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Green infrastructure and public policies: An international review of green roofs and green walls incentives

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ABSTRACT

Worldwide, green infrastructure is increasingly used to mitigate the impacts of dense urban areas, contributing towards the naturalization of the built environment. However, for investors, these systems often emerge as requiring substantial upfront cost (high installation costs) and, depending on the solution, might also have significant maintenance costs. On the other hand, policymakers are placing green infrastructure on the agenda, as a solution to consider in urban planning and design. There is a mismatch between the economic/social/environmental value of green infrastructure and their financial analysis. As the quantified benefits of these solutions may not compensate the high implementation costs, discouraging building owners to invest in them. The alignment of both expectations, public and private agents, regarding the development of green infrastructure, is done through the use of incentives, with distinct configurations and nature, that promote and facilitate the adoption of green infrastructure by private investors. This research aims to identify and analyse the incentive policies used by several municipalities to promote the installation of green roofs and/or green walls. The data set includes 113 cities in 19 countries. The incentive policies were classified into six different categories: tax reductions, financing, construction permit, sustainability certification, obligations by law and agile administrative process. The results show that incentive policies are mainly concentrated in Europe and North America, and most incentive policies focus on the promotion of green roofs, as no exclusive incentive policies for the promotion of green walls were found. From all incentive policies studied, financial subsidies and obligations by law are the most used ways to promote green infrastructure worldwide.

1. Introduction

In the context of densely urbanized areas green spaces are becoming scarce. However, green spaces have several benefits for the health and wellbeing of citizens (Contesse et al., 2018). Green infrastructure is being used, especially in European and North American cities, as a mechanism for the implementation of sustainable development policies (Lawlor et al., 2006), restoring ecological and hydrological functions.

Green infrastructure (GI) is a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services (European Commission, 2013), providing several functions and benefits (ecological, economic and social) through natural solutions (European Environment Agency, 2014). Green infrastructure (GI) mimic the natural processes to improve water quality and manage water quantity by partly restoring the hydrologic function of the urban landscape (United States Environmental Protection Agency, 2015). Also, Davies and Lafortezza (2017) refers to a more specific concept, urban green infrastructure (UGI), which emerged as a way to conceptualise the planning of connected greenspace in urbanised. Similar concepts include land development approaches that works with nature to manage stormwater and runoff closer to its source, as “LID - Low Impact Development” in North America (United States Environmental Protection Agency, 2012), “WSUD - Water Sensitive Urban Design” in Australia (T. H. F. Wong, 2007), "Sponge Cities" in China (Chan et al., 2018), "SuDS - Sustainable Drainage Systems" in United Kingdom (United Kingdom Environment Agency, 2016), and “LIUDD - Low Impact Urban Design and Development” in New Zealand (van Roon and van Roon, 2009).

Green infrastructure include, among other solutions, the integration of vegetated surfaces in buildings, as in rooftops (green roofs) or in building walls (green walls). Green roofs and green walls systems have great potential to mitigate the impacts of dense urban areas, bringing benefits at social, economic and environmental levels (Teotónio et al., 2018). Green roofs can be classified as intensive, semi-intensive or

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extensive (FLL, 2018). Green walls can be either green façades or living walls (Manso and Castro-gomes, 2015; Teotónio et al., 2019). These GI systems have the potential to improve the urban environment and the local area where are inserted in (Berardi et al., 2014; Perini and Rosasco, 2013; Shafique et al., 2018).

Green roofs contribute to stormwater management, due to the substrate capacity to retain and filter water, reducing in 54%–62% the water runoff in buildings, depending on the system characteristics and local climate conditions (Mentens et al., 2006; Qin et al., 2012; Stovin et al., 2015; Tassi et al., 2014; Uhl and Schiedt, 2008; G. K. L. Wong and Jim, 2015). GI, as green roofs and green walls, also have an impact on urban noise reduction, as the vegetation and substrate absorb, scatter and reflect the airborne sound, improving the acoustical characteristics of the surrounding environment (M. Connelly and Hodgson, 2015; Lacasta et al., 2016; Van Renterghem and Botteldooren, 2011; Wong et al., 2010). They can help mitigating the urban heat island effect by reducing the surrounding ambient temperature 0.5 °C–2 °C (Qin et al., 2012; Savio et al., 2006; Susca et al., 2011). They can improve the air quality by retaining air pollutants (Abdo et al., 2019; Jayasooriya et al., 2017), as ozone (52 %) and particulate matter (14 %) (Yang et al., 2008). Also, these GI are important for the biodiversity enhancement of urban areas, creating quality habitat for diverse species (Colla et al., 2009; Collins et al., 2017; Garmendia et al., 2016; Kadas, 2006; Mayrand and Clergeau, 2018; Oberndorfer et al., 2007).

Likewise, on a local scale, these GI systems have the potential to decrease buildings energy consumption, reducing the needs for active systems for heating and cooling (Ascione et al., 2013; Coma et al., 2017; Jaffal et al., 2012; Silva et al., 2016) and improve the acoustic performance of buildings, reducing sound transmission in 10–20 dB (Connelly and Hodgson, 2013; Getter and Rowe, 2006). They also have other social and economic benefits, like increasing buildings economic and aesthetic value while creating a sense of well-being to its users (Bianchini and Hewage, 2012b; Kotzen, 2018).

Despite their benefits, green infrastructure installation costs can be burdensome, depending on the typology and the technology level employed. The installation cost can range, for extensive green roofs, between 50 and 200 €/m^2 (Cruz et al., 2018; Peck and Kuhn, 2010; Peng and Jim, 2015; Sproul et al., 2014; William et al., 2016); for intensive green roofs, between 150 and 500 €/m^2 (Bianchini and Hewage, 2012a; Cruz et al., 2018; William et al., 2016); for green façades between 10 and 800 €/m^2 and for living walls between 300 and 2800 €/m^2 (Cruz et al., 2018; Francis et al., 2014; Perini et al., 2011; Riley, 2017). It should be noted that less developed green infrastructure markets may have higher installation costs.

In this regard, science-practice collaborations between academics, policy makers and practitioners can be important for knowledge transfer on green infrastructure, helping cities and urban regions to develop appropriate strategies for the implementation of green infrastructure (Di Marino et al., 2019). Across the world, cities have adopted different GI solutions, for instance: in São Paulo, vertical gardens were installed in buildings along the Elevado Presidente João Goulart expressway (City of São Paulo, 2017); in Mexico City, the municipal authorities allowed the construction of green walls on columns along the Periférico highway, which rings the central city (Paisajismo Digital Webpage, 2019); while in Nanjing, China, greenery covers the retaining wall of a railway station (Elmich Pte Ltd., 2014). As shown, the GI type, configuration and technical solution varies significantly, as a result of different objectives and distinct local technical restrictions.

Similarly, city planners and public decision-makers when promoting green infrastructure, like green roofs and green walls, have difficulties in reaching the investment of private owners in these solutions (Mell et al., 2016). The main reason is that, at a financial level, the quantified benefits of some solutions are not compensated by high implementation costs, discouraging building owners to invest in green roofs and green walls (Cruz et al., 2017; Ngan, 2004; Perini and Rosasco, 2013; Teotónio et al., 2018). In fact, many of their socio-environmental benefits are not easily economically quantifiable (Cruz et al., 2018; Nurmi et al., 2013), and consequently are not considered by investors in the decision-making process. However, some studies using cost-benefit analysis have demonstrated that the application of these systems can become viable to building owners if environmental and social benefits are taken into account (Hassanain et al., 2017; Teotónio et al., 2018). From this perspective, it is important to recognize the non-monetary benefits of green infrastructures when formulating incentive policies, which are able to foster and promote their installation (Hughes, 2014).

In addition, many other barriers can hinder green infrastructure dissemination. According to Dhakal and Chevalier (2017), these barriers can be classified as: federal and state policies; city policies; governance policies; financial resources and cognitive barriers. In this context, the development of incentive programmes can contribute to green infrastructure' implementation in cities. The application of incentive policies can be done through environmental education programs, building codes and regulations, performance rating systems, regulatory measures, tax reductions and financial incentives (Lawlor et al., 2006).

The motivations to develop programs and policies vary according to local climate, political position, environmental approach and resource capacity (Lawlor et al., 2006). Furthermore, the presence or absence of suitable legislation and policies can have a great impact on the effective implementation of green infrastructure (Brudermann and Sangkakool, 2017).

In this regard, many cities in the world have already stepped forward to promote green infrastructure' development with distinct approaches. This work provides an overview of the existing green infrastructure incentive policies focused on the promotion of the application of green roofs and green walls. This paper aims to identify the different types of incentive policies used by several municipalities around the world and recognize their particularities and predominance in certain regions. Moreover, this paper can be a useful tool for decision-makers in the process of implementing green infrastructure incentive policies through the knowledge and analysis of successful examples.

The paper is organized into five sections. Section 1 includes an introduction to the topic in discussion, providing an overview of the concepts of green infrastructure, green roofs and green walls. Section 2 shows the different GI incentive policies classifications, the research methods identifying the keywords used, and presents the data collection methods, and methods used for data analysis. Section 3 presents the different incentive policies used around the world focusing some case studies where a certain policy was more relevant. Section 4 discusses the main considerations regarding the strategies to implement GI. Finally, Section 5 presents the main conclusions.

2. Research methods

2.1. Data collection

Data were collected between January and February 2019. The methodology used was a web-based search for worldwide documents (e.g. technical reports, legislation, municipal regulation, policy papers, etc.) to be able to identify two main elements: i) which cities currently have any policy incentive towards the adoption of these solutions (these incentives can exist in distinct formats and configurations as discussed next) and ii) what are those incentives. To do that, the authors have performed a web search using the following keywords: "green infrastructure"; “incentive policies"; “subsidies"; "green roofs"; "green walls”; "green façades” and several combinations thereof. The keywords were chosen based on prior literature review. The search was conducted in different languages (e.g. Portuguese, Spanish, German, Dutch, French and Mandarin) as most information is not available in English.

The search was made using ScienceDirect and local or regional government websites through a textual analysis at official information given on the sites and documents available online. The authors did not

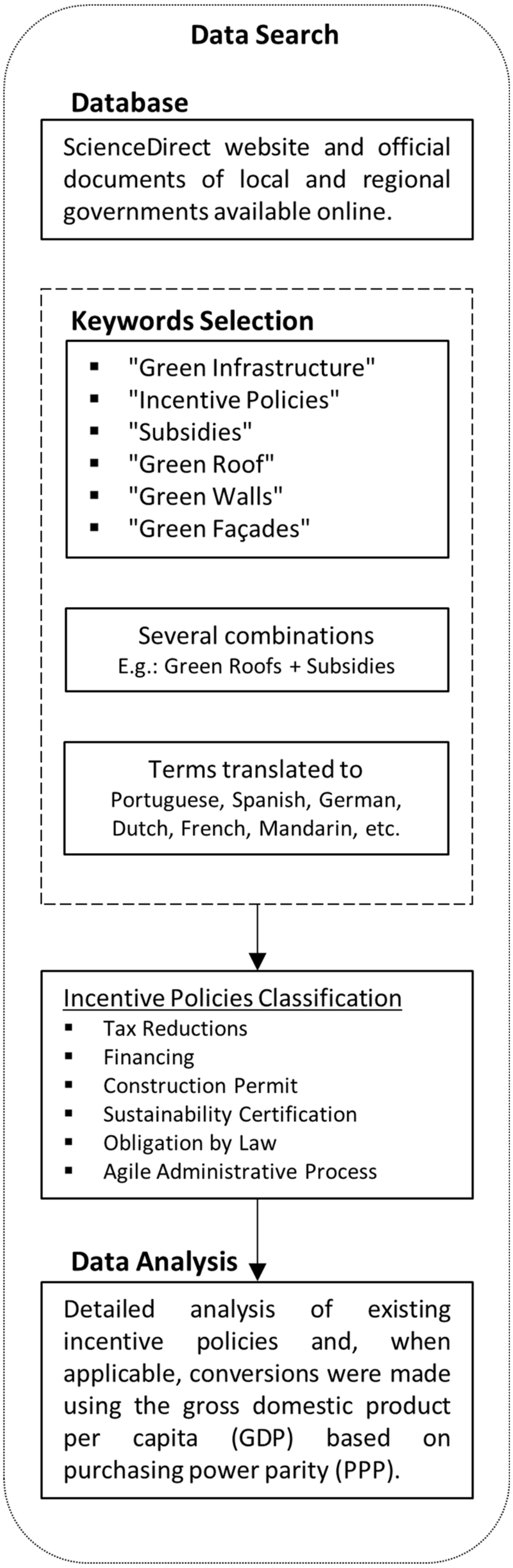

Fig. 1. Paper methodology scheme.

define a minimum sampling. The criteria for selecting the studied cities were the availability of information about green infrastructure incentive policies. The information regarding green roofs/walls incentive policies has been compiled into an Excel spreadsheet, and subsequently analysed. Fig. 1 systematizes the methodology used in order to conduct the study.

2.2. Data analysis

Several documents were analysed (approximately 330 documents). Data analysis was focused on the municipalities with incentive policies to promote green roofs and/or green walls. The incentive policies of 113 cities located in 19 countries and 4 continents were analyzed: Argentina, Brazil, Colombia (South America), Canada, Mexico, United States of America, (North America), Austria, Belgium, Czech Republic, Denmark, France, Germany, Italy, the Netherlands, Switzerland (Europe), China, Japan, Singapore and South Korea (Asia).

The main identified incentives were classified into six categories: Tax Reductions; Financing; Construction Permit; Sustainability certification; Obligation by law and Agile administrative process, as shown in Table 1. These categories were defined by the authors, based on the initial assessment of different types of incentives found.

Regarding financial subsidies, to equally compare the effective subsidized value given by local governments, it was necessary to convert using the gross domestic product per capita (GDP) based on purchasing power parity (PPP) for each country. The source for the PPP data was the World Bank database. Gross domestic product per capita (GDP) of OECD members was used as a calculation base (World Bank, 2017). Finally, each currency was converted into euros to allow a comparison of results, using the annual exchange rate for 2018 (last full available year).

3. Results

3.1. Incentive policies around the world

The study included a total of 113 cities from 19 countries in 4 continents. Since some cities have more than one type of incentive policy, a total of 143 different incentive policies were analysed (Fig. 2). Likewise, Table 2 shows the distribution of different types of incentive policies (IP) for each continent and, finally, from a global perspective. The percentage of each incentive policy is based on the total number of incentives found in that continent. Therefore, the sum of each line (continent) corresponds to approximately 100 %.

Worldwide, the largest concentration of incentive policies was observed in Europe and North America (71 and 40 incentive policies, respectively). It can also be noted that incentive policies focus mainly on the promotion of green roofs (121 policies). Or, when specified, of both, green roofs and green walls (22 policies). No exclusive incentive policies were found for the promotion of green walls (Fig. 2).

The concentration of incentive policies in North America and Europe may be explained by the fact that most researches in this field has been happening there in the last decades in these continents, leading to a better understanding by decision-makers of the several benefits provided by these technologies. Only recently, few countries from Asia and South America have started conducting research on green infrastructure.

Furthermore, as observed in the Sustainable Economic Development Assessment (SEDA) rakings of 2019 South American countries do not have the same socioeconomic conditions and market forces as Europe and North America (Hrotko et al., 2019). In these countries, funding may be directed to other priority areas, such as health, safety and education issues. In this context, the municipal programs for the promotion of green infrastructure have specific approaches, focusing on incentive policies that do not require a direct financial investment, such as obligations by law and tax reductions.

Another important remark concerns the lack of variability of incentive policies in almost all continents. In Europe, 85 % of green infrastructure incentives are categorized as financial subsidies. In other words, governments aid with a certain financial value to encourage owners to install green roofs and/or green walls.

This study also demonstrates that in Asia the incentive policies are concentrated in two categories, namely, obligations by law and

Table 1
Description of incentive policies categories.

Incentives		Description
1 - Tax Reductions	1.1 - Tax Property	Tax property is the annual amount paid by a landowner to the local government to support public services maintenance.
	1.2 - Stormwater Fee	Stormwater fee is a tax charged according to the impervious surface area for stormwater management.
	1.3 – Other Taxes Reduction	In this category are included less frequent types of tax reductions, such as in sewage, public lighting, sweeping and cleaning fees.
2 - Financing	2.1 - Subsidies	A subsidy or government incentive is a form of financial aid or support extended to individuals or companies, usually in the form of a cash payment.
	2.2 - Reduction of Interest Rate	Reduction of interest rate is a financial loan with a lower interest rate provided to building owners.
3 - Construction Permit		Construction permit is a build density bonus for landowners that install green infrastructure in their urban plot. For each square meter of vegetated area, the owner earns permission to build an additional area.
4 - Sustainability Certification		Sustainable certifications are systems that assess the sustainability of the built environment.
5 - Obligation by Law		Obligations by law is a legal requirement that imposes the installation of green infrastructure like green roofs and green walls in certain new constructions.
6 - Agile Administrative Process		Projects that include the installation of green infrastructure, receive priority in the licensing process.

financial subsidies (both with 37 %) representing 74 % of the total amount of incentive policies. While in South America, property tax reductions prevail (31 %) in relation to other categories, as shown in Table 2.

Also, North America presents a more balanced distribution of incentive policies focusing mainly on subsidies (23 %), obligations by law (18 %), stormwater fee discount (15 %) and sustainability certifications (15 %).

Fig. 3 shows the incentive policies distribution in a global context. It is notorious that public financial subsidies and obligations by law are among the most widely incentive policies used, representing 53 % and 15 % respectively. According to Fig. 3-B, European cities stand out in the provision of financial subsidies, representing 79 % of the total of this incentive. This study did not find any financial subsidies for green infrastructure in South American cities.

Reduction of interest rates is another form of financing. However, its application is less frequent than financial subsidies. Financial loans are also provided in some cities with a lower interest rate for building owners. Only few cases of this incentive policy were found in this study (see Section 3.3.2).

Tax reductions (Fig. 3-C) represent 16 % of the overall incentive policies being subcategorized as property tax reduction (5%), stormwater fee discount (6%) and other types of tax reductions (5%) (lighting, sweeping, cleaning and permit fees, etc.). This last category of incentive policy appears mainly in North America where it represents almost 60 % of the total world, followed by South America (29 %) and Europe (14 %). In fact, many of the analysed incentive policies were found in North America. Only in property tax reductions, South America exceeded North America by 57 % versus 43 %.

The stormwater fee discount prevails in North America with 67 % followed by Europe with 33 %. This type of incentive policy was not identified in other continents.

From the last four categories of incentive policies (construction permit, obligations by law, sustainability certification and agile administrative process), it was observed that obligations by law is the only incentive policy found in all studied continents, representing 15 % of all incentive policies (Fig. 3-A).

Another incentive policy with significant notoriety is sustainability certifications, such as LEED Certifications (mainly in the USA), and GBEL (People's Republic of China). These are green certification programs that evaluate building sustainability where green infrastructure (green roofs and green walls) contribute to achieving higher scores.

The next section presents more details about each incentive policy and some relevant aspects observed in certain cities.

3.2. Taxes reduction

3.2.1. Property tax reduction

Property tax is the annual amount paid by a landowner to the municipal government. This property tax burden can be significantly reduced in some municipalities when the local government promote specific policies, for example, to encourage green infrastructure application, such as green roofs and green walls.

In South American cities, property tax reduction is the most common of green infrastructure incentive policies (31 % - Table 2). In Brazil, cities like Goiânia/GO, Guarulhos/SP, Salvador/BA and Santos/SP are good examples of property tax reduction in South America. Goiânia and Guarulhos offer tax discounts to encourage the adoption of sustainable practices. In these cases, a maximum property tax reduction of 20 % is applied to landowners who adopt the Best Management Practices (BMPs). Green roofs contribute up to 3% of the total permitted discount. Landowners can receive the discount for a maximum period of 5 years (City of Goiania, 2012; City of Guarulhos, 2010) - Fig. 4. Likewise, the city of Santos/SP offers a property tax reduction between 1.5 and 3%, according to the green roof total coverage area, for a maximum period of 3 years (City of Santos, 2015).

Another successful example in Brazil, is Salvador, capital of Bahia state. The city has the Sustainable Certification Program "*IPTU Verde*" to encourage municipal works sustainability. Tax property reductions are granted from 5% to 10 % annually, for a period of 3 years renewable for another three. This certification is optional and applicable to new developments or extensions and/or renovations of existing buildings (City of Salvador, 2017).

On the same hand, in North American cities, such as Mexico City, the reduction rates of annual property tax vary between 10 % and 25 %, depending on the green roof typology (extensive or intensive, respectively) (Mexico City, 2015). However, some other locations have been at the forefront in this type of incentive policy. More than promoting the installation of green roofs, it encourages the integration of multiple green technologies. New York City and New York State have developed incentive policies to promote solar green roofs installation (photovoltaic panels associated with green roofs). In this case, the owner can receive a one-year tax abatement, or tax relief of $4.50 per square foot built with solar green roofs (New York City, 2019).

The property tax reduction incentive policy was not identified in Europe and Asia.

3.2.2. Stormwater fee discount

The stormwater fee is a revenue obtained by municipalities from the infrastructure users to support the maintenance and upgrade of the storm drainage system (Tasca et al., 2017). It can be calculated in several ways where the most impervious land area pays a greater municipal tax (USEPA, 2006). In this sense, the application of green technologies, such as green roofs, can reduce municipalities expenses with stormwater management.

Stormwater utility fees reduction incentive policies was not identified in South America and Asia. On the other hand, in North America, cities as Minneapolis and Portland offer a stormwater fee discount of up to 100 %, while in Washington D.C. and Nashville the maximum discount can reach up to 55 % and 75 %, respectively (City of Minneapolis, 2019; City of Nashville, 2019; City of Portland, 2019; Washington D.C., 2019).

It is important to note that stormwater utility fees in North America are becoming more common after regulatory changes (allowing for their billing) implemented by the Environmental Protection Agency (US-EPA) (City of Goodlettsville, 2019). In this sense, regulating this tax may be the first step for other cities in the world to use stormwater utility fees reduction to promote green infrastructure adoption.

In Europe, some German cities also adopt this incentive practice. Hannover and Hamburg discount up to 70 % and 50 %, respectively, of the annual stormwater fee to landowners with green roofs and/or other stormwater reduction practices (City of Hamburg, 2018; City of Hannover, 2019). While Munich exempts, in some cases, the total payment of this fee (Green Roofs in Germany, 2017).

In the United States of America and Germany, the average discount in stormwater fees for the analysed cities is close to 76 % as shown in Fig. 4.

3.2.3. Other taxes reduction

Some cities offer other municipal tax reductions, not necessarily property tax reductions or stormwater fee discounts. In South America, the city of Buenos Aires, through the law number 4428/2012 regulates a tax reduction of up to 20 % in lighting, sweeping and cleaning taxes to building owners that install green roofs in their properties. Thereby promoting the installation of this type of green infrastructure in the city (Law N° 4428, 2012).

In the United States, the city of Indianapolis, state of Indiana, offers a reduction in permit fees for projects achieving certain green building criteria (Water Quality/Quantity; Transportation; Energy; Materials; Site and Innovation Design). The minimum discount is 30 %, and the maximum rebate amount can be up to 50 % (City of Indianapolis, 2019).

Likewise, in Port Coquitlam, Canada, in addition to the obligations by law, in some cases, the landowner may be exempt from the municipal application fee, if the green roof project complies with some specific requirements (City of Port Coquitlam, 2015).

In Europe, the city of Venice, Italy, the installation of green roofs contributes to lower permit fee costs, contributing up to 20 % to tax reduction calculation. In this case, green roofs must cover at least 80 % of the total rooftop area available (Venice Municipal Council Resolution

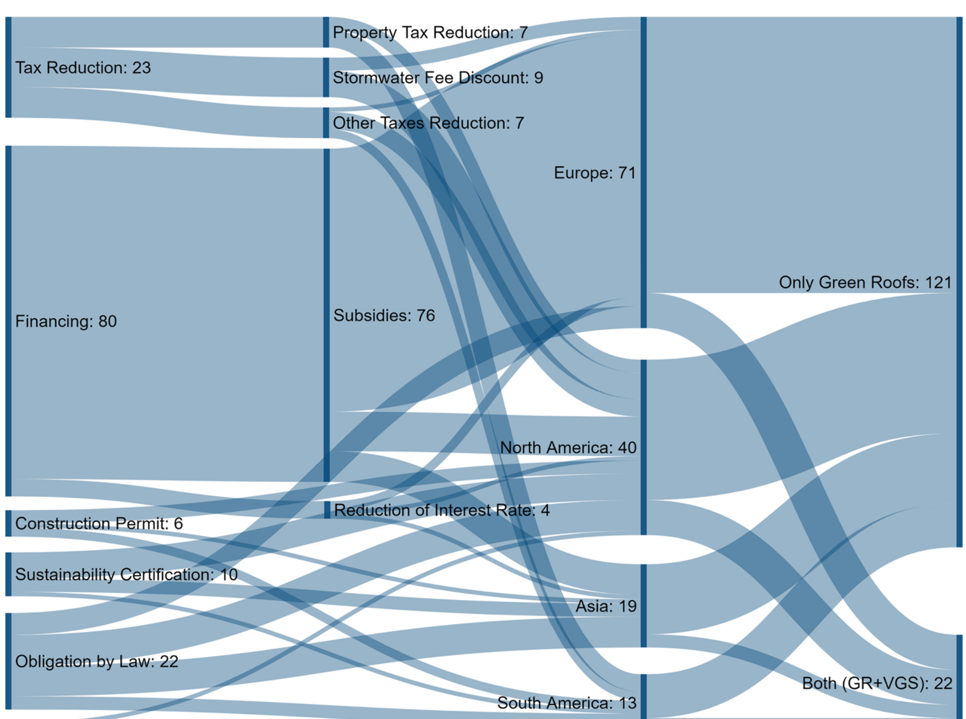

Fig. 2. Continental concentration of incentive policies targeting to green roofs (GR) and green walls, in absolute numbers.

Table 2
Distribution of incentive policies (IP) in the world and by continent.

Continent	1. Tax Reductions			2. Financing		3. Construction Permit	4. Sustainability certification	5. Obligation by law	6. Agile administrative process	Total IP by continent
	1.1	1.2	1.3	2.1	2.2					
North America	8% (2)	15 % (7)	10 % (4)	23 % (9)	3% (1)	8% (3)	15 % (6)	18 % (7)	3% (1)	≅ 100 % (40)
South America	31 % (4)	–	15 % (2)	–	–	15 % (2)	8% (1)	23 % (3)	8% (1)	≅ 100 % (13)
Europe	–	4% (3)	1% (1)	85 % (60)	3% (2)	–	–	7% (5)	–	≅ 100 % (71)
Asia	–	–	–	37 % (7)	5% (1)	5% (1)	16 % (3)	37 % (7).	–	≅ 100 % (19)
Worldwide	**5%**	**6%**	**5%**	53 %	**3%**	**4%**	**7%**	15 %	**1%**	**143**

1.1: Property Tax Reduction; 1.2: Stormwater Fee Discount; 1.3: Other taxes reduction; 2.1: Subsidies; 2.2: Reduction of interest rate; IP: incentives policies.

N° 64, 2006). Other types of taxes reduction were not identified in Asia.

3.3. Financing

3.3.1. Subsidies

Direct financial subsidy to promote green infrastructure is a popular incentive policy in many countries worldwide, especially in Europe. This incentive policy plays a major role in the implementation of green infrastructure since it is rebating the owner's installation costs. In general, the municipalities demand some minimum requirements to obtain the financial subsidy, depending on covered vegetation area, substrate thickness, water retaining, maintenance period, etc.

Each city has specific requirements that are dependent on local factors and social conditions. These specifications can be variable, also within a single country. In the Netherlands, the minimum green roof area required to receive the government subsidies varies from 6 m^2 in cities like Groningen, Hengelo and Leeuwarden up to 30 m^2 in Nijmegen. In Amstelveen, it is also possible to combine several roofs in one application in order to exceed the minimum required area (City of Amstelveen, 2019; City of Groningen, 2019; City of Hengelo, 2020; City of Leeuwarden, 2019; City of Nijmegen, 2018).

Another important requirement to be able to apply to a municipal subsidy is the substrate thickness, or in other cases water storage capacity. German cities like Frankfurt, Hamburg and Stuttgart require a minimum substrate depth of between 8 cm and 12 cm (City of Frankfurt, 2018; City of Hamburg, 2019; City of Stuttgart, 2019). In addition to the minimum substrate depth of 8 cm, a discharge coefficient of less than 0.3 is also required in Dusseldorf (City of Dusseldorf, 2019).

Other cities establish a minimum water retention capacity, regardless of substrate thickness. That is because the water retention and storage capacity is related to substrate physicochemical properties and not necessarily with its depth. In the Netherlands, the cities of Almelo and Hengelo, the water retention capacity needs to be at least 15 L per square meter. In the case of Den Bosch is required a minimum of 30 L per square meter (City of Almelo, 2019; City of Den Bosch, 2019; City of Hengelo, 2020).

Moreover, to access the public financial resources the owner may have to maintain and preserve the green roof system for a minimum period. The city of Leiden, in the Netherlands, requires at least 5 years, while Stuttgart, in Germany, requires 10 years and Merelbeke, in Belgium, requires 15 years (City of Leiden, 2019; City of Merelbeke, 2019; City of Stuttgart, 2019). Furthermore, other specifications may be required by each municipality. In Stuttgart, for example, it is mentioned that this measure should not be a reason for rent increase (City of Stuttgart, 2019).

This research also identified different public funding to promote the application of green roofs. Municipalities can finance the installation of green infrastructure per area or cover a percentage of installation costs. In general, it is limited to a maximum amount of subsidy by request and/or per year. Most funding is focused on green roofs, not being very frequent for green walls.

The subsidy value may also vary from city to city, depending on public funds availability and local green roof industry development (law of supply and demand). It is underlined that these factors have not been sufficiently discussed and enriched in this study.

Different cities around the world were analysed and compared after data conversion using the gross domestic product per capita (GDP) based on purchasing power parity (PPP). Of the 113 analysed cities, 76 of them presented some financial incentive for green roofs and green walls. Of these, 64 have specified a value per square meter of green infrastructure built. However, to simplify the data presentation, a national average was considered (Table 3). No direct financial subsidies have been identified in South America.

Table 3 shows that countries regarded as developed are not necessarily the ones that offer the largest green infrastructure financial subsidies. Considering the purchasing power parity (PPP) calculation was found that China, offers subsidies equivalent to countries like Singapore, Canada and the United States (Fig. 5).

Variation of the subsidy value is notorious between countries and municipalities but in some cases, variations may occur within a single municipality. For example, in Amstelveen, the Netherlands, the amount of real subsidy per square meter is between 10 and 30 €/m² depending on the green coverage area. If the same green roofs are designed to increase biodiversity the value goes up to 30–50 €/m² (City of Amstelveen, 2019).

Although not identified in this study, another possibility refers to the implementation of direct financial subsidies in priority areas within the city, usually where there are major problems related to dense urbanization. Therefore, not all homeowners who build green roofs or green walls in their properties could be able to receive such financial support (Ngan, 2004).

Finally, it is important to highlight that the subsidies policies vary from municipality to municipality. However, the amount paid to the investor should be at least the difference between private costs and benefits (Claus and Rousseau, 2012). Ngan (2004), also affirms that subsidies should be calculated based on a minimum percentage of 10%–50% of construction costs.

Therefore, before promoting financial subsidies in a specific municipality is necessary to review each individual case and compare to similar realities to draw more appropriate conclusions concerning the best way to promote this incentive policy.

3.3.2. Reduction of interest rate

The reduction of interest rate is another possibility of financing green infrastructure. In South America it was not possible to identify this type of incentive. However, in North America, for instance, the city of San Francisco, California (USA), the property owners can finance up to 100 % of green roof costs with fixed rates. Funds can be repaid in the long term. The financing program includes all related costs, such as materials, engineering, labour, installation, maintenance contracts, etc. (Alini, 2017).

In Europe, cities like Berlin and Cologne promote natural roof insulation in the form of green roofs under the energy efficiency program "*Energieeffizient Sanieren*". In this case, it is possible to raise state funding for green roofs' installation or replacement with a low-interest loan

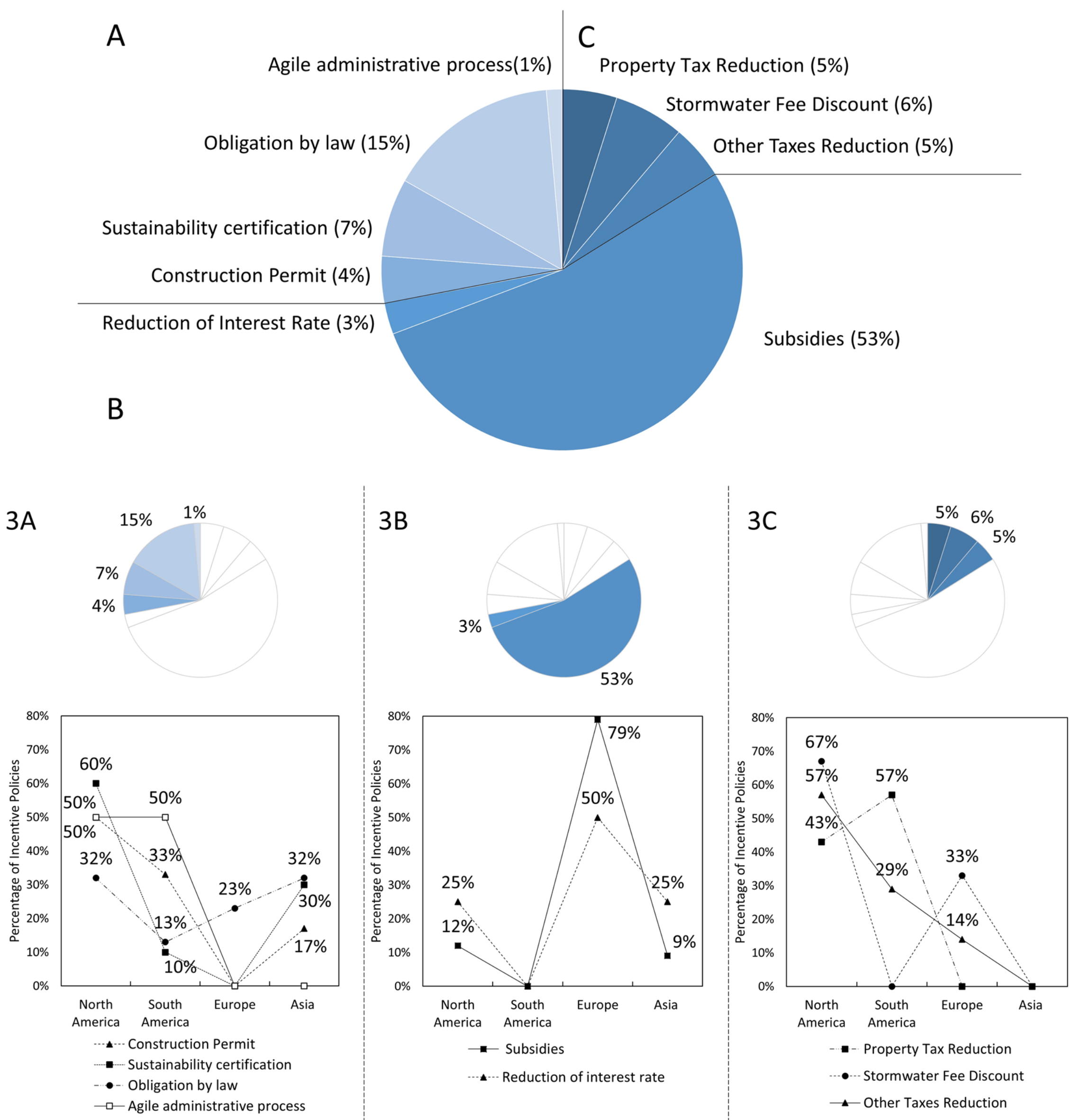

Fig. 3. Percentage of incentive policies in a global and continental context (A, B, C).

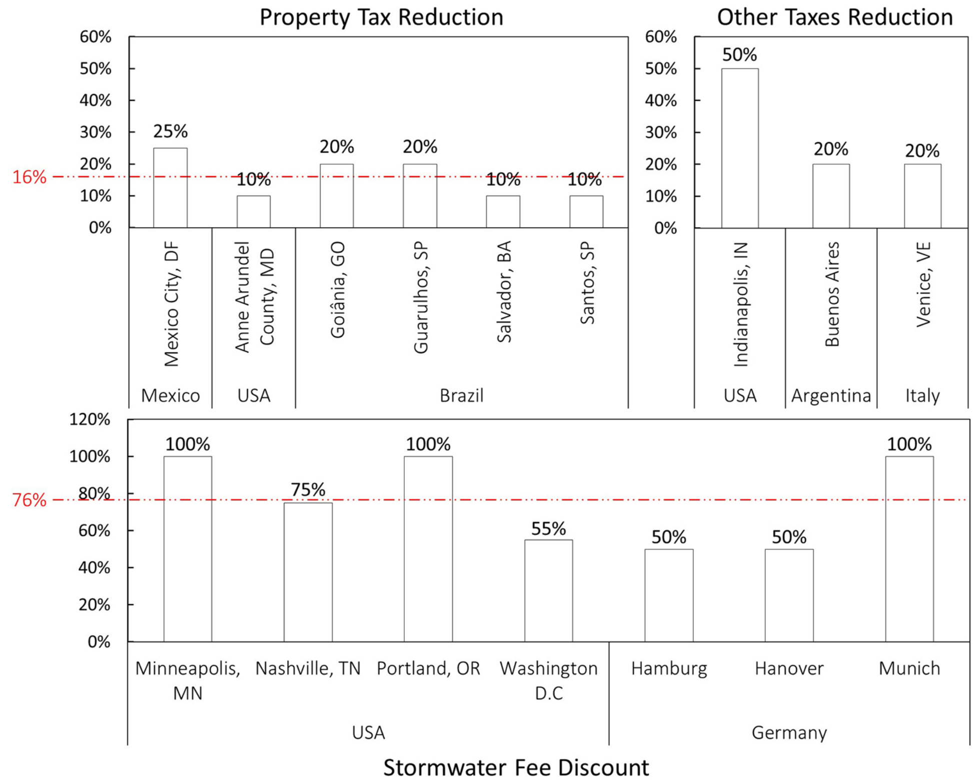

Fig. 4. Tax reductions in different cities around the world (discount average highlighted in red).

(Berlin, 2014; Neumann, 2020). In Cologne, the municipality also offers a subsidy of 50 % of eligible costs, up to a maximum of 40€ per square meter, and no more than 20,000€ per year to promote green roofs and green wall systems (City of Cologne, 2018) (see previous section - Subsidies).

In Asia, the city of Nagoya, Japan, offer several possibilities to economic incentives for green initiatives. Among these opportunities, "Nice Green Nagoya" certification system is one example that provides the advantage to get the $0.1-0.2\%$ discount bank home loan in some national banks (see Section 3.5).

3.4. Construction permit

The construction permit enables landowners to build an area above the limit considered by municipal norms provided that this increase is compensated by permeable structures, including green roofs and other green infrastructure.

Several cities around the world are required to maintain a minimum permeable area in each urban plot. In South America, the cities of Canoas and Porto Alegre, in the State of Rio Grande do Sul/Brazil, indirectly supports the installation of green roofs considering them as a compensatory measure to highly waterproofed areas (Instruction N° 22, 2007; Law N° 5840, 2014).

In North America the city of Austin (Texas) allows increasing the buildable area for each square foot of green roof that is added. The additional area granted is related to the green roof area and total rooftop area. If the green roof occupies 30%–49% of the total rooftop area, two additional square feet can be built. If the green roof area is above 50 %, three additional square feet can be built (City of Austin, 2020).

Likewise, the City of Portland, state of Oregon has developed the “Ecoroof FAR Bonus” (Floor Area Ratio), also, in this case, the bonus area granted to owners depends on the green roof area in relation to the building footprint. However, the municipality has a series of requirements to grant the bonus area. Among them are the planting and drainage plan, soil specifications, construction elements, operations and maintenance plan, etc. (City of Portland, 2009).

3.5. Sustainability certification

Sustainability certifications are voluntary programs that promote sustainable construction practices and mitigate the associated environmental impacts. There are several types of sustainability certifications worldwide, some of them with an international reach while others may be specific to a given country or city (York et al., 2018).

One of the most popular sustainability certifications is LEED (Leadership in Energy and Environmental Design). It certifies

Table 3
Average of the real subsidy offered per square meter of green infrastructure per country and average value converted according to purchasing power parity (PPP).

Continent	Country	Subsidies Average (EUR/ m^2)	Number of analysed cities	GDP (PPP) OECD = 100	Subsidies GDP (PPP) Average (EUR/ m^2)
North America	United States	72,914	6	73	53,227
	Canada	65,385	1	93	60,808
Europe	Switzerland	34,629	1	67	23,201
	Austria	13,250	2	83	10,998
	Czech Repub.	19,000	1	119	22,610
	Germany	40,375	8	86	34,723
	Netherlands	24,925	20	83	20,688
	Belgium	27,618	17	91	25,132
	France	45,000	3	101	45,450
Asia	Singapore	125,581	1	46	57,767
	China	20,331	4	258	52,455

GDP: Gross domestic product per capita; PPP: Purchasing power parity; OECD: Organisation for Economic Co-operation and Development.

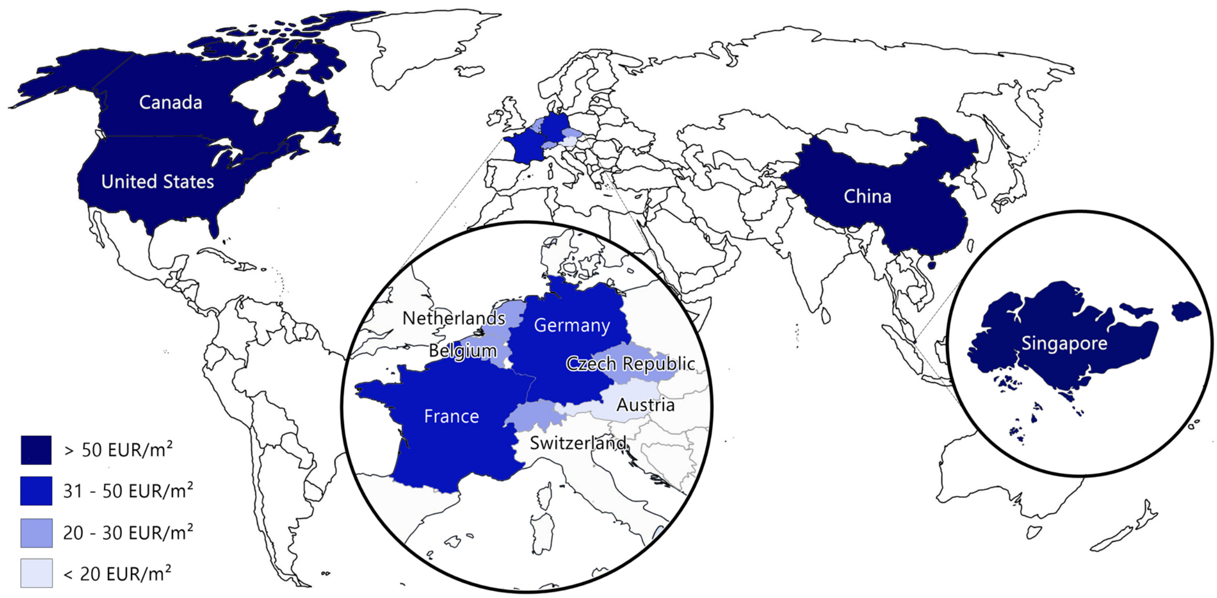

Fig. 5. The average value of the financial subsidies offered per square meter of constructed green infrastructure in different countries.

environmentally sustainable projects that minimize their environmental footprint. The so-called green buildings seek to use environmental resources in a way that is ecologically maintainable and incorporates green features, such as green infrastructure (Howe, 2011; United States Green Building Council, 2018).

In South America, the city of Rio de Janeiro, Brazil, has created at the municipal level the "*Qualiverde*" qualification, an optional certification aimed at encouraging citizens to include sustainable actions and practices. The certification is applicable to new and existing buildings, residential, commercial, mixed or government use (Decree N 3574, 2012).

In North America, cities like Boston, Chicago, Los Angeles, Seattle and Vancouver adopted requirements for LEED certification. This incentive policy isn´t mandatory but encourages green roofs and green walls implementation (Growing Green Guide, 2013).

In China, the Green Building Evaluation Label (GBEL) Certification was developed by the local government and is administered by the Ministry of Housing and Urban-Rural Development. This green building certification program is voluntary and evaluates projects based in different categories, just as LEED Certification. GBEL uses a star rating system where three-stars represents the highest rate (Khanna et al., 2014; Lu-Hill and Chen, 2013).

In Japan, the city of Nagoya has a voluntary program certification named "Nice Green". This sustainability certification is based on certain criteria such as the ratio of green area to the total built-up area and the greening of rooftops and walls, for instance. The certification provides a ranking according to the greening facilities. And the owners can get benefits such as preferential treatment, discount bank home loan, etc. (City of Nagoya, 2019; Hayashi, 2010).

Likewise, Singapore has developed the BCA Green Mark Scheme Certification. An initiative to promote sustainability in the national industry of civil construction through the development of green and smart buildings (Singapore Government, 2019). Or in the case of Portugal, the voluntary system called LiderA supports sustainable solutions design and certifies constructions that have proven environmental performance (LiderA, 2019).

In sum, there is a multitude of systems for the assessment of sustainable construction at different levels (global, national or municipal). These systems value the application of green infrastructure and consequently are an important incentive policy to promote green spaces like green roofs and green walls.

3.6. Obligation by law

According to the obtained results, obligations by law is the second most popular incentive policy in the world, corresponding to 15 % of the total incentive policies evaluated. Generally, the obligations by law apply to new commercial, institutional and residential developments (Brudermann and Sangkakool, 2017).

In South America, the City of Guarulhos (Brazil), has a mandatory requirement for new buildings with more than three floors to include the construction of green roofs. In Recife (Brazil) and Cordoba (Argentina) building projects with a covered area more than 400 m^2 must include green roofs to be approved by municipal authorities (Law No 18112, 2015Law No 18112, 2015; Law No 7031, 2012; Ordinance No 12548, 2016).

In North America, the city of Port Coquitlam (Canada) requires green roofs to cover at least 75 % of the rooftop area, when the building area is equal or over 5000 m^2 (City of Port Coquitlam, 2015). Likewise, the city of Toronto (Canada) requires green roofs to cover 20%–60% of the rooftop area depending on the building gross floor area (Growing Green Guide, 2013).

Guangzhou was the first city in China to implement a green roof regulation in 1997. It requires green roofs in all new large-scale public buildings (Urban Planning Network, 2013). Subsequently, other cities such as Hangzhou, Shanghai and Shenzhen have created similar regulations requiring the implementation of green roofs. In fact, green infrastructure in China have gained notoriety, especially after the creation of the "Sponge Cities" program (Chan et al., 2018).

Obligations by law is an important incentive policy to promote urban greening and it can be an interesting solution in cases where financial resources are scarce. This incentive policy was not identified in European municipalities.

3.7. Agile administrative process

Another form of promotion by public administration, but less frequent, is the agility and priority procedure in the permit process of new green projects. In South America, the city of Rio de Janeiro (Brazil) projects that obtain qualification as "*Qualiverde*", a municipal sustainability certification, have priority in the permit process (Decree N 3574, 2012). For instance, in North America, the City of Devens (Massachusetts, USA), is committed to a short-term to approve green projects (City of Devens, 2014). This incentive policy was not identified in European and Asian municipalities.

4. Discussion

The implementation of urban sustainability strategies has become popular in recent years mainly due to climate change concerns and a growing environmental awareness. In this sense, green infrastructure is a worldwide trend to create more resilient and sustainable cities, thus providing a significant contribution towards increasing the social well-being (Kotzen, 2018; Staddon et al., 2017; Vargas-Hernández and Zdunek-Wielgołaska, 2020).

Each country, region or city has particular climatic conditions, specific economies and a distinct urbanization form. So, choosing one, or more, incentive types to promote green infrastructure will be dependent on the understanding of these factors and the interrelationship between them.

Furthermore, the presence of green infrastructure in cities can be an interesting indicator to measure the municipal government's capacity to implement environmental initiatives (Loder, 2011). In this sense, the policy implementation process is as important as the final policy itself (Loder, 2011). It is fundamental to engage all stakeholders (e.g. building owners, marketers, local residents and wider community) to understand municipal singularities in order to seek the best incentive alternatives, and thus achieve an effective green infrastructure implementation strategy.

The use of cost-benefit studies can be an important tool (Cruz et al., 2018; Teotónio et al., 2018) to support draft bills and promote "green policies" adoption by legislators (Loder, 2011). Also, municipalities usually have a limited budget, which restricts financial incentives for green infrastructure and their dissemination depends on governance capacity to raise investment funds to be used for incentive policies.

The role of public managers in green infrastructure promotion is to analyse specific conditions of their municipality and implement effective incentive policies according to local needs. Identifying and describing the key components of the available financing mechanisms in the municipality could be a first step to start a green infrastructures' incentive program (Hughes, 2014).

However, green infrastructure lack of political support can be observed on many political levels, mainly when it comes to public funding. This is because from a financial or political perspective, providing subsidies might not be feasible for some municipalities dealing with shortage of public funds to improve basic systems (e.g. water supply, sanitation, energy, etc.). In these cases, indirect incentives, which do not require additional budget could be the best alternative (Brudermann and Sangkakool, 2017).

In this context, green policies should have support from political decision-makers (Ngan, 2004), by indirect incentive strategies like the incorporation of green infrastructure in public buildings and/or in other public services (Hughes, 2014). These can be real examples to motivate private investors and to promote the green infrastructure industry, which can lead to a decrease in unitary costs. Clearly, these strategies need to be combined with direct incentive tools, such as density bonusing and financial subsidies, to be effective (Loder, 2011).

The absence of green infrastructure in some cities can be attributed to a number of limiting factors, such as lack of research or information about their socio-environmental benefits; limited environmental awareness; lack of standards; high installation costs; lack of professionals and effective public policies (Irga et al., 2017; Williams et al., 2010).

Therefore, government investments are important, especially in places where the use of these technologies is still in an early stage of development. Furthermore, municipalities' role in the initial development of green infrastructures' market is fundamental to the adoption of these technologies by citizens. For this reason, it is essential to implement public policies capable of stimulating the adoption of sustainable strategies, creating greener cities, with a better quality of life and social welfare. Moreover, the insertion of green infrastructure in urban centres plays an important role in the adaptation to climate change, increasing cities resilience and improve environmental quality.

5. Conclusions

Providing a comprehensive picture of all different types of green infrastructure incentive policies is a difficult task, particularly since municipalities are continually changing their environmental policies and each municipality adopt specific requirements according to their needs. This work provides an overview of different incentive policies that promote the implementation of green infrastructure, namely green roofs and green walls.

A total of 143 different incentive policies from 113 cities were analysed. In a broader analysis, it was found that most green infrastructure incentive policies are concentrated in Europe and North America. This may be justified by the fact that most scientific researches in the latest years were conducted in these areas.

In South America, incentive policies are mainly focused on property tax reduction (31 %) and obligations by law (23 %), while in North America, there is a more balanced distribution of incentive policies focusing on subsidies (23 %), obligations by law (18 %), stormwater fee discount (15 %) and sustainability certifications (15 %). In Europe, it was noticed a lack of variability of incentive policies, where 85 % of incentives are financial subsidies. In the Asian continent, incentive policies are mainly focused on financial subsidies (37 %) and obligations by law (37 %). From all analysed incentive policies, the obligation by law is the only incentive policy found in the four continents, representing 15 % of the total worldwide incentive policies.

It is important to note that, regardless of the type of incentive policy used to promote green infrastructure, policy effectiveness is the most important. In this sense, public managers must be responsible for the implementation and management of public policies that stimulate the reduction of environmental impacts resulting from the urbanization process.

Besides, a way of encouraging homeowners to install green infrastructure may be the integration of different types of incentive policies that support and reinforce each other. In this light, understanding the influence behind each incentive program and the adaptation according to local conditions is the key to develop new successful incentive programs.

Finally, it is emphasized that the problems associated with the urbanization process may be similar in different places. Therefore, information sharing about consolidated and successful green infrastructure' incentive policies may help other cities to implement more effective policies. The creation of international networks to discuss "green policies" can also provide great opportunities to exchange successful results and consequently increasing green areas in many cities worldwide.

CRediT authorship contribution statement

Tiago Liberalesso: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization. **Carlos Oliveira Cruz:** Supervision, Conceptualization, Methodology, Validation, Writing - review & editing. **Cristina Matos Silva:** Methodology, Validation, Project administration. **Maria Manso:** Writing - review & editing.

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