach, demonstrating that an urban agriculture system based on digital technologies and focused on human well-being is possible and consistent with what has been explored by other papers in the literature. Corroborating previous studies, important relationships were identified between agriculture, digital technologies, and the social and environmental benefits of these practices. It has noted the need for holistic application of technologies 4.0, mainly IoT, automation and data acquisition and processing to build autonomous systems capable of managing food production. In addition, the socio-environmental benefits of UA deployment, in line with the principles of the super smart society, were highlighted.

In fact, 35 convergence points were identified between UA and Industry 4.0, suggesting that this type of practice has great potential to be driven by a technological approach to achieve better results. Likewise, 43 points of alignment between UA and Society 5.0 were obtained, showing that UA is associated with the construction of a sustainable and resilient society with a concern for the well-being of the urban population. These findings fostered the conceptual design of UA 5.0 from a multifaceted approach so that the practice of UA in a people-centric super-smart society is connected to the domains of technology, spatial, social, economic, sustainability, and systems integration.

Besides filling a gap in the literature, this article contributes to in-depth discussions, and aligned approaches among policy makers for building a more resilient urban food system as a strategy directly embedded in smart cities. Holistic exploration of the dimensions of UA 5.0 acts as a framework for the development of industries that truly consider not only the technological dimension, but also the social and environmental impacts and benefits of implementing UA. Therefore, an excessive technical and economic focus can take away from the urban food system the possible social and environmental benefits that can further contribute to the sustainability and success of the urban system as a whole. It is imperative that industries and other stakeholders involved in this type of implementation are aware of these other dimensions.

Based on systems engineering fundamentals, future studies include the development of an urban food system architecture, considering the six identified dimensions of UA 5.0, to ensure that the implementation of the system achieves the proposed objectives, as well as guarantees food security and optimization of food production in urban territories.

Conflict of Interest
The authors confirm that there is no conflict of interest to declare for this publication.

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