Urban agriculture in the framework of sustainable urbanism

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Doctoral thesis

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Chapter 3

Research questions, motivations & objectives

CHAPTER 3 - Research questions, motivation and objectives

3.1. Research questions

The origin of urban agriculture is as old as the constitution of cities. Currently, it is a great ally for the sustainable development of cities and is developed in different typologies or modalities around the world. This includes both developed and developing countries (the global North and global South), in which their use responds to diverse and varied needs according to the context. Although globally it contributes to the social, environmental and economic system, it is its particularities in each of the regions that characterize its development.

Given this, the research questions and the objectives of this dissertation are grouped according to the region in which they are developed: developed countries and developing countries.

- Developed countries

Within the framework of developed countries cities, in a context characterized by the lack of space, a constant demand for food - coming mostly from rural areas - and where urban agriculture is promoted as a strategy for urban sustainability, vertical urban agriculture typology grows day by day and it adapts to meet the population's needs (social, environmental and economic) and requirements. In the case of rooftop greenhouses, if they are interconnected to the building, they allow the exchange of the residual flows of water, energy, CO_2 and food. In recent years, some tools have been developed in order to implement this typology of urban agriculture within compact cities.

Therefore, the following research questions are suggested:

5. **Can the integration of a greenhouse on the rooftop of a building, taking advantage of its exchange of residual thermal flows, contribute technologically and architecturally to the development of urban agriculture?**

6. **To what extent do urban-architectural, social and sustainable tools contribute to assessing the potential for implementation of agriculture on roofs of existing buildings in cities in southern Europe?**

- Developing countries

Currently, Latin America and the Caribbean is going through a process of urban expansion that impacts (among many aspects) in the loss of natural resources, the transformation of land into artificial surfaces and the family economy, limiting the ability of families to access nutritious food. In this sense, urban agriculture is a strategy to support food security in the region.

Therefore, the following research questions are suggested:

7. **What is the current panorama of urban agriculture in developing countries in Latin America and the Caribbean?**

8. **What are the implications of urban planning and social housing in the promotion of urban agriculture for the sustainability of the medium-sized Latin American city?**

3.2. Motivation and objectives

3.2.1. General objective

Urban agriculture (UA) is part of the strategies to solve the problems caused by urban development and growth, both at the environmental and food safety levels. Nowadays, it has become increasingly important as a means to contribute to the sustainability of cities, to food supply, to consumption of nutritious foods and to family economy, among other benefits -as described in the introduction. But despite this, there are still many aspects that need to be analyzed in detail.

The objective of this dissertation is to analyze and propose technological, urban-architectural and social strategies for the development of urban agriculture at neighborhood and building scale for the improvement of sustainability and food security in developing countries (Latin-America; Mexico, Ecuador) and in developed countries (Mediterranean; Spain).

3.2.2. Specific objectives

- Developed countries

Inside vertical agriculture modality, rooftop greenhouse (RTG) is a typology that allows to grow food on roofs of buildings under the cover (protection) of a greenhouse. When the rooftop greenhouse is interconnected with the host building, it can interchange energy, water, and CO_2 residual flows and is called Integrated rooftop greenhouse (iRTG). iRTG is a novel strategy and although there are researches that address its different advantages (Cerón-Palma et al., 2012b; Sanyé-Mengual et al., 2015c; Specht et al., 2014), they do not address, in particular, their energetic behavior.

Although it is known that conventional greenhouses -in land- allow raising the productivity of the crop by controlling the environmental conditions (with respect to a crop without greenhouse), it is also known the high energy consumption to achieve it (Kittas et al., 2014, 2012). In this point, it is necessary to know the thermal performance of rooftop greenhouses compared to conventional greenhouses, since the characteristic of being on a building can influence its environmental conditions and the residual energy flows. This influence of the building on the greenhouse (and vice versa), as well as the energy flows that are established between both systems, can be particularly useful and has been little studied. For what it is necessary to study if rooftop greenhouses (integrated) have some representative (relevant) energy advantage over conventional greenhouses and, if so, to quantify and analyze it.

Having a rooftop greenhouse located in a building with a scientific research use in Bellaterra, Barcelona (ICTA-ICP building of the Universitat Autònoma de Barcelona), as a case study.

Specific objective 1: To Report the measured annual data that outlines the symbiosis between the integrated rooftop greenhouse (iRTG) and the building in energy terms and using computer simulation to quantify the heating energy that iRTG passively and actively recycles in a year.

Despite the positive results that rooftop greenhouses can generate, physical space is key to its development -mainly in compact cities. And in a context of high land surplus value, there is a need to develop tools and methodologies that allow the identification of roofs that have the adequate characteristics to develop a greenhouse. In this sense, there are investigations that successfully address this problem through the use of secondary information and agronomic, legal and urban requirements, expressed through a step-by-step guide (Sanyé-Mengual et al., 2015a). But it turns out to be a long and complicated process. Therefore, it is necessary to explore the use of technologies that allow the acquisition of first-hand, current data, quickly, efficiently and accurately, supporting decision-making in urban planning and in the rehabilitation of architectural spaces.

Specific objective 2: To develop and validate a semi-automated procedure to identify the feasibility and quantify areas of roofs for the implementation of greenhouses in urban non-residential areas in Barcelona using data from airborne sensors, and to identify opportunities and barriers for the application of this procedure in different real cases.

But it is not enough to identify and quantify the optimum spaces for the development of rooftop greenhouses. It is necessary to be able to make objective decisions about the choice of the best site for its implementation based on economic, environmental and social aspects. Therefore, it is necessary to promote research that allows multicriteria analysis based on what is the most sustainable option for such work, since currently, the available possibilities are limited.

Based on results of objective two, this one extends the requirements for greenhouse implementation in cities, considering the social aspect.

Specific objective 3: To develop a procedure to assess the potential installation of rooftop greenhouses (RTGs) in a Mediterranean coastline compact city taking as a practical case the selection of schools RTGs in the city of Barcelona.

- Developing countries

Urban agriculture does not develop on the same form, scale (city, neighborhood, building), nor with the same objectives and with the same typologies in all the world. Latin American and Caribbean cities (LAC) have undergone a considerable metamorphosis since they were founded, and now face serious problems of poverty, food insecurity, and destruction of nature. Although UA has been strengthening as part of the strategy to solve these problems - through international aid programs and municipal strategies - there are not studies that identify the functions that UA performs in this region and which are the areas of scientific interest in this subject, that allow to visualize its future development.

Based on a systematic review of scientific literature.

Specific objective 4: (i) To identify the main functions of urban and peri-urban agriculture (UPA) in Latin-America and Caribbean (LAC) countries reported in the scientific literature; (ii) to compare the existing research gaps with current legal and cooperation strategies seeking to stimulate further development of UPA; and (iii) to determine whether literature on UPA is paying attention to the situation of countries prone to natural hazards and socio-political emergencies in LAC.

Usually, traditional orchards are the most popular UA typology in the region. And an unexplored point of UA in LAC is vertical agriculture, and specifically, studies that quantify its potential for that context. So, it is interesting to explore whether vertical or more technological agriculture is viable in this area. Since LAC region grows largely due to the development of social housing, it is even more interesting to explore those viability in it.

Supported, in part, in the criteria developed in the specific objectives 2 and 3 of the present thesis.

Specific objective 5: To identify the potential of implementation of rooftop greenhouses in the social neighborhoods of Latin America, taking as a case study the city of Quito in Ecuador.

Emphasizing the above, LAC cities continue to grow by leaps and bounds, expanding their borders through the construction of social housing. But despite being a current and important phenomenon, the relationship between social housing and urban agriculture as a means to sustainable development is not addressed as a research topic in the region. Having explored the potential for urban agriculture (in rooftop greenhouse typology in social housing), it is necessary to deepen the vision that users have on this topic in general.

Specific objective 6: To identify and understand the relationship between the role of urban agriculture (UA) in social housing neighborhoods in Latin America and the perceptions of stakeholders about current and future developments in UA with specific application in Mexico as case study.

After exploring the vision of users of social housing and exposing the relationship between housing and the development of urban agriculture in the LAC region, it is imperative to continue investigating at a more detailed level to understand the implications of this relationship.

Specific objective 7: To expose the relationship between the social patterns of the inhabitants and the characteristics of social housing with respect to the models of urban agriculture developed in the neighborhoods of social housing with specific application, again, in Mexico as case study.

In view of this, the present dissertation focuses on covering these research gaps, contributing to improve knowledge for the support of urban sustainability and food security in cities of developed and developing countries, through the analysis of UA.

Research questions	Specific objectives						
	1	2	3	4	5	6	7
Can the integration of a greenhouse on the rooftop of a building, taking advantage of its exchange of residual thermal flows, contribute technologically and architecturally to the development of urban agriculture?	●						
To what extent do urban-architectural and social tools contribute to assessing the potential for implementation of agriculture on roofs of existing buildings in cities in southern Europe?		●	●				
What is the current panorama of urban agriculture in developing countries in Latin America and the Caribbean?				●			
What are the implications of urban planning and social housing in the promotion of urban agriculture for the sustainability of the medium-sized Latin American city?					●	●	●

Chapter 4

Methodology

CHAPTER 4 - Methodology

This chapter presents the methodological framework of this dissertation, which is divided into assessment procedures and case studies, and involves architectural, geographical, social and sustainable tools.

4.1. Method overview

The thesis focuses on the close relationship between city and agriculture, which are complex and multidisciplinary issues. Therefore, it is necessary the use of different methods and approaches to be able to understand the relationship between both of them. Interdisciplinary methodological framework is proposed (Table 4.1), that includes architectural, geographical, social and sustainable development tools. Also, secondary data, experimental and field work are presented in almost all chapters of the dissertation.

Table 4.1 Overview of the methods applied in each part and chapter of the dissertation

Sections			Procedure approach					Experimental and field work
			Architectural	Geographical	Social	*Sustainable development	Documentation review	
PART 2	Chapter 5	Building-integrated rooftop greenhouses: An energy and environmental assessment in the Mediterranean context	●					●
PART 2	Chapter 6	Urban planning and agriculture. Methodology for assessing rooftop greenhouse potential of non-residential areas using airborne sensors		●			●	●
PART 2	Chapter 7	Rooftop greenhouses in educational centers: A sustainability assessment of urban agriculture in compact cities		●	●	●	●	●
PART 3	Chapter 8	Urban agriculture in Latin America and the Caribbean: what do we know so far?					●	
PART 3	Chapter 9	Feasibility assessment of rooftop greenhouses in Latin America. The case study of a social neighborhood in Quito, Ecuador		●			●	
PART 3	Chapter 10	Social perception of urban agriculture in Latin-America. A case study in Mexican social housing			●		●	●
PART 3	Chapter 11	Social-housing model influence in social perception of urban agriculture in México			●		●	●

*Multi-Criteria Decision Making tool

Chapter 5 presents an architectural approach, exposing the annual thermal behavior of the ICTA-iRTG and describing the symbiosis between the iRTG and the building in terms of energy. In chapter 6, under a geographical approach, a guide for the identification of roofs with potential for the implementation of rooftop greenhouses in non-residential buildings making use of airborne sensors is proposed. Chapter 7 takes up the guide presented in chapter 4 and uses the MIVES methodology (Viñolas et al., 2009a) and tool to evaluate -from a sustainability perspective- the possible installation of rooftop greenhouses in Mediterranean schools.

Through a documentary review, chapter 8 focuses on identifying the main functions of urban and peri-urban agriculture in Latin America and the Caribbean, thus introducing the research section developed in those geographical areas. Using geographic information systems (GIS) and the guidance developed in chapter 6, identification of the potential for the development of rooftop greenhouses in Quito (Ecuador) is discussed in chapter 9. For its part, chapters 10 and 11 present a social approach and focus on the social perception that social housing inhabitants have in Mérida (Mexico) regarding the relationship between urban and peri-urban agriculture and housing, for which tools of social science research are used.

4.2.Materials and methods

Figure 4.2 shows the materials and methods used in each chapter, in data collection and analysis stages. Specific methods are used in each chapter. For this reason, experimental and analytical methods are described more in depth in each chapter.

Table 4.2 Materials and Methods applied in each part and chapter of the dissertation

	Procedure approach	Classification	Materials / Methods	PART 2 Chapter			PART 3 Chapter			
				5	6	7	8	9	10	11
Data acquisition	Architectural	Weather and indoor climate conditions monitoring sensors	Air and surface temperature sensor	●						
			Humidity sensor	●						
			Temperature & humidity sensor	●						
			Pyranometer	●						
	Geographical	Airborne hyperspectral sensors	TASI-600 airborne sensor		●					
			Leica ALS50-II airborne sensor		●					
	Social	Social data collection	Semi-structured interview			●			●	
			Structured interview							●
			Documentation review	●	●	●	●	●	●	●
			Focus group			●				
	Social	On site data collection	Sketch on site		●					
			Qualitative observation						●	●
	Social/ Geographical		Photographic documentation		●				●	●
	Social/ Geographical/Sustainable development		On site visit		●	●			●	●
	Architectural		On site monitoring	●						
Data analysis	Social	Social data analysis	Coding				●		●	●
			Descriptive statistic				●		●	●
	Architectural	Softwares	Design Builder + Energy Plus (E+)	●						
			Siemens control software	●						
			Campbell data acquisition system	●						
	Geographical		ArcGis					●		
			QGIS		●					
	Social		Microsoft Excel				●		●	
			Statistical Package for the Social Sciences (SPSS)						●	●
	Sustainable development		MIVES			●				

4.2.1.Description of tools

Below, the most significant instruments indicated in section 4.2 of this methodology, will be introduced. Further details are provided in each study system, in the following chapters.

4.2.1.1.Architectural

- DesignBuilder: The energy simulation software "DesignBuilder" (DesignBuilder Software Ltd, 2016a) is used in chapter 5 to quantify the thermal flow between the rooftop greenhouse (ICTA-iRTG) and the ICTA-ICP building. To generate the geometric model, the dimensions, the thermo-physical properties of the rooftop greenhouse construction materials, the thermal loads and the building operation regimes were introduced in the software. Then, the complete model was used for the Design Generator to create the input data file (IDF) for the EnergyPlus (E +) engine (DesignBuilder Software Ltd, 2016b), which allowed the detailed energy simulation.

  In chapter 5, more information is provided. And for additional details, DesignBuilder Software Ltd website at https://designbuilder.co.uk/ and the online help supplied at http://files.designbuilder.cl/200000040-92fe693f9f/ManualDB-Espa%C3%B1ol_2014-12-03.pdf can be visited.

- Siemens control system: The Siemens control (© Siemens AG, 2018) operating software of the ICTA-ICP building allows the management of the thermal conditions of the greenhouse based on the requirements of the crop by means of the regulation of the opening or closing of the windows and the roof, of various thermal curtains as well as through the introduction of ventilation air (from other spaces of the building) in the rooftop greenhouse . The Siemens control system sets the performance of the greenhouse depending on the environmental conditions of the ICTA-iRTG, the rest of the building and the outdoor. This system improves continuously with the incorporation of real-time data for automatic decision-making according to the ideal requirements for the development of user activities. For the acquisition of data, the building has different sensors and probes for temperature, humidity, air quality, solar radiation and air speed, among others, distributed indoors and a weather station outside. All the sensors have been previously calibrated by Siemens company.

  In chapter 5, more detailed information is provided. For more information, see Appendix 1.1. PNT Energy and the online information at https://www.siemens.com/global/en/home/products/buildings.html

- Campbell data acquisition system: The Campbell system of continuous data acquisition is made up of various sensors of air and surface temperature, humidity, solar radiation, air quality and pH and conductivity of irrigation water; which are programmed and the data collected through the support software package of the Campbell datalogger. This software allows the generation of operational programs for the datalogger, the communication of PC and datalogger and the visualization of values at real time or historical data. It is made up of the Short Cut and PC200W softwares. The Short Cut program generator is the software by means of which the operation programs for the datalogger are created. The PC200W software allows to adjust the logger's clock, load programs to the logger and monitor and download logger data.

  In chapter 5, more detailed information is provided. For additional information the Campbell website at https://www.campbellsci.es/datalogger-software can be visited.

4.2.1.2.Geographical

Geographic Information Systems (GIS) is a collection of software, hardware, and data which operates in an institutional context for the processing and analysis of spatial data that supports decision making in different activities and areas (Maguire and Dangermond, 1991). GIS is used for diverse applications and is a tool widely used in environmental research, specifically in the field of urban agriculture. For instance, Sanyé-Mengual et al. (2015) uses it to generate a database to quantify the potential of urban agriculture on rooftops in the Zona Franca industrial park of Barcelona. Berger (2013) analyzes the potential of urban agriculture on rooftops (in farms rooftops, greenhouses and intensive green roofs modalities) of the North Brooklyn Industrial Business Zone (New York) through a GIS analysis. La Rosa et al. (2014) presents a Multiple Criteria Suitability Model based on GIS for the characterization of the non-urbanized areas of Catania (Italy), in terms of physical, ecological and social characteristics, to improve its ecological and social function, as well as its accessibility and general connectivity. Luo et al.(2011) analyzes in China the use of GIS technology and Google Earth to assess the environmental impact and energy savings generated by green roofs.

Geographic information systems were used in the present dissertation for . urban planning data analysis:

- For identification of roofs with potential for the implementation of greenhouses in the industrial area of Rubí (Barcelona, Spain) and in social housing in Quito (Ecuador). Also, for analysis of roof dimensions in elementary education centers in Barcelona (Spain) (in chapters 6, 7 & 9 more detailed information is provided).
- For analysis of spatial data referring to roofs slope, dimensions, solar radiation and shadows (in chapters 6, 7 & 9 more detailed information is provided).
- For identification and generation of data referring to spectral profiles of different roofing materials (in chapter 6 more detailed information is provided).

In general, databases used were developed in three steps:

1. Base: Orthophoto, consultation of available maps and use and data of airborne sensors.
2. Layer: roof and digitalization of buildings roofs in the study area.
3. Database: main characteristics of roofs are compiled to determine which ones have potential for development of greenhouses.

In chapter 6, airborne sensors TASI-600 (ITRES, 2010) and Leica ALS50-II (Leica Geosystems ©, 2016) were used to acquire data regarding agronomic and architectural characteristics of rooftops analyzed: dimensions, area, slope, solar radiation and building materials.

In this sense TASI-600 hyperspectral sensor (Thermal Airborne Spectrographic Imager 600) from Itres © brand is based on the analysis of long wave infrared waves (LWIR) (ITRES©, 2016; ITRES, 2010). TASI-600 allows to measure and recover information of the surface temperature distribution of a material and the emissivity spectrum of the photographed scene. Therefore, TASI-600 is a viable instrument for detection of heat leaks through roofs, while patterns detected in hyperspectral emissivity images usually represent different properties of cover materials (Pipia et al., 2011, 2010).

Leica ALS50-II sensor from Leica Geosystems © (Leica Geosystems ©, 2016) makes use of LIDAR data and is designed for the acquisition and return of topographic data. The data is calculated using measurements of the intensity and return signal range recorded during the flight, together with position and altitude data derived from GPS in the air and inertial subsystems (Leica Geosystems ©, 2016).

A more detailed description of TASI-600 and Leica ALS50-II sensors is included in chapter 6 of present dissertation. All of the above use the QGIS 3.0 (QGIS Development Team, 2015) and ArcGis 10.2 (ESRI, 2013) software. For additional information, QGIS website at https://www.qgis.org/en/site/index.html, and ArcGis website at http://resources.arcgis.com/es/help/ can be visited. Also, http://www.itres.com/tasi-600/, http://www.nts-info.com/inventory/images/ALS50-

II.Ref.703.pdf and https://www.campbellsci.es/datalogger-software can be visited for more detailed information about airborne sensors.

4.2.1.3.Social

The use of social procedures in the present dissertation is addressed in its first part, as a mean to identify the perception and interest of the parent's school association and the school's staff for the implementation of greenhouses on the roof of elementary education schools in Barcelona (Chapter 7). In the second part, these instruments were used to understand the social perspective of urban agriculture and its relationship with social housing in Mexico (chapters 10 and 11). The tools used for these objectives were interviews (semi-structured and structured), focus groups and documentary review, since it sought to gather information in a flexible, friendly and relaxed manner, in which the diverse perspectives of the participants were integrated and allowed a greater structuring as the field work progressed.

- Interviews: the semi-structured interviews were based on a guide of subjects or questions and the interviewer was free to introduce additional questions to specify concepts or obtain more information about the desired topics (Clifford et al., 2010; Dunn, 2010). In structured interviews, the interviewer carries out the work based on a guide of specific and unchangeable questions (Phellas et al., 2011a; Wilson, 2014). Finally, focus groups consisted of meetings of small to medium number of people, in which the participants talk about one or several topics in an informal environment and under the guidance of a specialist in group dynamics or in the interested party to encourage session interaction (Hernández Sampieri et al., 2006; Morgan, 2003).

  In turn, qualitative research, due to its characteristics, requires flexible but targeted samples (Hernández Sampieri et al., 2006), composed of voluntary subjects, experts, and case-types. Figure 4.1 illustrates the various steps of social research that made up in part through semi-structured and structured interviews. In general, 8 steps were followed:

  - Definition of objectives: The objective and scope of the research are defined and, based on them, the most appropriate instrument for data collection is selected.

  - Documentation review: This step is done through secondary information collected on the internet, reports, news, laws and projects in order to know the context and the public information available of the subject investigated, and thus avoid not collecting information that can already be consulted.

  - Definition of the sample: Because the sample can be very broad and complex, it was opted to work with a representative one. This is limited according to the level of uncertainty that one wants to work with and the number of cases in the sample universe. In the case of chapter 10, a sample of 65 social housing units and in chapter 11, 157 social housing units were selected.

  - Tool design: The design of the tool consisted of the elaboration of questions that will serve as a guide for the semi-structured or structured interview. It included open, closed and multiple-choice questions as the case may be; integrating conceptual, categorical, general, complex and closing questions. Also, it included the selection of the statistical software for data analysis.

  - Pilot-Test: Tools were tested for the first-time through their application in a small group belonging to the final samples, with the purpose of checking their effectiveness for the data collection, identifying errors, accounting for the time of their application and improving the tools.

- Data collection: Data was collected firsthand through the application of the interviews during fieldwork. Additional information recorded as supplementary notes was also collected, as well as the use of other complementary tools such as photographic surveys and the sketches.

- Data organization: Data collected were filtered, sorted, encoded and classified to corroborate that there were no duplicate data, capture possible errors and facilitate analysis.

- Data analysis: Once data has been encoded, transferred to an array, saved in a file and cleaned of errors, the analysis starts. It is carried out on the data matrix, and includes the execution of the software, exploration of data to analyze them descriptively by variable, evaluate the reliability and validity achieved by the measurement tools, analyze the hypotheses and prepare the results to be able to present them (Hernández Sampieri et al., 2006). For the present dissertation Microsoft Excel and SPSS software were used.

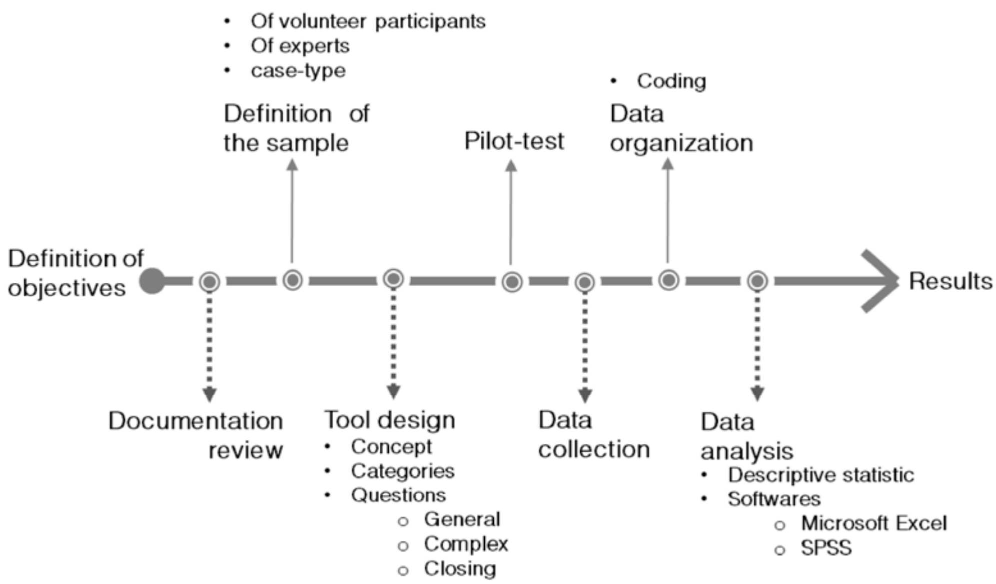

Figure 4.1 Social research process through semi-structured and structured interviews.

In chapter 7 the focus groups are described. And in chapters 10 and 11, the structure and contents of the interviews are exposed in depth.

- Documentation review: Documents, projects, news and others are very valuable sources of qualitative data as they help to understand the central study phenomenon. One of the advantages of the use of documentation is that many are produced by study participants or institutions that analyze research subjects. The main disadvantage is that it is sometimes difficult to obtain them and it is convenient to have several sources of information. The analysis consists of structuring and interpreting the data received (Hernández Sampieri et al., 2006).

The documentation review has been used in all dissertation chapters, mainly to know the investigated subjects background so as not to repeat information and knowledge already published and to be able to create a solid base from which to guide the investigation.

- Focus group: Its objective is to generate and analyze the interaction between participants (Barbour, 2007), and are used in qualitative research in all knowledge fields. They are used when there is an interest on the part of the researcher for how individuals form a perspective of a problem, through interaction (Hernández Sampieri et al., 2006). The format of the session or sessions depends on the objective and characteristics of the participants and the approach of the problem (Krueger and Casey, 2009), and they are considered positive when all members intervene and none is needed to lead the discussion (Hernández Sampieri et al., 2006). Furthermore, they don't only have descriptive potential, but also a great comparative potential that must be taken advantage of in qualitative research (Barbour, 2007).

Focus groups were used on two occasions in chapter 7 of present dissertation, with the objective of gathering information for the conformation of the decision tree -for the selection of the best option for the implementation of greenhouses in schools of elementary education in Barcelona- based on the points of view of various actors from different organizations and areas.

The first focus group was composed of 10 specialists in the fields of architecture, sustainability, agriculture and urban planning, and it had the objective of defining the requirements, criteria and indicators of the requirements tree; the second had the objective of assigning the functions of weights and values of the requirements tree, and was composed of 20 multidisciplinary specialists that included specialists in the areas of education, agriculture, urban planning, architecture, engineering and sustainability.

For more information, see: https://www.esup.edu.pe/descargas/dep_investigacion/Metodologia%20de%20la%20investigacion%205ta%20Edici%C3%B3n.pdf

4.2.1.4. Sustainable development

The Value Integrated Model for Sustainable Evaluations (MIVES) is a methodology and decision support software that allows to structure, quantify, homogenize, weigh, aggregate and assess the characteristics of the alternatives to be evaluated in order to guarantee an objective process of choice (Viñolas et al., 2009a). It is based on the Multi-Attribute Utility Theory (MAUT) and Value Analysis.

This methodology focuses on selecting different parameters of the evaluation and defining a model that is capable of assessing each of the alternatives, through a dimensionless magnitude (Aguado et al., 2006). Then the dimensionless values are compared with the other alternatives, and an objective choice is made. MIVES was employed in chapter 7 of this dissertation, for the selection of the elementary education buildings in Barcelona with the highest sustainability indexes for the implementation of a greenhouse on the roof.

For more information, see MIVES website at https://deca.upc.edu/es/proyectos/mives and online help supplied at https://deca.upc.edu/es/proyectos/mives/ficheros/aplicacion-v1/mivesmanual.pdf

4.2.1.5. On site data collection

- The sketch is a quick and simple tool and activity that allows to record information during the field work in order not to lose information that may be necessary in the research process (Sainz, 2005), as it was in the case of the verification of the roofs sizes analyzed in chapter 6.

- Photographic documentation is a great ally in exploratory research (Jiménez Rosano, 2005a). The use of photography in the fieldwork of chapters 6, 10 and 11 allowed to back up quickly and with high detail some of the information collected through other methodologies and tools. It can also be used as a strategy for the primary collection of information, support of existing information and as a result of the research itself (Gamboa Cetina, 2014; Hernández Espejo, 1998; Jiménez Rosano, 2005b).

- Qualitative observation: Observing implies going deep into social situations and maintaining an active role, as well as a permanent reflection. It is necessary to be attentive to details, events and interactions in order to gather information regarding the physical, social, human environment, individual and collective activities and more (Hernández Sampieri et al., 2006; Phellas et al., 2011b). In the present case, the complementary data collected through observation during the field work, was of great importance, since it allowed to corroborate the information gathered with the tools and main methods in chapters 10 and 11.

4.2.2.Case studies

Different infrastructures and scales were analyzed in the present dissertation (Figure 4.2), in which the tools mentioned in the previous section were applied. Urban agriculture topic was studied in three scales (neighborhood and city) and in three countries (Spain, Mexico and Ecuador), including developing and developed countries.

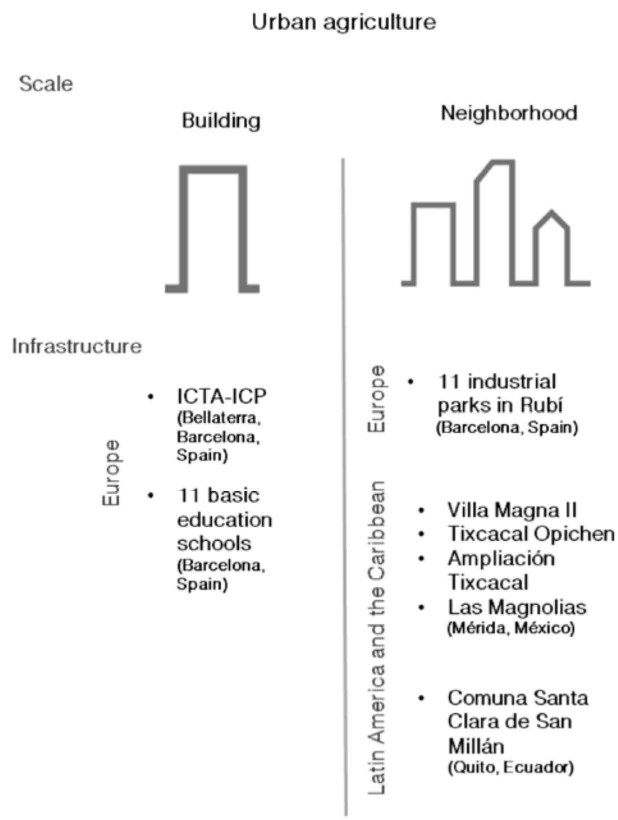

Figure 4.2 Scales (building and neighborhood) and countries (Spain, Mexico and Ecuador) studied.

- On the building scale, the ICTA-ICP building was the stage of the study to know the thermal behavior of the integrated greenhouse on the roof, as well as the energetic advantages that this can generate for the building itself or the greenhouse (Chapter 5). The viability for the implementation of rooftop greenhouses in 11 schools in Barcelona, Spain was also analyzed (Chapter 7).

- On a neighborhood scale, in Europe, was analyzed by means of airborne sensors to know the viability for agriculture on roofs of 11 industrial parks in Rubí, Barcelona, Spain, based on physical characteristics and location (Chapter 6). In Latin America and the Caribbean, specifically in Mexico, 4 neighborhoods of social housing in the city of Merida, Yucatan, were the location to know the social perception that the inhabitants have about the development, problems and opportunities of urban agriculture and its relationship with housing (Chapters 10 & 11). In Ecuador, the Santa Clara Commune of San Millán in Quito, was analyzed to quantify and identify the roofs that possess the basic characteristics such as dimensions, slope, solar radiation and others for the development of greenhouses (Chapter 9).

Figure 4.3 illustrates the location of these study areas and the chapter where they are addressed. For a better understanding, a detailed description of each case study area is provided in their respective chapters.

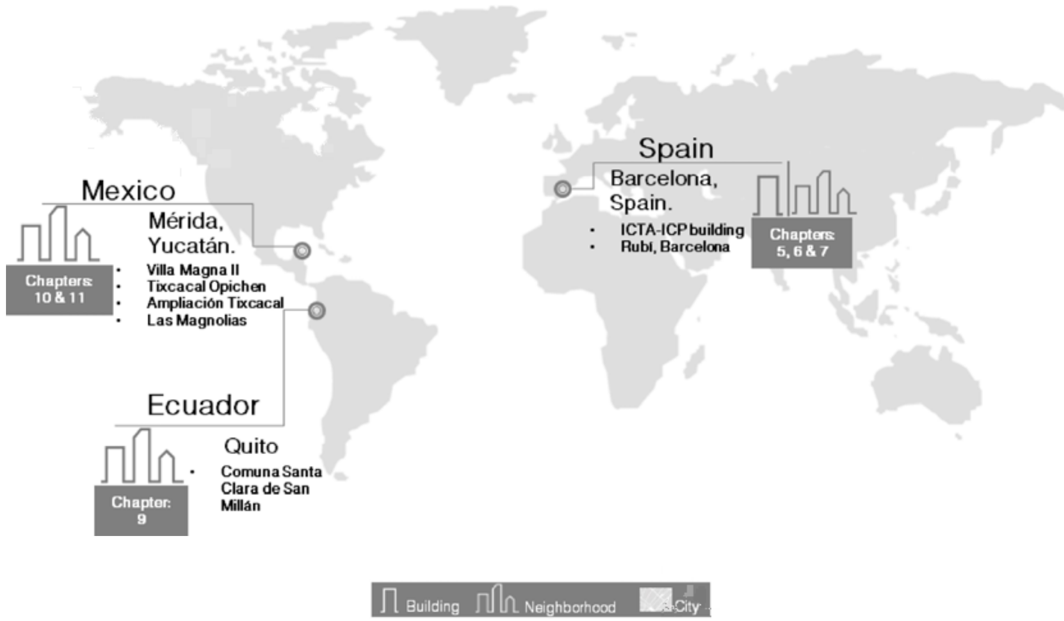

Figure 4.3 Geographical distribution of the case study areas

Urban agriculture: The European city

PART 2

Chapter 5

Building-integrated rooftop greenhouses: An energy and environmental assessment in the Mediterranean context

CHAPTER 5 - Building-integrated rooftop greenhouse: An energy and environmental assessment in the Mediterranean context

This chapter is based on the following journal paper:

Nadal, A., Llorach-Massana, P., Cuerva, E., López-Capel, E., Montero, J. I., Josa, A., … Royapoor, M. (2017). Building-integrated rooftop greenhouses: An energy and environmental assessment in the Mediterranean context. Applied Energy, 187, 338–351. https://doi.org/10.1016/j.apenergy.2016.11.051

Abstract

Sustainable and secure food supply within a low carbon and resilient infrastructure is encapsulated in several of The United Nations's 17 sustainable development goals. The integration of urban agriculture into buildings can offer improved efficiencies and in recognition of this the first south European example of a fully integrated rooftop greenhouse (iRTG) was designed and incorporated into ICTA-ICP building by the Autonomous University of Barcelona. This design seeks to interchange heat, CO_2 and rainwater between the building and its rooftop greenhouse. 2015 annual temperatures in iRTG showed average air temperatures of 16.5°C (winter) and 25.79°C (summer), making iRTG an ideal growing environment. Using detailed thermophysical fabric properties, 2015 site-specific weather data, exact control strategies and dynamic soil temperatures the iRTG was modelled in EnergyPlus to assess the performance of an equivalent 'freestanding' greenhouse. The validated result shows that the thermal interchange between iRTG and ICTA-ICP building offers considerable moderating effects on iRTG's indoor climate, as average hourly temperatures in an equivalent freestanding greenhouse would have been 4.1°C colder in winter and 4.4°C warmer in summer under 2015 climatic conditions. The simulation results demonstrate that case study iRTG recycled 43.78 MWh of thermal energy (or 341.93 kWh/m^2/yr) from the main building in 2015. Assuming 100% energy conversion efficiency, the iRTG has delivered equivalent carbon saving of 113.8, 82.4 or 5.5 kg.CO_2(eq)/m^2/yr , and economic savings of 19.63,15.88 or 17.33 €/m^2/yr against freestanding greenhouses heated with oil, gas or biomass systems respectively. Under similar climatic conditions, this symbiosis between buildings and urban agriculture makes iRTG an efficient resource management model and supports the promotion of a new typology or concept of buildings with a nexus or symbiosis between energy efficiency and food production.

Keywords

Rooftop greenhouse, Building performance simulation, Measured energy data, Energy Plus, Energy-food nexus, Building-rooftop greenhouse symbiosis.

Chapter 6

Urban planning and agriculture. Methodology for assessing rooftop greenhouse potential of non-residential areas using airborne sensors

CHAPTER 6 - Urban planning and agriculture. Methodology for assessing rooftop greenhouse potential of non-residential areas using airborne sensors

This chapter is based on the following journal paper:

Nadal, A., Alamús, R., Pipia, L., Ruiz, A., Corbera, J., Cuerva, E., … Josa, A. (2017). Urban planning and agriculture. Methodology for assessing rooftop greenhouse potential of non-residential areas using airborne sensors. Science of The Total Environment, 601, 493–507. https://doi.org/10.1016/j.scitotenv.2017.03.214

Abstract

The integration of rooftop greenhouses (RTGs) in urban buildings is a practice that is becoming increasingly important in the world for their contribution to food security and sustainable development. However, the supply of tools and procedures to facilitate their implementation at the city scale is limited and laborious. This work aims to develop a specific and automated methodology for identifying the feasibility of implementation of rooftop greenhouses in non-residential urban areas, using airborne sensors. The use of Light Detection and Ranging (LIDAR) and Long Wave Infrared (LWIR) data and the Leica ALS50-II and TASI-600 sensors allow for the identification of some building roof parameters (area, slope, materials, and solar radiation) to determine the potential for constructing a RTG. This development represents an improvement in time and accuracy with respect to previous methodology, where all the relevant information must be acquired manually.

The methodology has been applied and validated in a case study corresponding to a non-residential urban area in the industrial municipality of Rubí, Barcelona (Spain). Based on this practical application, an area of 36,312 m^2 out of a total area of 1,243,540 m^2 of roofs with ideal characteristics for the construction of RTGs was identified. This area can produce approximately 600 tons of tomatoes per year, which represents the average yearly consumption for about 50 % of Rubí total population.

The use of this methodology also facilitates the decision making process in urban agriculture, allowing a quick identification of optimal surfaces for the future implementation of urban agriculture in housing. It also opens new avenues for the use of airborne technology in environmental topics in cities.

Keywords:

Cities sustainability, urban agriculture, food security, smart cities, vertical farming, industrial parks

Chapter 7

Rooftop greenhouses in educational centers: A sustainability assessment of urban agriculture in compact cities

CHAPTER 7 - Rooftop greenhouses in educational centers: A sustainability assessment of urban agriculture in compact cities

This chapter is based on the following journal paper:

Nadal, A., Pons, O., Cuerva, E., Rieradevall, J., & Josa, A. (2018). Rooftop greenhouses in educational centers: A sustainability assessment of urban agriculture in compact cities. Science of the Total Environment, 626. https://doi.org/10.1016/j.scitotenv.2018.01.191

Abstract

Today, urban agriculture is one of the most widely used sustainability strategies to improve the metabolism of a city. Schools can play an important role in the implementation of sustainability master plans, due their socio-educational activities and their cohesive links with families; all key elements in the development of urban agriculture. Thus, the main objective of this research is to develop a procedure, in compact cities, to assess the potential installation of rooftop greenhouses (RTGs) in schools. The generation of a dynamic assessment tool capable of identifying and prioritizing schools with a high potential for RTGs and their eventual implementation would also represent a significant factor in the environmental, social, and nutritional education of younger generations. The methodology has four-stages (Pre-selection criteria; Selection of necessities; Sustainability analysis; and Sensitivity analysis and selection of the best alternative) in which economic, environmental, social and governance aspects all are considered. It makes use of Multi-Attribute Utility Theory and Multi-Criteria Decision Making, through the Integrated Value Model for Sustainability Assessments and the participation of two panels of multidisciplinary specialists, for the preparation of a unified sustainability index that guarantees the objectivity of the selection process. This methodology has been applied and validated in a case study of 11 schools in Barcelona (Spain). The social perspective of the proposed methodology favored the school in the case-study with the most staff and the largest parent-teacher association (social and governance indicators) that obtained the highest sustainability index (S11); at a considerable distance (45%) from the worst case (S3) with fewer school staff and parental support. Finally, objective decisions may be taken with the assistance of this appropriate, adaptable, and reliable Multi-Criteria Decision-Making tool on the vertical integration and implementation of urban agriculture in schools, in support of the goals of sustainable development and the circular economy.

Keywords

Integrated Value Model for Sustainability Assessment, Schools, Multi-Criteria Decision Making, Circular economy, Vertical farming, Rooftop greenhouse