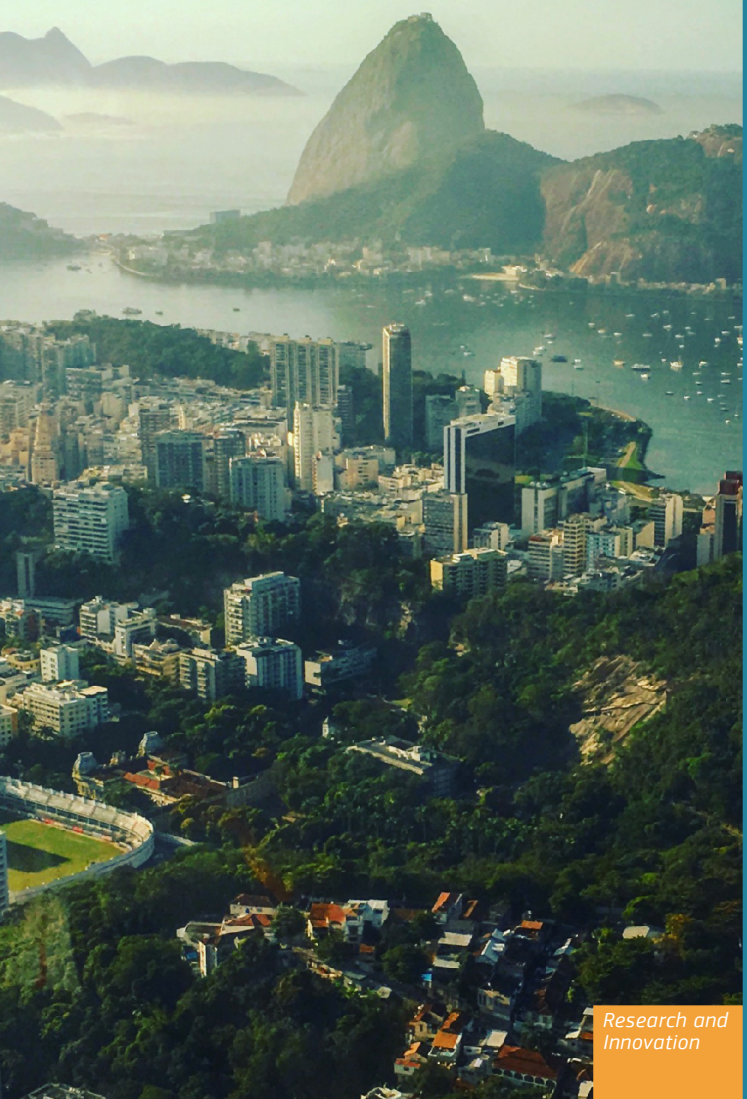
European Commission

The EU – Brazil Sector Dialogue on nature-based solutions

Contribution to a Brazilian roadmap on nature-based solutions for resilient cities



Written by Cecilia P. Herzog
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Research and Innovation

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EUROPEAN COMMISSION

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edited by Tiago Freitas, Guilherme Wiedman and Josefina Enfedaque

Authors: Cecilia P. Herzog and Carmen Antuña Rozado

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Abbreviations and acronyms

CEC	City of Edinburgh Council
CELAC	Community of Latin American and Caribbean States
GEF	Global Environmental Facility
GHG	greenhouse gas
H2020	Horizon 2020, the EU framework programme for research and innovation
HDI	human development index (UN)
IBGE	Brazilian statistical office
INEA	the Environmental Institute of the state of Rio de Janeiro
MCTIC	Ministry of Science, Technology, Innovation and Communication
MHDI	municipal human development index (UN)
NBS	nature-based solution(s)
NGO	non-governmental organisation
NUA	new urban agenda
R&I	research and innovation
SCI	Site of Community Importance (EU)
SCIO	Sustainable City Innovation Observatory
SDG	sustainable development goal
SUDS	sustainable urban drainage systems
UFF	Fluminense Federal University

Contents

Brazilian case studies

1 Foreword

In moments of unprecedented challenges, solutions often arise from dialogue and mutual learning. This is true for the European Union and Brazil, two regions with distinct socio-economic and environmental contexts but both facing global challenges such as climate change, biodiversity loss and unsustainable urbanisation.

Both UN intergovernmental panels, IPCC and IPBES, conclude that climate change and biodiversity loss are inseparable threats to humankind and must be addressed together. Nature-Based Solutions (NBS) are emerging as one of the most promising approaches to address both climate change and biodiversity loss, to achieve the objectives of the three Rio Conventions, and the 2030 Agenda for Sustainable Development. By bringing nature closer to people.

Four years ago, we started a dialogue with Brazil in which NBS were chosen as the theme that could benefit from transatlantic discussion. A Bilateral Agreement on Science and Technology between the EU and Brazil confirmed later on the importance of collaboration in key strategic areas such as sustainable urbanisation and NBS.

During the dialogue, hosted by the Brazilian Ministry of Science, Technology, Innovation and Communication, Brazilian and European experts collaborated to study the occurrence and potential of NBS in Brazil. They highlighted good practices in the EU for possible adaptation to the Brazilian context, and contributed to the elaboration of a NBS strategy in Brazil. An international seminar took place in Brasília in July 2018 with the support of the EU Delegation. For the first time, all major Brazilian stakeholders involved in NBS met with European experts and EU-funded Research and Innovation projects. Importantly for the implementation of these solutions, the Brazilian ministries of Cities, Environment, and Planning also joined the event.

European and Brazilian experts have built a body of knowledge demonstrating a strong case for how protecting and restoring nature can be a solution to social, environmental and economic challenges. You can find in this report 25 case studies from both sides of the Atlantic illustrating how nature can have a positive impact on people's lives. The Brazilian case studies span all regions and the country's most threatened biomes (the Atlantic Rainforest, the Cerrado, and the Amazon). The chosen examples address many challenges: from water management, to ecosystem restoration, urban heat island effect, floods, landslides or coastal erosion. They hence display how Brazil's mega-biodiversity could be the solution to a series of issues and provide inspiration to us all.

One of the main conclusions of this report is that NBS are not only economically smart investment choices, often much cheaper than technological solutions, but they can also enhance quality of life and provide an opportunity to shift to a new economy and a new lifestyle - more connected to nature. Biodiversity is not a problem, but a solution!

The EU is determined to support research and innovation to enable the transition towards a fair society within the limits of the planetary boundaries. Brazil is an important partner in such an endeavour, as it is a crucial country for any future scenario of the global environment. By connecting Europe's pioneering work with the Brazilian experience, the EU-Brazil Sector Dialogue on NBS provided key insights on how to unlock the potential of NBS. This dialogue can also inspire the broader Latin American region and other countries facing similar challenges in Africa and Asia. As the EU continues to fund research and innovation open to international cooperation, we hope to build on this dialogue for future collaborations on NBS, biodiversity and ecosystem services to accelerate and support the transition to a sustainable healthy planet operating within our shared planet's boundaries.

John Bell, Director

European Commission
Directorate-General for Research & Innovation
Directorate C – Healthy Planet

2 Key messages

- **Unsustainable urbanisation** has caused extensive landscape transformations, with a severe impact on the functioning of urban systems. Cities are threatened by **floods, landslides, droughts, water shortages, food insecurity, the urban heat-island effect,** and to make matters worse, the negative consequences of a fast-changing climate. This situation is urging decision-makers, researchers and practitioners to **search for innovations to respond to the new uncertain reality.**

- **Nature-based solutions (NBS)** have been implemented to **address urban challenges,** providing new **opportunities to regenerate urban systems** with the implementation of numerous projects at multiple scales worldwide.

- **NBS are supported and inspired by nature** and aim at enhancing **environmental processes and functions** to provide numerous **benefits for people.**

- Climate change, water scarcity, food insecurity, air pollution and urban heat islands are some of the issues affecting people's health and compromising quality of life in cities. **NBS** such as green corridors, water source restoration and river renaturalisation are viable options for **sustainable and resilient cities**. They help **achieve global agendas**, such as the sustainable development goals (SDGs), the new urban agenda (NUA) and disaster risk reduction.

- **NBS** are not only **smart investment** choices but also a means to **enhance the quality of life and well-being** of residents whilst contributing to improved social cohesion and decreasing urban inequality.

- In order to **accelerate the development of NBS in Brazil**, it is important to recognise them as an **opportunity to shift to a new economy and a new lifestyle more connected to nature and natural processes**, based on **natural capital.**

- NBS require **multiple stakeholders** to be involved in planning, design, implementation, management, maintenance and monitoring.

- NBS are **place-based**, can mobilise **local knowledge** and, through **co-designing and co-implementing**, they can have positive effects on **social inclusion**.

- NBS can be **high-tech** or **low-tech**. Different solutions can be developed on the spot without the need for expensive technology coming from elsewhere.
- Investment in **research and innovation (R&I)** is key to **developing and adapting solutions for each context**.
- **Cases studies** already implemented in European and Brazilian cities are not only inspiring, but could be **adapted** and **replicated to address multiple issues.**
- Brazil has the opportunity to **export its know-how** for the solutions applied under its unique circumstances to **other countries** with similar (climate/urbanisation) conditions.
- There are vast **opportunities for the EU and Brazil to cooperate** in this ground-breaking field of **knowledge and practice**, through **policies** that can induce the **urban transformation** so urgently needed; affordable and locally adapted technology solutions; planning and decision support tools; new business models and financing instruments; adequate governance; transparent and fair processes to guarantee the participation of all stakeholders; monitoring tools and key performance indicators.

3 Introduction

More than half of the world's population is concentrated in cities. In Brazil, more than 85 % of inhabitants live in urban areas that continuously expand over ecosystems and agricultural regions, very often at the expense of the best soil for food production, as is the case in many cities in the world. In most cases, the landscape and its natural processes and flows are not taken into consideration in urban planning and design. 'Urban sprawl is defined as a low-density and land-consuming urban expansion' [1]. In the process of urbanisation, soil is sealed for the development of residential, commercial and industrial areas and 'grey' infrastructure (mainly car-oriented roads and car parks). Also, rivers and creeks disappear underground or are canalised, with profound transformation of the local and regional environment. The impacts are numerous, for instance: more frequent and worse floods and landslides; urban heat-island effect; air, water and soil pollution; loss of biodiversity and peri-urban agricultural areas and dryer air reaching desert moisture rates [2]. Human health [3] has a close relationship with environmental conditions, thus people suffer a myriad of physical, psychological and spiritual problems in densely urbanised and impervious areas. Those problems are aggravated by climate change, biodiversity depletion, potable water scarcity, healthy food insecurity and loss of fertile soil.

What are Nature-Based Solutions?

The EU defines Nature-Based Solutions as solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits, and help build resilience. Such solutions bring more and more diverse nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions.

1. Science for environment policy — In-depth report — Soil sealing, p. 7. Available at: http://ec.europa.eu/environment/archives/soil/pdf/sealing/Soil %20Sealing %20In-depth %20Report %20March %20version_final.pdf
2. Air moisture reached as low as 5 % in Pires do Rio, and 7 % in Goiânia on 12 August 2018. Both cities are located in the state of Goiás, Brazil. https://g1.globo.com/go/goias/noticia/2018/08/13/goias-registra-menor-umidade-do-ano-de-5-e-inmet-divulga-alerta-de-emergencia-para-o-estado.ghtml
3. http://www.who.int/globalchange/ecosystems/urbanization/en/

Over the last few decades, urban planners and designers have taken a new approach to transforming grey-paved, mono-functional areas into spaces that offer manifold benefits for people, with biodiversity providing multiple ecosystem services. NBS have been developed around the world to address the abovementioned contemporary challenges and enhance the quality of urbanised areas, and therefore the well-being of their citizens.

Adopting ecosystem principles as the basis of their design, NBS are inspired and supported by nature and aim to regenerate and restore natural processes and flows, improving the urban environment at multiple scales [4] — from buildings or plots, including neighbourhoods or districts, to cities and beyond (Figure 1) [5]. As an example, cities depend on watersheds for their water supply. They are cost-effective and offer numerous social and economic co-benefits, such as the creation of green jobs. For instance, during the recession in the EU (2007-2011), jobs related to the environment and clean energy increased by 20 % [6]. NBS aim to contribute to building urban sustainability and resilience, enhancing quality of life and well-being in healthier cities.

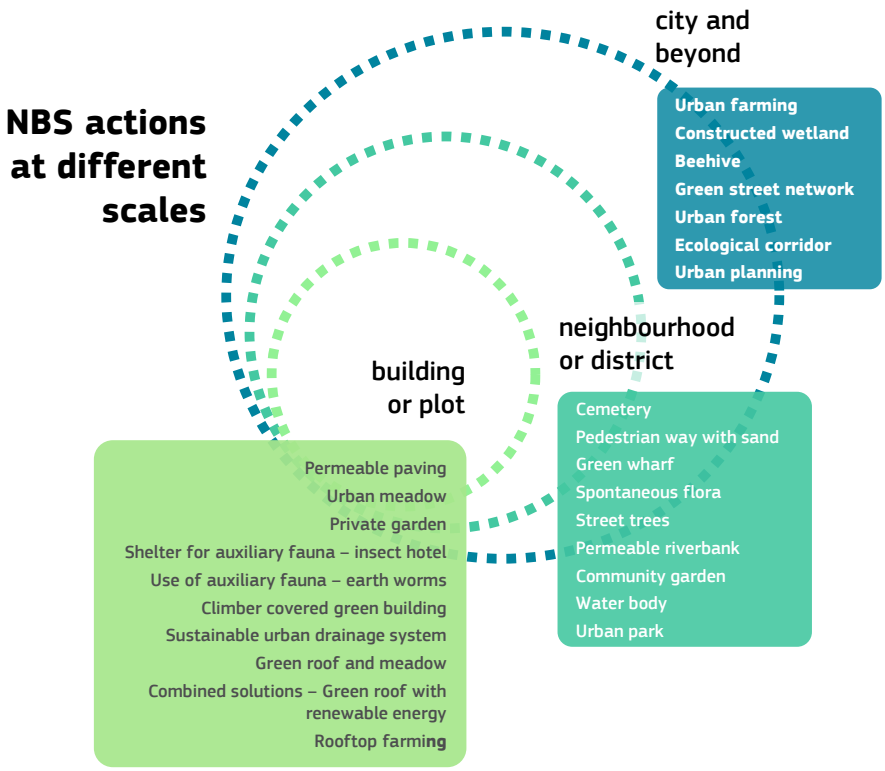

Figure 1. NBS actions as defined by EU H2020 research project Nature4Cities.

4. http://growgreenproject.eu/wp-content/uploads/2018/05/NBS-Climate-Adaptation-Basque-Country.pdf
5. https://www.nature4cities.eu/nature-based-solutions
6. https://ec.europa.eu/research/environment/index.cfm?pg=nbs

NBS offer opportunities to develop innovative solutions and thus create new scenarios for economic and social development with the reintroduction of nature into cities at multiple scales, protecting remnants of ecosystems and other green areas to provide explicit ecosystem services and all the related co-benefits. New ecosystem-based technologies adapted to local and regional contexts are already being planned, designed and implemented in many cities around the world, and the results can be measured by the fast pace of new printed and online publications, reports and manuals that are being produced in all continents. A good example of this is the Methodological guide on NBS for local climate adaptation in the Basque Country (Spain) [7], which was developed to provide local authorities with an easily replicable, consistent methodology for the identification and selection of NBS to be implemented as locally attuned climate change adaptation measures (Figure 2). Furthermore, virtual hubs like Oppla [8] gather the latest knowledge and good practices on NBS and make them easily available online to the wider community. In addition, there is a lot of potential for replicability and scalability of NBS through joint research and collaboration across countries and regions.

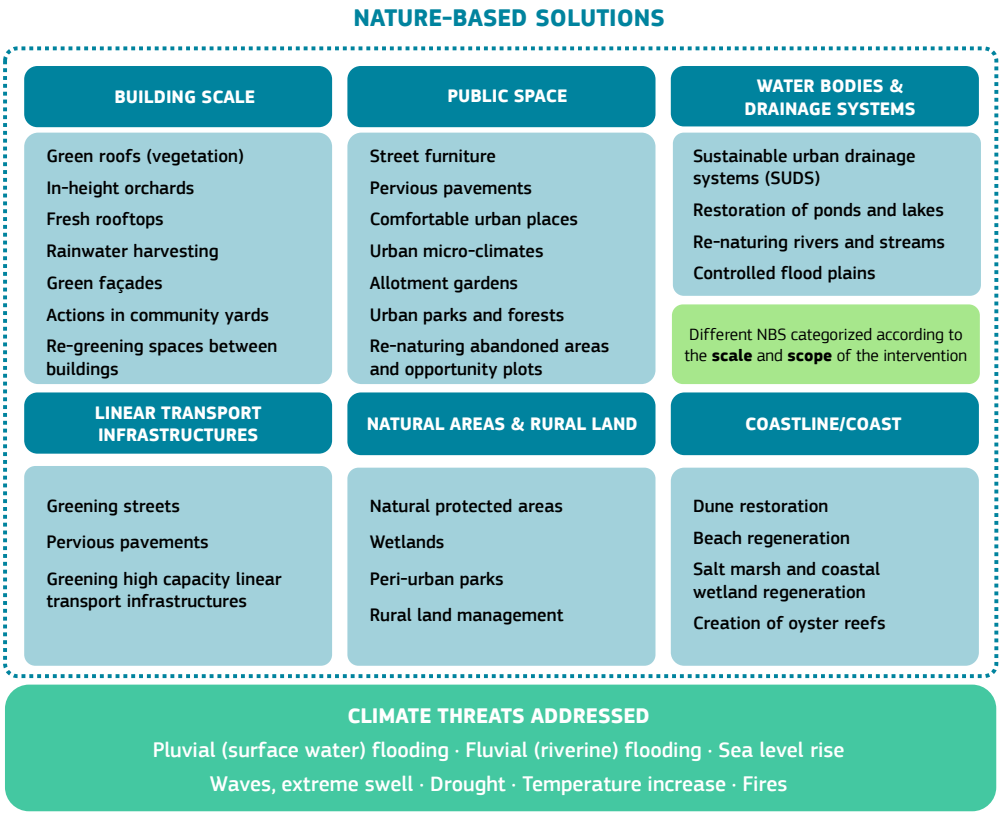

Figure 2. Classification of NBS proposed by the Methodological guide on NBS for local climate adaptation in the Basque Country.

7. http://growgreenproject.eu/wp-content/uploads/2018/05/NBS-Climate-Adaptation-Basque-Country.pdf
8. https://oppla.eu/

Concerning collaboration between the EU and specific countries, the EU–Brazil Sector Dialogues are a facility created to support the exchange of knowledge and best practices in relation to topics of common interest. The exchange can happen at a technical or political level (or both) and takes the form of regular meetings and joint activities in various domains. NBS is one of the topics of common interest where the EU and Brazil have identified plenty of opportunities for fruitful collaboration towards the achievement of their strategic objectives in relation to sustainable development and urbanisation, which in turn are in line with the international framework established by the SDGs and the NUA.

In Brazil, the Ministry of Science, Technology, Innovation and Communication (MCTIC) has created the thematic programme of technologies for sustainable cities [9], which aims to support cities in their transition towards more sustainable development with incentives for innovation and technologies in several fields. The strategies of the programme include as focal themes NBS, biomimicry and urban metabolism.

A first EU–Brazil Sector Dialogue on NBS was completed in 2016: '**Innovating cities with nature-based solutions: co-creating knowledge on nature-based solutions with EU–Brazil Sector Dialogues**'. It provided a framework for identifying and assessing NBS as well as defining future topics for collaboration. This dialogue focused on the conceptualisation of social and governance functions attached to NBS, as part of which a comparative analysis of governance structures in the EU and Brazil was carried out. This paved the way for further exchange also involving cities in the EU and Brazil to continue enlarging the knowledge and good practices related to NBS.

The present report outlines the main conclusions of the second EU–Brazil Sector Dialogue on NBS that took place in 2017 and 2018. This dialogue deepened the analysis of the previous one to cover other important aspects, particularly focusing on how to harness the Brazilian potential for NBS and how the EU's experience can contribute to accelerating the process. The report also maps relevant examples of successful NBS recently implemented or under development in both the EU and Brazil, with a special emphasis on their potential for replicability, scalability and adaptation to the local context. As a result, common R&I agendas for cooperation have been identified.

The EU experience and framework for collaboration on NBS

The EU is at the forefront of investing in a green economy and aims at becoming a leader in innovating with nature [10]. To that end, in 2016-2017 alone around EUR 120 million was invested in R&I activities for more sustainable and resilient societies both in cities and in rural areas. Such investments are in line with the present EU R&I policy agenda on nature-based solutions and renaturing cities, which focuses on two main thematic areas — renaturing cities and territorial resilience — but also includes relevant crosscutting issues like climate change adaptation and mitigation, and risk management. The EU R&I policy agenda on NBS is implemented mainly (but not exclusively) through Horizon 2020 (H2020), the EU framework programme for research and innovation.

As an example of the EU's efforts to promote NBS, H2020 call SCC-2016-2017 'Smart and sustainable cities' has provided grants to fund eight projects

9. Administrative measure (Portaria) MCT nº292/2010.
10. https://ec.europa.eu/research/environment/index.cfm?pg=nbs

Call Topic SCC-02-2016-2017

Demonstrating innovative nature-based solutions in cities

Project name	EU contribution (in EUR)
2017-2022	
Connecting Nature	11 394 282
GrowGreen	11 224 058
UNaLab	12 768 932
URBAN GreenUP	13 970 642
2018-2023	
CLEVER Cities	14 214 661
EdiCitNet	11 254 913
proGIreg	10 432 512
URBiNAT	13 019 300
Total EUR	**98 279 300**

Call Topic SCC-03-2016

New governance, business, financing models and economic impact assessment tools for sustainable cities with nature-based solutions (urban re-naturing)

Project name	EU contribution (in EUR)
2016-2020	
NATURVATION	7 797 878
Nature4Cities	7 499 981
Total EUR	**15 297 859**

Call Topic SC5-09–2016

Operationalising insurance value of ecosystems

Project name	EU contribution (in EUR)
2016-2019	
NAIAD	4 994 370

Call Topic SC5-08–2017

Large-scale demonstrators on nature-based solutions for hydro-meteorological risk reduction

Project name	EU contribution (in EUR)
2018-2023	
PHUSICOS	9 472 200
RECONECT	13 520 690
OPERANDUM	12 257 343
Total EUR	**35 250 233**

Other research projects funded by other calls

Project name	EU contribution (in EUR)
EKLIPSE, 2016-2020	2 997 271
ThinkNature, 2016-2019	2 974 164
BiodivERsA3, 2015-2020	11 988 018
ESMERALDA, 2015-2018	3 002 166
INSPIRATION, 2015-2018	2 598 761
Total EUR	**23 560 380**

Figure 3. European research projects on NBS or closely related aspects funded by H2020.

that are currently ongoing, under the topic **'Demonstrating innovative nature-based solutions in cities' (SCC-02-2016-2017)**, with a total budget close to EUR 100 million. Similarly, another two projects have been funded under the topic **'New governance, business, financing models and economic impact assessment tools for sustainable cities with nature-based solutions (urban renaturing)' (SCC-03-2016)**, with a total budget of over EUR 15 million [11]. Other H2020 calls have also addressed various aspects closely related to NBS (see Figure 3).

It is important to highlight that since H2020 is 'open to the world'[12], applicants from non-EU countries are usually free to participate even if this is not explicitly stated by the call or topic. Moreover, some calls target cooperation with non-EU partners from a specific region, e.g. H2020 call topic '**Strengthening international cooperation on sustainable urbanisation: nature-based solutions for restoration and rehabilitation of urban ecosystems**' (SC5-13-2018-2019) [13], in which one of the subtopics is precisely targeting collaboration between the EU and the Community of Latin American and Caribbean States (CELAC). In short, H2020 offers opportunities for both collaborative R&I projects and individual research projects (mainly funded by the European Research Council and Marie Skłodowska-Curie actions). However, not all international partners are automatically eligible for funding. While the EU will finance the participation of partners from developing countries, it does not automatically fund the partners from industrialised countries in collaborative actions [14].

In the particular case of Brazil, it being considered an industrialised country, individual Brazilian researchers are always eligible for EU funding under the Marie Skłodowska-Curie actions individual fellowships [15]and under the European Research Council programme [16]. For collaborative actions, Brazilian participants have to determine the sources of funding and resources for their part of the project themselves: these may be own funds of the participating institutions or funds received from Brazilian ministries, foundations and other research organisations. In-kind contribution is also accepted [17].

At this point, it is necessary to highlight the fact that, although sustainable urbanisation is amongst the current priorities for EU–Brazil cooperation, Brazilian participation in the projects mentioned in Figure 3 is almost insignificant. There is considerable room for increasing such participation and, as this report shows, there are plenty of reasons to do so. Not only should universities and research organisations be encouraged and provided with the means to engage in collaborative research with EU counterparts, but also — indeed especially — Brazilian cities, so that they can benefit directly from this collaboration.

Finally, it should be stressed that, even though NBS is an emerging field, in the EU it capitalises and builds on the findings and the knowledge developed by past (and present) research carried out in closely related areas like biodiversity and ecosystem services, sustainable urban development, natural resource management, climate change mitigation and adaptation and disaster risk reduction. Taking inspiration from these areas allows for a faster advancement of NBS in the EU, particularly in terms of developing adequate assessment frameworks and business models, which are so important in quantifying (and therefore justifying) the benefits and co-benefits of NBS and financing their implementation. As a result, the EU is an attractive partner that

11. https://cordis.europa.eu/home_en.html
12. http://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/international-cooperation_en.htm
13. http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/sc5-13-2018-2019.html

can bring added value for other countries and regions around the world interested in collaboration around NBS. To illustrate this, this report includes a selection of successful EU examples of NBS implementation at different scales and in various geographical locations across the EU (see Figures 5 and 6 and further information in the case studies chapters). This selection is by no means exhaustive, since many other EU cities also have interesting NBS initiatives to show.

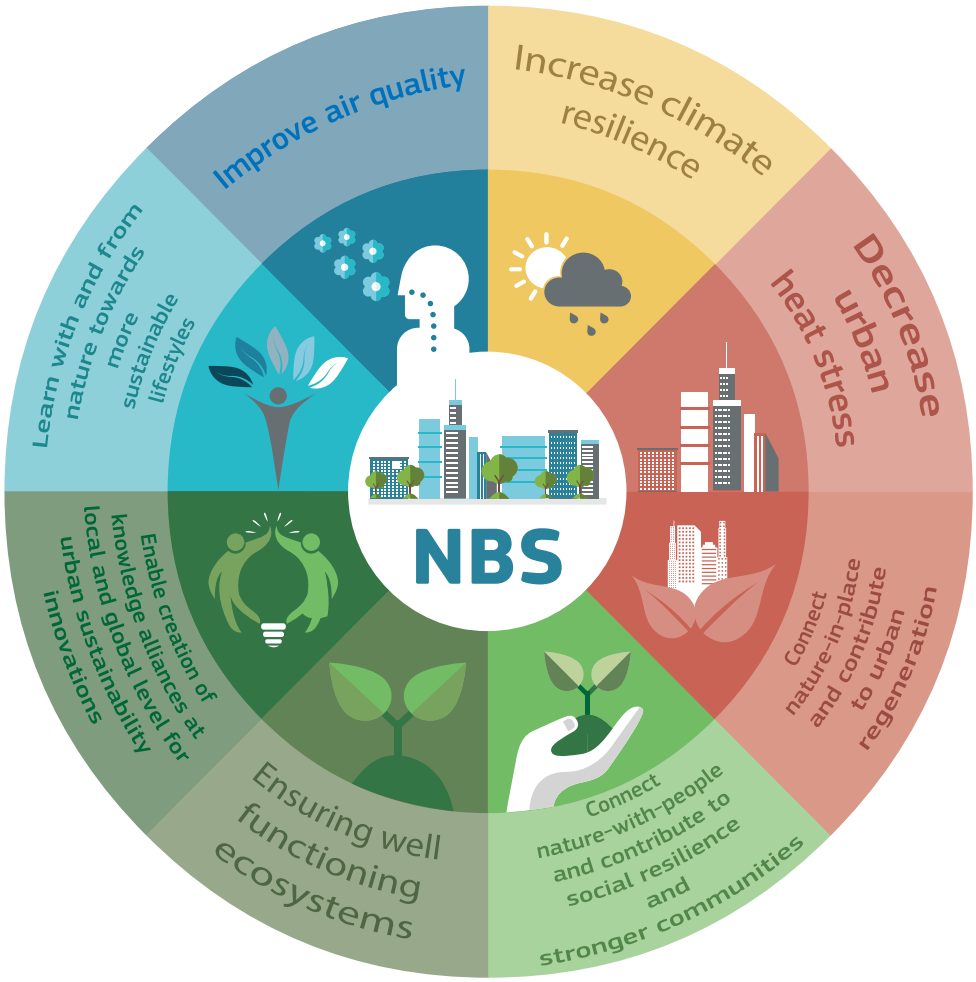

Figure 4. Examples of the multiple benefits provided by NBS.

14. http://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/3cpart/h2020-hi-3cpart_en.pdf
15. https://ec.europa.eu/research/mariecurieactions/actions/individual-fellowships_en
16. https://erc.europa.eu/
17. http://ec.europa.eu/research/participants/data/ref/h2020/other/hi/h2020_localsupp_brazil_en.pdf

Figure 5. Map showing the geographical location of the selected examples of NBS implemented in the EU.

European examples of NBS

1. Vuores eco-efficient district (Tampere, Finland)

2. The Field Duddingston, community work (Edinburgh, UK)

3. Bosco Verticale in Porta Nova neighbourhood (Milan, Italy)

4. Corredor Verde Monsanto (Lisbon, Portugal)

5. Increasing biodiversity (Eindhoven, the Netherlands)

The cases featured cover a wide array of NBS (storm water retention ponds, urban food production, green façades and roofs, green corridors, etc.) for different scales in very different contexts across Europe. From Tampere in the North to Lisbon in the South.

6. Former Gavoglio barracks to be transformed into a park (Genoa, Italy)

7. A leading example in sustainable development (Freiburg, Germany)

8. Salburua Ramsar wetland. Green Belt (Vitoria-Gasteiz, Spain)

9. Templehof, the former city airport turned into a park (Berlin, Germany)

10. NBS for stormwater management and flooding risk reduction (Copenhaguen, Denmark)

The cases featured here show the use of NBS for different purposes like the regeneration of degraded areas, stormwater management and flooding risk reduction, etc. But also the inspiring example of world's pioneer cities in environmental protection and sustainable development.

Figure 6. Some successful examples of NBS implementation in the EU.

4 Harnessing Brazilian potential

In Brazil there is federal legislation that aims to protect existing natural remnants, such as the Forest Code [18] and the National System of Nature Conservation Units [19]. States and municipalities have their own environmental legislation, and, in each case, the most restrictive act is the one that must be applied. Some cities in Brazil already have their own laws on urban greening, mainly green roofs, pervious areas, water harvesting and tree planting, such as Goiânia (Goiás)[20]; Canoas (Rio Grande do Sul)[21]; Recife (Pernambuco)[22]; Salvador (Bahia)[23] and Guarulhos (São Paulo)[24].

Brazil could lead and stimulate other Latin American countries with examples of national, regional and local policies that incorporate NBS to address critical issues that affect urban system functionality. In this manner, the whole region could prepare and adapt urbanised areas to climate change impact, building urban resilience to threats such as floods and landslides, the urban heat-island effect worsened by heatwaves (both local and global) and human health affected by air, water and soil pollution. Brazil could also focus on the development of nature-based urban technologies that may be applied in countries with similar climates, socioeconomic conditions and cultures.

In Brazil, NBS have shown how to solve multiple challenges at the same time. Some examples are the renaturalisation of rivers with greenways, rain gardens and bio-swales, green roofs and walls, biological waste-water treatment[25] (Figure 7), urban forests, detention and retention naturalised basins (wetlands) to treat diffuse pollution and pervious pavements. To illustrate this, a selection of Brazilian case studies is shown alongside this report (see annexes).

Urban living labs are taking place in some Brazilian sites with designing and testing, with community co-creation, are introducing 'learn-by-doing' NBS that aim to transform the mono-functional urban landscape. The results are encouraging and the labs are already offering multiple benefits for people in a more sustainable and resilient city (see São Paulo case studies).

The process of co-creation in urban living labs should be incentivised and extended to scale up, replicate, stimulate partnerships, create instruments of multi-governance to ensure the continuity of the programme or project, and formalise community projects and co-creation methods with instruments to transition to cities that are able to address contemporary challenges.

18. Código Florestal Brasileiro — Lei 12.727/2012.
19. Sistema Nacional de Unidades de Conservação da Natureza (SNUC) — Lei nº 9.985, de 18 de julho de 2000.
20. Lei Complementar Nº 235, de 28 de dezembro de 2012. Available at: https://www.goiania.go.gov.br/html/gabinete_civil/sileg/dados/legis/2012/lc_20121228_000000235.htmlviewed: 20.8.2018.
21. Avaliable at: https://leismunicipais.com.br/a/rs/c/canoas/lei-ordinaria/2014/584/5840/lei-ordinaria-n-5840-2014-dispoe-sobre-a-criacao-de-telhados-verdes-e-seus-criterios-tecnicos-especificados-nesta-lei-e-da-outras-providencias, accessed: 20.8.2018.
22. Available at: https://leismunicipais.com.br/a1/pe/r/recife/lei-ordinaria/2015/1812/18112/lei-ordinaria-n-18112-2015-dispoe-sobre-a-melhoria-da-qualidade-ambiental-das-edificacoes-por-meio-da-obrigatoriedade-de-instalacao-do-telhado-verde-e-construcao-de-reservatorios-de-acumulo-ou-de-retardo-do-escoamento-das-aguas-pluviais-para-a-rede-de-drenagem-e-da-outras-providencias, accessed: 20.8.2018.
23. Avaliable at: https://www.sefaz.salvador.ba.gov.br/Documento/ObterArquivo/1544, accessed: 20.8.2018.
24. Avaliable at: https://leismunicipais.com.br/a/sp/g/guarulhos/lei-ordinaria/2010/680/6793/lei-ordinaria-n-6793-2010-dispoe-sobre-o-lancamento-arrecadacao-e-fiscalizacao-do-imposto-sobre-a-propriedade-predial-e-territorial-urbana-iptu-e-da-outras-providencias?q=6.793 %2F2010, accessed: 20.8.2018.
25. http://www.osaqua.com.br/2016/06/22/ete-ponte-dos-leites-ganha-premio-firjan-de-acao-ambiental/

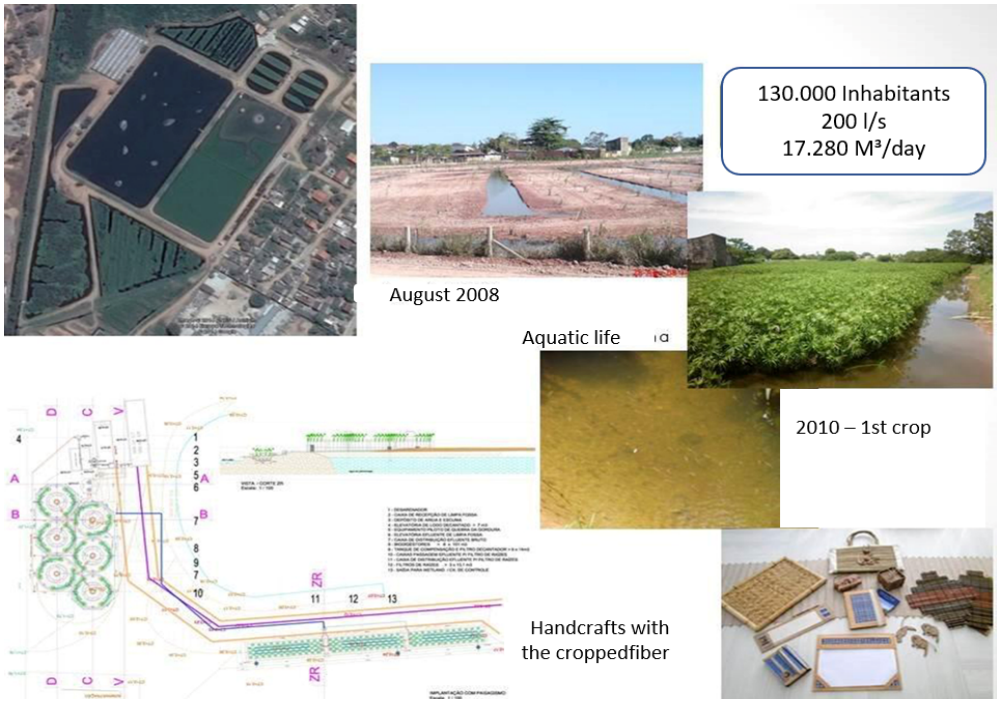

Figure 7. Biological wastewater treatment plant for 120 000 inhabitants in the city of Araruama, Rio de Janeiro. Treatment capacity: 200 litres/second; area: 6.8 hectares; wetland was implemented in 2009. It is a circular system that filters polluted water with macrophyte vegetation, and enhances biodiversity (fauna and flora), and offers economic development to local residents. It is an award-winning project.

Brazilian examples of NBS and the global agendas

In the context of the huge social, ecological and economic challenges that we are facing as we reach our planetary boundaries [26], several United Nations platforms have set global agendas to orient policies in many countries, regions and cities. Brazil, as a signatory of those agendas, must meet the objectives of the SDGs, the NUA (Habitat III) and the Sendai framework for disaster risk reduction, amongst others.

NBS is often associated with SDG 11 **'Sustainable cities and communities'** because the enhancement of ecosystems in urban areas offers multiple benefits that are vital for sustainable and resilient cities, as seen above. However, precisely because of those multiple benefits mentioned, NBS can consistently contribute to the achievement of other SDGs in the following manner.

- **Reconnect people to food sources** through organic urban agriculture — permaculture and agro-ecology (see Brazilian Case Study 14). Provide organic food, including native fruits (see Figure 8) and at the same time contribute to the restoration of ecosystems (with the implementation of agro-ecological urban food production) that are essential to water in peri-urban areas producing food, which in turn contributes to protecting and increasing water sources (SDG 2 'Zero hunger').
- **Enhance people's health** in many ways: cleaning up air, water and soil pollution; offering spaces for recreation, exercise, relaxation, spiritual health and well-being[27] and direct contact with nature (SDG 3 'Good health and well-being').

Re-discovering and harnessing the potential of native fruits

Native fruit trees from the Atlantic Rainforest (*Mata Atlântica*) have disappeared from most of their historical range due to the expansion of urban areas. Nowadays endangered and barely known to the urban populations, these species are being re-introduced in cities such as São Paulo and Rio de Janeiro, in pocket forests or urban agriculture projects (see case studies Araucárias and Corujas squares, or the Rio de Janeiro Green Corridor). The rich Brazilian biodiversity is an opportunity for more diverse and multi-beneficial Nature-based Solutions, including food production. These solutions can in turn contribute to raising awareness on the conservation and sustainable use of native fruit species.

Figure 8. Native fruits in Brazilian nature-based solutions.

26. Rockström, J. et al., 'Planetary boundaries: exploring the safe operating space for humanity', Ecology and Society, Vol. 14, No 2, JSTOR, 2009. www.jstor.org/stable/26268316

- Increase the **production of water** for the population in cities and peri-urban areas by protecting and planting forests and other ecosystems (see Brazilian Case Study 1); contribute to **improving water quality** by retaining and filtering contaminated storm water run-off, and biologically treat waste water in plants that apply NBS (see Brazilian Case Study - 9) (SDG 6 'Clean water and sanitation').

- **Save energy** using passive features (e.g. shading) and the evapotranspiration of trees, or other solutions like green roofs and walls (see Brazilian Case Study 15). All these can be successfully combined with renewable energy sources thus contributing to **climate change mitigation** and a **healthier indoor environment**. (SDG 3 'Good health and well-being'; SDG 7 'Affordable and clean energy'; SDG 13 'Climate action').

- **Provide green jobs** to research, plan, design, implement, manage and monitor green areas (SDG 8 'Decent work and economic growth') (see Brazilian Case Study 3).

- **Boost a green economy** focused on natural capital, creating an innovative industry related to NBS and green infrastructures that offer multiple benefits for all living organisms (SDG 9 'Industry, innovation and infrastructure') (see Brazilian Case Studies 6, 7 and 10).

- Contribute to **reducing inequalities and improving social cohesion**, generating a fairer urban environment and **jobs for all residents** (SDG 10 'Reduced inequalities') (see Brazilian Case Studies 1, 2 and 3).

- **Mitigate greenhouse gas (GHG) emissions**, with the enhanced urban forest as carbon sink, and adapt cities for climate change impact, reducing risks related to weather events (SDG 13 'Climate change') (see Brazilian Case Study 3).

- **Protect watercourses and the sea** from polluted storm-water run-off from paved surfaces by introducing riparian corridors, coastal ecosystems and other NBS components that retain, detain and filter the contaminants that pollute and affect life below water (SDG 14 'Life below water') (see Brazilian Case Studies 3, 7, 8, 10 and 11).

- NBS in cities are important not only for the ecosystem services they provide, but also for **connecting people with nature** and nurturing all forms of life through a systemic understanding of the role of forests and ecosystems on earth, and enabling inhabitants to raise children who care about biodiversity conservation (SDG 15 'Life on earth').

- The development and effective implementation of NBS require the participation of **multiple stakeholders** and can certainly benefit from collaboration across countries and regions to exchange experiences and co-develop new knowledge (this EU–Brazil study is an example), as well as from the establishment of **long-term partnerships and commitments** (SDG 17 'Partnerships for the goals').

27. Hawks, S. R., Hull, M. L., Thalman, R. L. and Richins, P. M., 'Review of spiritual health: definition, role, and intervention strategies in health promotion, American Journal of Health Promotion, Vol 9, No 5, pp. 371-378.

- NBS enabling people living in cities to have direct contact with nature by providing public green and natural spaces for recreation and other purposes can help them better understand the cycles of life and possibly inspire them to make more responsible consumption choices. NBS can contribute, implicitly or explicitly (for example in the case of brownfield areas and derelict landscapes being transformed into educational parks), to raising the awareness of the population on the importance of **adopting more sustainable lifestyles.** (SDG 12 'Responsible consumption and production').

The NUA appears in a global context where, even though they occupy only 2% of the total land, cities are responsible for over 60% of global energy consumption, 70% of GHG emissions and 70% of global waste, while generating 70% of the global GDP[28]. NBS can contribute to the achievement of the new standards for sustainable urban development set by the NUA. NBS offers a plethora of opportunities to transition to a new urban environment that is people-centred, protects remnants of ecosystems and reintroduces nature in cities (green infrastructure, water source restoration and other NBS components) as the foundation of a more sustainable and equitable society where all citizens have access to basic services and equal opportunities as envisioned by the NUA. Apart from the abovementioned links to the SDGs, which are also in line with the objectives of the NUA, NBS can strengthen the resilience of cities thus minimising the impact of natural climate-related disasters [29].

28. http://habitat3.org/the-new-urban-agenda/
29. https://www.un.org/sustainabledevelopment/blog/2016/10/newurbanagenda/

Figure 9. Map showing the geographical location of the selected case studies of NBS implemented in Brazil.

All case studies can be found in Oppla,
the EU repository of nature-based solutions:
https://oppla.eu/nbs/brazil

Brazilian examples of NBS

1. Campinas: several initiatives

2. Curitiba: several initiatives

3/8/15. Rio de Janeiro: Mutirão Reflorestamento, Green Corridor and Favela Green Roof

4. Brasília: Serrinha do Paranoá waters project.

5/12/13/14. São Paulo: Jaguaré Creek, Spring's Park, Rain Garden and Pocket Forest, Owls Square Food Garden

6. Niterói: Piratininga Lagoon

7. Recife: Antonio Maria Square

9. Petrópolis: Waste-water treatment

10. Benevides: Ecopark Natura

11. Cabo Frio: Seashore ecosystem restoration

Figure 10. Some successful examples of NBS implementation in Brazil. More information can be found in the Brazilian case studies section .

Stakeholder involvement

In order to properly design policies for NBS, it is important to have scientific evidence and data on geo-biophysical (ecological/natural) and sociocultural (human) processes, flows and interactions. Urban ecology is a field of knowledge that is the foundation for contemporary and innovative strategic landscape planning and design. Ecological engineering, urban planning and landscape architecture play crucial roles in this new paradigm of the nature-based planning and design of green infrastructures and other types of solutions to our vital challenges.

Multi-stakeholder co-creation is decisive in the development of systemic, holistic, inclusive and sustainable practices and policies that enable cities to build resilience, adapt and prepare for climate-change challenges.

Figure 11. Community planting, 16.12.2017, the first rain garden in a Brazilian city, in a central area in São Paulo. A learn-by-doing experience. (Brazilian Case Study 13).

NBS may involve multiple stakeholders depending on the context and the scale. Besides academy and research organisations, all levels of public administration, NGOs (non-governmental organisations), grassroots movements, organised civil society entities (e.g. residents', commercial, and industrial associations), financial institutions and international organisations are some of the actors that may participate in the development of NBS.

Innovative landscape architecture and design companies that have developed nature-based technologies in many countries are already working in Brazil. For instance, three case studies in this report demonstrate how a French leader in NBS is participating, with the provision of technologies adapted to the Brazilian contexts (see Brazilian Case Studies 6, 7 and 10). Others, including several Brazilian businesses (e.g. landscaping companies), are prospecting for new opportunities to adapt their nature-based technologies to local contexts. National and international governmental and non-governmental institutions such as the Global Environmental Facility (GEF), Local Governments for Sustainability, 100 Resilient Cities (funded by the Rockefeller Foundation), the Nature Conservancy — Cities, Conservation International and The German Society for International Cooperation, contribute to enabling local administrations to act with tools and methodologies that support the development of tailor-made solutions for local challenges.

In Brazil, the MCTIC has the ability to work in an inter- and trans-disciplinary manner, very much acting as an intermediary agent. The MCTIC is in charge of developing the NBS agenda for Brazilian cities, integrating other ministries that focus on different areas: cities, planning, and environment. As concluded by the previous

EU–Brazil Sector Dialogue on NBS, establishing political commitment and empowering intermediary agents at all levels are essential governance functions for the uptake and integration of NBS in cities.

Developing knowledge and culture for NBS

NBS as means to prepare and adapt cities for contemporary challenges should be a priority for R&I in Brazil. There are new and innovative NBS that are being developed in many cities around the world. Numerous cities already have policies to guide the urban transformation, such as Freiburg, Germany (which was a pioneer in innovative sustainable urban technologies) [30]; Berlin, Germany[31]; Portland, United States [32]; New York, United States [33]; Paris, France [34]; Singapore [35]; Medellín, Colombia[36]; Lisbon, Portugal [37]; Seoul, South Korea [38], amongst many others.

In Brazil, the recently created Sustainable City Innovation Observatory (SCIO) [39] is a major component of the Brazilian National Platform for Sustainable Cities under development by the Centro de Gestão e Estudos Estratégicos (Management and Strategic Studies Centre) within a GEF project. The SCIO is a virtual platform that monitors, curates and displays context-based and innovative urban sustainability content and solutions, with a special focus on NBS. Identified solutions are organised according to urban-specific challenges and city-region typologies. The SCIO is the first initiative of its kind since it connects the multiple ecological and socioeconomic benefits of NBS to a comprehensive set of urban challenges, including but not limited to: mobility, energy, water, solid waste, a built-in environment, innovation, education, poverty, inequality and inclusion, participatory governance, integrated long-term city planning, the restoration of ecosystem services, the circular economy and climate change. Currently, the SCIO is mapping NBS worldwide to be adapted to the Brazilian context and building partnerships with key players globally, such as Oppla from the EU, to integrate solutions, functions and databases.

Universities and cities are hubs to develop a new vision for a sustainable, resilient, healthy and fair urban environment, where natural processes and flows, local culture and values and people are critical (see Brazilian Case Study 5). Campuses of universities should implement sites to develop and test, manage and monitor innovative NBS pilot projects that may address local issues such as floods, quality of water, the enhancement of biodiversity and the urban heat-island effect, amongst others. The University of São Paulo has a site where rain gardens have been tested and monitored by graduate students, and this is a source of knowledge that can be replicated in other

30. https://www.portlandoregon.gov/bes/34598, accessed: 23.8.2018.
31. http://www.nyc.gov/html/dep/html/stormwater/using_green_infra_to_manage_stormwater.shtml, accessed: 23.8.2018.
32. http://www.driee.ile-de-france.developpement-durable.gouv.fr/trame-verte-et-bleue-r31.html, accessed: 23.8.2018.
33. https://www.pub.gov.sg/abcwaters/designguidelines, accessed: 23.8.2018.
34. https://www.medellin.gov.co/irj/go/km/docs/pccdesign/medellin/Temas/Contratacion_0_0/noticias/Shared %20 Content/Documentos/2017/Presentacio %CC %81n %20Ciudad %20Verde.pdf, accessed: 23.8.2018.
35. https://www.pub.gov.sg/abcwaters/designguidelines, accessed: 23.8.2018.
36. https://www.medellin.gov.co/irj/go/km/docs/pccdesign/medellin/Temas/Contratacion_0_0/noticias/Shared %20 Content/Documentos/2017/Presentacio %CC %81n %20Ciudad %20Verde.pdf, accessed: 23.8.2018.
37. http://www.cm-lisboa.pt/viver/ambiente/alteracoes-climaticas/adaptacao, accessed: 23.8.2018.
38. https://seoulsolution.kr/en/node/3577, accessed: 23.8.2018.
39. https://www.cgee.org.br/projetos/-/asset_publisher/W0hI4ElAHtL5/content/observatorio-de-inovacoes-para-cidades-sustentaveis?inheritRedirect=false

areas (see Figure 12). These experiments are sometimes limited by their temporary nature — some end up being discontinued for political or financial reasons — but they do offer scientific foundations for practitioners to apply in actual projects.

Urban landscapes offer countless opportunities to develop continuous, experimental, and adaptive projects at small and medium scales to locally test the performance of NBS suitable to the local context. The projects can be managed and monitored by local researchers, graduate and undergraduate students and/or engaged citizens and grassroots movements, and then be applied at larger scales (see Brazilian Case Study 13).

Figure 12. Experimental rain garden in the University of São Paulo.

Community engagement is transforming local landscapes with urban agriculture. Planting native trees and protecting watercourses in public spaces are helping cities transition to a more sustainable and resilient state (see Brazilian Case Study 14 and Incredible Edible [40] in the United Kingdom). Urban living labs have brought grassroots movements to a new level of collaboration to change culture and influence decision-makers. Awareness-raising through hands-on collective activities stimulates people to connect with urban ecology, as well as strengthening the sense of community. Active environmental learning is crucial in the process of transitioning to new urban environments that are fairer, safer, more sustainable and more resilient. In this manner, such learning is a path towards shifting from the usual linear, cradle-to-grave economy to a circular economy based on the concept of cradle-to-cradle production, where there is minimum waste of material and energy.

Political will and social commitment are critical to boost the development of a new vision for cities, where nature (natural processes and flows — water and biodiversity) and people play a central role. Education is the basis to shift the paradigm of trying to control nature to the new

40. https://www.incredibleedible.org.uk/

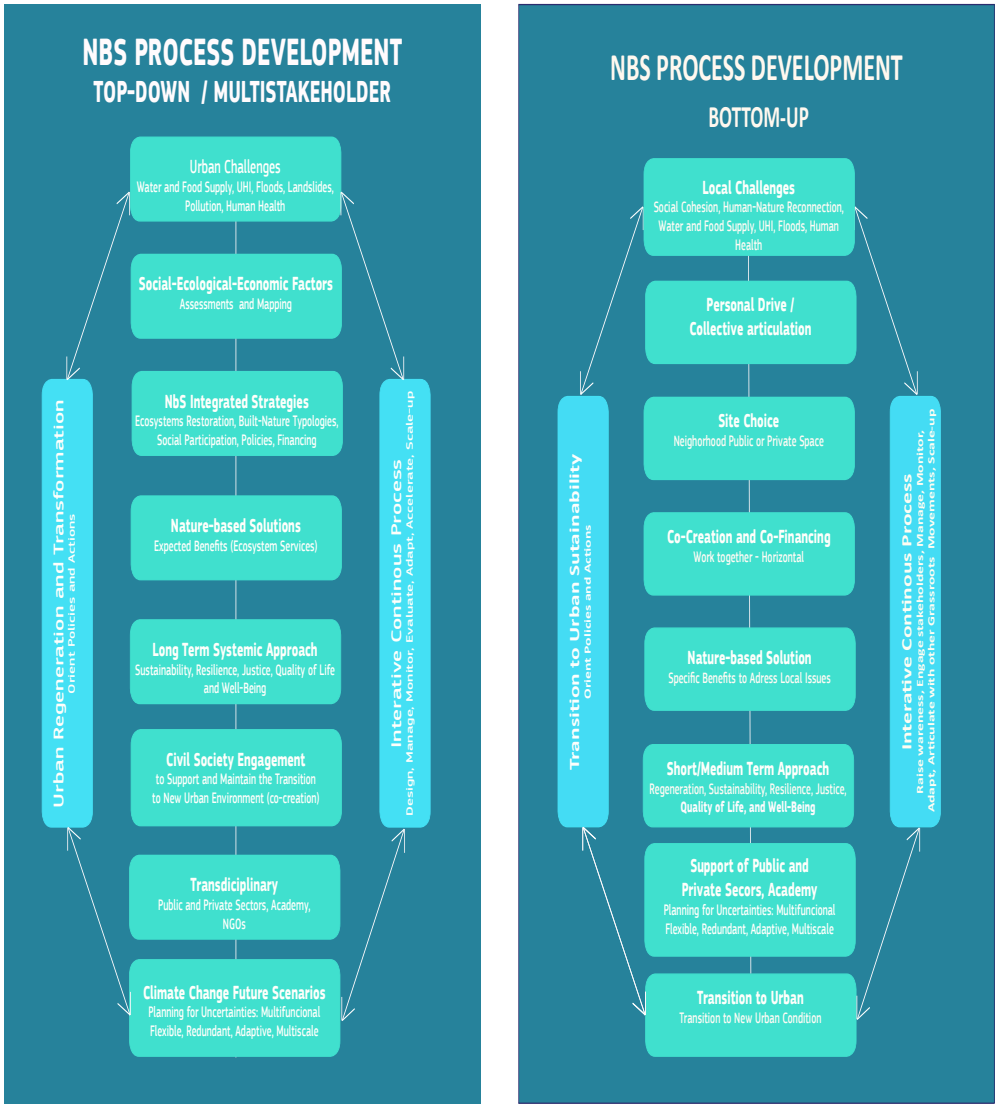

Figure 13. Left: vertical, strategic, systemic planning method for climate change adaptation, continuous process. Right: successful grassroots movements' usual process as seen in the Brazilian case studies section.

standard that aims to re-learn to live with nature. So, investing in ecological and social knowledge builds a society that values and prioritises all life on earth (see European Case Study 8 and Brazilian Case Study 2).

European universities, research and technology organisations and companies are at the forefront of NBS development. They are important partners in the process of transforming cities from mono-functional grey to green (in some cases hybrid green-blue-grey) high-performance landscapes. As explained in the introduction, their role is supported by the European research framework, currently H2020, which offers the opportunity for all key stakeholders, and even for non-EU partners, to collaborate in the development of new knowledge and solutions for NBS.

Financing NBS

Loss of biodiversity can compromise the provision of ecosystem services, livelihoods, natural habitats and food security in both developed and developing countries. In contrast, actions to reduce the negative impacts of biodiversity loss can bring a broad range of benefits. According to the Global biodiversity outlook 4, reducing deforestation rates has resulted in an annual benefit of USD 183 billion in the form of ecosystem services [41]. Nevertheless, despite its fundamental role and the efforts made to correct the situation, valuable biodiversity continues to be lost every year, which results in an annual reduction in the global GDP of 3 % [42]. The EU biodiversity strategy up to 2020 was adopted in 2011 to reverse biodiversity loss and speed up the transition towards a resource-efficient and green economy [43]. Therefore, it is a wise decision to invest taxes in cost-effective, adaptive, flexible NBS that contribute to the goals of the strategy while providing numerous co-benefits.

NBS may be implemented in public or private areas, and may be voluntary or enforced by strategic urban planning and/or regulations that benefit the city, minimising the losses caused by floods, landslides, urban heat islands, air, water and soil pollution and impact on human health, amongst others. However, even though their benefits are recognised, one of the main challenges hindering their wider implementation is the lack of proper economic valuation of NBS and their services (see Wild et all, 2017). Consequently, comparison in terms of costs/benefits between NBS and alternative solutions is not easy, commonly leading to an under-provision of nature in cities. In the EU, research is being carried out to bridge this gap. As an example, the Naturvation Financial and Economic Value Database includes monetary values of NBS together with their respective sources and calculation methods [44].

Regarding the financing of NBS, there are several instruments available. Examples include environmental compensation funds, whereby ecologically harmful projects are compensated for by investment in planting trees and restoring ecosystems in cities and rural areas; payment for environmental services, which is already being used to maintain and enhance water sources in many Brazilian cities; and tax incentives for projects that offer ecosystem services to urban environments, for instance green roofs.

In Latin America there are several potential financing institutions, both national and international, that can provide financing for NBS. These include but are not limited to the Brazilian Development Bank, Caixa Econômica Federal (a Brazilian Financial Institution), the World Bank, CAF (Development Bank of Latin America) [45], the Inter-American Development Bank [46] and the AFD (French Development Agency). Some of the abovementioned international financing institutions have specific instruments that may be more suitable for financing NBS. As an example, The GEF Trust Fund was established in 1992 to address the planet's most pressing environmental challenges [47]. The World Bank acts as the GEF's trustee, administering the financial contributions made by the fund's 39 donor countries. Similarly, the Climate Investment Funds established in 2008, also managed by the

41. Secretariat of the Convention on Biological Diversity, Global biodiversity outlook 4, Montréal, 2014, p. 7. https://www.cbd.int/gbo/gbo4/publication/gbo4-en.pdf
42. https://www.eea.europa.eu/soer-2015/europe/biodiversity
43. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0244&from=EN
44. https://naturvation.eu/result/review-economic-valuation-nature-based-solutions-urban-areas
45. https://www.caf.com/en/about-caf/
46. https://www.iadb.org/en
47. https://www.thegef.org/

World Bank, support scaling up mitigation and adaptation action in developing and middle-income countries with the contribution of 14 donor countries [48].

The Green Climate Fund is a financial mechanism under the United Nations Framework Convention on Climate Change set up in 2010 to support adaptation and mitigation activities in developing countries through grants, loans, equity or guarantees [49].

Other programmes can help raise funding for NBS. For instance, the 10-year framework of programmes on sustainable consumption and production (10YFP) managed by UN Environment and adopted in 2012 at the World Summit on Sustainable Development to accelerate the transition towards sustainable consumption and production (now included as a stand-alone goal, SDG 12, in the 2030 agenda for sustainable development) in both developed and developing countries [50]. The One Planet network is a multi-stakeholder partnership formed to implement the commitment of the framework through its six programmes: public procurement, buildings and construction, tourism, food systems, consumer information and lifestyles and education. NBS can be linked to the content of all these programmes. The One Planet Multi-Partner Trust Fund for SDG 12 has been established as a means to finance the implementation and scaling-up of SDG 12 globally.

In Brazil, the Brazilian Development Bank has established the climate fund programme, which offers subprogrammes for sustainable cities and climate change [51]and for sanitation and water resources.

Figure 14. 'Pocket Forest' funded by Vivo Telecom. Design and implementation Cardim Arquitetura Paisagística.

Both could be a source of financing NBS in related areas. State water resource funds are also agencies that may aid the development of NBS to improve water quality in cities, with the recognition of the effectiveness of several typologies such as built wetlands, greenways, rain gardens and bio-swales. Moreover, 'Ecological ICMS' instrument [52] has already generated results in many cities incentivising the protection and restoration of water sources and ecosystem fragments (forests). It is a state tax transferred to cities in some Brazilian states to promote environmental protection [53].

48. https://www.climateinvestmentfunds.org/
49. https https://www.eea.europa.eu/soer-2015/europe/biodiversity://www.greenclimate.fund/home
50. http://www.oneplanetnetwork.org/who-we-are
51. https://www.bndes.gov.br/SiteBNDES/bndes/bndes_en/Institucional/Social_and_Environmental_Responsibility/climate_fund_program.html
52. http://www.icmsecologico.org.br/site/index.php?option=com_content&view=article&id=61&Itemid=74
53. http://www.icmsecologico.org.br/site/images/artigos/a024.pdf (ecological value added tax).

Private financing for NBS, particularly if innovation is involved, is not easy to mobilise mainly because the benefits are partly public and the risks are high, making it less attractive for investors. However, there has been some advancement and different financing models have been developed for different types of urban NBS (green roofs and facades, urban green spaces and forests, community gardens and urban agriculture, biological sanitation stations, etc.) [54]. The visibility of the pocket forests in São Paulo has attracted a private company to finance the planning of one such forest in front of its main office on a very visible motorway on the margins of the Pinheiros River in São Paulo. Also in Brazil, the Boticário Group [55] Foundation for Nature Protection supports nature conservation initiatives all across the country. In 2016, the foundation organised the workshop 'Nature-based solutions: opportunities for adaptation to the new climatic scenario' that brought together different stakeholders to find ways of using NBS to increase society's resilience and guarantee the population's well-being. A series of next steps ultimately leading to the development of concrete projects is already being planned [56].

In Latin America, a good example of multiple public–private financing is the Green Watershed, Water Fund of Medellín (Cuenca Verde, Fondo de Água) [57] in Colombia, currently under development to protect the rivers that provide water security for 3.5 million people in the Aburrá Valley (see Figure 15).

GREEN WATERSHED, WATER FUND OF MEDELLÍN

Figure 15. View of Aburrá Valley, Medellín, Colombia.

The funding to restore the watershed comes from the Cuenca Verde Corporation, a partnership of the City of Medellín with: EPM, Cornare, Grupo Nutresa, Postobón, Área Metropolitana del Valle del Aburrá, Coca-Cola - FEMSA, and the Latin America Water Funds Alliance (formed by The Nature Conservancy (TCN), Inter-American Development Bank, Foundation FEMSA and the GEF. In addition, a donation from Grupo Familia.

54. https://naturvation.eu/sites/default/files/news/files/naturvation_characterizing_nature-based_solutions_from_a_business_model_and_financing_perspective.pdf
55. Boticário is one of the largest cosmetic groups in Brazil. https://www.boticario.com.br/
56. http://www.fundacaogrupoboticario.org.br/en/pages/default.aspx
57. http://fondosdeagua.org/esp/wp-content/uploads/2017/06/Brochure_Cuenca_verde_Fondos_de_agua.pdf

5 Discussion

NBS have already been implemented in many cities around the world, at multiple scales: green roofs to lower urban heat-island effect; rain gardens and bio-swales to prevent floods and enhance water quality in urbanised areas; built wetlands to treat water run-off of entire regions combining multiple uses in recreational parks; and river renaturalisation to restore ecological processes and offer clean mobility (pedestrians and bicycles) in safe and comfortable environments, amongst many others. All of them offer co-benefits that go beyond the initial objectives.

In the EU and in some cases in Brazil, the research community has been monitoring the results of implemented projects to learn the best practices and inspire other cities to adapt the relevant typologies to their own contexts and social, ecological and economic challenges and opportunities. More concretely, the eight demonstration projects under H2020 call topic '**Demonstrating innovative NBS in cities**' (see Figure 3) are monitoring NBS across the EU and testing an NBS impact evaluation framework. Moreover, even though monitoring individual projects is certainly useful, it is necessary to develop standardised assessment criteria to quantify the direct benefits and co-benefits of NBS to maximise their positive impacts. To that purpose, a critical analysis [58] has recently been carried out benchmarking the mapping and assessment of ecosystems and their services [59], the Knowledge and Learning Mechanism on Biodiversity and Ecosystem Services (EKLIPSE) [60] and the smart city performance measurement framework [61] against SDG 11 'Sustainable cities and communities'. In addition, the impact evaluation framework to support planning and evaluation of nature-based solutions projects [62] developed by the Eklipse Expert Working Group on Nature-Based Solutions to Promote Climate Resilience in Urban Areas was also further selected for comparison with SDG 11.

In Brazil, institutions that finance research and development should include NBS-related innovation and technology as a priority to transform cities and regions by reducing their vulnerability to extreme weather events, and helping them to adapt to climate change challenges. There are numerous academic programmes, social organisations and cities that are focusing on NBS as a means to transform and regenerate the urban environment. Examples are increasing and are accessible on open source websites.

In the EU and Brazil, NBS have already addressed an ample array of urban challenges working with nature, introducing biodiversity to offer multiple benefits (see case studies). There is an urgent need to recognise that green, soft solutions are more efficient and cost-effective than most of the conventional grey and expensive engineered projects that aim to control nature and natural processes and flows. In many cases, a combination of NBS and conventional engineering is necessary to address

58. https://www.frontiersin.org/articles/10.3389/fenvs.2018.00069/full
59. European Commission, Mapping and assessment of ecosystems and their services, Technical report 2018-001, Publications Office of the European Union, Luxembourg, 2018. http://catalogue.biodiversity.europa.eu/uploads/document/file/1673/5th_MAES_report.pdf
60. http://www.eklipse-mechanism.eu/home
61. http://www.citykeys-project.eu/citykeys/cities_and_regions/Performance-measurement-framework
62. http://www.eklipse-mechanism.eu/apps/Eklipse_data/website/EKLIPSE_Report1-NBS_FINAL_Complete-08022017_LowRes_4Web.pdf

the problems caused by unsustainable urbanisation that ignores natural landscape processes. This is a paradigm shift that is already happening around the world (see European case studies).

NBS can be high-tech or low-tech: different solutions can be developed on the spot without the need for expensive technology coming from elsewhere: each Brazilian city can find its own, adapted NBS. In addition, there is also clear potential for establishing mutually beneficial links with other emerging fields like the circular economy to promote more systemic approaches to sustainability; or frugal innovation enabling the implementation of low-cost and low-maintenance solutions.

NBS can contribute to preparing and adapting cities to reduce disaster risks caused by the changing climate. Extreme weather events and rising sea levels are already causing major impacts in urbanised areas around the world. GHG emission mitigation is also related to the introduction of nature in urban areas where urban forests capture carbon and filter the air. NBS also enables reduced energy demand in buildings that combine proper insulation with green roofs and walls. Clean active mobility — walking and cycling — is stimulated in safer areas shaded by trees and where the air is cleaner far from vehicle pollution and noise, reducing dependence on motorised private transportation.

A frequent barrier for planning, designing, managing and financing green solutions is ignorance about them. Investing in ecological education and awareness-raising is as important as training professionals in all areas related to cities about the role of nature in urban contexts. In Brazil, the federal, state and municipal administrations must have technical staff with the necessary knowledge to evaluate and approve investments in NBS.

The introduction of policies that induce and incentivise NBS in cities, can reach multiple targets with the transformation of urban landscapes: from grey (high impact) to green (high performance) landscapes. NBS contribute to build resilience, enhance sustainability, increase social justice, promote economic development, and offer better quality of life and well-being to people. Thus, policies should focus on bringing NBS to the spotlight of innovation and economic development to enable the achievement of SDGs, the NUA, reduce disasters risk, and enhance biodiversity in urban areas.

Brazil has been identified as a megadiverse country (the most biodiversity-rich country in the world), and the extension of its ecosystems, the services they provide and the scale of environmental degradation make it a crucial country in any future reflections on the global environment. Nature in cities also plays a role here, especially given that most of Brazil's urbanisation has occurred along the Atlantic coast (e.g. Rio de Janeiro, São Paulo, Salvador, Recife) in the biodiverse and nowadays highly threatened Atlantic Rainforest. NBS enhancing biodiversity in these cities and their peri-urban areas can contribute to the restoration of ecosystem functions whilst providing a plethora of societal benefits, notably the provision of clean water.

Given the diversity of Brazilian bio-climatic and urban contexts and building on the high biodiversity of the country, a multitude of NBS can be implemented to address the different challenges facing Brazilian regions and cities, as illustrated in the case studies section.

Furthermore, Brazil has the opportunity to export all the know-how applied under its unique circumstances to other countries with similar (climate/urbanisation) conditions, namely in the CELAC region.

Suggested roadmap for NBS in Brazil

1. **Mainstream NBS across political scales (federal, state and local) and sectors (e.g. different ministries).**
2. **Develop R&I for testing locally adapted NBS in the different Brazilian bioclimatic regions, in connection with local universities and municipalities. Develop local technical capacity.**
3. **Develop monitoring schemes and contribute to the evidence base. Communicate NBS effectiveness to both decision-makers and citizens.**
4. **Explore financing and business models, involve companies in NBS and develop R&I for business uptake.**
5. **Explore novel governance mechanisms and co-creation, creating communities of practice.**
6. **Foster international cooperation (e.g. within CELAC; with the EU).**

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This report, as well as its case studies, can be found in Oppla, the EU repository of Nature-based Solutions:
https://oppla.eu/nbs/brazil

EU case studies

Tampere, Finland

Tampere is the third-largest city in Finland and the largest inland centre in the Nordic countries. Tampere is home to 225 150 inhabitants and close to half a million people live in the Tampere region, which comprises Tampere and its neighbouring municipalities. It is a centre for cutting-edge technology, research, education, culture, sports and business.

It is estimated that rainfall in Finland will increase by 25 % in the coming years due to climate change. A critical issue for the city is therefore flooding and storm-water management. Other challenges include air and water pollution and reduced biodiversity. In this regard, Tampere's main interests are:

- adopting and further developing innovative nature-based storm-water management;
- monitoring performance in boreal/arctic climate conditions;
- developing the city's administrative processes;
- finding business models for the implementation of the NBS in the future.

Figure 16. The new Vuores eco-efficient district under development.

Vuores eco-efficient district

Tampere's main NBS demonstration site is Vuores, a green district to be completed by 2030, providing homes for 13 000 people and jobs for 3 000 to 5 000 people. Innovative, co-created NBS systems demonstrated in Vuores will be scaled up and further developed in Hiedanranta, and also in Tampere. Hiedanranta is a former industrial area slated for development into a housing area for 25 000 inhabitants and more than 10 000 jobs.
A lot of emphasis has been put on storm-water management in Vuores. The main goals in this regard are prevention of urban floods, maintenance of moisture conditions in valuable natural attractions, regulation of flow rates to pre-construction levels by drainage area, prevention of solids and nutrient load to waterways and handling of the first flush. Other NBS to be implemented in the demonstration areas in Tampere include public green spaces and storm-water ponds, green roofs and walls for buildings and permeable pavements.

Figure 17. Plan of Vuores by Studio Dreiseitl, the office that designed the large storm-water management system to be built with the resources provided by the housing fair.

Main success factors

Co-creation processes with different stakeholders have provided the opportunity to map different viewpoints for further development of existing NBS, and in addition have increased social cohesion. In Hiedanranta an important success factor has been the cooperation between local universities and a company producing bio-char to develop new bio-filtration solutions to treat contaminated waters, which also creates new business opportunities around NBS.

Challenges

NBS is a challenging concept and stakeholder contribution has partly been 'something around the topic', and focused on health and biodiversity. The changing Nordic climate limits the effectiveness of NBS during winter. Therefore, there is a risk that people won't value NBS if they don't have enough knowledge. NBS also presents maintenance challenges, for example should wetland vegetation be harvested, and if so, how often?

Lessons learnt so far

Water quality has been compromised due to the sulphur content of the soil. Had the measurements been taken in advance, this could have been taken into consideration during the land-use planning phase. NBS is a relevant aspect for future city development. Communicating information to stakeholders is crucial, for example understanding the importance of wetland vegetation in nutrient binding helps them understand the function of bushes.

Edinburgh, United Kingdom

With a population of 480 300 (core city), Edinburgh faces three main challenges, as identified in its local development plan: climate change, demographic change and sustainable economic growth. The City of Edinburgh Council (CEC) is committed to addressing the reduction of greenhouse emissions through renewable energy, recycling and sustainable transport and buildings while using the green network to capture and store carbon, and to contribute to climate adaptation through preventing flood risk.

The pollinator pledge

The main aim of this project is to encourage 10 000 individuals, organisations and businesses to get involved in creating more pollinator-friendly green spaces in Edinburgh and to enable the CEC and other landowners to understand how, and where, they can improve green spaces for pollinators across the city.

Granton community gardeners

This is a grass-roots community gardening initiative in a deprived area in northern Edinburgh. It was started in 2010 by local people living in flats without a garden, who wanted to grow vegetables near their homes. It is a good example of a project with multiple benefits, as it aimed to enhance green spaces, support gardening and food production, promote community cohesion and encourage healthy habits and environmental awareness.

The Field Group Duddingston

This is a group formed by local residents who came together to request a lease on a 2.5 ha field which had become vacant. They aimed to create and manage semi-natural habitats, especially woodland, using sustainable practices and promoting environmental education and recreation. The CEC supported the initiative and the group has planted more than 2 000 trees, a community apple orchard and a willow coppice, and has created walkways to improve access.

Figure 18. The Power of Food Festival 2017.

Figure 19. Group of volunteers at work.

Main success factors

There were opportunities to tie in with existing plans; for example the pollinator pledge fitted into the CEC's aims to improve biodiversity and the size and quality of the green network and to increase provisions for food-growing and allotments, which are good for hoverflies. Community-led initiatives benefit when they receive a high level of support (e.g. financial, advisory and/or material support) and trust from the local authority. The success of the Field Group Duddingston has led to the CEC having more confidence in the community, possibly creating space and support for the rise of other initiatives. Key individuals, for example in the Parks department, have been important in promoting the naturalisation of the CEC's property, for example through woodland planting on managed grasslands.

Challenges

Tension is sometimes created in the group by the need to involve (too) many different user groups and the volunteers' desire to have a tranquil green space, but a close-knit community and the flexible management approach have helped keep conflict to a minimum. The CEC has been investing in the green network as part of the open space strategy, but the estimated costs for continuing from 2015 were GBP 3 000 000, hence the need to tie it in with development and to make sure there are sufficient resources for ongoing management and maintenance.

Lessons learnt so far

A social return on investment valuation of Edinburgh's parks concluded that they are worth over GBP 100 million per annum, primarily due to the revenue they generate from visitors for local business and the economy. Their health and well-being benefits are worth GBP 40.5 million per annum and their impact on social inclusion and community capacity is calculated to be worth over GBP 6 million. Using the i-Tree Eco model, it was estimated that in 2011 the structural value of trees was GBP 382 million, as they provided GBP 484 689 per annum of non-traded value through net carbon sequestration.

Milan, Italy

Abandoned areas in the metropolitan area of Milan, whose population is over 4.1 million (2014 OECD), have recently been redeveloped. This has been an opportunity to implement green solutions when regenerating entire districts. Milan also needs to deal with traffic pollution resulting from the increased urbanisation of recent years; it poses a significant risk to human health and well-being. Reducing soil consumption is also a major challenge for Milan. More than 60 % of the soil is sealed, one of the highest levels in Italy.

Urban gardening

In 2012 the City Council of Milan approved guidelines for agreements with non-profit organisations to create new urban gardens in the municipality in less time and at no cost to gardeners (ColtivaMi project). Allotment gardens in Milan are mainly plots on public and municipal-owned land, exclusively intended for growing fruit and vegetables for private consumption.

Gorla water park

The Gorla water park is a multi-purpose green infrastructure (a series of built wetlands surrounded by a park) developed with the sponsorship of the Lombardy Regional Authority and co-funding by the Fondazione Cariplo, through a participatory process. The whole area is about 3 ha. It includes a flood-prevention area (1 ha), a pollutant-removal area (0.4 ha of a phragmites reed bed and 0.3 ha of nature-like multispecies wetland) and a leisure and recreational area (1.3 ha of park).

Figure 20. Bosco verticale.

Bosco verticale (vertical forest) by Stefano Boeri

The Porta Nova project, which includes the bosco verticale, is a city plan (2004) to transform the Porta Nova neighbourhood into a business–residential district implementing green solutions. It is an investment totalling more than EUR 2 billion. The bosco verticale consists of two residential towers, 110 and 76 m high, hosting 900 trees and over 20 000 plants distributed according to the sun exposure of the facade. It is estimated that the ecosystem services from the plants in the two towers (CO2 storage, air quality, biodiversity improvement) are equal to the services of 2 ha of forest.

Figure 21. View of the Parco Agricolo.

Parco Agricolo Sud

A key area of the green belt, the Parco Agricolo Sud offers local inhabitants farming, forestry, cultural and recreational activities and the use of NBS. To ensure the protection of biodiversity, some areas have been dedicated to rebuilding ecosystems and reintroducing fauna species that are becoming rarer. The park has different agricultural areas and over 1 000 active farmers are involved. Peri-urban farming is of primary importance not only for soil conservation but also for food production, since more and more people want locally grown food.

Main success factors

With its development, implementation and effectiveness, the Gorla water park is an excellent example of an NBS. The park was developed through a participatory process with public–private sponsorship, and it serves as a multi-purpose infrastructure. It also shows how the EU's research and innovation funding strategy could be beneficial for the city's administration, since the OpenNESS project conducted an in-depth analysis on the site showing the positive impact of environmental protection and social support.

Lessons learnt so far

In 2015 Milan had more than 23.5 km2 of public green areas, which can be translated into 17.31 m2 of public green space per inhabitant (City of Milan, 2016). In addition, research has shown that increasing and optimising single components of park structures can improve the cooling effect of urban parks in Milan (Mariani et al., 2016). Boeri's bosco verticale proved to be an NBS which could be upscaled and replicated. The Nanjing vertical forest (or Nanjing green towers) will be the first vertical forest built in Asia and is currently being developed by Boeri. A real vertical forest, helping to regenerate local biodiversity, will absorb 25 t of carbon dioxide each year and produce about 60 kg of oxygen per day (Boeri, 2015; Pączek, 2017; van Dorn, 2017).

Lisbon, Portugal

Over the last few decades, Lisbon has lost a third of its residents because of uncontrolled urban development (urban sprawl in the suburbs coupled with depopulation and decaying neighbourhoods in the historical centre). This has led to a deterioration of the quality of life in the city, which is currently facing challenges such as the urban heat-island effect, floods, air pollution and unequal distribution of green spaces. Bearing in mind the importance of the environment and people's well-being, the administration has invested in the regeneration of the city as part of a wider strategy to enhance its tourism potential and attractiveness. The master development plan sets out guidelines and objectives for specific planning and local development. In particular, the municipal ecological structure takes into account the importance of preserving natural, forest, agricultural and cultural heritage. Together with the biodiversity 2020 strategy, the city also approved the biodiversity action plan in 2016 promoting green infrastructure and climate change adaptation and mitigation actions.

Urban farming

Integrated in Lisbon's green infrastructure and contributing to the regeneration of urban voids and abandoned areas, 16 urban allotment gardens have already been implemented, for example in Quinta da Granja, Jardins de Campolide, Telheiras Nascente, Parque Hortícola de Chelas (the largest designed horticultural park in Europe), Cerca da Graça, Casalinho da Ajuda, Rio Seco IV, Vale da Ameixoeira and Murtas/LNEC. In addition to promoting biodiversity and social inclusion, these initiatives also consider water and energy savings.

Figure 22. View of the Eixo Central.

Sustainable urbanisation

Urban regeneration of degraded and ageing historic neighbourhoods is key to improving citizens' well-being and cities' attractiveness. Promoting green infrastructure with sustainability criteria produces multiple benefits. The programme 'one public green area in each neighbourhood' contributes to bioclimatic comfort and biodiversity targets. The regeneration of the Eixo Central (central axis) replaces grey infrastructure with green areas, more permeable coatings and street trees in some of the main avenues of central Lisbon.

Figure 23. View of the Quinta da Granja urban allotment garden.

Urban green corridors and green streets

Nine green corridors contribute to both climate change adaptation and mitigation, and help close the water cycle together with natural water retention measures. From 2013 to 2017 the Lisbon municipality planted more than 30 000 street trees, especially indigenous species.

Main success factors

The urban regeneration measures taken so far have shown how the restoration of Lisbon's historical quarters and its riverfront using NBS helps both to improve the well-being of its inhabitants and to make the city more attractive for tourism and investments. As an example, the regeneration of the riverfront includes measures for integration into the city's ecological structure (connection with other green areas and the city's plan for flood control). It also creates a diverse range of leisure and sports activities, linking the new urban spaces with the river and protecting the city from rising sea water levels.

Lessons learnt so far

The regeneration of its eastern waterfront for the 1998 World Exhibition, today known as Parque das Nações, transformed an obsolete industrial area into 110 ha of green spaces, real estate, business centres and modern transport connections. Although it did not adopt an NBS approach from the beginning, the project made it possible to regenerate an obsolete and contaminated area through sustainable urbanisation, with a particular emphasis on green spaces. This and other similar projects that followed helped mainstream the idea that a healthy environment and urban regeneration have to complement each other in innovative ways. The case of Lisbon also shows that even during a financial crisis a city can improve its citizens' well-being and its ecological structure with small-scale, concerted measures that are relatively cheap to implement.

Eindhoven, the Netherlands

The city of Eindhoven is one of the five largest cities in The Netherlands with 230 000 inhabitants, while the Eindhoven region has more than 750 000 inhabitants. The city is one of the three economic engines of the Netherlands, delivering 14 % of the national GDP. Eindhoven's climate policy plan sets clear ambitions in relation to climate change and sustainability. It aims at creating a green city that is pleasant to live in, with a high-quality experience of the urban working and living climate by its citizens, companies and tourists. In addition to this, the city administration has set clear goals in terms of water management to bring blue spaces back into the urban fabric. Eindhoven is promoting innovative engagement processes such as co-creation and the natural step concept, engaging stakeholders in municipal policymaking and implementation. The Eindhoven municipality's major challenges are: improvement of storm-water management, reduction of heat stress and increasing biodiversity. Other challenges include the improvement of air quality and water quality.

Construction and restoration of watercourses

Figure 24. Left: map of existing watercourses to be restored (in blue) and new ones to be constructed (in red). Right: view of one example.

Less pavement and more green in the city centre

The city of Eindhoven has selected several locations within its city centre with different characteristics in which to implement and showcase different NBS. Examples include:

- implementing green spaces/shade;
- re-establishing watercourses;
- linking blue and green urban areas;
- preparing water storage areas;
- implementing green roofs and green facades.

Main success factors

Removing the pavement in parkland roads and replacing it by 'green' that needs to be mowed once a year has been very successful. Some new watercourses were built. The main success factor is that the city is managing to change the way people are building. On a small scale, the city is also trying to prevent people from paving their gardens completely; they should leave some green areas. There is funding available if private owners want to disconnect from the water system. The city provides information through leaflets, and educates children in schools on the advantages of nature in cities. A lot of signs show that concrete is not so desirable anymore; it does not contribute to quality of life.

Figure 25. Multi-level green, Het College.

Challenges

The main challenge for the reconstruction of watercourses has been space, because there is so much going on in the city centre that finding the space to reconstruct the watercourses is very difficult. In some parts it has been possible to open up the watercourses, but in others underground pipes have had to be used. Too much space is consumed by mobility, particularly cars. Bike paths (new models) consume less space because they combine different traffic streams.

More green and blue areas are still needed to make the city more liveable. At first, people were afraid of dangers such as disease and drowning. They also rejected the way the water margins looked because they were not manicured or perfectly mown. People need time to adjust to new ways of building public space. Changes should not be too dramatic as people need time to adjust. However, the city needs to speed up the process.

Lessons learnt so far

Good examples are very useful to show people the advantages of NBS and to encourage them to change their behaviour. More effort needs to be made on communication and awareness-raising — not only towards citizens, but also towards city officials in different departments (e.g. it is important to involve city officials from maintenance) and towards developers, etc. One story, and only one, needs to be created to inspire, to demonstrate advantages and to convince. Putting all agreements into writing is highly recommended.

Genoa, Italy

Genoa is the biggest city in the Liguria region and is characterised by a narrow coastal zone with hills and steep mountains further inland. Genoa is also the third largest city in northern Italy in number of inhabitants with a population of 610 000. This number increases to 850 000 when considering the whole metropolitan area. The city is seriously affected by frequent flooding which has resulted in significant destruction in the past, primarily due to intense rainfall on a highly urbanised landscape. In addition, Genoa faces numerous environmental challenges relating to extreme weather conditions, water management issues, heat stress and water and air pollution. Some of the city's main ambitions to combat this situation are:

- increasing climate resilience (carbon storage and sequestration, planting vegetation to cool, shade and shelter);
- improving water management (increasing infiltration and enhancing evapotranspiration, rainwater storage areas, removing pollutants);
- improving green-space management and biodiversity (demolition of former barracks to build urban parks, new outdoor sports facilities);
- improving air quality using 'green buffers';
- urban regeneration;
- participatory planning and governance;
- social justice and cohesion;
- public health and well-being;
- economic opportunities and green jobs.

Lagaccio district

Lagaccio is a central and densely populated district characterised by disorganised post-war urbanisation mainly formed by residential multistorey buildings and derelict sites. It connects the old port, the historic town centre and the 850-ha Peralto natural park with its historical architectural structures. In Lagaccio a number of NBS to key climate- and water-related challenges will be demonstrated. These are listed below for Parco Urbano Gavoglio.

Figure 26. View of Lagaccio district in Genoa.

Parco Urbano Gavoglio

Currently under development, this project aims at turning the former Gavoglio barracks into an urban park that will return to the population a vast area — 60 000 m2 — of the Lagaccio district. Funds have been secured from the government (EUR 5 million) and the Horizon 2020 project Unalab (EUR 3 million). A series of workshops involving associations and citizen groups took place during the spring of 2018 before the realisation of the final executive project. In parallel, a number of training courses on urban living labs have been provided for public officials and advisors, experts, universities, associations, inhabitants, businesses and professionals. The planned NBS consist of:

- soil unsealing;
- draining pavement;
- draining play areas;
- retention systems;
- infiltration basins;
- stone gabions;
- vegetated stone gabions;
- xerophilous flowered meadows;
- groups of trees.

Figure 27. Urban design plan for the new Parco Urbano Gavoglio.

Challenges

Local associations fear that the process of re-zoning the land will become endless due to the high estimated cost (EUR 78 million). The general assessment of the subsoil and the streams is already causing delays. This check is important because it will determine which buildings can be kept and which should be demolished, along with the necessary works and associated costs. The associations propose the creation of a 'technical committee' to steer the process, as well as a physical information point to encourage transparency and participation.

Figure 28. One of the workshops organised as part of the participatory process established for the transformation of Lagaccio district.

Freiburg, Germany

As one of the world's pioneer cities in environmental awareness and protection, over the years Freiburg has become a model 'green city' for other cities and towns worldwide. Located in the south of Germany with a population of 220 000 people, Freiburg's process towards sustainability began as early as the 1970s with action against the Wyhl nuclear power plant. A series of activities followed as part of the Local Agenda 21 and the Aalborg Commitments, supported by the sustainability targets set by the Freiburg Sustainability Council and adopted by the Municipal Council in 2009. To develop the 'green profile' of the city and the overall sustainability process in a systematic way, the Sustainability Management Unit reporting directly to the Mayor was established in 2011. In recognition of its commitment to sustainable development, in 2012 Freiburg received the German Sustainability Award.

Freiburg's sustainability process is the result of a comprehensive and participatory approach involving all relevant stakeholders (local administration, citizens, companies, academia and research centres, institutions, etc.), and covering a wide range of initiatives from environmental policy to climate protection. In addition, the city has become a successful example of reconciliation between the environment and the economy, fostering a growing market for green technologies and services. The companies that integrate the business network for environmental and renewable energy industries in Freiburg and the region provide around 12 000 jobs, significantly contributing to regional economic development.

Figure 29. Overview of Freiburg's main initiatives in relation to sustainable development. In the background, one of the city's trams.

Vauban neighbourhood

Located in the south of Freiburg, in an area formerly occupied by army barracks, the Vauban residential area has a population of 5 000 inhabitants and covers 42 ha. Planning started in 1993 with the development of a vision for an ecological car-free neighbourhood. A year later the Vauban Forum was established to turn that vision into a reality, and an urban design ideas competition was organised with the following specifications:

- mixed use (work and living);
- priority for pedestrians, cyclists and public transport;
- preservation of the tree population and the St. Georgener Dorfbach biotope;
- social diversity;
- accessibility to open spaces;
- local heating supply and low-energy buildings.

The competition was won by Kohlhoff & Kohlhoff from Stuttgart, and the new neighbourhood was completed in 2006 achieving remarkable results in terms of energy efficiency, traffic reduction, social integration and participation.

Nature-based solutions in Vauban

To address the risk of backwater and flooding from the nearby stream, a series of measures for storm-water management, both centralised and decentralised, have been implemented:

- sustainable storm-water drainage system parallel to the conventional sewage system;
- green trough-trench systems with gravel-filled drain trenches;
- green roofs;
- permeable pavement;
- private rainwater collection systems;
- green areas to prevent sudden run-off and promote infiltration.

The results have been positive, in terms not only of decreased run-off and flooding, but of increased biodiversity and reduced urban heat-island effect

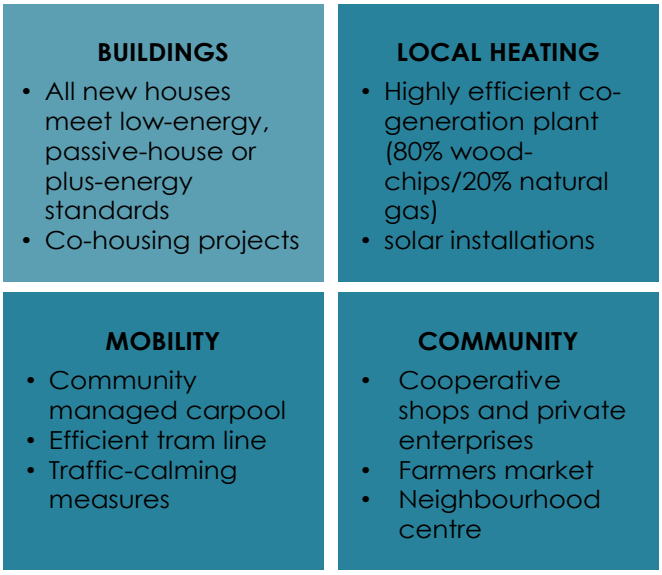


Figure 30. Vauban neighbourhood's main achievements in relation to sustainable urban development.

Vitoria-Gasteiz, Spain

A historical city founded in 1181, Vitoria-Gasteiz is the capital of the Basque Country in northern Spain. With a population of around 250 000 people and surrounded by an extensive rural area, Vitoria-Gasteiz is among the world's pioneering cities in environmentally friendly living and in bringing nature into the urban context. In 2012, the city was awarded the title of European Green Capital with an outstanding performance on five of the indicators — climate change, transport, air quality, noise pollution and its dissemination programme. Its achievements are the result of a successful process spanning more than 30 years characterised by political agreement, long-term integrated strategies, technical expertise and social participation. Even the business sector has been actively involved in the city's move towards a sustainable environment.

A compact and well-organised medium-sized city, so far it has managed to avoid the challenges faced by large urban areas such as high pollution, traffic congestion, urban poverty and social exclusion, thanks to rigorous urban planning. Vitoria-Gasteiz is also a cohesive city, known for its welfare and social integration services (it has the highest proportion of social housing in the country). Regarded as one of the greenest cities in Europe, the first environmental action plan was adopted in 2002. By 2012, all residents had access to public open and green areas within 300 m and one third of the municipal area was covered by forest (479 m2 per capita).

Figure 31. View of Vitoria-Gasteiz historical centre. Its renovation has revitalised the area and helped to prevent the loss of population.

The city counted 130 000 street trees, 210 organic farming plots and 613 ha of green belt (900 ha in the future). Half of the journeys were made on foot, and sustainable urban mobility was supported by two tramlines and 90 km of bicycle lanes.

Vitoria-Gasteiz urban green infrastructure

A work in progress since the early 1990s, the semi-natural green belt surrounding the city has received considerable investment to recover degraded areas like gravel pits, burnt ground and drained wetlands. The green belt links a series of lakes and wetlands and is formed by the following parks: Salburua, Zabalgana, Armentia, Olarizu and the Zadorra river. Two areas are of special ecological value: the Salburua wetlands, declared an EU Site of Community Importance (SCI) and a Ramsar Site of International Importance, and the Zadorra river, another SCI and part of the European Natura 2000 network.

The green belt acts as a connector but also a buffer between the outer agricultural green belt and the urban green layout (formed by parks, gardens, cemeteries and green areas), all part of the city's urban green infrastructure.

Figure 32. Inner green belt. Urban agriculture. Vegetable garden managed by Cáritas NGO. Organic food production and healthy living.

NBS in Vitoria-Gasteiz

The urban green infrastructure keeps expanding, supported by a high level of citizen awareness and effective participatory mechanisms, as well as by a wide array of NBS. The most recent projects under planning and development include Larragorri Park, the inner green belt and the refurbishment of Europa Congress Centre. The building displays a green facade and roof with local species, along with a number of other sustainability features such as:

- the integration of socially vulnerable people;
- energy-efficiency features and certifications;
- Reusing rainwater for irrigating green roof and facade
- heat-recovery ventilation;
- parking reservation through smartphone.

Figure 33. View of Europa Congress Centre's green roof.

Berlin, Germany

With a population of 3 700 000 inhabitants (2017), Berlin is the capital of and the largest city in Germany. Green and blue areas constitute approximately 40 % of the city. At present, its main objective in terms of sustainable development is to decouple growth from negative impacts on climate and the environment. To that purpose, the city aims at creating a green belt that will not only improve the connectivity of the existing green infrastructure and extend it through the transformation of vacant plots into new green spaces, but will also act as a barrier against urban sprawl. However, this conflicts with the increasing demand for building land due to the growing urban population. Therefore, the three layers of government that characterise Berlin's multi-level administrative structure have jointly agreed to establish the extension of the city's green infrastructure and the implementation of NBS as a common goal across the different levels, as is reflected in most urban planning documents.

BENE (urban greening)

Berlin's sustainable urban development programme gives priority to interventions in those areas of the city most affected by social problems (e.g. poverty, unemployment, lack of green areas). The programme provides subsidies for measures that improve the existing green areas from a double perspective: recreational use and sustainable management.

Nomadic gardening

This is a bottom-up initiative started in 2009 for the temporary use of vacant urban space awaiting development for community gardening and food production. Located in Kreuzberg, a densely built district, only removable containers are used for gardening. The city administration renews the lease periodically. The garden's own café is supplied with the food produced by the community.

Green Moabit

Moabit is a densely built district, which the city wants to adapt to climate change through a concept called 'Green Moabit' that includes a series of quantitative targets for:

- the greening of rooftops, facades and courtyards;
- the replacement of impervious surfaces by green surfaces;
- rainwater harvesting;
- the volume of humidity due to evapotranspiration (to be achieved by increasing vegetation, using stored rainwater to irrigate public green areas and to be evaporated on rooftops and pavements).

Figure 34. View of the former Templehof airport, now a large urban park.

Transforming vacant urban areas

Berlin has some large, centrally located vacant areas that have not been used for decades. Perhaps the most well-known is the former city airport, Templehof, which has been transformed into a park. Nowadays, the 'Tempelhofer Feld' offers 300 ha of open public space mainly for outdoor sports, but also for other uses such as urban gardens, playgrounds and picnic areas.

Challenges

Although public policies along with the existing legal framework support the creation or improvement of green areas, and the costs can be covered through compensation measures, the maintenance of those areas burdens the districts typically limited by tight budgets.

Twenty green walks

This project is the result of a citizens' initiative started in 2004 that was later adopted by the city administration. The 20 green walks project covers over 500 km of marked routes protected from road traffic connecting residential districts with recreational areas, thus contributing to the realisation of the abovementioned 'green belt' concept. A private non-profit organisation is in charge of the maintenance, including signage and trail mapping.

Lessons learnt so far

Bottom-up initiatives have contributed greatly to extending the city's green infrastructure and to transforming public policies, which in some cases have been integrated into mainstream policies.

Copenhagen, Denmark

Copenhagen is the capital of Denmark and the country's most populous city with around 780 000 inhabitants (2018), and a metropolitan area of 2 million people. A dynamic city with a strong urban and cultural atmosphere, Copenhagen is also one of the major financial centres of Northern Europe. The service sector, particularly information technology, clean technology and pharmaceuticals, is the main pillar of the city's economy. The construction of the Øresund Bridge connecting the Copenhagen metropolitan area with the Swedish province of Scania and its largest city, Mälmo, has enabled their increasing integration, forming the Øresund Region. In the last few decades, increasing precipitation due to climate change has caused great economic and structural damage. Therefore, climate change adaptation and mitigation have become a priority for the city administration since 2009.

Adaptation and mitigation strategies and policies

A series of plans have been made for climate change adaptation, such as the Copenhagen climate action plan (2011), the cloudburst management plan (2012) and the climate change adaptation and investments plans (2015). They propose a number of specific actions for storm-water management, gradual and exceptional higher sea levels and higher temperatures. They encourage the adoption of NBS to reduce flooding risks along with measures for monitoring their implementation. For climate change mitigation, the Copenhagen 2025 climate plan (2012) focuses on energy production and consumption, green mobility and city administration infrastructures. It considers the NBS potential for climate mitigation through retrofitting (e.g. green roofs), carbon dioxide sequestration (e.g. green areas) and traffic reduction (e.g. promoting walking and cycling along green corridors and green areas). Finally, in 2015 Copenhagen published the strategy for urban nature in Copenhagen 2015-2025, which aims to increase the number of green areas and the level of biodiversity in the city while enhancing the city's liveability. Additionally, the strategy sets ambitious targets for the city mainly related to the degree of satisfaction of the residents about the quality and accessibility of green areas.

Figure 35. View of a park in Copenhagen.

Sustainable urban drainage systems

The development of sustainable urban drainage systems (SUDS) is at the core of Copenhagen's approach, enabling water infiltration, transportation, storage, evaporation and filtration and purification, including for example:

- roadside infiltration beds (storage, filtration and purification, infiltration and evaporation);
- rain gardens (storage, infiltration, evaporation and filtration, purification);
- grass swales/turfgrass areas (storage, infiltration, evaporation and filtration, purification);
- ditches (alongside roads, they enable more storage, transportation, infiltration and filtration and purification);
- dry basins (storage, evaporation);
- wet basins (storage, filtration and purification, evaporation).

The urban regeneration of Sankt Kjelds

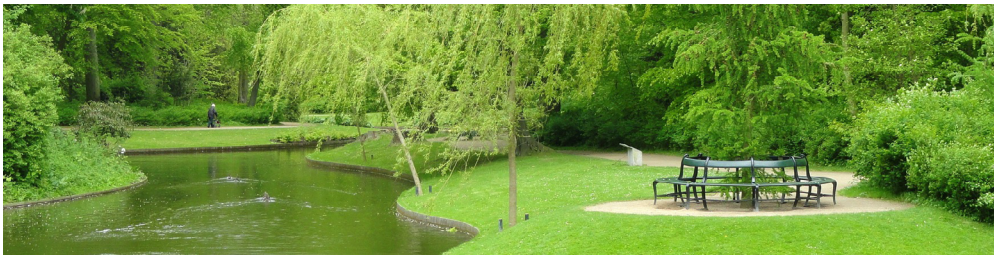
Located in Østerbro district, Sankt Kjelds was chosen to pioneer climate change adaptation through the implementation of various NBS coming from different action plans. The project is an outstanding example of a systemic approach enabling synergies between different individual NBS and their multiple benefits. The objectives of the integrated urban renewal of Sankt Kjelds were reached through the synergies achieved by parks, SUDS and green roofs. Other actions are still being implemented, such as cloudburst roads and green corridors. On the central Skt Kjelds Square and Bryggervangen more than 9 000 m^2 of asphalt was turned into a large green area for both storm-water management and recreational purposes. The vegetation was selected to enhance the drainage of storm water, to foster biodiversity and to reduce care and maintenance costs. Plants with a tolerance for high salt concentrations were preferred since salt is used during the winter to prevent ice formation on the surrounding streets. The total cost was around EUR 6.8 million.

Challenges

Financing was a critical issue. In Denmark, storm-water management is handled by water companies and paid for through water fees. However, mixing urban infrastructure with storm-water management was not possible within the national legislation. The city lobbied hard and finally managed to push for a change in the national legislation to enable the financing of new types of adaptation measures.

Lessons learnt so far

Experience shows that combining cloudburst water management with normal storm-water management gives the most effective and economically viable results.



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Brazilian case studies

1. Campinas: ecological strategic plans for biodiversity and water protection

Type: top-down (government initiative)

Region: southeast

State: São Paulo

Biome: Atlantic Rainforest, cerrado (Brazilian savannah)

City of Campinas

Population: 1.16 million

Area: 796.4 km² (51 % rural area)

Coordinates: 22.905800 S/ 47.060800 W
Located 98.3 km from São Paulo city

HDI: 0.805 (2010)

Campinas metropolitan region

20 municipalities

Population: 3.12 million inhabitants (Emplasa, GIP/CDI, 2019)

HDI: 0.792 (third in the country, 2010)

Context

Campinas metropolitan region represents the second largest GDP (8.92 %) of the São Paulo State, which concentrates the largest population (45.5 million inhabitants, about 21 % of the total Brazilian population [63]), and economic activity in the country (32.3 % [64]). Campinas has important industrial, agricultural, and educational areas, and is also a centre of innovation in scientific and technological research. The second cargo airport in Brazil, Viracopos, is located in the city [65]. It is part of the Macrometropolis of the São Paulo State.

63. https://www.ibge.gov.br/apps/populacao/projecao/
64. https://translate.google.com.br/translate?hl=en&sl=pt&u=http://www.seade.gov.br/produtos/pib-ual/&prev=search
65. https://www.emplasa.sp.gov.br/RMC, accessed: 24.7.2018.

Challenges

In spite of the good performance of the city and the region in economic areas, there is a historical lack of urban landscape planning that integrates adequate social housing and areas that should be protected, such as riparian corridors, ecosystem remnants and other relevant green areas that offer ecosystem services in the urbanised context. Disregard for poor people's needs has led to informal settlements in the urbanised areas in vulnerable and/or protected locations that the formal market is not allowed, by law, to occupy (this is common in Brazilian cities). Most of the ecosystems have been lost to urbanisation, and those that remain are disconnected fragments with impacts on essential functions that provide multiple ecosystem services.

Objectives

The existing plans, programmes and interventions at multiple scales aim to:

- restore the ecosystem remnants and improve connectivity;
- enhance biodiversity;
- increase and protect water sources;
- educate on and raise awareness about the environment;
- offer green areas for recreation and physical activities and healthier and safer spaces for residents who live in the less privileged areas;
- reduce risks of floods;
- control erosion.

Actions

Campinas has developed plans, projects and programmes to tackle regional, municipal and local issues related to environmental quality and offer of green areas to the least privileged residents.

At **metropolitan** level, the **'Reconecta' RMC** [66] plan (Campinas Metropolitan Region) is supported by the terms of technical cooperation signed by 20 municipalities of the metropolitan region. It aims to enhance biodiversity conservation with the creation of ecological corridors to provide ecosystem services, mainly related to water security.

The municipalities are working to: develop joint strategies to conserve and recover fauna and flora; integrate local actions already being implemented; connect the technical efforts of all the municipalities in the same regional plan and define inter-municipal actions aiming to improve the environmental conditions in the entire region.

This project is being implemented through workshops, meeting and surveys with public servants from the environmental departments of the municipalities and data collection with other entities, such as the Watersheds Committees. Connectivity areas have been defined in the whole metropolitan region aiming to guarantee the connection among forested natural fragments and Protected Areas and the protection of watercourses, enhancing the quantity and quality of water.

These actions are expected to contribute to ecological connectivity at the regional scale through the ecological

66. http://campinas.sp.gov.br/governo/meio-ambiente/reconectaRMC.php

corridors; develop and equalise knowledge among public servants in the environmental departments of all municipalities of the metropolitan region; develop stronger representation and influence in the dialogues with other federative entities (State and Federal governments); unify environmental data and information in the metropolitan region.

In the **municipality of Campinas, ecological corridors** are being designed to connect forested fragments and/or relevant ecological areas to enable genetic flow. The municipal green plan adopted the concept of a connectivity line to promote ecological corridors. The line points out places to be restored, generally on the margins of watercourses. The corridors also aim to connect conservation units that are protected by law (national system of conservation units). After designing the line, a buffer zone of 1 000 metres was determined to manage specific activities, constructions and interventions.

Implementation of sections can be done through the Green Areas Bank (Banco de Áreas Verdes — BAV), and other legal instruments include: the Compliance Commitment Term (Termo de Ajuste de Conduta), the Compensation Environmental Compliance Term (Termo de Compensação Ambiental), and the Compensation and Regularisation Environmental Compliance Term (Termo de Compensação e Regularização Ambiental).

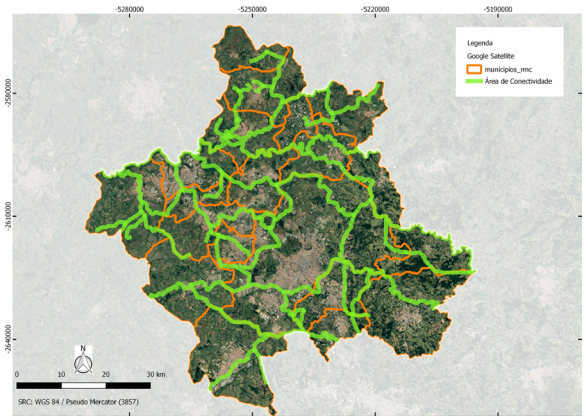

Figure 36. Reconecta metropolitan region ecological connectivity plan.

Four ecological corridors are already formalised:

- Santa Genebrinha forest;
- Capivari-Jatobás;
- São Vicente-Serra D'água;
- Santa Genebra connectivity core (first phase).

The municipality also intends to implement **linear parks** along channelised creeks for recreation, clean mobility, environmental education and enhancement of quality of life in dense and lower income urban areas. This initiative aims to reduce the deficit of green areas with social functions in the city, and targets the implementation of 49 linear parks. This programme also aims to avoid further illegal occupation of the rivers' margins. This action favours the enrichment of biodiversity, improvement of water quality with restoration (where possible) of watercourses' riparian corridors (in Brazil river banks and its floodplains are permanent protected areas), storm-water management, enlargement of floodplains, erosion control and the possibility to connect ecosystems as ecological corridors.

The urbanisation process and the lack of planning have often led to neglecting the demand for and care of green areas, resulting in an absence of vegetated and public spaces in lower economic neighbourhoods. The **municipal green plan** establishes efficient and integrated guidelines to develop and manage green areas where they are needed most. As part of the methodology used to identify the priority areas to implement the linear parks, the distribution of the 26 existing parks was mapped in 2016. The city developed an index of social green areas [67] to identify

67. Secretaria Municipal de Planejamento e Desenvolvimento Urbano.

the regions that had more or less accessibility to green areas, mapping the priority neighbourhoods. The social green spaces were mapped and graded from very high to very low. The mapping indicated where new linear parks should be planned, designed and implemented.

The municipal green plan proposes 49 linear parks, from which some will be implemented through compensation instruments by the landowners. Two parks, Taubaté and Santa Lúcia, are being implemented by the municipality with funds from a federal government programme to accelerate growth (Programa de Aceleração do Crescimento). Forty-three parks are in the final phase of the preliminary study, financed by the municipal fund for the environment.

Stakeholder involvement

Different stakeholders are involved in the abovementioned actions. For the inter-municipal Reconecta RMC these stakeholders are the Campinas Metropolitan Region Agency, Agemcamp, the PCJ Watershed Agency (Agência das Bacias PCJ), the José Pedro de Oliveira Foundation, the ICLEI — Local governments for sustainability, the Public Ministry of the State of São Paulo — the environmental defence group (Gaema) and the Environmental Council of the State of São Paulo.

For the ecological corridors in the municipality of Campinas the stakeholders are the Secretary of Green, Environment and Sustainable Development (Secretaria do Verde, Meio Ambiente e Desenvolvimento Sustentável). This same secretary is involved in the municipal green plan, together with the José Pedro de Oliveira Foundation. Finally, the linear parks were designed by the School of Architecture of the Pontifical Catholic University of Campinas.

Figure 37. Lagoa Creek Linear Park, before intervention.

Implementation

Implementation is ongoing. None of the plans, projects and programmes at any scale have been implemented yet. Funding is coming from different sources, as seen above.

Success factors

Reconecta RMC successfully integrated 20 municipalities of the metropolitan region to protect and connect biodiversity-rich areas and rivers to maintain and enhance water quantity and quality.

Outcomes

The expected outcomes are to:

- improve water quality and quantity;
- enhance the quality of life of residents;
- enrich and connect remnant biodiversity ecosystems;
- prevent floods;
- improve air quality;
- moderate urban heat-island effect;
- offer multiple open spaces for recreation, active mobility and sports.

The positive impacts that are foreseen are the creation of legal instruments that will enable the long-term implementation of multiscale projects.

- Plan of integrated development of the Campinas metropolitan region.
- Zoning of ecological and economic areas that incorporate the connectivity areas.

Figure 38. Lagoa Creek Linear Park, after intervention.

Limiting factors and risks

The most important limiting factor is the lack of understanding of the potential of NBS to solve water management issues by other municipal departments that are canalising rivers and creeks, and even burying some underground to make space for urbanisation.

Furthermore, at metropolitan level, there are differences in the political priorities of each city administration. There is no normative instrument to transfer technical and financial resources among municipalities.

It is not feasible to expropriate some private plots of land along the areas defined to implement the ecological corridors. There is also a lack of public properties and/or private owners' consent to convert areas into green corridors, as well as a shortage of funds to establish and design the overall project and build the fauna passages to cross new or existent roads.

Finally, there is a lack of trained personnel and financial resources to develop the projects for the linear parks, as well as for their implementation.

Lessons learnt

It is fundamental to have a multi-stakeholder approach to push forward the vision of a greener city. Environmental education of the residents and the involvement of all the municipalities of the metropolitan region are essential for the development of sustainable plans that are nature-based, and that need the cooperation and understanding of complex and systemic issues regarding biodiversity and ecosystem services.

Contacts

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2. Curitiba: Barigui watershed restoration

Type: top-down (government initiative)
Region: south
State: Paraná
Biome: Atlantic Rainforest

City of Curitiba

Population: 1 908 359 (2017 [68])
Area: 435.036 km²
Elevation: 935 m
Coordinates: 25.4809° S / 49.3044° W
MHDI: 0.823 (2010)

Context

Curitiba is the largest city in the southern region. It is an important regional economic and cultural centre. The meaning of Curitiba in the indigenous language of Tupi-Guarani is 'land of Araucárias' (the native pine tree), though these are no longer present in the urban landscape.

Curitiba is a point of reference in biodiversity conservation and enhancement. Since 1972 the city has implemented parks to improve the urban environment. In 1992, after the Rio ECO92, the city started mapping the Barigui watershed with aero-photogrammetry. Curitiba hosted the 8th Convention on Biological Diversity in 2006. From then on, the municipality decided to launch several actions to assess its biodiversity (with the collaboration of the Museum of Natural History), capture carbon, and as a co-benefit lower the urban heat-island effect.

68. https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/16131-ibge-divulga-as-estimativas-populacionais-dos-municipios-para-2017

Objectives

The Barigui river is still flowing on its original course and has not been canalised. The programme 'Viva Barigui' [69] aimed to protect and enhance areas to store storm water to prevent floods (built wetlands), connect biodiversity fragments, restore riparian corridors, prevent river bank erosion, and offer public spaces for several social, sports and cultural activities. In order to restore the river's margins, it has relocated low-income residents from vulnerable areas along some riparian areas.

Figure 39. Curitiba's Botanical Garden.

Actions

The implementation of eight parks along the watershed. The first Barigui park opened in 1972, located in the city centre. It has a total area of 1 400 000 m², of which 34 000 m² is under the management of the Environmental Secretary. It was designed to prevent floods with wetlands that are habitats for biodiversity and to offer multiple activities for residents. It has floodgates to manage the water flows.

Two large parks have been implemented in the northern area:

- Tingui (opened in 1994, total area 427 492 m²) [70];
- Tanguá (opened in 1996, total area 235 000 m²) [71].

Five parks have been implemented along the river in the southern area:

- Cambuí (opened in 2008, total area 99 301 m²);
- Guairicá Natural Municipal Park (opened in 2014, total area 118 178 m²), extends 1 381 m along the river, financed in partnership with the municipality and the French Development Agency;
- Mané Garrincha (named after a famous Brazilian soccer player) (opened in 2014, total area 87 006 m²), extends 1 550 m along the river;
- Mairi (opened in 2016, total area 29 806 m²), financed by the French Development Agency;
- Yberê (opened in 2016, total area 238 105 m²).

All the parks except Mané Garrincha were given indigenous names. They are all multifunctional, offering diverse activities, with spaces for active and passive recreation and sports fields for people of all ages. There are honey gardens for environmental education with five native bee species in many sites. All the eucalyptus trees that were removed were used in the parks' equipment. The sports areas are jointly managed by the Secretary of

69. Decreto No 342/2011.
70. http://www.curitiba.pr.gov.br/conteudo/parques-e-bosques-parque-tingui/321
71. http://www.curitiba-parana.net/parques/tangua.htm

Stakeholder involvement

The Department of Parks and Squares plans, designs, implements and manages all parks (some they manage partially). Several city departments were involved in the process of the development of 'Viva Barigui': the Environmental Department (design on integrated green areas, biodiversity and human activities), the Housing Department (housing), the Public Works Department (mobility, paving, drainage, bridges, lighting), the Urban Planning Department (planning and geometric design of bike lanes to connect the city north to south) and the Traffic Agency (traffic, traffic lights, and pedestrian crossings).

Implementation

The parks were created from 1972 onwards, as seen above. Investment in the last four parks was BRL 26 million, and they were co-financed by the French Development Agency and the municipality (50 % each).

Figure 40. Multifunctional park along the Barigui river with retention basin that prevents floods in urbanised areas.

Outcomes

- Flood prevention.
- Enhancing and connecting ecosystems.
- Lowering urban heat-island effect.
- Providing active and passive recreation.
- Improving the quality of urban environment.
- Building resilience to extreme climate events.
- Enabling active and clean mobility.

Success factors

The same political group has been in power for the last 25 years, which was important for the continuity of the projects. Environmental education helped connect people to nature.

Limiting factors and risks

- The city needs funds to buy the properties in the area from which the residents must be evicted.
- In the riparian protected areas, the owners have the right of pre-emption.
- A decree has decreased the riparian corridors [72] that were protected by law from 30 to 15 metres, because of a 'social priority interest'.
- There is not enough time to open a public tender that requires 4-5 months, because the city budget is annual (from August to August).
- The reduction of financial resources leads to the reduction of the personnel that have the capacity to carry the projects forward.

Lessons learnt

- Protection of riparian corridors maintained the river in a good ecological condition.
- Don't bury, canalise or concrete over the river: keep the river alive.
- Don't allow illegal occupation.
- Don't hire external companies to implement the projects. Public personnel know the problems and develop solutions to address them through appropriate design and implementation.

Contacts

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Figure 41. A view of Curitiba from the Botanical Garden.

72. In Portuguese — (APP) Área de Proteção Permanente, Faixa Marginal de Proteção (FMP).

3. Mutirão Reflorestamento: reforestation collective action

Type: top-down (government initiative)
Region: southeast
State: Rio de Janeiro
Biome: Atlantic Rainforest

City of Rio de Janeiro

Population: 6 520 266 (2017 [73])
Area: 1 264.2 Km² [74]
Elevation: from 2 m to 1 024 m high at the Pedra Branca peak
Coordinates: 22.902778 S / 43.207500 W
MHDI: 0.799 (2010) [75]

Context

Rio de Janeiro is a coastal city that ranges from 2 m above sea level to forested massifs [76] that divide the city into zones: central, north, south and west. The highest peak is Pedra Branca (White Rock), at 1 024 m high. The city has significant forested areas that cover most of the massifs. The population living in slums in 2010 was 19 % of the inhabitants (last census) [77]. The informal occupation of steep slopes and flood-prone areas occur mainly because of the lack of social housing planning, and the laws that protect vulnerable areas where formal occupation cannot occur. The landscape has been highly altered during the urbanisation process, with massive dismount of hills and creation of land over wetlands, mangroves, the Guanabara Bay and along the coast of Copacabana. Most of the 267 rivers and creeks [78] have been canalised or buried underground. The city has suffered massive landslides and floods, and the coastal areas are prone to erosion caused by storm surges and rises in sea level.

73. https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/16131-ibge-divulga-as-estimativas-populacionais-dos-municipios-para-2017
74. https://www.geografos.com.br/cidades-rio-de-janeiro/rio-de-janeiro.php
75. https://cidades.ibge.gov.br/brasil/rj/rio-de-janeiro/pesquisa/37/0?tipo=grafico
76. https://ceciliaherzog.files.wordpress.com/2011/01/sumc3a1rio-relatc3b3rio-vulnerabilidades-rmrj.pdf
77. https://www.brasil247.com/pt/247/brasil/31334/IBGE-Brasil-dobra-nasil %BAmero-de-moradores-de-favelas-em-20-anos.htm
78. https://oglobo.globo.com/rio/bairros/rios-cariocas-entre-esquecimento-o-futuro-15652879

Objectives

- Restore degraded landscapes through forest planting.
- Prevent sedimentation of the drainage system and the watercourses.
- Connect forested patches through ecological corridors to enable genetic flows.
- Enhance biodiversity in conservation units and ecosystem remnants.
- Regulate hydrologic processes and flows of the urban watersheds.
- Use mechanic soil stabilisation to reduce the risk of landslides.
- Prevent river banks and estuaries from eroding.
- Limit illegal occupation of vulnerable areas.
- Promote jobs in low-income areas, mostly in slums.
- Provide environmental education.
- Capture and store carbon.

Figure 42. Before and after: reforestation of Morro da Saudade.

Actions

Since 1986 the programme has reforested native ecosystems: Atlantic forest, mangroves, restinga (dry sandy ecosystem) and sand dunes along the beaches. Planting has been carried out by residents of low-income communities (mainly favelas — slums), who were educated and trained to participate in the long-term programme.

The programme developed five nurseries to produce native species. They were able to produce 90 000 seedlings per month. By 2016 the reforested area was 3 100 ha, with 9 million trees planted as part of 166 projects.

At the peak of the programme, more than a thousand jobs were created for communities' residents.

The city developed a monitoring tool named SIG Foresta that mapped the ecosystem fragments in 2010, 2014 and 2016, available online [79]. The city has 28 % of natural land-cover [80].

The programme is still ongoing, although the change in the government has slowed the process due restraints on financial resources.

79. http://www.arcgis.com/apps/webappviewer/index.1fbae7d3418ab69ea88aea1c51b5&extent=593426.9615%2C7427711.1316%2C740021.7665%2C7500168.668%2C29183, accessed: 8.10.2018.
80. http://prefeitura.rio/web/seconserma/exibeconteudo?id=7514548, accessed: 8.10.2018.

Stakeholder involvement

The programme was developed by the city of Rio de Janeiro and the Secretary of Environment, coordinated by the Environmental Restoration Department. Under the current administration, the Secretary of Environment has been downgraded to coordination status by Mayor's Act 43915/2017 [81]. The programme was implemented by hiring local residents in local low-income areas who benefited from the afforestation ecosystem services and obtained green jobs.

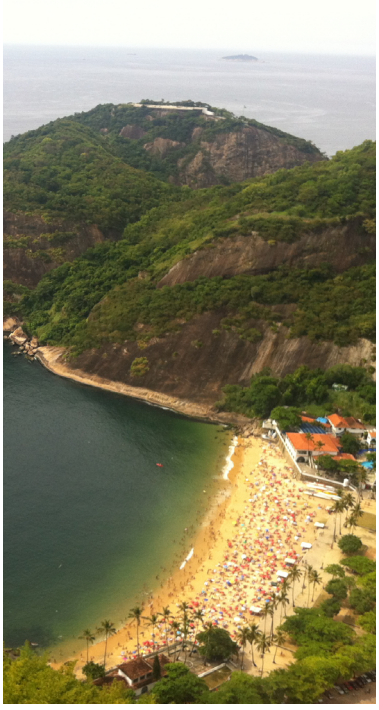

Figure 43. Praia Vermelha seen from the Sugar Loaf Mountain.

Implementation

The programme's implementation began in 1986 and has continued to the present day, with no interruptions, using municipal financial resources. During the 1990s when the programme focused on the Favela-Bairro (Slum-Neighbourhood), Mutirão Reflorestamento received more funds from the Inter-American Development Bank as compensation for the improvement of the slums' urbanisation and job creation.

Outcomes

- Restoration of ecosystems.
- Stabilisation of vulnerable slopes and sand dunes.
- Protection from erosion of lagoon banks.
- Relocation of residents from some vulnerable areas (this is a huge challenge because there is no continuity in the disaster reduction programmes).
- Creation of green jobs — nowadays about 500 people are being paid to manage afforested areas.

From 1987 to 2009 the Mutirão Reflorestamento programme achieved 1 800 ha of planting. By 2016, 3 046 ha had already been planted, through this programme and environmental compensation and fiscal incentives.

81. http://www.sinduscon-rio.com.br/n_agenda/d_011117/43915.pdf

Success factors

Continuity of the programme, participation by community residents and local job creation are the most noticeable success factors. The continuity of the programme is due to the public servants' engagement. Also, the partnership between the city and the communities was essential to the programme's success.

Awards received:

- selected by 'Megacities Project' (UN, 1990), published in Environmental innovation
- selected among '100 Brazilian experiences for the sustainable development and Agenda 21' (MMA, 1997);
- selected among the 20 best projects in the competition 'Public management and citizenship' (Fundação Getúlio Vargas/Ford Foundation, 1997);
- selected to be part of the 'world data bank of best practices and local leadership programme' (UNCHS-Habitat, 1998);
- CREA-RJ (Brazilian Council of Engineering and Architecture) Environment award (1998);
- Model Project Award by the Society for Ecological Restoration (SER, 1999);
- Honours Award in the Metropolis Award, 2002.

Limiting factors and risks

- Violence (insecurity, drug dealers and militia dominate in most areas).
- Lack of financial resources since 2016.
- Although recruitment is done in the local communities, it is difficult to get labour and to qualify and retain recruits because they don't receive the benefits of a formal job.
- In the northern hillsides, where the sun is stronger, there were more fires that impacted the plantings.

Contacts

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4. Brasília: Serrinha do Paranoá waters project

Type: multi-stakeholder

Region: centre-west

Biome: cerrado (Brazilian savannah)

City of Brasília

Population: 3 039 444 (estimated in 2017 [82])

Area: 5 779.997 km²

Elevation: 1 091 m

Coordinates: 15.826700 S / 47.921800 W

MHDI: 0.824 (2010) [83]

Context

Brasília is the capital of Brazil and its third largest city in population. The city was built according to a modernist plan by the famous Brazilian urbanist Lucio Costa, eliminating extensive areas of the cerrado biome (Brazilian savannah), which is being devastated by the spread of urbanisation and by agribusiness.

The city was planned with a core, where the buildings host all federal institutions. The city is zoned for specific uses, such as residential, hotels and businesses. Residents need cars to move around. Low-income housing is located in 'satellite cities' that are far away from the central neighbourhoods. The city has the fastest growing population in the country, with an 11.5 % increase from 2012 to 2017 [84]. The Paranoá lake was built in 1960 after an idea that dated from 1885 [85]. The lake supplies water for the Brazilian capital.

82. https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/16131-ibge-divulga-as-estimativas-populacionais-dos-municipios-para-2017
83. https://cidades.ibge.gov.br/brasil/df/brasilia/panorama
84. Pesquisa Nacional por Amostra de Domicomic Conttomi (Pnad), do Instituto Brasileiro de Geografia e Estattata e (IBGE), 2017, available at: https://www.correiobraziliense.com.br/app/noticia/cidades/2018/04/26/interna_cidadesdf,676318/populacao-do-df-tem-maior-crescimento-do-pais-entre-2012-e-2017.shtml
85. Superficial area: 37.5 km²; total volume: 498 million m³; average depth: 12.4 m; deepest depth: 40 m (Paranoá dam); perimeter: 111.8 km; length: 40 km; maximum width: 5 km

Challenges

- Lack of long-term public policy continuity.
- Severe water scarcity.
- Invasion of public lands and lack of land rights.
- Bureaucracy.
- Loss of biodiversity.
- Limited clean and active mobility.
- Low public environmental consciousness, civic and governmental engagement.

Figure 44. Community planting.

Objectives

Reforestation of the springs located in the northern watershed that flows to the lake Paranoá. Creation of a multi-stakeholder long-term governance process in the territory, which implements the project's vision and fosters public policies towards making the Serrinha do Paranoá a reference in the following areas.

- Water production.
- Ecotourism.
- Active mobility.
- Organic farming.
- Proper land rights and regulations.
- Active environmental and cultural citizen engagement.
- Creation of parks and public wildlife conservation units in a large ecological corridor that connects the National Park, the Paranoá Lake and the environmental preservation area of São Bartolomeu, integrating the current irregular settlements with new, more sustainable planned satellite cities.

Actions

- 115 water springs mapped and geo-referenced using an open-source, low-cost participatory methodology.
- 25 degraded water springs, rivers and lake shores recovered in public planting gatherings, with direct involvement of thousands of people from schools, local neighbours, public servants, NGOs, religious groups, military, boy scouts, motorcycle clubs, university students, pensioners and social and artistic movements.
- One environmental education, ecotourism and artistic large-scale project called 'Relíquia do cerrado' (the cerrado remnant).
- One park and four other conservation units at the final approval stage.
- Approximately 80 newly licensed organic farming families, supported by a Swedish cooperation project, for the next 5 years.
- Two organic markets inaugurated, and two more in the final approval stages.

- Seven mountain bike eco-trails and one urban cycling lane inaugurated, with the integration infrastructure plans at an advanced stage.
- Four parks in the initial stages of implementation on the Lake Paranoá shore.
- One public tree nursery producing 55 000 native trees a year for donation to the population and to support different environmental projects in Brasília.
- Four citizen councils and commissions implemented: the Rural Sustainable Development Council, the Local Planning Council, the Culture Council and the Environmental City Commission.
- One global environment facility project at the initial implementation stage, focused on using agroforestry techniques for ecological regeneration.

Figure 45. A view of Paranoá lake.

Stakeholder involvement

Public institutions such as the North Lake Regional Administration (Administração Regional do Lago Norte), the Environment Secretary, the Federal District parliament (Câmara Legislativa do DF), the University of Brasília and the Public Ministry of the Federal District (Ministério Público do Distrito Federal).

In addition, several NGOs and civil society institutions are involved such as: Oca do Sol, Rebas do Cerrado, Rodas da Paz, Ilumina, Junior Achievement, Ocupe o Lago, Calvaria Motoclube, Cavaleiros Solidários, Community City Hall of the North Lake (Prefeitura Comunitária do Lago Norte), Community City Hall of Taquari (Prefeitura Comunitária do Taquari), Residents' Association of the Palha Creek (Associação dos Moradores do Córrego do Palha), Agriorgânica, Instituto Alternativo Terrazul, Rede Terra do Futuro, Instituto Providência, Terreiro Ilê Axé Oyá Bagan, Catholic Sanctuary of Our Lady of Schoenstadt (Santuário Católico Nossa Senhora de Schoenstadt), Parish of Our Lady of the Lake, Boy Scouts Lis of the Lake, Boy Scouts Gavião Real, Colégio do Sol, INDI School, Movement Save the Vulture (Movimento Salve o Urubu), or Embragea.

Implementation

From 2011 to present (2019).

Outcomes

- Mapping of water springs at the Serrinha do Paranoá that flow into the Paranoá lake.
- Protection and enhancement of ecosystems to increase water flows.
- Creation of conservation units.
- Wildfire management.
- Organic food production.
- Environmental education.
- Citizen engagement.
- Active recreation and clean mobility (bicycles).
- Increase from one certified organic farm to approximately 80.
- Increase from 11 water springs mapped and protected to 115 mapped, protected and under ecological restoration.

Success factors

Connection between civil and public institutions to ensure long-term governance and prevent government interruption of successful public policies.

Limiting factors and risks

- Corrosion of social bonds and exhaustion of civil-society protagonists.
- Governmental shifting of priorities or interruption of policies.

Figure 46. The National Congress seen from the Ministry of Foreign Affairs.

Lessons learnt

Creation of transversal governance networks between government and state institutions with civil society and international cooperation can ensure long-term impacts. The new governance arrangement allows projects to mature and flourish and creates new protagonist relations between communities, NGOs and public servants and the renewal of participatory movements that build on previous experiences and develop local social innovation.

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5. Jaguaré creek restoration

Type: multi-stakeholder

Region: southeast

State: São Paulo

Biome: Atlantic Rainforest, cerrado (Brazilian savannah)

City of São Paulo

Population: 12 176 866 (estimated 2018)

Area: 1528.5 km^2

Elevation: 760 m

Coordinates:: 23.557386 S / 46.737778 W

HDI: 0.805 (2010) [86]

Context

Located in a central area of São Paulo city, the Jaguaré creek is canalised along its full 25 km length. Some parts are buried underground and others are contained in concrete canals between traffic lanes. The watershed has been deeply modified through the urbanisation process and receives a significant load of domestic and industrial sewage and diffuse pollution. The Jaguaré watershed has a diverse set of landscapes and urban contexts, from its springs to the heavily urbanised area where it flows to the Pinheiros river. The watershed corresponds to 1/10 of the total 270 km^2 drainage area of the Pinheiros river, one of the two main watercourses crossing the metropolitan area of São Paulo.

86. https://cidades.ibge.gov.br/brasil/sp/sao-paulo/panorama

Challenges

Nowadays, most of the 300 named rivers and creeks of the city are invisible and run into channels, and the majority are buried underground. They are contaminated with sewage and receive diffuse pollution from the storm-water run-off of impervious surfaces and solid litter. The city is vulnerable to frequent floods, urban heat-island effect and related health problems. The traditional concreted 'piscinões' (built storm-water reservoirs) have already demonstrated that they are not effective in addressing the recurrent floods that occur in the city.

There are several challenges at the Jaguaré watershed that are common to most of the water basins of the city. Water quality and storm-water management are intrinsically related to buildings, natural resources, litter and interventions in watercourses, such as:

Figure 47. Before — as it is nowadays.
After — Landscape transformation with built wetlands to restore ecological functions in a multifunctional park that offer multiple ecosystem services.

- land use and land cover change without planning;
- contamination of waters by sewage and industrial release, and by improper litter discharge in the vicinity of the watershed;
- slums and illegal occupation of vulnerable areas, many without proper sanitation systems;
- private and public settlements that don't follow the urban and environmental legislations, or where built before the laws were created;
- invasive plant species;
- erosion and risk of landslides in some parts of the river banks;
- canalisation of the creeks in engineered infrastructure, both opened and buried underground;
- inefficiency of government interventions in avoiding illegal occupation of the watercourses and flood-prone areas.

Objectives

The nature-based project to restore ecological functions to the Jaguaré creek was developed to establish new concepts and guidelines to enhance the quality of the Pinheiros river and its tributaries. The Jaguaré creek is a pilot project that developed new technologies in multifunctional high-performance landscapes combining manifold urban issues with integrated long-term monitoring and management. The project has an innovative approach to addressing point pollution (sewage and industrial discharge) and diffuse pollution (caused by storm-water run-off). It is a pioneer project proposed for a megacity that is the financial and cultural core of the country. It aims to become a reference of hybrid nature-based and engineered solutions to build urban resilience, support sustainable development and offer quality of life and well-being to urban dwellers.

The Jaguaré renaturalisation project embraces the watershed with an integrated and systemic approach. It aims to restore the ecological processes and functions of the remaining areas that are in the river floodplain and to relocate some occupations in flood-prone areas to create multifunctional wetlands to store, treat and infiltrate storm water, with multiple benefits to the city. There are many challenges due to the heavily transformed landscape and car-oriented urbanisation.

The primary target of the nature-based project to revitalise the Jaguaré creek is to develop a methodology to restore urban landscapes as infrastructures combining technology, urban planning and design, and advocacy. The main objectives are:

- to manage storm water, avoiding floods;
- to moderate local climate extremes;
- to provide a habitat for biodiversity;
- to offer an array of social-cultural benefits.

In order to achieve these goals, a double strategy was used.

- Intercept discharge of illegal sewage and industrial effluents into the drainage system.
- Control diffuse pollution and manage run-off through a series of multifunctional nature-based solutions, such as built wetlands, bioswales and rain gardens.

Actions

The methodology used to develop the innovative project addresses combined strategies of technologies, urban planning and design, and advocacy. The project explores new possibilities to approach storm-water management and water quality with a landscape-friendly method, understanding the ecology of the area with flexible and adaptive design. The 'learning-by-doing' tactic is key in this project, which aims to monitor landscape performance with multidisciplinary cooperation.

The project proposes an innovative approach to dealing with urban waters and enhancing the landscape with NBS, building a series of NBS instead of heavy infrastructure (known as piscinões in São Paulo, whose sole function is to store storm water during strong events).

Stakeholder involvement

The project was led by the NGO Águas Claras do Rio Pinheiros (Clear Waters of Rio Pinheiros), which advocated for the quality of the urban waters and actively engaged stakeholders to:

- raise funds from private companies located in the vicinal region;
- engage academia to develop the plan and design;
- obtain financial support from the State Fund for Hydric Resources to enable the project's development.

Águas Claras do Rio Pinheiros (a non-profit organisation) organised the fund-raising and hired the University of São Paulo as the Foundation Hydraulic Technological Centre (FCTH) of the polytechnic school responsible for developing the hydrological models to accommodate the storm water and give the framework to the design by LabVerde (Landscape Architecture laboratory of the Architecture and Urbanism School).

Implementation

The design project was carried out from 2015 to 2017 but has not yet been implemented.

Figure 48: The very green University City, next to Jaguaré Creek.

Outcomes

The project is expected to offer multiple benefits:

- managing storm water in the nature-based retention and detention basins (built wetlands), bioswales and rain gardens along the Jaguaré creek;
- treating diffuse pollution before the contaminated water reaches the watercourse;
- mitigating urban heat-island effect;
- providing a habitat for biodiversity;
- offering multiple cultural and social benefits.

Success factors

The interdisciplinary design is a successful experience that integrates strategies of technology, urban planning and design, and advocacy to propose a shift in the approach to dealing with storm-water floods and diffuse pollution.

Limiting factors and risks

Cultural and economic factors are limiting the continuity and implementation of the project as an experimental model that can be monitored and managed, and then be applied in other watersheds. There is no clear understanding of the multiple benefits of this nature-based alternative by the decision-makers or by the population, nor of the long-term economic gains that it might bring to the city. Also, the company that is responsible for the sewage collection and treatment has not demonstrated any interest in investing in new and more sustainable and multifunctional NBS.

Figure 49: Capybara in the Jaguaré Creek region.

Lessons learnt

A holistic methodology to address the multiple aspects of urbanisation, such as housing, governance, waste management, sewage and diffuse pollution, is essential to shift the paradigm to introduce NBS that are flexible and adaptable over time. 'Learn by doing' is a concept that is fundamental for fail-safe projects because it allows for redundancies and enables adjustments over time, measuring successful results and adapting undesired outcomes in innovative ways.

The technical and design knowledge to develop projects based on NBS exists, but there is no real integration among different disciplines to concentrate on the implementation. There is too little information and no synergies created among the decision-makers and funding agencies to enable the paradigm shift from grey to green solutions. Also, there is a need to educate and raise awareness among residents of the benefits that bioremediation and mimicking natural processes and flows offer to provide healthier, more sustainable and resilient cities for all.

Contacts

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Paulo Pellegrino (LabVerde)

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Marques, T. H. N., Rizzi, D., Pellegrino, P. R. M. and Moura, N. C. B., 'Projeto Jaguaré: metodologia para requalificação de bacias hidrográficas urbanas', Revista Labverde, Vol. 9, No 1, 2018, available at: http://www.revistas.usp.br/revistalabverde/article/view/143742/139279, accessed: 12.3.2018 (in Portuguese)

Piscinões verdes contra as enchentes ('Green piscinões against floods'), available at: http://www.forumdaconstrucao.com.br/conteudo.php?a=9&Cod=1616, accessed: 5.12.2018 (in Portuguese).

6. Piratininga waterfront park

Type: top-down (government initiative)
Region: southeast
State: Rio de Janeiro
Biome: Atlantic Rainforest

City of Niterói

Population: 511 786 (estimated in 2017 [87])
Area: 5 134.74 km²
Elevation: 2 m
Coordinates: 22.947908 S / 43.075472 W
MHDI: 0.837 (2010) [88]

Context

Niterói is a city located in the Rio de Janeiro metropolitan region, about 20 km from the state capital. The city is divided by the forested and protected Tiririca Massif. The landscape goes from sea level to the highest peak of Elephant Rock at 412 m. The centre faces Guanabara Bay. A new tunnel has been built to enable rapid connection to the ocean region. This connection accelerates the urban expansion to the area where two ocean lagoons are located. The region has been developed as a resort for weekend houses and slums that occupied vulnerable areas. There are several social and ecological challenges, as in most Brazilian cities.

The Piratininga waterfront park project is an innovative experience in Brazilian city landscapes, with the ecological restoration of the watershed using NBS. The municipality is investing to enable adaptation to and mitigation of climate change and to become a reference in sustainability and resilience.

87. https://cidades.ibge.gov.br/brasil/rj/niteroi/panorama
88. https://cidades.ibge.gov.br/brasil/rj/niteroi/panorama

Challenges

The ocean lagoon of Piratininga has been neglected and the environment is degraded. There is direct sewage discharge in the surrounding rivers, contamination by diffuse pollution, and solid waste (from plastic bottles to furniture and electronics) that is discarded in the water catchments that flow to the lowlands. There is a vegetated canal that collects the contaminated water before it reaches the lagoon, but the infected waters infiltrate and pollute the groundwater table and the riparian vegetation. The lagoon is the final destination of the watersheds Viração creek, Cafubá river, Arrozal river, Jacaré river and Santo Antônio creek, with a total area of 22 km².

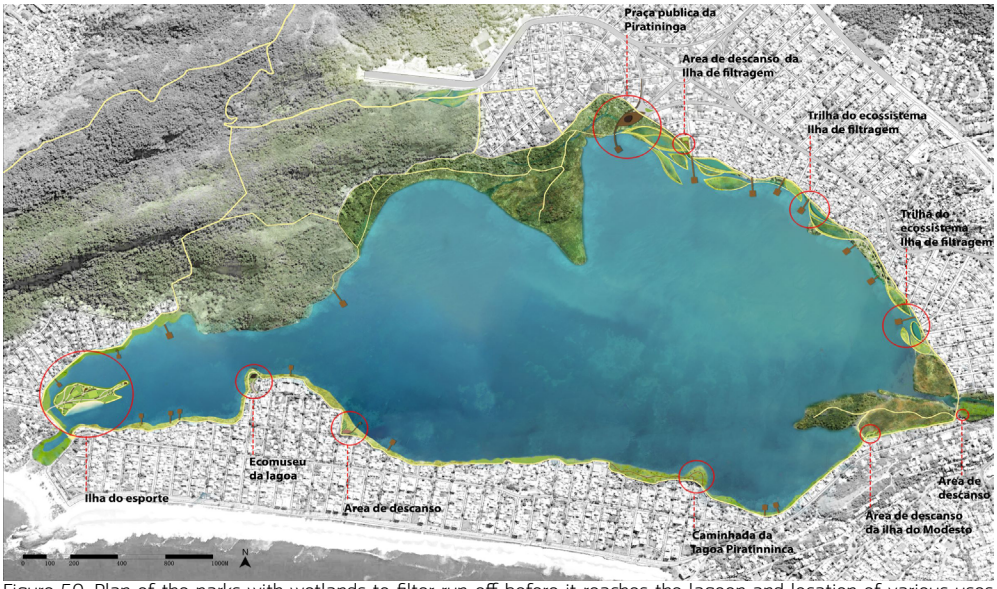

Figure 50. Plan of the parks with wetlands to filter run-off before it reaches the lagoon and location of various uses and equipment.

Objectives

There was a competition for a new park and the winner is a project using NBS to address the challenges of the lagoon's restoration. The design of a multipurpose park aims to offer manifold ecosystem services, such as water quality, protection and enhancement of native biodiversity; to prevent floods and sedimentation and provide multiple active and passive recreation areas, as well as bike lanes to incentivise clean mobility.

The masterplan aims to:

- manage water quality, treat and depollute the lagoon through ecological restoration (phytoremediation) with built wetlands;
- manage solid waste;
- protect and enhance biodiversity to integrate an ecological nature park into the urban landscape;
- design and plan opportunities for ecotourism to incentivise socioeconomic development in a sustainable environment.

Actions

The project, with 685 107.70 m², proposes a water-sensitive design with phytoremediation components (built wetlands) that, applied at the watershed scale, prevent eutrophication in multifunctional green spaces.

Implementation

The executive project was delivered in July 2019. The implementation is still to be determined, without allocated funds to guarantee that it will be done.

The city started a programme to renaturalise the Jacaré river that is a tributary of the lagoon, and in the process the administration decided to extend the project to the entire lagoon to offer a better urban environment with a holistic vision. A public servant produced academic research proposing an ecological park to restore and protect the lagoon. In this process the city opened a competition to develop a project design with funds from the Development Bank of Latin America and from the city. The process involved the residents' associations Amaf, Amjo, Amac, Amorbela, Puma and Amji.

The consortium Parque Orla Piratininga won the competition and is developing the design for the lagoon and part of the tributary watersheds.

Outcomes (expected)

- Conservation, enhancement and valorisation of the lagoon's natural heritage, which has a recognised landscape and ecological potential.
- Native biodiversity (local ecosystems) conservation and enhancement.
- Depollution and water quality improvement.
- Development of plural ecological niches for biodiversity habitats.
- Enhancement of the local identity, with a focus on ecotourism and traditional fishing.
- Development of sustainable urban infrastructure and architecture in the park.
- Incentivising the use of sustainable solutions with recycled materials, certified wood and renewable energy.
- Promoting universal accessibility in all spaces.

Stakeholder involvement

The city hired a consortium of five landscape and urban design studios to develop the project: Phytorestore, Village, Gesto, Embyá — Paisagens e Ecossistemas e Kaan.

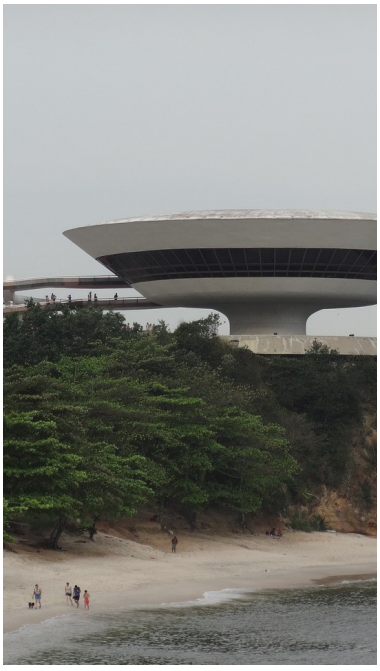

Figure 51. View of Niteroi's coastline: Museum of Contemporary Art.

Success factors

Successes and failures will depend upon the way the project is implemented, especially regarding the focus on sustainable economic development of the local communities. Also, the new common area, with plenty of accessible nature, aims to offer intensive social life, recreation and sports facilities and promote active, passive and healthy spaces in direct contact with nature. The educational and research facilities are targeted at creating stronger social ties that will maintain the park, with knowledge about biodiversity and ecosystem services. An important issue will be long-term political support and citizen engagement.

Lessons learnt

The Orla de Piratininga park is a pioneer project that focuses on NBS to address multiple ecological and social issues. So far it has had a successful paradigm change: from trying to control nature to learning how to live with nature in a tropical coastal city.

Contacts

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7. Antonio Maria Square: restoration of an urban river

Type: top-down (government initiative)
Region: northeast
State: Pernambuco
Biome: Atlantic Rainforest

City of Recife

Population: 1 633 697 [89]
Area: 218.435 km²
Coordinates: 8.052200 S / 34.928600 W
HDI: 0.772 (2010) [90]

Context

Recife is known as the Brazilian Venice, because of its location on the estuary of the two large rivers Capibaribe and Beberibe. The city is a famous tourist destination, with beaches, peninsulas, islands and mangrove remnants. It is a contemporary city, with an important historical and cultural centre. There are many problems with the sewage that runs directly into the rivers. Recife has a plan named Rec500 [91] to prepare for its 500-year anniversary in 2037. The plan incorporates a project for a 15 km-long park system along both sides of the Capibaribe river [92]. The aim is to incorporate the river into the daily lives of the residents through a series of integrated parks that will offer multiple social and ecological functions and be the backbone of the city. The park plan was developed with public participation.

The Antonio Maria square restoration project will be part of the series of parks that will transform the Capibaribe, with the renaturalisation of one of its tributaries within a multifunctional park.

89. https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/16131-ibge-divulga-as-estimativas-populacionais-dos-municipios-para-2017
90. https://cidades.ibge.gov.br/brasil/pe/recife/panorama, accessed: 12.10.2018.
91. Recife 500, http://www.rec500.org.br/, accessed: 12.10.2018.
92. http://parquecapibaribe.org/

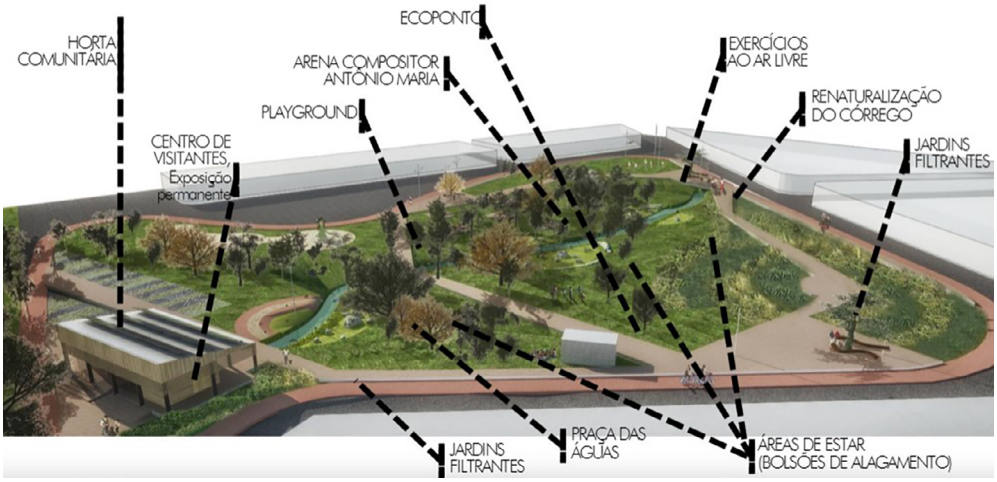

Figure 52. Antonio Maria park design.

Objectives

In the new Antonio Maria Square park, the French company commissioned to develop the ecological project, Phytorestore, designed wetlands along the river banks and filtration gardens to clean the water. The project aims to promote the following social and ecological benefits.

- Create niches to enhance native biodiversity.
- Provide a pedagogical space.
- Offer a natural playground for children that aims to raise awareness about the environment.

The square will be connected to the Capibaribe river through a floating wooden deck and a jetty for electric boats.

Recife is working on the ecological restoration of its rivers, so incorporating NBS to recover the water quality through filtering gardens was the best option.

Actions

The executive project has been finalised, but not yet built. The city has developed a phasing timetable for Rec500 plan that incorporates this project in the future.

Stakeholder involvement

Rec500 was developed by an innovative agreement between the city of Recife, through the Secretary of Sustainable Development and Environment and the INCITI, a research network of the University Federal of Pernambuco.

Regarding Antonio Maria Square, the project was developed by a partnership between the Recife Agency for Innovation and Strategy and Phytorestore, a French landscape architecture studio. Research has been carried out to assess local history and learn what the expectations of the residents are.

Figure 53. Artist view of the future renaturalised river.

Implementation

The Antonio Maria Square project was developed in 2016, but has not yet been implemented. The funding to develop the executive project came from the Recife Agency for Innovation and Strategy, which select the Phytorestore design through a public open tender.

Outcomes

This project was an opportunity to validate the technology of the filtering gardens as an NBS that can be applied in other parts of the city.

Expected outcomes:

environmental:

- river bank restoration,
- enhanced water quality,
- creation of new habitats for aquatic fauna and birds and consequently an increase in local biodiversity;

social and economic:

- more and better public urban open spaces,
- environmental education,
- development of the regional economy.

Success factors

Success or failure of the implementation will depend on the engagement of the local community. It is critical that the place be appropriated by people that will care for biodiversity conservation, waste generation and disposal and maintenance of the spaces, facilities and equipment, among others.

Limiting factors and risks

Rec500 is planned over a long period, so there are risks related to change of government and political will to implement the project.

Lessons learnt

Every situation is unique, based on the local context. The lesson learnt with the development of the project was how to adapt the NBS to the local urban environment and to social expectations.

Contacts

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Figure 54. Mangroves in the city of Recife.

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8. Recreio green corridor

Type: top-down (government initiative)

Region: southeast

State: Rio de Janeiro

Biome: Atlantic Rainforest

City of Rio de Janeiro

Population: 6 520 266 (2017 [93])

Area: 1 264.2 Km² [94]

Elevation: from 2 m to 1 024 m high at the Pedra Branca peak

Coordinates: 22.902778 S / 43.207500 W

MHDI: 0.799 (2010) [95]

Context

Rio de Janeiro is a coastal city that ranges from around 2 m above sea level in the lower areas to forested massifs [96] that divide the city into zones: central, north, south and west. The highest peak is Pedra Branca (White Rock), 1 024 metres high. The city has significant forested areas that cover most of the mountains. The landscape has been highly altered during the urbanisation process, with massive dismount of hills and creation of land over wetlands, mangroves, the Guanabara Bay and along the coast of Copacabana. Most of the 267 rivers and creeks [97] have been canalised or are buried underground. The city has suffered massive landslides and floods, and the coastal areas are prone to erosion caused by storm surges and rises in sea level.

The west area of the city, where the Recreio green corridor is located, has undergone rapid urbanisation with the eradication of ecosystems caused by urban sprawl, after a modernist urbanisation with gated communities and informal occupation of lowlands due the lack of proper social housing planning.

93. https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/16131-ibge-divulga-as-estimativas-populacionais-dos-municipios-para-2017
94. https://www.geografos.com.br/cidades-rio-de-janeiro/rio-de-janeiro.php
95. https://cidades.ibge.gov.br/brasil/rj/rio-de-janeiro/pesquisa/37/0?tipo=grafico
96. https://ceciliaherzog.files.wordpress.com/2011/01/sumc3a1rio-relatc3b3rio-vulnerabilidades-rmrj.pdf
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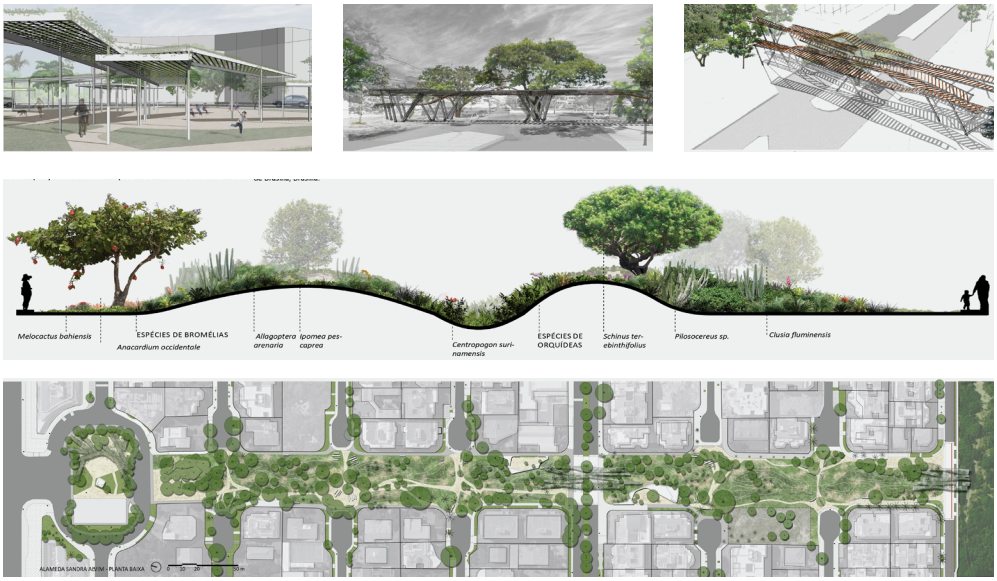

Figure 55. Partial view of the awarded project — the green street with restinga landscape design and ecological features to connect people and biodiversity.

Objectives

The city of Rio de Janeiro has significant national, state and municipal protected areas. However, these fragments are disconnected and threatened by sprawling formal and informal urbanisation.

The city has therefore decided to map 11 priority areas to connect important ecosystem remnants as part of its programme, Carioca mosaic of protected areas [98]. The Carioca mosaic was one of the objectives of the municipal plan to conserve and restore the Atlantic Forest of the city of Rio de Janeiro, developed by the Municipal Secretary of the Environment in 2015. The approach was based on the landscape ecology of the city to identify the potential connectivity corridors and buffer zones.

The first green corridor that was implemented is located in the west zone, in the lagoon system of Jacarepaguá and Sernambetiba Fields (Campos de Sernambetiba). One of the components of this project is the Recreio green corridor, which connects the natural parks of Marapendi, Chico Mendes and Prainha, including the Rangel Hill (an Inepac Designated Cultural Area [99]. The area is in the Jacarepaguá lowlands, with a rich mosaic of Atlantic Forest ecosystems and water bodies (lagoons and canals). The plan is multiscale, ranging from the lagoon system water catchments to local interventions.

The main objective is to protect and enhance the rich biodiversity to maintain the ecosystem services that give sustainability and resilience to the region. There are many ecological and social challenges that the project has addressed since the beginning of its implementation in 2012 [100].

98. http://mosaico-carioca.blogspot.com/p/pnt_04.html
99. State Institute for Cultural Heritage, http://www.inepac.rj.gov.br/
100. Grupo de Trabalho — Corredores Verdes — Resolução SMAC P nº183 de 7.11.2011 18/4/2012.

Actions

The Recreio green corridor project was designed to preserve and connect 320.76 ha of protected areas and add 60.73 ha of open public spaces and squares. The parks are connected by the das Tachas canal that flows from the Marapendi lagoon to Lagoinha lagoon and continues west, where locally endangered species such as caimans [101], capybaras [102], and the beach butterfly [103] live. The corridor has managed invasive species, introduced native vegetation along the canal. The strategy was based on local urban ecology, with three main elements:

preserve:

- existent biodiversity core areas;

connect:

- the core areas that present less human use,
- green streets, considered buffer zones of the core and connection areas,
- multifunctional streets, collector roads with 'green islands' in the middle as corridors of biodiversity and connectors with the urban tissue;

expand:

- green neighbourhoods — all urban areas that can have more native trees in public or private open spaces —, including green roofs and walls.

Figure 56. Capuchin monkey.

The project also provides for clean mobility, with comfortable and safe bike lanes and walkways, and the enhancement of public transportation with green bus stops.

Environmental education programmes have been developed and implemented to engage and educate the residents, and also raise awareness about the role of biodiversity and ecosystem services for quality of life and well-being.

Stakeholder involvement

The plan of the green corridors was developed by an interdepartmental study done by several city departments [104], with the participation of external experts.

The city commissioned a landscape design studio and an urban planning company to design the green corridor. They worked on projects that address local issues, understanding the role of each part in the whole project — an inter-scale and multifunctional approach.

101. Caiman latirostris — Jacaré-do-Papo-Amarelo.
102. Hydrochoerus hydrochaeris — Capybara.
103. Parides ascanius — Borboleta da Praia.
104. SMAC, SMU, SMH, SubPC, FPJ, CAU, RIO- RIO-, FPJ, CAU, R.

Implementation

The working group delivered the report to orient policies and practices in 2012 [105]. Actions started to be designed and implement after that. They are not yet fully implemented.

There have been many public events to present the plan for the green corridor to various audiences and in different formats throughout the years since 2012.

Environmental compensation was the main source of financial resources. The Olympic Games in 2016 meant that many developments had to comply with legislation on the eradication of natural areas.

The personal efforts of public servants must be highlighted. Some are responsible for pushing forward the green corridors along the lagoons until the present.

Figure 57. A view of a lagoon with a mangrove forest in the Recreaio Green Corridor.

105. Resolu CA SMAC P nU, RIO- RIO-, FPJ.

Outcomes

The Recreio green corridor has achieved the protection of many core areas, removed invasive species and introduced native vegetation.

Some interventions have provided more space for caimans and capybara populations, at the same time allowing for people to observe these animals (with no physical contact). All core areas are protected by fences to avoid the transit of animals out of the protected areas and to limit the circulation of people in those areas.

Limiting factors and risks

- The city administration has no real interest in the restoration project.
- There is a slum that occupies the borders of the canal.
- Some parts of Recreio green corridor are dominated by militia, and they occupy vulnerable and biodiversity-rich areas without public control.
- The area receives raw sewage in the waters, and the eutrophication is destroying the underwater life. Caimans are mostly male, because the eggs of females don't hatch due to the high temperature caused by excessive organic matter in the environment.
- There are conflicting issues with wildlife: caimans must be separated from people; capybaras are vectors of the tick that transmit Lyme disease.

Lessons learnt

It is extremely challenging to work on the enhancement of green areas with NBS projects when there is no political will to introduce them or to protect ecological areas.

Partnerships between public and private institutions and the involvement of qualified professionals and engaged citizens to protect and enhance nature in urban areas are very important.

There is a need to educate people from all areas so they can understand the need to introduce NBS and protect and improve native biodiversity in urbanised areas.

Contacts

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Parque Natural Municipal Chico Mendes

9. Petrópolis: biological waste-water treatment

Type: multi-stakeholder
Region: southeast
State: Rio de Janeiro
Biome: Atlantic Rainforest

City of Petrópolis

Population: 305 687 (estimated 2018 [106])
Area: 776.6 km²
Elevation: 809 m [107]
Coordinates: 22.505000 S / 43.178611 W
MHDI: 0.745 (2010) [108]

Context

Petrópolis is located about 70 km from the city of Rio de Janeiro. It is an important destination in the mountain region known as the Imperial City, named after Emperor Dom Pedro II who used to spend summer in the hills because of the more pleasant climate. It is an important historic site, with many tourist attractions, and is well known as a gourmet and nature-oriented destination because of its surrounding conservation units with impressive and vulnerable landscapes. The city has 82.1 % [109] of its waste water treated, which is higher than the national average of sanitation treatment of 44.92 % [110]. In the census of 2010, 25 117 people lived in subnormal housing (slums), mainly in vulnerable areas prone to floods and landslides.

106. https://cidades.ibge.gov.br/brasil/rj/petropolis/panorama
107. https://www.geografos.com.br/cidades-rio-de-janeiro/petropolis.php
108. https://cidades.ibge.gov.br/brasil/rj/petropolis/panorama
109. https://cidades.ibge.gov.br/brasil/rj/petropolis/panorama, accessed: 2017
110. http://www.tratabrasil.org.br/saneamento/principais-estatisticas/no-brasil/esgoto, accessed: 5.8.2018.

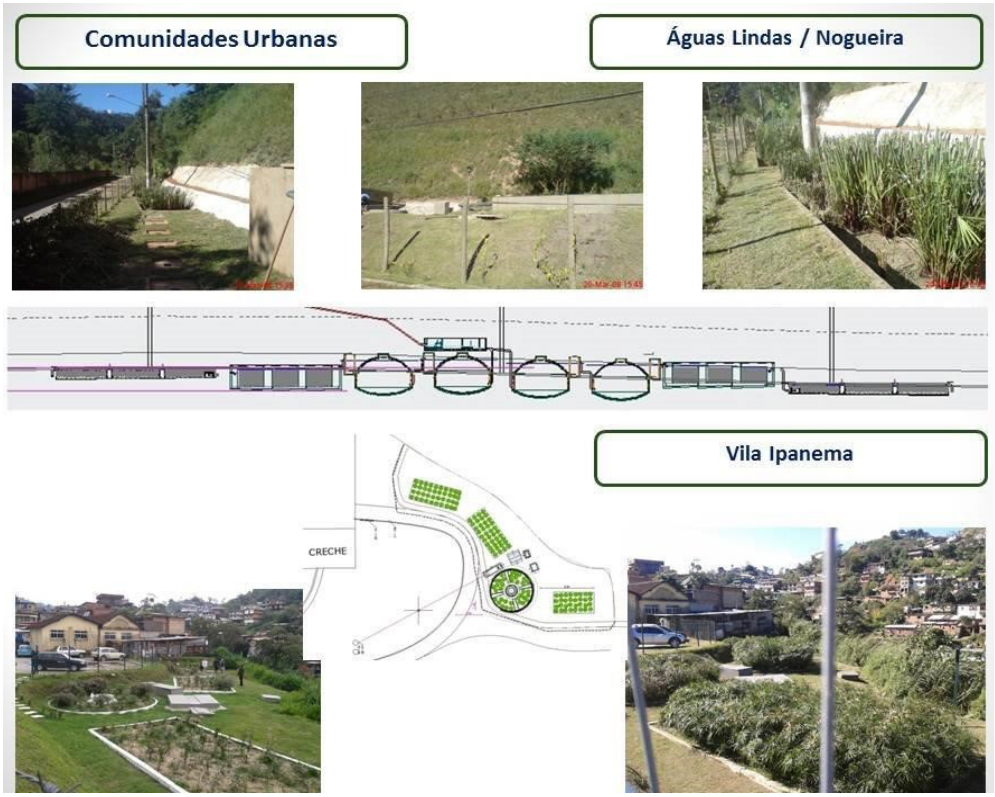

Figure 58. Waste-water treatment system and implementation images in different locations in Petrópolis.

Challenges

Difficult access to treat waste water in the high and steep hills, where low-income people lived in unplanned dwellings. In many areas, sewage was discharged directly into the watercourses.

Objectives

The aim of the micro waste-water treatment with biodigestor and wetlands for depuration was to clean waste water, to reduce energy demand, and to use biogas.

Actions

The decision of the water company was to implement NBS with biodigestors and built wetlands to treat the waste water locally and improve river water quality.

The biodigestor is partially made with recycled materials, such as old tires and plastic bottles.

Ten neighbourhoods in Petropólis already have implemented NBS to treat their waste water: Quarteirão Brasileiro, Vila Rica, Córrego Grande, Vila Ipanema, Nogueira, Siméria, Bonfim, Independência, Morro do Gavião e Caxambu.

Figure 59. Nature-based solution to treat waste water: biodigestor and built wetland in Vila Ipanema, Petrópolis.

Stakeholder involvement

The Environmental Institute, an NGO headed by the architect Jorge Pires, who is an expert on waste-water treatment has extensive experience in designing nature-based water treatment systems uses biologic-based technology. The private water company Águas do Imperador educated and trained local residents who participated in the implementation and are co-responsible for managing and maintaining the systems.

Implementation

The first plant began operating in 2002. Ten plants are in operation nowadays, thanks to a collaboration between Águas do Imperador, the city of Petrópolis, the Environmental Institute of the state of Rio de Janeiro (INEA) and the Environmental Institute (NGO).

Outcomes

Waste-water treatment plants based on NBS are five times less expensive than conventional plants and do not require energy input. They are effective, as the effluent that goes back to the watershed is up to 90 % cleaner. They are socially aware as it was decided not to charge low-income residents for waste-water treatment. Furthermore, biogas is used in kindergartens and by the community.

These plants recycle and reuse water, organic matter present in the sewage and methane gas.

The water company invested in environmental education programmes for local residents.

There was an improvement in the environmental and aesthetical local conditions, as in the case of Vila Ipanema (see image above).

Success factors

The city had to bring its sanitation in line with federal legislation and received funds to implement the projects to protect the Paraiba river watershed, which provides water for a large population in the state of Rio de Janeiro.

Lessons learnt

Nature-based waste-water treatment is economically viable, ecologically reliable and benefits the neighbourhood and its residents. The NBS waste-water plants have received awards and have attracted visitors from other cities and countries to learn from their experience, including staff from the World Bank.

Residents must be educated and participate in the process to achieve a shift in the paradigm of traditional waste-water treatment.

Topography is a barrier to transferring sewage to a distant conventional treatment plant, so this is the only option for many cases in the mountainous region.

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Figure 60. Petropolis is located in a mountainous region of the state of Rio de Janeiro.

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http://diariodepetropolis.com.br/integra/aguas-do-imperador-conquista-mais-um-premio-por-praticas-socio-ambientais-sustentaveis-123215

10. Ecopark Natura: filtration gardens

Type: private
Region: north
State: Pará
Biome: Amazon

City of Benevides

Population: 61 689 (estimated in 2018 [111])
Area: 177.7 km²
Elevation: 28 m
Coordinates: 1.36138 S / 48.244722 W
MHDI: 0.665 (2010) [112]

Context

Benevides is an industrial city that is part of the Belém metropolitan region (capital of the state of Pará). It is in the Amazon biome, on the equator, with high temperatures and insulation during the whole year. Humidity is high, with rainfall in all seasons.

Objectives

To treat the Natura cosmetics factory's industrial and sanitary effluents in a beautiful filtering garden, tackling multiple issues in the same place at the same time.

The filtering gardens are located at the main access point of the production facility and are the focal point of the ecopark where the Natura cosmetics factory is located. They give a fresh look to waste-water treatment, bringing NBS to the vanguard to offer numerous benefits.

111. https://cidades.ibge.gov.br/brasil/pa/benevides/panorama
112. Idem.

Figure 61: A view of the filtration gardens

Actions

This waste-water biologic treatment project treats 132 m³ of sanitary effluents daily.

- The filtering gardens were implemented in 2013 and have been efficient ever since. There is a weekly garden maintenance service (plants grow quickly because they are located in a very favourable environment).
- The clean effluents flow to a watercourse nearby.
- The Environmental Department demands periodic water quality analyses with high restrictions of contaminants.

Implementation

The project was financed by the private company Natura, developed in 2012 and implemented in 2013.

Stakeholder involvement

This is a private project with the following companies involved.

- Conception and management: Phytorestore.
- Contractor: Sinetel.
- Client: Natura.
- Contractor management: Concremat.
- Project management: Gesto Ambiental.

Outcomes

Besides cleaning water, it offers a nice place to rest and contemplate and enhances biodiversity. The innovative treatment plant allies the aesthetics of a garden with the water depuration process. It has given a lot of visibility to the brand in the media.

After 5 years in operation, water analyses have shown that the parameters are better than conventional waste-water treatment plants and go beyond environmental requirements.

- Treatment of all the industrial and sanitary effluents to meet the high environmental standards required by the city department.
- It is a biologic treatment that enriches biodiversity, with low energy consumption.
- There is no sludge generation because all the organic matter is filtered and consumed by the plants, eliminating the need to dispose of it.
- There are great gains compared to the conventional waste-water treatment plants that require chemicals, generate sludge and demand high energy to function.

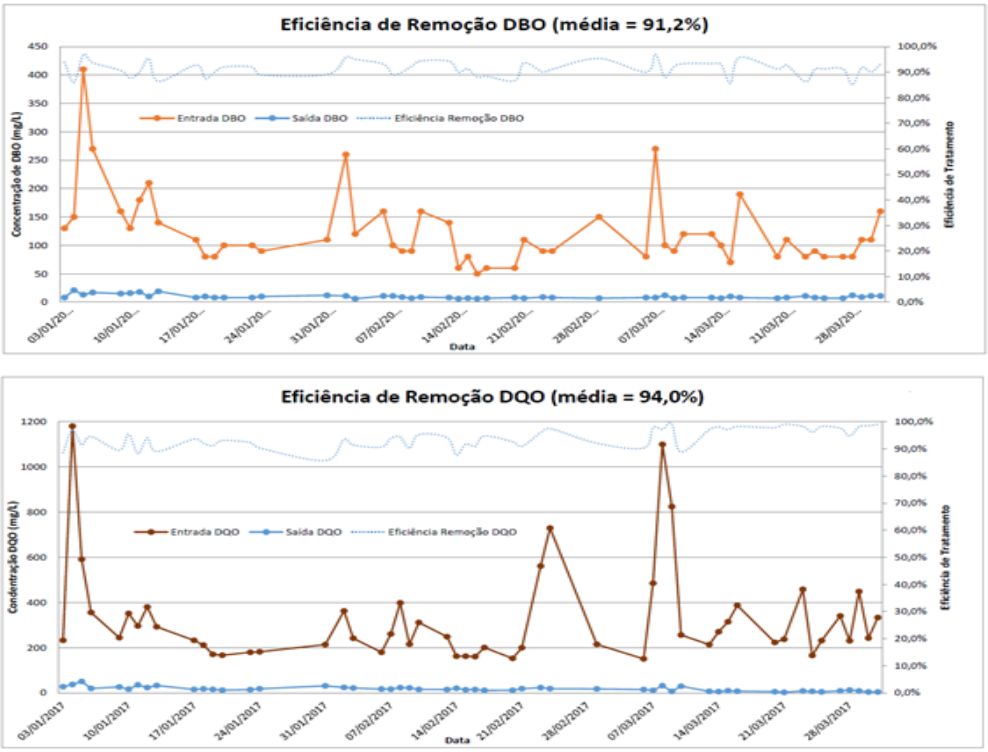

Figure 62. The positive impacts are measured in periodic analysis. In the graphs above it is possible to verify the high removal of biochemical oxygen demand (DBO below), always below 21 mg/L, with high removal efficiency (91.2%); and chemical oxygen demand (DQO below), always below 50 mg/L, removal efficiency of 94%.

Success factors

Establishing from the outset the correct dimension and configuration of the system, according to the quantity and quality of effluents.

Limiting factors and risks

There was a delay in the building process caused by more rain than usual, which caused a small increase in the planned implementation cost.

Lessons learnt

As Phytorestore conceived the treatment and not the piping system of the factory's effluents, there was an initial difficulty in adjusting the operation and supervision. From this project on, the company established the parameters for the effluents' piping system to be implemented by another contractor.

It was possible to demonstrate the efficiency of the filtering gardens in the biologic treatment of industrial and sanitary effluents and the possibility to implement the same technology in other biomes and climate zones.

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11. Seashore ecosystem restoration

Type: multi-stakeholder
Region: southeast
State: Rio de Janeiro
Biome: Atlantic Rainforest (restinga — dry sandy ecosystem)

City of Cabo Frio

Population: 216 030 (estimated in 2017 [113])
Area: 410 418 km²
Elevation: 4 m
Coordinates: 22.886944 S / 42.026111 W
MHDI: 0.735 (2010) [114]

Context

Cabo Frio is a tourist destination with many second homes near the beaches. Urbanisation has spread along the seashore with single family homes in several real estate developments.

Challenges

The Brazilian shoreline is already being affected by beach erosion, storm surges and strong winds, altering the coastal geography. The seaside ecosystems provide protection against those threats, reducing the vulnerability that climate change and associated events are bringing.

The region is a low plain area that was previously covered by restinga ecosystem and alluvial areas between the estuary of the rivers Una (south) and São João (north). There are protected areas in both rivers. There is an important aquifer named Tamoios

113. https://cabofrio.rj.gov.br/dados-gerais/
114. https://cidades.ibge.gov.br/brasil/rj/cabo-frio/panorama

that supplies water to the region, which depends on soil perviousness, and there is risk of salinisation due to seawater intrusion.

In the northern areas where the ecosystems have been eradicated and urbanisation has spread up to the beach, the effects of the rise in sea levels and storm surges are eroding the shore. In the southern areas, coastal vegetation has been better preserved between the urbanisation and the beach, and this has led to lower levels of erosion.

Objectives

The restoration and management of the restinga ecosystem, in front of the real estate developments Florestinha, Orla 500, Vivamar e Terramar in the Tamoio district, aims to enhance and maintain the sand dunes that prevent sand and waves from advancing over the road and into urbanised areas. The vegetation within the developments covers a total area of 120 000 m^2.

Actions

The project has undertaken the following activities.

- Connecting with residents and organising educational activities, also using digital and social media.
- Conducting field research identifying vegetation species — native and exotic — with undergraduate students from the Fluminense Federal University (UFF).
- Installing information panels to educate and restrain public access to ecosystem remnant areas. Many signs have been made and put in place by residents.
- Fencing vegetated areas and closing secondary pathways within the green patches.
- Transferring rubbish bins from the beach to the local street.
- Contact and meetings with public institutions to establish partnerships for the project: the municipality, the navy and INEA.
- Promoting periodic vegetation pruning.
- Fostering rubbish collection in appropriate areas.
- Opening proper pathways to access the beach.
- Protecting birds' nests.
- Setting up projects to raise funds in development agencies.
- Advertising the project through posters, digital and social media.

Stakeholder involvement

The project was an academic initiative of the Department of Geography of the UFF. It was implemented with the effective participation of the local communities, with the efforts and support of public sectors, as the city of Cabo Frio, INEA, the Brazilian navy and the Public Ministry.

Implementation

The extension project of the undergraduate course took place from 2016 to 2018. The activities are continuing with residents' engagement and voluntary supervision by the UFF researchers.

The strategy was to involve the public institutions and the City Environmental Secretary, as mentioned above. Also, residents from all four communities were engaged through awareness-raising and were educated to value the ecosystem services provided by the restinga. This enabled them to continue the ecosystem conservation. There was no funding or material participation from governmental institutions; the resources came from the local community. This is a multi-stakeholder project led by academia and supported by people interested in their own well-being.

Figure 63. Aerial view of the restored restinga, with partial view of the housing developments Orla 500, Vivamar e Terramar.

Outcomes

- The vegetation has protected the coastline and urban developments from marine and wind erosion, and sand movement that used to cover the road and the urbanised areas.
- Edible and pharmaceutical plant species have been identified.
- Public debates have been carried out on the role of the vegetation in the protection of urbanised areas (ecosystem services).
- The rubbish that was left on the beach was collected. Rubbish bins were relocated to the street next to the protected vegetation.

A technical report with further analysis of the impacts is being prepared by UFF students.

Success factors

The project was selected in 2017 as an example of an NBS for coastal areas, by the Boticário Foundation and Getúlio Vargas Foundation (a recognised Brazilian academic institution).

The main achievements were:

- Spontaneous participation of the communities in the project and the awareness raised about environmental issues and quality of life.
- Although without funding, this initiative raised debate about urbanisation and vulnerability in coastal areas.

Limiting factors and risks

- Lack of actual municipal commitment to fence the restored area, provide proper signage, and lack of participation of public servants in the hands-on activities.
- The financial resources to implement the activities were only from the communities' mobilisation, with no participation by the municipality.
- Absence of technical support from the public institutions in the establishment of plans and actions to restore the degraded areas, and proper management.
- Lack of political will to orient and support proper legislation and control to regulate the circulation and activities on the beach, mainly during holidays and high-season periods.
- The participation and engagement of only some of the residents, due to the cultural understanding of the aesthetic value of the restinga — many people are used to the controlled and homogenised gardens, with mostly exotic ornamental species, so they see the native ecosystem as 'messy' and of little value.
- Lack of environmental awareness of many residents and beach-goers that kept throwing away rubbish in the area.
- Pedestrians walking on planted areas and opening new pathways.
- Circulation of horses, vehicles, and motorcycles on the beaches and over the vegetation, impacting plants and birds' nests and increasing the risk of erosion.
- The menace of fires is high because there are no controls or designated areas for barbecues.

Lessons learnt

- If there is interest of any agent, public or private, there are positive results.
- Municipal engagement in the process is difficult, even if there are no high financial costs involved.
- National programmes and projects are good in conceptualisation, but when applied at state or municipal scales they don't always convert into positive results. The example of the national plan of coastal management is failing because the states and cities don't have financial resources to apply the plan.

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12. Springs Square: nurturing urban waters

Type: bottom-up (grass-roots initiative)

Region: southeast

State: São Paulo

Biome: Atlantic Rainforest, cerrado (Brazilian savannah)

City of São Paulo

Population: 12 176 866 (estimated 2018)

Area: 1528.5 km^2

Elevation: 760 m

Coordinates:: 23.557386 S / 46.737778 W

HDI: 0.805 (2010) [115]

Context

São Paulo is the capital of the state of São Paulo and the centre of the largest metropolitan area in South America with 21.2 million [116] inhabitants. The city has expanded over the landscape with the eradication of the original ecosystems, burying most of the creeks, with larger rivers straightened and canalised. Nature is restricted to some parks, mainly in the peripheral areas. São Paulo has been called the City of Waters due to the 300 rivers and creeks that were originally in the landscape. Many springs remain active, despite the urbanisation. There is a growing movement of awareness-raising regarding nature in the city, and the relationships between biodiversity, waters and people.

115. https://cidades.ibge.gov.br/brasil/sp/sao-paulo/panorama 8.11.2018.
116. https://www.worldatlas.com/articles/biggest-cities-in-south-america.html 8.11.2018.

Challenges

The Homero Silva square (the legal name of the Springs Square) is situated in the Sumaré neighbourhood of São Paulo. The vicinity is mainly residential. This square of 12 000 m² is the largest green space of the neighbourhood.

It used to be a derelict area where people would throw rubbish. It was unsafe; nobody used to go there. A grass-roots movement called Ocupe&Abrace (occupy and hug) started to take care of the place to recover the springs and biodiversity, aiming to gain direct contact with nature and natural processes and flows.

Actions

The Springs Square is a groundbreaking initiative created by the community to occupy the small, derelict park and restore the springs located there.

Figure 64. Built pond to collect the water from the eight springs of the Água Preta creek — social ecological benefits in the heart of the city.

- Restoration of eight springs of the Black Water creek (córrego Água Preta) that flows into one of the main rivers that cross the city, the Tietê river.
- Plantation of more than 600 native and fruit/food species in collective events.
- Building of two ponds.
- Introduction of about 100 aquatic species in the ponds to enhance the ecological balance, and to biologically control mosquitoes.
- Promotion of social activities.
- Organisation of 13 festivals that attract people to celebrate nature, rivers and springs. The event has become a tradition that has permeated to other neighbourhoods and is inspiring more people to care for their green areas.
- Celebration of other civic initiatives, such as music festivals and a 'drums circle'.

There is an independent project named cerrado infinito (infinite savannah) inside the square that has introduced vegetation from the cerrado (Brazilian savannah), the native dry ecosystem that had disappeared from the urban landscape. Daniel Caballero is an artist who is passionate about this ecosystem. He has been collecting, planting and educating residents about the importance of getting back this ecosystem that has deep roots, thus enhancing the water flows of the springs.

Stakeholder involvement

- The design and implementation were carried out by the grass-roots movement Ocupe&Abrace.
- The introduction and monitoring of the aquatic biodiversity and most of the new trees were done by the biologist Sandro Von Matter.
- Daniel Caballero planted in the square what he has called cerrado infinito. There is signage to explain and educate readers on the species and functions of the ecosystem along the pathways.

Implementation

The collective movement started in 2013 and has been very active since then.

- Community engagement and collaboration maintains the square's activities. The festivals are carried out with residents' contributions.
- Daniel Caballero finances the cerrado infinito.
- There is no funding from any institution.
- The city collects rubbish, mows the lawn and maintains the lighting.

Outcomes

- The pond and the fauna have reduced the mosquitoes in the region. It has gained space in the media (newspapers, magazines and TV programmes) to call attention to the importance of NBS in promoting a balanced and healthy environment.
- Schools and universities promote field trips to learn what has been done in the square and learn about science outdoors.
- Residents enjoy the quiet and peaceful green area daily.
- Residents and other grass-roots movements are more cohesive and work together to mobilise people to environmental causes.
- Temperatures and air moisture close to the park are better than in other places.
- Awareness has been raised about civic responsibility for water security and conservation, especially in the city that has faced shortages of water for several dry years.
- The springs have been recognised by the Geographic and Cartographic Institute of the state of São Paulo.
- Water quality has been approved by the state environmental company and is monitored monthly by the project Observando Rios (observing rivers), of the non-governmental organisation SOS Mata Atlântica (Atlantic Forest).

Success factors

- This is a successful bottom-up project that has been a reference that transcends the city's borders due to social media.
- Biodiversity in the area is impressive, due to the collective work and engagement.

Limiting factors and risks

Planning is underway for a 22-story building to be built on the edge of the square, with an underground garage that will affect the water table and its ecological balance. Ocupe&Abrace is fighting against the construction because there are springs in the lot, and is demanding that the city protect and incorporate this plot of land into the square.

Lessons learnt

The grass-roots movement Ocupe&Abrace is a civic initiative that incorporates every collaborator's talent. There is no leadership. The informality of the group is not an obstacle to keeping the work flowing well and productively. The biggest challenge is when it has to be represented in public sessions, or to the public institutions.
There seems to be a small and silent revolution occurring, progressively changing people's minds and reconnecting them to nature.

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13. Araucárias Square: rain garden and pocket forest

Type: bottom-up (grass-roots initiative)

Region: southeast

State: São Paulo

Biome: Atlantic Rainforest, cerrado (Brazilian savannah)

City of São Paulo

Population: 12 176 866 (estimated 2018)

Area: 1528.5 km^2

Elevation: 760 m

Coordinates:: 23.557386 S / 46.737778 W

HDI: 0.805 (2010) [117]

Context

The climate in São Paulo has changed [118] from light rain and cool year-round, to mostly dry and hot. The city is vulnerable to urban heat-island effect and recurrent severe floods with the strong storms caused by land-cover change. The waters are contaminated by sewage discharge and diffuse pollution [119] caused by storm-water run-off.

Challenges

In São Paulo, with urban growth and consequent landscape change, about 3 000 km of watercourses disappeared from the landscape, which leads to constant floods. This square is located about 50 m from the larger, mainly paved Batata's [120] Square. Before the car-oriented urban development, the neighbourhood was calm and walkable, with

117. https://cidades.ibge.gov.br/brasil/sp/sao-paulo/panorama, accessed: 8.11.2018.
118. Lima, G. N. and Rueda, V. O. M. (2018), 'The urban growth of the metropolitan area of São Paulo and its impact on the climate', Weather and Climate Extremes, Vol. 21, pp. 17-26, available at: https://www.sciencedirect.com/science/article/pii/S2212094718300082
119. Vivacqua, M. C. R. 'Qualidade da áda de escoamento superficial urbano — Revisão visando o uso local' (master's thesis), Escola Politécnica da Universidade de São Paulo, 2005 (in Portuguese).
120. Batata means potato in Portuguese. http://largodabatata.com.br/, accessed: 30.1.2018.

mixed uses (residences, shops and services), and social life happening in the former square in front of the local church. The area was severely impacted by the opening of large streets, with negligible consideration for residents, users and pedestrians.

Objectives

- Recover ecological functions.
- Introduce native biodiversity.
- Manage storm water to avoid floods.
- Provide urban public spaces.

Actions

The urban polygon is around 650 m2. The first thing that was done was to take the fences out, remove 10 full truckloads of debris and waste, and remove four men who informally lived inside. Social assistants from the Social Assistance Agency took care of them and relocated them to a more adequate place. Then the company that had built the three petrol tanks underground was hired to remove them, and during the excavation process two more illegal tanks were discovered. The area went through a decontamination process. Under the debris they discovered fertile soil from the Pinheiros river floodplain. The river was rectified and channelised and is now located 650 m to the west.

The design was made on-site, due to the unique conditions and financial constraints. Benches were strategically located to provide resting places for users.

The area was a petrol station that was deactivated to open a new high-traffic street, which divided the lot into two separated spaces. Then the lot was fenced and abandoned for years following the demolition of the petrol station. It was used as a rubbish dump site.

Figure 65. Before, the area was fenced and derelict.

Figure 66. After the transformation with planting of native species.

The vegetation selected for planting is autochthonous, with small patches of three different ecosystems: forest, cerrado (Brazilian Savannah), and wetlands. Among the forest trees there is a rare species, Ficus organensis, in addition to the Araucaria angustifolia pine trees and palms that were present in the riparian forest along the Pinheiros river before urbanisation took place. Herbaceous native and edible plants were also planted; many seedlings and seeds were also brought by the participants in the planting.

Stakeholder involvement

There was active participation by residents and leaders of the grass-roots movements to transform this remnant derelict piece of land and the triangle-shaped lot across the road. The grass-roots movements involved are: A Batata precisa de você [121] (the potato square needs you), Florestas de Bolso de São Paulo [122] (pocket forests of São Paulo) and Novas Árvores por Aí [123] (new trees all over).

The planting of the pocket forest was carried out in June, and the rain garden in December 2017. Social media is being used to invite and motivate volunteers to participate in the collective efforts to plant pocket forests in small plots of land in a few hours. It is a social experience, with people of all ages coming from various districts to actively contribute to reintroducing nature in the city.

The city, represented by the district mayor (sub-prefeito de Pinheiros), gave the authorisation to implement the project, once the process was done.

Figure 67. After the transformation with planting of native species.

Implementation

The project was implemented in June and December 2017.

A resident committed to contributing to the neighbourhood funded the project and adopted the area to maintain and protect the new pocket park. Other leaders worked voluntarily and an engineer was hired to develop the run-off collection and drainage system.

Figure 68. After the planting, storm water of 1 000 m2 of paved surface was conducted to the rain garden and infiltrated, avoiding recurrent floods in the region.

121. http://largodabatata.com.br/a-batata-precisa-de-voce/
122. https://arvoresdesaopaulo.wordpress.com/florestasdebolso/
123. https://novasarvoresporai.wordpress.com/

Outcomes

Araucárias [124] Square is a pioneer public rain garden in São Paulo city that collects, filters and infiltrates the run-off [125] of impervious land cover, and has become an example that can be implemented in other public and private spaces.

The rain gardens are being monitored by the team who led the planning, design and implementation. On 21 January 2018, a storm led to 67 mm of rainfall in 45 minutes. The rain garden collected the run-off of approximately 900 m², and in 4 hours the water had already percolated underground. The plants grew fast; 10 months later the biodiversity is blooming with flowers, butterflies and trees, offering multiple benefits:

- milder temperatures with shaded paths for pedestrians;
- mitigation of floods in the area;
- areas for people relax and enjoy nature in the heart of the metropolis;
- the disappearance of the rats that were abundant in the area.

Rubbish being brought to the area remains a problem. People are helping to keep it clean.

Success factors

- The confluence of active citizens' activities enables the transformation of the urban landscape.
- A local resident that has the financial capacity to fund the project, and the vision of the crucial role of NBS.
- Two activists that have been advocating and implementing NBS at local level and have a passion and knowledge about indigenous ecosystems.
- An engineer that has been developing NBS at local level.
- Public engagement and participation in the project's implementation.

124. Araucaria angustifolia is the only native conifer in Brazil. The square was named after it because it was part of the Atlantic Rainforest ecosystem that previously existed there and that is now being restored.
125. http://fluxus.eco.br/portfolio/jardim-de-chuva-largo-das-araucarias/#toggle-id-2, accessed: 30.1.2018.

Limiting factors and risks

This is a personal investment of a resident, so it is dependent on his continuous effort to maintain the space that now belongs to the public.

Lessons learnt

This is the first rain garden implemented in a Brazilian city with the involvement of joint grass-roots movements. The rain garden collects 100 % of the run-off of 900 m^2 that would otherwise go directly to the drainage system that used to flood lower areas. The storm water is detained and filtered and infiltrates to the underground water table that flows to the Green river. Ten months after its implementation the vegetation is thriving, and the run-off provides nutrients.

The garden is blooming well even in the dry season (100 days without rain in 2018). The area is also booming because of the proximity to the metro stations and new building developments. The shops located in front of the square have been renovated and a building that was empty for a long time now houses a medical clinic. Rubbish is the most relevant problem that affects the square.

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https://catracalivre.com.br/cidadania/plantio-vai-transformar-largo-das-araucarias-em-praca-de-lazer/

Figure 69. **Araticum** (*Annona sp.*), an example of a native fruit tree planted in the Araucaria square.

14. Owls' community food garden

Type: bottom-up (grass-roots initiative)

Region: southeast

State: São Paulo

Biome: Atlantic Rainforest, cerrado (Brazilian savannah)

City of São Paulo

Population: 12 176 866 (estimated 2018)

Area: 1528.5 km^2

Elevation: 760 m

Coordinates:: 23.557386 S / 46.737778 W

HDI: 0.805 (2010) [126]

Context

São Paulo is the capital of the state of São Paulo, and the centre of the largest metropolitan area in South America with 21.2 million [127] inhabitants. The city has expanded over the landscape with the eradication of the original ecosystems, and burying most of the creeks, with larger rivers straightened and canalised. Nature is restricted to some parks, mainly in the peripheral areas. Agriculture is located in the countryside or in the urban fringes, far from most of the population.

Objectives

- Convert a lawn (known as green desert) [128] into a high-performance landscape.
- Introduce food production in the heart of a metropolis, reconnecting people to food sources, biodiversity and natural cycles.
- Restore natural cycles of water and biodiversity.

126. https://cidades.ibge.gov.br/brasil/sp/sao-paulo/panorama, accessed: 8.11.2018.
127. https://www.worldatlas.com/articles/biggest-cities-in-south-america.html, accessed: 8.11.2018.

Actions

The small park Dolores Ibarruri, 48 000 m², is known as Springs Square, named after the river that crosses the low area in a canal. The park received a new landscape design in 2010. It was the first project of a local green infrastructure composed by rain gardens and bioswales to slow the storm water that flows down the hill [129]. The slopes were all covered with lawns that require high maintenance.

Figure 70. Owls' Square slopes covered with lawn in 2011.

Stakeholder involvement

The planting and appropriation of the areas followed the principles of permaculture and agroecology. Claudia Visoni and Tatiana Achcar started the movement and citizens started to participate in planting and caring for the new urban productive space. Claudia Visoni, a journalist, started to plant in the public space in 2011, using social media to invite people to collective plantings. In 2012, a group of 50 people who attended a first workshop of agroecology by Claudia and Tatiana opened a Facebook page called Hortelões Urbanos (urban farmers) to reverberate the need to plant food locally. The Facebook group now has more than 80 000 members from different places. They help people start their own food garden, create opportunities

Figure 71. Owls' Square with the Owls' Food Garden in 2017.

to exchange experiences, promote the placement of new community food gardens and organise the exchange of seeds and seedlings and other events in the garden [130].

The Regional Council for Environment, Sustainable Development and the Culture of Peace of the Pinheiros District (Conselho Regional de Meio Ambiente Desenvolvimento Sustentável e Cultura de Paz, da subprefeitura de Pinheiros) has supported the actions and practices.

128. https://www.ecobeneficial.com/wp-content/uploads/2014/03/Replacing-the-Green-Desert.pdf
Ignatieva, M. and Ahrn, K., 'Biodiverse green infrastructure for the 21st century: from "green desert" of lawns to biophilic cities', Journal of Architecture and Urbanism, Vol. 37, No 1, Routledge, 2013, pp. 1-9, available at: https://journals.vgtu.lt/index.php/JAU/article/view/4243/3602
129. http://elzaniero.com.br/urb/praca_corujas.html, accessed: 9.11.2018.
130. https://hortadascorujas.wordpress.com/sobre-a-horta/#surgiu

Implementation

This is a continuous process that started in 2012. The district mayor gave informal authorisation to start food planting in the area, but there are no formal partnerships or external funding. The resources come from volunteers.

Outcomes

- The food garden is a social ecological experience, where people reconnect with nature and learn about nutrition, and reconnect with their community.
- The agroforestry techniques applied to restore the soil have brought back water springs that are now stored in small built ponds and are used during drought periods to irrigate the planting.
- The slopes that used to slide in heavy rains are now stable thanks to the ecosystem restoration that avoids erosion. In areas where there is no planting, the soil leaks down the hill.
- Over the years the food garden has enabled thousands of people to transition to a new lifestyle: from consumerism to local food planting and other sustainable habits, such as learning how to value non-commercial plant species to maintain a healthy life with a low-cost local organic diet.

Limiting factors and risks

- Not enough committed people to work on a regular basis in planting and management.
- People can damage or steal plants, tools, seedlings and compost.
- Many people interfere in the garden without knowing how to properly manage the vegetation. Also, people deposit materials that they believe to be useful to the garden but that are not suitable for the ecological garden, such as tyres and plastic items.
- Many people come to ask about the garden, but don't participate in the daily work required to maintain the garden.

Success factors

People are responsible for the successes. Volunteers participate in the collective plantings and cleaning efforts and maintain the garden. They organise seed exchange and learn with each other about their own planting and nutrition experiences.

Lessons learnt

An open democratic planting in an urban space must deal with a diversity of people. Education is key to make them understand that ecological aesthetics are different from an ornamental controlled garden that most of them are used to recognising as a beautiful place. The Owls' Food Garden has given the opportunity to shift the paradigm from low- to high-performance landscapes with high levels of biodiversity that offer multiple ecosystem services. The repercussions are wide and have spread far beyond the borders of the city and food production. The garden is helping to transition to a new vision of a more sustainable, resilient and just society.

The 800 m^2 Owls' Food Garden has become nationally known and recognised by UN Food for Cities. It is a reference and has inspired many others in the city and around the country.

Contacts

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15. Favela green roof

Type: multi-stakeholder
Region: southeast
State: Rio de Janeiro
Biome: Atlantic Rainforest

City of Rio de Janeiro

Population: 6 520 266 (2017 [131])
Area: 1 264.2 Km² [132]
Elevation: from 2 m to 1 024 m high at the Pedra Branca peak
Coordinates: 22.902778 S / 43.207500 W
MHDI: 0.799 (2010) [133]

Context

In Rio de Janeiro the population living in slums (favelas) in 2010 was 19 % of the inhabitants (last census) [134]. The informal occupation of steep slopes and flood-prone areas occurs mainly because of the absence of social housing planning, inducing low-income people to use protected areas that the formal real-estate market cannot occupy. The climate is tropical, with extremely high temperatures especially in the northern zone where there are almost no green areas and where the low-income population live in extensive slums (favelas). The temperature can reach over 60 °C in this region [135].

Objectives

Introduce biodiversity to reduce the temperature and filter rainwater in a residence located at the dense Arará slum, in the northern zone of the city.

131. https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/16131-ibge-divulga-as-estimativas-populacionais-dos-municipios-para-2017
132. https://www.geografos.com.br/cidades-rio-de-janeiro/rio-de-janeiro.php
133. https://cidades.ibge.gov.br/brasil/rj/rio-de-janeiro/pesquisa/37/0?tipo=grafico
134. https://www.brasil247.com/pt/247/brasil/31334/IBGE-Brasil-dobra-n %C3 %BAmero-de-moradores-de-favelas-em-20-anos.htm
135. For more information on the urban heat-island effect and urbanisation in the city of Rio de Janeiro, see Lucena et al. in the reference list.

Figure 72. Green roof at the Arará community in the heart of a highly built-up and paved area with extremely hot temperatures all year round.

Actions

The existing 36 m^2 (6 × 6m) wavy fibre cement tile roof was retrofitted with the support of an academic, who developed the technicalities and monitored the roof for 2 years as part of his doctoral research. The support used for planting the 'natured' roof consisted of three layers of: (1) geotextile RT10; (2) PVC impervious membrane; and (3) geotextile RT16 to enable the rooting of the vegetation. A simple three-quarter-inch pipe irrigation system was installed, perforated on the deep part of the wavy roofing. The irrigation was used every night without rain. Native species of orchids and bromeliads are among the species used.

Stakeholder involvement

Bruno Rezende Silva designed the green roof and selected the epiphyte and litophite plants. The planting was done by two young ladies that could walk over the roof, and the owner Luiz Cassiano (known as Careca) coordinated and gave visibility to the project to encourage other favela residents to implement similar roofs.

Implementation

The project was implemented at the end of the summer in 2016. The academic researcher and the owner, who is an activist who advocates the introduction of nature in slums, organised a collective effort to implement the vegetated roof.

Outcomes

The monitoring of the temperatures comparing the vegetated roof and the bare neighbouring control roof showed that the inside of the green-roof house was 20 °C cooler at the peak of the heat during the day. The reduction of storm-water run-off was also verified.

Success factors

The synergy between the residents' desire to have a green roof and the knowledge of the researcher was essential to implement the project.

Figure 73: Detail of the green roof at the Arará community: native bromeliads are some of the chosen species.

Lessons learnt

Green roofs can and should be implemented in slums as low-cost, lightweight, and low-maintenance solutions to lower indoor temperatures, reduce the urban heat-island effect and storm-water run-off and improve quality of life in low-income communities.

Limiting factors and risks

Extreme heat limits the diversity of plants that can live in this hostile environment.

Contacts

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KI-04-18-972-EN-C

The European Commission and the Brazilian Ministry of Science, Technology, Innovation and Communication started a dialogue on Nature-based Solutions (NBS) in 2015. In this report, European and Brazilian experts analyse the occurrence and potential of NBS in Brazil, highlight good practices in the EU for possible adaptation to the Brazilian context, and contribute to the elaboration of a NBS strategy in Brazil. This body of knowledge results in a strong case for nature as a solution to social, environmental and economic challenges.

25 case studies from both sides of the Atlantic illustrate how working with nature can have a positive impact on people's lives. The chosen examples address many challenges: from water management, to ecosystem restoration, urban heat island effect, floods, landslides or coastal erosion. In particular, the Brazilian case studies span all regions of Brazil and the country's most threatened biomes (the Atlantic Rainforest, the Cerrado, and the Amazon). They display how Brazil's mega-biodiversity could be the solution to a series of issues and provide inspiration to us all.

The report concludes that Nature-based Solutions are not only smart investment choices but also a means to enhance quality of life and an opportunity to shift to a new economy and a new lifestyle - more connected to nature.

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