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CONEXUS
Co-producing Nature-Based Solutions and Restored Ecosystems: Transdisciplinary Nexus for Urban Sustainability

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EXECUTIVE SUMMARY

- This report presents a series of developments, trends and case studies that exemplify the growing importance that Nature-Based Solutions (NBS), as well as other closely related concepts, are having in thinking and practice around reconciling urban planning, human well-being and sustainability, in cities in both the European Union (EU) and the Community of Latin American and Caribbean States (CELAC).
- The report builds upon a shared knowledge about NBS and other related interventions that have been conceptualised or put into practice to address urbanisation challenges in the EU and CELAC, as well as to respond to several societal challenges in people well-being.
- The use of NBS and similar concepts in cities in the EU and CELAC has had multiple developments, which are evident in a review of scientific documents published between 2007 and 2020. Publications on these topics have been growing exponentially, especially in the case of NBS in the last decade. These scientific publications show to be more numerous and diverse in the case of EU cities, specifically in studies involving green infrastructure and urban forests concepts. However, the use of the concept of NBS in the EU is progressing very quickly. In Latin American cities the use of the NBS concept is comparatively rather new, although it has also linked since some decades ago to a growing number of studies on green infrastructure, urban forestry of urban agriculture, to name a few.
- To highlight the growing number of studies involving NBS, as well as two related concepts (Urban Green Infrastructure (UGI) and Urban Forests (UFOR)), in both regions, 21 of 27 countries in the EU have been working on nature-based responses, while in CELAC this proportion is only 12 out of 33 countries. In the EU only 8 countries gather more than 80% of the NBS cases found in this region, while there is little information of Eastern countries. In CELAC, there are 5 countries that gather more than 80% of the case studies, with significant gaps especially in Central American countries and the Caribbean Islands.
- This report integrates both benefits generated or projected by NBS in cities of the EU and CELAC, as well as identifies barriers that are preventing their implementation and maintenance in the long term. This document also presents several case studies that exemplify lessons learned and how several types of NBS have been facing local and global societal challenges found in both regions.

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1. Introduction

Currently more than half of the world's population (54.5%) lives in urban areas. This proportion barely reached 15% at the beginning of the 20th century and 30% by 1950, which has meant a transition from 200 million people to 4 billion in just 100 years. If this trend continues, it is estimated that by 2050 the global urban population will rise to about 69% and the land area covered by urban areas will triple (Seto, Güneralp, & Hutyra, 2012; United Nations, 2018). However, this urban population growth has not been equally throughout the planet. The demographic transition from rural to predominantly urban populations has already been overcome in both developed and developing countries, especially in the European Union (EU) and the Community of Latin American and Caribbean States (CELAC), where cities house around 80% of their population. If this trend continues, the urban population in both regions is expected to reach 90% by 2050 (United Nations, 2018).

The growth and expansion of cities in the EU and CELAC countries have favoured the concentration of goods and services that have positively influenced the social, economic, and political development (Cerrutti & Bertoncello, 2003; Chen, Zhang, Liu, & Zhang, 2014; Vlahov, Galea, & Freudenberg, 2005). However, growing urbanisation has generated also significant liabilities related to the loss and degradation of the natural ecosystems where cities have settled, degrading their ability to provide contributions to people's well-being (Al-Mulali, Ozturk, & Lean, 2015; Lankao, 2007). Air and water pollution, the loss of natural and agricultural covers, as well as the increase in the population's vulnerability to disasters such as floods, landslides, and heatwaves, are some of the effects of the ecosystem transformation driven by urbanisation. These impacts, although variable in magnitude and intensity, are usually related to poor planning processes that prioritise solutions based exclusively on the use of grey infrastructure. Although some of these types of responses could be effective in the short term, they also could be affecting the structure and functioning of the biophysical base of the territory in which cities are located, degrading their ability to provide several types of ecosystem services (Cárdenas Rodríguez, Dupont-Courtade, & Oueslati, 2016; Chrysanthou, Van Der Schrier, Van Den Besselaar, Klein Tank, & Brandsma, 2014; Dobbs, Hernández-moreno, Reyes-paecke, & Miranda, 2018; Lankao, 2007).

To mitigate impacts and liabilities associated with urban expansion and promote urban people's well-being, a growing number of cities in the EU and CELAC have been incorporating concepts and practices that seek to reconcile urban development with the restoration and maintenance of green spaces with different degrees of anthropisation. The planning of green-space networks, usually represented by different types of Urban Green Infrastructure (UGI) or Urban Forests (UFOR), is a good example of these efforts. Several types of UGI and UFOR have been implemented in EU and CELAC cities as ecological networks that have the purpose of integrating components, interactions, and ecosystem processes in line with the basic needs of their population (Barona et al. , 2020; Breen, Giannotti, Flores Molina, & Vásquez, 2020; Stephan Pauleit et al., 2019; Randrup, Konijnendijk, Dobbertin, & Prüller, 2005).

New concepts and approaches have recently emerged reflecting the societal needs to restore and rehabilitate functions and ecosystem services associated with green spaces networks and natural land cover. One of the concepts that have gained more attention is that of Nature-Based

Solutions (NBS). According to the International Union for Nature (IUCN), NBS refers to "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (IUCN WCC-2016-Res-069-EN, 2016). The concept of NBS makes a call to recognise the importance that the protection, restoration, and management of ecosystems and biodiversity can have in cities as the best way to face challenges associated with food and water security, human health, disaster risk reduction, and climate change mitigation and adaptation (Cohen-Shacham, Walters, Janzen, & Maginnis, 2016; Escobedo, Giannico, Jim, Sanesi, & Lafortezza, 2019).

This report discusses developments, trends, and several case studies that exemplify the importance of NBS, as well as other closely related concepts such as UGI and UFOR, for EU and CELAC urban planning processes to reconcile urban growth, human well-being, and sustainability. In the first place, this report presents a general overview of the most important urbanisation trends in the EU and CELAC as well as those social challenges that urbanisation and a growing population pose to human well-being. Similarly, an overview is presented on the opportunities that the use of NBS can generate to effectively address different societal challenges (e.g. pollution, runoff, heat island, disaster risk, climate change), as well as the tools that have been used for their incorporation into city planning in both regions. Second, this report presents a current and comparative overview of developments that use NBS and similar concepts in EU and CELAC cities, based on the results of a structured systematic review of documents published between 2000 and 2020. And finally, several case studies of NBS in cities in the EU and CELAC are showed, in order to discuss lessons learned in planning and keeping different ecosystem services that promote human well-being. This information is expected to generate a shared understanding between decision-makers and urban planners about NBS benefits, opportunities, and challenges for moving towards sustainability in EU and CELAC countries.

2. Urban growth patterns in EU and CELAC countries

Countries in the EU and CELAC show contrasting patterns of urban population growth and in the area that their cities cover. By 2018, it was estimated that the number of people living in urban areas in the EU reached 553 million inhabitants, a similar quantity to that found in CELAC of 526 million. However, while the urban population in CELAC has increased sevenfold since 1950, growth rates barely doubled in the EU in the same period. As a result, CELAC's share in the global urban population has increased from 9% to 13%, while EU countries' share has been reduced by about two-thirds from 38% to 13%. Despite these differences, it is expected that by 2050 both EU and CELAC will experience decreases in their annual urban growth rates, and therefore a slow growth in the proportion of the population living in cities (V. Alberti et al. , 2019; European Union & United Nations, 2016; Ezquiaga Arquitectura, 2015) (Figure 1).

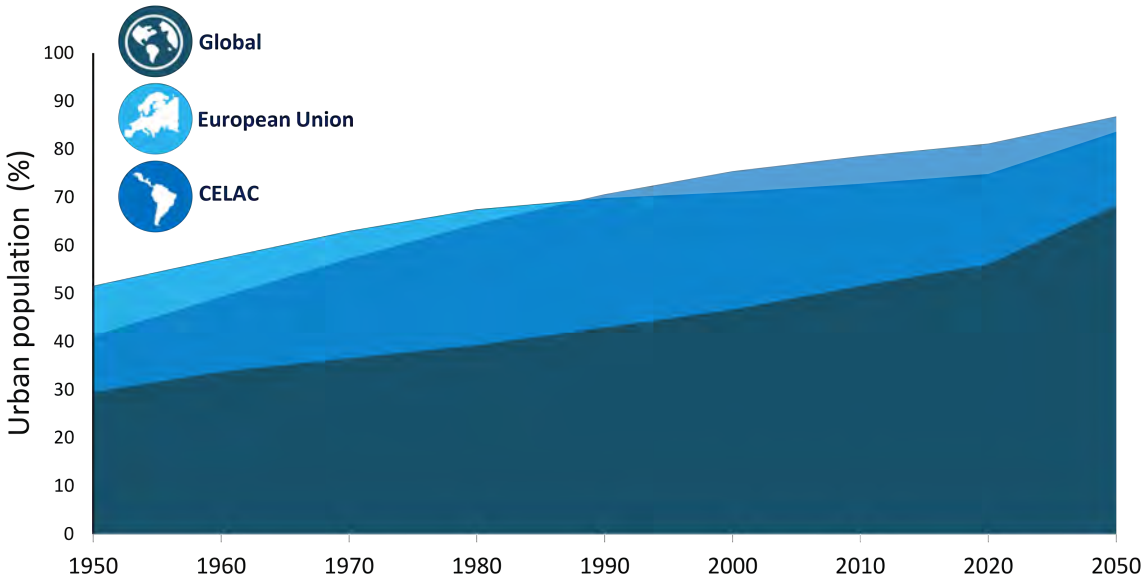

Figure 1. Evolution in the proportion of the urban population on a global scale, in comparison to EU and CELAC regions. Source: United Nations, 2018.

Currently, the EU is home to the second largest urban population worldwide, although usually in settlements with low densities that on average represent 3,000 inhabitants per km^2. The comparatively low population densities in EU cities are related to the fact that almost two-thirds of all urban inhabitants in this region live in settlements with fewer than 500,000 inhabitants. However, while in 1990 the EU did not have any city with more than 10 million inhabitants, it currently has two megacities (London and Paris), as well as 4 large cities (Madrid, Barcelona, Rome and Berlin) that are home to 50 million people representing 9% of the global urban population. Among those countries in this region with at least 90,000 inhabitants in 2018, Belgium shows the highest concentration of urban population (98%), followed by Malta (95%), Iceland (94%) and the Netherlands (92%). The urban population average in European countries could reach 83% in 2050, including 17 countries in which this urban proportion may reach more than 90% (European Union & United Nations, 2016; United Nations Human Settlements Programme, 2020).

On the other hand, CELAC region is home to the fourth largest urban population in the world, but unlike Europe, with high population densities that on average reach 8,000 inhabitants per km^2. As a result, CELAC has a total of 6 megacities (Buenos Aires, Mexico City, Rio de Janeiro, São Paulo, Bogota, and Lima) that concentrate around 18% of the global urban population. However, although CELAC's urban growth rate is close to that of continents such as Africa (4.6%), it has been falling rapidly to 1.3% in 2020. In 2018, all the countries of CELAC with more than 2 million inhabitants were urban in more than 50% and the average proportion increased to 73.5%. Brazil's total urban population is the largest in the region and it is estimated that 87% of its 211 million inhabitants dwell in urban settlements. If this trend continues in CELAC countries, it is estimated that in 2050 the urban population will reach 83% (Ezquiaga Arquitectura, 2015; United Nations Human Settlements Programme, 2020).

3. Local and global societal challenges in EU and CELAC cities

Although there are differences in the historical and projected patterns of the urban population growth in CELAC and the EU, the rise of cities in both regions shows a common contrast of opportunities and challenges linked to the human well-being of their inhabitants. On the one hand, with the growing agglomeration of human groups in both regions, there has been a significant improvement in the social and economic conditions of the population (V. Alberti et al. , 2019; European Union & United Nations, 2016; Ezquiaga Arquitectura, 2015). Cities in the EU and CELAC have become hubs of access to basic services, health, education, housing, as well as to physical infrastructure, roads, railways, electricity, and telecommunications. Also, cities in both regions have been promoting the development of skills, technical knowledge, and processes of technological and social innovation (Marrocu, Paci, & Usai, 2013; Shapiro, 2006). This relationship between economic development and urbanisation in the EU and CELAC is explained, in part, by industrialisation that has boosted agricultural productivity and the large-scale production of goods and services in cities. These processes have generated an increase in productivity as a result of economies of agglomeration through which cities have become engines of economic and social growth (European Union & United Nations, 2016; United Nations Human Settlements Programme, 2020).

In the case of EU countries, growing urbanisation has led to GDP growth in cities of around 50%, as well as an increase in the rate of employment close to 7% in relation to rural areas. Specialisation and innovation have created a demand for a highly educated workforce. As a result, by 2010, EU cities had already reached the Europe 2020 target of 40% of their 30-34 year old population having tertiary education (European Union & United Nations, 2016). Similarly, in CELAC countries, cities have been important drivers of opportunities in terms of supplying a demand for basic services, as well as for work, education, health, safety and social relations. These opportunities, added to displacement phenomena generated by the social and economic gap between rurality and cities, land grabbing, and violence, have made Latin America today one of the most important centres of urban population growth on a global scale (Cohen, 2004; Montgomery, 2008).

However, the cities' growth and expansion in the EU and CELAC countries have also brought costs in terms of mobility as well as higher house prices and crime rates, among other phenomena (Rodríguez & Martine, 2008; Shaker, 2015). Furthermore, the migration of low-income rural population and immigrants from regions and countries searching for better opportunities or fleeing from violence, have increased poverty and inequality within cities, especially in CELAC. In fact, the accelerated growth of cities in CELAC has been directly related to the creation of informal settlements with limited access to public services and many located in places with high disaster risk (Deneulin & Sánchez-Ancochea, 2018). While just over 10% of the world's inhabitants live in informal settlements and in the EU barely reaches 0.1% (with high variability and a higher percentage in some countries), in CELAC this percentage currently reaches close to 22% (United Nations Human Settlements Programme, 2020).

In addition to poverty, informality, exclusion, and inequality phenomena that takes place in both regions but with different dimensions and implications, we must note the effect that urbanisation has had on the transformation and degradation of natural ecosystems. The urbanisation processes

in the EU and CELAC have generated a significant degradation of ecological structures and functions considered the main source of goods and services demanded by the growing population in cities (e.g. water, food, construction materials) (Grimm et al. , 2008; Inostroza, Baur, & Csaplovics, 2013). The loss and degradation of these ecosystems has usually been the result of historical processes of fragmentation, and isolation of natural land cover, which usually is transformed into small patches of highly intervened green spaces with low similarity to the natural environment (Tratalos, Fuller, Warren, Davies, & Gaston, 2007). As a direct effect of this loss of ecosystems and natural land cover environmental liabilities such as the generation of heat islands, air pollution, and water sources, water stress or runoff are common phenomena (M. Alberti, 2005; Grimm et al. , 2008). Likewise, urban growth in both regions has led to increase the vulnerability of the population to natural disasters (e.g. floods, landslides) and climate change (Garschagen & Romero-Lankao, 2015). This is a particularly sensitive phenomenon in CELAC where a high proportion of informal settlements occupies areas prone to disaster risk (United Nations Human Settlements Programme, 2020). All impacts, ultimately, associated with reducing the capacity of ecosystems to provide services (e.g. climate regulation, pollutants removal, recreation), as well as people's well-being.

The effects of the ecosystems degradation, natural land cover reduction, and biodiversity loss in large part of cities of the EU and CELAC vary in severity and persistence. The magnitude of the effects of urbanisation in ecosystems changing in function to the structural, biophysical, and social features that cities historically face (e.g. ecosystem diversity, population density, land uses, impermeable covers proportion, climate variations, cultural practices) (McPhearson et al. , 2016) . Despite city context differences, the negative effects of urban expansion in CELAC and the EU pose the impact that deficient, informal, or unplanned urbanisation may have had, to preventing and mitigating unwanted effects (Panagopoulos, González Duque, & Bostenaru Dan, 2016; United Nations Human Settlements Programme, 2020).

Additionally, cities in the EU and CELAC also face important challenges associated with the degree of inequality in the distribution and access to green spaces and ecosystem services between human communities under different demographic, social, economic, and cultural conditions (Escobedo, Clerici, & Staudhammer, 2015; Kabisch, Haase, Jennings, Gaither, & Gragg, 2014; Lin, Meyers, & Barnett, 2015). This challenge is possibly more urgent in the case of CELAC, where the liabilities from unplanned urbanisation are magnified by high levels of poverty. Also, a significant part of the population is forced to live in informal settlements that many times lack access to basic services, as well as to quality green spaces that ensure the provision of ecosystem services that promote well-being (Pedlowski & Jasmim, 2002). Under these conditions, vulnerability to risks associated with environmental degradation shows a high degree of inequality in cities of the EU and CELAC countries.

4. Nature-based responses

The ability of cities to improve the well-being of their residents mainly depends on public policy and the participation of different actors of society. In this context, a growing number of cities in the EU and CELAC has been incorporating concepts, measures, and practices that seek to reconcile urban development with restoration, rehabilitation, and maintenance of an ecological

natural network capable to ensure people's well-being (Barona et al. , 2020; Breen et al. , 2020; Stephan Pauleit et al. , 2019; Randrup et al. , 2005).

One of the most used concepts and with a greater impact in the EU and CELAC, is that of Urban Green Infrastructure (UGI), which refers to "an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife" (Benedict & McMahon, 2006). This concept seeks to influence spatial planning in order to provide a better link between urban development and the need for a network of green spaces that provide people's well-being in cities. Under this framework, UGI has been implemented in several cities of the EU and CELAC, as ecological networks with the purpose of integrating natural components, interactions, and processes that are capable of providing essential ecosystem services (Andrade, Remolina, & Wiesner, 2013; S. Pauleit, Zölch, Hansen, Randrup, & van den Bosch, 2017). These urban green spaces networks usually include patches of native vegetation, wetlands, parks, ecological corridors, gardens, green roofs, and urban trees that altogether, make up a net of living elements and organisms that remain in cities spontaneously or by planning decisions (Stephan Pauleit et al. , 2019). UGI is framed in disciplines that promote spatial planning of the territory, such as landscape architecture and landscape ecology.

Another similar case is the widespread use in the EU and CELAC of the concept of Urban Forests (UFOR), which describes the management that in cities is made of tree and shrub covers that occupy green spaces (e.g. large and pocket parks, green corridors, house gardens) and spaces on built areas (e.g. street trees, atriums) (Barona et al. , 2020; Escobedo et al. , 2019). UFOR, as part of UGI found in cities, is usually represented in natural and secondary forests, riparian forests, ecological corridors, green belts, public spaces (e.g. parks, squares, cemeteries), and private premises (e.g. schools, sports fields, gardens). Also, UFOR is found along the avenues and streets for vehicular and pedestrian use. However, this definition and typologies are usually adjusted in a variety of management scenarios such as urban forestry and city planning (Randrup et al. , 2005).

The concept of Nature-Based Solutions (NBS) has recently emerged in the EU and CELAC with the purpose of highlighting the need to restore and rehabilitate natural structures and functions associated with green spaces networks, in order to expand their capacity for providing ecosystem services and face those social challenges that cities in both regions pose. NBS calls to recognise the importance that the protection, restoration, and management of ecosystems and biodiversity in cities can have to face social demands, such as food, water security, human health, disaster risk reduction and climate change (Cohen-Shacham et al. , 2016). EU and CELAC cities have been incorporating some of these conceptual and practical approaches, which are occasionally integrated into urban planning, in order to guide the transition of their cities towards sustainability (Escobedo et al. , 2019; S. Pauleit et al. , 2017).

5. NBS concept use in EU and CELAC cities

The growing interest in the concept and use of NBS in the EU and CELAC, responds to the requirement of prioritising nature over the use of grey solutions to solve environmental, social, and economic challenges generated by the ecosystems degradation and their capacity to provide

human well-being (Escobedo et al. , 2019; S. Pauleit et al. , 2017). Within the framework of NBS, a broad portfolio of potential interventions in urban areas has been created by the European Commission, including more than 300 examples of actions related to the protection and restoration of green spaces in order to remove air pollutants, soil bioremediation, carbon storage or stormwater retention (European Union, 2015). For these reasons, NBS has become an umbrella concept that has gained great interest in both regions by incorporating a broad vision of the positive contributions that the keeping of several types of UGI and UFOR can offer, including their ability to provide ecosystem services that increase the people's well-being in urban areas (Escobedo et al. , 2019; S. Pauleit et al. , 2017).

The use of NBS, as well as other related concepts such as UGI, UFOR, urban forestry, eco-urbanism, among others, is increasingly frequent in the EU and CELAC. For example, NBS has been appearing with a lot of frequency in various scientific publications, as well as in other types of national and regional reports and documents that indicate results associated with the benefits they can offer to face human well-being challenges in cities (see section 7). Similarly, this term is also beginning to be incorporated into public policies and the practice of urban planning, especially in the EU countries, where multiple calls have been generated to increase the use of NBS, and to ensure fair and equitable access to its benefits (Wild et al., 2020).

Organisations such as IUCN and the European Commission (EC) have become important promoters of knowledge and dissemination about the benefits of NBS in the EU, in particular through the Horizon 2020 Research and Innovation Programme (Wild et al., 2020). Through this initiative, relevant projects have emerged in the EU cities such as Green Surge, EKLIPSE, Mapping Assessment of Ecosystem and their Services- Urban Ecosystem (MAES: Urban Ecosystems), and NATure-based URban innoVATION (NATURVATION), that have made it possible to identify, develop and test ways of linking green spaces and biodiversity, with people and the economy, to face the urban challenges related to land use conflicts, adaptation to climate change, demographic changes, and human health and well-being (Wild et al., 2020). These projects have left important learnings and lessons that have been actively communicated through platforms such as OPPLA and disseminated through courses and other spaces that seek to increase the interest and use of NBS in other urban areas around the world.

In CELAC, public policies and the practical use of the NBS concept is still incipient (Portugal Del Pino, Borelli, & Pauleit, 2020). Although Nature-based interventions linked to the use of UGI and UFOR, or the protection of ecological networks, have been more widely implemented the urban planning and environmental management of cities of this region. Most of these concepts have been developed in countries of the northern hemisphere, which has limited their application in the context of CELAC given the very different eco-systemic, societal and economic conditions that characterise the region’s cities (Escobedo et al. , 2019). The convergence of mega-diverse neotropical areas, in which urban populations with a high population density have settled, largely in informal and poverty conditions, are some of the differential challenges faced by the use of NBS in this part of the world.

Countries like Brazil, have a proposed roadmap for the implementation of NBS (Wild et al., 2020). Likewise, the IUCN-South America office has been using NBS as an umbrella concept in

order to work in several approaches such as Ecosystem-Based Adaptation (EbA), Landscape-scale Restoration, Natural Water Infrastructure and Disaster Risk Reduction based on Ecosystems (Eco-RDD). These approaches have been incorporated into various projects that IUCN-South America has been promoting (IUCN, 2020). Similarly, Horizon 2020 projects, promoted by the European Commission, have begun to link cities in Latin America as a way to share knowledge and promote the use of NBS in this region. An example is the NATURVATION project, that explored lessons learned in Mexico City with the use of NBS (Wild et al., 2020). Similarly, the INTERLACE project that began in September 2020, seeks to promote cooperation to restore and connect urban environments in Latin America and Europe. This project also aims to apply an integrative, city-driven approach to address urban challenges through the restoration, rehabilitation and (re) connection of natural and social processes between places. Additionally, INTERLACE will strengthen cooperation and peer-to-peer interactions on the local, regional (EU and CELAC) and global scales. Six EU and CELAC partner cities are part of this endeavour (European Commission, 2020b).

Finally, CONEXUS aims to strengthen cooperation between cities in the EU and CELAC for the development of NBS and contribute to sustainable urbanisation. To fulfil this purpose, CONEXUS proposes to co-produce, structure and promote access to shared and contextualised knowledge necessary to support cities and communities in both regions, to co-create and implement NBS based on ecosystem restoration processes and their capacity to provide ecosystem services. This project includes 7 cities in both regions (São Paulo, Bogota, Santiago, Buenos Aires, Lisbon, Barcelona, and Turin) that will become true Life Labs in which various pilot projects will be implemented around the use of NBS to promote and demonstrate an effective management of problems associated with air quality, access to water or disaster prevention. CONEXUS will use a place-based approach to solve problems together with citizens. The combined palette of socio-cultural, ecological and governance contexts presents the opportunity to move forward faster together, and to inform urban policy and practice (European Commission, 2020a).

6. Facts in the use of NBS in EU and CELAC cities

This section explores some facts and trends on the use and application of NBS in cities of the EU and CELAC. This information was obtained from a review of scientific literature that has been published between 2000 and 2020. The main purpose of the review was to build an updated state of the art around the working concepts used associated to NBS, benefits, barriers, and lessons learned on the use and application of the concept in EU and CELAC cities. For this review, it was only considered scientific articles with explicit use of the NBS concept and/or practice, or the implicit use of NBS through other approaches such as UGI or UFOR, focused on addressing local and global societal challenges of cities of the two regions. Similarly, the selected case studies that follow this section, represents both those that conceptually are linked to potential uses and benefits of NBS in cities, as well as those that present progress and results completed or on-going.

In order to develop a structured and objective capture, and for the analysis of the case studies, after Wild et al. (2020), the steps suggested in the framework called Restricted Systematic

Review (RSR) were followed (Plüddemann, Aronson, Onakpoya, Heneghan, & Mahtani, 2018). Below a summary of the steps in the RSR developed:

1. To define the group of research questions to be addressed to guide the RSR specifically in the context of the EU and CELAC cities:
a) How has NBS been incorporated temporally and geographically?
c) What typologies of NBS can be identified?
d) What evidence is there on ecosystem services and benefits provided by NBS?
e) What barriers are observed affecting the design, implementation and monitoring of NBS?

2. To identify published literature in order to answer the questions previously stated. Scopus and Web of Science (WOS) were the scientific databases used to develop a searching process and capture, searching papers published in English, Spanish and Portuguese. In order to increase the effectiveness of the search, several keywords were identified using the framework PICO and a searching string was created.
3. Inclusion or exclusion criteria for filter scientific articles and data was implemented, using a peer-review process and the use of indicators based on the questions.
4. Finally, the information and data found were analysed and synthesised to obtain a comparative state of the art on NBS in EU and CELAC cities.

EU and CELAC overview
As a result of the RSR 311 scientific publications were identified related to the conceptual or practical use of NBS, or the concepts UGI and UFOR in the EU and CELAC cities. Although, these studies seek to be a representative sample of progress on these topics in both regions, they may be underrepresenting some progress and trends in countries where information may be publishing in other types of grey literature (e.g. public reports, public policies, working papers).

Based on the information obtained in this RSR, it is observed how the interest in NBS as well as in similar approaches (UGI and UFOR) has been temporarily growing with the main purpose to use nature in order to face multiple local and global challenges in the EU and CELAC cities (Figure 2). This interest is evident in the exponential increase in the total of publications since 2007 in both regions, particularly on UGI that is the most frequently used type of concept and NBS that has been growing rapidly since 2016 (Figure 2).

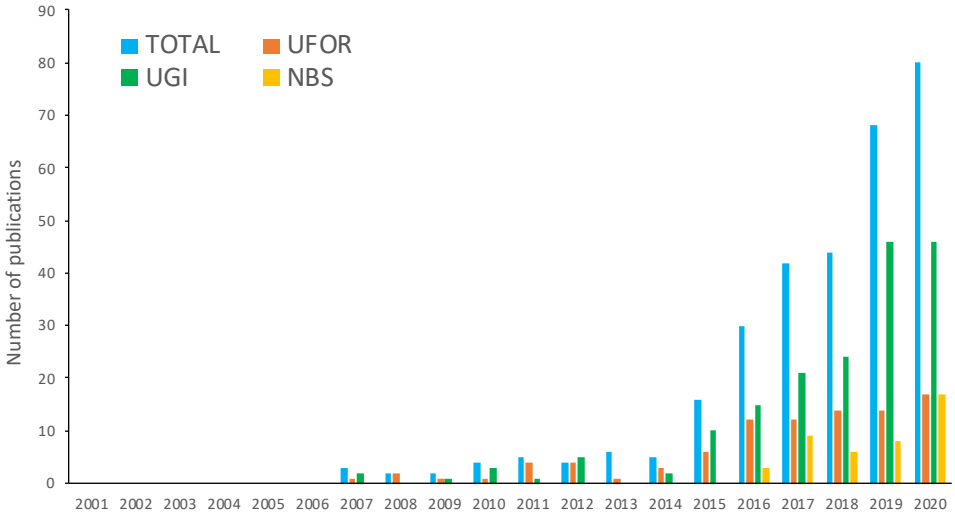

Figure 2. Temporal evolution in the number of publications of case studies for EU and CELAC cities on NBS, as well as in those that use concepts with a similar purpose such as UGI and UFOR.

This growth in studies involving NBS or related concepts has been particularly significant in the case of UGI, which reaches around 56.6% of the studies in both regions, while the recent incorporation of the NBS concept barely reaches 13.8%. However, this trend has not had the same direction in both regions. In the case of the EU cities, a proportion of studies published is 3 times higher than that reported in CELAC cities. A trend that is kept although with a less degree for the studies that involve UGI and NBS, particularly in the case of the latter, which has only begun to be addressed since 2018 (Figure 3).

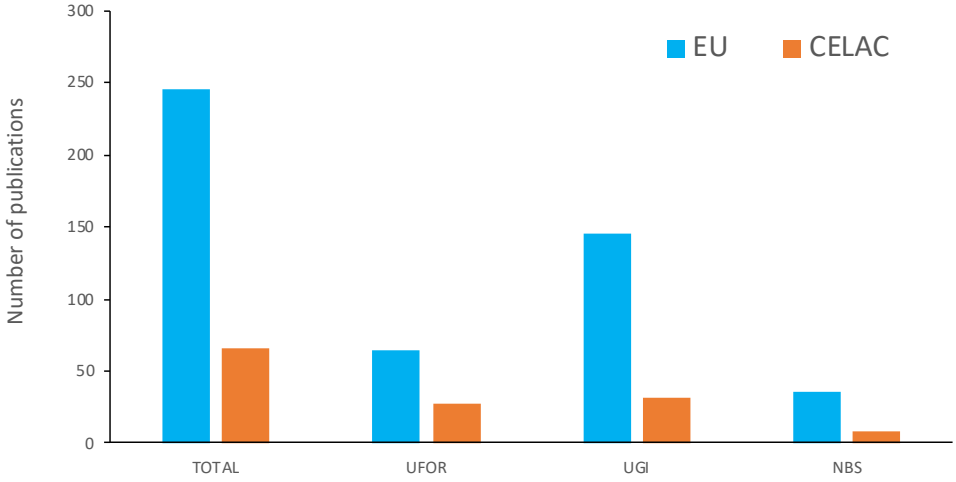

Figure 3. Distribution in the number of publications that involve the conceptual and practical use of NBS, UGI, and/or UFOR in EU and CELAC cities.

Regarding the distribution by country of studies involving NBS, UGI and/or UFOR, in the case of the EU, it is observed that 21 of the 27 countries in the region (78%) have been working on nature-based responses. Particularly, 8 countries (Italy, Germany, United Kingdom, Spain, Poland, Portugal, Finland, and the Netherlands) register more than 10 studies, and gather more than 80% of the cases found in this region. On the contrary, little information was found in countries in East Europe. In the EU, the trend of those studies that explicitly use only the concept of NBS was similar, but showed a significative smaller number of countries (13). Italy, Portugal, Poland, Sweden, and Germany are found to be where the use of the NBS concept has received more attention (Figure 4a). For CELAC countries, studies involving NBS, UGI and/or UFOR barely reach 36.4% (12 countries out of 33). 5 countries (Brazil, Argentina, Colombia, Mexico, and Chile) add up to more than 80% of the case studies found, showing a significant information gap in Central American countries and the Caribbean Islands (Figure 4b).

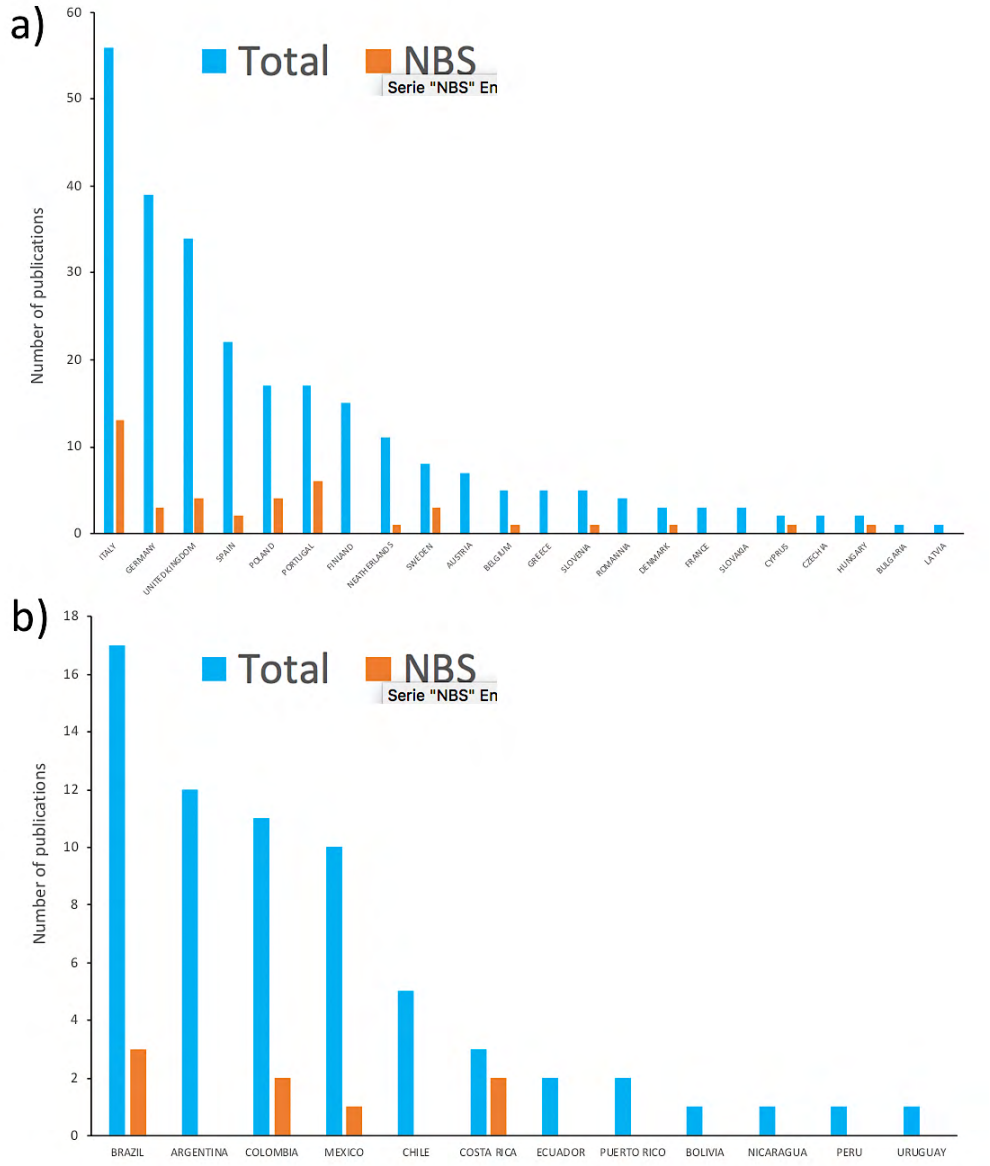

Figure 4. Country-scale distribution for a) EU and b) CELAC on the number of publications that integrate the use of NBS, UGI or UFOR (Total) or only the use of NBS.

Finally, in 160 cities of the two regions, 77.5% case studies were found using conceptually or practically approaches related to NBS. In the EU, 8 cities have more than 5 studies detected for each case, including Rome, Florence, Milan, Berlin, Munich, London, Lisbon, Helsinki, Barcelona and Vienna. On the other hand, 3 countries show the largest network of cities in which these concepts have been used, Italy with 24, the United Kingdom with 21, and Germany with 17 cities (Figure 5a). In the case of CELAC, a small group of cities shows more studies than the rest: Mendoza, Buenos Aires, Bogota, Rio de Janeiro, Mexico City, and Santiago (Figure 5b).

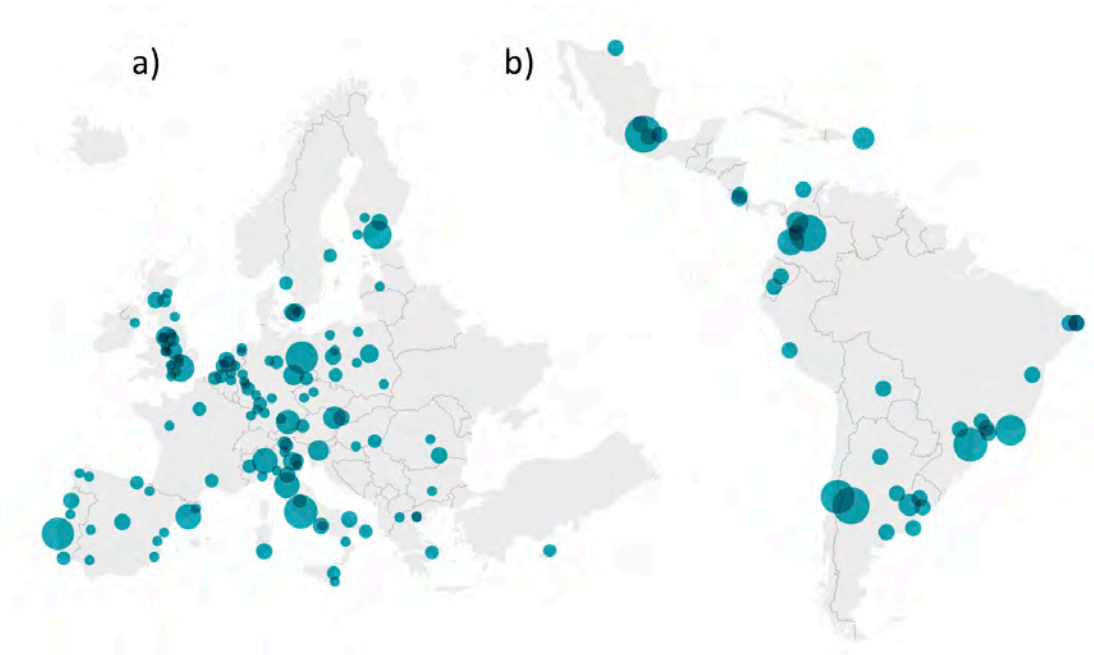

Figure 5. Distribution in a) EU and b) CELAC at the city level on the number of total publications that involve conceptually or practically the use of NBS, UGI or UFOR.

NBS typologies and societal challenges addressed

In relation to the use of the NBS, UGI and/or UFOR concepts in EU and CELAC cities, a relative majority of the published studies have addressed these topics from a practical approach (51.8%) in relation to other conceptual and predictive approaches (48.2%). Practical approaches have been usually related to the real development of nature-based interventions that have taken place in different urban areas of the EU (Blau, Luz, & Panagopoulos, 2018; Maiolo, Mel, & Sinopoli, 2020) and CELAC (Navarrete-Hernandez & Laffan, 2019; Targino, Coraiola, & Krecl, 2019), as well as the measurement and monitoring of the contributions and benefits for people well-being (McClymont et al. , 2020; Speak, Escobedo, Russo, & Zerbe, 2020). On the contrary, conceptual approaches have been concentrated in the use of theoretical and methodological models to project potential interventions based on nature, predict their possible positive effects, and guide the development of future intervention plans or decisions related to urban planning (Augusto et al. , 2020; Rafael, Augusto, Ascenso, Borrego, & Miranda, 2020).

The conceptual and practical approaches found have focused on responding to various societal challenges from local to global scales in the EU and CELAC cities. The studies published show that NBS interest in facing challenges are mainly related to: the urban heat island (16.6%), the low access of people to green spaces and its benefits (15.6%), the air pollution (14.1%), the reduced area covered by green spaces available for human contact with nature (14.1%) as well as the control of the runoff, floods and stormwater (13.4%) (C. S. S. Ferreira et al. , 2020; Li, Van Eetvelde, Cheng, & Uyttenhove, 2020; Marando, Salvatori, Sebastiani, Fusaro, & Manes, 2019; Muñoz-Pizza et al. , 2020). To a lesser extent, the studies have sought to understand and manage challenges related to the degradation of ecosystems and ecosystem services, climate change, food

security (Artmann, Sartison, & Vávra, 2020; Belčáková, Świader, & Bartyna-Zielińska, 2019; Gratani, Varone, & Bonito, 2016), or even some ecosystem disservices (von Döhren & Haase, 2019) that nature can cause as a result allergies or damage to grey infrastructures (Figure 6).

However, there are some differences in the trends that are found on these challenges in both regions (Figure 6). While in the EU the low access of people to green spaces and its benefits are presented as the most important challenge (Majekodunmi, Emmanuel, & Jafry, 2020; Pozoukidou, 2020), this is only the fourth in importance in CELAC, where the control of runoff, floods, and stormwater is the main challenge identified (López-Valencia, 2019; Singh, Sarma, & Hack, 2020).

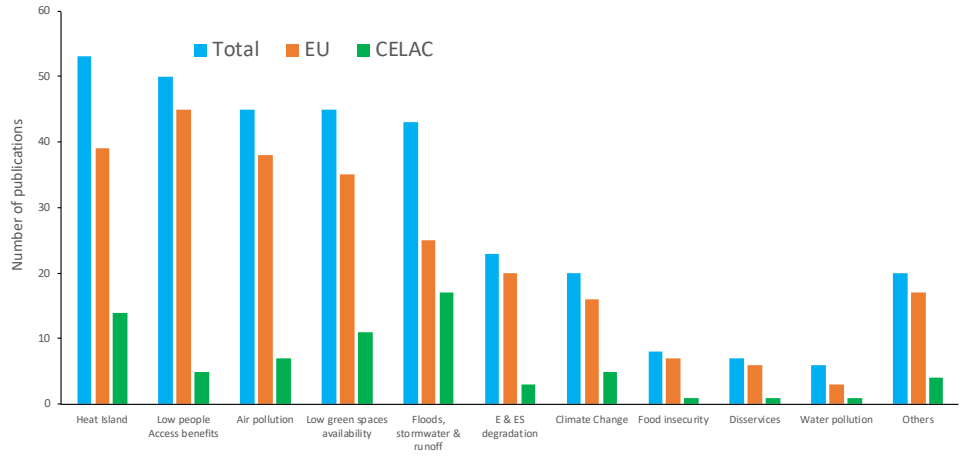

Figure 6. Distribution of the number of publications that define explicitly local and global societal challenges in EU and CELAC cities that can be addressed through the conceptual or practical use of NBS, UGI and UFOR.

On the other hand, the responses that from the use of the concept of NBS can be found in the EU and CELAC, have been mainly focused on increasing the sustainability of urbanisation and their effects on the well-being of the people (66%). In a significantly lower proportion, other conceptual proposals and practical projects in NBS in both regions are about mitigation and adaptation of cities to climate change (28%) and the protection and restoration of ecosystems (6%) (Figure 7).

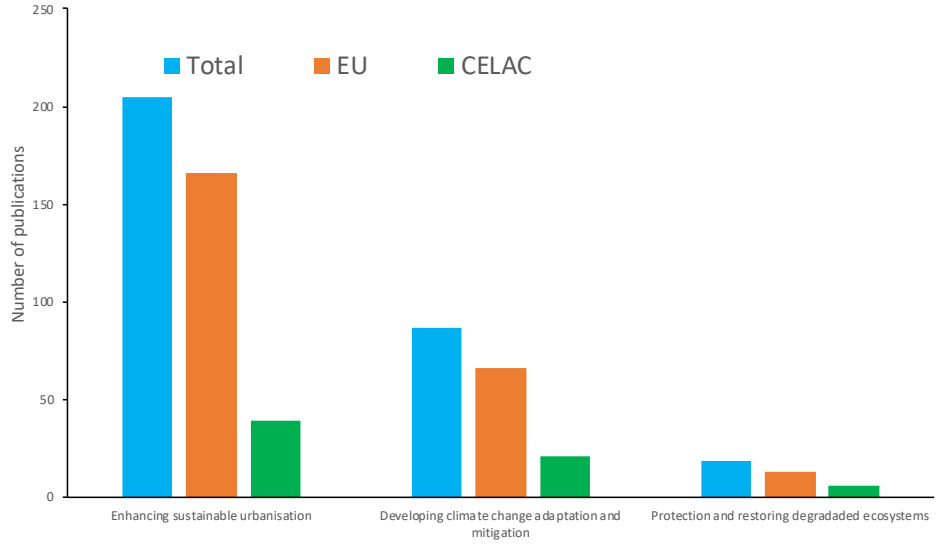

Figure 7. Distribution of the number of publications that define the main purpose of the conceptual or practical use of NBS, UGI and UFOR to face social challenges in EU and CELAC cities.

Benefits derived from the use of NBS in the EU and CELAC cities

The benefits from the conceptual or practical use of NBS in the US and CELAC cities have been mainly related to the provision of different types of ecosystem services. The highest proportion of NBS, UGI and UFOR show to be focused on providing regulation services (59%), mainly related to the urban micro-climate, hydrological cycles and air quality (Figure 8). The second most important group of ecosystem services in both regions provided by NBS, correspond to cultural benefits (27%), such as recreation, physical and mental well-being, aesthetics and a sense of belonging (Figure 8). On the contrary, provisioning services such as obtaining food for consumption or wood for energy or construction, have been scarcely identified in both regions (9.8%).

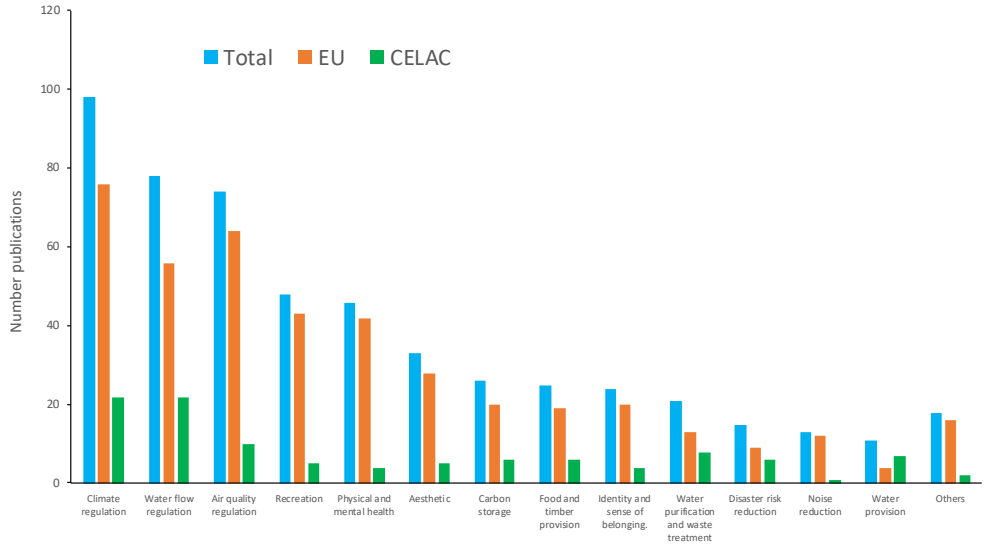

Figure 8. Distribution of the number of publications that explicitly define types of ecosystem services that have been evidenced in conceptual and practical approaches used for the use of NBS, UGI and UFOR in the EU and CELAC cities.

It is also worth mentioning the low importance given to NBS in relation to provide some specific ecosystem services. For example, urban vegetation plays an important role in the carbon storage and the mitigation of the impacts of gas emissions in EU cities, therefore, can contribute greatly in the reduction of the potential effects of climate change on a global scale. Something similar happens about the importance that an ecosystem service, such as the provision of water, has in the case of CELAC.

Barriers related to the use of NBS in cities of the EU and CELAC

The main barriers that can be identified around the conceptualisation and implementation of NBS in both regions, include in a significant proportion, the difficulty of evaluating and measuring the benefits derived from these interventions (Figure 9). This barrier is especially generated by the scarce development of reliable and replicable methodological tools to measure contributions to human well-being, as well as difficulties related to the scales of analysis used (Palliwoda, Banzhaf, & Priess, 2020; Rathmann et al. , 2020). Another persistent barrier, especially in the EU cities, is the poor understanding of society about the benefits that NBS may deliver, which generates other barriers associated with the long term maintenance of these interventions, and some negative perceptions in relation to other grey solutions (Williams et al. , 2019). In the case of CELAC, the lack of information and data necessary to measure the potential benefits, is one of the most important barriers, also with apparent contradictory policies to promote the use of NBS (L. M. R. Ferreira, Esteves, de Souza, & dos Santos, 2019).

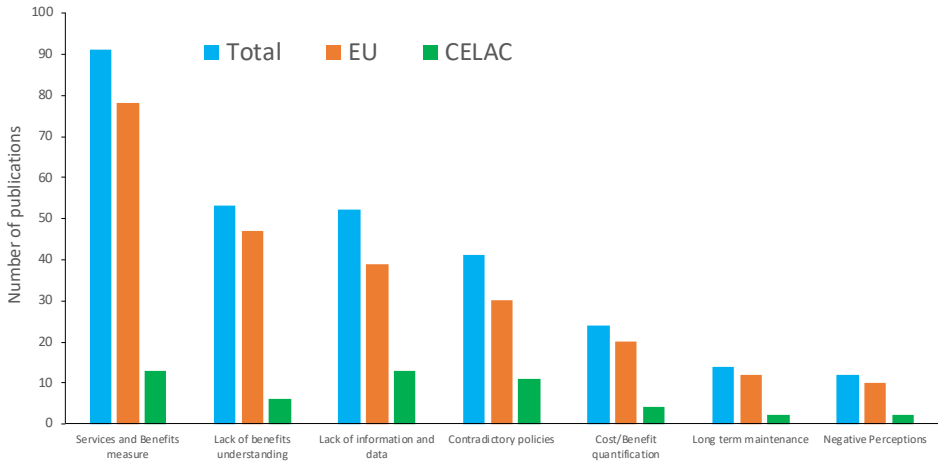

Figure 9. Distribution of the number of publications that indicate persistent barriers affecting the conceptual or practical use of NBS, UGI and UFOR in the EU and CELAC cities.

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7. Case studies

Case 1: Urban gardens in Barcelona: multifunctional green to enhance Nature-Based Thinking in cities

Nature-Society relationship, local challenges and relationships with global challenges
Barcelona City Council and the Metropolitan Area implement specific policies to enable nature to fit into the city and to enhance biological diversity based on the philosophy that a city with greater green infrastructure is a city where people can benefit from higher levels of health and wellbeing. The concepts and assessments of biodiversity and ecosystem services are closely related to the design and management of the main urban regeneration and green infrastructure plans.

The Olympic Games in 1992 marked an important milestone for urban regeneration in the city, with important landscape transformation, focused of the ecological restoration of the seafront and the creation of many new parks and districts covering old industrial land. More recently, at the metropolitan scale, the Besòs and Llobregat Rivers had been ecologically restored, and new plans of enhancing ecological connectivity of green spaces had been shaped for Collserola Natural Park, the green belt of the city. Recently, new green areas have emerged in Barcelona (such as the Park of Canopia Urbana or the Superblocks, which reduces car traffic and provides a healthier and greener model of public space (Figure 10), as the result of the strategies and policies designed to establish and implement Nature-Based Solutions (renaturing the city), to tackle the main challenges (climate change and air quality).

Figure 10. Left: Canopia Urbana, the new urban park with 20.400 m2 of green and 400 trees, inaugurated in 2019. Right: Superblocks in the district of Born. Photo captures: Corina Basnou.

An important step towards socio-environmental justice and urban regeneration was marked by The Neighborhoods Plan of Barcelona. The plan, with a recent new phase developed for 2021-2024, it's an ambitious strategy which addresses sustainable urbanisation and social inclusion in the most deprived areas (with a large proportion of immigrants, low family income, limited educational facilities, and high unemployment).

Another government measure related to inclusiveness is the Plan for Play in Barcelona's Public Spaces. The Plan is looking to move from a city with play areas to a playable city by 2030. Its aim is to improve and diversify opportunities for play and physical activity in public spaces, due to the great benefits these activities have for children's and teenagers' development and well-

being and for health and community life. The plan is the result of a cross-cutting process involving over 400 professionals, organisations and members of the public – both children and adults – and is inspired by pioneering play plans implemented in other cities, such as Dublin and London. It also responds to the United Nations' recommendations to enhance the right to play, a specific human right for children and adolescents. With this plan, Barcelona is seeking to achieve a paradigm shift, becoming a city with specific play areas that are more diverse, creative, accessible and inclusive while placing the entire city's urban planning at the service of play. One of the plan's axis is focused on "Transforming the schoolyards", with various actions related to greening the schoolyards, mitigating heat waves, increasing social cohesion or enhancing outdoor learning and inclusive play.

Currently, NBS efforts in Barcelona are marked by two main strategic plans led by the City Council: The Barcelona Green Infrastructure and Biodiversity Plan 2020[1] and The Programme of Enhancing Urban Green Infrastructure.[2] The Barcelona Green Infrastructure and Biodiversity Plan 2020 established the main objectives and shaped the city's compromise and future work on biodiversity, ecosystem services sand NBS. Its diagnosis of the state of green infrastructure in the city clearly links the different types of urban ecosystems and their biodiversity to the provision of a series of ecosystem services, including air quality and climate change mitigation and adaptation. The proposed measures focused on increasing green connectivity, include an increase in street tree number and species diversity, the provision of more soil for street trees, and a further increase in the number and quality of green spaces in the city.

The Programme for Enhancing the Urban Green Infrastructure is an ambitious government measure approved in 2017, which establishes the main strategies for enhancing the quality and quantity of green infrastructure in Barcelona till 2030. Barcelona wants to renature the city (Figure 11) and create in this period 165 ha of new green spaces, which is, increasing $1m^2$ the green spaces/inhabitant.

As Barcelona is a compact city, there are various strategies to improve, transform or create new green spaces. The actions will take place at various urban scales (street, district or city scale) and they are organized in four main objectives (I. Increasing green infrastructure; II. Enhancing green infrastructure to obtain more ecosystem services; III. Co-responsibility in the maintenance of urban nature; IV. Monitoring and evaluating the green infrastructure), each with clearly related interventions in the public space. Especially related to the 3rd objective (Co-responsibility in the maintenance of urban nature), the city contributes to the concept of Nature-Based Thinking. Among they main actions of this objective, it is highlighted the impulse of the ecological agriculture in the city, the creation of new urban and school gardens and the importance of co-management and co-creation to enhance citizens' empowerment and engagement with urban nature. Another action is related to the enhancement of communication and educational strategies to promote the importance of biodiversity and urban nature. And finally, one of the actions related to the last objective (IV. Monitoring and evaluating the green infrastructure) is focused on developing an information system on biodiversity and green infrastructure in Barcelona.

Figure 11. Renaturing Barcelona: various green typologies in the centre of the city. Bellow, on the left: Cover of the government measure "The Programme for Enhancing the Urban Green Infrastructure". Photo captures: Corina Basnou.

The urban gardens in Barcelona

Urban gardens (Figure 12) are multifunctional green spaces and they are key spaces to enhance biodiversity, ecosystem functions and services. Urban gardens favour resilient and biodiversity friendly cities and they are related to key concepts such as urban green infrastructure planning, urban regeneration or NBS. They enhance social cohesion and increase health and well-being. Moreover, urban gardens are important part of the city sustainability and food production. An urban garden not only provides fresh and 0 km food, but it also enhances nature accessibility for the most vulnerable (i.e. elderly, disabled or children). In Barcelona, active ageing and social inclusivity programs are encouraged in urban allotments and community gardens. Elderly low-middle income and migrant people are among the main beneficiaries of such initiatives. Barcelona has also a large network of school gardens. In total, Barcelona has a complex red of 361 urban gardens (including the 267 school gardens). Many urban gardens in Barcelona have special educational programs and, during COVID measures, they acted as "satellite" schools to enforce outdoor learning. The municipal urban gardens in Barcelona (15 urban gardens in various districts) are also of special interest for enhancing NBS in the city. They are designated for residents older than 65 years, who can cultivate and manage their proximity urban gardens,

using always the ecological agriculture principles and following the city's Strategy for urban agriculture (Estratégia de agricultura urbana). These gardens, with lots varying from 25 to 40 m^2, have sometimes complex green typologies and areas for rest (benches, shadow areas, biodiversity refugees, bee hotels, etc.).

Figure 12. Above: Can Mestres, the first urban municipal garden for older adults in Barcelona Bellow: The first urban garden in Barcelona, L´Hort de l´Avi (Grandfather´s Garden), dating from 1986. Photo captures: Corina Basnou.

In line with recent government measures, there is not only an increased interest from part of researchers and municipalities to improve the red of urban gardens in Barcelona, but also to establish a Knowledge Information System related to urban gardens (i.e. Urban Gardens Observatory containing updated information on biodiversity, food production and consumption, community involvement or food safety). Gathering all these data is also a question of public health. Air quality has been, since the 70s, one of the major environmental challenges for the city of Barcelona. The importance of green spaces to enhance air quality is still little studied at detailed city scales. Recent studies in Barcelona assessed heavy metal pollution in various urban gardens,[3] and they will contribute to the future Urban Gardens Observatory in CONEXUS.

Lessons learned and conclusions

The importance of urban gardens in Barcelona is widely recognised and they are considered excellent examples of NBS by various studies and assessments.[4] Their incorporation, at various urban strategies, especially in the last 20 years, contributed to increasing urban biodiversity and improving the quality of urban green. Urban gardens are key in recovering the cultural memory and fostering the interaction with nature. Urban gardens help bridging rural-urban connections and show how history is present in the management of urban biodiversity, recovering cultural

landscapes and knowledge on biodiversity and ecosystem services. They are perfect living laboratories to discover, learn and experience urban nature. Having a huge potential for education (i.e. promoting outdoor learning activities and enhancing interactions with nature), the urban gardens are NBS of special interest for children. Children who experience a sense of wonder through direct contact with nature are more likely to develop a life-long respect and value for the existence of natural areas, the habitats they contain and the species they support[5].

The recently developed Programme for Enhancing the Urban Green Infrastructure in Barcelona enforced city´s strategy on green infrastructure (including the urban gardens), through actions at various levels. A key to the successful implementation of this ambitious plan was the efficient communication strategy, to mainstream population acceptance of the new management criteria of the green spaces (Figure 13). Future educational activities and co-design sessions or specific activities focusing schools, could largely benefit the implementation of the plan. However, only during 2019, Barcelona City Council developed 146 activities across the red of urban gardens, with more than 2.500 participants.

One of the next directions related to urban gardens in Barcelona envisage creating a knowledge information system, diversifying the cultivated species in the urban gardens (i.e. more fruit-bearing trees), or the green typology and land-uses (i.e. incorporating urban meadows or enhancing the apiculture).

Figure 13. Slogans of the communication campaign "Let´s go green. Renature Barcelona", led by Barcelona City Council.

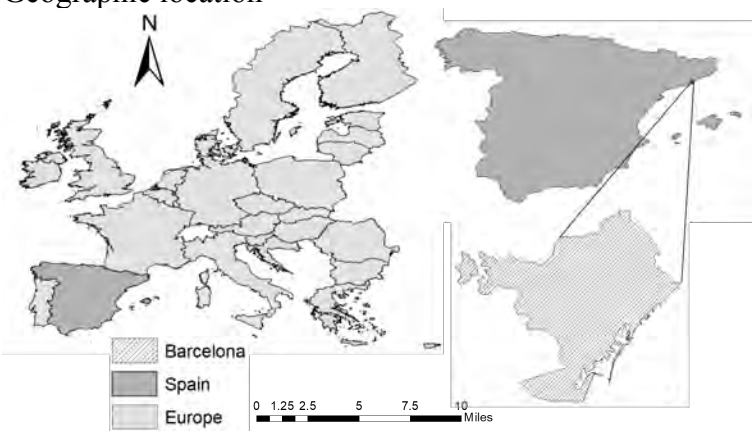
Projections and upscaling

The Programme for Enhancing the Urban Green Infrastructure is a remarkable example of urban regeneration strategy and climate change adaptation in Europe and beyond. The pillars of this government measure are criteria that are key for the management and governance of the green infrastructure in cities (multifunctionality, population accessibility to green areas and designing a strategy in line with city´s infrastructure). The development of a user-friendly Urban Gardens Observatory will incorporate data gaps (i.e. on less studied ecosystem services, e.g. air quality, or data on biodiversity, such as spontaneous flora or invertebrates) and it will booster data democratisation, green areas planning and management. This Observatory can be upscaled and replicated at various administrative scales, and adapted to various users. In this way, the Observatory will be a projection of the actions undertaken within the Programme for Enhancing the Urban Green Infrastructure, establishing a knowledge data base and contributing to NBS monitoring, assessing and successful implementation.

Wider contextual information

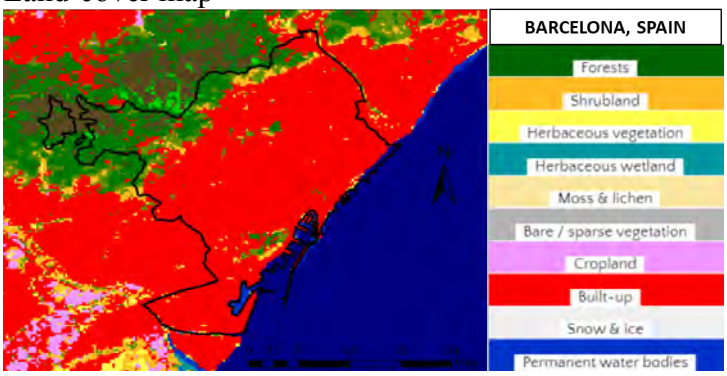
General description
Core city: Barcelona
Biogeographic region: Mediterranean
Localisation: Europe, Spain
Area: 102 km2
Population: 1,666,530 inhabitants
Public recreational green space per capita: 17 m^2 per inhabitants (including The Park of Collserola); aprox. 6,64 m² per inhabitant, without counting Collserola

Geographic location



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana

Land-cover map



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana, based on: Buchhorn, M.; Smets, B.; Bertels, L.; Lesiv, M.; Tsendbazar, N.-E.; Masiliunas, D.; Linlin, L.; Herold, M.; Fritz, S. (2020). Copernicus Global Land Service: Land Cover 100m: Collection 3: epoch <2019>: Globe (Version V3.0.1).

Barcelona is one of the biggest metropolitan cities in Europe and one of the densest and most compact urban areas, with a population density of around 16.000 inhabitants per square kilometre. The municipality covers a total area of 102 km2, with a population of 1,66 million inhabitants.[6] Barcelona is one of the 36 municipalities of the Metropolitan Area. City's future urban plan, at the metropolitan scale, is established by the ongoing Urban Metropolitan Plan (Plan Director Urbanistico Metropolitano, PDU), which incorporated various co-design processes. The city has a rich multicultural biodiversity, as 27,8% of its inhabitants are foreign-born.[6]

Barcelona and the peri-urban areas suffered dynamic landscape changes, especially at beginning of the 1960s. The socio-economical changes were particularly intense along the coast, with important pressures on biodiversity and green areas, when almost a half of the agricultural land was lost. Barcelona increased the green spaces with 44,41 ha (between 2017-2019) and aims to increase even further with 165 ha (between 2020-2030) the green areas.

The metropolitan food system is promoted by various mechanisms and policies to ensure citizens better access to healthy and affordable food. The policies also seek to bring metropolitan area food producers and consumers closer together in order to promote social and environmental responsibility as well as local food production and consumption. The goals of the Food system action plans are to guarantee production and access to healthy and affordable food, based on the principles of equality, conservation and environmental sustainability.

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https://ajuntament.barcelona.cat/ecologiaurbana/en
•Superblocks (Supermanzanas):
https://ajuntament.barcelona.cat/superilles/es/
•Atlas of Biodiversity of the city of Barcelona:
https://ajuntament.barcelona.cat/atlesbiodiversitat/en/
•Plan for Play in Barcelona's Public Spaces:
https://ajuntament.barcelona.cat/ecologiaurbana/en/what-we-do-and-why/quality-public-space/barcelona-plays-things-right

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Case 2: Socio-ecological networks: an opportunity to integrate nature, urban planning and social appropriation in Bogota, Colombia

Addressing urban growth, ecosystems services and social well-being.

Figure 14. Bogota city, the capital and the largest urban agglomeration of Colombia. Photo capture: Juan David Amaya-Espinel.

The expansion and consolidation of the city of Bogota (Figure 14) favoured the concentration of goods and services that had a positive influence on the social, economic, and political development of the population. However, at the same time, this rapid urban growth generated significant environmental pressure related to the transformation and degradation of the natural ecosystems. Air pollution, degradation of water bodies, loss of natural and agricultural covers and green spaces, in addition to the population vulnerability to disasters such as floods and landslides, are some of the most visible effects observed by a rapid and arguably a disordered expansion of the city.[1,2] Some of the most significant impacts of the urbanisation processes of Bogota have been related to the extreme pollution of several streams and rivers that cross the city, particularly the Río Bogota that runs through its western limit. The Río Bogota is considered one of the most contaminated in the country, having been exposed for years to several sources of pollution. The river receives 149,633 tons / year from Bogota. In addition, there is a loss and degradation of an extensive coverage of wetlands that covered the city until the beginning of the 20th century. These wetlands played a key role in regulating flood pulses during rainy seasons. Currently, these wetlands have lost valuable functions in terms of flood prevention. The same has happened with the forest covers in the hills that surround the eastern part of Bogota. These were extensively transformed from the colony, and only in the 20th century did a reforestation process begin, however based on the use of exotic species of

eucalyptus and pine. In addition, the hills have been strongly pressured by urban expansion, which has led to numerous conflicts regarding their protection or development.[2]

As a result, Bogota has seriously compromised the vital supply of essential ecosystem services included those related to the provision of drinking water, capture of atmospheric pollutants, climate regulation, runoff control and disasters mitigation such as landslides and floods. Similarly, this environmental degradation has effects on social and cultural services and behaviours in relation with recreation, mental well-being, sense of belonging and social cohesion.[3,4] The gradual degradation of native ecosystems which are the biophysical base of the city, has contributed to the loss of ecosystem services. Likewise, this is the result of a growing loss of green and blue infrastructures, especially related to river degradation, the filling and pollution of wetlands, the urbanisation of large green areas and ecological corridors, as well as the transformation of parks and gardens in recreational areas with less natural features.[5,6]

The significant loss and degradation of ecosystems, green areas and their contributions to human well-being in Bogota, also impacted the progress in meeting goals such as the Sustainable Development Goals. Particularly, the progress achieved in the reduction of poverty, informality, and inequality (SDGs 1, 3, 8 and 10) is limited. To achieve those goals, it is a priority to advance in actions that contribute to reduce the effects of climate change and increase the resilience of the city (SDGs 7, 13, 14, and 15). Also, Bogota should work towards to be a sustainable and inclusive city (SDGs 11 and 12). Only recently SDGs were explicitly included in the main management instrument of the city, the District Development Plan (Plan Distrital de Desarrollo). This plan seeks to create a new deal to increase social inclusion on the basis of changing life habits, greening Bogota, and adapt and mitigate climate change.

Socio-ecological responses and NBS initiatives

In response to the effects of urban growth, Bogota was a pioneer in Colombia in the adoption of concepts that could guide the incorporation of ecosystems and green and blue infrastructures in urban planning instruments. In fact, the embracement of the local concept of Main Ecological Structure (EEP for its Spanish abbreviation), has contributed to the protection and management of ecological networks[7] that reconcile urban development with the conservation of structures and functions of ecosystems, as well as their ability to provide ecosystem services. Additionally, EEP has major impacts in the decision-making process to guide territorial planning at the city level and it was incorporated into national legislation.

The EEP defines the “set of biotic and abiotic elements that support the essential ecological processes of the territory, whose main purpose is the preservation, conservation, restoration, use and sustainable management of renewable natural resources, for the socioeconomic development of the populations” (Law 388 from 1997). Different types of natural and semi-natural spaces make up the EEP of Bogota (e.g. networks of protected areas, metropolitan parks, ecological corridors), the protected areas are extended from the urban and peri-urban areas of the cities, to the rural and natural areas around the city. Furthermore, there are other complementary green infrastructures that do not constitute protected areas, but are integrated into the EEP to support the functions and connectivity. These infrastructures make up the Complementary Ecological Structures (EEC for their Spanish acronym), which includes green spaces such as pocket parks,

streams, urban trees, green roofs, urban gardens, among others. The EEC plays an important role in recreation and urban aesthetics, and as priority spaces in risk prevention and runoff control.[8,9]

Therefore, in the long term to continue to deliver ecosystem services in the quantity and quality required by the city, the biggest challenge for Bogota is keeping the ecological networks that make up those green spaces, included in EEP and EEC. In particular, it is a priority to promote the persistence of these ecological networks based on social participatory work with several academic, governmental, and civil society stakeholders for the protection, restoration, and sustainable use of these green spaces. This participatory action is becoming more frequent in Bogota as the best way – through tools based on nature – to understand and communicate the importance and benefits that green and blue spaces have over citizens' well-being.[10] The close interaction and positive feedback between green spaces network in EEP and EEC and people involved in their conservation, leads us to think of them as socio-ecological networks linked by the ecosystem services provision and the human sustainable management.

For example, the case of the hills around the eastern part of the city called the "Cerros Orientales de Bogota" (COB for its Spanish abbreviation) is an emblematic project that shows the efforts to maintain the EEP in Bogota. The COB is part of the protected area "Reserva Forestal Protectora del Bosque Oriental de Bogota". This protected area, at the beginning covered about 14,000 ha, is considered natural heritage and strategic ecosystem of the EEP of Bogota due to its role as an ecological corridor, and provider of multiple ecosystem services.[11] However, the legal protection statement of this area has not stopped the formal and informal growth that has gradually invaded and degraded the reserve. For this reason, in a court order issued by the state of Colombia, it was decided to create a type of adequacy strip in which different institutions and authorities were requested to develop environmental standards, normalise human settlements and formulate a management plan for un-occupied lands on COB, in order to give them an ecological and recreational use for all Bogota citizens.

As a result of the COB protection, several projects have been carried out, such as the consolidation of a socio-ecological corridor, which seeks citizen hills appropriation through various strategies. Besides, integrating by different people that inhabit these hills and people in of Bogota, there has been created a border pact along the 57 kilometres of the COB. This social agreement has allowed to develop behavioural changes that promote ecological culture through processes of participation and coexistence. Another biophysical strategy for the ecological recovery of ecosystems, has been the promotion of the ecological connectivity through ecological corridors connecting city with the region.[12] These initiatives make the COB a living laboratory of valuable projects of social cohesion and ecological recovery.[13, 14]

Another initiative originated within civil society based on an interest to build shared knowledge, social appropriation, and a positive impact on the COB, was the creation of the Cerros de Bogota Foundation (FCB for their Spanish acronym), which has been promoting various programmes to protect the COB. The Umbral Cultural Horizontes Reserve stands out as a space of 3ha for collaborative and territorial transformation strategies. In this context, there are several interventions that the FCB has achieved at an ecological and social levels to generate citizen appropriation around the CBO; some of them related the ecological restoration participatory

programmes. Other interventions correspond to collective works such as the creation of barriers and filters to retain plant material, thus mitigating the impact of the rains on the area. Also, social interventions, such as the consolidation of an open-air gallery that encourages artists, young people, and children to creatively transform the place with materials that are friendly to the ecosystem or with open citizen talks and workshops.[10, 12–14]

Moreover, in the northern edge of the city, there is an ecological restoration initiative that emerged about five years ago in the COB. This initiative seeks to exchange citizen knowledge and make visible the ecosystem services offered by the COB to the city. This restoration process, led by a government agency in charge of research and conservation of biodiversity in Colombia, the Alexander von Humboldt Institute (IAvH), was possible thanks to an interinstitutional effort with the Botanical Gardens of Bogota to carry out a careful exercise of ecological restoration, and social appropriation. After evaluating several options, a gradual restoration process was implemented in which exotic trees were removed in a controlled manner, seeking to open light gaps in the land and plant new native species. The selection of the species was carried out with the support of the Botanical Gardens of Bogota after searching for seeds in strategic areas of the hills around the city and then sowing them in urban gardens located in 30 restoration centres. As a result of this work, around 2,000 trees have been planted, including about 40 native species that have not been there before in there. Also, an environmental education process focused on non-scientific audiences started in 2016, promoting knowledge exchange and interactions with great value in the sustainability of this ecological intervention. Likewise, a plan was developed to establish links with the citizens of Bogota, which has led to receiving visitors, offering tours and pedagogical experiences on the trails and urban gardens, as well as content to give visibility to the importance of the COB in the quality life of Bogota.[10]

Lessons learned and conclusions

The incorporation of socio-ecological networks on the urban planning instruments of Bogota has made it possible to mitigate the negative effects of arguably a disordered at one hand, and informal at the other hand, urban growth of Bogota on their biophysical structure and population well-being. However, the protection, restoration, and sustainable use of these spaces in the long term, as well as the maintenance of their contributions to human well-being, will only be possible with intervention processes based on collaborative work with different academic, governmental, business, and community stakeholders. Nature-Based Solutions such as those developed in the COB are an excellent example of how to progress in this purpose. Conservation initiatives in the COB should be a reference on how to reduce and manage the conflict between society, economic development, and nature in Bogota. Also, it is necessary to effectively address the indifference and the lack of interest of people and decision-makers around the value of EEP green and blue spaces.

Projections and upscaling

Bogota requires a firm effort around scientific research and community involvement for quantifying the benefits offered by green and blue spaces such as the COB that reduces the degradation and the capacity to deliver ecosystem services, as well as monitoring and indicators to assess the effectiveness of interventions at both ecological and social scales. Achieving the ecological and social objectives that were raised with the recognition of the EEP in Bogota, will

require governmental political will in the efforts for their protection and restoration, as well as a more active appropriation of civil society through different stakeholders. The processes that have been developed in the COB, although with some limitations and barriers, are a reference that could be replicated in other areas of the EEP. In particular, it is a priority to look for alternatives that make it possible to make compatible the needs of infrastructure development (e.g. housing and roads) and the functional maintenance of the EEP's network of spaces and the services it provides to the city. Conflicts around EEP spaces such as the Regional Ecological Corridor of the Bogota River and the Thomas van der Hammen Forest Reserve require a common effort that recognises the importance of EEP green spaces for the sustainability of the entire city and the surrounding areas.

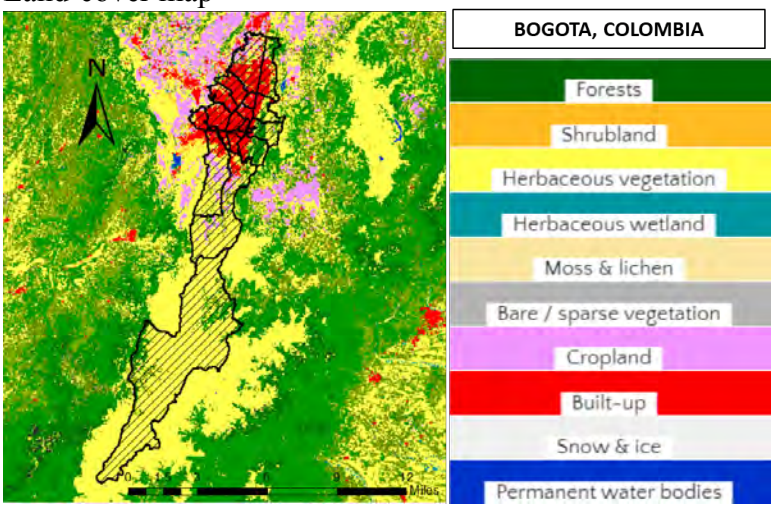
Wider contextual information

General description
Core city: Bogota
Biogeographic region: Neotropics
Localisation: North of South America, Colombia
Area: 1775 km^2 including rural and urban area
Population: 8,062,100 inhabitants
Public recreational green space per capita: 11.4 m^2 per inhabitant

Geographic location

Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana

Land-cover map



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana, based on: Buchhorn, M.; Smets, B.; Bertels, L.; Lesiv, M.; Tsendbazar, N.-E.; Masiliunas, D.; Linlin, L.; Herold, M.; Fritz, S. (2020). Copernicus Global Land Service: Land Cover 100m: Collection 3: epoch <2019>: Globe (Version V3.0.1).

Bogota is the capital and the largest urban agglomeration of Colombia with a population close to 8 million inhabitants. Located at 2.600 m.a.s.l in the Eastern of the Andes mountains, it is characterised by a climate with annual average temperatures that are between 7 and 18 °C and a rainfall that reaches 1,400 mm.[3, 4]

In the last three decades, the population of Bogota has increased from 4,22 to 8 million inhabitants, as well as its urban area from 302 km^2 in 1988 to 385 km^2 in 2015, reaching a population density close to 20,5 inhabitants per km^2.[2, 15, 16] Bogota grew rapidly during the 20th century through migration processes from rural areas.[17] This expansive growth is the result of factors such as migratory processes motivated by more opportunities and the violence generated by the armed conflict in Colombia.[18] At political and administrative level, Bogota is organised into 20 localities that represent a wide variation in demographic indicators (density, ages, gender), as well as on socio-economic conditions.[19] In terms of urban planning, the city has been organised in smaller areas known as Zone Planning Units (UPZ for its Spanish abbreviation) which guide urban development and land use at the local level.

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Case 3: Living fences in Buenos Aires: improving quality of air

The Planetary Ecological Crisis and the Role for Greener Cities

Meeting the environmental challenge requires understanding how city making increasingly implicates land management. In the context of the thorough and extensive urbanisation of the world, cities not only house humanity's majority but also produce footprints that reach far beyond city limits: peri-urban zones exhibit widening buffers and lengthy urbanisation corridors proliferate.[1,2] Furthermore, high levels of resource consumption and the concentration of command and control functions mean that what happens and is decided in cities affect broad swaths of the planet. In this sense, global sustainability depends largely in the strategies and actions cities can develop.[3]

Therefore, sustainable cities have intrinsic value in the connection to global sustainability. Their urgency is given by the sheer number of people impacted by environmental threats in urban areas. The devastating impacts of urban air pollution on human health constitute a case in point. In 2016, 91% of the world population was living in places where the WHO air quality guidelines levels were not met and ambient air pollution was estimated to cause 4.2 million premature deaths worldwide.[4] In this sense, evidence is accumulating on how and where green infrastructure, including green fences and hedges, can reduce the ground-level concentrations of pollutants.[5]

In Buenos Aires, the city's overall levels of contamination exceed WHO air quality guidelines, and in some neighbourhoods they are three times acceptable levels.[6] Despite this, local policy engagement with air pollution is incipient.[7,8] Yet social awareness on the issue is growing.[6] This inspired the Breathe/Respirar Project (BRP) international collaboration predicated on knowledge exchange and mutual learning rather than one-way technical assistance from the UK. Locally led from the Landscape Architecture programme at the University of Buenos Aires, the initiative received enthusiastic initial support from academics of multiple disciplines, government institutions, professional and business circles and advocacy groups.

Breathe/Respirar Project

Breathe/Respirar Project (BRP) began with a clear objective of addressing local air quality concerns in a school community of Sheffield, UK. A group of staff, parents and university researchers collaborated on planning, designing, building, monitoring and maintaining a green barrier to abate the air pollution that the schoolyard was exposed to due to its near-traffic location. Such green barriers are increasingly used in the UK and elsewhere as a response to growing concern with air quality and its implications for health and wellbeing.[9]

The project's implementation in Buenos Aires required a participatory process with several rounds of trial and error to identify and enrol stakeholders in a broadly defined green infrastructure initiative; select opportunity areas of schools with the locational characteristics required for an effective intervention (a city-run public primary school; with a schoolyard at the front facing the road; in an area of the city identified as having poor air quality); and most critically, starting open-ended dialogues on what potential co-benefits would partners and

beneficiaries value most intuitively in the fences, and how we could build on those to make issues of air quality and social-ecological sustainability more graspable. This process drew on international lessons with Urban Living Labs (ULL); local expertise on pluralistic environmental education; and social science insights on how the politics of urban greening play out in the city given its salient inequalities and fragmentary development. The landscape design for the pilot project was developed by Landscape Architecture staff and students from the University of Buenos Aires (UBA) with input from international partners, in a small schoolyard of irregular shape adjacent to the infants' (aged 4-5) classroom (Figure 15).

The design involved planting in three strata:

1) Ivy (Hedera helix) constituted the first line between the exterior and the interior of the schoolyard. This species was chosen because it is a hardy, low maintenance plant that adapts easily to different sites. It has minimal water requirements and persistent foliage. The ivy made up the first layer of the living fence. It was compactly mounted on top of an existing railing, which ensured that the plants grew vertically.
2) Non-invasive canes (Phyllostachys aurea and Bambusa multiplex) constitute the second level of the living fence, facilitating density and height. In our choice of species, we prioritised rapid growth while avoiding invasiveness as to limit competition with the plants in the third strata of our design.
3) The third strata was made up of plants that aligned with our premises concerning a landscape architecture that is aesthetic, recreational, sensory and has environmental benefits and/or environmental education value, such as re-connecting with nature and increasing biodiversity

Figure 15. Plan for the pilot project schoolyard with its three strata. Credits: Fabio, Mouzo, Inomata, Jaume, Parisi, Piccini, Rifahi, Rubinstein.

With the first living fence planted between November 2019 and February 2020 (Figure 16), the analysis below presents our early findings. These are based on lessons learned in the process of planning, building and maintaining the fence as well as exploring opportunities to upscale the model with additional living fences in schools throughout the urban region. Additionally, our analysis is informed by the multiple workshops, policy advocacy and dissemination activities undertaken since the 2018 launch of BRP in Buenos Aires.

Figure 16. Pilot living fence and garden, December 2019.

Lessons learned and conclusions

Engaging City Government: The project obtained recognition from the City Council and engaged with multiple units within the local government, most notably the Buenos Aires Ministry of Education and its sustainability education programme. We recognised the importance of working in an integrated way with policy makers. We focused on exploring the opportunities for integrating the living fences and associated activities with the Escuelas Verdes (Green Schools) programme. This programme has focused primarily on sustainability issues, e.g. recycling and energy efficiency, rather than on connecting to nature and understanding ecosystems. There is an opportunity here to put the 'green' into 'green schools', which would facilitate the multiplication and the normalisation of living schoolyards (and increase the social demand for environmentally committed landscape architecture). In parallel, the curriculum could be adapted to reflect increased understanding of Nature-Based Solutions and of the many benefits of engagement with nature for both people and environment.

Our Breathe Deep Experimental Training Course provided an opportunity for people who are working, or hoping to work, in landscaping to receive training and practical experience of creating living fences and schoolyards (Figure 17 left). Most of the participants were members of cooperatives, which in Argentina serve to assist people in meeting pressing needs, including skills development and access to employment. This is increasingly important when the industrial sector is changing and jobs are disappearing. In this context, facilitating access to work in an emerging green economy is vital. The training was also an important way to embed one of our premises, integrating environmental commitment as a central pillar of landscape architecture,

across a range of people who will be working on the ground – and sharing their practices with other cooperative members, encouraged by the organisational structures of their cooperatives and the spirit of cooperativism (Figure 17 right).

Figure 17. (left) Cooperative members participating in training, May 2019, (right) Cooperative members and students creating living fence, November 2019.

Applied Learning with University of Buenos Aires (UBA) students involved them in research, analysis, design and implementation of the first living fence and schoolyard in Buenos Aires (Figure 18 left). As in the case of the cooperative members, this activity gave students who will pursue careers in related fields an opportunity to participate and learn through an intense experience of professional practice. This exercise reflected our premises by highlighting the centrality of environmental commitment; taking an integrated multidisclipinary approach to maximise multifunctionality in the landscape; and offering students hands-on educational activities that deepened their understanding (Figure 18 right).

Figure 18. (Left) Students involved in creating garden, February 2020, (right) Design students developing a design for a second school, August 2019.

School-based activities with children and teachers: 5th year primary schoolchildren took part in an arts-based workshop facilitated by environmental educators using art, music and games. The children were asked to think about how plants meet the needs of individual human beings, such as food and clothing, and also about how plants keep the planet healthy for all living things. Each child was given a potted plant to take home and care for, giving them a chance to immediately apply their heightened awareness of the importance of plants and the role of humans in appreciating and caring for them. Bringing home their own plant also opened up a potential channel for sharing their experience of the workshop with their families and hopefully leading to further discussion, and perhaps action, at home. This activity represented a successful example of the complementary activities that can facilitate connection with nature, in this case bringing to bear other cultural elements such as art, music and play in a way that is effective for children, among others. Teachers at the school have also engaged with the initiative and offered useful input concerning the importance of speaking to children about environmental quality rather than contamination.

Exchange and Collaboration: In order to extend the network of academic and professional collaboration, UBA and the Sociedad Central de Arquitectos convened an international conference in Buenos Aires on green infrastructure in Latin American cities, which attracted approximately 50 participants and led to creation of a Bioremediators Network facilitating continued collaboration. Members of our team also presented at a meeting on climate change organized by the Centro Argentino de Arquitectos Paisajistas, and at an interdisciplinary meeting held at the Consejo Profesional de Arquitectura y Urbanismo. We were also invited to a forum organised on adaptation to climate change at the city council.

Projections and upscaling

We still have much to learn about living fences, from the optimum design specifications for air quality improvement to the manifold social and ecological co-benefits that this layer of vegetation enhancement yields. Whereas the former has a clear site-specific focus, which in the case of schoolyards is of critical importance to secure environmental health for children, the latter can and must accrue at multiple scales, and link as much as possible with broader networks of Nature-Based Solutions.

The BRP's implementation in Buenos Aires has taught us that landscape architecture plays a critical role if living fences are to live up to their potential, transforming them into activated landscapes with multifunctionality rather than simply building them as sustainability artefacts with limited remit and affordances. Furthermore, we learnt that if landscape architecture is to be put at the service of urban environmental aims, it must also be put at the explicit service of a plurality of intended beneficiaries. If effectively enrolled and attended to, diverse communities of users and producers will also become likely advocates and place-keepers if not initiators of green infrastructure innovations such as living fences.

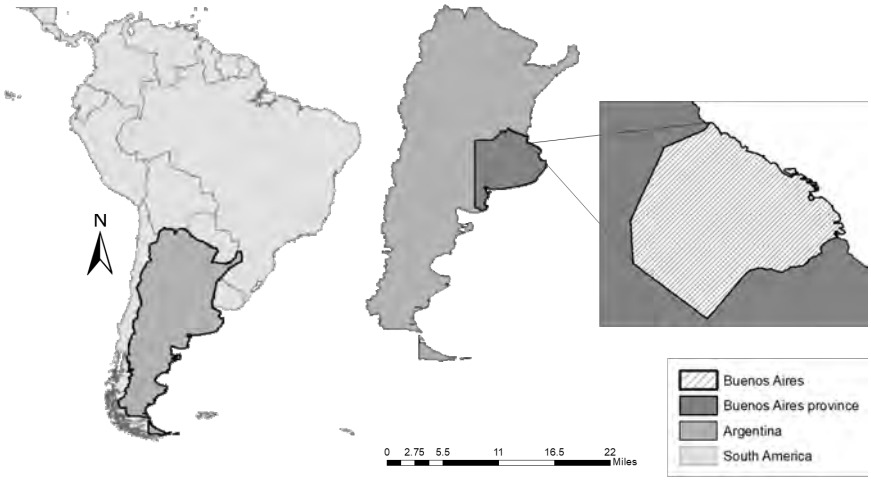
We have much exciting work ahead with living fences in Buenos Aires and beyond. We need to produce clear and robust evidence from urban living lab activities to inform policy shifts and continuing governmental engagement. Additionally, we plan to explore their role in site-specific and creative pedagogies of urban environmental quality in early education. Our activities of

planting and maintaining the fences will be designed as to provide as many formal and informal opportunities as possible for involving parents and broader school communities. Feedback from the initial training and ongoing engagement with the participating grassroots cooperatives will provide us a guide for future programme improvements. Businesses, professional associations and academics are some of the stakeholders with whom we will need to build capacity and continuously assess our working assumptions. It is certainly an ambitious agenda but one that is called for by the pressing needs for greening the city in any way possible and contribute to the broader transitions in urban environments to face our planet's crisis.

Wider contextual information

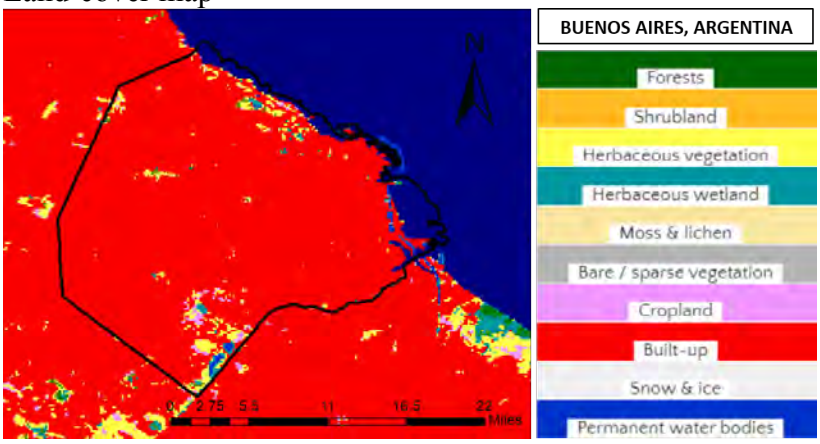
General description
Core city: Buenos Aires
Biogeographic region: Neotropics
Location: South of South America, Argentina
Area: 200 km^2 the core city and 4.700 km^2 the metropolitan area
Population: 15.200.000 inhabitants
Green space per capita: 2 m^2 per inhabitant

Geographic location



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana

Land-cover map



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana, based on: Buchhorn, M.; Smets, B.; Bertels, L.; Lesiv, M.; Tsendbazar, N.-E.; Masiliunas, D.; Linlin, L.; Herold, M.; Fritz, S. (2020). Copernicus Global Land Service: Land Cover 100m: Collection 3: epoch <2019>: Globe (Version V3.0.1).

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Breathe/Respirar Project **https://www.aguayverde.com.ar/proyecto_respirar_/**

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Case 4: Nature-Based Solutions as integral and multiscale responses to social and environmental challenges in Lima, Peru

Climate change challenges in Lima and NBS opportunities

The metropolis of Lima, the capital of Perú, congregates approximately 10 million inhabitants, representing almost 30% of the country's population and produce about the same percentage of the national GDP. The city, located on a coastal desert with extremely limited water resources, grew – demographically and spatially – squeezed between the Pacific Ocean and the lower Andean hills, expanding horizontally to accommodate the high influx of people, most of them who settled their self-constructed houses on public land. Healthy and safe living conditions in Lima are dependent on the city water security which, on the other hand, depends on healthy and functional ecosystems in the upper, water-producing Andean watersheds as well as the urban diverse ecosystem matrix.

Strategies and policies designed to face these challenges in an integrated way – using a green infrastructure or ecosystem focused approach – are very recent, such as the Water Fund initiative; the Lima Ecological Infrastructure Plan; and the payment for ecosystem services Law (MERESE for its Spanish acronym) that supports the Seeding Water Programme. Previous intents suffered from sectorial, short term approaches focused primarily on grey infrastructure, such as constructing new reservoirs or damns to transfer water from the Atlantic to the Pacific watershed to satisfy the increasing water demand.

Recently, partly encouraged by the country adoption of the 2030 Sustainable Development Goals (SDG- UN) and the COP21 Climate Agreement,[1] the government prepared national and regional policies and strategies to face climate change. The Climate Change Framework Law and its Regulation recognise the need for Ecosystem based Adaptation and Watershed based Adaptation.[2] The Peruvian National Adaptation Plan includes Ecosystem Based Adaptation (EbA) and Natural Infrastructure (NI) actions; and the Peruvian Nationally Determined Contributions (NDC) for the fishery and agriculture sectors have a strong ecosystem management, EbA. There is therefore an increasing recognition of the need for "integral solutions" for adaptation.

The NI approach is structural to Peruvian national policies. Defined as "a network of natural spaces that conserves ecosystems values and functions, providing ecosystem services", the Natural Infrastructure has mainly been adopted as a strategy to regulate water flows, prevent water-related risks, and guarantee the provision of freshwater by conserving, restoring and regulating ecosystems in the headwaters of watersheds that feed urban settlements along the country.[3] The NI approach implies policy articulation and demands the creation of multi, inter and transdisciplinary groups[4] to design, install, maintain, and monitor solutions, a task which still represents a challenge for governmental agencies at the district, regional and national level, especially for simultaneously tackling both socioeconomic and ecological challenges.[5]

As part of the conceptual umbrella proposed by IUCN,[6] these approaches could well fit into the Nature-Based Solutions (NBS) category. The very recent interest in NBS from the Ministry of Environment MINAM, is an opportunity to strengthen policies and create synergies between

different initiatives to face the city water security and climate change challenges, tackling – at the same time – social and equity challenges (such as water access and availability) usually treated apart from environmental ones.

NBS initiatives contributing to the Lima Climate Change Plan

For most Peruvian stakeholders, Nature-Based Solutions is a new concept that has been gaining popularity very recently and keeps sustaining much interest. A range of different groups from the academy, local governments, private parties and NGOs are actively involved in NBS discussions, design and application of strategies, production of evidence and political incidence at different levels.

In Lima, the Local Climate Change Plan is in its final design stage, focused to attend the goals defined in the Paris Agreement. The Plan defines three main objectives: to reduce 30% greenhouse gas emissions by 2030; to increase the resilience of the metropolis and finally, to reduce social vulnerability. These objectives are supported by an "Ecosystem" strategy which integrates NBS to conserve the largest natural areas in metropolitan Lima and improve its resilience in the face of increasing temperatures, heat waves and water scarcity.[7]

Whilst the city Climate Change Plan is being developed, a number of actions are underway to tackle long-term water security and increase the city resilience through ecosystem protection. Some of these have a NI or NBS approach. We identified three main initiatives on three different scales: (1) Water Security Actions (investments in water catching and water flow regulating systems in the upper Lima watershed, through the Aquafondo private investments and the Sembramos Agua Programme); (2) the Lomas Programme (conservation of the fog oasis "lomas" network in the whole Lima province); and (3) the Green belt of Independencia (an interphase of urban-natural on district scale). These three strategies have a direct impact on the metropolis of Lima by considering the challenge "ecosystem conservation-land use-housing-wellbeing" using a similar conceptual approach, albeit different strategies.

A common vision for different scale interventions

The Water Security Actions are based on investments in water catching and flow regulating systems in the upper Lima watershed which are currently being deployed through a private water fund, Aquafondo, and a payment for ecosystem services channeled through the Lima water company, SEDAPAL (Sembramos Agua Programme). Aquafondo has implemented several small-scale solutions such as pre-Inca "amunas" (ancestors ditches), for water infiltration and aquifer recharge, the restauration and protection of pastures and the construction of small retention basins, that support upper watershed local communities' agriculture and grazing activities, whilst increasing and regulating water flows for Metropolitan users. As an example of its achievement, by restoring 1 km of old amunas, it is estimated the water availability may increase by 178,000 m^3 of per year on the lower watershed. (Figure 19).

Figure 19. Natural Infrastructure type amunas, to increase infiltration and recharge of aquifers (Figure from Aquafondo, 2020).

These initiatives, deployed thanks to non-profit organisations and private funding, are complemented by public investments financed through the water tariff (MERESE mechanism), where 1% of the tariff is allocated to a portfolio of 59 projects for approximately $ 30 MM. The MERESE mechanism allows the direct relationship between the interests of water producers (the Andean communities), who are responsible for conserving the integrity of headwaters ecosystems, with the stakeholders that benefits from the provision of this ecosystem service (urban activities and consumers).[8] The design of each project under the Sembramos Agua Programme involves a sequence of coordinated steps with different interest groups to identify and valorise economically the ecosystem services (ES) potentially provided, in addition to identifying who the producers and consumers are and where they are located.[9]

Focused on the metropolitan limits, the Lomas Programme involves different initiatives by the city government, as well as citizen organisations grouped under the proposal of a Lomas Network to protect this ecosystem. Moreover, it is expected to improve the distribution and equitable safe access to qualified urban green areas (UGA), whose accessibility is largely related to human health, well-being, and social justice.[10] It comes under the umbrella of the Lima Ecological Infrastructure Plan (PEAIE) proposed in 2014; though not approved, its approach is currently being integrated into the new Metropolitan Urban development Plan (Plan 2040) and the Lima Climate Change Plan, through its Ecosystems Strategy. An important accomplishment was made in 2019, when a considerable portion of Lomas (more than 11,000 hectares) has been declared as a Regional Conservation Area (ACR) and a EbA Master Plan is currently being developed with intense community participation, focusing on two main strategies: ecosystem

conservation, land use and occupation control; development of ecotourism routes while empower urban communities[11] (Figure 20).

Figure 20. Lomas, touristic routs along the fog oasis of Lima. Photo captures: Taícia Marques.

Finally, a complementary strategy is being designed to create a green belt alongside the lomas-city interface, which acts as a buffer zone for this sensitive ecosystem and creates a protective border against the expansion of irregular human settlements while providing different cultural services and improves biodiversity. The Green Belt Independencia initiative is a pilot intervention that is being implemented in the middle lower-class district of Independencia, in the Northern part of the urban territory, where 19% of the population lives in high-risk conditions, settled on steep slopes, and threatened by landslides hazard. Here, an urban forest park of 4,800 native trees irrigated with treated wastewater has been installed in two phases by a consortium formed by multiple private, public, national, and international parties with strong community support. During the first phase, 3,300 trees were planted by PREDES with USAID support in 2015; and another 1,500 have been recently planted by PERIFERIA (consultants) with a carbon compensation fund from a local construction company.

The most recent plantation was undertaken through a greenhouse gas emission mitigation action related to a building construction, that soon showed to be a great opportunity to effectively incorporate Nature-based thinking.[12] The process is being conducted through a NBS co-creating strategy, with a transdisciplinary approach, involving a variety of stakeholders from the local community, municipality, university, NGO, and private parties. The Green Belt proposal integrates biodiversity and Lomas protection objectives as well as a range of other societal challenges such as: discouraging land trafficking, preventing landslides, generate greater identity and a sense of belonging and care. Developed during the COVID-19 pandemic, the co-creation process seems to have placed hope on local community and stimulate their participation and empowerment as actors of change (Figure 21).

Figure 21. (left) NBS Co-creation process for the Green Belt Independencia, (right) first stage forestation. Photo captures: Taícia Marques.

Lessons learned and conclusions

The city of Lima is developing an array of Plans, Programmes, and projects under the NI approach, deriving from national policies, and including interventions at a regional (watershed), metropolitan and local scale. Recently, MINAM has expressed a positive perspective regarding the Nature-Based Solutions and its related approaches development in the country. According to the Ministry, it might provide the guidelines for investments that contributes to the formulation of instruments based on NBS actions associated with the post-COVID-19 economic activation, including the creation of jobs related to sustainable production of water by expanding the area covered by Natural Infrastructure.

One of the main challenges for the accomplishment of these goals is represented by the conceptual, strategic, and operational integration of such scales involving different governmental levels and groups of stakeholders. For example, at the scale of the metropolis, one of the main barriers is Lima's jurisdictional fragmentation, which requires an arrangement by a large group of mayors oriented and articulated towards a common goal. The application and expansion of the Nature-Based Solutions also requires evidence and monitoring, which represents greater complexity related to the medium and long-term financing of these actions.

It has been shown that the three interventions provide a variety of benefits, but the quantification and valuation of ES are still in its early stages. There is an evident gap related to the existence of national funds for applied research that must be filled to guarantee the increase of studies and the provision of a large number of arguments on which to build policies and incentive programmes to support the NBS. Another general challenge concerns the conceptual opening of the definition and application of principles, criteria and indicators related to NBS, which can represent uncertainties for potential investors and stakeholders.

Projections and upscaling

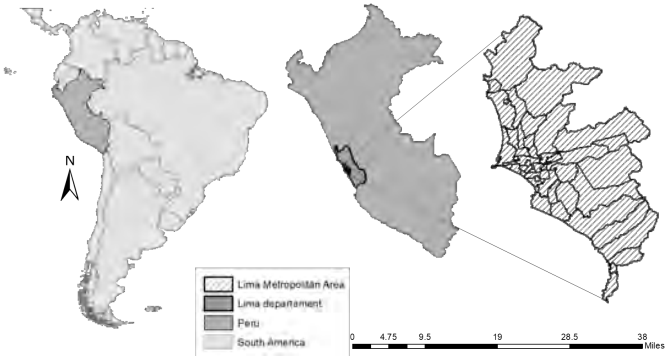
Water Security Actions might be soon upscaling since the first MERESE project has been recently approved. It is expected that the experience gained by projects such as the ones lead by

the Aquafondo, may contribute with evidence and lessons learned to be scaled on a high number of Natural Infrastructure interventions across the watersheds in different regions of the country.

The Lomas Programme is supported by an increasingly strong group of organisations and communities interested on conserve, inform, and boost touristic routes along the different zones of Lomas designing and practicing more sustainable ways to conserve these ecosystems while strengthen essential socio-economic relations. The Green Belt Independencia_follows a similar path of the Lomas Programme, supported by an empowered community eager to achieve better conditions of living and a healthy place to grow their families. Recognising this fact is extremely relevant on a politic unstable country as Peru, where usually people take the lead and might be responsible for the continuity, management, and maintenance of those actions.

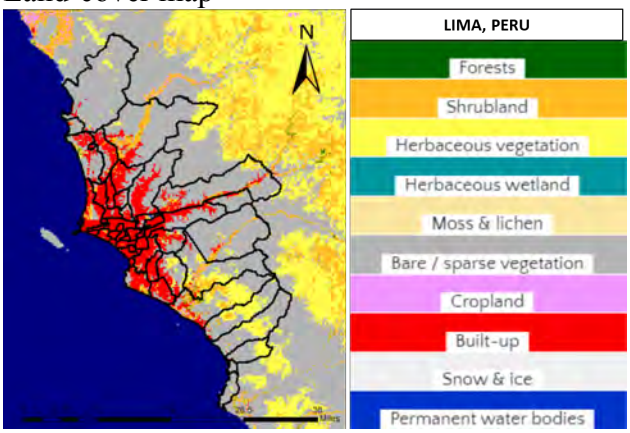
Wider contextual information
General description
Core city: Lima Metropolitan
Biogeographic region: Neotropics
Location: Centre of South America, Perú
Area: 2800 km^2
Population: 10,000,000 inhabitants
Green space per capita: 2.6 m^2 per inhabitant

Geographic location



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana

Land-cover map



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana, based on: Buchhorn, M.; Smets, B.; Bertels, L.; Lesiv, M.; Tsendbazar, N.-E.; Masiliunas, D.; Linlin, L.; Herold, M.; Fritz, S. (2020). Copernicus Global Land Service: Land Cover 100m: Collection 3: epoch <2019>: Globe (Version V3.0.1).

Lima metropolitan is the second biggest capital city in the world located on a desert (after Cairo in Egypt). It has exceptionally low rainfall, close to 16 mm per year, and an estimated 56 m^3/s provision of superficial water that comes from its three temporary rivers and its Andean lagoons and glacial reserves, threatened by climate change. Glacier surface area has already diminished by 51% since 1948,[13] whilst different climate change scenarios predict more intermittent rainfall and, eventually, drought. The city is in a recurrent hydrological stress and struggles to ensure water security for its 10 million inhabitants, apart from irrigation of the surrounded rural landscape, energy generation (70% of the electrical energy used in Lima comes from hydropower), commercial and industrial consumption, as well as other urban uses such as green areas irrigation and maintenance.

The landscape history of the city is marked by the transformation of this arid landscape into three fertile valleys, a productive land designed by ancient pre-Inca Peruvian cultures who created a complex irrigation network whose traces can still be found in the densely occupied Lima. Since the 1940s, these former fertile coastal lands suffered an irreversible change to urban uses which caused the loss of large amounts of hectares of agricultural plots. Currently Lima is considered a vulnerable city:[i] almost 70% of its households are built by auto-construction methods,[14] much of them on high-risk slopes along the Andean hills, affecting its ecological structure and especially the fog oasis or Lomas ecosystems, challenged by unstable soils and earthquake threats (Figure 22). The Lomas are a temporary, fragile, terrestrial ecosystem complete of endemic species that develops when the sea fog condenses onto the nearby arid slopes, during the wet, winter seasons along the coast of Peru and north of Chile.

Figure 22. (left) general view of Lima from the pacific coast, (middle) ancestral irrigation channel, (right) settlement on loma´s ecosystem. Photo captures: Taícia Marques

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Predes: https://predes.org.pe/
PERIFERIA: https://periferia.pe/

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Case 5: The Green Corridors Network as the background of a NBS approach in Lisbon, Portugal

Lisbon's plans to address ecological sustainability, biodiversity and green space quality

In common with many other regions, Lisbon and its metropolitan area is transforming rapidly, having suffered the consequences of a car-centric model and urban sprawl. This necessarily affected part of the regional ecological continuity with these trends lasting more than 60 years, and even today Lisbon City Region is still a cluster of 18 municipalities not acting under a coordinated planning vision. With the paradigm of a more concentrated urban pattern underway, Lisbon acts as the core of the metropolitan region. For several reasons, protecting important ecological areas from urbanisation has become even more difficult. Remnant areas of natural habitat have gained particular importance in consolidating the green corridors network, benefiting from the fact that much of this land is still within the municipality's property holdings.

One of Portugal's masters of landscape architecture – also referred to as the 'father of the green structure' in Lisbon – Gonçalo Ribeiro Telles, who died in 2020 aged 98 years old, had conceived first an idea of a green city based on ecological corridors where the principles of urban landscape and nature could live side by side in the city.

The "Lisbon Green Plan" published in 1996 set out the approach used in 2008 to implement safeguarding measures to protect the ecological structure under development threat at that point (Figure 23). It triggered an update to the Master Plan at a time when climate issues were rising up the agenda alongside the development of a Biodiversity Strategy to 2020 for Lisbon,[1] activating a relevant policy to adopt ecosystem services. This resulted in the approval of the Biodiversity Local Action Plan.[2]

Figure 23. The green structure for Lisbon, a landmark to change the ecological paradigm.

Thus, the Lisbon Master Plan,[3] which received the ISOCARP Award for Excellence in 2013, defined the most sensitive ecological areas for preservation. It also promoted ecological sustainability, biodiversity and quality of green public space, through a green corridors network to be built on the forthcoming decade (2012/2022). This plan predicted a >19% increase in greenspace (up to more 400ha defined), with the target to reach 25% green areas across the city. The scale of the green corridors was defined to connect to the Lisbon Metropolitan Area, where possible.

Overlapping the most ecological sensitive areas of the land, this multi-beneficial Green Infrastructure (GI) network proposal responded to the recommendations of several studies regarding climate change scenarios including increased frequency of flooding, heat waves and droughts, giving new inputs to tune the local design (Figure 24).

Figure 24. The green corridors of Lisbon 2012-2022 (Mata, D. adapted from Lisbon Master Plan).

Planning with Nature-Based Solutions: green corridor network

The European Climate Initiative "The New Covenant of Mayors for Climate and Energy"[4] brought together the mitigation and adaptation for the first time within a single pact. A Climate Adaptation Strategy[5] was also published with cross-cutting measures within which the green infrastructure plays a key role. These documents drew on ecosystem services targets from the Biodiversity Action Plan (2015-2020), defining measurable indicators that are periodically submitted to the public. In this way, the most important achievements of the green infrastructure programme were openly reported, and the results could be checked as part of the successful technical application to become European Green Capital Award.[6]

The evolving green corridors and ecosystem services policies therefore provided important, direct responses through which the city could act to tackle the effects of climate change. The targets for GI followed the principles of ecosystem services, responding to:

• Climate action: tackling heat wave effects using shade, responding to water scarcity scenarios.
• Resilient: contributing to balancing water cycles, namely through groundwater recharge and retention.
• Socially active: dynamic, participative and useful, promoting physical and mental wellbeing.
• Biodiversity active: native species & regeneration, blooming, flora and fauna habitats.
• Environmentally functional: Air pollution removal, sustainable mobility leverage (e.g. Bicycle Network), providing for improved quality of life.
• Maximize Sustainability: reducing implementation and maintenance costs, thereby raising the range of implementation.

As regards budgeted costs and savings, the total value of the project is today estimated to reach 65M€, considering different green parks, pedestrian and bicycle connections, including dedicated bridges on the green corridors (excluding riverside renovations). The investment is largely supported using municipal budgets (including an EIB loan), Casino Lisbon's obligations, agreements and partnerships with public and private companies, Cohesion Funds, and other EU Funds (e.g. LIFE CLIMA).

Approximately 16% of the green corridors budget comes from EU funds. The rate of implementation of NBS increased by more than threefold during the 2008-2018 period, representing more than 250 ha of new green space in this period. The policies have led to a 55ha improvement in soil connectivity (2010-2018), with an expected increase of 70ha until 2022 and a total targeted increase of 350ha (2008-2022). A climate resilient GI has been crucial in allowing high rates of implementation with an average cost of implementation about 25€/sqm, a low value in comparison with conventional landscaping (ca. 45-55€/sqm).

NBS in action
The creation of green corridors provided for larger and more connected areas of intervention, along with the opportunity to implement a comprehensive NBS approach, involving a wide range of typologies where biodiversity and natural capital play a key role in the resilience of ecosystems. This has also enabled the consolidation of diverse green infrastructure where woodlands, biodiversity meadows and urban allotment gardens work together, embedded into new and existing greenspaces wherever possible (Figure 25).

Urban Allotment Gardens (UAG). A specific normative and quality designed detailed guideline facilitates the creation of integrated plots under an organic farming process, based on mandatory skills. Low height fences give permeability to the interior designated areas, where collective shelters, potable water and composters are displayed. More than 750 families grow their own food and the municipality intends to reach to 25 UAGs by 2025 (1.000 families), reaching 35 UAGs by 2030 (Figure 26).

Figure 25. The first green corridor implemented in Lisbon (2012) connected the Parque Eduardo VII (central green park) with Monsanto Forest Park along 2,5km. Derelict land previously used for random car parking was refurbished, allowing for the implementation of a range of NBS such as Biodiverse Meadows, Urban Allotment Gardens and Massive Tree Planting, among others.

Figure 26. 22 UAG parks were installed since 2011 as part of a process of social inclusion, where quality of the public space was the decisive point for citizen engagement and approval.

Natural drainage (ND) - Two major retention basins were implemented in public parks acting as efficient systems providing for retention and infiltration. Simultaneously, new parks on green corridors usually incorporate total or partial ND with no conventional connection to the grid. NBS approaches include the use of swales, kerbside rain gardens, small rocky rills, and absorbing wells (Figure 27).

Praça de Espanha Green Park, expected to open in 2021, provides an inspiring case of de-paving, removing large areas of road asphalt to create 6 ha of ND within new green areas, and re-creating a stream channel to help solve local flooding. Road runoff is drained and treated elsewhere to prevent probable hazard in infiltration quality. A small pilot of a 100% ND, controlling and monitoring the quality of the runoff from different pavements is planned to commence in late 2021 under a financed prototype of the EU funded LIFE LUNGS.

Figure 27. 15 green places are being built to accommodate ND solutions, including small detention basins to retain flash floods.

Rain-fed Biodiversity Meadows (BM) - 6.3ha of BM are in place and 30 new hectares are planned to be created by 2030, with 20% resulting from existing irrigated lawns reconversion. Pollinators are a target under the biodiversity action plan, highlighted through the production of urban honey production to be supported in designated areas (Figure 28).

In conjunction with EU LIFE LUNGS (2019-2024), large parts of the pilot 1 “RENATURA” in CONEXUS will provide for enhanced NBS engagement, profile and testing.

Figure 28. Since 2012, a seed mixture resulting from EU LIFE Extensity was employed for the first time within a pilot green corridor from Monstanto to the city's central park, with the purpose to enhance flora and fauna biodiversity and attractiveness, whilst increasing soil carbon and nitrogen storage.

Massive Tree Planting (TP) - trees in Lisbon are considered to be extremely precious issue due to urban heat island mitigation. In the last decade the city has planted around 20.000 trees and shrubs with the capacity to provide better shading. In 2020, 40.000 were planted, more than 50% by volunteers (Figure 29).

The city is mapping its heat waves and predicting the scenarios for the forthcoming periods on the framework of climate change studies. Tree canopy continuity increased by 7.6% during the period 2010-2018 (an increase of 636 ha) and street tree planting on streets has been increased. At the same time a municipal regulation was approved to oversee street tree management, in part to increase tree lifetimes, as well as enhancing the provision of ecosystem services. Through the LIFE LUNGS project, 240,000 trees and shrubs will be planted by 2024, in order to increase shade and reduce ambient temperatures.

Figure 29. Volunteers collaborating in 2020 with the municipality at the creation of high-density tree planting areas, under the European Green Capital Award 2020.

Lessons learned and conclusions

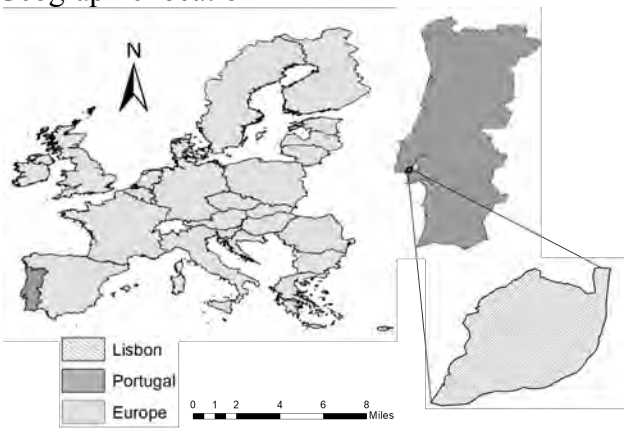
Lisbon's NBS programme has been successful in terms of the speed of implementation, starting from scratch with a Master Plan that required updating under ecological principles. The planning of green corridors allowed considerable increases in the rates of green infrastructure implementation, across a continuous ecological network, linking all the city and touching the neighbourhood municipalities, providing new ecosystem services. New green corridors generated an opportunity to consolidate a range of NBS solutions where climate adaptation, resilience, biodiversity and social inclusion were the main priorities. Completion of the first phase of green corridors' consolidation was facilitated by the municipal ownership of most of the land previously zoned for urbanisation.

Programmes of NBS have included the creation of Urban Allotment Gardens, Natural Drainage, Biodiversity Meadows and Massive Tree Planting. Many NBS schemes have been successfully implemented so far. However, deeping NBS into the neighbourhoods or creating new connections in the coming years is likely to be much slower, due to the complexity of de-paving and land ownership issues. Although ecosystem services benefits are wider, nature and biodiversity in the city is not a settled issue among the populations, specifically during the dry season. Some citizens do not yet have a grasp of NBS as being more effective measures to respond to a range of urban problems. Some view green infrastructure only from a rather simplistic perspective, akin to installing recreational equipment (e.g. a swimming pool). The need for wider understanding of the slower pace of natural processes, and an impatience for quick results, may prove challenging for the future implementation and protection of green infrastructure.

Wider contextual information

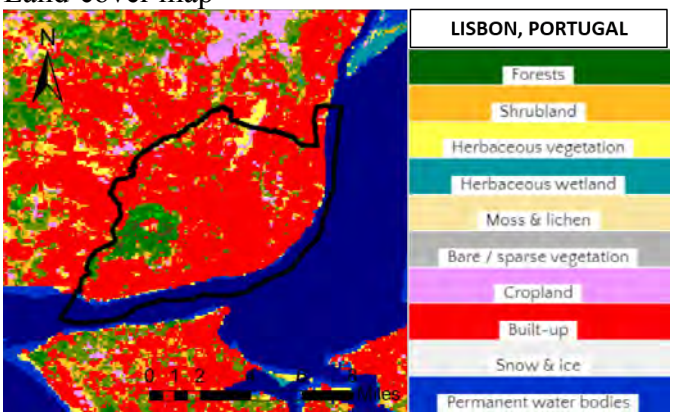
General description
Core city: Lisbon, Portugal
Biogeographic region: Mediterranean
Location: Europe, Portugal
Area: 100,05 km²
Population: 545.000 inhab. in the core city and 2,821,876 inhab. in the metropolitan area
Green space per capita: Lisbon has an average of 26.8 m^2 of green areas per capita

Geographic location



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana

Land-cover map



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Lisbon is the capital of Portugal and the most populous city in this European country. Lisbon is located on the right bank of the River Tagus and this city is characterized for a Mediterranean climate (mild winters and hot and dry summers). The average temperature in Lisbon is 23 °C, total average precipitation is less than 7 mm in July and August, increasing to 28 mm in September. The Metropolitan Region of Lisbon includes other 17 other municipalities.

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Sustainable Land Use: https://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2018/07/Indicator_4_Lisbon_EN.pdf
Nature and Biodiversity: https://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2018/07/Indicator_5_Lisbon_EN.pdf

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Case 6: Wetland Baquedano Park, City of Llanquihue, Chile

Addressing socio-ecological pressures with green infrastructure

The Green Infrastructure Plan of Llanquihue in which is inserted the Baquedano Wetland Park occurred through the joint work between the Landscape Architecture Master Program Universidad de Chile and NGO called Legado Chile Fundation as a response to several socio-ecological pressures of the urban life that were affecting the ecosystems within the city boundaries. In 2016 both institutions called on an open dialogue with 300 members of the community, including residences, local authorities, school community, regional services, representative of productive industries, scientist and planners to co-create the principles for the design of a Green Infrastructure Plan. As a result, the first future image of the city on a middle term and a long term was developed together with a portfolio prioritising projects to be done.

The plan included the execution of a pilot project that served as a milestone and reference of planning with green infrastructure, done with the Baquedano Wetland Park. The project was funded by different institutions including the Regional Government and the municipality, through Funds for Local Initiatives. The project was implemented by Legado Chile Fundation, Landscape Architecture Master Program UC and the Municipality of Llanquihue, under the Conservation Plan "Llanquihue, city of wetlands" (report released July 9th 2020).

The restauration of the wetland

The Baquedano wetland is located in the north side of the city and is classified as permanent wetland on inorganic soils by the Ramsar Convention, specifically the subtype of forest swamp. It is habitat for several species that are exclusive of wetlands such as Piden (Pardirallus sanguinolentus), Chilean Frog (Calytocephalla gayi) and remnant of swamp forest species such as Pitra (Myrceugenia exsuca), highlighting the role of these urban wetlands on biodiversity conservation. At the same time this wetland fulfills a role for the city, contributing to the mitigation and protection against flooding.

Despite of its important role in the urban ecosystem, this wetland is highly fragmented and disconnected from the wetland network. In 1962 the wetland covered 4350 m^2 and at the present shows a loss of 92% of its surface given housing construction. In addition, the wetland is cover in debris, garbage, polluted by runoff and disturbed by stray dogs and parked vehicles (Figure 30).

Figure 30. Baquedano Wetland, Llanquihue, year 2016. Source: Fundación Legado.

The green infrastructure plan had three main objectives:

1) to restore the ecology of the urban ecosystem as it has a key role for the city, its need to be valued and integrated into planning
2) integrate social programs in the restoration initiatives, promoting the sense of place from the community
3) to connect the diversity of wetland patches through a continuous network of public spaces, developing circuits and corridors that socially and ecological enable connections.

The mobility strips favour the direct contact with the landscape elements, contributing to maintain ecological and hydrological processes, promoting ecological connectivity. These strips are managed through soil management, the design of infiltration strips, walking circuits at the level of the natural elevation, with fine gravel soils to favour infiltration and elevated walkways to regulate accessibility, allowing the ecological recovery and hydrological function of the urban wetland.

The nodes of the system are places to notice in the landscape, given by the landscape components in the area, the visibility towards the surrounding landscape or given its role and significative public space such as playgrounds, refugees or lookouts.

The areas are recognised as elements of management of larger spaces that have a significant ecological or cultural role which require management actions for its recovery and/or conservation. This includes actions of restoration of wetland vegetation, native tree planting to restore habitat functionality and capacity to serve as a refugee for fauna.

The resulting project is shown in Figure 31. After a year of the implementation of the project the change in perception was evaluated using qualitative analysis evaluating 9 dimensions of the wetland. Most people recognise the value of wetlands and its benefits by given positive adjectives such as beautiful, important, attractive, related with identity and biodiversity. A third of the surveyed people visited the park once a day, while more than 50% visited the park weekly. The most mentioned activities done in the park corresponded to walking, contemplating, resting and observing nature. Perception changes from the previous wetland conditions which had negative attributes associated to it such as ugly, dirty, dangerous, when the majority of the surveyed people didn't visited the wetland.

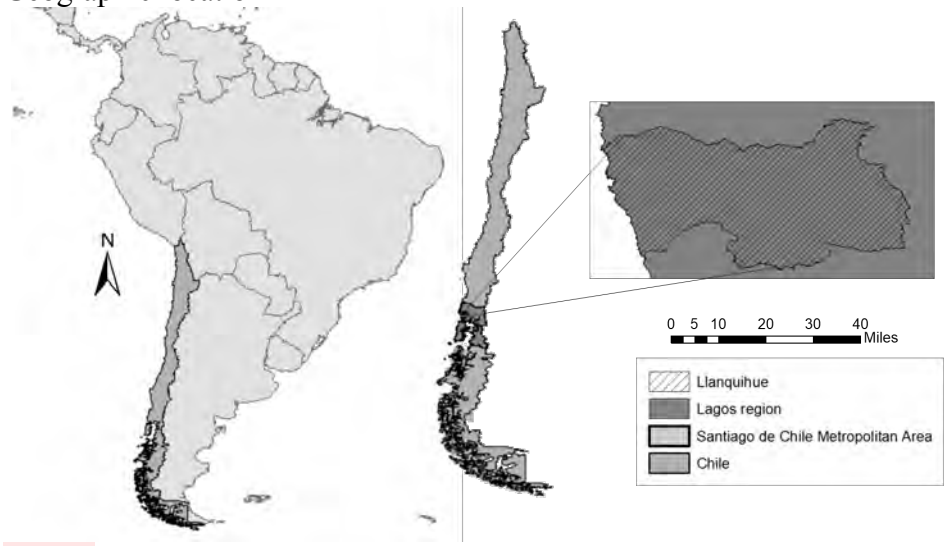
Finally, the people recognised that the responsibility of taking care of the wetlands should be shared by public institutions, NGOs and the community. In the case of the park itself the people recognized that the responsibility lies on each person for the caring of the environment.

Figure 31. Wetland Baquedano after project implementation, year 2018. Source: Fundación Legado.

Wider contextual information:
General description
Core city: Llanquihue
Biogeographic region: Neotropics
Localisation: South of South America, Chile

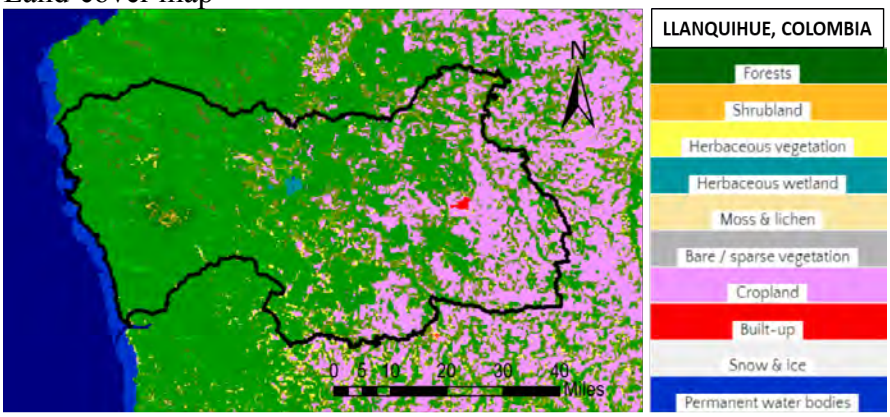
Area: 421 km^2 including rural and urban area
Population: 17591 inhabitants
Public recreational green space per capita: No data available

Geographic location



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana

Land-cover map



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Llanquihue is located at the south of Chile in the Los Lagos Region and is situated at the border of the Llanquihue Lake, the second biggest lake in the country, overlooking the Osorno volcano. The city has a complex hydrological system including the border of the lake, the birth of Rio Maullin and a network of freshwater wetlands. The current wetlands existing in the city are highly vulnerable to housing development and sprawling (Figure 32).

The city of Llanquihue derives from a German immigration period around 1894 and it became an official commune in 1968. The lushness of the area with its vegetation and water promoted a rapid development of the city associated mainly to agriculture and the related manufacturing industries.

The city lies over a network of wetlands and small creeks with superficial and subsurface connection to Llanquihue lake and Maullin River leading to highly disturbed ecosystems in the middle of the city. Given the unplanned growth of the city in the past several parts of this system have been lost. Nowadays the city has four main wetlands: Baquedano, El Loto, Los Helechos and Las Ranas. These wetlands are habitat for more than 70 species of birds. 100 species of plants and 20 species of native fish, besides nearly 50% of the migratory birds from Chile. Present threats to this wetland system include invasive species, such as stray dogs and lotus, the filling of wetlands and its impermeabilisation, the illegal deposit for garbage and debris, industrial liquid residues and illegal wood extraction in addition to the low sense of place from the community.

Figure 32. Llanquihue, Chile.

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Legado Chile https://legadochile.cl/parque-humedal-baquedano/

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Case 7: Multisectoral and multiscale articulation for urban regeneration in Medellín and its Metropolitan Area

Facing the urban sprawl and the loss of ecosystems

As other Latin American cities, Colombian urban agglomerations are characterised by the presence of numerous self-produced settlements, called informal or popular settlements.[1] Although in this type of socio-spatial units some of the needs are met through self-help and self-management mechanisms, access to the city's goods and services is limited, with serious spatial, environmental and social inequalities.[2] In addition, informal settlements present many times critical overcrowding and precarious housing conditions (in relation to their physical structure and surroundings), absence of some public services and illegal tenure in many cases.[3]

Medellín and its metropolitan area, is a good example of this informal urban sprawl, which has deepened as a result of increasing migration from the countryside to the city as a result of violent events in the country and industrialisation processes in the Aburrá Valley region[4] (Figure 33). Despite efforts of the local governments and the private sector to supply the housing demand (some authors explain this as a lack of political will and elites to perpetuate their hegemony), a wave of displacements caused by the armed conflict meant that, by the 1960s, the informal city was home to 50% of the population[5] and that, by 2011, 25% of the city's territory corresponded to neighbourhoods with different levels of marginality.[2]

This accelerated growth, mainly to the peripheral and usually informal areas of the city, significantly reduced the citizen's quality of life, with a drastic increase in poverty and inequality. Likewise, the occupation of risk zones such as mountain slopes is increased, and conurbation processes with municipalities surrounding the city also is on the rise, favouring the establishment of what is now known as the metropolitan area of Medellin.[6] This accelerated and "unplanned" –others argue as a different way of planning – urbanisation process have resulted in the loss of important parts of the region's fertile and agricultural soils, fragmentation of urban and peri-urban ecosystems,[7] air pollution[8] and degradation of soils and water bodies, and consequently, a considerable decrease in the provision of ecosystem services.

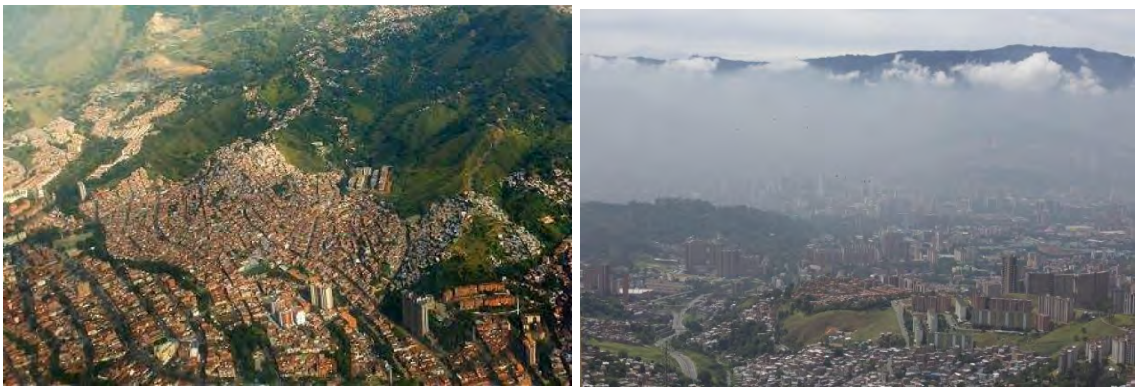


Figure 33. Medellin's accelerated growth has increased occupation of risk areas such as mountain slopes and has deepened problematics such as air pollution.

In response to the challenges arising from Medellín expansion and the conurbation process with neighbouring municipalities, the Metropolitan Area of the Aburrá Valley (AMVA for its Spanish abbreviation) was established in 1980 as a regional public transportation and urban environmental authority.[9] Being a territorial associative scheme, it constitutes an integrating planning and coordinating entity for the decisions taken at regional level, as well as an articulating axis for security and coexistence issues. In addition, starting in the early years of the 21st century, local government priorities began to focus on improving living conditions in the poorest areas of the city, with urban renewal strategies aimed to increase public space quantity and quality in these marginal neighbourhoods.[10]

Macro, Meso and Micro NBS initiatives

Against the earlier explained panorama, the current city government, in coordination with other municipalities of the AMVA, focused its development plan (Plan de Desarrollo) priorities on the implementation of actions to improve urban environment, including Nature-Based interventions from the neighbourhood to the metropolitan scale, with the articulation of diverse stakeholders: public institutions, private actors, civil society organisations and academic bodies. Thus, the interventions in urban green spaces that have taken place in Medellín in recent years, are today one of the most notable examples of implementation of public policy and a fundamental step in urban transformation, as an effective tool to overcome social challenges associated with insecurity, multidimensional poverty and socio-spatial segregation. Considering regional (macro), urban (meso) and local (micro) scales, these nature-based transformations are made explicit in the following three examples:

Metropolitan system of protected areas - Macro scale.

The Metropolitan system of protected areas in the Aburrá Valley is a network of urban biological corridors managed to enhance the conservation of biodiversity, environmental goods and services, and socio-cultural values associated with regional ecosystems.[11] As an environmental authority, the AMVA leads actions for the conservation of ecosystems with high ecological and cultural values, based on the articulation between institutions of Medellín and the other 9 municipalities that compose the metropolitan area. In addition to having 5 declared protected areas that contribute to improving ecological connectivity and provide habitat for diverse species,[11] this metropolitan system is currently an important part of the citizen's identity and core of initiatives that contribute to social cohesion and appropriation of nature, such as hiking activities, participatory science projects and research. It has also helped to reduce deficits of quality of public spaces in different areas of the city.

Regarding governance, this metropolitan system is recognised in the country for articulating public and private entities, universities and research institutes, and citizens towards conservation objectives, and for achieving the integration of management actions for biodiversity conservation from an urban-regional perspective.

Parques del Río – Meso scale

In recent years, as a strategy of the Mayor's Office and the Secretariat of Environment to recover the city's relationship with water bodies, a series of linear parks have been developed as connecting elements between eastern and western zones of the city and, in many cases, as the

only public space areas in the poorest sectors of Medellín.[7] These linear parks were established as public spaces to connect citizens with nature, conserve biodiversity and clean micro watersheds, providing at the same time, spaces for enjoyment and recreation, and prioritising pedestrian mobility. Parques del Río is a notable example among these parks, because it was conceived as an urban management instrument to stimulate the city's real estate development in central areas, through quality public space generation and reducing urban expansion pressures on Medellín's peripheral areas.[4] In addition, as a corridor that crosses the city, Parques del Río connects different sectors and urban actors, coming from the city's most disadvantaged areas or from the industrial neighbourhoods with higher incomes (Figure 34).[1]

Figure 34. Parques del Río is a linear park that integrates both riversides of the Medellín River.

Cerro de Moravia - Micro scale

"Moravia Florece para la Vida" is a project recognised as an example of environmental and urban innovation. Since 1977, Cerro Moravia was used by the municipality as an open-air municipal garbage dump. Subsequently, hundreds of migrant and low income families, settled near this dump, but in 1984 the municipal administration decided to close it.[6] After population relocation in 2012, the Secretariat of Environment started a project for the recovery of Cerro Moravia. Actions in this territory included consolidation of two productive units for community economic development and strengthening of social organisations, planting of several gardens by the community, establishment of phyto- and bio-remediation plots for soil recovery, construction and maintenance of wastewater treatment plants, support for two gardening cooperatives, among other actions that have benefited thousands of citizens (Figure 35).[14,6,12]

The recovery of Cerro Moravia has been as an example of recovering a dumping site, and provide a green urban area the community that evidences the urban renewal process that Medellín has recently experienced.[12]

Figure 35. Transformation of Cerro Moravia.

Lessons learned and conclusions

An implementation of Nature-Based Solutions that integrate different scales and stakeholders is essential to make explicit the contributions of biodiversity and ecosystem services to urban development and for their effective incorporation in city planning. Prioritising interventions that promote social interactions and citizen re-connection with nature not only improved indicators associated with ecological processes and urban biodiversity, but also contributed to improve other social al well-being indicators, particularly in informal settlements. Furthermore, prioritising environmental education and citizen involvement in the design and management of green areas, has facilitated protected areas and infrastructure interventions such as Cerro El Volador or Parques del Río become part of the Medellinenses' (Medellin people) identity.

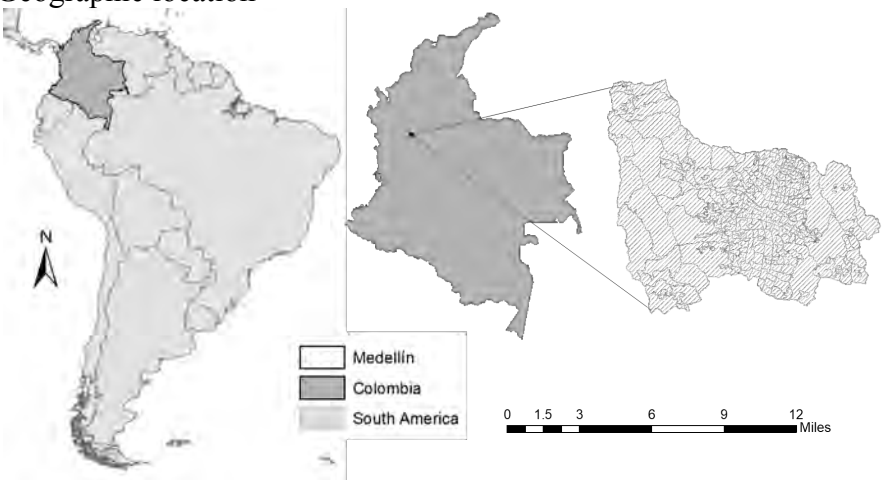
Projections and upscaling

After the urban renewal of Medellin, which prioritised green areas and public space, several of the city's public policies and government plans turned environmental issues and biodiversity conservation into the central axis to the city and metropolitan area's development. However, it is still not only necessary to promote research for improving space management, but also to make progress in defining a monitoring framework that allows establishing direct correlations between urban nature and citizen wellbeing. This would allow the inclusion of other urban actors, such as health of security sectors, that could represent a critical voice to promote Nature-Based Solutions. It is also necessary to strengthen financial mechanisms, for example, through mandatory and/or voluntary contributions from construction and transportation industries to ensure the projects' sustainability.

Wider contextual information

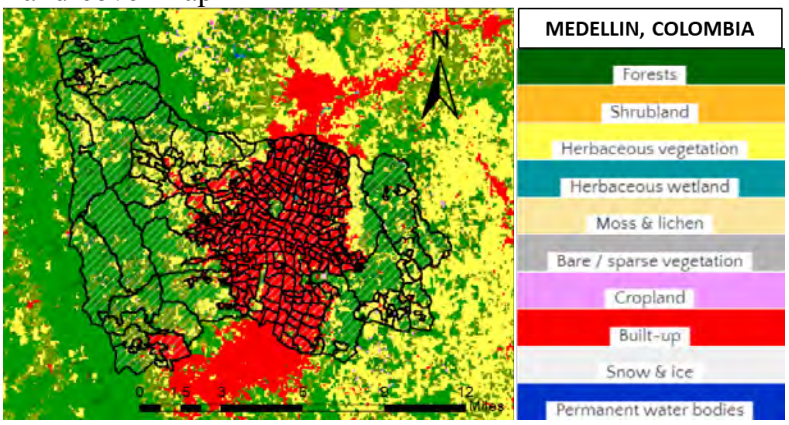
General description
Core city: Medellín
Biogeographic region: Neotropics
Location: North of South America, Colombia
Area: 375 km^2 including rural and urban area.
Population: 2,427,129 inhabitants
Effective public space per inhabitant: 3.7 m^2

Geographic location



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana

Land-cover map



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana, based on: Buchhorn, M.; Smets, B.; Bertels, L.; Lesiv, M.; Tsendbazar, N.-E.; Masiliunas, D.; Linlin, L.; Herold, M.; Fritz, S. (2020). Copernicus Global Land Service: Land Cover 100m: Collection 3: epoch <2019>: Globe (Version V3.0.1).

Medellín is the second most important and populated city in Colombia. Its average temperature is 24º C and it is located at 1,479 m.a.s.l. in the center of the Aburrá Valley, which is part of the Andean Central Mountains.[8,17]

The city is distributed politically and administratively in sixteen communes or districts, and has a total of 249 official urban neighborhoods. In economic terms, Medellín is recognised as one of the country's main financial, industrial, and commercial centers, especially in the textile and manufacturing industries, which generate 53% of the region's industrial employment.[13,15,16]

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Websites of municipality and core organisations

Alcaldía de Medellín: https://www.medellin.gov.co/
Área Metropolitana del Valle de Aburrá: https://www.metropol.gov.co/

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Case 8: Heritage zone of Xochimilco: Tlahuac and Milpa alta, Mexico City. The importance of Nature-Based Solutions

Addressing social and environmental challenges for the sustainability of Xochimilco

Socio-environmental problems increase with the size of the city. The growing population and the income per capita intensify the demand for goods and services, which means pressure on natural resources and ecosystems.[1] Such a pattern is typical in expanding cities, such as Mexico. Despite several components affected by the unsustainable use, the water supply is at the top of the climate change challenges in urban areas.[2] In Mexico, urban development is demanding a greater per capita water consumption. Climate change supposes an additional challenge to resolve the urban population's ever-growing consumption requirements (e.g., food, water, energy, infrastructure), resulting in environmental impacts extending beyond current urban areas.[3]

Mexico City is not the exception. In the particular case of Heritage Zone of Xochimilco, including the areas of the Municipality of Xochimilco (49.6% of the polygon is in Xochimilco), Tláhuac (48.8%), and Milpa Alta (1.4%). Xochimilco is facing an additional threat with high environmental degradation and pressure due to the expansion of informal settlements, which resulted in an inadequate provision of urban services. Therefore, Xochimilco faces high dynamic vulnerability and fragility, and even its existence is at risk. The original water system has changed, and the traditional land use has come under significant pressure due to urbanisation and lack of sanitation. The urban growth, the massive land use, the discharge of the household drainage to the canals, the malfunction of the treatment plant, among others; could cause Xochimilco to disappear in the future. Also, invasive species (e.g. carp and tilapia) in Xochimilco waters are predators of the Ajolotes (Ambystoma mexicanum) and erode the canals' bottom and damage the borders on the banks, as these species lay their eggs in there, causing the loss of land and plant diversity.

Xochimilco is an important tourism attraction of Mexico City, and in this sense, public policies have been focused in conservation, tourism infrastructure and ecotourism. Therefore, address social and environmental challenges are a priority: the dredge and cleaning of the canals, garbage collection and reforestation on channels, exotic species control, improve hydraulic infrastructure, Axolotl conservation, Chinampas rehabilitation, and productive projects.[4]

Facing Xochimilco threats with NBS

Against the above panorama, natural systems or solutions based on nature can contribute to reduce the presence of pollutants in the environment, maintaining the conservation of endemic species and ecosystems; and mitigate problems in Xochimilco. The integrated approach to resolve the threat has been focused on flood prevention, water supply, water quality, drinking water supply, wastewater treatment, risk prevention, and urban planning[5]. Some initiatives have been suggested, using NBS to provide a structural and functional Restoration of Waters:

Reconnection of the Rio Amecameca to increase water volume for water management, allowing the river water to flow, combined with infrastructure to direct the water to the heritage Zone's right areas. In this sense, this intervention improves the quality of the water that flows into the area. The water quality improvement may likely be carried out with the localised treatment of

river water, such as a combination of decentralised wastewater treatment plants and purification of wetlands. The expected impact is to reduce water shortage, a better control of water levels, improve water quality, and in general the ecosystems health. On the socio-economic front, the intervention can improve agriculture, tourist navigation, recreation, and health. Also, it can contribute to the preservation of biodiversity and emblematic species, help with the irrigation and maintenance of chinampa groundwater levels (Figure 36), keep sufficiently high water levels in the channels and prevent stagnant areas (Figure 37).

Figure 36. Chinampa Atliacac harvest agrochemical-free products in Tláhuac. The chinampa is a cultivation method used by native indigenous groups to expand the territory in the lakes and lagoons of the Valley of Mexico, and they use them to grow flowers and vegetables.

Figure 37. Evidence of the current use of Xochimilco wetland and the social conflicts. Remediation.

The research is moving on to the use of natural coagulants obtained from the seeds of Moringa oleifera. In addition to their effect as coagulants, these seeds absorb filter materials, and have an inhibition effect on pathogenic micro-organisms. The ultimate goal is to have an alternative to treat water with a natural and economic system, and reduce fecal pollution in water used for agriculture. Such a system could disinfect the outflow effluents of treatment wetlands and biofilters, allowing the reuse for agriculture.

Imitate the Soil filter function - Linear wetlands
Convert and enable the streets bordering the Xochimilco channels as passive treatment systems for the wastewater of surrounding houses to discharge clean water into the wetland's canals. Enable sewage treatment systems of a semi-passive nature under the fixed bed principle (biofilm reactor) in the streets next to the canals. Enable biodigester batteries to give primary treatment to wastewater. Deliver high-quality clean water to the channels.

Ecological Restoration - Green corridors
These green corridors may follow the original streams' valleys that flow from the springs at the Teutle Volcano's foothills in the Xochimilco chinampa area. The water flowing through these green corridors feeds the chinampa area. The former springs that are now dry because of groundwater abstraction can be partially restored to feed the corridors. The corridors also work as linear parks that connect the urban public space, south of the Xochimilco heritage zone, with the Unesco world heritage zone.

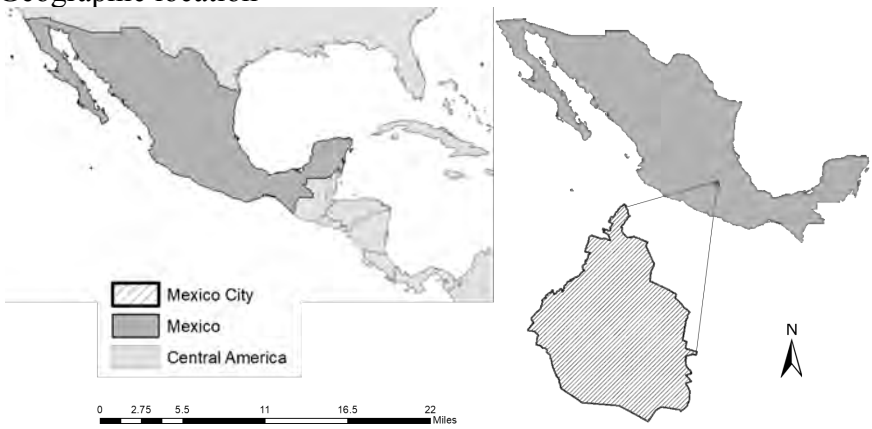
Lessons learned and conclusions
The local, technical, and scientific communities are working to stop the Xochimilco social and environmental threats. However, the pressure of the urban expansion and the high demand for water and food does not stop. Rubio et al. (2020)[4] stand out the over-simplification that characterises the rationale behind environmental policy and the limitations associated with short-term perspectives, eluding political costs and the lack of social and environmental indicators to evaluate performance. Every initiative mentioned above needs to be pushed by the local and national authorities. Education, economic investment, and continued research could move on the Xochimilco area into a functional ecosystem. "Negotiation and co-construction of policies through transdisciplinary approaches are necessary and, as has been shown, local actors can make a central contribution with their first-hand experience and knowledge. Effective social participation in conservation policies design has been acknowledged for decades, but it has still to become a reality in most contexts".[4]

The feasibility, efficiency, and adequacy of policies may depend on these processes. City growth can lead to different urbanisation intensities and ecological restoration decisions.[6] In Mexico, urban sprawl and urban and territorial planning cities are negatively related, this is to say that regulation actions are remedial and not preventive. Promoting effective urban and territorial planning legislation must be a clear goal of policy for improving Mexican cities' sustainability [6].

Wider contextual information
General description

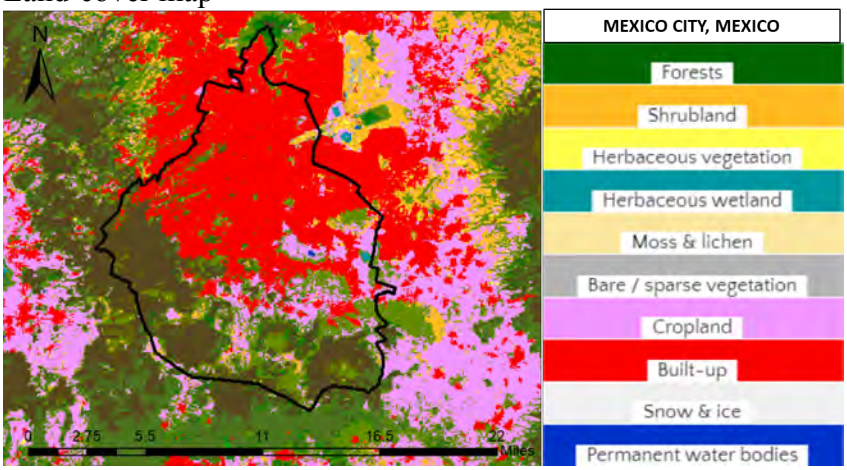
Core city: Mexico City
Biogeographic region: Neotropics
Localiton: North America, Mexico
Area: 1,485 km^2, including the rural and urban area
Population: 25,000,000 inhabitants
Public recreational green space per capita: 1,94 m^2

Geographic location



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana

Land-cover map



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana, based on: Buchhorn, M.; Smets, B.; Bertels, L.; Lesiv, M.; Tsendbazar, N.-E.; Masiliunas, D.; Linlin, L.; Herold, M.; Fritz, S. (2020). Copernicus Global Land Service: Land Cover 100m: Collection 3: epoch <2019>: Globe (Version V3.0.1).

Mexico City is one of the world's most populated areas (close to 25 million people). It is also the country's cultural, economic, and industrial centre. It houses almost all government offices, national and international business centres, cultural activities, universities, and the most important research institutes. The biggest challenge of the city is in relation with the increasing population associated with the urban sprawl. In connection to this, a major concern is the water-related shocks and stresses that impact the city's development. In Mexico City, events such as flooding, water shortages, droughts, low water quality, surface and groundwater degradation are

frequent. Also, the depletion of groundwater resources in the regional aquifers, subsidence associated with the high groundwater abstraction rates, high costs related to long-distance transportation of potable water and wastewater, inefficiency due to substantial leakage from the water supply system, insufficient wastewater treatment capacity, and lack of infrastructure for water reuse, and limited storage of rain-water.

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Websites of municipality and core organisations/programmes

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Xochimilco: https://whc.unesco.org/en/list/412/
Agriculture in Chinampas: https://www.gob.mx/agricultura/es/articulos/la-agricultura-en-chinampas
Water in Xochimilco: https://es.unescosost.org/post/recuperaci%C3%B3n-del-agua-en-xochimilco-m%C3%A9xico
Milpa Alta: https://antropologiachinampera.wordpress.com/2014/10/23/bienvenidos/

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Case 9: City districts as testing grounds: integrated sustainable stormwater solutions through retrofitting in existing neighbourhoods and as part of urban transformation processes in Malmö, Sweden

Nature-Society relationship local challenges and relationships with global challenges
Malmö is the third largest city in Sweden and is situated on the coast and surrounded by top quality agricultural land, which has led to an expansion into the sea. This makes the city vulnerable to a raising sea level, which is further enhanced in Southern Sweden being on a bulging edge, or forebulge, of ancient ice layers. Therefore, the land is still slowly sinking from forebulge collapse, stemming from the last ice-age which appeared around 11,500 years ago.

The city's green and blue areas have a long history, and are even today seen as an important and integrated part of the city of Malmö, as reflected in the recent Master plan.[1] The ambitions are to create a close, dense, green and mixed functioning city, with densification as a driver, rather than expansion into the outside highly productive farmland. Urban green is a vital component of the future of the city and is in the master plan brought forward under such diverse headings as Green city, Green and Blue environments, Biodiversity, Countryside and Agriculture, Children's perspectives, Public Health and Safety, Climate Adaptation – Cloudburst and Stormwater. The term Ecosystem Services (ES) are frequently used within the master plan and is defined as encompassing all products and services that nature provides and that contributes towards human well-being and survival.[1]

Malmö's Master plan has a dedicated section on the SDGs, and states that they should be the starting point for the city's work on sustainable development. A large part of the role identified for urban vegetation are to help with the SDG 13-Climate Action, where their role for cloud-burst and stormwater management are key. The conservation of important and typical biotopes as well as rare species are proposals which provides a clear link to the SDG 15- Life on Land. Urban natures role in providing important regulating ES that influence public health and well-being is recognized, thereby contributing to SDG 3-Good Health and Well-being. This includes vegetation's role in improving air quality, providing shade but also through the provision of cultural ES through recreational activities and opportunity for social interactions. Also accessibility to green spaces is a central goal, highlighting specific groups such as disabled, elderly and children gaining access to green areas with emphasis on providing equal access for all. Several UGI initiatives are linked to increasing social cohesion and sustainable communities (SDG 11-Sustainable Cities and Communities). These initiatives include processes such as citizen dialogues within planning efforts, but also community gardening and self-management of green spaces. These are mentioned as explicit examples of how UGI could contribute to social sustainability within communities. For instance, the master plan explicitly states that parks have an important role in helping people with different ethnic backgrounds to overcome barriers in the city. Malmö's master plan also clearly states that the UGI is an important component of an attractive city. This identifies one potential role that UGI could have towards SDG 8-Decent work and Economic Growth.

The role of UGI for health and recreation has been demonstrated in several Malmö-based studies, with themes including promoting physical activity,[2] green school yards,[3] urban agriculture's role for social cohesion[4] and developing health related indicators.[5]

Malmö has also been included as a case city in multiple research studies focusing on challenges in governance aspects related to urban green infrastructure (UGI), with a particular focus on ES provisioning[6], and stormwater management.[7,8] While both the concepts of ES and sustainable stormwater management are familiar within the city government, there are governance related challenges to their wider implementation,[6,7] which includes lack of political prioritisation, lack of funding, as well as a general lack of trust in storm water management performance. Also the requirement for long-term maintenance is a common challenge. In the following, we describe two long-term and strategic initiatives within Malmö with emphasis on storm water management, and ecosystem service provisioning at the local scale, but with emphasis on upscaling for learning and potential wider applications.

Figure 38. Augustenborg in Malmö.

Nature-based initiatives and responses

In 1998, the city of Malmö launched the project Ekostaden Augustenborg, initiating nature-based green solutions as an answer to an environmental concern of stormwater management. Augustenborg was built during the 1950s by MKB, Malmö's public housing company, proving tenements flats close to the city centre (Figure 38). The area fell into decline from the 1970s onwards and in the 1990s, MKB took initiative to upgrade the flats. The project 'Ekostaden' Augustenborg was a collaborative project between Malmö Stad City Administration and MKB in order to make the area more socially, ecologically and economically sustainable. A basic principle for the redevelopment was to include local residents in both co-creation and co-management of this change. Many of the green and blue solutions applied in the area were inspired by nature and could hence be classified as Nature-Based Solutions including first and foremost local stormwater solutions through open soil drainage, local ponds and overflow areas but accompanied also by the installation of green roof tops and green walls. More recently, the project 'BiodiverCity' has been active in the development of new green roofs and green walls – including an eatable wall – in the area, too. It is documented that changes carried out have been

successful in terms of the regeneration of this urban area, with a 20% decrease of tenancies turnover, and with regards to stormwater, with up to 70% of the total stormwater dealt with locally. After a severe and extreme weather event in 2014, the success of the stormwater solutions in Augustenborg was proven, compared to neighbourhood areas with conventional drainage solutions.[9]

Following on the success of Augustenborg, Malmö launched an extensive harbour development in the Western harbour, and starting this transformation was the housing exposition Bo01 which opened in 2001 (Figure 39). When it opened it was launched as the Sustainable City of Tomorrow, and it turned the old contaminated shipyard area into a leafy green neighborhood of housing blocks with nature-filled courtyards, pocket parks and meeting spaces with novel sustainable stormwater solutions. The area contains beds of mix native herbs and wildflowers, that together with the drainages provides wildlife habitats.

A crucial instrument in the development of the green courtyards was the introduction of the Green Space Factor (GSF). This was a city policy that demanded that every housing development need to balance its building footprints by setting aside greenspace that together with a biodiversity bonus point system for adding elements such as tall trees, birdhouses and wildlife ponds. The GSF provided an incitement for the developers to increase the quality of green space rather than focusing on the amount of area green. Instrumental for the success of Bo01 was also the work with landscape architects to integrate the work with the courtyards into public parks and pocket parks providing a green structure to the areas. In the further harbour development, the GSF point system was later simplified and work with landscape architects less extensive, resulting in a lower amount of green areas. Unfortunately, studies have shown that while the Bo01 was successful in establishing green spaces initially, over time green elements have been exchanged to hard surfaces.

Lessons learned and conclusions

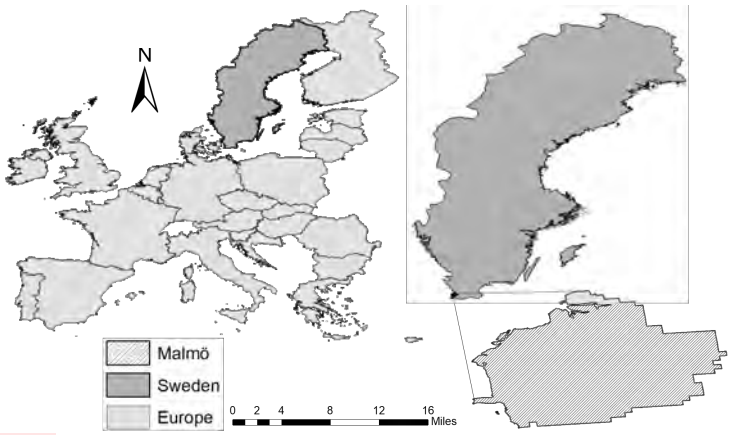
The City of Malmö has led several projects to develop urban green space for climate adaptation as well as urban biodiversity and socioeconomic development. The development of the Augustenborg and western harbour areas during the last 20 years are international flagship projects,[9,10] which both highlight Malmö as a forward thinking city, intending to lead and promote city development for some of the most prominent future challenges.

Figure 39. Bo01 in the west harbour Malmö.

However, there has not been a strategic continuation through new project areas or via new strategies integrated across the city. The latest municipal master plan[1] has a prominent overall green focus, but is deliberately less concrete and spatially explicit as previous plans. This has proven to not always be in favour of green matters. Simultaneously, several specific green space related plans have been developed, including a cloudburst plan, an urban blue-green infrastructure plan and a tree strategy. These supporting documents have not been politically adopted, leaving the focus areas without formal plans or strategies. Currently, there are no political decisions on long-sighted plans or strategies related to green spaces.

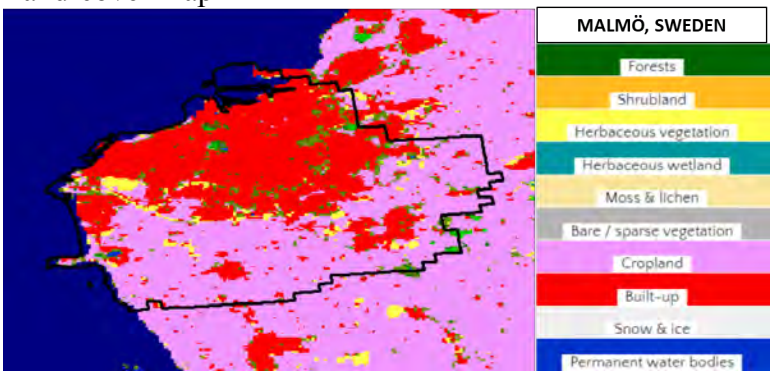
Wider contextual information
General description
Core city: Malmö
Biogeographic region: Boreal
Localisation: Skåne län; Sydsverige, Sweden
Area: 155,998 km^2
Population: 316,588 inhabitants
Public recreational green space per capita: 33m^2 per inhabitants

Geographic location



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana

Land-cover map



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Malmö is the largest city in the Swedish county (län) of Skåne. It is the third-largest city in Sweden, and the sixth-largest city in Scandinavia, with a population of 316,588. Malmö is one of Sweden's fastest growing metropolitan centres.[11] The 2020 population forecast shows, among other things, that the number of Malmö residents is expected to increase by about 50,000 new residents by 2030.[12]

Malmö has an industrial background with a focus on heavy industry until the mid 1970s, followed by an economic downturn and decrease in population. Malmö's transition into a post-industrial city has been developing since the mid 1990s. In 1995, Malmö had Sweden's highest unemployment rate. However, during the last decades there has been a revival, where Malmö has established itself as a multi-cultural city with a multi-faceted economic base. One of the main contributing factors has been the economic integration with Denmark brought about by the Øresund Bridge. Almost 10 percent of the population in Malmö works in Copenhagen, Denmark.

Malmö is a natural hub for people and cultures from worldwide. The city's inhabitants come from around 180 countries, which has changed Malmö's demographics. By the turn of the 2020's almost half of the municipal population had a foreign background.[13] The city contains many historic buildings and parks, and is also a commercial center for the western part of Skåne

County. Malmö has a very mild climate for the latitude and normally remains above freezing in winter, with prolonged snow cover being rare.

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Malmö city: https://www.malmo.se

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Case 10: Socio-ecological urban river restoration to mitigate flood risk, improve recreational potential and provide suitable habitats for fauna and flora: The Isar in Munich, Germany

Nature-Society relationship with local and global challenges

'Isar' means a fast flowing torrential river.[1] Naturally, the river Isar is an alpine braided river with large gravel bars that sources in the Austrian Karwendel Mountains. It flows north through southern Germany and joins the Danube River in Deggendorf. It crosses the city of Munich (third-largest in Germany and the 12th largest city of Europe). Between 2000 and 2011, eight kilometers of the Isar River in southern Munich were restored as part of the Isar-Plan. In 2007, it won the first German award "Gewässerentwicklungspreis" for river development (Figure 40).

Figure 40. Isar river that flows through southern Germany and cross the city of Munich.

Since prehistoric times, the Isar was an important trade route from Italy to the Danube River using traditional wooden rafts[2]. Munich was one of the largest raft ports in Europe and provided a safe passage across the river in the Middle Ages[3]. Local authorities have long managed and engineered the Isar at a local scale[4]. Since medieval times, water of the river Isar was diverted into small canals to supply mills and industry[2]. After a major flood in 1813 which killed more than 100 people and caused the collapse of a bridge of Munich[2], the first systematic hard engineering and flow regulation of the Isar[2] was implemented. With great hydro-electrical potential, the late 19th and early 20th centuries saw a radical turn from this traditional use of the river and caused severe river degradations to the Isar. Today, 43 hydroelectric power plants change the character of the entire river[5]. Since 1924, the Isar water is diverted in Krün to supply additional water for the natural Walchensee Lake which feeds the largest hydroelectric storage power station in Germany (300 GWh). In Munich, the river water was discharged into a side canal since 1907 to supply a hydroelectric power plant[6] while the Isar was reduced to a dry riverbed except during floods (Figure 41).

Figure 41. Isar river that flows through southern Germany and cross the city of Munich.

In the second part of the 20th century, three major challenges led towards a new thinking and the implementation of river restoration as a nature-based solution at the Isar. First, after decades of river regulation, water diversion and hydro-morphological modifications, the resulting degraded morphological status and related losses of ecological and social quality triggered serious concerns from civil society and citizens[7]. Second, the Isar River was very popular for swimming and other water-related outdoor recreational activities as one of the key elements of the local culture. While the Isar benefits from adjacent extensive agriculture and very little industry conducive for good water quality, with water diversion and urban sewage runoff flowed directly into the dry riverbed, the water quality had become unsafe for recreational uses despite the construction of the Sylvenstein Reservoir between 1954-1959 to ensure a minimum flow of water also in dry periods[8]. Local municipalities and the district authorities that were responsible for public health were concerned about citizen health and safety. Due to the ratification of the European Bathing Water Legislation (1975), minimum flow requirements for ecological and social quality standards needed to be achieved and urged the city of Munich and the federal state water agencies to safeguard water related recreational uses[9]. Third, the riverbed volume could not contain the 100-year return period within the city of Munich. Despite the development of massive flood retention and protection infrastructure including the Sylvenstein reservoir, in the case of a HQ100 flood, the freeboard deficiency was over one meter and a solution was urgently required to decrease Munich's exposure to flood risk.

Nature-Based initiatives and responses

Despite the urgency to take actions, it took more than forty years of intense efforts before the restoration of the Isar river in Munich transpired. The first plan of a river restoration was designed in 1970 by Alwin Seifert and titled "The Isar North, Within, and South of the city of Munich - A Plan for Recovery". From 1970 to 1985 civil society and lobbyists demanded for a near-natural river in Munich and pressured the politicians with very little success at the beginning. Numerous initiatives composed of citizens, municipalities and environmental

associations were created such as the "Emergency Community Save the Isar now e.V."6. The EU Bathing directive enabled civil society and its representatives to legally demand restorative measures. In 1980, the Bavarian Ministry of the Environment presented planning objectives for the Isar River targeting at improved water quality and increase of the minimum discharge in order to improve socio-ecological quality. An urban wastewater management plan was ratified the same year, resulting in a rapid improvement of water quality. In 1985 with the expiration and renewal of water use rights for hydropower, a window of opportunity was opening. Public pressure on the Munich City Council led to the enforcement of a minimum annual outflow of 5 m^3 / s in the Isar at the southern entrance into Munich. Between 1985 and 1990, advocacy groups gradually gained recognition and were invited to co-design the restoration. The hydraulic calculations investigating Munich's exposure to HQ100 risk led to the formal start of planning in 1987 and this lasted until 1999, when energy producers, state offices for water management, nature conservationists, fishermen, as well as consultants from water management, hydraulics, biology, ecology, river morphology and landscape architecture collaboratively planned a new, more natural river morphology. In 1995, working groups composed of experts and government administrations started to work together with local NGOs under the direction of both the State Office of Water Management and the City of Munich (Department of Public Construction, Department of Urban Planning and Building Regulation and Department of Health and Environment). Over 100,000 citizens altogether were involved during workshops and round table discussions to elaborate on planning goals and to map potential measures.

The participative approach was decided by the Munich City Council and organized by the Münchner Forum[7], an NGO that aims to promote participation in urban development in Munich. In 1990, the Münchner Forum presented to the City Council the requests of civil society, namely more water in the riverbed, better water quality to allow and to authorize for water-related recreation activities, more recreational potential at the river embankment and direct access to the river. Working groups with input from civil society designed a river that provides improved flood protection, while also being restored to near-natural conditions and providing much more outdoor recreation potential. All planning and implementation steps were communicated to the civil society within the framework of cooperative participation by the Münchner Forum. Information campaigns were carried out by info-brochures, excursions, television, and press releases[7]. The city´s Department of Building Construction was assigned the responsibility to implement the plan. The restoration was subdivided into three sections, beginning from the south of the city northwards towards the city centre.

For the design of the last section of the river in the city center, the planning procedure took a decisive turn. The site was composed of sensitive and protected habitats with large gravel bars, historical monuments, and a narrow urban riverscape. To face these challenges, a competition was held to find the best solution for this extremely complicated stretch of river. Design competitions are the usual planning procedures for urban greening projects. While the collaborative planning had been intense for the other sections, none of the NGOs were invited to join the awards committee for this last section[10]. Consequentially, the design of the winning design team composed of landscape planers, landscape architects, hydrologists and civil engineers met strong resistance as it did not meet public expectations of a "natural" appearance but favoured instead to maintain parts of the concrete structures. Civil society pressured both the

State Office of Water Management and the City Government of Munich which were the project leaders to implement another design[11]. After months of negotiations and requesting an external moderator, a compromise between the winning design and the second prize of the planning competition as the public's favourite was agreed upon[10]. This design was tested by the Technical University of Munich using a 1:20 scale model and flow simulation to ensure that the river design would be both capable to handle a HQ100 flood and would not change the characteristics of the protected habitat north of the restored section[7].

Lessons learned and conclusions

The Isar River restoration project in Munich achieved the first German award for river development ('Gewässerentwicklungspreis') in 2007[12]. It was a predecessor of a nature-based solution to mitigate flood risk in urban areas, a pioneer in collaborative planning, which started out with advocacy groups and rapidly evolved into a Living Lab approach[7,13] and is also a prime example for polycentric governance. The governance and planning approach stimulated the cooperation between different decision-making institutions in order to decide on implementation beyond institutional boundaries and helped develop new, creative and innovative NBS. The Isar River restoration is widely recognized as a model of good practice and a well-known example of socio-ecological river planning[14] (Figure 42).

Figure 42. Isar river restoration is widely recognized as a model of good practice and a well-known example of socio-ecological river planning.

The main lessons highlighted by the Isar case are the following[4]:

• The nature-oriented river landscape designed in the city centre of Munich demonstrated that a near-nature urban river development can be achieved.
• Civil society can influence major socio-ecological changes in the riverscape.
• When the citizens care, the politicians take action.
• Mutual trust and understanding among different stakeholders is a key of successful collaborative planning, although it may take time. Civil society should be involved early on in collaborative planning to take their concerns on board and thus reduce the risk of later strong

conflicts. Formal planning procedures such as planning competitions should be adapted to enable participation.
• Processes and negotiations need time and patience.
• Long-term collaboration helps to avoid planning mistakes or pitfalls.
• Importance of understanding how to take advantage of the "windows of opportunities" to re-establish hydro-morphological processes
• Socio-cultural and ecological needs should be balanced to achieve resilience
• Flood protection does not mean ecological degradation
• Better management of recreational use and raising awareness among citizens for nature and river conservation is needed. Moreover, the project demonstrated that collaborative processes may be more time consuming but promote innovations.

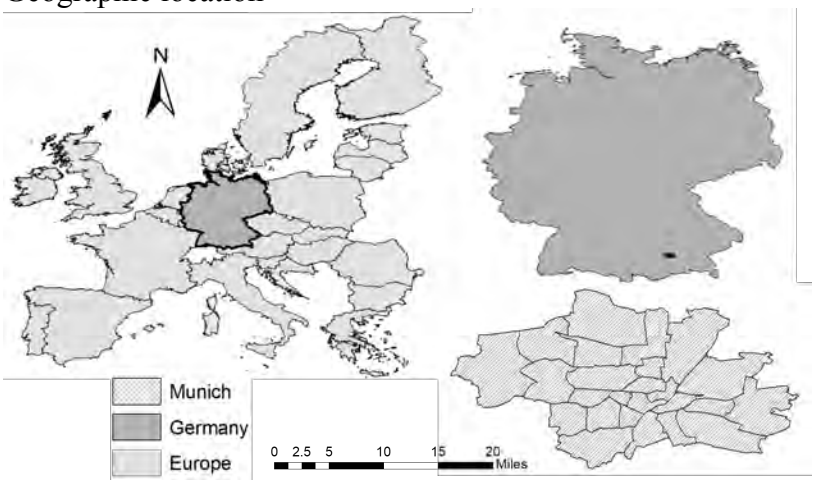
Projections and upscaling
At the international level, the Isar River restoration has been designated as a learning case by multiple networks and actors, including the River Network, the European Center for River Restoration, the European Climate Adaptation Platform Climate-ADAPT, the NATURVATION project and the PHUSICOS project which is funded by the European Union's Horizon 2020 research and innovation program, and the SEE-River project funded by the European Union's South-East Europe Transnational Cooperation Program. Within the PHUSICOS project, the Isar River restoration helps to demonstrate the effectiveness of Nature-Based Solutions and their ability to reduce the impacts from small, frequent events (extensive risks) in rural mountain landscapes. Furthermore, it is meant to inspire nature-based solution design in three demonstrator cases.

At the regional level, the restoration of the Isar from south of Munich to its mouth, of which the urban Isar is one important part, and especially the collaborative planning process inspired the Amper Rhei project. The Amper River is the largest tributary of the Isar River. The Amper Rhei project intends to achieve the same goals as that of the Isar-Plan but at a larger scale. At the level of the Isar River, the success of the restoration in the south of Munich has driven discussions regarding the northern section within the city of Munich. Since approximately 10 years ago, experts and NGOs have started to meet in public round tables to find a suitable design together.

Wider contextual information:

General description
Core city: Munich
Biogeographic region: Alpine
Localisation: Central Europe, Germany
Area: 310,4 km^2
Restored river stretch: 8km
Population: 1.472 million of inhabitants
NBS cost: 35,000,000 Euro (45% funded by the city of Munich, 55% funded by the Bavarian water agency)
Construction: 1999-2011

Geographic location



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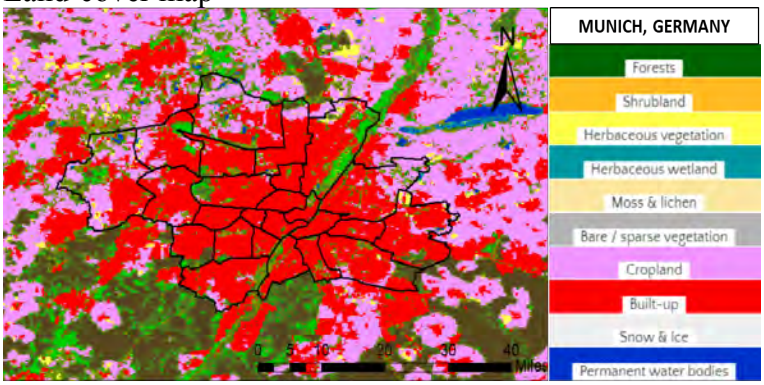
Land-cover map



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Munich is Germany's third-largest city and the capital and the largest urban agglomeration of Bavaria with a population close to 1.5 million inhabitants. Including the surrounding suburban areas, the Munich agglomeration comprises up to 2.6 million inhabitants. Munich's population is projected to reach 1.8 million by 2040[15]. This expansive growth is the result of the strong economic development. Munich is often known as the "economic capital" of Germany because it holds the headquarters of many companies, has the strongest economy of any German city with more than a million inhabitants and a low unemployment rate. This city is located around 50 km north of the northern Alps, which is within the Northern Alpine Foreland. It is built on the elevated plains of Upper Bavaria that results from the fluvio-glacial out-wash and previous glacier melts. The construction of the city benefited from its proximity to the Isar River, but its frequent and extreme flooding have long affected the settlements within the floodplain.

Consequently, Munich benefits presently from vast housing-free riverine areas with high recreational potential.

The Isar River is 292.3 km long and has a catchment area of 8,964.57 km². The river has historically exibited a nival hydrological regime, which is characterized by short and violent flooding following massive snowmelts. But presently, flooding relies on summer rain events. Munich is within the oceanic climate zoning with warm to hot summers and cold winters. The nearby Alps cause precipitation increase and high rainfall volume during the summer. Climate change is expected to increase extreme weather even in the alps and models suggest an increase of up to 25% of the rain volume within the Isar catchment area and an increase of 12% in the 100-year return period maximum discharge of the Isar River[16,17]. Currently, the Isar River has high discharge variability throughout the year. In Munich, it varies between 8.63 m³/s during drought periods to 1050 m³/s during extreme flooding. Flooding of the Isar usually occurs within a few hours and recedes within a few days[18].

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Munich city government: https://www.muenchen.de/rathaus/Stadtverwaltung/baureferat/freizeit-sport-natur/isar/isar-plan.html

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Case 11: Quito: Urban Agriculture as Nature-Based Solution for facing Climate Change and Food Sovereignty

Addressing local and global nature-society challenges.

Figure 43. Aerial view of the historical district and el Panecillo. Source: Quito turismo, 2013.

Climate change and food provision are arguably the two most pressing issues in an increasing urbanised world, particularly in the global south. The Quito (Figure 43) municipality project "Participatory Urban Agriculture" AGRUPAR (acronym in Spanish) aims to tackle both, by supporting urban gardens in public or private lands with community participation, for food security and sovereignty, environmental management, employment and income improvement, social inclusion, sustainability and resilience[1].

Urban and Peri-urban agriculture (UPA), as a type of green infrastructure in cities, can be seen as a multifunctional nature-based solution to face climate change[2], while also address food scarcity and accessibility, especially in informally developed urban areas of Latin America[3]; two important societal challenges of our times. UPA can contribute to at least 10 societal challenges, including climate change, food, biodiversity and ecosystem services, among others[4]. Regarding climate change, UPA contributes to water regulation, improve air circulation and cooling, offer microclimates; and in combination with other green and blue infrastructures, it can help to mitigate urban heat island effect[5]. At the same time, UPA can help to mitigate food insecurity[6,] and contribute to poverty reduction and health strategies for cities[7]. UPA, and NBS in general, are not something additional for cities, and should be integrated in the planning of them[8].

Against the above panorama, the Metropolitan District of Quito issued in 2017 the resilience strategy in which food economy is one of the main pillars. A Multi-Actor Platform, called the Agri-Food Pact of Quito (PAQ) was assembled, with the participation of private, public and social sectors, including also cooperation agencies[9]. The AGRUPAR project, operating between 2002 and 2004 under the Sustainable Human Development Office and since 2005 under the Economic Promotion Agency (ConQuito), promoted the creation of the Agrifood Pact of Quito by gathering all involved stakeholders and becoming one of the main actors in the food policy of the city. AGRUPAR is an emblematic project of the municipality, which in addition to contributing to food security and sovereignty, has contributed to improving the income of participants, particularly low-income population, as well as to generate savings through the consumption of its own production. Due to its integrated nature of agricultural and livestock activities, marketing of surpluses, food processing, solidarity exchange of the harvest, environmental management and contribution to urban agroecology, constitutes an important strategy for social cohesion as well[10]. AGRUPAR contributes to face environmental, economic and social challenges of the city.

Food, Climate and Economic Initiatives in Quito

From 1980 to 2000, there was a massive migration from the rural Andean indigenous rural communities to Quito[11]. As a result, the city almost doubled its population, from 780,000 to 1,4 million[12]. Large percentage of this people established their shelters on several of the 64 hillsides and ravines around the consolidated urban area. In order to survive, they practiced small scale urban agriculture on the hillsides and slopes, growing corn and potato, and raising guinea pigs and chickens as an additional source of income[11]. In September 2000, the municipality and international partners, organised a pilot programme in El Panecillo, a 200m high hill in downtown Quito where construction is not possible due its steep slopes, and where around 1,900 low-income families including internal migrants have settled their living. The programme consisted in helping to increase food production in home gardens, promoting the recycling and re-use of organic wastes and establishing a community plant nursery. It also developed a microcredit system and implemented four projects, codesigned with the community, for production, processing and marketing.

In 2002, the Quito's local government through the city's Directorate for Sustainable Human Development created AGRUPAR, with the goal of empowering vulnerable urban population through food security, income alternative, self-employment, capacity building, entrepreneurship management, microcredit access and applied research on agroecology, along the entire food supply chain[13]. From 2005, the programme is managed by the corporation for economic development: CONQUITO. The entity organises workshops with agronomists to provide seeds and seedlings, give technical training, support for commercialisation, and strengthen the management skills and micro-enterprises of urban farmers[11].

The main impacts of AGRUPAR have been the improvement and availability of healthy food for poor urbanites, the increment of economic opportunities for urban farmers, environmental benefits, and significant changes in consumers' behavior by creating 4,400 gardens covering 63 hectares of the city. The develop of an urban agriculture policy offers an holistic social approach,

that can respond to the needs of different groups of the population; for instance, school-aged children to learn about the origins of food, nutritional diversity and the problem of food waste (Figure 44), adults with disabilities giving a feeling of usefulness and integration in society, woman-led household by allowing them to work at home while taking care of their children and even migrants and refugees can be integrated into society through farming and supported when they leave their roots. 85% of urban and peri-urban farmers of Quito are women[13] (Figure 45). The project is essentially focused to address food security and sovereignty through urban agriculture production, however, it provides numerous co-benefits to its participants, such as recreation, occupational therapy, education, citizen participation, climate adaptation and women empowerment. The beneficiaries of the project cover a wide range of vulnerable citizens as female heads of households, children, elderlies, disabled people, refugees and migrants.

Figure 44. School students learning in one of the urban orchards. Source: CONQUITO, 2018.

Quito's urban orchards have a production capacity of 1.35 million kgs of healthy food each year, of which 57 percent (769000 kgs) is consumed by producers and their families and 43 percent (581,000 kg) is sold via various short supply chains. Each week, about 11 tons of fresh and healthy food are delivered to the city's most vulnerable neighborhoods[14]. The substantial reduction of the carbon footprint within the food chain due the proximity between producers and consumers is one of the main climate mitigation contributions of the initiative, by minimizing the need for transportation, packaging, refrigeration and warehousing. In addition, the practice increases the urban biodiversity, carbon sequestration, rainwater infiltration and reduce of urban heat island effect.

Moreover, AGRUPAR combined several adaptation measures in all their processes, for example, they ensure an organic production by agro-ecological practices, engage an efficient water consumption by using drip irrigation or water harvesting, they promote to re-use of materials such as boxes, bottles or pallets for the constructions of the orchards and close the cycle by producing compost with organic waste, thus, preventing food loses.

Figure 45. Women orchards located in their home's backyards. Source: CONQUITO, 2018

Lessons learned and conclusions

One of the main challenges of the programme is the legal framework related to land use. Urban agriculture still needs to be recognized within the urban districts of Quito as part of the land management instruments, and efforts are being made to include it. Despite this, agriculture at a larger scale is considered as a possible use in the peri-urban areas and rural districts. In practice, although there is no restriction for urban food production, local farmers are faced with the risks of expulsion or termination of their leases since some may occur in land with no official titles, or without permission to use public space. As a result, urban agriculture may also be a victim of land trafficking and illegal occupation. Yet, the number of orchards is increasing and have become an active alternative during the last year of crisis due to the pandemic.

While the world is being severely affected by Covid19, AGRUPAR is helping the city to cope with the challenge of distributing food. As the access to supermarkets has been controlled and limited due safety measures, citizens have searched for alternative providing means. Thus, the city's urban and peri-urban gardens have offered solutions to the food provisioning problems at various scales, emphasizing healthy, uninterrupted, and diverse food for families through three channels:

a. Occasional sales as crops are ready for harvest (a few bundles of radishes, a few kilos of tomatoes or potatoes, a couple of heads of broccoli, cabbage, lettuce, a chicken, among others).
b. Weekly sale of baskets of 10 - 15 seasonal varieties, possibly including chicken, pork or eggs, to families from the neighborhood or from nearby areas; the transaction takes place in the garden.
c. Sale of a fixed quantity and selection of produce via collaborative supply chains. Transactions are made through a third party, who establishes contacts with consumers,

puts together baskets by collating surplus produce from various producers, and delivers them to homes.

The diversification of distribution channels has helped to improve the resilience of the food system, has forged more direct relationships between producers and consumers, and has reminded people that they need to consume a significant quantity of fruits and vegetables every day preferably agro-ecological (at least those who are aware of urban-rural linkages and the right to healthy food) (Figure 46). The COVID-19 pandemic has undoubtedly facilitated the future transformation of e-commerce platforms in the agricultural sector, and the emergence of collaborative economy ventures[14].

Figure 46. Vegetable's harvesting and delivery baskets during pandemic times. Source: CONQUITO, 2020

Projections and upscaling

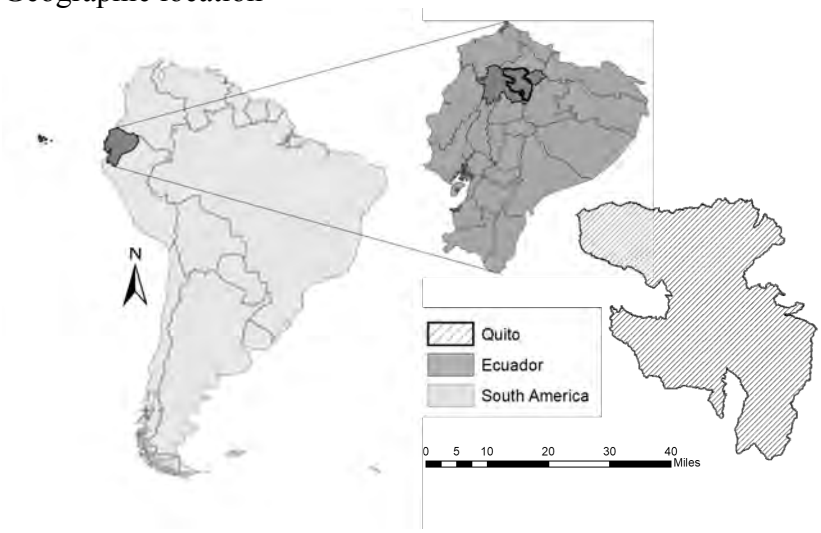
In 2013, Quito inaugurated its new international airport located in the rural parish of Tababela, 35km. outside the consolidated area, leaving the open area of the former airport destined to be an urban park. The design of the park provides an area at the northern head for urban agriculture activities. AGRUPAR is proposing to implement an Urban Agriculture Interpretation Centre for co-production dissemination and of knowledge to benefit more citizens, having productive areas for the community, but also a showroom for different irrigation systems and cultivation techniques[13].

Wider contextual information

General description
Core city: Metropolitan District of Quito
Biogeographic region: Neotropics
Location: North of South America, Ecuador
Area: 4,218 km^2 including rural and urban areas

Population: 2,600,000 inhabitants
Green space per capita: 21.66 m^2

Geographic location



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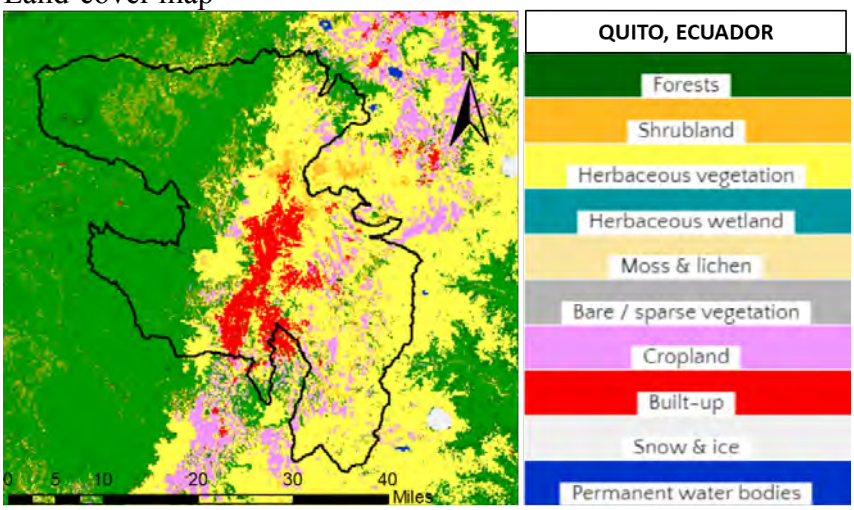
Land-cover map



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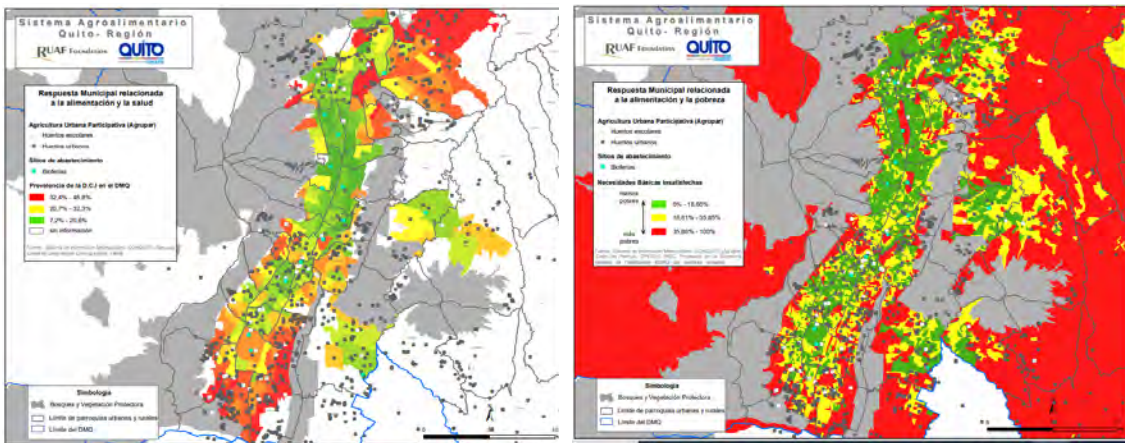

Agri-Food System (left) and Social atlas for the Quito urban area, 2009. Elaborated by: RUAF Foundation 2018. Source: Andean University Simón Bolívar - Agricultura Urbana. CONQUITO 2018.

The Metropolitan District of Quito is the capital of Ecuador with a population of 2,6 millions of people, 63.8% in the urban area[15]; and is organised into 32 urban parishes or districts and 33 rural and suburban parishes. Poverty in Quito, as unsatisfied basic needs, affects almost 30% of the population, while extreme poverty reaches 7%. Chronic malnutrition of children under 5 years old is 30%, according to data from the 2015 Metro Quito Plan for Development and Land Use Planning[16]. The city has an unemployment rate of 5% and an underemployment rate of 40%[17].

Quito is located in the equatorial zone with 75.0% of relative humidity and an average temperature of 14.8°, with rainfall almost all year round. It has two different seasons, a dry season from June to September and the rainy season from October to May, which define the agricultural circuits and establish specific forms of relationship between geography and population. Quito is within the province of Pichincha, on the Guayllabamba basin, with two distinct zones: to the east, an area dominated by the eastern and western Andes; and to the west, a subtropical area with sub-Andean ramifications, and with an average altitude of 2,908 mm[18].

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Case 12: Green roofs in the slums of Rio de Janeiro, Brazil

Local and global nature-society challenges.

Environmental problems are a common issue in most cities of the world. Out of these problems, heat islands are one of the most iconic effects of urbanisation leading to increases in temperature far superior to that caused by global climate changes[1]. The heat islands are a result of the increasing built infrastructure using materials with high heat retention combined with the consistent reduction in the vegetation and their ecosystem services[2]. The reduction in temperature control results in various negative effects for the cities and citizens, including higher energy consumption for climatisation, lower thermal comfort and even higher risks of health outcomes, to name a few.

Mortality risks, mainly related with cardiovascular issues, increase exponentially above certain thresholds of temperature in many cities worldwide[3], and is expected to further increase with the future warming trends in cities of all continents[4]. The effects of high temperature are especially critical in the slums or informal settlements of the tropical world[5], where these densely populated areas are mostly built without proper thermal insulation and often completely lack green spaces for thermal control[6]. These are the environmental conditions found in the more than 700 slums, where 19% of the population of the city of Rio de Janeiro, Brazil, live nowadays[7].

Green roofs to reduce temperature and face climate change

These densely urbanised areas of the city of Rio de Janeiro impose significant challenges for the use of Nature-Based Solutions in controlling the heat island effects. Often, there are no open space available for planting trees, and building new green spaces is virtually impossible for lack of space. One solution, however, is to bring green to the rooftop of the houses. A case study was conducted at the Arará slum, northern Rio de Janeiro, based on the development and monitoring of green roofs[8]. The common use of cement or metal tiles required the development of specific techniques and materials to allow the growth of the vegetation while keeping the overall weight low for safety (Figure 47).

Figure 47. Pilot project of green roofs in a community of Rio de Janeiro, Brazil (Image from Herzong and Rozado 2019).

Because of the weight restrictions, succulents, herbs and small shrubs were planted in the green roof. Most of them were epiphytes or lithophytes, in other words, plants adapted to low substrate, high wind and solar exposure, making them ideal for low maintenance green roofs[9] (Figure 48). Plants growing in the in the green roof showed rather consistent performance as measured by various physiological parameters when compared to plants of the same species growing on the soil. This successful performance of the planted species in the green roof translated in an effective decoupling of temperature and thermal insulation. The recorded temperature in the green roof was rather constant throughout the day and in average 40% lower than that observed in the surrounding regular roofs. The implementation of the green roofs also brought and additional benefit by reducing the storm-water runoff.

Figure 48. The extensive use of bromelias on the green roofs for keeping the weight of the structure low for safety (Image from Herzong and Rozado 2019).

Lessons learned and conclusions

This successful implementation of green roofs in a slum of Rio de Janeiro brings new avenues for development and implementation of similar interventions in other vulnerable communities in Brazil and abroad. Especially in the warm tropics, the observed reduction of about 20˚C represent a significant improvement in well-being. This improvement in thermal comfort may also be the difference between being exposed to temperature above or below thresholds from which mortality risks are greatly improved. Considering the current scenario of global warming, and expansion of slums worldwide, it is clear that well-panned and designed green roofs may represent feasible solution for improving well-being of the most vulnerable urban populations.

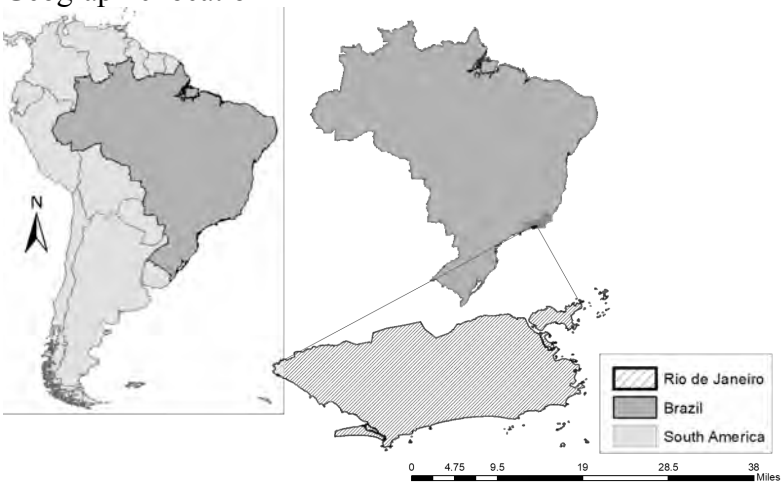
Projections and upscaling

The example discussed here represent only a pilot project that has a great potential for expansion in slums of Rio de Janeiro and other cities. This development strongly depends on the engagement of the local population together with the technical development support from the academia[10]. Although not thoroughly explored in the aforementioned example, it is clear that this solution must be developed using species from the local flora to avoid the introduction of invasive species, while promoting the local biodiversity. The performance of this biodiversity, under such conditions of the green roofs, must be therefore evaluated to promote the development of the plant individuals for the best thermal control. This could include non-conventional food plant and other species with local cultural meanings. It is also key to develop cheap and light weight combinations of substrate and plant species to cope with the structural constraints that may be found in the slums.

Wider contextual information

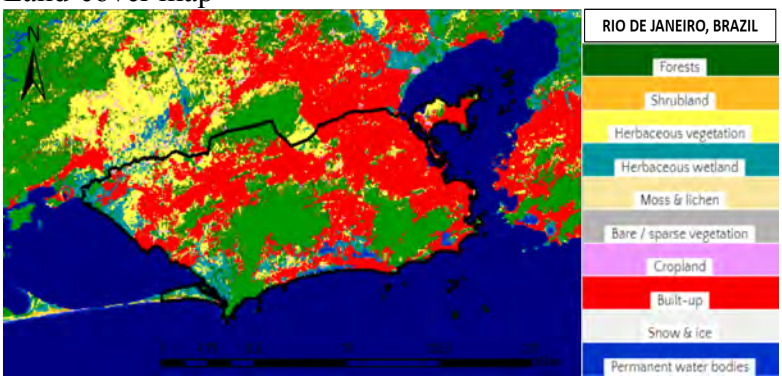
General description
Core city: Rio de Janeiro
Biogeographic region: Neotropics
Location: South America, Brazil
Area: 1250 km^2
Population: 13.540.000 inhabitants
Green space per capita: Not available

Geographic location



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana

Land-cover map



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana, based on: Buchhorn, M.; Smets, B.; Bertels, L.; Lesiv, M.; Tsendbazar, N.-E.; Masiliunas, D.; Linlin, L.; Herold, M.; Fritz, S. (2020). Copernicus Global Land Service: Land Cover 100m: Collection 3: epoch <2019>: Globe (Version V3.0.1).

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Case 13: Sweet City: Facing Climate Change and Biodiversity Loss in Urban Costa Rica

Addressing local and global nature-society challenges

Figure 49. Panoramic view of the city of Curridabat. Source: www.curridabat.go.cr

Nature-Based Solutions are grounded in biodiversity, while facing multiple socio-economic and environmental challenges, including climate change adaptation and sustainable urban development[1,2]. The city of Curridabat (Figure 49), located at the east of the Greater Metropolitan Area of Costa Rica, as many other cities in the Latin America, is facing climate change and biodiversity loss due to global challenges and local pressures, including rapid urbanisation and densification processes; the same as environmental, social and ecological conflicts[3]. For the purpose of tackling these problems, the municipality has created the "Sweet City" progamme, based unintentionally in NBS.

This city presents densely populated areas some with reduced drainage capacity of the channels due to the narrowing of the riverbeds. These bodies of water cause floods and other problems when extreme climate conditions affect the city, with high intensity in short periods. A total of 217 events related to extreme weather conditions were recorded in Curridabat in the period between 1988 and 2018, and the main cause of disasters by those extreme conditions (67%) occurred in the period of rains[4]. The increase of temperature is also a main preoccupation as being recorded an increment of 0.09 Celsius grades each decade since 1960, and according to the climate change monitoring, for Central America an increase of 1.5 Celsius grades is projected to 2050, with a reduction in precipitations for the rainy season, as well as a harder mid-summer drought with an intensification of extreme temperatures as well[3].

A positive note shows that the city of Curridabat still has a significant proportion of urban vegetation. However, this coverage is heavily fragmented and distributed with significant signs of asymmetry between districts. This is mainly caused by an unplanned densification process and transportation networks. Only 34 hectares of a total of 772 hectares of green infrastructure in the city (urban forest, green parks, river sides, etc.) correspond to public green parks, so preservation

and optimisation of the other green areas of the city is needed to give some response to climate change and the loss of biodiversity[3].

Against this panorama, in an effort to restore the balance between urban and natural areas, preserve and increase biodiversity into the city and face climate change, the municipality of Curridabat established "Sweet City". It is a programme with a vision and city model that seeks to install natural conservation as an urban activity from an integrated perspective that includes environmental, political, urbanistic and pedagogical objectives. In particular, Sweet City aims to create the conditions to improve the quality of life of all the inhabitants of the territory, humans and not humans, including pollinators, by providing better conditions for their productive activities and as a result obtaining a more biodiverse, comfortable, clean, colourful and better organised urban environment[5].

Pollinators and biodiversity

Natural resources are arguably a big asset in urban areas, with this in mind the Municipality of Curridabat created in 2015 the programme "Sweet City". It mainly proposes to eliminate the historical antagonism that has existed between the city and nature through the preservation of biodiversity[6]. This programme has as a relevant precedent in the promulgation of the Urban Regulatory Plan in 2013 that removed Curridabat from the logic of segregated or dedicated land uses (current logic of most urban regulatory plans in the Greater Metropolitan Area of Costa Rica) and introduced mixed land use and the densification of transects. This last understood as an urban planning tool that designates the urban areas based on their physical characteristics and their relationship with the environment; different to zones that defines uses[7].

The Sweet city programme, as its name indicates, seeks to be a model that consolidates a territory and urban systems that are friendly, receptive and responsive to the different ways of life that inhabit the city, not just humans. In this sense, the programme considers pollinators (mostly bees) as part of the community, not only as part of the productive dynamic of a biodiverse urban environment, but as an ethical position that cares about other forms of life, close to the idea of post-humanism[8]. In a more poetic way, the programme suggests humble and simple gestures to give pollinators their rightful place in a city full of beautiful experiences: "If you grow a sweet plant, you will see that one day a butterfly, a bee or a hummingbird approaching. From that moment on, they will be in charge of making the city sweet."[6].

Different activities are designed in order to achieve the objectives of the programme. They include: the reintroduction of native biodiversity; public awareness of the importance of the interactions between human beings and nature; the transmission of skills to the population for territorial micro-management and neighborhood by neighborhood self-management, and the incorporation of design and planning into the collective culture of communities. So, it implements "design thinking"[9] strategies to improve the daily experiences of the different constitutive elements of the city, from citizenship to vital elements for life[5].

The programme is based on five dimensions and ten experiences to accomplish sustainable development in a small city. The first dimension is biodiversity, which understands Curridabat as a natural territory, or in other words how Curridabat is a city inside a natural environment. The

second dimension is infrastructure, that tries to align landscape architecture and urban infrastructure in respect of biodiversity, for example, instead of conducting rain to water bodies as fast as possible, it keeps rain in the place it falls to let it flow naturally. The third dimension is habitat. It intends to create a less segregated society by giving to the population more access to opportunities and services in the city, so walking distances are prioritised with a variety of activities and experiences, having in mind in particular, people with mobility difficulties (Figure 50). The fourth dimension, coexistence, seeks to bring resources to achieve a more connected and inclusive society within humans but also with not humans, from a bee to every person in the city. For this, a peace and coexistence department has been created in the municipality. The fifth and last dimension is productivity. It is understood as the capacity of the city to produce instead of only consume (natural and other types of resources) and destroy the environment[10].

Figure 50. Pavement with a textured path for blind people. Source: www.curridabat.go.cr

The sweet city programme works with the existent territorial resources, in multidisciplinary teams with participatory processes with communities for the design and implementation of experiences in the city (Figure 51). So far, ten experiences has been implemented: ‘water drop’, for the awareness of water use; ‘earthworm’, for better waste disposal (compost and soil regeneration); ‘sap’, for having areas to grow fresh vegetables and give access to them in order

to have a more conscious eating; 'mariola' (native plant), for creating safe and accessible paths prioritising vulnerable populations; 'ants', for peaceful neighborhoods and social interactions; 'hive', for confidence in the inhabited place; 'neuron', for the prevention of mental issues in the population; 'guide birds', for improve the attention given to citizens by the municipality; 'hummingbird', for joyful physical exercise; and 'güitite' (native tree), for a better relationship with nature, the last as the experience that materialise the main goal of the programme[5].

Figure 51. Synthesis diagram of the programme. Source: Irene García, Curridabat Mayor`s office.

Lessons learned and conclusions

To get a more participatory implementation, a communication strategy had to be made in order to explain how the programme would benefit the life conditions of everybody, including graphic aids, metaphor names and language adequation (Figure 52). Since the implementation of the programme, that began with raising awareness about the importance of pollination for the environment; officials now believe that it is a vision of development and a city model, because at the end of the day, what the programme seeks is to give a more satisfactory sense of life to the inhabitants.

In this sense, the actual government believes, that beyond the traditional public services a municipality has to give to the people; the most thing to be given to the population is to guarantee ecosystem services in conditions of equality and equity.

Projections and upscaling

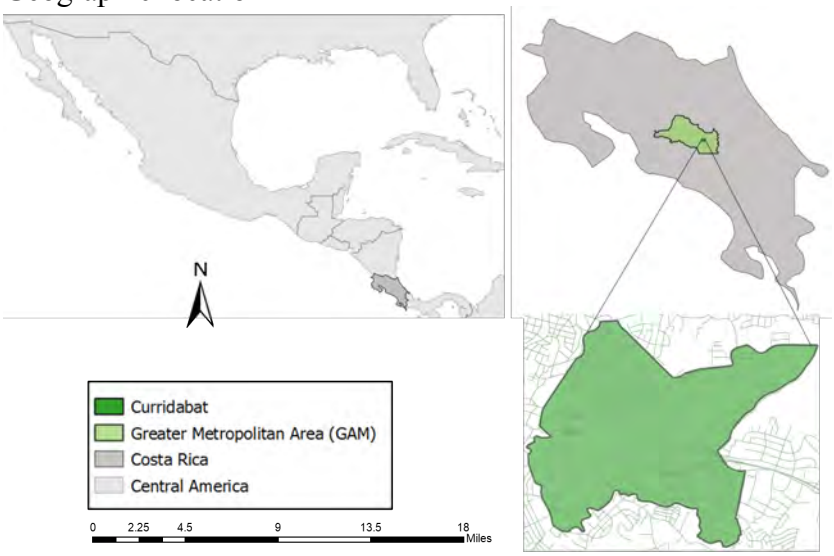
"The Sweet City programme is inspired in pollination and aims to be a role model for small and medium-sized cities around the world. It deals with a series of situations or "ways of doing things" of the traditional urbanisation model in contradiction with the processes of nature. It tries to answer the following question: how to redesign a city that adds value to the planet instead of taking it away?[10].

In this context, the effort made so far in the city of Curridabat with the implementation of the Sweet City programme constitutes the local version of what is globally known as the Biophilic City, implemented in other cities in the world. It begins with the establishment of urban green networks, which aim to reestablish the urban ecological functioning of green areas, parks and urban corridors through ecological design (Figure 4). This is done to bring a better environment for the people, and a better relationship with nature, instead of "optimise" resources, as a traditional "green" approach would do[11].

Figure 52. Park path with solar lighting and endemic sweet plants for pollinators. Source: www.curridabat. go.cr

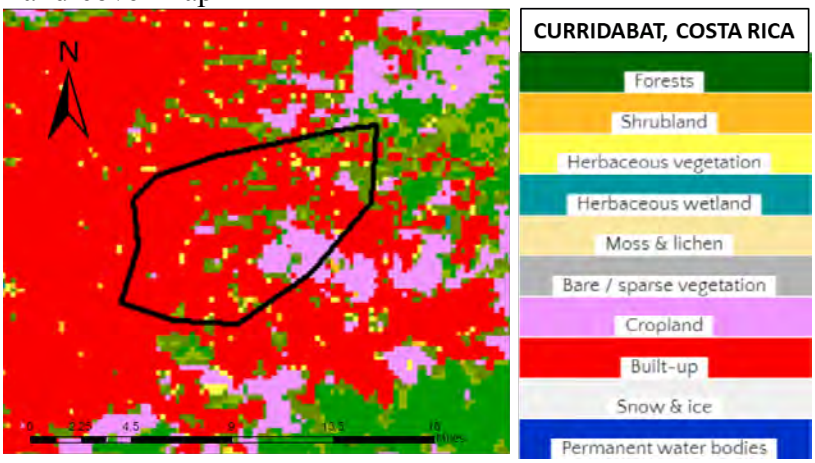
Wider contextual information
General description
Core city: Greater Metropolitan Area
Biogeographic region: Neotropics
Location: Central America, Costa Rica
Area: 2,044 km^2
Population: 3,000,000 inhabitants
Green space per capita: Not available

Geographic location



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana

Land-cover map



Source: Buchhorn, M.; Smets, B.; Bertels, L.; Lesiv, M.; Tsendbazar, N.-E.; Masiliunas, D.; Linlin, L.; Herold, M.; Fritz, S. (2020). Copernicus Global Land Service: Land Cover 100m: Collection 3: epoch <YEAR>: Globe (Version V3.0.1) [Data set]. Zenodo. DOI: <DOI>

The city of Curridabat is located within the Greater Metropolitan Area, that is the main conurbation of the country with an extension of 2,044 km^2, including 31 cities (counties) divided in 164 districts in which lives 53% of the population of the Costa Rica, about 3 million people[12]. Curridabat has an extension of 15.95 km^2 (all urban) and a population of 77,028 inhabitants in 2016, with a density of 5,623.75 inhabitants / km^2.[4] It is divided into four districts: Curridabat, Granadilla, Sánchez and Tirrases. Although, it is meant to be city with a high degree of economic and educational development, it has some informal settlements close to the south and east hills and by the rivers in the central area, and one of the districts (Tirrases) is a very disorganised territory with low quality housing and high affectation to natural resources.

The Greater Metropolitan Area is placed within the division that defines two climatic regimes for the Central Valley of Costa Rica. This particular geographic location defines the climatic and ecological patterns of the area. The average elevation is 1,200 m.a.s.l., the average temperature fluctuates between 16.5 ° C and 25.0 C and the average rainfall is 2,000 mm per year. In Curridabat, the original forests correspond to two life zones, according to the Leslie Holdridge classification system: Premontane Moist Forest (36% of the total area of the canton) and Premontane Wet Forest (64% of the total area of the city[13].

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https://www.minae.go.cr
https://www.biophiliccities.org/curridabat

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Case 14: The Santiago Green Infrastructure Plan: towards a green infrastructure system

Green infrastructure in Santiago for all

In Chile, municipalities have a legal obligation to develop an urban land use plan that incorporates a system of green spaces; however, this faces two important limitations. The planning and design of the green space system does not incorporate the principles of Urban Green Infrastructure such as multifunctionality, connectivity and integration. Therefore, green spaces appear disconnected and with exclusively dedicated to recreation and leisure, leaving other functions such as biodiversity, stormwater control and air quality improvement, all relevant for improving the quality of life in Santiago.

A second limitation concerns to implementation. In Santiago low-income municipalities face two main issues, they largely concentrate social housing developments that are extremely dense and do not incorporate an adequate provision of urban green infrastructure, and they do not have sufficient resources to meet their legal obligation to maintain public green areas. Thus, a low-income municipality such as El Bosque has 1,8 m^2/inhabitant of public green areas while a high-income municipality such as Vitacura has 56.2 m^2/inhabitant (Figure 53)[1,2]. Several studies have demonstrated that inequitable distribution of urban green infrastructure is one of the main problems in Santiago[1,3,4].

Figure 53. Inequity in distribution and quality of urban green infrastructure in Santiago.

In response to the latter, in 2010 the Ministry for Housing and Urbanism (Ministerio de Vivienda y Urbanismo – MINVU) began the Urban Parks program aimed at developing large parks in low-income municipalities with a deficit of green spaces and resources for their maintenance. These parks are designed, implemented and maintained by the MINVU, and although this program has given good results, it is not enough to substantially reduce the large gap in green space provision among municipalities[5].

The Stgo+ Green Infrastructure, from a plan to a system

In the last ten years, several academic and social groups concerned about Urban Green Infrastructure have emerged and mobilised the debate and agenda in Santiago. For example, an academic group from the University of Chile has developed the Stgo+ Green Infrastructure plan, which is a green infrastructure plan at city scale. Within the same realm, the Cerros Islas Foundation promotes the transformation of 26 hills into metropolitan parks; and the Aldea and Mi Parque foundations develop green areas in low-income municipalities, involving neighbors in the design and construction, the municipality in the maintenance and the private sector in the funding[5]. Furthermore, social movements such as "El Panul" and "Parque La Salle" are self-organised groups have emerged aiming at protecting green spaces threatened by urban expansion, through political action and social protests. This growing social interest in neighborhoods quality beyond access to housing, is one of the most important opportunities and enabling factors of urban green infrastructure initiatives in Santiago, but certainly it should be strengthened and expanded if a greater impact is sought.

Vásquez et al. distinguished that the main challenges for urban green infrastructure development in Santiago were the extreme sectorial fragmentation and the lack of coordination among public institutions. This becomes a barrier to introduce the principle of multifunctionality in projects and plans, since it requires intense intersectoral dialogue and coordinated interventions. In addition, funding is a relevant challenge since there is a deficit of resources for construction and especially for maintenance of urban green infrastructure in Santiago. This is especially true in low-income municipalities and for initiatives carried out by community organisations.

Beside sectoral fragmentation, coordination among different municipalities with very different resources is a major issue for the development and maintenance of metropolitan green infrastructure initiatives in Santiago. As municipalities have a large control over their territories, including the establishment of specific territorial regulations and plans, the lack of coordination among them affects the capacity of maintaining the functionality and spatial integrity of green corridors along roads and watercourses that go through several municipalities[6].

In the last two decades urban green infrastructure in Santiago has been developed through the construction of plazas and small parks by the municipalities, and large urban parks by the regional and national government. These efforts have left beside the conservation of natural areas located especially in the urban fringe, which provide important ecosystem services and are relevant for future urban development, and the development of green corridors to improve landscape connectivity[6]. The consolidation of a green infrastructure system in Santiago requires the incorporation of urban green infrastructure principles in statutory planning instruments -such as the PRMS -at multiple scales.

The design and implementation of a green infrastructure plan in Santiago offers an opportunity to catalyse the collective interest in green infrastructure of different types and scales, and articulate the different public, private and citizen initiatives with a strategic vision of integrated planning. At the same time, a green infrastructure plan can significantly contribute to mitigate some of the most important in the city.

Since 2017 we started a process aimed to develop a green infrastructure plan in Santiago, as a shared territorial strategy and a convener of the different actors relevant for decision making and implementation at different spatial scales. The plan has been named Stgo+ Green Infrastructure and has been led by the Grupo Paisaje-FAU (University of Chile), the Ministry for Housing and Urbanism and the Regional Ministerial Secretariat of the Ministry for Housing and Urbanism, and with the participation of 20 public institutions, 16 civil society organisations, 6 academic institutions and 3 private organisations (Figure 54).

Through a participatory approach, including multiple stakeholders workshops and collective mappings sessions were developed and problems were identified for the justification of the plan, goals were agreed, and key spatial components were identified.

Figure 54. Stgo+ Green Infrastructure Plan.

The problems identified by the multiple stakeholders that could be overcome by an integrative planning of green infrastructure including:

1. Social segregation of the city, including newly arise physical and cultural barriers
2. A grey city with a low cover of green spaces and unequal distribution of those
3. A disconnected city for mobility and for flora and fauna dispersion and movement
4. City in a biodiversity hotspot that highlight its relevance for conservation
5. The city at risk from increasing climate, volcanoes and earthquake events
6. Pollution puts population and ecosystems at risk, including water, soil and air pollution problems

The stakeholders group agreed on the main strategic goals of the Stgo+ green infrastructure:

1) To contribute to the social and spatial integration of the city, and
2) To help to climate change adaptation in Santiago.

And specifically for green infrastructure, the main concerns arising from the stakeholders were:

1. Resources for the maintenance of green spaces, especially in low-income municipalities.
2. The current inequality of urban green spaces distribution in terms of quantity and quality.

3. To assess and make visible ecosystem services provided by the green infrastructure
4. Governance and collaborative planning of urban green infrastructure

Challenges and opportunities

Once the objectives of the plan were established opportunities and barriers need to be identified in order to have a pathway for developing and implementing the plan. Some of the barriers included short term political support that don´t align with the development of green infrastructure, lack of a robust institutional arrangement that coordinates and catalyzes efforts, low priorities for green infrastructure resource allocation, lack of valuation for green infrastructure benefits included in the social valuation of projects and inequalities on green infrastructure municipalities resources, among others.

Opportunities identified included society pressures for having more quantity and better quality of green spaces, better knowledge on the benefits of green infrastructure, alliances with private institutions, using of the green infrastructure concepts by public institutions, among others. Additionally, a mapping of relevant actors was done, including private and public institutions, academia, civil society. Finally, a participatory mapping of the potential network was also undertaken.

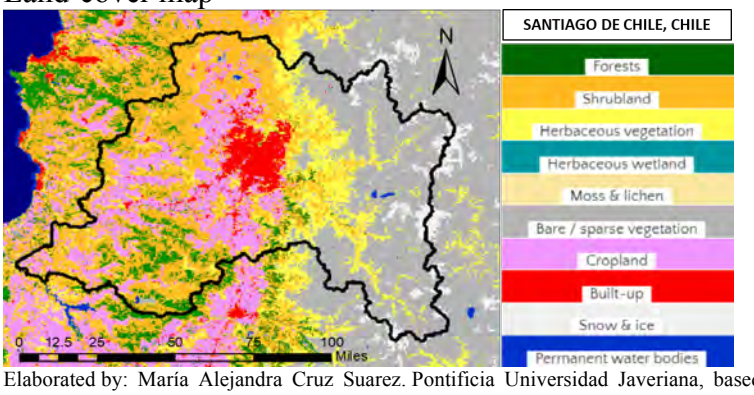
Wider contextual information:

General description
Core city: Santiago
Biogeographic region: Neotropics
Localisation: South of South America, Chile
Area: 617 km^2 including rural and urban area (Greater Santiago, includes urban municipalities)
Population: 6.585.000 inhabitants (Urban population)
Public recreational green space per capita: 6.05 m^2 per inhabitants (INE, 2019 http://siedu.ine.cl/cantidad_BPU_29.html)

Geographic location

Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana

Land-cover map



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana, based on: Buchhorn, M.; Smets, B.; Bertels, L.; Lesiv, M.; Tsendbazar, N.-E.; Masiliunas, D.; Linlin, L.; Herold, M.; Fritz, S. (2020). Copernicus Global Land Service: Land Cover 100m: Collection 3: epoch <2019>: Globe (Version V3.0.1).

Santiago de Chile is situated in a fairly closed watershed in the central valley, surrounded on the eastern side by the high Andean mountain chain with altitudes of more than 5,000 m.a.s.l. and at the western border by the Coastal Range of lower altitudes. The climate is temperate with dry summer with temperatures ranging between 8-30ºC. The annual rainfall averages 350 mm concentrated in the winter months, however in the last ten years the region is under extreme drought with annual rainfall reaching only 70 mm during 2019.

Santiago is the capital of Chile and the undisputed economic, cultural and political center of the country. With its almost 7 million inhabitants it one of largest city in Latin America with a density near 10,000 inh/km^2. This city is a representation of rapid urbanisation processes, demographic transition and urban sprawl that characterizes the development of Latin American cities[7]. Its administrative boundaries cover 2274 km^2 of which 617 km^2 corresponds to urban land cover[8].

The city has experienced population growth since 1990 until late 2000´s resulting in sprawled urbanisation (Inostroza et al. , 2013). Between 1985 and 2017 the population of Santiago has increase from 3.9 million to nearly 7 million inhabitants, with an increase of the urban area in a similar rate[9]. Urban development in Chile has been characterized by the implementation of neoliberal policies and, consequently, Santiago´s urban expansion has been poorly regulated and has produced strong social-environmental patterns of segregation[5].

In administrative terms, the Metropolitan Area of Santiago is a conurbation comprised of 36 municipalities that are autonomously administrated by local governments. Despite the existence of a land use plan for the Santiago Metropolitan Area (PRMS, Plan Regulador Metropolitano de Santiago), the design and implementation of infrastructures and public works mainly depend on different ministries and departments, while the municipalities have the power to make their own urban regulations, e.g. land use plans and urban forest ordinances.

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Santiago Municipality https://www.munistgo.cl/
STGO+ http://infraestructuraverdesantiago.cl/

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Case 15: Urban forests and promotion of native ecosystems in São Paulo, Brazil.

Urban growth and natural environment, looking for a balance

Although one of the largest cities in the word, São Paulo was only a small village by the end of the 19th century. This village used to lie on top of the hills, surrounded by an exuberant Atlantic Rainforest and fields of savanna, locally known as Cerrado[1,2,3]. However, this natural landscape changed significantly ever since, with the rapid expansion of the city, mainly after the second half of the 20th century.

The expansion of the city occurred at the expense of the natural environment, with a significant loss of biodiversity, and addition of alien species to the city[4]. Out of the more the 3,000 tree species from the Atlantic Rainforest[5], a world hotspot of biodiversity, only 577 are currently found in the city that must coexist and not rarely compete with additional 185 exotic species[6]. Most of these exotic species were, and still are, introduced by projects of landscape design in public spaces and private properties. There is, however, a recent growing trend of reintroducing and restoring to some extent the ecosystems that were previously found in the area occupied by the city today.

Restoration of ecosystems with urban forests

In the light of the above explained, the trend of using native species is strongly support by the local laws and regulations of the city of São Paulo, but the vision of ecosystem restoration is mainly advocated by few organised groups of activists working in the city[4]. Such activists take support on the local regulations to promote the re-introduction of native tree species to the city, but they step forward by using ecological concepts such as succession and competition to aim at restoring these ecosystems[4]. For instance, instead of planting trees of specific height and trunk diameter, at specific distances as defined by law, activities use a mix of plant sizes, from sapling to young trees, and plant them at various distances to somehow mimic what is found in their natural environment. In this scenario, pioneer species will grow faster and provide shade and microenvironmental conditions required for the development of early and late secondary tree species. Dense planting schemes such as the used by activists not only favor the development of the specimens, but also promote pollination and seed dispersal, protection of the soil against lixiviation, and consistent reduction in the mortality of young individual[7]. Evidence also point to a positive impact of such biodiverse and dense planting scheme. More trees of various species tend to locally maximize the reduction in air temperature and air pollution, the increase in air humidity and thermal comfort, rainfall interception and carbon sink[4]. In addition, more biodiversity and higher tree density may be related to an improved perceived well-being. Although these plantings are concentrated in small areas that are available for this purpose in the city, they take several plant individuals for such dense plating scheme.

This planting scheme translates into a laborious activity and is only possible by the support of the local engaged population. Although the environmental activism started on the second half of the 20th century in Brazil, it gained strength after the Earth-Summit (Eco-92) with the creation of national institutions and laws that gave the support for the local activism mostly focused on natural areas[8,9]. Environmental activism in the cities is a recent, but an ever-growing movement in Brazil. In São Paulo, different groups are working in increasing the biodiversity and tree cover in the city by planting small forests patches, locally known as pocket forests. These activities are

first planned with the local stakeholders, and then the area is prepared for the planting, including the eventual removal of pavement, preparation of the soil, among other measures. The act of planting per se is undertaken by the local population, and engaged people from various parts of the city that gather for this activity.

Several areas of the city have received such NBS interventions, including squares, parks and even abandoned open areas[4]. One example is the restoration of a small forest patch in the Batatas Square, west region of the city of São Paulo[10]. The local responsible authorities gave the authorisation for the intervention in an area of 650 m^2 previously occupied by an abandoned gas station. All tanks were removed, the soil was remediated, and the area was revitalized by removing pavement and waste, and planting several species from the Atlantic Rainforest and Cerrado, including the development of a rain garden capable of collecting water from an equivalent 1,000 m^2 of paved area, with a significant contribution to the control of local floods. Most of the work in this area was conducted by volunteers of all ages that were invited through social media. Another example is the Homero Silva Square, a 12,000 m^2 green area also located in the west region of São Paulo[11].

The restoration processes undertaken in this area were mainly focused on the protection of eight springs that flows to the Tietê river, one of the largest in the city. The project consisted in the restoration of biodiversity using elements of the Cerrado and Mata Atlântica, including aquatic species from the wet physiognomy of these biomes (Figure 55). These are just two examples of interventions whose success depend thoroughly on the combination of: government support, vision and planning from organized activists with a large experience in the field and the engagement of many volunteers who aspire to live in a more sustainable city.

Figure 55. Example of a forest restoration planned and conducted by activists and local engaged population in the city of São Paulo (image courtesy by Ricardo Cardim).

These interventions, among many others in the city, lean towards a more sustainable city. Many environmental and social benefits have been reported in these areas. They include a higher flora and fauna biodiversity, consistent temperature reduction and increase in air humidity, protection of springs, mitigation of local floods and promotion of areas for social interaction and well-

being, not to mention the promotion of social cohesion. It is clear, therefore, that these interventions meet the criteria of multi-functionality expected for any NBS intervention. As new forests are planted and green corridors are formed, it is expected that these benefits will spread throughout the city reducing the evident environmental inequality currently found in the city of São Paulo[4].

Another example are the rain gardens that are multiplying from the central areas of the City to the most outlier neighborhoods, taking advantage from parking spaces, remnants of the street grid leftovers and other spaces that had been covered in asphalt or cement without any reliable ecosystem service for the urban environment (Figure 56). Besides its humble origins, these interventions can be both official, from public services agencies, to deep root actions originated from dwellers own initiative, taken mostly without any support.

Figure 56. Example of raingardens in the streets of São Paulo. Source: (https://avidanocentro.com.br/cidades/gentileza-urbana-jardins-de-chuva/)

Lessons learned and conclusions

The initiatives presented here show how it is possible to slowly restore the biodiversity in the city by creating small interventions that will eventually integrate across the city. These interventions in the west region of the city are especially successful examples NBS for combining the restoration of the flora and the protection of the water, either by preserving springs, or by creating rain gardens for a more effective water percolation in the soil. Slowly, these interventions increase the environmental quality in the city while promoting more social interactions and cohesion in different parts of the city. A sense of place-keeping is therefore created and shared among all those involved in these projects, and those that locally benefit from them. At the same time, they represent are strategies that start to break the traditional mindset to dry out all the available open space in the cities, allowing for the implementation of a more comprehensive plan for a Green Infrastructure in the cities.

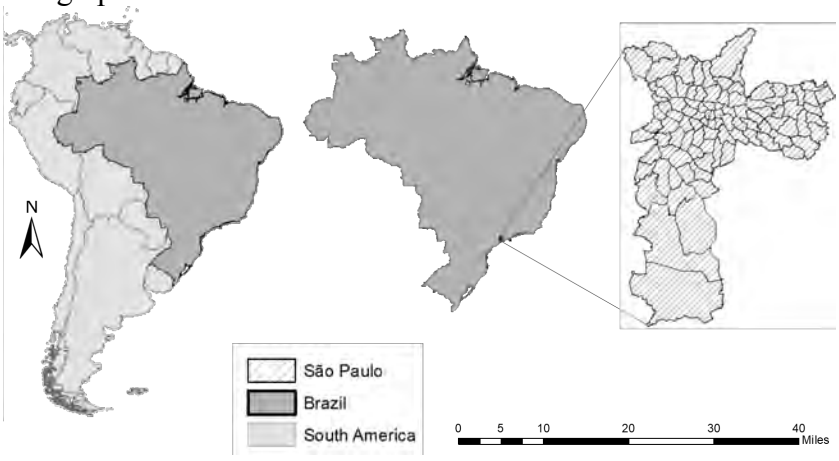
Projections and upscaling

Because of the significant local biodiversity, it is still not clear to what extent these species will flourished in the city and promote the best of the ecosystem services, considering that the environmental conditions changed significantly after urbanisation. São Paulo is an emblematic example, with an increase in mean temperature of more than 3˚C in the last century, which is about 5 to six folds higher than that observed in the Southern Hemisphere. Warming also promoted profound changes in the convective activities with more extreme rainfall events that leads to more flood problems. So, it is necessary to understand how these tree species will perform growing under these adverse environmental conditions. In addition, planting is still not coordinated under a more systemic evaluation of the city. These are local interventions that are not necessarily thought to integrate with other local and regional green infrastructure, which may jeopardize the potential ecosystem services that they may provide for the entire city. Therefore, it is still necessary to create mechanisms capable of integrating these different variables in order to produce the best benefit to the city and citizens. That is exactly the goal of the pilot projects chosen for Conexus: the role of functional forests within the City, in this case demonstrated by three parks, each representing a different stage of forest consolidation, structure and the function that they perform. All this for the ultimate purpose to see a more resilient and healthy urban forest, able to give to the city the services that it is so in need, and then configuring the green infrastructure that can complement the urban fabric.

Wider contextual information

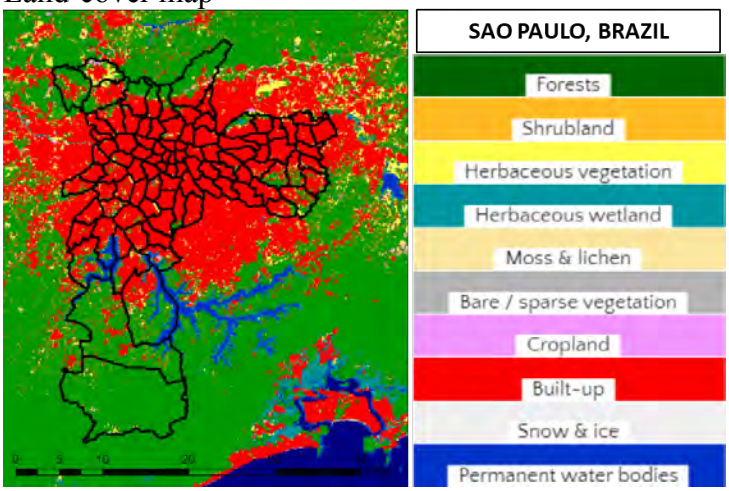
General description
Core city: Sao Paulo
Biogeographic region: Neotropics
Location: South America, Brazil
Area: 7.900 km^2
Population: 18.8 millions of inhabitants (Metropolitan área) and the Municipality of São Paulo has 11,446,275 inhabitants
Green space per capita: 15m^2 per inhabitants

Geographic location



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana

Land-cover map



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana, based on: Buchhorn, M.; Smets, B.; Bertels, L.; Lesiv, M.; Tsendbazar, N.-E.; Masiliunas, D.; Linlin, L.; Herold, M.; Fritz, S. (2020). Copernicus Global Land Service: Land Cover 100m: Collection 3: epoch <2019>: Globe (Version V3.0.1).

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Websites of municipality and core organisations

Prefeitura Municipal de São Paulo: http://www.capital.sp.gov.br
Secretaria do Verde e Meio Ambiente de São Paulo:
https://www.prefeitura.sp.gov.br/cidade/secretarias/meio_ambiente/

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Case 16: Nature-Based Solutions initiatives in Sheffield, United Kingdom

Nature-Society relationship local challenges and relationships with global challenges

Sheffield is an industrial city in the North of England, with a long history of environmental activism and partnership working, as well as a reputation for innovating with NBS, particularly relating to urban water, community forestry and public realm landscape improvements. Significant progress has been made to address challenges associated with the declining steel, coal and other industries, including river pollution, landscape fragmentation, biodiversity loss, socio-economic deprivation and a legacy of brownfield land (including unattractive vacant and derelict sites). Climate change mitigation and adaptation challenges have been added to longer-standing problems, with flooding representing an important threat to local people and businesses, including particularly catastrophic impacts resulting from the 2007 event.[1] Urban forestry has been an important NBS-type intervention in the city and wider sub-region. Tree cover has been increased significantly, but remains patchy in its distribution with fewer trees in more deprived urban areas.

Nature-Based initiatives and responses

Macro-scale

At the macro- level, the city and wider sub-region have together implemented a series of spatial green infrastructure strategies and socio-ecologically informed plans. The list is long but includes the South Yorkshire Green Infrastructure Strategy, the Breathing Spaces strategy, City Centre public realm masterplans, the Sheffield Waterways Strategy, a series of River Don catchment and green corridor plans, and a comprehensive set of biodiversity action plans promoting practical restoration measures.

Most recently, the city-region set out its intentions for work to understand natural capital in South Yorkshire. This builds on the above programmes and strategies, as well as two other sub-regional plans, the Integrated Infrastructure Plan and the Sustainable Urban Development Strategy (see below). None of the above documents or initiatives name NBS in their titles but several provide frameworks, incentives and schemes to promote and deliver NBS on the ground. This case study examines in particular the interface between four sets of plans and strategies, providing important context for further examination of meso- and micro-scale interventions covered in subsequent sections. This case also touches on other formally adopted plans and strategies only in relation to the above meso- and micro- scale initiatives, in an attempt to better understand contexts.

<u>Sheffield City Centre Breathing Spaces Strategy</u>

This Strategy[2] built on a range of existing policies (such as Sheffield's local plan and its parks and countryside strategies) to deliver a programme of open space projects in the city centre. The Breathing Spaces initiative, starting in 2009, set out a vision for new high quality open spaces, linked by a network of pedestrian routes, with many of these spaces and links being heavily landscaped and featuring regreening interventions.

The Strategy pre-dated the development of the NBS concept, but made strong signals towards nature-based approaches and highlighted the critical role of ecological networks and biodiversity.

The document, and resulting projects, emphasised the importance of using native species in the development of city centre breathing spaces. In turn, the programme was heavily influenced by lessons learned in the development and implementation of the Lower Don Valley Masterplan, and particularly, the creation of the Five Weirs Walk.[3] The Breathing Spaces Strategy was forward thinking in how it brought together proposals for schemes to deliver direct benefits for people (mental health, community cohesion), alongside other invaluable environmental benefits (biodiversity provision; climate change mitigation and adaptation). The Strategy provided the impetus for NBS integrated within public realm investments worth multiple millions.

South Yorkshire GI Strategy

The South Yorkshire Green Infrastructure Strategy[4] was developed by the four local authorities (municipalities) in the sub-region, the nature conservation agency Natural England, and two organisations no longer in existence, the South Yorkshire Forest Partnership, and the 'regional development agency' Yorkshire Forward. It was prepared with funding from the EU and the 'housing market renewal' body, Transform South Yorkshire.

This was one of several GI strategies adopted nationally. Natural England[5] lists GI Strategies in place in England. Following the abolishment of the English Regions in the early 2010s, the removal of associated spatial and economic planning frameworks brought some uncertainty to the role and place of GI Strategies. Curiously, these strategies, developed in accordance with official Guidance document NE176 were never officially withdrawn, but were rather left hanging without significant efforts from the incoming Government to secure their delivery, nor resources to implement NBS and GI network improvements put forward. However, several local or sub-regional GI strategies were sufficiently embedded to remain influential and to have developed sufficient momentum to promote and deliver successful NBS schemes.

The Strategy set out a vision and delivery programme to create and improve the sub-region's 'green network'. It sought to "provide a framework and a programme to support local action".[6] The strategy's vision of a "multi-functional green network" with "the capacity and strength to link South Yorkshire's communities" recognised and addressed the challenge that the sub-regions GI was not yet achieving its full potential, and that doing so required significant efforts to boost partnership working across sectoral siloes, professional disciplines and most importantly, geographical administrative boundaries. The Strategy was intended to build on the progress made with environmentally-led regeneration brought about as part of the South Yorkshire Forest (1991-2016), which led to the planting 1 million trees, and over £32 million investment in community-led restoration programmes.

The Strategy sought to respond to a series of global and local challenges including climate change, inclusion, brownfield regeneration and wellbeing. The Strategy, which has been the subject of significant research and study[7,8] was arguably fairly successful in "supporting sustainable change within a resilient and biodiverse ecological network while helping to deliver social cohesion". The South Yorkshire GI Strategy identified individual and connected schemes described in the subsequent sections, and provided the framework for partnership support of these as well as other NBS in the neighbouring districts of Barnsley, Rotherham and Doncaster.

Sheffield Waterways Strategy and Action Plan

The Sheffield Waterways Strategy Group was formed in 2003, and is a long-standing partnership between voluntary sector groups and statutory organisations having an active role in the care and regeneration of Sheffield's various rivers, waterways and water bodies. The partnership group has together delivered many co-created NBS schemes. The Strategy,[9] accompanied by an action plan, proposed a vision that "By 2022 our rivers will once again be central in *Making Sheffield*, providing places where people choose to live, work and invest. Our watercourses and river corridors will be the defining features of a modern competitive, sustainable and attractive city, rich in wildlife and offering a wonderful quality of life to its residents, workers and visitors." The history of the Strategy's development, associated challenges, impacts and dissemination has been well documented elsewhere,[10,11] notably in an URBACT 'good practice' guide.

Sheffield City Region (SCR) Sustainable Urban Development (SUD) Strategy

Sheffield City Region's Sustainable Urban Development Strategy,[12] drafted by the author and Ben Morley (SCR), delivered significant investment in NBS as part of a wider transformational programme for green growth. It focussed on the provision of funding for 'whole-place low carbon' solutions and 'build-with-nature' approaches (NBS were not explicitly mentioned). A key strand of the Sustainable Urban Development (SUD) Strategy related to green investment coupled with brownfield regeneration, to address "specific issues faced by South Yorkshire particularly the legacy left by its industrial past".

This document met the EU's Structural and Investment Fund's local requirements for so-called Integrated Territorial Investment, or ITI for short. The SUD Strategy played an important role in securing resources for large-scale NBS demonstrators, to complement existing public sector schemes and interventions delivered by private investors. The result was the approval by the local and national government of calls for proposals for large-scale interventions,[13] with a total value of £7.5m. This was achieved by bringing together two thematic objectives (TOs) of the EU, namely on low carbon economy (T04) and climate change adaptation (TO5). By combining the different funding streams, the SUD enabled extensive NBS implementation schemes "integrating climate change mitigation and adaptation measures along with resource efficiency investment priorities". [12]

Meso-scale

Riverside parkways: blue-green corridors

Routes along Sheffield's network of river corridors, for pedestrians and cyclists, have long been an ambition in the city. Abercrombie's[14] 'civic survey' plan for Sheffield proposed a radial park system for Sheffield, based on a network of 'riverside parkways'. These linear parks would be established along the city's major watercourses, and the rivers Rivelin, Loxley, Don, Sheaf and Porter. This latter river, the Porter Brook, already had the makings of an inspirational case, which he called "the finest example in this country of a radial park strip, an elongated open space leading from a built-up part of the city direct into the country". The parallels with Ebenezer Howard's more famous Garden Cities are striking. Significant progress has been made to extend this network of 'blue-green corridors'. Major interventions, which variously sought to deliver several environmental, social and economic outcomes, include the Five Weirs Walk,[3,15] the Blue Loop linking with the Tinsley canal, and the Upper Don Trail. More recently, the Sheaf and

Porter Rivers Trust has sought to integrate a range of interventions with existing/partial riverside routes such as the Sheaf Walk.

Two connected NBS schemes provide a particularly useful illustration of the potential value and processes involved in creating these blue-green routes. The Wicker Riverside scheme involved the creation of a 'pocket park' at Nursery Street (funded by Yorkshire Forward and Interreg MARE project), connecting with a separate multi-functional intervention at Blonk Street (funded by the Interreg VALUE project). Both integrated flood risk management, access, river restoration and stewardship elements.[16,17] Together these two schemes linked up the Five Weirs Walk (which Blonk St completed) and the Upper Don Trail. Place-keeping approaches were pioneered by the River Stewardship Company, providing a mechanism for volunteering support and action in the form of habitat enhancement and maintenance, set up with a separate EU grant from the Creating a Setting for Investment project.[15,18] The sites were highlighted as priorities for action in the Breathing Spaces Programme, the GI Strategy and the Waterways Strategy.[2,4,9]

Micro-scale

Retrofitting sustainable drainage systems (SUDS)

The Grey to Green schemes are probably the most high profile NBS interventions in Sheffield. It has been called the UK's largest[19] and most successful[21] retrofit SUDS scheme. The approach combines various NBS in an attractive package, including sustainable drainage, urban tree planting, cyclepaths and walkways and other landscape improvements.[21] The first phase was completed in 2016, and cost £3.4m[22]; Grey to Green II cost over £5m.[12] In both cases came funding from the Sheffield City Region, Sheffield City Council and ERDF. Grey to Green II benefited from synergetic funding enabled by the SUD Strategy, providing for NBS addressing climate change adaptation and mitigation as well as brownfield regeneration.

Deculverting: daylighting and restoring buried rivers

Deculverting or daylighting can be defined as 'opening up buried watercourses and restoring them to more natural conditions'; to date, two Sheffield river daylighting projects have been completed and reported in the literature.[23,24] These two NBS projects were implemented in parallel, one being positioned in a central urban setting, the other in a borderline peri-urban/rural location. Pinkham describes the daylighting of culverted rivers as a 'radical expression' of river restoration.[25] Although still a relatively rare form of NBS, deculverting is receiving increasing international attention. This is perhaps because the problems associated with burying rivers in culverts – notably flooding, pollution and habitat loss – are becoming more prevalent or apparent. The two Sheffield daylighting schemes were funded by the EU SEEDS project, the Environment Agency and Sheffield City Council. The urban scheme, near the railway station, cost approximately ten times more than the rural project, to the West of the city.[17,24]

The costs of these daylighting projects were broadly in line with calculated mean costs reported[24] of 21,000 $/m for urban daylighting and ~6000$/m for non-urban schemes (2017 prices). However, culverts tend to cause greater problems in urban areas, and daylighting in urban areas arguably delivers wider benefits and values. The flood risks associated with culvert blockages, or rainfall events that quickly cause flows exceeding culvert capacities, can be expected to affect more homes and businesses than would be the case in non-urban locations. There is also

increasing evidence of the 'spikes' in ecosystem services that restoration schemes in urban areas can deliver; almost 80% of Europeans live in urban landscapes, which are the environments most people experience on a day-to-day basis.

Lessons learned and conclusions

- The more celebrated and pioneering NBS in Sheffield tend to relate strongly to historical development and deeply embedded challenges including environmental quality degradation, urban flood risks, and oversupply of brownfield land. These issues cannot be separated from extant socio-economic conditions and land-use dynamics, including property values and markets.
- South Yorkshire benefited significantly from EU funding for green infrastructure and Nature-Based Solutions, especially in relation to market-failure locations. It is not yet clear what will/ not replace those resources.
- Spatial planning has until now exhibited a relative high degree of connectedness across spatial scales of NBS implementation, and between different sectors as regards innovative approaches. However, in comparison with neighbouring cities such as Manchester, its global reputation in this field does not necessarily match this capacity or track record (which may reflect a commonly held view in the city that it is better not to shout too much about one's successes).
- The city's reputation for NBS type innovation is perhaps overshadowed by other areas of R&D such as advanced manufacturing and healthcare; its green credentials have undoubtedly been tarnished by some fairly high profile adverse cases.
- There is a risk that natural capital mapping and accounting approaches, using methods currently favoured in UK policy, may be insufficiently nuanced or sensitive to address critical, underlying socio-economic conditions and processes (e.g. highly- fragmented land-use and ownership patterns; divergent deprivation), undermining meaningful application in cities like Sheffield.

Projections and upscaling

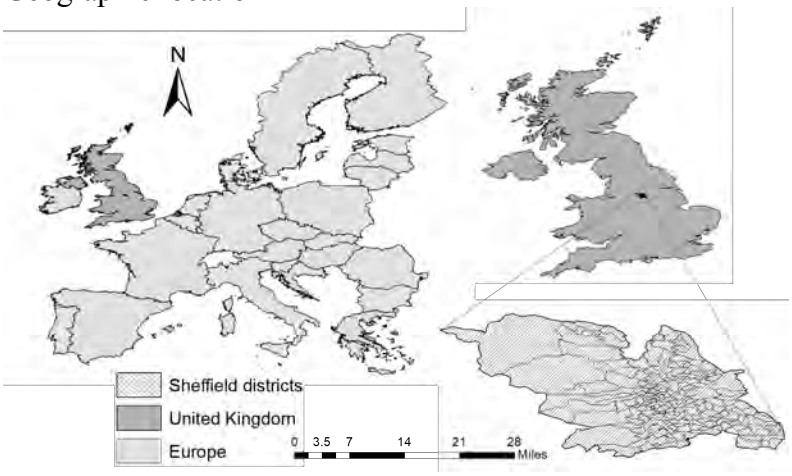
NBS implementation in Sheffield continues apace, being primarily focussed on SUDS, urban forestry and also natural flood management schemes in rural areas. NBS designed specifically for certain outcomes such as urban heat island and new urban food allotments are less common. Anecdotally, the rapid proliferation of green roofs that occurred in the city in the early 2000s and 2010s has slowed greatly, especially since the introduction of new national planning policy guidelines and relaxation of the planning conditions for most large new buildings to incorporate green roofs, although this may change with time. Extensive use and retrofitting of NBS can be anticipated in Sheffield's city centre linked with the £15.8m Future High Streets Fund and the Heart of the City II project. Tree-planting in the has received a boost through the Mayor's recent commitment to plant a million trees in the city region. It remains to be seen whether the proposed natural capital assessment provides a further impulse for the upscaling of NBS implementation.

Wider contextual information

General description
Core city: Sheffield
Biogeographic region: Atlantic
Location: Europe, United Kingdom
Area: 368.19 km^2

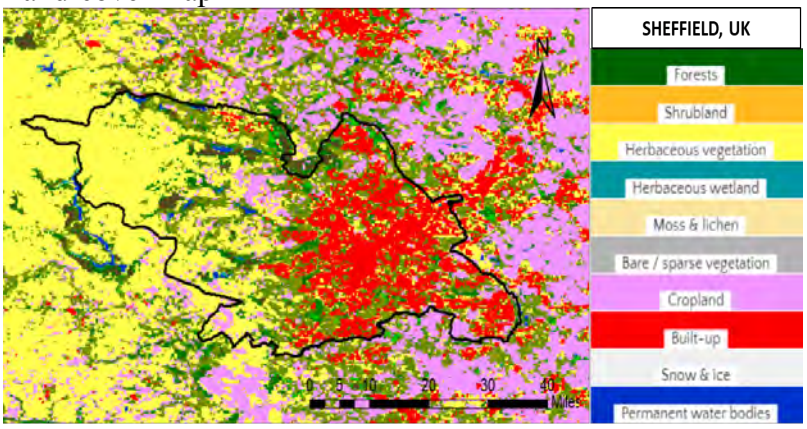
Population: 585.000 inhab.

Geographic location



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana

Land-cover map



Elaborated by: María Alejandra Cruz Suarez. Pontificia Universidad Javeriana, based on: Buchhorn, M.; Smets, B.; Bertels, L.; Lesiv, M.; Tsendbazar, N.-E.; Masiliunas, D.; Linlin, L.; Herold, M.; Fritz, S. (2020). Copernicus Global Land Service: Land Cover 100m: Collection 3: epoch <2019>: Globe (Version V3.0.1).

During the 18th to 20th centuries, the industrial revolution fuelled an almost tenfold increase in the city's population.[26] Industrialisation and urbanisation led to significant environmental quality degradation in the city and wider region. For instance, the main river in the region, the River Don earned the unenviable title of being one of Europe's most polluted rivers, until well into the 1980s.[27] River water quality had until recently been improving significantly[10] but recent analyses indicate that these trends may be reversing or at best slowing.[28]

Ironically, despite rapid urbanisation and heavy industrialisation, Sheffield always retained a reputation for having an attractive setting throughout its history, with beautiful countryside being visible throughout the city. In 1760, Horace Walpole wrote that Sheffield was: 'one of the foulest towns in England…' set 'in the most charming situation'.[26] Sheffield was always well known for its green areas and woodlands, which both surround and penetrate the city. This was formalised

in Abercrombie's civic survey and development plan,[14] which proposed protection and extension of the green corridors that span the city along its major urban rivers – effectively shaping development patterns up until present times –. Sheffield has 22% of its urban area classed as green space, making it the 6th greenest city in the UK.

Sheffield has a long history of environmental volunteering, partnership working and activism linked with ecological issues,[29] but its green city reputation was significantly tarnished by the street trees debacle during the last decade. [30,31]

The decline of steel manufacturing in Sheffield was accompanied by restructuring of the coal-mining industry throughout South Yorkshire. In 1984-85, disputes with trade unions culminated in the infamous 'Miners Strike'. These compounding factors led to the closure of many industrial sites in the sub-region, with massive losses in employment, and far-reaching effects for local families. Some major steel production sites and coal mines continued to operate, but many other sites became vacant and derelict, highlighting an urgent and extremely visible need for redevelopment and investment.

Nowadays, the city has a generally good reputation as a place to live, work and invest, and is growing with a predicted 5% population growth between 2016 and 2026,[32] which is a medium-high population growth rate by UK standards. However, socio-economic inclusion and skills gaps remain significant challenges in this part of England. At the time of writing, unemployment stood at over 6%, with claimant counts rising sharply since the Covid-19 pandemic, particularly amongst young people.[33]

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Websites of municipality and core organisations/programmes

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Biodiversity action plans: https://www.wildsheffield.com/wildlife/a-living-landscape/sheffield-local-biodiversity-action-plan/
Natural capital: https://sheffieldcityregion.org.uk/wp-content/uploads/2020/10/PS2021-027-Part-3-Specification-v1.0.docx.
Integrated Infrastructure Plan: https://sheffieldcityregion.org.uk/wp-content/uploads/2018/01/Integrated-Infrastructure-Plan_Executive-Summary.pdf
South Yorkshire forest: https://en.wikipedia.org/wiki/South_Yorkshire_Forest
URBACT good practice guide: https://urbact.eu/urban-waterways-strategy-action-plan
Fair Weirs walk: https://en.wikipedia.org/wiki/Five_Weirs_Walk
Blue loop: https://the-rsc.co.uk/riverlution/riverlution_projects/the-blue-loop-community-project
Upper Don trial: http://www.upperdontrail.org.uk/
Sheaf and Porter rivers trust: https://www.sheafportertrust.org/
Interreg MARE project: https://keep.eu/projects/6395/Managing-Adaptive-Responses--EN/
Interreg VALUE project:
https://www.sheffield.ac.uk/polopoly_fs/1.448529!/file/VALUE_water_output.pdf
River Stewardship Company: https://the-rsc.co.uk/
Naturvation: https://naturvation.eu/nbs/sheffield/grey-green-project
EU SEEDS project: https://keep.eu/projects/6383/Stimulating-Enterprising-Env-EN/
Mayor's recent commitment to plant a million trees in the city region:
https://www.danjarvis.org/my_policy_proposal_for_sheffield_city_region

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