Urban agriculture in the framework of sustainable urbanism

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Doctoral thesis

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Urban agriculture :The Latin-American cities

PART 3

Chapter 8

Urban agriculture in Latin America and the Caribbean: planned activity or emergency measure?

CHAPTER 8 - Urban agriculture in Latin America and the Caribbean: planned activity or emergency measure?

From this chapter, a paper has been extracted and submitted in a peer-review indexed journal and had the following collaborators:

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Abstract

Currently, urban and peri-urban agriculture (UPA) is a topic that is gaining momentum every day. It is known that numerous cities around the world are implementing various strategies for their development and in search of urban sustainability. Despite this, the progress and direction of the UPA is unknown in the Latin America and the Caribbean (LAC) region. Therefore, it is necessary to focus on the topic and quantify the generated scientific literature. This research identifies the main functions of UPA, compares existing research gaps with current legal and cooperation strategies; and determines if the UPA literature is paying attention to the current situation of the countries. To do this, we explored the research that refers to the UPA in the Latin American region and are grouped into the functions of the same. Also, we identify the legal and cooperation strategies for the development of the UPA that have been implemented in recent years in the region. The results show a dispersion of the scientific literature throughout the region, but a higher prevalence in five countries (Brazil, Cuba, Mexico, Colombia and Argentina) which represent 86% of the total production. And in which the environmental function (46%) is the most developed and far from the Urban-political and economic functions, which are the least developed (12 and 3%). While the social (23%) and productive (16%) functions remain constant. Although the UPA has a diversity of functions in LAC, its development is focused on emergency situations, mainly hunger and poverty, which makes it a "lifesaving" strategy and does not develop as a planned activity. What becomes a challenge to be overcome in order to achieve sustainable cities; and that could only be achieved through the integration of the UPA in a specific and personalized way in urban-political and economic areas to meet the needs that each of the cities of LAC presents.

Keywords

Latin-American cities, urban agriculture, peri-urban agriculture, developing cities, food security, food programs

8.1. Introduction

Around the world, cities are the main habitat of contemporary societies (CEPAL, 2017). Throughout history, rural population has migrated to cities in search of new opportunities, which generated several problems associated with urban growth and new lifestyles (FAO, 2016c), such as air and water pollution, marginalization, violence, and loss of fertile land and biodiversity (Adamo, 2010), and changes in food consumption patterns (Berger, 2013; Warner, 2010). In the case of Latin America and the Caribbean (LAC), urban lifestyles, with their opportunities and challenges, determine the present and future sustainable development in the region (CEPAL, 2017).

In LAC, urbanization entailed demographic and economic concentration and high social inequalities in the main metropolitan areas (ONU-Habitat and CAF Banco de Desarrollo de América Latina, 2014; UN, 2016). As a result, the main sustainability challenges in LAC not only revolve around environmental degradation but also social and urban vulnerability, as impoverished populations are at a high risk for health issues, natural disasters, and lack of access to basic goods.

Food supply is a foremost example. LAC is the world's largest net exporter of food since 2015 (FAO, 2015c), yet 42.5 million people in the region suffer from hunger and 90 million people have obesity (FAO et al., 2015). Hence, the problem is not the lack of nutritious food, but the economic access to it (FAO, 2018a; FAO et al., 2017). The double burden of malnutrition encompasses undernutrition along with overweight, obesity or diet-related noncommunicable diseases (NCDs), related to –sometimes simultaneously – nutritional, epidemiological and demographic transitions (UNICEF, 2013; World Health Organization, 2017). All these factors compromise the Food and Agriculture Organization's (FAO) objectives towards sustainable development in LAC, i.e., to end hunger, to support family farming and inclusive food systems, and to respond to climate change by managing natural resources and disaster risk (FAO, 1997).

In this context, urban and peri-urban agriculture (UPA) offers innovative solutions towards environmental and economic sustainability of urban food supply, and promotes food of high nutritional quality (FAO, 2014c, 2011b, 2007, 2001). Additionally, UPA generates several benefits for cities regarding health, local economy, social integration and improvement of the urban climate, while stimulating the productive reuse of urban organic waste and reducing the urban energy footprint (Cerón-Palma et al., 2012b; De Zeeuw, 2010; Nadal et al., 2018; Orsini et al., 2013).

UPA is a widespread activity in LAC cities. For instance, it is common practice in 40% of Cuba's households. In the main cities and municipalities of Bolivia, 50,000 families produce food, and so do about 8,500 families in Bogotá. In Haiti, 25,500 families cultivate 260 ha of land in and around Port-au-Prince and other cities (FAO, 2014a). In this respect, UPA could help to offset the negative effects of urbanization (Berger, 2013) thus contributing to FAO's objectives and to United Nations' (UN) Sustainable Development Goals (SDGs) (FAO, 2014c, 2011b; Holdsworth, 2005; Mougeot, 2005).

Seeking to stimulate the benefits of UPA practices, international and LAC-based institutions are developing *ad hoc* programs and policies. Sometimes, these follow natural hazards and/or human emergency situations in which malnutrition and poverty converge. An example is FAO's work in assisting governments to restore supporting services to agriculture, supplying goods and reconstructing basic infrastructure after emergencies (FAO, 1997). But despite these programs, initiatives, and models of UPA, such as the cases of Havana in Cuba, ProHuerta (INTA, 2018) in Argentina, Fome Zero (FAO, 2006)in Brazil, it is difficult to understand what the current dimension and the areas of interest of UPA in the region is. Since there is no exhaustive evaluation of the state of research in the region, that it deepens to what extent urban agriculture responds to a planned activity or if it is the result of emergency response.

To what extent has scientific research systematized the benefits of UPA in LAC? This question leads us to formulate the three main goals of this paper, namely: (i) to identify the main functions of UPA in LAC 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. To do so, we conducted a systematic review of scientific literature.

After this section, the methodology is presented included collection and data analysis, followed by the results of the current state of the UPAs research and programs, which are addressed in the discussion. In the conclusions, we present future perspectives regarding UPAs scientific research in LAC.

8.2.Methodology

Our methodology follows three steps, consisting in data gathering and processing (section 2.1.), and data analysis (section 2.2).

8.2.1.Data collection and processing

The literature review comprised peer-reviewed scientific articles retrieved from "Web of Science", containing the SciELO database (with journal collections based in LAC, Spain, Portugal, and South Africa). The search included papers published in English and Spanish from 1900 to March 1st, 2018. Because a variety of terms refers to UPA and its different typologies (Nadal et al., 2015), we used a set of keywords in the literature search. These were "*urban agriculture*", "vertical farm*", "*urban garden*", "community garden", "allotment garden", "*urban farm*", and "*urban orchard". The spatial scope of the literature has been geographically limited to research within the LAC region following the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2017a) definition. We narrowed down the selection by combining these terms with "Latin America*", "South* America*" or the complete list of countries belonging to the LAC region. An equivalent query was conducted using the Spanish translation of these terms. Only peer-reviewed research papers were considered.

The data collection resulted in a first list of 331 scientific papers in English and 39 in Spanish. This list was processed further. First, we checked for duplicates and verified that the same paper did not appear in both languages. Second, we reviewed the topic consistency of the sample. We discarded the items in which "urban agriculture" may be mentioned in the title and/or abstract but it is not the core of the study contents. After this stage, we obtained a sample of 220 articles (190 publications in English and 30 in Spanish).

8.2.2.Data analysis framework

A data analysis framework was defined to screen the scientific literature based on the functions of UPA and the UPA programs promoted in LAC (Figure 8.1.). UPA is characterized by a great variety of forms and a wide capacity to generate services or benefits. Therefore, the first step was to define a basic list of functions of UPA based on conceptual references (e.g.,(Mougeot, 2000)), by classifying services and benefits in types of functions, namely economic, environmental-ecological, productive, social and urban-political functions.

The first group covers the economic aspects of UPA, such as job generation, support for markets and local businesses or stronger local economies. The environmental-ecological function includes conservation of biodiversity, development of low-impact agriculture, efficient use of water or soil conservation. The productive function deals with the improvement of crop yields, use of traditional technologies, ecological innovation and related aspects. The fourth function refers to the social services that UPA can generate in a community, such as environmental education, social cohesion and sense of community, improvement in food and health or promotion of cultivation. Finally, the urban-political function involves topics about the city, its operation, the generation of public spaces for cultivation, and the legal and institutional framework for the development of UPA.

The second step of the analytical framework led to assessing the status of UPA in the LAC region in terms of scientific production, legal and cooperation strategies, and indicators on natural and socio-political emergencies that might benefit from UPA initiatives. First, we categorized the scientific literature based on the five functions of UPA to determine the extent to which our sample covered each function in LAC. Second, we screened legal and cooperation strategies in support of UPA and its implementation across LAC countries.

In addition, we considered the programs developed in the region by FAO, due to its programmatic interest in UPA to eradicate hunger and strengthen food security in LAC (FAO, 2015d). Here, two key references were the official reports “Growing Greener Cities in Latin America and the Caribbean” (FAO, 2014a) and “Urban and Peri-urban agriculture in Latin America and the Caribbean: Compendium of case studies” (FAO, 2014d). Similarly, the Community of Latin American and Caribbean States (ECLAC) has taken the fight against hunger and poverty as a priority since its foundation. This is reflected in its Plan for Food Security, Nutrition and Hunger Eradication 2025 and in the Platform for Food and Nutrition Security (ECLAC et al., 2018), an information system on public policies and indicators that helps to monitor the advances of LAC in the eradication of hunger. Through this platform, we gained a regional overview of key institutional tools (i.e., socioeconomic, nutritional and productive indicators; regulatory and institutional frameworks; and public policies, strategies and programs within the framework of food and nutrition security) for eradicating hunger and poverty, in compliance with the Millennium Development Goals (MDGs) and, more recently, the SDGs.

Finally, we included information regarding the emergency situations (i.e., natural hazards and socio-political emergencies) in which FAO has collaborated, as well as data on malnutrition and obesity in the LAC countries. This information was obtained from the two reports mentioned above (FAO, 2014a, 2014e). Poverty and extreme poverty data were obtained from the ECLAC's (2018) report “Social Panorama of Latin America 2017”.

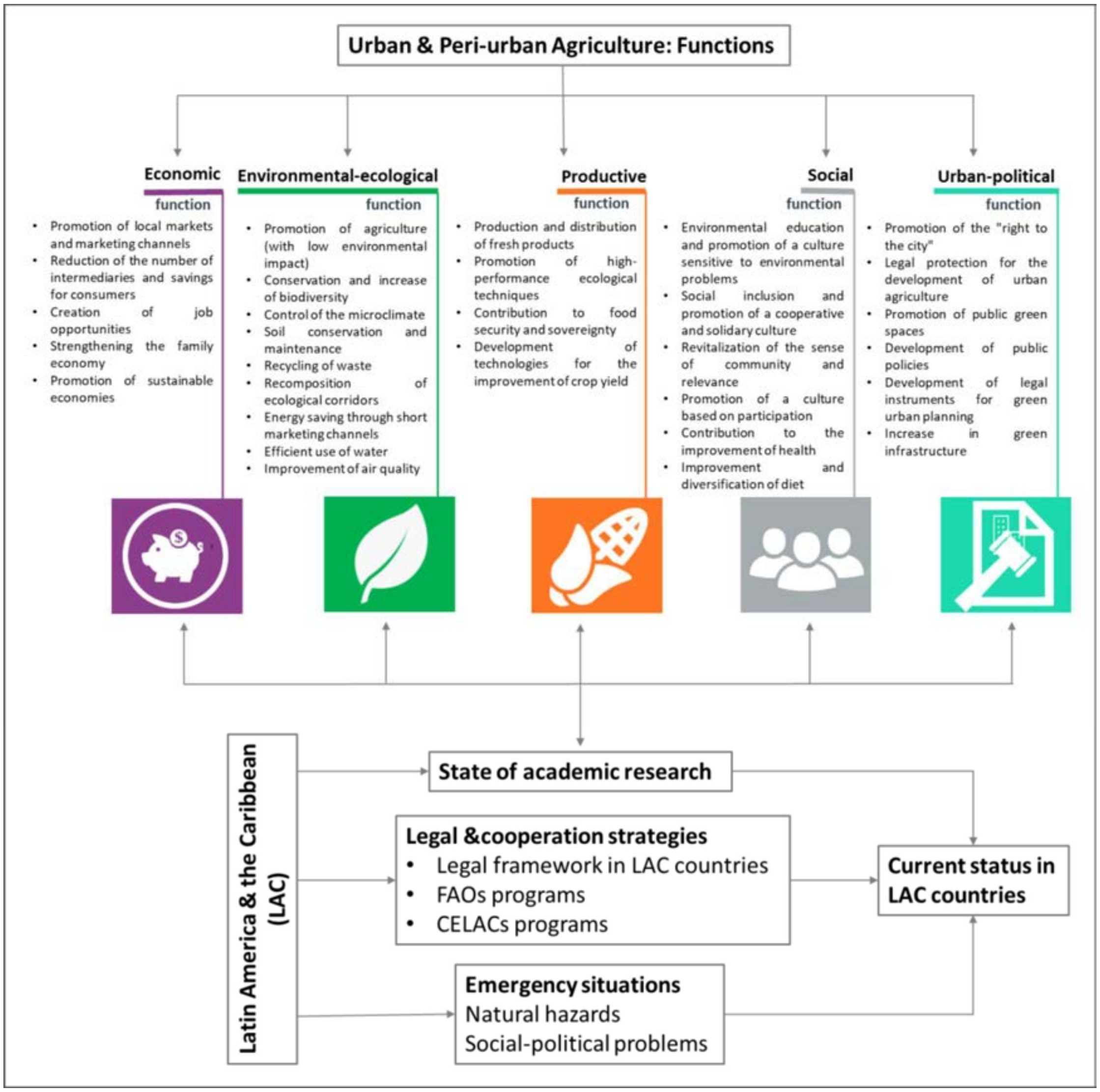


Figure 8.1 Structure of the data analysis and classification functions.

8.3.Results

8.3.1.Scientific production on urban and peri-urban agriculture in Latin America and the Caribbean

8.3.1.1.Spatiotemporal distribution of the academic literature

We found 220 relevant research papers for 14 LAC countries (Figure 8.2.), that is, 35% of UNESCO's LAC country list. Most of the papers (87%) were published in English, which is not the mother language of any of the countries covered in the literature. This fact indicates a certain maturity of the UPA research in LAC and the interest to communicate the results of the research to the international scientific community, a point already made by López Navarro et al. (2015).

Each country was classified according to their level of scientific production from high to null (High: more than 20 papers available, Moderate: between 2 to 20 papers, Low: 1 paper, Null: zero). The results show that 65% of the LAC countries have not been studied in the literature thus far. This group is mainly located in the Caribbean area (excluding Cuba) and Paraguay. Similarly, Central America comprises the countries with a low publication index (12%).

In contrast, Mexico, Brazil, Colombia, Cuba and Argentina are the most studied areas, with Brazil leading the production with 62 publications (28% of all papers). Cuba is recognized worldwide as a global reference of the UPA in LAC (FAO, 2014a), yet occupies the second place in the list, with 49 research papers (22%). Other remarkable cases are Mexico, Colombia and Argentina with 29, 26 and 24 research papers that represent 13%, 12% and 11% of the sample, respectively. The remaining percentage is divided among Chile, Costa Rica, Ecuador, Peru, Bolivia, Guatemala, Honduras, Nicaragua, and Panama, with 9 papers or less each.

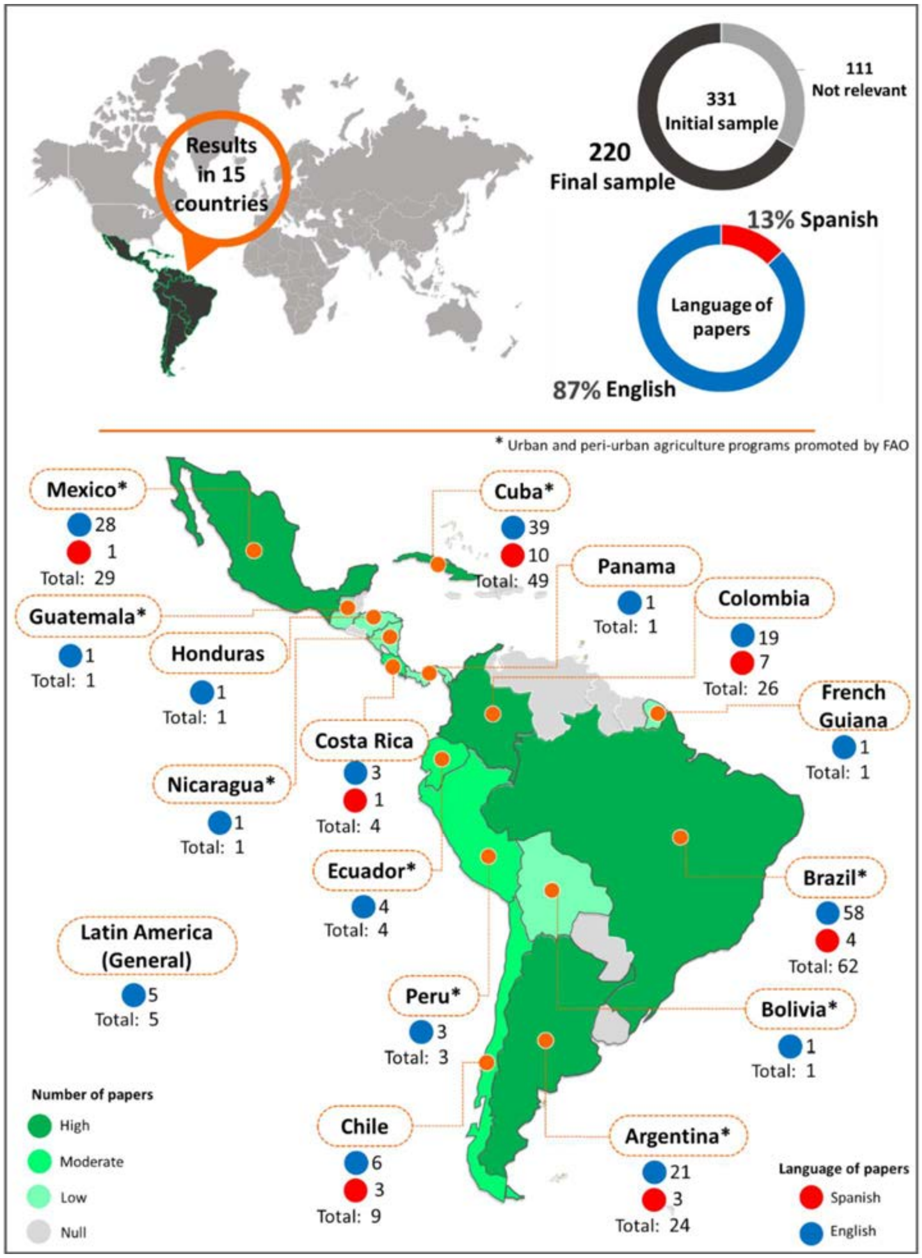


Figure 8.2 Distribution, location and number of research papers of urban and peri-urban agriculture in Latin America and the Caribbean.

Figure 8.3 shows the temporal evolution of UPA research in LAC, characterized by a positive trend, with 30% increase in the publication records in the last 25 years. The first publication dates back to 1983 and deals with the nutrition and diet of UPA workers in Brazil (Desai et al., 1983), although there is a time gap of a decade until the next paper was published, also in Brazil.

Figure 8.3 also unveils three key stages in the UPA research evolution. A plateau stage of low presence of publications (4% of the total) spans from 1983 to 1999, with Brazil leading the field with contributions from Mexico and Colombia. Another stage of incipient increase between 2000 and 2008 includes 34 publications (16% of the total), with a noticeable contribution from Cuba. The third phase (from 2009 to nowadays) corresponds to the exponential increase of the research on UPA in the region. The annual productivity ranges between 9 and 32 publications (excluding early 2018) and a total of 173 publications (79% of all records). In this stage, both Brazil and Cuba reaffirm their leadership in the field.

Summarizing the role of the major contributors of UPA scientific papers in the LAC region:

- Brazil pioneers the field, maintaining its leadership throughout the three stages.
- Cuba appears in the second stage and reaffirms its presence in the third one.
- Mexico starts in the first stage and remains productive during the second stage, but its contribution falls in third.
- Colombia emerges with strength precisely in this third stage, currently leading the scientific production together with Brazil and Cuba.
- Argentina remains constant and with continuous growth.
- Chile and Costa Rica lead in 2004 and 2007 (second stage) the number of publications.

The decade of the 2000s marks the tipping point in the publication rate about UPA, and as of 2010s the exponential ascent remains. This trend continuing, the number of scientific publications in the region could be expected at its peak by 2020s, with substantial interest on UPA also in practice and management.

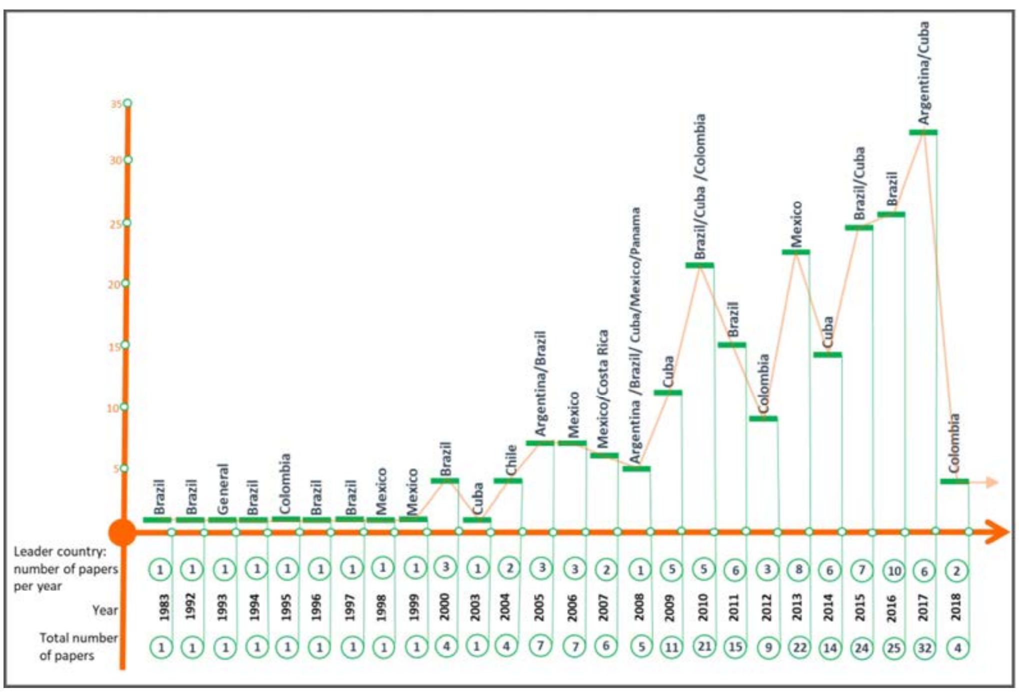


Figure 8.3 Urban and peri-urbans research papers timeline (1983 -1st March, 2018) in Latin America and the Caribbean.

8.3.1.2. Tracking the functions of UPA in scientific production

The sampled papers were classified according to function of the UPA (Figure 8.4) they address. Results are presented in (Figure 8.4). The most frequently reported in the literature is the environmental-ecological function (46% of papers), followed by the social (23%), productive (16%), urban-political (12%), and economic (3%) functions. The uneven distribution between functions of the UPA in LAC, and the predominance of the environmental function, occurs in both Spanish and English publications.

It should be noted LAC comprises six megadiverse countries: Brazil, Colombia, Ecuador, Mexico, Peru and Venezuela. The region harbors the most biodiverse habitat in the world, the Amazon rainforest (UNEP, 2012a) and more than 40% of the planet's biodiversity (UNEP, 2010). However, there is also a regional intensification of the pressures on biodiversity in terms of soil degradation and changes in land use; climate change; pollution of terrestrial origin; unsustainable use of natural resources and invasive alien species (UNEP, 2010). Therefore, a remarkable preference for or interest in the environmental and ecological benefits of UPA is understandable.

In the Spanish publications, papers regarding the Environmental-Ecological and Productive functions are similarly frequent (around one third of the production each). The Social function (23% of the papers in this language) and the Urban-political function (10%) follow, and the economic function is missing in the literature. In opposition, this latter function does appear in the English publications, albeit in just 4% of them. The Environmental function is covered in nearly half of all papers in this language, while the Social and Urban-political functions present similar percentages than their counterparts in Spanish. The main difference between the production in both languages lies in the interests in the Productive function, remarkably higher in Spanish than in English. Cuba is the country that leads the publications in Spanish with 33%, and Brazil those of English with 33%.

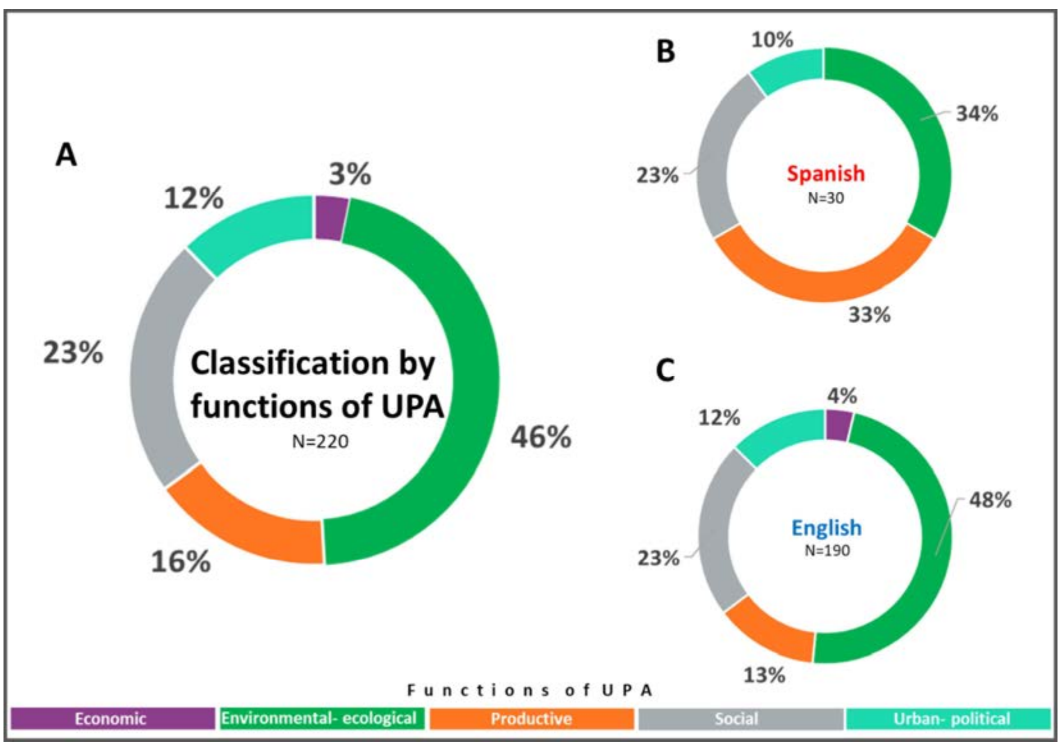
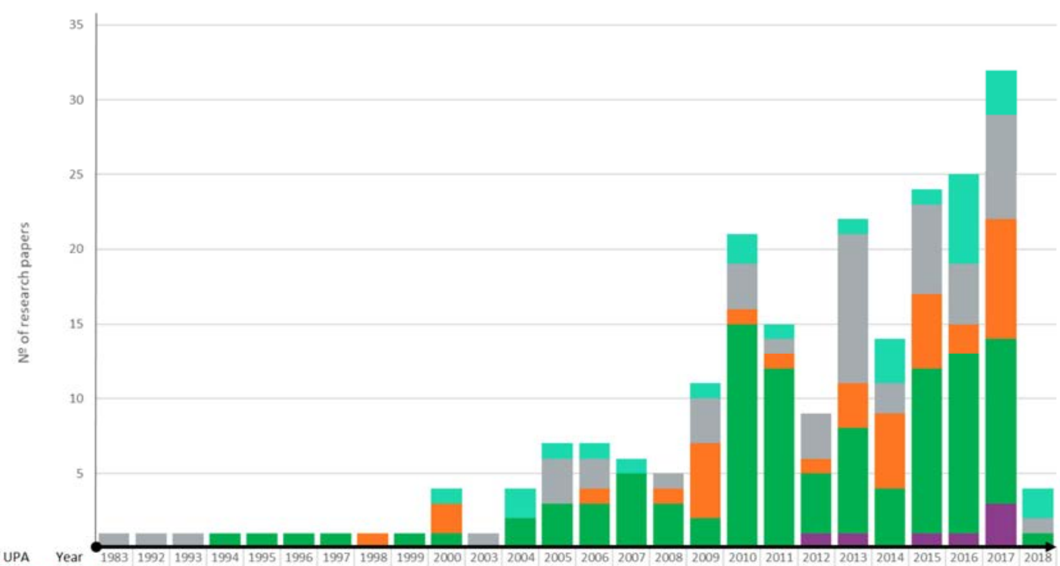


Figure 8.4 Relative frequency in the literature of each function of urban and peri-urban agriculture (UPA) in Latin America and the Caribbean (LAC). A) In all reviewed papers (N=220); B) In papers published in Spanish (N=30); In papers published in English (N= 190)

The social function of UPA has been present since the earliest publications in the field (Figure 8.5), and the studies on the actors, health and perception predominate. The environmental-ecological function emerged in the mid-1990s and soon became the most frequent in the last 24 years, covering studies on species diversity, metal, biological, air and water pollution and waste. The productive function appears in 1998, focuses on the topics of irrigation systems, technologies to increase crop productivity; 14 years earlier than the economic function despite the fact that both topics are closely linked (FAO, 2011c). The economic function focuses on financing strategies and product markets issues and the urban-political focuses on policies that promote urban agriculture and successful experiences in architecture and urban planning. The joint development of the different UPAs functions starts being apparent since the early 2000s, and in 2013 when the five functions already appear together.



Functions of UPA / Year	1983	1992	1993	1994	1995	1996	1997	1998	1999	2000	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Urban- political	0	0	0	0	0	0	0	0	0	1	0	2	1	1	1	0	1	2	1	0	1	3	1	6	3	2
Social	1	1	1	0	0	0	0	0	0	0	1	0	3	2	0	1	3	3	1	3	10	2	6	4	7	1
Productive	0	0	0	0	0	0	0	1	0	2	0	0	0	1	0	1	5	1	1	1	3	5	5	2	8	0
Environmental- ecological	0	0	0	1	1	1	1	0	1	1	0	2	3	3	5	3	2	15	12	4	7	4	11	12	11	1
Economic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	3	0
TOTAL	1	1	1	1	1	1	1	1	1	4	1	4	7	7	6	5	11	23	15	9	22	14	24	25	32	4

Figure 8.5 Timeline (1983 -1st March, 2018) of the evolution of UPAs functions in Latin America and the Caribbean.

As mentioned above, some countries (Brazil, Cuba, Mexico, Colombia and Argentina) lead the scientific production in LAC. In fact, they produce 86% of all papers in the sample. Figure 8.6 shows the functional profiles of these countries. While the five functions appear in the papers from Brazil, including the economic (5% of papers), the environmental-ecological function represent more than half of the publications in that country They focus on aspects of biodiversity conservation, taxonomic and physiological analysis, biological control of pests, and environmental pollution (Amato-Lourenco et al., 2016; Peroni et al., 2016; Proni, 2000; Siviero et al., 2011; WinklerPrins and Oliveira, 2010).

The economic function is missing from the scientific production in Cuba, but this country has the largest number of publications related to the productive function (33%) in the region. In this respect, its research primarily seeks to improve crop yield processes, including the creation of the “organoponic” system that uses an organic substrate, obtained from crop residues, household wastes and animal manure (FAO, 2014a). The environmental-ecological function also presents a remarkable 41% of publications.

Publications from Mexico also address the five functions of UPA. This country shows the highest interest in the Economic function (7% of papers produced there), dealing with issues of local business and social capital (Mendez-Lemus and Vieyra, 2017; Pensado-Leglise and Smolski, 2017). Yet this percentage is considerably low compared to papers addressing the environmental-ecological (45%) and productive (27 %) functions.

Colombia follows the pattern of predominance of the environmental-ecological function (50%), in coherence with the domestic high levels of biodiversity (UNEP, 2012b). The social and the productive function are similarly frequent, while Urban-policy represents only 8% of the publications in the country.

Argentina leads the interest of scientific production on Social and Urban-political functions (with 29% and 21% respectively). Topics covered involve health risks, social cohesion, vulnerable population, right to the city and urban planning (Dubbeling et al., 2009; Hughes et al., 2006; Machado et al., 2017; Paolini et al., 2016). Again, the environmental-ecological function (46%) far exceeds both percentages. Contrarily, the Productive function has the lowest numbers with 4%, and the Economic function is missing.

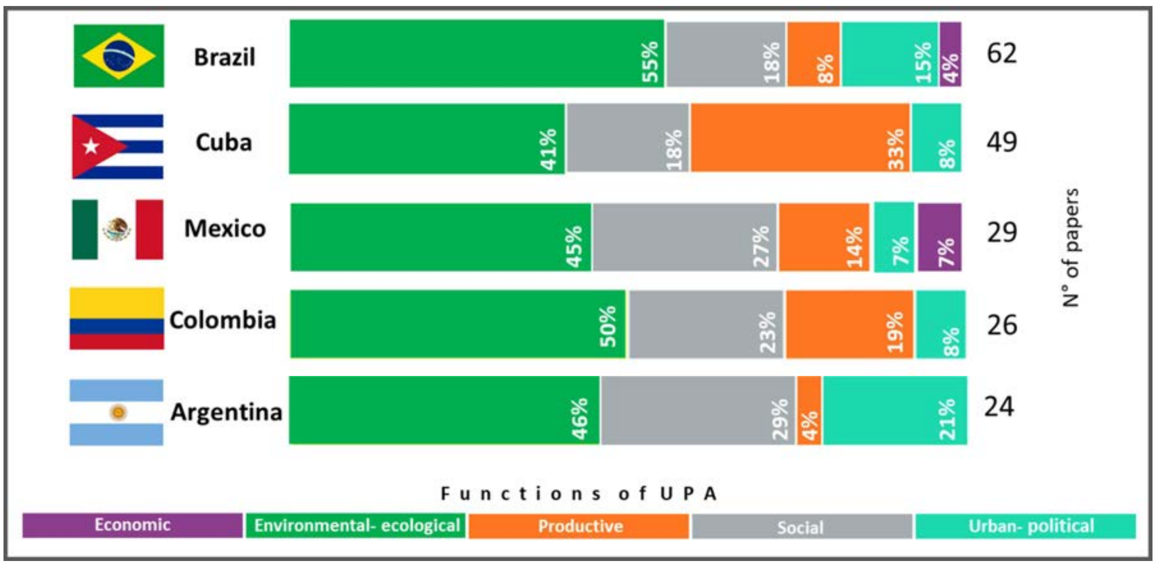


Figure 8.6 The 5 LAC countries with the largest number of UPAs research papers.

8.3.2.The importance and role of UPA in LAC: a planned activity or an emergency measure?

Table 8.1 summarizes the topics shown in Appendix 5.1, 5.2, 5.3 and 5.4 that address the aspects of interest for the development of the UPA in LAC, namely *ad hoc* programs developed by FAO, occurrence of natural hazards and or social-political emergencies, UPA development initiatives, and data referring to population, malnutrition, obesity and poverty. The countries are ranked according to the number of scientific papers on UPA.

A first distinction to be made is the presence or absence of scientific publication on the matter. In this respect, those countries in which FAO has developed a program in support of the UPA are the top paper producers. In fact, 9 out of the 14 countries (64.28%) with UPA publications received support from FAO between 2002-2014 (FAO, 2014a). Two cases diverge from this fact: Colombia and Antigua and Barbuda. Colombia is a leader in scientific production that has not received support from FAO for this purpose, while Antigua and Bermuda lack publications despite having received such support in 2009. It is noteworthy that Brazil, Cuba and Mexico started their scientific production on UPA long (from 9 to 29 years) before FAO implemented a series of projects in these countries.

When analyzing the legal-institutional framework and the initiatives aimed at promoting the development of UPA, two groups of countries can be distinguished: a) countries where the national government establishes laws or develops projects that impact the entire territory, for example, Cuba, Antigua and Barbuda and Nicaragua; b) countries where the projects are managed by municipal governments to address extreme poverty in their metropolitan areas, which include cities such as: Tegucigalpa, Quito, Lima, El Alto, Mexico City, Belo Horizonte and Rosario. This demonstrates that more and more municipalities of LAC recognize the policies and actions for the development of the UPA as useful strategies for a more sustainable and equitable urban management.

Another remarkable point is the relationship between the UPA and natural hazards and social-political emergencies in the region. Within the sample studied, 50% of the strategies and projects of the UPA have a social origin (e.g., migration) and the remaining 50% respond to economic needs. This coincides with findings by Méndez et al.(2005) in the cataloging of the origin of the UPA. All the LAC cities in which the FAO developed a project had the precedent of a natural hazard or a social emergency to address. The great majority of government initiatives arise as a strategy for the support of the population in these circumstances. In Cuba, however, the governmental strategy had already developed before the period of economic crisis (or 'Special period') (FAO, 2014a). Undoubtedly in this case, UPA was reinforced as a mitigation measure to solve the food crisis, which positioned Cuba as a world leader in the production of sustainable and organic foods, particularly in urban and peri-urban settings (Novo and Murphy, 2001). The success of the UPA has been such that Cuba is the only country in LAC that achieved the minimum average consumption of fruits and vegetables recommended by WHO (400 grams per day) (FAO and INIFAT, 2012).

Table 1 show the same downward trend in the case of poverty in those countries where the malnutrition rate is low. This decrease is deeper in the case of extreme poverty: Brazil presents 4.2% of poverty compared to 42.5% of Honduras. Therefore, it can be inferred that the development of UPA in LAC may be part of a strategy in the fight against malnutrition and poverty. This is also reflected in the number of research papers on the topic. An exception is Mexico, where despite having a considerable number of research papers, UPA development programs and a legal-institutional framework, the poverty has increased considerably to reach 50.6% of the population total and 17.5% of extreme poverty; figures only surpassed by Guatemala (59.3% and 23.4%) and Honduras (65.7% and 16.8%).

Finally, the highest rates of obesity occur in those countries that have a moderate and high number of scientific publications, reaching values of between 20 and 30% of the adult population, such as the cases of Argentina (28.7%), Chile (29.5%), Costa Rica (23.6%) and Brazil (20.8%). In the case of childhood obesity, Chile (9.3%) and Ecuador (7.5%) have the highest rates.

Table 8.1 UPA in LAC: FAOs programs, natural disasters and social-political problems, government initiatives, legal framework, population, malnutrition, obesity and poverty (summary).

Country [a]	Research papers		FAO program [b]		Natural hazard / social-political emergency [b]		Government initiative for UPA [b]:			ECLAC program	Population [d]	Prevalence of diet-related condition [e]			Poverty [f]	
	N°	Year of first publication	Program exists	program year	Occurrence	Year of occurrence	Municipal	National	Year of initiative	ECLAC: FNS [c]	Total population (N.)	Undernourishment in the total population (%)	Overweight in children (< 5 years) (%)	Obesity in the adult population (≥18 years) (%)	%	%Extreme poverty [f]
Brazil	62	1983	•	2012	•	1990	•		1992	•	210 867 954	<2.5		20.8	13.3	4.2
Cuba	49	2003	•	2011	•	1991		•	1987	•	11 489 082	<2.5		25.5		
Mexico	29	1998	•	2007	•	2000	•		2000	•	130 759 074	4.2	5.2	27.8	50.6	17.5
Colombia	26	1995								•	49 464 683	7.1	4.8	20.1	28.0	8.5
Argentina	24	2004	•	2013	•	2001	•		2002	•	44 688 864	3.6		28.7	30.3	6.1
Chile	9	2004								•	18 197 209	3.7	9.3	29.5	11.7	3.5
Costa Rica	4	2007								•	4 953 199	5.6		23.6	20.5	6.3
Ecuador	4	2012	•	2002	•	1980-2000	•		2000	•	16 863 425	12.1	7.5	18.4	22.9	6.3
Peru	3	2012	•	2008	•	Since 1950	•		2000	•	32 551 815	7.9		19.5	20.7	3.8
Bolivia	1	2004	•	2014	•	2000	•		2004	•	11 215 674	20.2		16.4	38.6	16.8
Guatemala	1	2015								•	17 245 346	15.6	4.7	16.9	59.3	23.4
Honduras	1	2017	•	2009	•	Since 1970	•		2009	•	9 417 167	14.8	5.2	16.2	65.7	42.5
Nicaragua	1	2013	•	2010	•	2010		•	2010	•	6 284 757	17.0		17.4	29.6	
Panama	1	2008								•	4 162 618	9.3		24.8	22.1	9.9
Antigua & Barbuda	0		•	2009	•	2008		•	2009	•	103 050	26.7		28.6		

Blank cell means that the data is not available
a: (UNESCO, 2017b) b: (FAO, 2014c) c: (ECLAC, 2018) d: (UN, 2017) e: (FAO et al., 2017) f: (ECLAC, 2018)
Latin American countries that were not included in the table due to lack of information (those with * are part of CELAC): Anguilla, Aruba, Bahamas*, Barbados*, Belize*, British Virgin Islands, Cayman Islands, Curaçao, Dominica*, Dominican Republic*, El Salvador*, Grenada*, Guyana*, Haiti*, Jamaica*, Montserrat, Paraguay*, Saint Kitts & Nevis*, Saint Lucia*, Sint Maarten, Saint Vincent & the Grenadines*, Suriname*, Trinidad & Tobago*, Uruguay*, Venezuela*.

8.4.Discussion

The LAC region is characterized by enormous contrasts, asymmetries and inequalities, which manifest themselves in a clear and extreme contrast in the lifestyles of the inhabitants (CEPAL, 2017). In this respect, the present investigation highlights the importance given to the UPA as a strategy for the fight to eradicate hunger and achieve food security and sovereignty in the region, as indicated by FAO (1997)and CEPAL (2017).

The scientific research on the subject of the UPA in LAC has been developed for approximately 35 years in 14 countries with major nutritional and socio-economic needs. Often, such needs appear after the occurrence of a natural hazard or a social or economic emergency. Among the latter, the main ones are migratory processes from the countryside to the city as a result of displacement from violence or rural impoverishment; also relevant are the pervasive high rates of urban poverty in the region, all of the above coinciding with that indicated by the (FAO, 2014f) for the Latin America region.

The present study supports the assertion that the vast majority of the UPA development in LAC has its origin in an emergency situation, coinciding with the indicated by Cittadini et al (2002) and Lavell (1997). Yet, as UPA develops, the needs or strengths of each country are mirrored in the nuances of their scientific production through a focus on the specific UPA functions. For instance, Brazil strongly prioritizes the Environmental-Ecological function over all others, directly reflecting the country's potential and expertise in the preservation of biodiversity. Meanwhile, Cuba shows the strongest emphasis on the Productive function, which indicates the knowledge gained as a result of lessons and innovations from the 'Special period'.

Despite the diversity of functions, the Social function is usually the second most important across all countries. This fact reaffirms the UPA origin as an emergency strategy. In turn, it exposes the prevalent problems of malnutrition and impoverishment in LAC, adding to this obesity in recent years; reinforcing the double-edged concept of The double burden of malnutrition (UNICEF, 2013; World Health Organization, 2017). The study of the Urban-Political and Economic functions is still in the beginning of their development.

In this context, it is worrying that despite the decrease in malnutrition in the region, obesity increase puts at risk all the work done in past decades. The increase in obesity is not a consequence of overcoming the economic crisis in the region. On the contrary, it is a consequence of complex social-economic-environmental processes that revolve around the global openness of the region. In line with insights by Perez-Izquierdo et al.(2012), we link the rise in obesity to the consumption of ultra-processed foods (rich in sugars and fats), which is cheaper than access to nutritious and culturally appropriate foods, either due to lack of financial means or due to the lack of space for its cultivation.

The current condition of LAC calls for a reconsideration of the projects and strategies of the UPA. Urban agriculture must be addressed from a productive and social cohesion point of view in the context of sustainability and food security (Sasson and Malpica, 2018; Trigo et al., 2013). UPA cannot be anymore the "lifeline" in an emergency situation. On the contrary, as indicated by the FAO (2001) and the RUAF Foundation(2015) it should become an intrinsic and fundamental element for the sustainable development of LAC. Hence advances are required in monitoring and control of the initiatives and projects developed. While the implementation of a program may be successful in terms of fighting against hunger and / or poverty, the improvement may fail in being constant and lasting. Therefore, governments in LAC should regularly encourage UAP as a way to ensuring the people's welfare and sustainability in the long term.

The scientific publications are a reflection of the recognition of the importance of the UPA's development programs in the region (De Bon et al., 2010; Orsini et al., 2013; Zasada, 2011; Zezza and Tasciotti, 2010). According to the figures presented above, there has been a remarkable development of scientific research in UPA in the last decade. It is worth mentioning that although international cooperation programs are a support for the development of the UPA, there are also cases in which the UPA develops organically without an institutional program. In this context, scientific research on UPA is a key ally in the struggle to achieve the SDGs and MDGs, eradicate hunger and promote more sustainable lifestyles. Working on functions of the UPA that have been relatively less addressed, such as the Economic and Urban-Political aspects, can help to underpin such effort.

8.5.Conclusions

This paper started with the objective of examining the extent to which scientific research in LAC addressed the functions of UPA. The main functions of the UPA in LAC are the Economic; Environmental-ecological; Productive; Social, and Urban-political. The review of the scientific literature on UPA in LAC found results in 14 countries in the region, which date back to 1983 and are distributed throughout the region. Based on these 220 scientific publications, it was possible to successfully assess the interest on such functions of the UPA over time and across the countries of the region

The five UPA functions are actually present in the region, although they are not investigated with the same intensity. The scientific interest on them depends on the priorities and issues of domain of each country. The Environmental-Ecology function tops the list of scientific publications, with almost half; and the Urban-political functions and Economic are the least developed functions. Reinforcing the investigation in these addresses can promote the role of UAP and its development. In this sense, the research carried out in the different countries follows the same line of action as the objectives of the FAO, since they focus on achieving food security in its four dimensions, on developing agricultural mechanisms with a social character, on preserving and increasing biodiversity and environmental benefits for the enjoyment of future generations and providing solutions in emergency situations. emergency situations.

Seeing urban agriculture as a measure for emergency situations, is it enough to achieve sustainable development in cities? It is clear that in the countries of Latin America the UPA is presented as a strategy to combat poverty and hunger. But it is not enough for achieving sustainable development and so that the UPA can be a complementary strategy for families, to support leisure and therapy functions, to strengthen feelings of relevance for the community, to facilitate social cohesion and the transmission of intergenerational knowledge, as in developed countries. It is necessary to take the next step towards a planned and guided UPA following the characteristics and potentials of each city. As reflected in the investigations, each country has specific and unique strengths that point the way forward for sustainability; Therefore, UPA promotion programs should be generated taking into account the particular needs of each site and not replicating strategies. In this way, there would be more opportunity to involve the population and to generate a true and lasting development of the UPA in the region.

Despite the encouraging achievements that the UPA has had in the fight against malnutrition, hunger and poverty, they are still part of the daily reality of the LAC countries. Most nations, policies and specific strategies to promote food security are far from being an objective confrontation that focuses on integrating the UPA as a fundamental part of a sustainable city. There is a lack of political and governmental commitment, there is a tendency to use generic strategies and the initiatives are still weak and are not prepared to face the new challenge represented by the obesity epidemic in the region. Specifically, the scientific community can support by developing future studies that focus on the urban-political and economic functions of the UPA, such as: the economic feasibility for local initiatives, the integration of areas for the UPA in strategic areas of the city, new master plans of urban development, potential markets for local production, architectural design strategies that integrate the UPA into buildings and potential economic and social advantages that can be developed in the LAC region.

Chapter 9

Feasibility assessment of rooftop greenhouses in Latin America. The case study of a social neighbourhood in Quito, Ecuador

CHAPTER 9 - Feasibility assessment of rooftop greenhouses in Latin America. The case study of a social neighborhood in Quito, Ecuador

From this chapter, a paper has been extracted and submitted in a peer-review indexed journal and had the following collaborators:

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Submitted to Science of the Total Environment

Abstract

In Latin America, there are numerous cases of urban agriculture. The purpose of this study is to identify the implementation potential of rooftop greenhouses in social neighborhoods in Quito. Standard methods to assess the potential use of rooftop greenhouses were adapted to a social neighborhood. The results showed that 33.2% (7.70 ha) of the neighborhood rooftops had a short-term feasibility to become rooftop greenhouses, with the potential to produce 1,579,140 and 56,720 kg/year of tomato and lettuce respectively. The research has developed reliable guidelines that prove the feasibility to install rooftop greenhouses in similar large Latin-American cities area.

Keywords: vertical farming; sustainable cities; food security; food self-sufficiency; rooftop greenhouse, Latin-American cities.

9.1. Introduction

Today, urban agriculture (UA) emerges as a tool to mitigate and prevent the negative effects on food flows caused by a quick urbanization process (Halloran, 2011) and is gaining support as an important part of the solution (Orsini et al., 2013). Urban agriculture is developed in different forms, one of which is through crops protected by a greenhouse on the roofs: Rooftop greenhouse (RTG)(Nadal et al., 2015). This form of UA uses specific substrates for hydroponic crops and have modern irrigation systems often combined with rainwater harvesting. RTGs are more efficient than other UA systems, such as UAs and green roofs achieving up to five times more productivity due to substrate use, which is lighter than soil, which reduce the RTG weight and therefore their loads on the building structure (Dubbeling and Massonneau, 2014; Sanyé-Mengual et al., 2015a).

In some high densely populated cities, where soil availability is limited, RTGs has been installed for vegetable production (Baker, 2000). As an example, in developed countries, in New York, Gotham Green has 1,400 m^2 of RTGs and aims to reach 18,000 m^2 and The Vinegar Factory produces its own vegetables and fruits in 830m^2 of RTGs. In Montreal, Canada, Lufa Farms has built 2,900m^2 of RTGs (Sanyé-Mengual et al., 2015a). There are also interesting experimental experiences. For example on the rooftop of ICTA-ICP (Environmental Cience and Technology Institute and Catalonian Paleontology Institute) building at the Autonomous University of Barcelona, there is an integrated RTG in which CO_2, energy and water connected flows between the RTG and the building are studied so they can improve the edifice matabolism (A. Nadal et al., 2017b). In this sense, Latin-American countries such as Argentina, Brazil and Cuba have approved policies and programs to promote UA (Moran-Alonso, 2011; Moran-Alonso and Hernandez, 2011; Orsini et al., 2013). There are also several examples of UA as an initiative led by local governments, organizations and multilateral organisms (mostly FAO), which aim to encourage involvement from the unemployed and socially excluded population, in order to improve their socio-economic conditions, malnutrition and confront famine (FAO, 2014c; Orsini et al., 2013; Zaar, 2011). A real example is La Habana, Cuba, which uses 12 % of its surface area for UA, to grow organic crops mainly for self-consumption (Cruz and Sánchez-Medina, 2003). There are also further cases of UA in Latin-American cities (Table 9.1).

Table 9.1 Urban Agriculture experiences in Latin America.

Country	City	Kind of orchard	Number of orchards	Production Ton/year	Urban Farmers	Beneficiaries	Reference
Argentina	Rosario	Household	-	-	1,800	-	FAO, 2014
Brazil	Belo Horizonte	Household	233	-	-	-	FAO, 2014
Colombia	Bogotá	Household	-	-	10,000	8,500 Families	FAO, 2014
Antigua and Barbuda	Conglomerate of cities	Household	-	280	-	-	FAO, 2014
Cuba	La Habana	Household	-	6700	90,000	30,000 inhabitants	Liendo and Martínez, 2006; FAO, 2014
México	Ciudad de México	Household	12,300	-	-	-	Torres-Lima et al., 2010
Bolivia	El Alto	Household	-	-	-	89,000 inhabitants	FAO, 2014
Nicaragua	Conglomerate of cities	Household	250,000	-	-	-	FAO, 2014
Ecuador	Quito	Household	800	-	10,250	-	FAO, 2014
		Communitarian	140	-		-	
		Scholar	128	-		-	

Ecuador is widely recognized for its socially focused UA system. In April of 2000, the Quito Declaration took place in Ecuador, which was signed by representatives of 27 cities in 10 Latin-American and Caribbean countries, with a commitment to develop and promote UA in the region (FAO, 2014c, 2012). These UA developments were based on the urban-architectonic features shared by cities in this region, with free and horizontal roofs. On an urban scale the extensive use of UA in Quito is remarkable (CONQUITO, 2009; FAO, 2014c).

The present research aims to identify the implementation potential of rooftop greenhouses in social neighborhoods in Quito. To do so it develops a new version of a previous guideline through an interdisciplinary scope, which was applied in a representative neighborhood selected for the research. And has three following specific objectives:1) carry out research about existing guidelines for installing RTGs to take relevant cases that could be useful in Latin-American cities and adapt them to a series of guidelines for social Latin American neighborhoods; 2) identify a social neighborhood in Quito, Ecuador with the typical features of a Latin American city to test this guideline; 3) determine the available surface area for a short-term use of RTGs, and then estimate the potential results: production, self-sufficiency and the surface area needed to self-supply. This could allow to identify the potential of RTGs to achieve food security and social urban rehabilitation.

9.1.1. Background. Urban Context of Quito

The Metropolitan District of Quito (DMQ) is considered as a disperse city, which is on the way of becoming a compact city due to new urban regulations, therefore, nowadays it is a mix of high density and low density areas located in differentiate areas (Correa, 2012; Jaramillo and Van Sluys, 2012). The same process of compactation is happening in other Latin-American cities (Garza, 2009). High density or compact cities are areas that are characterized by population concentration in buildings where several families live, on the other hand on a low density or disperse city, consists on single family households with neighborhoods with lower construction diversity (Chavoya et al., 2009).

There were three important phases during its urban configuration. First, during the first half of the 20th century, its growth focused on a North-South axis, generating an urban expansion process without precedent, based mainly on an important migration flux from rural areas (Clavijoo Palacios, 2013) that consolidated the compact urbanization process of DMQ (Correa, 2012). Then, the second half of 20th century was characterized by an exponential urban growth in the valleys located at the East of DMQ that extended the boundaries of the city (Correa, 2012). Third, at the beginning of 21st century, the new Metropolitan Land Use Plan for the DMQ 2012-2022 (PMOTDMQ) priorized vertical growth and city densification, leading to a second ongoing compaction process (Jaramillo and Van Sluys, 2012; MDMQ, 2012a; Vaca, 2015). These phases have defined the present mixed urban conformation, nonetheless, it is still mainly has a disperse configuration and therefore similar to most Latin-American cities (Garza, 2009; Quintero and Gómez, 2012). Therefore, studies and experiencies in Quito can be used as a reference for the region.

There are numerous DMQ particular conditions that make Quito specially suitable for UA experiences. For example the local building guidelines, the technical rules for architecture and urbanism, consider the residential agriculture as a land use (MDMQ, 2011a). Quito's location and weather conditions also favor UA (Appendix 6.1), with mid-high precipitation and stable temperatures throughout the year, and optimal sunlight hours for agriculture production (MDMQ, 2012). The demographics features (rural-urban migration) and architectural features of Quito also endorse UA, with a dense city with unfinished buildings located in peripheral areas (Correa, 2012; Figueroa, 2012).

In Quito the main construction material is reinforced concrete, roughly 75 % of the households are build on this material and have unfinished rooftops (INEC, 2010). This is relevant for RTGs assessment and showed a potentiality to its implementation. Moreover, there are vulnerable sectors, in which there is a need for food security and access to acceptable food. This is fundamental for decision makers, whom require well planned methods to consider the use and installation of UA facilities, in particular RTGs, when the urban layout and architecture make this option feasible.

9.2.Methodology

9.2.1.Guideline Adaptation

Existing guidelines for installing RTGs have been analyzed and an adaptation was made from two researchs developed in Barcelona by Sanyé-Mengual (2015) and Nadal (2017) and focused on several factors to determine the economic viability of installing RTGs. The guidelines follow three steps shown in Figure 9.1.

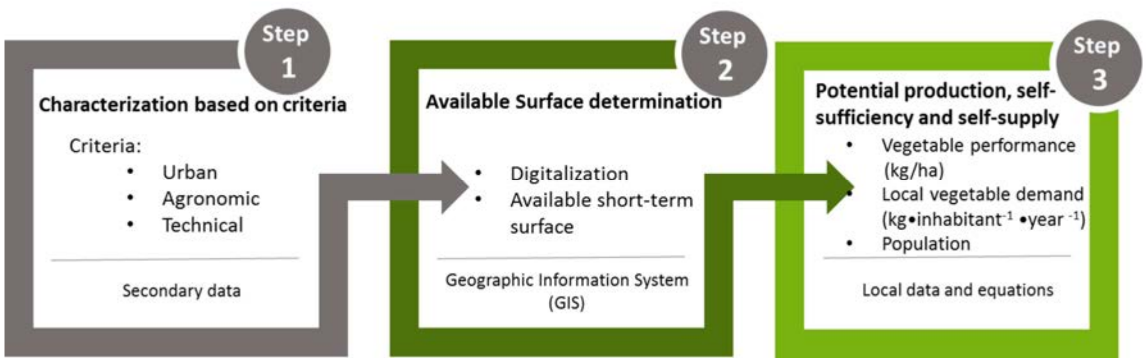

Figure 9.1 Methodology diagram based in Sanye-Mengual et al., (2015) and Nadal (2017) guidelines.

Relevant aspects of the guidelines were used together with features that were developed for this research to define the proposed guidelines, presented in Table 9.2. These guidelines have been applied to analyze the feasibility of RTGs implementation in the study area.

Table 9.2 Graphical representation of the methodology (guide specifications) proposed for identifying the feasibility of RTG implementation in social neighborhood in Quto.

		CRITERIA	ASPECT	REQUIREMENT	IMPLEMENTATION FEASABILITY Direct Short-term Digitalization: polygon	 Middle and long-term Digitalization: point	RESOURCES AND TOOLS
STEP 1	CHARACTERIZATION BASED ON CRITERIA	Urban	Legal *	Rules, ordinances, development plans and other official local documentation.	X	X	Local cadastral plan, orthophoto. GIS
		Agronomical	Social **	Covers >10 m^2 Ranges (m^2): •10-90 •90-170 •170-250	X		Orthophoto or site inspection. GIS
			Sunlight availability **	Minimum: 4-6 hours of sunlight	X	X	Local official documentation. Websites of local institutions.
		Technical	Architectural *	Load Capacity and Free of occupation (Antennas, water tanks, water heaters, craft workshops)	X	X	Local secondary information. NASA Surface meteorology and solar energy (web application)
			Rooftop Material*	Reinforced concrete	X		Orthophoto or site inspection. GIS
				Metal		X	
				Asbestos		X	
				Zinc		X	
				Roof tile		X	
				Palm or straw		X	
			Slope*	Flat	X	X	Orthophoto or site inspection. GIS
				Inclined		X	
				Gabled		X	
				Hipped		X	
				Convex		X	
STEP 2	AVAILABLE SURFACE DETERMINATION	Middle & long term available surface					Rooftops were digitalized as polygons, to obtain available surfaces considering criteria defined on Step 1
		Term available surface (ha)					Middle and Long-term implementation required an reconstruction to adapt the roof for an RTGs structure
STEP 3	PRODUCTION, SELF-SUFFICIENCY &	Selected vegetables	$Production\ (kg/year) = Potential\ Area(ha) \cdot Vegetable\ output \left(\frac{kg}{ha \cdot year}\right)$				
			$Self - sufficienc\quad (persons/year) = \frac{Production(kg)}{average\ vegetable\ intake\ \left(\frac{kg}{percapita \cdot año}\right)}$				
			$Self - supply\ surface\ (ha) = \frac{average\ vegetable\ intake\ \left(\frac{kg}{percapita \cdot año}\right) * population}{Vegetable\ output \left(\frac{kg}{ha}\right)}$				

*Taken from Guidelines proposed by Sanyé-Mengual, et al 2015 and Nadal, et al 2017. **Include for this research

- Step 1: Chracterization based on criteria

The following three criteria were applied and adapted for this research: urban, agronomic and technical. Urban criteria include 3 aspects (Legal, Architectural and Social). The legal background, which considered a revision on rules, ordinances, development plans, laws and other official documentation from the study area location, at local and national level, to determine conditions which could limit or enhance RTGs implementation. Also, environmental regulations on UA and RTGs were analyzed, and finally commercial regulations were checked. Finally, insititutional background is reviewed.

Second, the Agronomic criteria, here social aspects were include as an aditional feature on the guidelines, related with self-supply and food security at household level, which considers that the needed surface to produce enough vegetables for a family of four people is 10 m^2 (FAO, 2005a; Jeavons and Cox, 2007), in this sense lower surfaces will be considered as not feasible. On the other hand, the main factor which limit agricultural production is sunlight hours was considered because it is fundamental for vegetative growth and thus for RTGs implementation.

Third, the Technical criteria, architectural features were analyzed, the structural capacity of buildings is important to determine whether it would support an RTG on its rooftop, therefore, guidelines for buildings design, which show structural capacity and security regulations were researched. Besides, in order to optimize RTGs implementation, it was determined that potential surfaces must be free of permanent equipment, like solar panels, aclimatization equipment, water tanks among others. Nonetheless, the surface can also be considered as feasible if this equipment can be removed.

Feasibility clasification is based on rooftop construction materials (reinforced concrete, steel or timber structure and asbesto cement, zinc, roof tile, palm or straw finishing layers) and slope (flat, pitched, gabled or hipped roof). This characteristics were used to separate short term feasible from middle and long term feasible RTGs implementation.

- Step 2: Available surface determination

Geographical data analysis was made using ArcGis 10.2 (ESRI, 2013). It consisted in counting all buildings determined as middle and long term feasible, digitalizing them as a point, and measuring all short-term feasible RTGs implementation, digitalizing them as polygons. The data source were orthophotos obtained from a project of Ecuadorian Agriculture Ministry (SIGTIERRAS, 2016), and satellite pictures obtained from Google™Earth.

- Step 3: Production, self-sufficiency and self-supply

Finally, production, self-sufficiency and self-supply were measured taking the surface results obtained for short-term feasible implementation, two equations (1 and 2) where obtained from an assessment for RTG feasibility (Sanyé-Mengual et al., 2015a), and the third equation was developed to measure self-supply capacity, which is relevant for this research. There were considered no difference between periods because the productivity in greenhouses remains similar all year in this region. The equations used were the following:

$$Production\ (kg/year) = Potential\ Area(ha) \cdot Vegetable\ output \left(\frac{kg}{ha \cdot year}\right) \quad (1)$$

$$Self - sufficie \quad (persons/year) = \frac{Production(kg)}{average\ vegetable\ intake\ \left(\frac{kg}{percapita \cdot \text{año}}\right)} \quad (2)$$

$$Self - suppl \quad surface\ (ha) = \frac{average\ vegetable\ intake\ \left(\frac{kg}{percapita \cdot \text{año}}\right) * \text{population}}{Vegetable\ output\left(\frac{kg}{ha}\right)} \quad (3)$$

There were chosen two highly demanded vegetables to use the equations, which avarerage intake per year and output were obtained from secondary sources, in order to estimate the RTGs potential benefits that would be obtained through their implementation.

9.2.2.Case study

Study area was defined to satisfy three key points:

- First the discontinuous, heterogeneous and fragmented urban configuration that exists in Quito and most Latin-American cities (Borsdorf, 2003; de Mattos, 2002; Jaramillo and Van Sluys, 2012; Matossian, 2015).
- Second a population composed of rural-urban migration that could provide human talent based on prior knowledge of agriculture in the RTG installations (Orsini et al., 2013).
- Third the possibilities of developing UA within the urban planning and construction laws (Torres-Lima et al., 2010).

The social neighborhood, "La Comuna Santa Clara de San Millán" (CSCSM) was selected as study area (Appendix 6.2). It is located in Northwestern zone of Quito (Figure 9.2), on the foothills of Pichincha Mountain, which limits its expansion. Regarding to services there are a coverage of potable water of 64 %, sewage system 77 %, electricity 99 % and 38.1 % finished roads (paviment, cobble and concrete). It fullfils the criteria defined to select the study area, it constitutes as an ambiguous territory between urban and rural, where social differences are related to division on urban space, creating a distinction between social classes on the urban territory (Matossian, 2015). Heterogeneity within the neighborhood means that dwellers from low and high social strata coexist within the same administrative boundaries while physically separated (CIC, 1992; CEPAL, 2012).

On the other hand, neighborhoods located next to foothills present similar characteristics because of their similar topography and natural conditions (Carrión and Erazo, 2012). These neighborhoods also have the same structure than those located on peripherical rings, considered as disperse areas, that form the city (Jaramillo y Van Sluys, 2012), which made a portion of CSCSM also representative of this areas. To sumarize, this neigborhood has two different areas which represent a compact and disperse (peri-urban) area respectively.

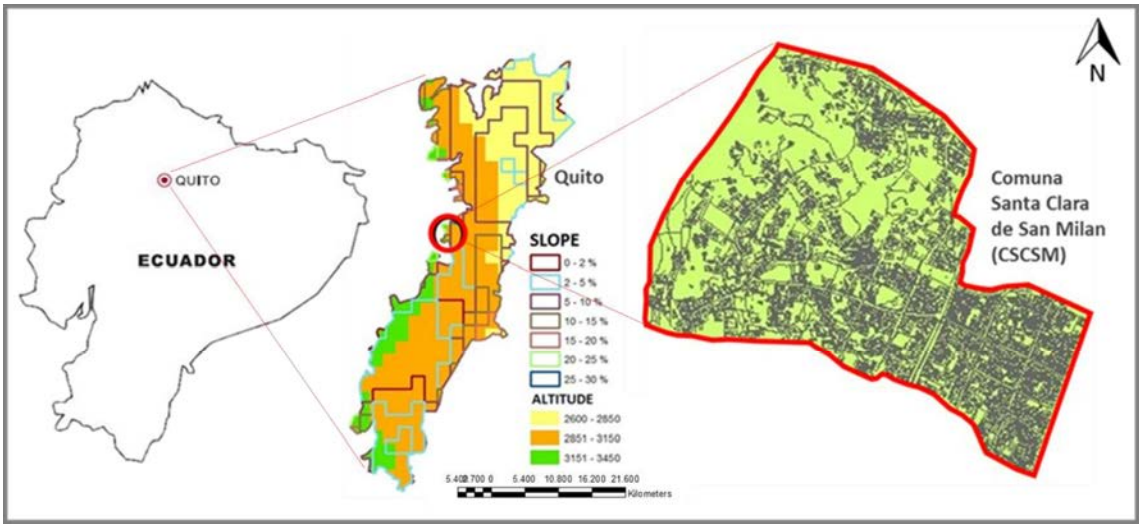

Figure 9.2 Location of social neighborhood Comuna Santa Clara de San Millán.

The CSCSM had 35% of rural origin population (INEC, 2010; Larrea et al., 2009; MDMQ, 2011b) with experience on agriculture practices that will improve RTGs implementation results.

On the other hand, there is an ordinance related with Land Use (MDMQ, 2011a) that establishes UA as a land use. In the urban planning and construction laws attached to this ordinance, green roofs are considered and described, which not include RTGs, giving general requirements for their implementation and construction methodologies, also mentioning their classification, importance and economic and environmental benefits. Nonetheless, in this document, green roofs are considered mainly as aesthetycal features (MDMQ, 2011b). Furthermore, CSCSM has a metropolitan ordinance (MDMQ, 2014) which is a sustainable development plan for the neighborhood that includes guidelines related to land use. It establishes that all areas could apply ecological protection, which includes UA inside land use regulations.

In order to improve the assessment of this study results, CSCSM has been divided in the following two areas: a (Figure 9.3).

- Area A: Disperse zone with great heterogeneity, low construction density (with irregular blocks related with its topography) and numerous green areas, which is representative of peri-urban cities. These areas are not parceled and end being occupied illegally by precariously built constructions from migrants.

- Area B: Compact zone, with a relative homogeneity and high construction density WITH orthogonal shaped blocks, which is representative of compact cities.

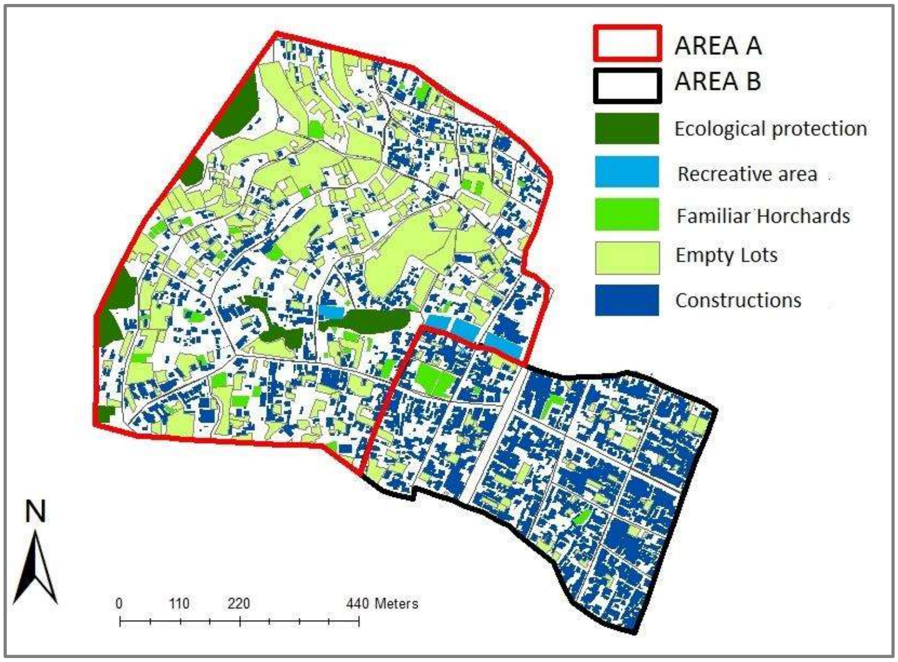

Figure 9.3 Map of Comuna Santa Clara de San Millán, Land Use.

Regarding to their constructions CSCSM presents unfinished buildings that are mainly households owned by single families. Area B is full of 3 to 4 storey buildings 12 to 16 m high that occupy their whole parcels while area A has 1 to 3 storey buildings (MDMQ, 2014), and parcels have lower built surfaces. These buildings have reinforced concrete columns and solid load bearing slabs with masonry non-load bearing facades. Most roofs, about 75 %, are reinforced concrete slabs without any other material or layer on top. These roofs lack finishing, waterproof or insulation layers. The rest of roofs have metallic, asbestos cement or zinc finishing layers leaning on a light structure of steel or timber joists and beams (INEC, 2010). Older buildings have load bearing rammed earth walls and pitched roofs with light joists and beams covered with roof tiles.

In the CSCSM, urban orchards were found, which are mainly focused in self-consumption. Also, ecological protection areas and recreation areas were found, which had poor infrastructure such as soccer fields without grass and playgrounds in poor conditions.

9.3.Results

9.3.1.Local data

Specific data are needed for the application of the presentmethodology in the case study. To validate the Agronomic criteria of Step 1, the maximum surface found in the study area was 250 m^2. Studied rooftops were between this minimum and maximum surface values and classified in the three following categories: 10-90, 90-170 and 170-250 m^2, the selected ranges were applied to have similar intervals between them. Sunlight hours in Quito, vary little during the year because it is located close to Ecuadorian meridian. To obtain this data the Atmospheric Science Data Center was used (NASA, 2016), and an availability of 12,1 sunlight hours per day during all year, without seasonal differences was found, which covers the requirement of between 4 and 6 sunlight hours for UA (FAO, 2003). And reinforced concrete , which in Ecuador have a load capacity of minimum 200 Kg/cm (MIDUVI, 2014), and flat roofs have been considered as short-term feasible while all other materials and slopes have been considered as middle and long-term feasible (Sanyé-Mengual, 2015b; Sanyé-Mengual et al., 2015a).

In the Step 3. To determine these parameters, two vegetables were selected, considering two of the most consumed vegetables in Quito, tomato and lettuce. They were also chosen because they are representative of Ecuadorian diet (MAGAP, 2016). They have a big difference in demand and productivity. Respective values of consumption per capita of 5.43 and 0,56 kg·habitant^{-1}·year^{-1} were used (MAGAP, 2016). The production considered for these vegetables with Ecuador hydroponic greenhouse features , were 192,000 and 7,900 kg·year^{-1} respectively (AIC, 2003; Rendón and Yance, 2012). These productions were distributed in areas A (tomatoes) and B (lettuces) in order to obtain self-sufficiency capacity of two different types of vegetables, with different performances, for all Quito's urban population. For self-supply the population of CSCSM (8,862 inhabitants) was considered, (INEC, 2010).

9.3.2.Results of the Case Study

Step 1: Chracterization based on criteria. Regarding legal background, in Ecuador there is the National plan of good living 2013-2017 (SENPLADES, 2013), which consists in national guidelines for public affairs. This plan aims to promote, develop, guarantee and transversalize social cohesion, and local and national environmental sustainability. However, the Agriculture and Environmental Ministries do not include UA in their plans. Moreover, Environmental Ministry activities catalog to get environmental licenses does neither include nor standardizes UA activities.

On the other hand, in Quito, UA is included in municipal planning as an objective (MDMQ, 2012a) and guidelines for performing it are specified in the Urban planning and construction law (MDMQ, 2011a). Fresh food production is regulated by an Agriculture Ministry agency (AGROCALIDAD) and by Ecuadorian Institute of Normalization (INEN) which establish law for vegetable production, packaging and all measures needed from distribution to sale (AGROCALIDAD, 2013; INEN, 2011, 1996). Besides, there is a guideline for good practices specific for tomato cultivation (AGROCALIDAD, 2015). CSCSM differs from other neighborhoods because it is led by a council composed of five members, which control activities and relations with external stakeholders. This council is elected each year by CSCSM households' owners. This is an advantage to apply a new experience such as RTGs, because the implementation process would be done supported by the neighborhood owners' representatives.

Finally, Quito has an ongoing experience in UA, primarily incentivized by AGRUPAR project, which assembles urban farmers and 380 communitarian organizations who work in UAs, and is supported by NGOs, Quito's municipality and universities (Duenas, 2010). This project has promoted commercialization of products holding fairs called "*bioferias*", to attract consumers with organic and urban soil agriculture products. It started to incentivize the use of balconies and rooftops in zones without access to soil, promoting vertical UA in Quito, using recycled materials (FAO, 2014c).

Step 2: Available surface determination. First data was gathered from Quito municipality dependencies. Then base geographical data was obtained from the Secretary of Territory, Habitat and Dwelling (MDMQ, 2012b) to delimit the CSCSM and it was contrasted with data included in its especial development plan (MDMQ, 2014). Ortophotos on scale 1:5,000 obtained from Agriculture Ministry (SIGTIERRAS, 2016), satellite images gathered from Google™Earth were processed with ARCMAP 10.2 (ESRI, 2013). All rooftops were identified in the aforementioned two groups: 1) short-term feasible and 2) medium and long-term feasible (Figure 9.4). In CSCSM 3,494 rooftops were found, from which 1,160 were short-term feasible (33.2 %).

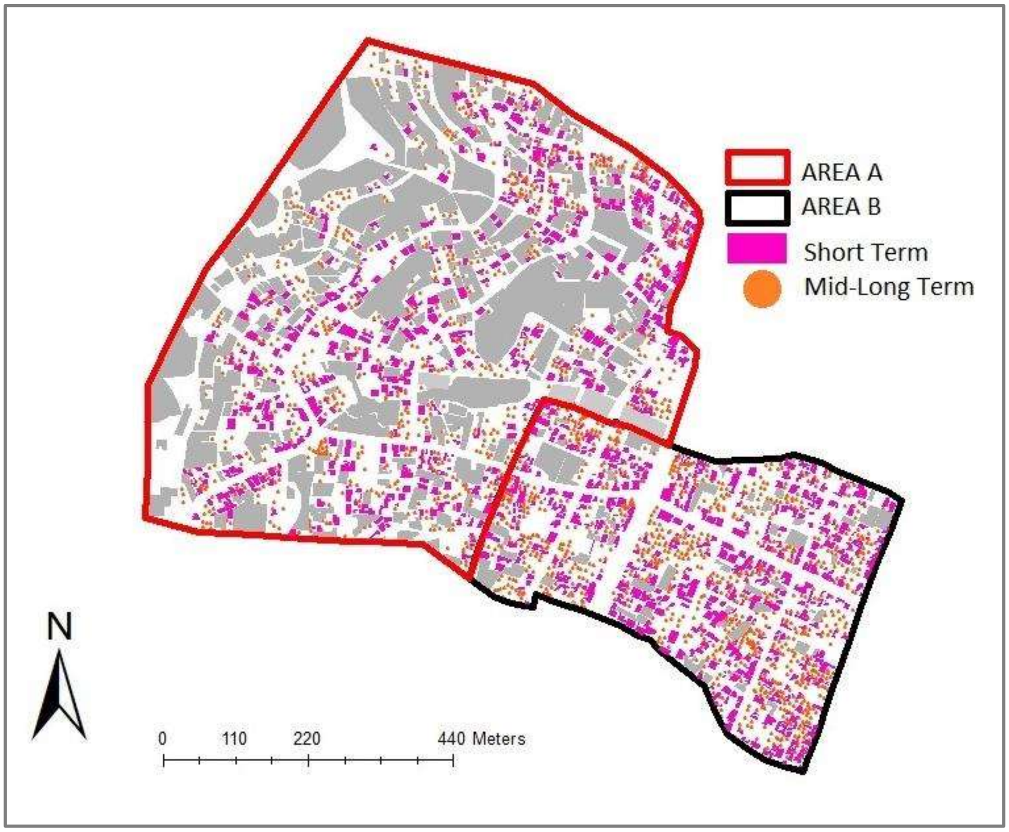

Figure 9.4 Characterization of covers in CSCSM.

Through digitalization each polygon surface was measured and the total surface available for RTGs implementation was 7.70 hectares (4.11 in Area A and 3.59 in Area B). These were classified for both areas in the aforementioned three categories shown in Figure 9.5. Most rooftops found were between 10 and 90 m^2 (76 %) and only a small amount was between 170 and 250 m^2 (3 %).

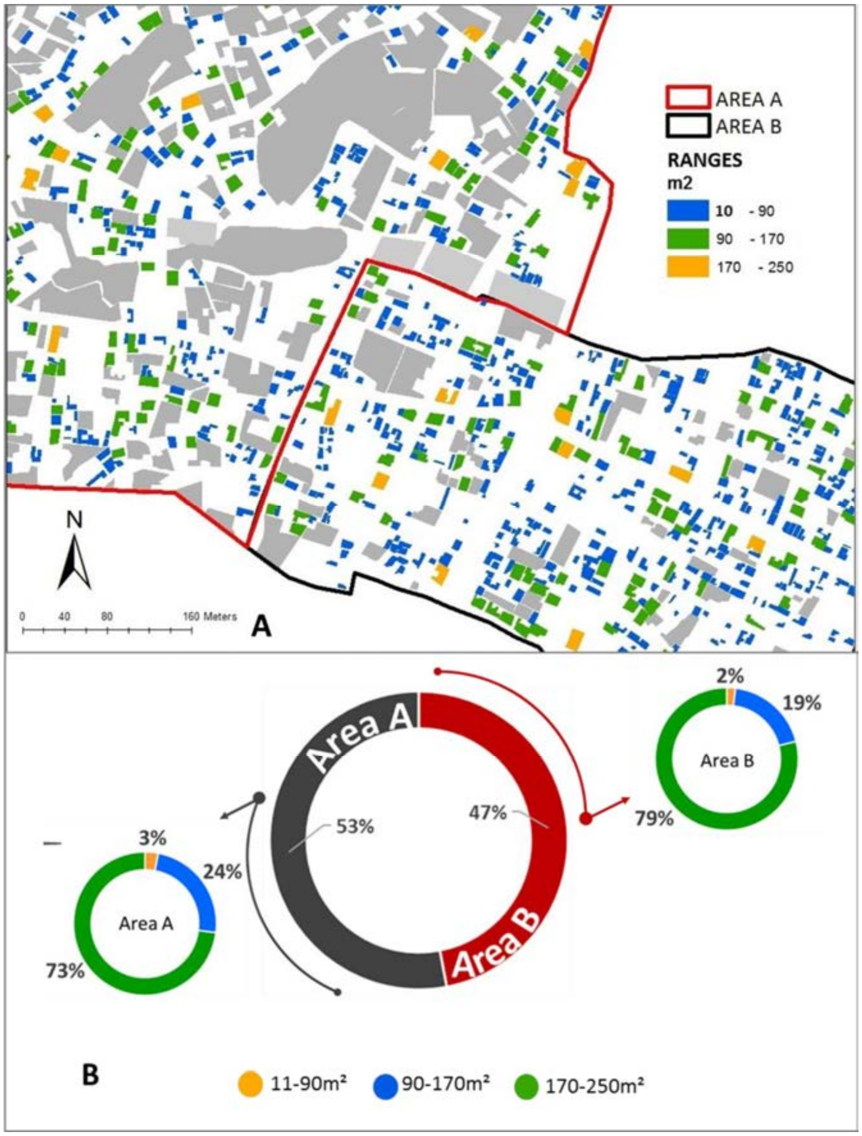

Figure 9.5 A. Ranges of short term available surfaces in CSCSM by ranges. B. Percentages of available surfaces per range for short term implementation of RTGs.

Step 3: Production, self-sufficiency and self-supply. The data obtained was studied along with results from the previous step for available surfaces in the studied area and analyzed in equations 1, 2 and 3. Results showed that available surface for RTGs implementation, would produce 789,750 kg of tomato in area A and 28,360 kg of lettuce in area B (Equation 1). This production would satisfy 145,408 and 50,642 inhabitants demand respectively, roughly 9 and 4.5 % of Quito's population (Equation 2).

As expected from results obtained for self-sufficiency, the required surface to achieve self-supply for CSCSM would be only 0.25 hectares in area A for tomato and 0.61 hectares in area B for lettuce, which represented 3.25 and 8.16 % of available surface for short term feasible for RTGs implementation, in each respective area (Equation 3). Afterwards, the surface needed for self-supply was compared with available surface for the three ranges used, showing that from 10 to 170 m^2 would self-supply tomato and lettuce for the neighborhood but the 170-250 m^2 range would only achieve self-supply of tomato (Table 9.3).

Table 9.3 Potential Production and Self-Sufficiency for CSCSM short-term feasible RTGs implementation.

	Area A (Tomato)			Area B (Lettuce)		
Surface Ranges (m^2)	10-90	90-170	170-250	10-90	90-170	170-250
Short-term available surface (ha)	2,16	1,64	0,32	2,14	1,23	0,22
"PR" Potential Production (kg/year)	413,900	315,000	60,700	16,91	9,75	1,70
		7,895,700			28,36	
"SS" Self-sufficiency (personas)	76226	58011	11170	30194	17415	3033
		145408			50642	

Note: ***Tomato performance is 192,000 kg/ha/year (AIC,2003),lettuce performance is 7,900 kg/ha/year (Rendón and Ledesma,2012), demand of tomato is 5,43 kg/person/year, and of lettuce is 0,56 kg/person/year*** **(MAGAP, 2016)**

9.4.Discussion

9.4.1.Study area selection and methodology use

The selected study area combined characteristics representative of both urban and periurban territories. It was useful to test the guidelines in both urban configurations (high building density, Area B) and peri-urban configuration (middle building density, area A). The results obtained using the guidelines validate their application, even though, some further verification may be required in similar studies due to differences in the quality of existing data with those of the chosen study area. Despite fieldwork would get better results, GIS is an useful tool to save time and resources and made these guideline useful for this kind of researches.

The main features found in the study area were the ongoing experience in Quito with UA and the legal background, which would facilitate a future RTGs implementation, because the neighborhood already has an organization with attributes to negotiate this kind of initiatives (MDMQ, 2014). This is relevant for further research and for cooperation with universities and NGOs (Non Governmental Organizations). At national scale there was not enough data about UA from central government. Despite of this, UA aligns with some social and environmental objectives of the Ecuadorian government guidelines, contained in the National plan of well living (SENPLADES, 2013).

Criteria to determine short-term feasibility rooftops was adapted from the chosen guidelines (A. Nadal et al., 2017a; Sanyé-Mengual et al., 2015a), nonetheless, some characteristics were modified to adapt the guidelines to be used in social neighborhoods. The modifications were: 1) In the legal background, intitutional review was included, to assess posibilities of institutional support on a future RTGs implementation 2) the size of rooftops found in the study area were shorter than the value of 500 m^2 determined as feasible in the followed guidelines, therefore, new considerations were necesary to clasify them, thus considering a minimun surface based on self-supply capacity at household level was chosen. 3) Despite the base guidelines mentioned sunlight influence in RTGs implementation, related to crop growing capacity, a measure methodology was not mentioned, in this sense, in the proposed guidelines, sunlight determination was included to know sunlight hours available in any location. 4) An equation to measure the self-supply capacity for the study area, which gives a focus to social characteristics and to food security in social neighborhoods.

Most rooftops had a surface between 10-90 m^2 while the maximum surface was 250 m^2. This important difference is remarkable, but the main criterion considered in this analysis, focused on a social neighborhood, was self-supply capacity rather than economic threshold. Nonetheless, selling surplus production will still be important to generate extra income for families. For this reason self-sufficiency results are also relevant.

For the case of this research, medium and long term feasibile rooftops are not considered, because in the case of a social neighborhood extra expenses that would be caused to dwellers, could prevent the RTGs implementation to fulfil the chosen social approach. Only 33.2 % of rooftops were short-term feasible, a value much lower than the expected one of 75%, which is the proportion of reinforced concrete rooftops found in the neighborhood in the Ecuadorian census of 2010 (INEC, 2010). This showed the importance of performing a research in neighborhood scale, because results could vary from general statistics for city level. Sources to gather data could be local governments, NGOs, research facilities, universities, local agencies, international development agencies or other sources relevant on the chosen study area.

9.4.2.Production, self-sufficiency and surface for self-supply

The sources used in the equations were gathered from secondary local sources, with expirience in vegetable production in traditional greenhouses (AIC, 2003; Rendón and Yance, 2012). The results would require validation from a future real experience in the study area, to compare the average vegetable output. On the other hand, average vegetable intake could be obtained for the most demanded vegetables in the study area, to use the guidelines with other vegetables. These results showed that the application of the guidelines, using data obtained for other study areas, would help to understand the potentiality of RTGs in other research projects.

Self-sufficiency equation showed that the study area would cover 9 % and 4.5 % of Quito's demand of tomato and lettuce respectively, which shows the big potential of RTGs implementation because CSCSM represents only the 0.17 % of Quito's area (INEC, 2010; MDMQ, 2012b). Results showed that only 5.8 % and 14.6 % of surface of the first range of available rooftops, 10 to 90 m^2, would be required to self-supply CSCSM (Table 9.4). This presents an opportunity for using all other available area to produce other vegetables demanded for CSCSM residents, which could be cover with the remaining surface, and perhaps surplus for commercialization could also be obtained. If the previous case is demonstrated, the self-supply production could be focused in the first range (10-90 m^2), while surplus production could be cropped as monoculture in medium and bigger range surfaces (90-250 m^2). Commercialization would be done using the existing structure in Quito for UA products.

Table 9.4 Required surface for self-supply of CSCSM.

Self-Supply required area (ha)				
Vegetable			**Tomato %**	**Lettuce %**
"SPA" (*ha*)			*0,25*	*0,63*
Short-term available surface by ranges (*ha*)	***10-90***	*4,3*	5,83	14,61
	90-170	*2,87*	8,73	7,19
	170-250	*0,54*	46,41	100*
Percentage needed of Total available surface			***3,25***	***8,16***

*Note: Population CSCSM: 8862 inhabitants; "SPA" Self-supply required area, Short-term available surface by ranges: 7,7 ha; *Characterized area is lower than required area*

9.5. Conclusions

This methodology has proven to be a promising and adaptable tool for identifying all rooftops with the potential for the implementation of RTGs with a social perspective in a study area. For this research, in the study area there were found a total of 3.494 rooftops, from which 1.160 (33.2 %) were considered as short term feasible. There were obtained a surface of 7.70 hectares (around the 12% of the study area surface) of short-term feasible rooftops. In the area A (disperse zone), which represents a peri-urban area, 4.11 hectares were found, in area B (compact zone), which represents the compact city, 3.59 hectares were found.

Showing that there were available rooftops in both configurations, and the potential for the application of the guidelines in similar areas in Quito, and other Ecuadorian and Latin-American cities. To apply the guideline, it will be necesary to take into account each urban area particularities. This aplication would require and independent analysis of conditions, which surely would change from one country to the next and even between sub national administrations. Besides, limited availability and quality of data can difficult applying the guidelines in the chosen study area and may require fieldwork. Nonetheless, the guideline could be used as a baseline in places with similar limitations saving time and resources.

Regarding self-sufficiency and self-supply, two vegetables were used, nonetheless, the equations used can be applied with any vegetable crop. Results showed that the study area would supply the 9 % and 4.5 % of Quito's demand of tomato and lettuce, with a production of 789,750 kg of tomato in area A and 28,360 kg of lettuce in area B. For self-supply, there would be required 0.25 hectares in area A for tomato and 0.61 hectares in area B for lettuce, which represented 3.25 and 8.16 % of available surface respectively. The results for self-supply showed that there is a potential to produce more vegetables demanded in the neighborhood, which would allow to persue food security inside the neighborhood.

This guideline can be useful for Latin American decision makers, researchers, students, communitarian organizations, schools, universities and local governments among others. These parties could assess their own RTGs initiatives adapting the guidelines to their goals. This would allow to create opportunities and to project the future of the cities with a self-supply perspective that would improve city resilience. Future research could be done supported by local organizations as CSCSM council. In this sense, universities could create agreements with similar local organizations, which would generate knowledge beneficial for local neighborhoods and professionals involved in this research field. And further analysis of some socio-economic situation and household composition factors could improve perform real scale RTGs implementation.