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Potential Key Factors, Policies, and Barriers for Rooftop Agriculture in EU Cities: Barcelona, Berlin, Bologna, and Paris

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The main objective of this study is to contribute a framework and to provide an overview of potential key factors, policies, and barriers associated with the integration of rooftop urban agriculture (RUA), building on stakeholders' perspectives in four European cities (Barcelona, Berlin, Bologna, and Paris). The research was developed in two phases, namely, a workshop and a survey of stakeholders involved in RUA from the four cities. Education, environmental, research, technological innovation, food production, and social factors play an important role in implementing RUA. Productive spaces, cultural values, social cohesion, social rural-urban links, and the high cost of urban land are highlighted as factors that "promote" RUA. In contrast, the cost of water and pollution are major contextual factors that constrain RUA. Policies related to food trade and urban planning are those that most limit RUA development. Major architectural and technical barriers related to the limits on building heights, historical buildings, a lack of specific building codes, building design and roof accessibility were identified. The high cost of infrastructure and policies that prohibit RUA product sales emerged as economic constraints. Major differences among the cities studied included the perceived effect of urban policies on RUA diffusion as well as the perceived relevance of economic and pollution factors. This study revealed that extensive dissemination and the development of appropriate information about RUA are needed. The creation of new regulations, as well as modifications to urban and building codes to support RUA, is also envisaged. This approach will consider a more flexible land-use policy that allows agriculture to take place in cities as well as marketing frameworks for RUA products. For future studies, it would be useful to apply the framework developed in this study to a larger sample. A study is also needed to confirm hypothetical differences between cities.

Keywords: stakeholders, perceptions, local food production, urban sustainability, buildings

INTRODUCTION

In recent decades, the world population has undergone revolutionary changes. Population dynamics have resulted in the rapid growth of the global population since 1950. Today, 55% of the world's population lives in urban areas, and according to projections, by 2050, 68% of the world's population is expected to live in cities (United Nations, 2018). Cities, as spaces where human activity is more concentrated, must develop a key role in the management of the present and future of humankind and the development of a more sustainable organizational model (European Commission United Nations Human Settlements Programme, 2016).

Land and water systems face the risk of a progressive collapse of their productive capacity under a combination of demographic pressure and unsustainable agricultural practices. Intensive forms of agriculture can cause serious environmental damage, with food crops also competing for land, water, and energy resources (Bilan et al., 2018). Factors such as rapid urban growth, scarce resources, and the effects of climate change contribute to highly vulnerable food systems (FAO, 2011; Martellozzo et al., 2014). The COVID-19 pandemic has underlined the need for modifications and changes in the governance of food systems. To address food resilience, it has been suggested that European governments promote local production involving innovative small-scale initiatives, whose social benefits have been emphasized by the pandemic (Vittuari et al., 2021). Indeed, the integration of food production within cities may offer opportunities to address these challenges (Armanda et al., 2019).

Cities, especially those with a high population density, lack sufficient space for agricultural uses. In this sense, real estate speculation and the increase in population density in urban areas have led to a decrease in the availability of vacant lands where urban agriculture (UA) may be developed (Gasperi et al., 2016). Thus, given the multiple benefits in terms of social, economic, and environmental functions provided by UA and the growing interest in the creation of sustainable cities with improved quality of life, city farming, made up of a diversified set of growing systems and business strategies (Orsini et al., 2020), is being widely promoted (Taylor and Hochuli, 2017). Among possible strategies for fostering urban food production, vacant building rooftops have been proposed as locations where the transformation from underused to productive spaces may take place (Orsini et al., 2014; Toboso-Chavero et al., 2018).

Urban Agriculture Benefits and Barriers

In recent years, a growing number of UA projects have been established on existing buildings, for example, using façades and rooftops as crop production space (Thomaier et al., 2015). Rooftop urban agriculture (RUA) can play an important role in improving adaptation to climate change (De Zeeuw et al., 2011), can reduce the urban heat island effect (Alexandri and Jones, 2008; Susca et al., 2011; Lee et al., 2014), and may ultimately lower energy and greenhouse gas emissions by decreasing the distance that food products are transported (Heinberg and Bomford, 2009). Other benefits are also associated with the integration of disadvantaged population groups and the promotion of social cohesion (Draper and Freedman, 2010; Lovell, 2010), while also providing economic benefits within communities.

However, even in the face of such benefits, several concerns must be addressed for the successful integration of UA in cities (Fletcher et al., 2012), with urban planning and economic, social, and environmental issues representing the main challenges. Policies, regulations, and land-use zoning bylaws can also act as barriers to UA (Roehr and Kunigk, 2009). Until recently, many municipalities excluded agriculture or related activities within their regulations for residential land use. For instance, until June 2010, the City of Los Angeles (California, USA) prohibited residents from growing crops in residential-zoned areas (Fletcher et al., 2012). Restriction on sales of food products grown in residential areas is also a barrier and major concern, although exceptions exist. In 2012, the Berkeley Planning Commission adopted the definition of "Non-Processed Edibles," which includes locally produced fruit, vegetables, nuts, honey, and shell eggs, but not meat, allowing the sale of such items in residential districts, provided that they meet certain safety requirements (Fletcher et al., 2012). Other cities were also highly active in implementing policies to support UA, including New York City, Washington DC, Chicago, Toronto and Singapore, where pioneering programs related to food production on building rooftops were launched. The New York City council also included the use of rooftops for food production in local plans (The New York City Council, 2010). Additionally, the city of Chicago reformed city laws regarding UA, allowing urban farms on rooftops (Urban Sustainability Exchange, 2011; City of Chicago, 2020). Globally, North America (81) and Europe (49) are the world regions with the highest number of RUA projects (Appolloni et al., 2021).

Rooftop Urban Agriculture Integration in European Cities

In Europe, the lack of land has led to exploring new ways to promote horticulture in cities, with pioneering practices of RUA taking place, for example, in Barcelona, Berlin, Bologna, and Paris.

In Barcelona (Spain), a pilot rooftop greenhouse (RTG) started to operate in the ICTA-ICP building of the Universitat Autonòma de Barcelona in 2014 (Fertilecity, 2018). Other local examples of RUA include the L'Hort al terrat (Garden on the roof) program, promoted by the City Council and aimed at fostering the integrated production of different kinds of vegetables (Barcelona City Council, 2018b). Additionally, the recently released Barcelona's Climate Plan 2018–2030 considers RUA implementation as a means to mitigate climate change and improve the quality of life in the city (Barcelona City Council, 2018a). Barcelona will also host the international meeting of the Milan Pact, becoming the World Capital of Sustainable Food in 2021 (Barcelona City Council, 2020).

In Berlin (Germany), commercial urban farming enterprises have developed different prototypes and technologies for food production on buildings (Specht et al., 2016b). The high potential for integrating RUA was recently detailed (Altmann et al., 2018),

and RUA projects are already operative, including two open-air rooftop gardens and one RTG, located on the Humboldt University building (Tao et al., 2020).

Bologna (Italy) was one of the first cities in Italy to adopt a local plan for adaptation to climate change. Greening strategies were proposed to mitigate the effects of urban heat islands, with the ambitious objectives of integrating 5 hectares of urban vegetable gardens and greening intervention on ten public buildings (Comune di Bologna, 2014). Although the actual development was on a smaller scale e.g., three temporary pilot community rooftop gardens installed on the 10th floor of social housing buildings (Orsini et al., 2014), new RUA projects are currently being developed, including an educational rooftop greenhouse at the multifunctional space SALUS (Pennisi et al., 2020).

Paris (France) has been very active in promoting projects concerning biodiversity, greening, UA and food initiatives (Delgado, 2018). According to the Paris Climate Action Plan, the city promotes UA on roofs of municipal buildings. One of the objectives is to install 100 hectares of green roofs and walls, one-third of which will be devoted to urban agriculture (City of Paris, 2018). Accordingly, the Parisculteurs program was launched in 2016 for installing urban agriculture on buildings (Collé et al., 2018).

While the RUA sector is growing steadily in different European cities, economic, social, environmental, legal, technical, and architectural limitations are also being identified, as will be detailed in the following section.

Rooftop Urban Agriculture Barriers in European Cities

Although pioneering RUA projects exist, most suffer from a lack of promotion, specific laws, legal procedures, and urban codes (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2013). Studies in Barcelona, Berlin, and Bologna developed a preliminary classification of such barriers (Cerón-Palma et al., 2012; Specht et al., 2015, 2016a; Sanyé-Mengual et al., 2016; Specht and Sanyé-Mengual, 2017). Social obstacles include limited acceptance by users, the conceptualization and perception of UA, by many stakeholders, that it is not "true" agriculture, and the urgent need for training qualified technical personnel (Sanyé-Mengual et al., 2016; Specht et al., 2016a; Specht and Sanyé-Mengual, 2017). Social and health risks have also been repeatedly identified in several surveys on citizen perceptions (Sanyé-Mengual et al., 2016, 2018b; Specht and Sanyé-Mengual, 2017). Additionally, the possible environmental impacts associated with materials used for the construction of RTG facilities require careful consideration (Cerón-Palma et al., 2012). The low level of income generated by RUA products and difficulties in developing a viable business model were found to be the principal economic concerns (Palmer et al., 2016; Specht and Sanyé-Mengual, 2017). Technological and architectural barriers included the visual/aesthetic impact (especially within historical centers), structural load limitations in buildings, building height limits according to the building size, and the overall building envelope (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016; Specht et al., 2016a). Legal challenges range from the lack of RUA regulations in current urban building codes and the difficulties in managing food safety protocols and certification schemes within small-scale farms. While the few studies that have been conducted have identified the barriers, opportunities, and risks associated with urban agriculture, there is a gap in identifying specific policies and key factors that can contribute to or limit urban agriculture on rooftops.

Approaches for Identifying Rooftop Urban Agriculture Barriers and Opportunities

Table 1 presents studies conducted to identify barriers and opportunities for implementing RUA in European cities from the point of view of stakeholders or citizens.

As revealed in **Table 1**, Barcelona and Berlin are the cities where the greatest number of studies have been conducted. Interviews are the most frequent method used for data collection (Specht et al., 2015, 2016a; Sanyé-Mengual et al., 2016; Specht and Sanyé-Mengual, 2017). Most of the key approaches are related to barriers, opportunities and risk. Regarding related approaches, two studies identified the level of relevance of benefits and risks (Specht et al., 2016a; Specht and Sanyé-Mengual, 2017), one study identified key issues for implementing UA (Specht et al., 2015), another compared its results on RUA with findings of previous studies (Sanyé-Mengual et al., 2016), and finally, one study used a Likert-scale evaluation to identify the degree of social acceptance of uses of open and green spaces, including RTGs and rooftop farms in the city of Bologna (Sanyé-Mengual et al., 2016).

Studies that consider data collection methods where stakeholders interact and share their knowledge and experiences to address barriers, opportunities, key factors, and policies regarding the implementation of RUA projects, as well as quantitative approaches about the frequency and degree of relevance of such projects, are also lacking. RUA is advancing driven by local initiatives, affected by both the circumstances of each location and the restrictions (or support) that exist in each case. There is, therefore, a crucial need to identify the key factors, policies, and barriers associated with the implementation of RUA in cities, especially when there are recent experiences. The identification of these little-explored aspects is relevant and helpful to find common factors, collect constraints, ways to overcome them and propose lines of action. This would likely help in the development of policies and programs to promote urban agriculture more efficiently and overcome constraints. These actions could bring various social, educational, environmental, and economic benefits in the urban context, as well as contribute to building more resilient cities.

The present study includes four cities from different European regions where incentives to support RUA have recently emerged and projects have already been built with different focuses, ranging from social inclusion to technological development and research. This study primarily elaborates on a participatory workshop. Participatory workshops are processes by which communities of practitioners can collaboratively share knowledge and personal experiences and reflect on the challenges they face and the methods for addressing them (Mor et al., 2012). Research methodology workshops aim to produce reliable and valid data about the domain in question

TABLE 1 | Studies of barriers and opportunities from stakeholders' perceptions.

City	Data collection			Key approach	Related approach				References
	I	S	Q		K	R	C	S	
Barcelona		•		Barriers and opportunities					Cerón-Palma et al., 2012
Berlin	•			Opportunities and challenges	•				Specht et al., 2015
Barcelona	•			Barriers and opportunities			•		Sanyé-Mengual et al., 2016
Berlin	•			Benefits and risks		•			Specht et al., 2016a
Berlin and Barcelona	•			Risks		•			Specht and Sanyé-Mengual, 2017
Bologna			•	Social acceptance				•	Sanyé-Mengual et al., 2018b
Germany and U.S.	•			Perception of sustainability, acceptance factors, and acceptance barriers					Specht et al., 2019

Data collection was performed using interviews (I), seminars of discussion (S), and questionnaires (Q). Related approaches: key factors (K), relevance (R) of benefits and risks, comparison with previous studies on RUA (C), and scale of acceptance (S).

and regarding forward-oriented processes in addition to fulfilling participants' expectations to achieve something related to their own interests (Ørngreen and Levinsen, 2017). The workshop cocreates a space for negotiating collaborative meanings, not just between participants but also between researchers and participants who discuss, perform, and learn during the workshop (Ørngreen and Levinsen, 2017).

In this context, the main objective of this research is to provide an exploratory overview of potential key factors, policies, and barriers associated with the integration of RUA from stakeholders' perceptions in four European cities (Barcelona, Berlin, Bologna, and Paris). The specific objectives of this work are (1) to identify key factors for integrating RUA and their level of relevance, (2) to identify context factors and their perceived effect on RUA diffusion, (3) to identify policies and their perceived effect on RUA diffusion and (4) to identify barriers to RUA and the frequency with which they occur.

MATERIALS AND METHODS

An exploratory method and non-probability sampling were used. The results are therefore not to be considered statistically or demographically representative of stakeholders from Barcelona, Berlin, Bologna, and Paris. The exploratory approach was considered appropriate because it offers preliminary insights into a previously little or unexplored topic (Hernández-Sampieri, 2014).

Figure 1 shows the workflow, structured in two phases and seven stages. The first phase consisted of a workshop. The main goal of the workshop was to obtain an overview of key factors, contextual factors, policies, and barriers to RUA integration in cities based on stakeholders' experiences. The second phase aimed at identifying, and quantifying, stakeholders' perceptions about key factors relevant to integrating RUA, contextual factors and policies that promote or hinder RUA, and the frequency with which barriers occur. Within Phase 1, the research included a definition of the case studies (stage 1), the participant definition (stage 2), and data collection (stage 3). Phase 2 included key factor and barrier definitions (stage 4), a second round of participant definitions (stage 5), data collection (stage 6), and analysis (stage 7). Each of these stages is described in detail in the following subsections.

Phase 1 Workshop

The first phase consisted of a workshop with international stakeholders from diverse EU cities. A participatory workshop was developed to build knowledge concerning to RUA.

Definition of Case Studies

Four cities from Europe, Barcelona, Berlin, Bologna, and Paris were chosen as case studies, given that they recently hosted some highly innovative RUA projects aimed at social inclusion, technological development and research. Among them, policies for supporting RUA have been implemented only in Paris (Paris City Council, 2018), whereas in other cities, existing regulations do not specifically target these kinds of projects (Cerón-Palma et al., 2012; Orsini et al., 2014; Freisinger et al., 2015). **Table 2** shows a summary of the main characteristics of the case studies. Barcelona is a compact Mediterranean city (Rueda, 2007; Parés et al., 2013). It has 1.6 million inhabitants in 101 km^2 and features a population density of 16,420 inhabitants/km^2 (Statistical Institute of Catalonia, 2020), being among the densest and most compact municipalities in Europe (Barcelona City Council, 2018a). The lack of land has led to exploring new ways to promote horticulture in the city, such as the RTG located on the ICTA-ICP building with a focus on research for technology innovation (Fertilecity, 2018). The city of Berlin has 3.7 million inhabitants (Berlin Business Location Center, 2019) who live over a surface of 892 km^2 (OECD, 2010) with a population density of 4,147 inhabitants/km^2 (Environmental Atlas Berlin, 2018). Today, among existing RUA projects, two rooftop gardens have a particularly social focus, whereas an RTG for applied research in botany and plant biology can be found at the Humboldt University building. Bologna is the main city of the Emilia Romagna Region, situated in northcentral Italy, and with a population of 394,463 inhabitants in 140.7 km^2, resulting in a population density of 2,802 inhabitants/km^2 (ISTAT, 2010, 2021). Paris has 2.2 million inhabitants living on a surface area of 105 km^2. This results in one of the highest urban densities in the world, reaching values in inner Paris of 20,755 inhabitants

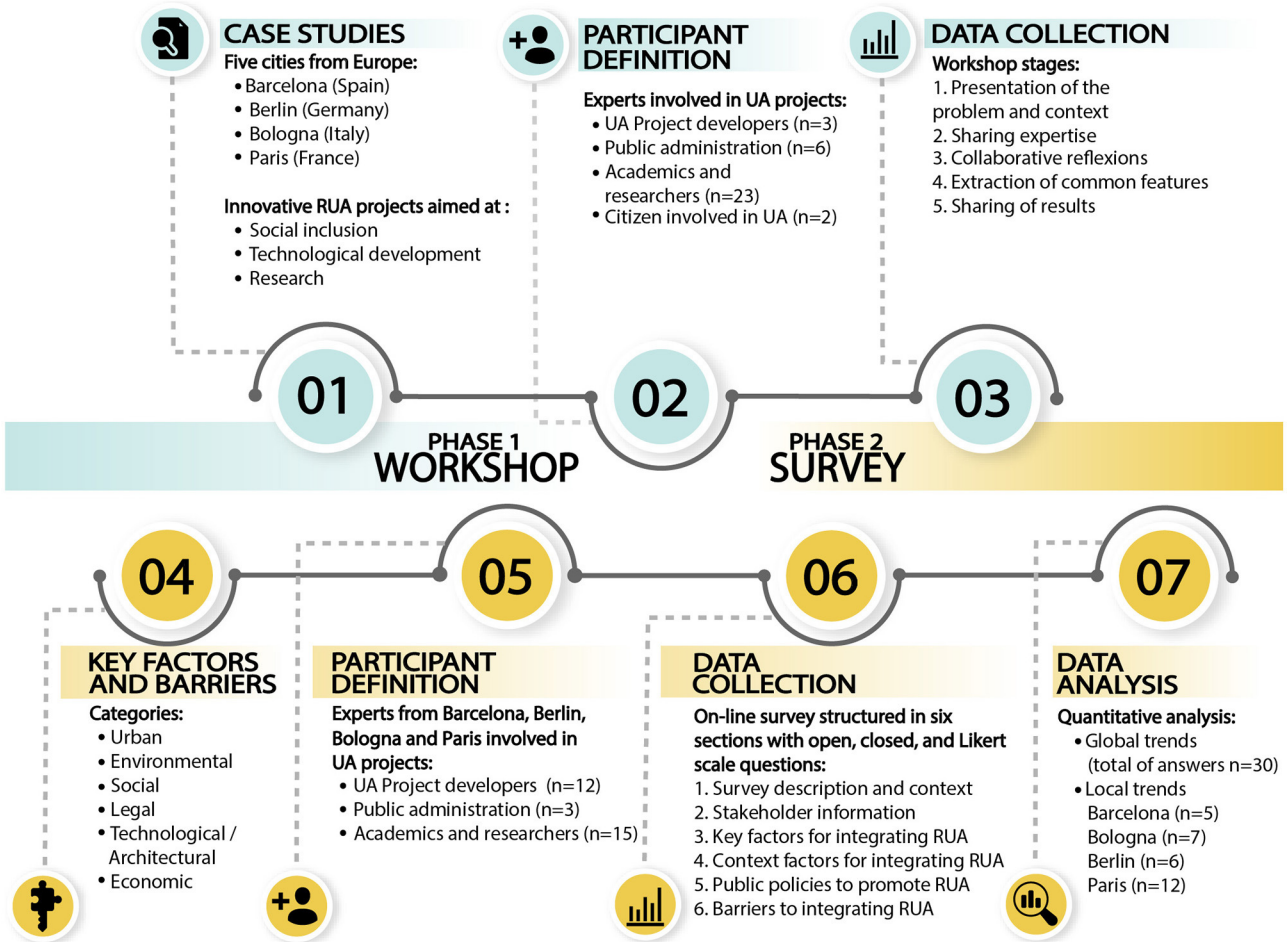

FIGURE 1 | Workflow for identifying key factors, policies and barriers in RUA projects based on stakeholder perceptions in four European cities.

TABLE 2 | Summary of cases studies.

City	Inhabitants (million)	Population density (inhabitants/km^2)	Rooftop urban agriculture projects		
			Technological development	Research	Social inclusion
Barcelona	1.6	16,420	•	•	•
Berlin	3.7	4,147		•	•
Bologna	0.4	2,802			•
Paris	2.2	20,755		•	•

per km^2 (INSEE, 2017). The City Council was recently very active in promoting projects targeting biodiversity preservation, greening, UA and food initiatives (Delgado, 2018). In 2016 and 2017, the first and second editions of the Parisculteurs program were launched, creating social inclusion and research spaces (Collé et al., 2018).

Participants' Definition

The second stage of the research consisted of the identification and classification of the UA experts to be involved. This included UA project developers (e.g., architects, agronomists), public administrators (with responsibilities in assigning municipal licenses and developing urban planning strategies), academics and researchers, and citizens involved in UA initiatives. Furthermore, relevant stakeholders from the cities of Barcelona, Berlin, Bologna, and Paris were identified and invited to define the state of the art of RUA in their cities.

Data Collection

To collect data from stakeholders, a workshop (Cerón-Palma et al., 2012) was conducted at the ICTA-ICP building (located

in Barcelona) in September 2017. During the workshop session, interventions were recorded by the workshop organizers. The five stages developed in the workshop for data collection are described below.

(1) Problem and context. The workshop began with an introduction about the problem and context of RUA panorama. This part of the workshop was presented by a member of the project team who is a lawyer specializing in environmental issues. As a second step of this phase, international speakers were presented.
(2) Sharing expertise. International experiences from Barcelona, Berlin, Bologna, and Paris were shared. The presentations set the context of key factors, policies, and barriers for integrating RUA, problems in the target domain, also RUA projects already built or in the project phase were presented. Experiences were shared by specialists on UA: from Barcelona, the Technical Director of the Municipal Institute of Urban Landscape from the Barcelona City Council; in the case of Italy, a representative from the Research Center on Urban Environment for Agriculture and Biodiversity of the University of Bologna; from Paris, a member of Agroparistech; and in the case of Berlin, a master's student enrolled in the Interdisciplinary Studies in Environmental, Economic and Social Sustainability program from the UAB.
(3) Collaborative reflections. A discussion session was held among the participants. The participants were asked to reflect and share experiences and perceptions about the following questions:
    - Which are the key factors for integrating RUA?
    - Which are the policies that promote RUA?
    - What are the barriers to integrating RUA?
(4) Extraction and grouping of features. Key factors, policies, and barriers from stages 2 and 3 were grouped.
(5) Sharing of results. Findings from the workshop were presented by the moderator of the session to all participants and final debate on the results obtained was developed.

Phase 2 Survey

The research then evolved into a survey, integrating results from phase 1 (workshop) with a comprehensive literature review. This phase comprised the four steps described below.

Key Factors and Barriers Definition

Six main categories were identified, namely, urban, environmental, social, legal, technological/architectural, and economic barriers and opportunities (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016; Specht and Sanyé-Mengual, 2017; Nadal et al., 2018).

Participants' Definition

Experts involved in UA, including project developers, public administration, academics, and citizen initiatives from Barcelona, Berlin, Bologna, and Paris, were identified and invited to participate in the survey.

Data Collection

Data collection was carried out from November to December 2017. The survey was designed to evaluate stakeholder perceptions through Likert scales that provided a range of responses to a series of statements. Five categories of responses were included (Croasmun and Ostrom, 2011), ranging from 5 to 1. The survey was structured into six sections: (1) survey description and context, (2) stakeholder information, (3) key issues for integrating RUA, (4) factors that hinder or promote RUA, (5) public policies to promote RUA, and (6) barriers to integrating RUA. Participants indicated their degree of agreement with a specific statement regarding the environmental, urban, social, legal, technological, architectural, and economic dimensions. Survey sections are further described in **Supplementary Material 1**.

Data Analysis

A quantitative analysis of the survey results was performed, enabling us to define local and global trends in the responses and overall perceptions of the stakeholders.

RESULTS

Phase 1 Workshop

The workshop was attended by 34 stakeholders, grouped by project developers (3), public administrators (6), academics (23), and those involved in citizen initiatives (2).

International Experiences of Urban Agriculture: Berlin, Bologna, Paris, and Barcelona

Figure 2 shows a summary of the results (see complete data in **Supplementary Material 2**, **Supplementary Table 1**). *Increased biodiversity, generation of green spaces, educational, research and social purposes, environmental CO_2 reduction, building energy optimization, new business generation, and new technology development* were identified as potential key factors for integrating RUA. *Urban planning, building laws, tax reduction, subsides, educational policies,* and local policies, e.g., the *Paris Climate Action Plan, Parisculteurs, and Plan Local d'Urbanisme de Paris* (Paris Local Urban Plan) from Paris and the *Primer Concurs de Cobertes Verdes* (First Green Roof Contest) from Barcelona, were identified as policies that potentially "promote" and are related to RUA. Potential barriers identified included *legal gaps, lack of a specific legal framework, building codes, administrative processes, restrictions on food sales, urban codes, health risks, historical building codes, rooftop accessibility difficulties, building designs, building structural features (overloading), high costs of infrastructure, climatic conditions, residents opposed to agricultural roofs on their buildings, lack of economic benefits, cost of water, firemen codes, food-free distribution, economic crisis, and a lack of interest by society*.

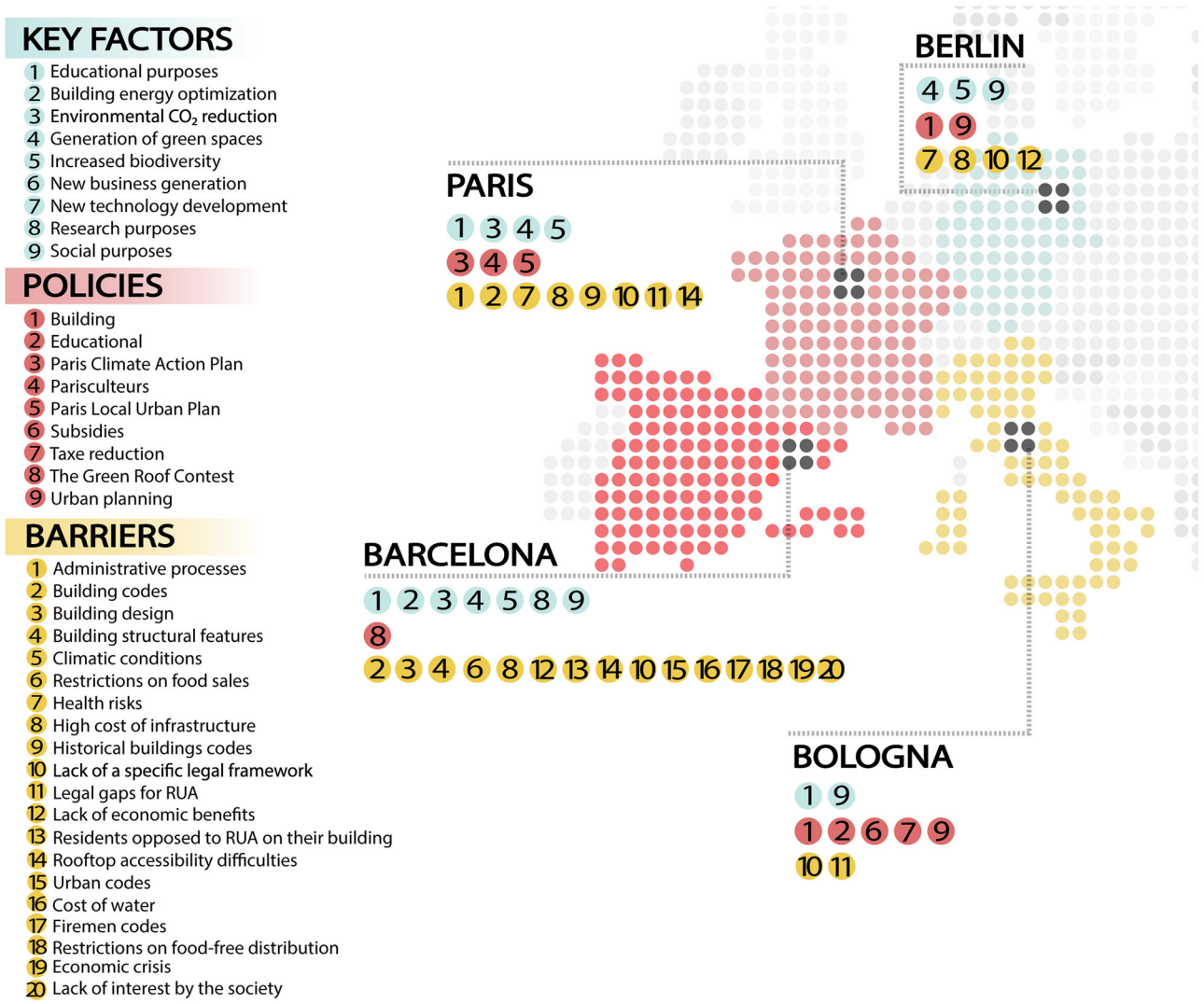

FIGURE 2 | Key factors, policies, and barriers regarding RUA projects according to stakeholder perceptions in four European cities.

Phase 2 Survey

Survey to Identify Potential Key RUA Factors and Barriers

Thirty stakeholders responded to the survey. **Figure 3** shows the distribution of participants and their field of expertise regarding UA, made up of five participants from Barcelona, seven from Bologna, six from Berlin, and twelve from Paris. Fifty percent of the respondents were academics and researchers, 40% of stakeholders were project developers, and 10% were public administrators.

Potential Key Factors for Integrating RUA

Figure 4 summarizes the key factors identified by more than 50% of participants (see all information in **Supplementary Figures**). Two factors—*educational* and *environmental*—were unanimously perceived as "relevant" by participants from Barcelona and Berlin. *Educational* factors refer to the integration of RUA as a tool for developing educational activities. *Environmental* factors include functions such as increasing biodiversity, generating green areas, reducing CO_2, and mitigating urban heat islands. *Research* from a multidisciplinary approach, including agriculture, environmental sciences, urban planning, architecture and social sciences, *technological innovation* related to new forms of UA, *food production* within city limits, and *social* functions are key factors perceived as "relevant" for integrating RUA.

Context Factors and Their Perceived Effects on RUA Diffusion

Figure 5 summarizes the contextual factors and global and local trends that hinder or promote RUA that were identified by more than 50% of the stakeholders (see all information in **Supplementary Figures**). Globally, *pollution* was the only factor identified as a condition that "hinders" RUA. Those

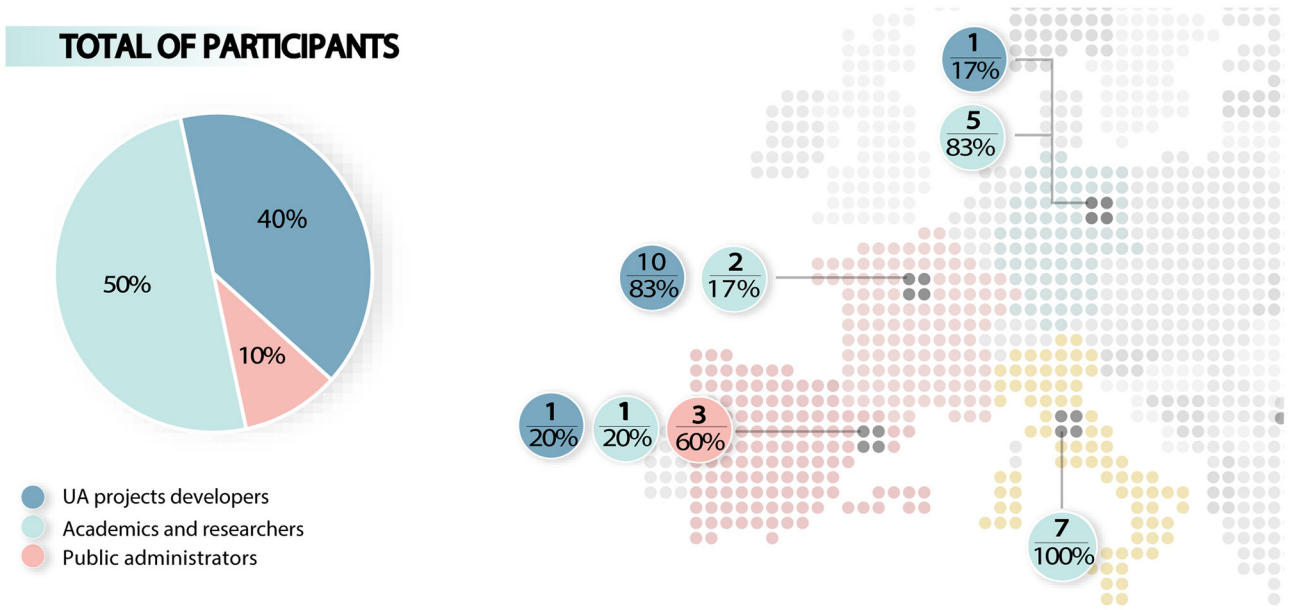

FIGURE 3 | RUA survey participants and their sectors.

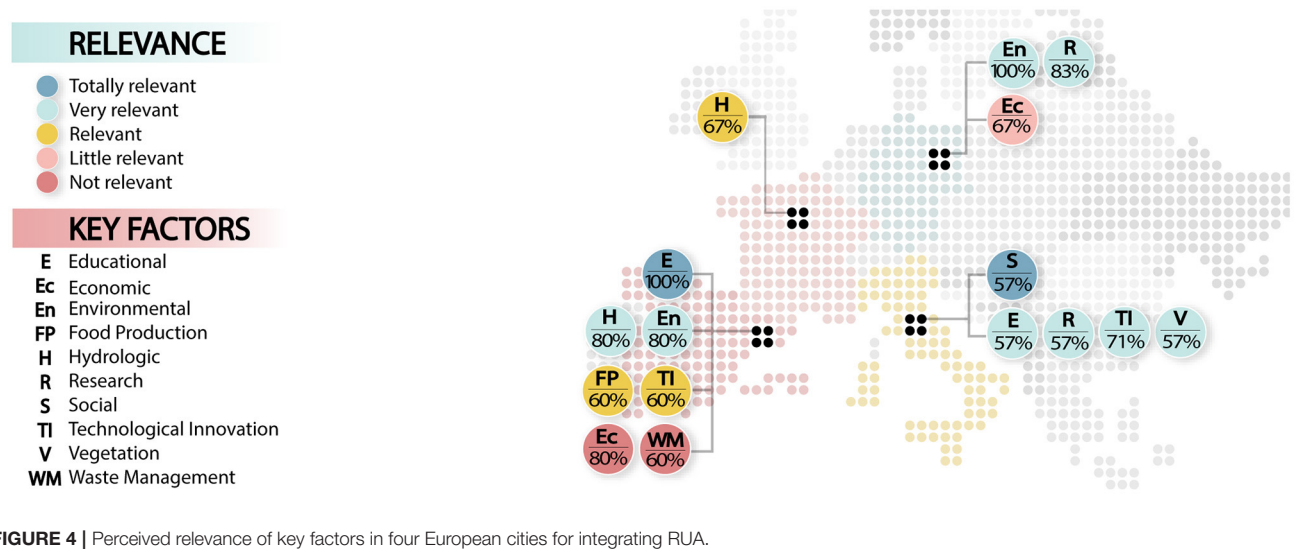

FIGURE 4 | Perceived relevance of key factors in four European cities for integrating RUA.

factors that "promote" RUA with the highest agreement (66%) among stakeholders were *cultural values* and *social rural-urban links*. Local trends showed five context factors perceived as "promoting" RUA: *productive spaces*, *cultural values*, *social cohesion*, *social rural-urban links*, and the *high cost of urban land*. The *cost of water* was perceived as a "hindering" factor to a similar degree both in Barcelona (75%) and Bologna (71%). There was some disagreement on the *pollution* factor; participants from Bologna (71%) identified it as a "promoting" factor, while participants from Barcelona and more than half from Paris (71%) identified it as a "hindering" factor.

Policies and Their Perceived Effects on RUA Diffusion

Figure 6 presents a summary of policies selected by more than 50% of participants, both globally and by city (see all information in **Supplementary Figures**). Five policies were identified in the target cities as "promoting" RUA. The *sustainability policy* obtained greater agreement (79%) among participants from all cities, followed by the *Milan Food Policy Pact* (62%). According to local trends, six policies were identified as "promoting" RUA. One was found to be common in all cities: policies targeting *sustainability*. The remaining five policies targeting *financial incentives*, the *development of new technologies*, *education*, and

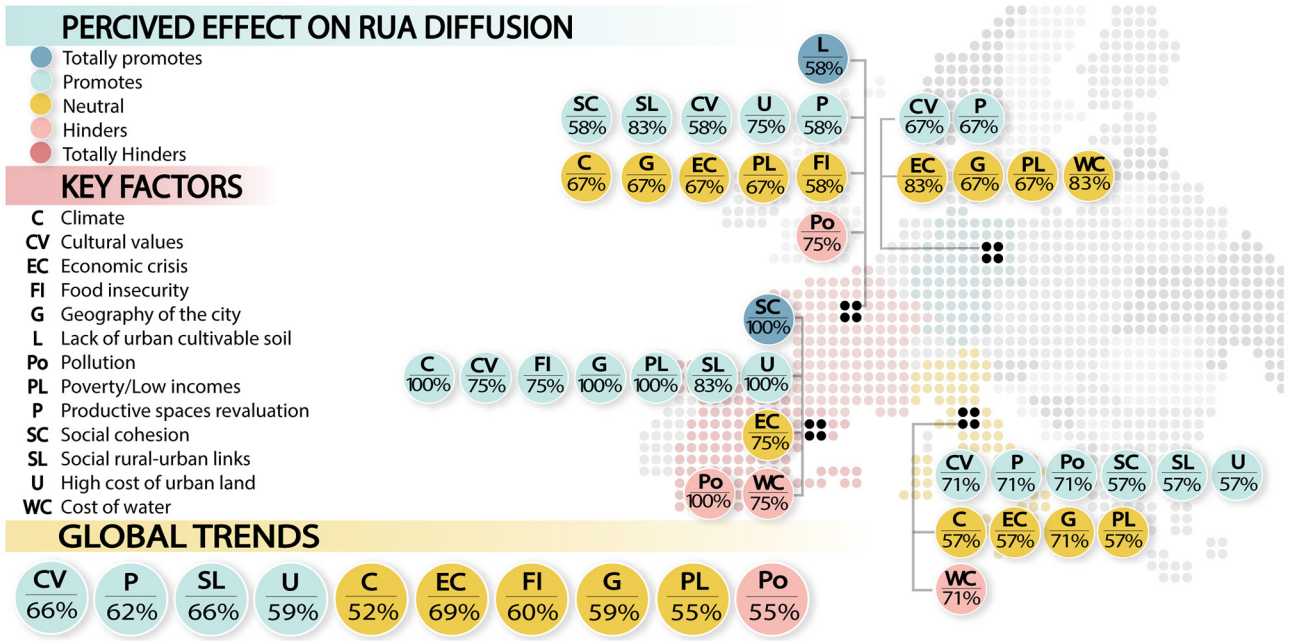

FIGURE 5 | Context factors and perceived effect on RUA diffusion in four European cities.

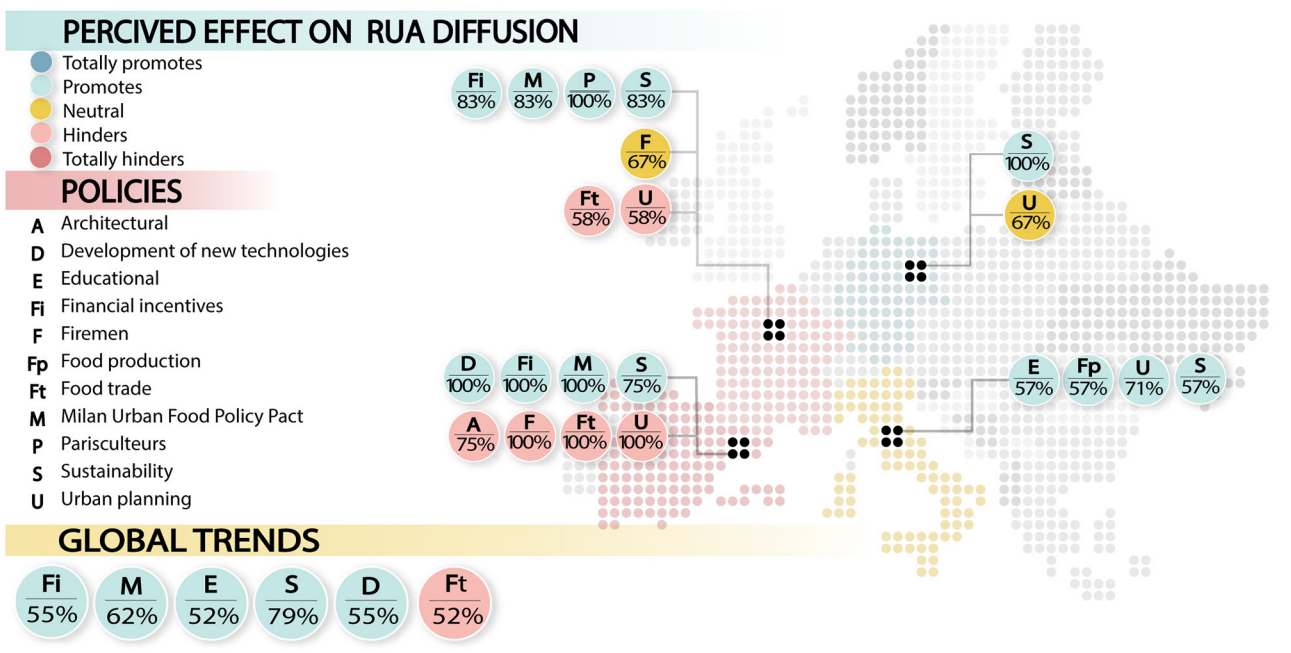

FIGURE 6 | Policies and perceived effect on RUA diffusion in four European cities.

food production, as well as the *Milan urban food policy pact* and the *Parisculteurs* program, were identified as "promoting" RUA. Policies related to *food trade* were considered to "hinder" RUA by all the participants from Barcelona and, to a lesser extent, by the participants from Paris. Policies related to *urban planning* were perceived by participants from Barcelona and Paris as "hindering" RUA and by those from Bologna as a "promoting" factor, while those from Berlin were "neutral."

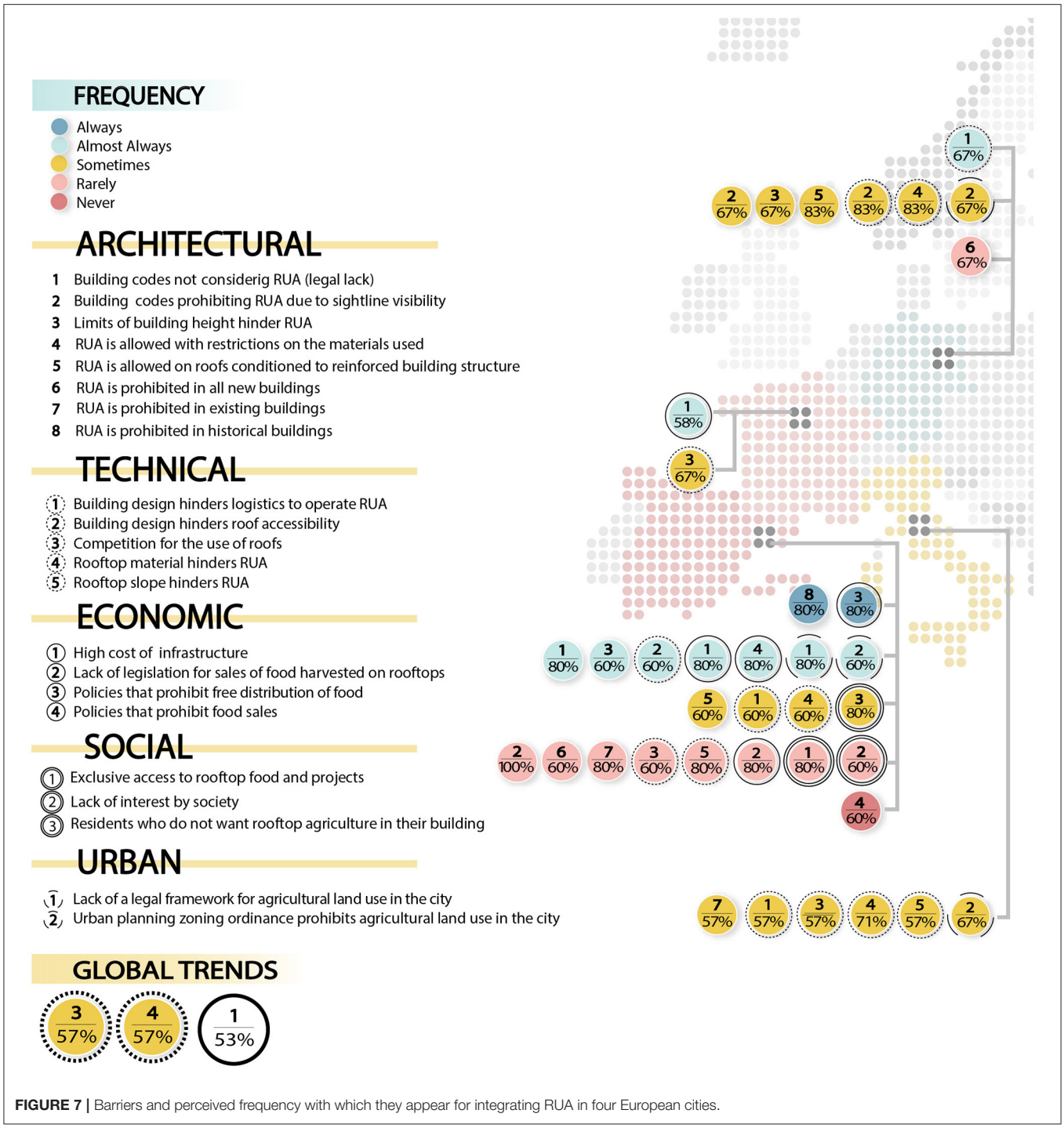

FIGURE 7 | Barriers and perceived frequency with which they appear for integrating RUA in four European cities.

Barriers for Integrating RUA

Figure 7 summarizes the barriers, and the frequency of their presence, to integrating RUA, both globally and by city. Only those barriers identified by more than 50% of participants are shown (see all information in **Supplementary Figures**). The following section presents the barriers, by category.

Architectural Barriers

There was no common architectural barrier for any of the cities studied. Three barriers were identified by stakeholders from Barcelona as factors that "always" and "almost always" hinder RUA: *prohibition in historical buildings*, *building codes that do not consider RUA* and *building height*. On the other hand, four architectural barriers were perceived as "rarely" or "never"

hindering RUA by participants from Barcelona and Berlin: that *RUA is prohibited in all new buildings*, *RUA is prohibited in existing buildings*, *RUA is allowed with restrictions on the materials used*, and *building codes that prohibited RUA due to sightline visibility* (from the rooftop to other building).

Technical Barriers

As was the case with architectural barriers, no common technical barrier was found in any of the cities. *Building design hinders logistics to operate RUA* and *building design hinders roof accessibility* were identified as "almost always" occurring by stakeholders from Berlin and Barcelona. *Sloping rooftop hinder RUA* was identified as "rarely" appearing by stakeholders from Barcelona. *Competition for the use of roofs* was identified by Paris (67%) and Bologna (57%) stakeholders as a barrier that "sometimes" appears and by participants from Barcelona (60%) as only "rarely" appearing.

Economic Barriers

The results showed that there was no economic barrier found by all cities; however, the *high cost of infrastructure* was reported as a barrier that is "almost always" present by participants from Barcelona (80%) and Paris (58%). *Policies that prohibit food sales* were reported by participants from Barcelona as a barrier that "almost always" occurs. In addition, Barcelona was the only city that identified barriers as "always" present—*policies that prohibit the free distribution of food*—and "rarely" present—the *lack of legislation for sales of food harvested on rooftops*.

Social Barriers

As in previous barrier categories, no common social barrier was found in the target cities. In this group, *exclusive access to rooftop food and projects* and *lack of interest by society* were identified as social barriers that are "rarely" present; the presence of *residents who do not want rooftop agriculture in their building* was identified by respondents from Barcelona as a barrier that "sometimes" appears.

Urban Planning Barriers

Again, in this category, no common barrier was found among all cities. However, the results showed that the *lack of a legal framework for agricultural land use in the city* was identified by stakeholders from Barcelona and Berlin as "almost always" and "sometimes" present, respectively. An *urban planning zoning ordinance that prohibits agricultural land use in the city* was perceived as "almost always" an issue by stakeholders from Barcelona.

DISCUSSION

This study has provided an exploratory overview of key factors, contextual factors, policies, and barriers associated with the integration of RUA based on stakeholders' perceptions in four European cities. It contributes to the literature on stakeholders' perceptions of RUA using a framework that can be applied extensively in EU cities. These perceptions likely shape the development of RUA agriculture practices and projects. One of the contributions was the identification of differences and similarities of four European cities. In the following sections, the most relevant factors, policies, and barriers that may promote or hinder the integration of RUA are discussed.

Potential Key Factors for Integrating RUA

Technological innovation, *food production* and *research* were factors identified in this study as relevant for integrating RUA that had not been previously reported (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016; Specht et al., 2016a; Specht and Sanyé-Mengual, 2017). This is likely due to the increasing relevance of RUA in the cities involved in the study, thanks to recent supporting policies and the development of new RUA projects, allowing stakeholders to identify both existing and new key factors. The *research* factor, scarcely addressed in the previous literature, was repeatedly mentioned, possibly as a result of the involvement of academics in the study. RUA, therefore, seems to be an opportunity for developing research projects. Other factors identified in the study that have also been previously mentioned in the literature include *environmental purpose*, *social community building* and *educational functions* of RUA (Sanyé-Mengual et al., 2016; Specht et al., 2016a). A relevant contribution concerns the perception about the *economic* factor perceived as "little relevant" (67%) by the stakeholders from Berlin and "not relevant" (80%) by participants from Barcelona, despite the proven evidence on the crucial role that economic considerations may play in the viability of RUA initiatives (Cerón-Palma et al., 2012; Specht et al., 2016a; Specht and Sanyé-Mengual, 2017).

Context Factors and Their Perceived Degree of Hindering or Promoting RUA

A relevant contribution is a perspective concerning *high urban land costs* which are perceived as a "promoting" factor of RUA. This posture is the opposite of the study conducted by Orsini et al. (2020) about urban agriculture and was not identified in previous RUA studies (Cerón-Palma et al., 2012; Specht et al., 2015, 2016a; Sanyé-Mengual et al., 2016). This finding could be due to the expansion of UA experiences in recent years. *Cultural values*, *social cohesion*, the creation of wasted areas into *productive spaces in urban areas*, and the interaction of *rural activities taking place in urban areas* rather than looking separately, showed correspondence with previous works where similar factors had been identified as opportunities for integrating UA (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016, 2018a). One difference to highlight was regarding *pollution*, perceived as both a "hindering" (Barcelona and Paris) and a "promoting" (Bologna) factor. Previous studies in Barcelona and Berlin had reported pollution as a barrier for RUA development (Sanyé-Mengual et al., 2016; Specht et al., 2016a). These differences could be associated with the field of expertise of the participants; however, this hypothesis was not addressed in this study, and a more in-depth analysis is required for its validation. The perception of RUA has been associated with health risks related to pollution, although the perceived risks have been partly negated by the results of scientific analyses (Antisari et al., 2015). According to a recent study, heavy metal concentrations in lettuce growing in open-air systems located in high-traffic areas

of Barcelona are below the EU-legislated level (Ercilla-Montserrat et al., 2018). However, research on this issue is still recent, and further empirical evidence is necessary to validate the findings in different contexts. This study further revealed that stakeholders perceived the *cost of water* as a "hindering" factor, which had not been identified previously (Cerón-Palma et al., 2012; Specht et al., 2015, 2016a; Sanyé-Mengual et al., 2016; Specht and Sanyé-Mengual, 2017; Zambrano-Prado et al., 2021). Water for irrigation of crops can be expensive in urban areas. In addition, water is an increasingly scarce resource. Different systems can be implemented to optimize water use, for example, leachate recirculation or the integration of rainwater harvesting systems. Thus, special attention and exploration of possible alternatives are needed.

Policies and Their Perceived Effects on Hindering or Promoting RUA

Policies related to *food trade* are a constraint for developing RUA. As other cities have already identified, restrictions on the sale of products from urban farms may limit products grown locally. Some cities (e.g., New York City, Chicago, Toronto) have addressed this restriction by changing policies and the zoning code (Fletcher et al., 2012). Barriers regarding *architectural* and *urban codes* were identified in this work. These findings are not new and still represent legal constraints for RUA, even in cases where UA is highly compatible with urban development strategies. A lack of consistency in various legal fields, such as hygiene and food processing laws, was reported in the previous literature. Nevertheless, major concerns refer to building laws, which are considered too strict and difficult to understand. In this sense, stakeholders perceived various uncertainties and regulatory gaps (Specht et al., 2016a). In the case of Paris, the city council has made some changes in the Paris Local Urban Plan (Paris City Council, 2018) to be more "friendly" to RUA projects. However, according to the results from this study, there is still a perception that *architecture* and *urban planning laws* "hinder" RUA development. In addition, *financial incentives*, the *development of new technologies*, *education*, *food production* and local policies such as the *Milan urban food policy pact* and *Parisculteurs* program were identified in this study as "promoting" RUA. Policies targeting the *development of new technology* not found in the previous literature (Cerón-Palma et al., 2012; Specht et al., 2015, 2016a; Sanyé-Mengual et al., 2016; Specht and Sanyé-Mengual, 2017; Zambrano-Prado et al., 2021) were also identified by the stakeholders in this study, possibly due to the involvement of academics. This finding is relevant for exploring techniques, procedures, and resource efficiencies for RUA. The importance of *educational* benefits has already been determined in the international literature (Cerón-Palma et al., 2012; Specht et al., 2015, 2016a). RUA could be integrated as an educational strategy for promoting environmental education, considering that many schools currently have meal services (Nadal et al., 2018) and, according to the main goal of The Global Education 2030, for developing sustainability competencies as a core of Education for Sustainable Development (Leicht et al., 2018). *Sustainable* benefits have also been extensively recognized (Cerón-Palma et al., 2012; Specht et al., 2015, 2016a; Sanyé-Mengual et al., 2016), although their frequency varies across cities. Contrary to a few years ago, currently in Barcelona, local environmental policies such as Barcelona's Climate Plan 2018–2030 integrate the inclusion of RUA, with the ambitious objective of reaching 34,100 m^2 of green roofs, walls, and facades by 2030. The Climate Plan 2018–2030 also includes drawing up bylaws to promote productive roofs and consolidate an annual green roof contest. In addition to developing the winning projects, which are not restricted to ornamental plants, projects could also integrate food production (Barcelona City Council, 2017). Additionally, the Paris Climate Action Plan (City of Paris, 2018) includes part of the "Objective 100 Hectares" initiative, one-third of which will be devoted to UA located on green roofs and walls (City of Paris, 2018). Differences between cities were found. This is especially true for the perceived effect of *urban policies* on RUA expansion. Assumptions for these differences could be due to the fields of expertise and personal experience with RUA. However, to confirm this hypothesis, a broader analysis is required.

Barriers for Integrating RUA

Architectural Barriers

Constraints for integrating RUA in historical buildings and the *limits on the height of buildings* according to building codes were identified in this study as barriers to RUA development but had not been reported before (Cerón-Palma et al., 2012; Specht et al., 2015; Sanyé-Mengual et al., 2016), perhaps due to the recent growth of RUA experiences. Regarding the limits on the height of buildings, since the implementation of the Parisculteurs program (Paris), the city council has changed urban regulations to allow farming on rooftops even when the building exceeds height limits (Brin et al., 2016). Nevertheless, according to stakeholders' perceptions, this barrier still applies. In Barcelona, RTGs cannot be built on some rooftops due to height/volume restrictions (Metropolitan Area of Barcelona, 2018). Among the constraints for RUA integration, it was mentioned that *building codes did not consider RUAs* and the *need for building structure reinforcement*. Indeed, building overloading and the need for reinforcement (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016) are still major barriers. Currently, many buildings may not have a suitable structure or load-bearing capacity for RUA (Toporova, 2018), which may also have economic repercussions due to the cost of building reinforcement and the need for professionals to develop and execute such projects.

Technical Barriers

Building designs to operate RUA and the *difficulties of roof access* were mentioned as factors that "constrain" RUA development. Cerón-Palma et al. (2012) also identified the complexity of adapting or renovating existing buildings; in this sense, it is essential to identify how users would access the roof spaces considering safety norms. In general, the technical adaptations necessary to operate RUA can lead to extra costs and limit the economic feasibility of projects. *Competition for integrating other systems and/or functions on roofs* is still present, as reported in previous works (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016). However, current practice demonstrates that the

integration of multiple systems/functionalities can also take place in parallel. In Barcelona, the RTG Lab Fertilecity integrates a rainwater harvesting system (RWHS) for crop irrigation, reaching 100% water self-sufficiency (Sanyé-Mengual et al., 2014). Five RUA projects recently built integrate RWHS and photovoltaic (PV) systems (Barcelona City Council, 2017). Thus, RUA, RWHS, and PV systems can coexist, providing significant benefits (Benis et al., 2018; Toboso-Chavero et al., 2018; Corcelli et al., 2019).

Economic Barriers

Regarding economic categories, stakeholders perceived that the *high cost of infrastructure* is a major barrier; previous studies also reported this constraint (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016). Such barriers can be addressed with the support of financial policies and incentives, such as those already implemented in Barcelona and Paris. However, the initial investment goes beyond the financial cost, since maintenance of this kind of infrastructure is also expensive and constitutes an additional barrier during the operation stage (Zambrano-Prado et al., 2021). Therefore, for RUA that are successful and do not turn into short-lived projects, maintenance costs beyond the initial costs must be studied and considered. *Food sales policies* are related to urban land zoning ordinances, and together with the perception of *high-cost infrastructure*, can lead investors with commercial interests to easily lose interest. If there is no specific legislation for the trade of products grown within the city, it is difficult to integrate large-scale RUA projects. Fletcher et al. (2012) recognized restrictions by municipalities on sales of locally grown products in cities. To address this barrier, some cities have made policy changes, especially in North America. In 2012, the Berkeley Planning Commission adopted the definition of "Non-Processed Edibles," which allowed the production of different kinds of food products within urban areas and their sale in residential districts (Fletcher et al., 2012).

Social Barriers

As in previous barrier categories, no common social barrier was found in the target cities. Compared to other barriers, social aspects were associated with fewer constraints. The survey revealed that *exclusive access to food growing on rooftops*, *exclusive access to developing RUA*, a *lack of interest by society in RUA projects* and *limited acceptance by residents of RUA on their building* are not frequent. However, during the workshop, stakeholders manifested their concerns about these social barriers. A risk that large companies may transform RUA into an exclusively profit-oriented (Specht et al., 2016a) initiative and, thus, aggravating social disparities in accessing systems and products (Sanyé-Mengual et al., 2016) have been identified by stakeholders in the previous literature. These risks could also be drivers of green gentrification in neighborhoods. Currently, however, this risk does not seem to be a major concern among stakeholders.

Economic Barriers

Urban planning codes that do not contemplate urban agricultural land use are still barriers. Castillo et al. (2013) identified barriers related to zoning codes, such as a lack of clear ordinances that are friendly to agriculture. In Singapore, urban planners included rooftop farms in the definition of urban green spaces and diversified the classification of agricultural land use, allowing this activity in urban areas (Diehl et al., 2020). Additionally, cities in the U.S., such as New York and Chicago, were included (The New York City Council, 2010; Urban Sustainability Exchange, 2011; City of Chicago, 2020). Of the cities involved in this study, in Barcelona, the General Metropolitan Plan does not allow agricultural activities inside the city, effectively making the commercialization of food produced in the city illegal. In the case of Paris, programs to encourage UA have been launched, which may allow agricultural activities in the city, while in Bologna, the workshop findings indicate that agricultural activities are not allowed in the city.

CONCLUSIONS

This paper explores the perceived key factors, contextual factors, policies, and barriers to integrating RUA by ranking their relevance and the frequency with which they are presented. It also revisits the concepts associated with environmental, architectural, technological, social, legal, economic, and urban planning from the perspective of stakeholders from four European cities (Barcelona, Berlin, Bologna, and Paris).

In all cities involved in the workshop, policies exist to support UA, often resulting in RUA experiences implemented by or involving local government. However, an explicit and singular public policy for RUA practices is still missing.

Major key factors that promote the development of RUA, not previously reported, include technological innovation, growing local food, research activities, and the high cost of urban land in cities. Major factors that hinder RUA were identified as the cost of water and pollution (Barcelona and Paris). The cost of water appears as a new barrier, and thus is a relevant topic for future studies and for efforts to find ways to respond to this constraint, including technological innovation, research, and policy creation. Regarding pollution, the need for disseminating proper information and conducting a deeper study on perceptions of the effects of pollution, as well as establishing quality management and quality control for crop production, are highlighted.

Policies targeting sustainability were found to be common in all cities as "promoting" factors. Currently, and contrary to some years ago, there are already policies that promote RUA for environmental purposes, such as Barcelona's Climate Plan 2018-2030 and Paris Action Climate Plan 2019. However, there is still a lack of urban, architectural, and product sales regulations for this kind of infrastructure, which continues to make the integration of RUAs difficult. Policies related to financial incentives that are generally included in city policies, the development of new technologies for crop production systems and buildings, educational programs, policies for food production within the city, such as the Milan urban food policy pact and Parisculteurs program were all identified as "promoting" RUA development. Limitations on marketing products grown within the city, as well as urban policies, continue to restrict the integration of the RUA. The inclusion of RUA in policies focused on climate change is insufficient. For the expansion and success of RUA projects,

it is necessary to consider these infrastructures in the different related codes. The creation of new legislation or modifications to support RUA is necessary, especially in the South European cities studied—Barcelona and Bologna. A flexible land use policy that allows UA in cities must be considered by urban planners as well as sales of products with production and distribution regulations. Changing regulatory barriers is a potential opportunity to create laws and programs to promote and expand RUA.

RUA faces several architectural, economic, and urban challenges that need to be addressed. The following architectural factors stand out as impediments: construction licenses in historic buildings, building codes that do not contemplate this type of infrastructure and the height limits of buildings stipulated in construction regulations, usually exceeded by RUA infrastructure. Two technical barriers were identified as major constraints: building designs that pose logistical difficulties in operating RUA and problems with roof access. In the economic category, the high cost of infrastructure and policies that prohibit food sales are major constraints. The lack of legislation regarding agricultural land use and urban zoning ordinances that prohibit agricultural activities also limit RUA integration.

Architectural and technical barriers can represent higher investment costs. Both financial incentives and business plans are needed to develop economically self-sufficient RUA projects. It was noted that access or exclusivity in projects is not a major concern. However, it is necessary to consider risks such as gentrification or commercial purposes and to study and anticipate these potential risks through legislation. The integration of urban agriculture must consider the social, educational, environmental, technological innovation and research functions that have been described as key factors for its integration in cities.

Although some differences were found between the targeted cities, these should be confirmed through more extensive research. To this end, the framework and set of statements elaborated here could be used for further data collection, allowing to analyze and characterize more stakeholder perceptions. Future research should be conducted on a larger sample of participants to confirm the empirical differences between cities.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

PZ-P: conceptualization, method design, investigation, data collection, formal data analysis, writing original draft, writing review and editing, and visualizations. FO: writing review and editing. JR: conceptualization, method design, supervision, and review the manuscript. AJ: review the manuscript. XG: conceptualization, method design, project administration, funding acquisition, and review the manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2021.733040/full#supplementary-material

REFERENCES

Alexandri, E., and Jones, P. (2008). Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. *Build. Environ.* 43, 480–493. doi: 10.1016/j.buildenv.2006.10.055

Altmann, S., Alcántara, M. S., Suhl, J., Ulrichs, C., Salazar, R., and Fitz-rodriguez, E. (2018). "Potential of urban rooftop farming in Berlin," in *DGG Tagung, BHGL Tagungsband* (Berlin).

Antisari, L. V., Orsini, F., Marchetti, L., Vianello, G., and Gianquinto, G. (2015). Heavy metal accumulation in vegetables grown in urban gardens. *Agron. Sustain. Dev.* 35, 1139–1147. doi: 10.1007/s13593-015-0308-z

Appolloni, E., Orsini, F., Specht, K., Thomaier, S., Sanyé-Mengual, E., Pennisi, G., et al. (2021). The global rise of urban rooftop agriculture: a review of worldwide cases. *J. Clean. Prod.* 296:126556. doi: 10.1016/j.jclepro.2021.126556

Armanda, D. T., Guinée, J. B., and Tukker, A. (2019). "The second green revolution: innovative urban agriculture's contribution to food security and sustainability–a review," in *Global Food Security, Vol. 22* (Amsterdam: Elsevier B.V.), 13–24.

Barcelona City Council (2017). *Primer concurso de cubiertas verdes 2017*. Available online at: https://ajuntament.barcelona.cat/ecologiaurbana/es/concurso-cubiertas-verdes/cubiertas-mosaico (accessed July 30, 2020).

Barcelona City Council (2018a). *Climate Plan 2018-2030*. Available online at: http://lameva.barcelona.cat/barcelona-pel-clima/sites/default/files/documents/eng_climate_plan_def.pdf (accessed September 20, 2019).

Barcelona City Council (2018b). *Ecología, Urbanismo, Infraestructuras y Movilidad*. Available online at: https://ajuntament.barcelona.cat/ecologiaurbana/es/noticia/barcelona-ya-tiene-cinco-huertos-urbanos-en-azoteas-municipales-gestionados-por-personas-con-discapacidad_750315 (accessed January 30, 2021).

Barcelona City Council (2020). *Barcelona será la Capital Mundial para la Alimentación Sostenible 2021*. Available online at: https://www.barcelona.cat/internationalwelcome/es/noticia/barcelona-sera-la-capital-mundial-para-la-alimentacion-sostenible-2021_864214 (accessed April 13, 2021).

Benis, K., Turan, I., Reinhart, C., and Ferrão, P. (2018). Putting rooftops to use - A Cost-Benefit Analysis of food production vs. *energy generation under Mediterranean climates. Cities* 78, 166–179. doi: 10.1016/j.cities.2018.02.011

Berlin Business Location Center (2019). *Demographic Data*. Available online at: https://www.businesslocationcenter.de/en/business-location/berlin-at-a-glance/demographic-data/ (accessed May 13, 2021).

Bilan, Y., Lyeonov, S., Stoyanets, N., and Vysochyna, A. (2018). The impact of environmental determinants of sustainable agriculture on country food security. *Int. J. Environ. Technol. Manag.* 21, 289–305. doi: 10.1504/IJETM.2018.100580

Brin, H., Fesquet, V., Bromfiel, E., Murayama, D., Landau, J., and Kalva, P. (2016). The State of Vertical Farming. Available online at: https://issuu.com/igrownews/docs/the_state_of_vertical_farming__sept (accessed January 06, 2020).

Castillo, S., Winkle, C., Krauss, S., Turkewitz, A., Silva, C., and Heinemann, E. (2013). Regulatory and other barriers to urban and peri-urban agriculture:a case study of urban planners and urban farmers from the greater chicago metropolitan area. *J. Agric. Food Syst. Commun. Dev.* 3, 155–166. doi: 10.5304/jafscd.2013.033.001

Cerón-Palma, I., Sanyé-Mengual, E., Oliver-Sol,à, J., Montero, J. I., and Rieradevall, J. (2012). Barriers and opportunities regarding the Implementation of Rooftop Eco.Greenhouses (RTEG) in mediterranean cities of Europe. *J. Urban Technol.* 19, 87–103. doi: 10.1080/10630732.2012.717685

City of Chicago (2020). *Planning and Development Urban Agriculture FAQ*. Available online at: https://www.chicago.gov/city/en/depts/dcd/supp_info/urban_agriculturefaq.html (accessed June 18, 2020).

City of Paris (2018). *Paris Climate Action Plan Towards a Carbon Neutral City and 100% Renewable Energies*. Paris: City of Paris. Available online at: https://cdn.paris.fr/paris/2019/07/24/1a706797eac9982aec6b767c56449240.pdf (accessed July 22, 2020).

Collé, M., Daniel, A. C., and Aubry, C. (2018). Call for projects "parisculteurs": catalyst for urban agriculture development on rooftops in Paris. *Acta Hortic.* 1215, 147–151. doi: 10.17660/ActaHortic.2018.1215.28

Comune di Bologna (2014). *Piano di adattamento città di Bologna: strategia di adattamento locale*. Available online at: http://www.blueap.eu/site/wp-content/uploads/2013/09/BLUEAP_Strategia_adattamento_locale.pdf (accessed February 12, 2021).

Corcelli, F., Fiorentino, G., Petit-Boix, A., Rieradevall, J., and Gabarrell, X. (2019). Transforming rooftops into productive urban spaces in the Mediterranean. An LCA comparison of agri-urban production and photovoltaic energy generation. *Resour. Conserv. Recycl.* 144, 321–336. doi: 10.1016/j.resconrec.2019.01.040

Croasmun, J. T., and Ostrom, L. (2011). Using likert-type scales in the social sciences. *J. Adult Educ.* 40, 19–22.

De Zeeuw, H., Van Veenhuizen, R., and Dubeling, M. (2011). The role of urban agriculture in building resilient cities in developing countries. *J. Agric. Sci.* 149, 153–163. doi: 10.1017/S0021859610001279

Delgado, C. (2018). "Critical keys to understand the emergence of a strong U. A. movement in Paris," in *Connections and Missing Links Within Urban Agriculture, Food and Food Systems* (Lisbon), 50–55.

Diehl, J. A., Sweeney, E., Wong, B., Sian Sia, C., Yao, H., and Prabhudesai, M. (2020). Feeding cities: Singapore's approach to land use planning for urban agriculture. https://www.sciencedirect.com/science/journal/22119124 *Glob. Food Sec.* 26:100377. doi: 10.1016/j.gfs.2020.100377

Draper, C., and Freedman, D. (2010). Review and analysis of the benefits, purposes, and motivations associated with community gardening in the United States. *J. Commun. Pract.* 18, 458–492. doi: 10.1080/10705422.2010.519682

Environmental Atlas Berlin (2018). *Population Density 2018*. Available online at: https://www.berlin.de/umweltatlas/en/land-use/population-density/2018/introduction/ (accessed April 27, 2021).

Ercilla-Montserrat, M., Muñoz, P., Montero, J. I., Gabarrell, X., and Rieradevall, J. (2018). A study on air quality and heavy metals content of urban food produced in a Mediterranean city (Barcelona). *J. Clean. Prod.* 195, 385–395. doi: 10.1016/j.jclepro.2018.05.183

European Commission and United Nations Human Settlements Programme (2016). *The State of European Cities 2016: Cities Leading the Way to a Better Future*. Brussels: European Commission.

FAO (2011). *The State of the World's Land and Water Resources for Food and Agriculture—Managing Systems at Risk*. Rome and Earthscan, London: Food and Agriculture Organization of the United Nations.

Fertilecity (2018). *Fertilecity*. Available online at: http://www.fertilecity.com/ (accessed August 27, 2018).

Fletcher, M., Rushlow, J., and Schwartz-Berky, J. (2012). Overcoming barriers to cultivating urban agriculture. *Real Estate Law J.* 41, 215–245.

Freisinger, U. B., Specht, K., Sawicka, M., Busse, M., Siebert, R., Werner, A., et al. (2015). *There's Something Growing on the roof. Rooftop Greenhouses. Idea, Planning, Implementation*. Müncheberg: Leibniz Centre for Agricultural Landscape Research (ZALF).

Gasperi, D., Pennisi, G., Rizzati, N., Magrefi, F., Bazzocchi, G., Mezzacapo, U., et al. (2016). Towards regenerated and productive vacant areas through urban horticulture: lessons from Bologna, Italy. *Sustainability* 8:1347. doi: 10.3390/su8121347

Heinberg, R., and Bomford, M. (2009). *The Food and Farming Transition: Toward a Post Carbon Food System*. Available online at: http://postcarbon.org/files/PCI-food-and-farming-transition.pdf (accessed January 25, 2020).

Hernández-Sampieri, R. (2014). *Metodología de la investigación (6th Edn.)*. Mexico: McGraw Hill.

INSEE (2017). *Comparateur de territoire département de Paris*. Available online at: https://www.insee.fr/fr/statistiques/1405599?geo=DEP-75 (accessed May 13, 2021).

ISTAT (2010). *I Censimenti Nell'italia Unita*. Available online at: https://www.istat.it/it/files/2011/01/I_Censimenti_nellItalia_unita.pdf (accessed May 13, 2021).

ISTAT (2021). *Popolazione Residente al 1/01/2021 nei Comuni Della Provincia di Bologna per Sesso ed età. Ufficio di Statistica Della Provincia di Bologna su Dati Delle Anagrafi Comunali*. Available online at: http://dati.istat.it/Index.aspx?DataSetCode=DCIS_POPRES1 (accessed January 6, 2021).

Lee, J. S., Kim, J. T., and Lee, M. G. (2014). Mitigation of urban heat island effect and greenroofs. *Indoor Built. Environ.* 23, 62–69. doi: 10.1177/1420326X12474483

Leicht, A., Heiss, J., and Byun, W. J. (2018). *Issues and Trends in Education for Sustainable Development (1st Edn.)*. Paris: United Nations Educational, Scientific and Cultural Organization.

Lovell, S. T. (2010). Multifunctional urban agriculture for sustainable land use planning in the United States. *Sustainability* 2, 2499–2522. doi: 10.3390/su2082499

Martellozzo, F., Landry, J.-S., Plouffe, D., Seufert, V., Rowhani, P., and Ramankutty, N. (2014). Urban agriculture: a global analysis of the space constraint to meet urban vegetable demand. *Environ. Res. Lett.* 9:064025. doi: 10.1088/1748-9326/9/6/064025

Metropolitan Area of Barcelona (2018). *Urban Planning and Building Codes*. Available online at: https://www.amb.cat/en/web/territori/gestio-i-organitzacio/numamb (accessed August 7, 2020).

Mor, Y., Warburton, S., and Winters, N. (2012). Participatory pattern workshops: a methodology for open learning design inquiry. *Res. Learn. Technol.* 20, 163–175. doi: 10.3402/rlt.v20i0.19197

Nadal, A., Oriol, P., Cuerva, E., Rieradevall, J., and Josa, A. (2018). Rooftop greenhouses in educational centers: a sustainability assessment of urban agriculture in compact cities. *Sci. Total Environ.* 626, 1319–1331. doi: 10.1016/j.scitotenv.2018.01.191

OECD (2010). *Higher Education in Regional and City Development Berlin, Germany*. Available online at: https://www.oecd.org/education/imhe/46006840.pdf (accessed May 13, 2021).

Ørngreen, R., and Levinsen, K. (2017). Workshops as a research methodology. *Electron. J. E-Learn.* 15:70.

Orsini, F., Gasperi, D., Marchetti, L., Piovene, C., Draghetti, S., Ramazzotti, S., et al. (2014). Exploring the production capacity of rooftop gardens (RTGs) in urban agriculture: the potential impact on food and nutrition security, biodiversity and other ecosystem services in the city of Bologna. *Food Sec.* 6, 781–792. doi: 10.1007/s12571-014-0389-6

Orsini, F., Pennisi, G., Michelon, N., Minelli, A., Bazzocchi, G., Sanyé-Mengual, E., et al. (2020). Features and functions of multifunctional urban agriculture in the global north: a review. *Front. Sustain. Food Syst.* 4:562513. doi: 10.3389/fsufs.2020.562513

Palmer, A., Santo, R., and Brent, K. (2016). *Vacant Lots to Vibrant Plots: A REVIEW of the Benefits and Limitations or Urban Agriculture*. Baltimore, MD: Johns Hopkins Bloomberg School of Public Health.

Parés, M., March, H., and Saur,í, D. (2013). Atlantic gardens in mediterranean climates: understanding the production of suburban natures in Barcelona. *Int. J. Urban Reg. Res.* 37, 328–347. doi: 10.1111/j.1468-2427.2012.01118.x

Paris City Council (2018). *Plan Local d'Urbanisme de Paris*. Available online at: http://pluenligne.paris.fr/plu/sites-plu/site_statique_50/pages/page_1070.html (accessed August 13, 2020).

Pennisi, G., Magrefi, F., Michelon, N., Bazzocchi, G., Maia, L., Orsini, F., et al. (2020). Promoting education and training in urban agriculture building on international projects at the research centre on urban environment for agriculture and biodiversity. *Acta Hortic.* 1279, 45–51. doi: 10.17660/ActaHortic.2020.1279.7

Roehr, D., and Kunigk, I. (2009). Metro vancouver: designing for urban food production. *Berkeley Plann. J.* 22, 61–70. doi: 10.5070/BP322 15359

Rueda, S. (2007). *Barcelona, a Compact and Complex Mediterranean City. A More Sustainable Vision for the Future*. Available online at: http://bcnecologia.es/en/publications/barcelona-compact-and-complex-mediterranean-city-more-sustainable-vision-future (accessed August 6, 2020).

Sanyé-Mengual, E., Anguelovski, I., Oliver-Solà, J., Montero, J. I., and Rieradevall, J. (2016). Resolving differing stakeholder perceptions of urban rooftop farming in Mediterranean cities: promoting food production as a driver for innovative forms of urban agriculture. *Agric. Human Values* 33, 101–120. doi: 10.1007/s10460-015-9594-y

Sanyé-Mengual, E., Cerón-Palma, I., Oliver-Solá, J., Montero, J. I., and Rieradevall, J. (2013). Environmental analysis of the logistics of agricultural products from roof top greenhouses in mediterranean urban areas. *J. Sci. Food Agric.* 93, 100–109. doi: 10.1002/jsfa.5736

Sanyé-Mengual, E., Llorach Massana, P., Sanjuan Demás, D., Oliver-Solà, J., Josa Garcia-Tornel, A., Montero, J. I., et al. (2014). "The ICTA-ICP Rooftop Greenhouse Lab (RTG-Lab): closing metabolic flows (energy, water, CO2) through integrated Rooftop Greenhouses," in *Finding Places for Productive Cities. Proceedings of 6th International AESOP Sustainable Food Planning Conference*. 693–701.

Sanyé-Mengual, E., Orsini, F., and Gianquinto, G. (2018a). Revisiting the sustainability concept of Urban Food Production from a stakeholders' perspective. *Sustainability (Switzerland)* 10:2175. doi: 10.3390/su100 72175

Sanyé-Mengual, E., Specht, K., Krikser, T., Vanni, C., Pennisi, G., Orsini, F., et al. (2018b). Social acceptance and perceived ecosystem services of urban agriculture in Southern Europe: the case of Bologna, Italy. *PLoS ONE* 13:e0200993. doi: 10.1371/journal.pone.0200993

Specht, K., and Sanyé-Mengual, E. (2017). Risks in urban rooftop agriculture: assessing stakeholders' perceptions to ensure efficient policymaking. *Environ. Sci. Policy* 69, 13–21. doi: 10.1016/j.envsci.2016.12.001

Specht, K., Siebert, R., Thomaier, S., Freisinger, U. B., Sawicka, M., Dierich, A., et al. (2015). Zero-Acreage farming in the city of Berlin: an aggregated stakeholder perspective on potential benefits and challenges. *Sustainability (Switzerland)* 7, 4511–4523. doi: 10.3390/su7044511

Specht, K., Siebert, R., and Thomaieres, S. (2016a). Perception and acceptance of agricultural production in and on urban buildings (ZFarming): a qualitative study from Berlin, Germany. *Agric. Human Values* 33, 753–769. doi: 10.1007/s10460-015-9658-z

Specht, K., Zoll, F., and Siebert, R. (2016b). Application and evaluation of a participatory "open innovation" approach (ROIR): The case of introducing zero-acreage farming in Berlin. *Landsc. Urban Plan.* 151, 45–54. doi: 10.1016/j.landurbplan.2016.03.003

Specht, K., Zoll, F., Schümann, H., Bela, J., Kachel, J., and Robischon, M. (2019). How will we eat and produce in the cities of the future? from edible insects to vertical farming—a study on the perception and acceptability of new approaches. *Sustainability* 11:4315. doi: 10.3390/su11164315

Statistical Institure of Catalonia (2020). *El municipio en cifras. Barcelona*. Available online at: https://www.idescat.cat/emex/?id=080193andlang=es (accessed May 15, 2020).

Susca, T., Gaffin, S. R., and Dell'Osso, G. R. (2011). Positive effects of vegetation: urban heat island and green roofs. *Environ. Pollut.* 159, 2119–2126. doi: 10.1016/j.envpol.2011.03.007

Tao, P., Yi Meng, W., Diebel, C., Wenye, G., Yi Heng, C., Sternfeld, E., et al. (2020). *Urban Farming Incubator Guide to Urban Farming in Shanghai and Berlin*. Berlin: Citymakers Urban Farming Incubator.

Taylor, L., and Hochuli, D. F. (2017). Defining greenspace: multiple uses across multiple disciplines. *Landsc. Urban Plan.* 158, 25–38. doi: 10.1016/j.landurbplan.2016.09.024

The New York City Council (2010). *FoodWorks: A Vision to Improve NYC's food system*. Available online at: http://growingfoodconnections.org/gfc-policy/foodworks-a-vision-to-improve-nycs-food-system/ (accessed October 10, 2019).

Thomaier, S., Specht, K., Henckel, D., Dierich, A., Siebert, R., Freisinger, U. B., et al. (2015). Farming in and on urban buildings: present practice and specific novelties of zero-acreage farming (ZFarming). *Renew. Agric. Food Syst.* 30, 43–54. doi: 10.1017/S1742170514000143

Toboso-Chavero, S., Nadal, A., Petit-Boix, A., Pons, O., Villalba, G., Gabarrell, X., et al. (2018). Towards productive cities: environmental assessment of the food-energy-water nexus of the urban roof mosaic. *J. Ind. Ecol.* 23, 767–780. doi: 10.1111/jiec.12829

Toporova, J. (2018). *Growing in Cities Rooftop Urban Agriculture for Sustainable Cities*. Stockholm: KTH Royal Institute of Technology.

United Nations (2018). *World Urbanization Prospects: The 2018 Revision-Key Factors*. New York, NY: United Nations.

Urban Sustainability Exchange (2011). *Urban Agriculture Ordinance, City of Chicago*. Available online at: https://use.metropolis.org/case-studies/urban-agriculture-ordinance-city-of-chicago (accessed July 18, 2020).

Vittuari, M., Bazzocchi, G., Blasioli, S., Cirone, F., Maggio, A., Orsini, F., et al. (2021). Envisioning the future of European food systems: approaches and research priorities after COVID-19. *Front. Sustain. Food Syst.* 5:642787. doi: 10.3389/fsufs.2021.642787

Zambrano-Prado, P., Pons-Gum,í, D., Toboso-Chavero, S., Parada, F., Josa, A., Gabarrell, X., et al. (2021). Perceptions on barriers and opportunities for integrating urban agri-green roofs: a European Mediterranean compact city case. *Cities* 114:103196. doi: 10.1016/j.cities.2021.103196

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