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Biodiversity in cities

TECHNICAL GUIDE

#WorldInCommon

TECHNICAL GUIDE BIODIVERSITY IN CITIES, AFD, September 2021.

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Our planet faces **a mass extinction, the sixth in 500 million years.** In the past century, the loss of species has been 100 times higher and, according to a recent United Nations Report, **a quarter of species on Earth are threatened with imminent extinction. All ecosystems are deteriorating and changing** rapidly, while they are the basis of human life.

Indeed, these disturbances – loss of soil productivity, forests and oceans, degradation of watersheds, disruption of carbon sinks and natural purification cycles, emerging diseases, etc. – affect **3.2 billion people** and the annual cost of the loss of services is estimated at **20% of world GDP.**

Urban development has in particular profoundly changed territories. Massive land take, the decline in the diversity of species used, deforestation, along with pollution and its concentration are all urban disturbances for ecosystems. The fact that **over 60% of the human population will be living in cities by 2060** shows the magnitude of the challenges.

There is an urgent need to **rethink the place of nature in cities** as of now. There are solutions. Taking nature into account in urban and territorial development is both an environmental and social imperative and a solution. Wherever it exists, through rewilding, protection, restoration or planning, **urban biodiversity renders essential and indispensable services for the well-being of city dwellers.** It must become a means and an objective for ambitious urban policies.

Agence Française de Développement (AFD) is committed to supporting this ambition. In a world where urban areas are increasing every year, AFD strives to protect and promote biodiversity in cities. Nature-based solutions (NbS) and, more generally, "nature-based design" are central to the projects it supports. In addition, mainstreaming biodiversity into its activity in urban areas will be essential for the **achievement of its climate and biodiversity convergence objective.** The Group is increasing its pro-nature investments in all sectors and geographical areas. The aim is **to devote €1 billion and 30% of its climate finance to biodiversity by 2025, in synergy with its social objectives.** It is thereby giving itself the means to contribute to the achievement of the objectives of the Paris Agreement, the 2030 Agenda and the upcoming COP15 on Biodiversity.

On the operational front, AFD develops appropriate tools. The Urban Transition and Mobility Department and Ecological Transition and Natural Resources Management Department have co-produced **a Technical Guide to contextualize, design, implement and manage urban projects with biodiversity, from the level of the main structural natural fabric of cities to neighborhoods, using a range of Nature-based Solutions.** This toolkit aims to provide project stakeholders with keys to understanding, lines of thought, methods and feedback to make biodiversity in cities a key driver for development and the achievement of the Sustainable Development Goals (SDGs).

Contents

Foreword: Objectives of the guide and how to use it

This is by nature a partial and living Guide which aims to provide operational staff and their internal and external contacts with a documented toolkit to **develop biodiversity "in all conscience" in the urban projects and public policies** financed by AFD. It has been produced at the initiative of the Urban Development, Town Planning and Housing Division (VIL) and is therefore firstly intended for project managers. It aims to **stimulate dialogue with counterparts and partners,** in order to ultimately improve the quality of projects and the services rendered to people by biodiversity. This technical document is entirely dedicated to Biodiversity in Cities and first and foremost aims to **promote the contextualization of projects before seeking the solutions to develop.**

The introduction of the guide gives a brief definition of the notion of "biodiversity" and presents the international context in this field. **The first part** is devoted to understanding biodiversity in urban areas. It comprises six chapters which firstly outline the main principles for analysis, design and evaluation and, secondly, describe the diversity of types of action for biodiversity in cities.

To go further with the reading and understanding of the chapters, **the second part** presents solutions for the implementation of biodiversity in projects with **Technical Sheets** and **Feedback Sheets** on projects. The sheets are supplemented by **appendixes** to specify or expand on certain aspects and are grouped into kits by type. Finally, the **Appendixes** make it easy to find the relevant reference material: AFD's Exclusion List, the databases and online resources, the list of signatory countries to the Rio Convention (1992).

4 types of Sheets

METHOD SHEETS

Key principles and concepts to optimize the ecological, economic and social inclusion of biodiversity in cities.

TOOL SHEETS

Useful instruments for the appraisal, implementation and management of a project (indicators, management, monitoring and evaluation tools).

TECHNICAL SHEETS

Advice for the implementation of a range of pro-biodiversity developments, supported by factual and statistical data.

FEEDBACK SHEETS

Presentation of inspiring urban projects and their development choices relevant to biodiversity.

"Ramblas" green corridor and historic public space connecting old suburbs with the sea.
© Creative Commons Niko Roussos https://www.flickr.com

Introduction: Sustainable cities for humans and biodiversity

Biodiversity in cities: definition and issues

Biodiversity refers to the diversity of living beings and the relations that individuals develop mutually and with their environment. It includes the **diversity of ecosystems** (wealth of the different environments on the planet), **specific diversity** (number of species per unit area) and **genetic diversity** (degree of variety of genes within a population of the same species). In cities, species live in an artificial ecosystem, dominated by human beings and with specific hydrological, upper-air and soil conditions.

Preserving biodiversity in cities **maintains a link with nature for residents, improves health and the quality of life and creates resilient and sustainable spaces.** Furthermore, biodiversity provides a number of human benefits in the form of goods and services. They are called "**ecosystem services**[1]",and preserving them is often **economically advantageous** compared to the implementation of technological engineering solutions for an equivalent level of services rendered[2]. Protecting biodiversity also **creates jobs and added value.**

DID YOU KNOW?

In France, €1 spent on biodiversity protection generates on average **€2.64** of production and **€1.31** of added value. €1 million of this spending creates **19 jobs** on average[3].

© Adobe Stock - PCH.Vector.

1, 2, 3: See the details of the sources in the End Notes.

Risks and opportunities

The urban environment is not, a priori, biodiversity-friendly: soil surface sealing and the development of urban infrastructure contribute to the destruction and fragmentation of vital habitats for flora and fauna. Species no longer have access to the resources they need for their life cycle and remain enclosed in isolated patches. Furthermore, the urban environment is marked by **specific physico-chemical parameters** due to pollution and the effects of heat islands. Generalist species, meaning they thrive in a large number of environmental conditions, are therefore favored, to the detriment of specialist species. This results in **a uniformity of species and a reduction in biodiversity.**

However, cities can **offer a great diversity of attractive spaces, in the form of receiving areas for biodiversity or passing places** (recreational green spaces, lines of trees, green walls and facades, etc.). Nature-based Solutions (NbS) used to develop and manage public spaces provide alternatives to conventional civil engineering techniques and offer benefits for flora and fauna. Biodiversity can also develop via urban agriculture, which benefits from a large number of consumers and can contribute to the social inclusion of disadvantaged people.

Permeable play area taking advantage of the existing plant cover.
©Aurelie Ghueldre, Teresina, Brazil, 2020.

International framework and development objectives

The **Convention on Biological Diversity** (CBD), which was signed during the Rio Earth Summit in 1992, structures all the global negotiations on biodiversity. It defines the conservation of biodiversity and the sustainable use of its resources as the main objectives. Its governing body, the **Conference of the Parties** (COP), met in Nagoya in 2010 and produced a strategic plan which has been converted and adapted in France via the **National Biodiversity Strategy 2011-2020.**

This strategy aims to:

- Generate the willingness to act in favor of biodiversity;
- Preserve life and its ability to evolve;
- Invest in a common good: our ecological capital;
- Ensure sustainable and equitable use of biodiversity;
- Ensure consistency across policies and the effectiveness of action;
- Develop, share and promote knowledge.

At the same time, the **European Union** (EU) has approved a biodiversity strategy for 2030, which aims to manage the biodiversity crisis at global level through the conservation and regeneration of nature, the preservation and improvement of ecosystems and their services and the fight against invasive species. With the doubling of financial flows for biodiversity during the decade 2010-2020, in line with the commitments of Member States, the EU wishes to increase its support for the period 2020-2030.

AFD has adopted a policy aligned with these various texts on biodiversity. It is set out in the **Cross-cutting Intervention Framework** (CIF) **2013-2018** and aims to:

- Mainstream the conservation of ecosystems into all sectoral development policies, by taking greater account of biodiversity during the appraisal phrases and promoting public-private partnerships to finance biodiversity-related issues.

- Protect, restore and develop ecosystems, by including local communities and building the capacities of institutions responsible for biodiversity protection.

- Strengthen partnerships between French, international, public, private, scientific and civil society stakeholders.

AFD's Territorial and Ecological Transition Strategy 2020-2024 focuses on the promotion of Nature-based Solutions (NbS) for the preservation of natural resources, the emergence of economic and social co-benefits, and climate change mitigation and adaptation.

Aerial photo of the three host cities for international biodiversity conventions
-Rio de Janeiro 1992, Brazil.
-Nagoya 2010, Japan.
-Kunming 2021-2022, China.
© Google Earth.

A spatial and temporal understanding of biodiversity in urban areas

©AFD, Stéphane Brabant, Ganvié lakeside city, Benin, 2018.

1.1. Biodiversity in the project cycle

It involves presenting the key stages in mainstreaming biodiversity into the appraisal cycle of an urban development project. **A list is provided of the basic parameters and fundamental questions on the context in terms of biodiversity,** independently of the level of ambition or priority that may be given to this aspect in the project.
Generally speaking, mainstreaming biodiversity into urban projects involves dealing with three parameters:

• The **reality of the territory of operation and its particularity** (climate, economic, cultural, historical, etc.).

• **The morphology of the site,** both natural (topography, existing structures, green corridor, watercourses…) and anthropogenic (urban fabric, infrastructure, roads, etc.). While developers are used to designing the city through the built environments, the full spaces, it is firstly structured through the empty spaces, which are the main basis for developing biodiversity (connection network for habitats), but also for social interaction (network of public spaces).

• The **level of ambition** in terms of institutional capacities, programming needs and political priorities, as well as the intrinsic physical potential of territories.

In an urban project or public policy, three questions can help identify, at an early stage, the feasible level of ambition in terms of biodiversity:

- Support and competences: Are there local stakeholders that are drivers for biodiversity conservation, as well as local expertise and a strong local culture for the protection of natural spaces and environments?
- Biodiversity capital: Are the multiple and simultaneous functions provided by nature in cities known and recognized and/or the risks of their disappearance identified?
- Integrated approach (at varying levels): Are there systems to protect nature and projects integrating Nature-based Solutions (NbS)? Are the issues of biodiversity and nature in the city addressed in a cross-cutting and strong manner in the actions of the various services (local authority) or in sectoral public policies (territorial policy)? Are the actions for biodiversity a priority and are they monitored via widely communicated indicators?

When the primary objective of a project is not to develop, conserve or protect biodiversity in urban areas, in contrast to a project to restore a watercourse or create a linear urban park to interconnect "natural" spaces, for example, it can integrate biodiversity on an ad hoc or more cross-cutting basis, such as via the implementation of Nature-based Solutions (NbS).

From the analysis to the selection of the site, up to the project evaluation, the key stages to clearly define the biodiversity issues during the project appraisal cycle are summarized below:

The first point requiring attention is when **the submission sheet is produced or, at the latest, the identification sheet.** It concerns the first verification of the project with regard to the Exclusion List for AFD's activities. In this respect, projects that cause a net loss of biodiversity in critical habitats cannot be appraised and financed, as set out in the Exclusion List (see Appendix 1).

During the identification committee meeting, it is essential to **ensure that there is no net loss of biodiversity** (Avoid-Reduce-Compensate sequence, or ARC, to manage via the impact assessment) and an understanding of the biodiversity-related issues with regard to the nature of the project and the territory concerned (existing diagnostics or that need to be planned). These issues can be analyzed for **the entire urban territory using appropriate indicators,** in order to ensure the fit between the urban context and the biodiversity objectives targeted by the project.

During the feasibility study, it may be advisable to include a number of points and tools in the Terms of Reference (ToR) to ensure that better account is taken of biodiversity and/or include them in the analysis of the baseline by the **Environmental and Social Impact Assessment** (ESIA) which will have been launched at the feasibility stage. To develop biodiversity-friendly practices, an **ecological diagnostic** can be conducted, at the same time as surveys on the interactions between biodiversity and the populations present, as well as the various existing modes of ownership (by the native communities, women, etc.) or conflicts. At this stage, opportunities to develop biodiversity can emerge and the investment planning can define the desired level of ambition.

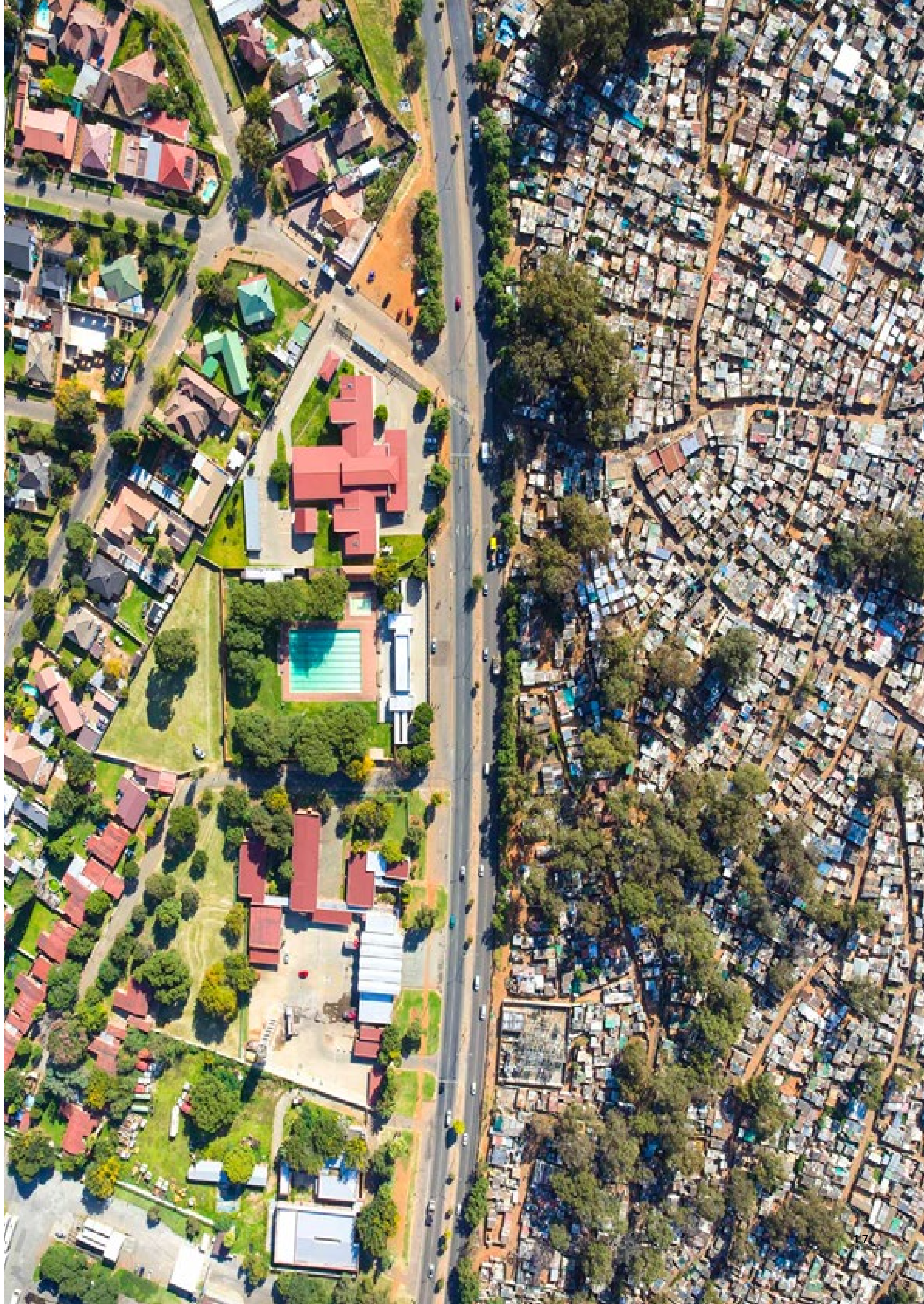
The project **design study** is the appropriate stage for initiating or furthering the dialogue with the contracting authority on the uses of the environments and natural resources present, the introduction of new biodiversity spaces, and the implementation of NbS as alternatives to civil engineering, if relevant. Furthermore, the project design **may include approaches for deconstructing and unsealing soil** in order to recreate naturalized and permeable spaces. To do so, it may be necessary to use the cultural dimension related to nature and biodiversity, identify the needs of cities in terms of resilience to natural disasters or climate change, or promote the economic and health benefits of these developments. This stage must also **anticipate the management costs and maintenance methods** that need to be planned. They must be clearly identified and assumed by the contracting authority and its possible manager.

When the comprehensive ESIA is carried out (analysis of the baseline flora-fauna and analysis of the project alternatives to be conducted in advance, if possible, to provide input for the feasibility study and project design), the **definition of measures to avoid or reduce impacts** and, otherwise, **the compensation of potential impacts** (budget secured, site identified, competent and experienced contracting authority) must be clearly set out (ESIA mandatory for projects classified A or B+ and, at the minimum, an Impact Notice). The assessment, as well as the ecological study conducted during the feasibility stage, may define recommendations:
i.e. the mobilization of local genetic resources, the diversification of species and vegetation cover, etc. The online biodiversity databases are useful for identifying locally adapted species.

The **phase for the procurement of implementation studies and works** requires the identification and management of the functional risks (relating to the installation, management and operation of the construction site), mainly comprising the destruction of habitats and introduction of invasive alien species. This phase can be an opportunity to raise the awareness of the site operators and create temporary biodiversity areas, with support from the identified and defined stakeholders (volunteer site managers, etc.).

Finally, the **monitoring of the project** implementation, then beyond, during the operating phase by the contracting authority, requires the **definition of indicators** on the biodiversity or environment. They must be measurable over time and relevant with regard to the initial state of the site (before the project) and the expected development objectives (with the project). The **effective monitoring of these indicators** makes it possible to promote the project, identify its successes, limits, and possibly both the positive and negative unexpected effects. This evaluation can be combined with awareness-raising campaigns for stakeholders, as well as the training of a knowledge network on biodiversity.

Right from the phase for the analysis of the territory and project planning, ongoing **citizen participation** can be a driver to ensure the right level of ownership and mobilization of residents or groups of population to support the management and preservation of the biodiversity spaces created or restored, or the monitoring of the indicators on these spaces.

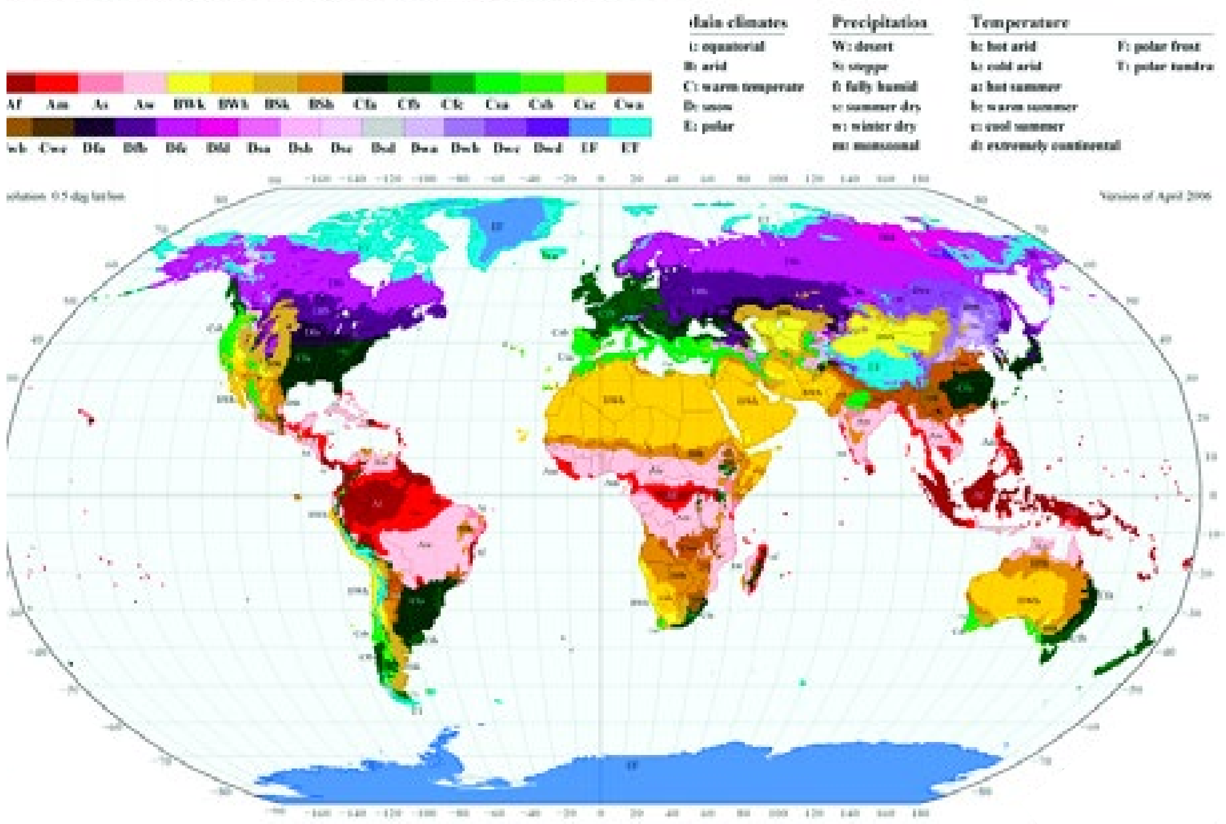


Typologies of the presence of vegetation in cities, depending on urban forms and socioeconomic inequalities.
© World Bank, Johannesburg, South Africa.

1.2. What biodiversity for what territories?

By nature, the integration of biodiversity is extremely contextual and this Guide, along with the technical sheets it contains, is not intended in any way to propose one-size-fits-all, transferable or replicable solutions. It involves possibilities that must first and foremost be **based on knowledge of the territory and a good understanding of the interactions between its natural environment and the people who live in it.** Each project fits into a specific environment, characterized by climate parameters and specific constraints on environmental resources (humidity, temperature, etc.). The plant species selected to create habitats must be adapted to these environmental conditions.

***Köppen-Geiger world climate classification map*[4]**



MAIN CLIMATE	PRECIPITATION	TEMPERATURE
A: Equatorial B: Arid C: Warm temperate D: Snow E: Polar	W: Desert S: Steppe f: Fully humid s: Summer dry w: Winter dry M: Monsoonal	h: Hot arid k: Cold arid a: Hot summer B: Warm summer c: Cool summer d: Extremely continental F: Polar frost T: Polar tundra

Example: BWh = Arid for the main climate, Desert for precipitation, Hot arid for temperatures. See "Hot desert" in the table.

Otherwise, there will be a significant impact on their development and the ecosystem services they render due to an unsuitable physiology. Furthermore, a choice that does not take into account the social, cultural, economic or governance constraints of the territory can lead to an overconsumption of resources and the emergence of conflicts over uses or health and environmental risks.
The objective here is to give some guidelines in terms of the **climate and degree of adaptation of types of projects** for biodiversity, in order to highlight the variety of situations for operations, even before seeking the solutions and management methods to develop. A more detailed analysis of the specific context of the territory for the operation, which should be carried out during the feasibility studies and/or ESIA (if they are conducted sufficiently in advance of the project and allow real iterations with the design), is therefore a prerequisite for maximizing the biodiversity potential of projects. The variety of climates, which are classified according to the **Köppen-Geiger typology,** form a first set of constraints by grouping together scales of temperature, precipitation, humidity and seasonality.

Correlation table between climates and relevance of potential projects

Climate	Areas concerned	Relevant projects*	Non-relevant projects
EQUATORIAL	North West South America • Democratic Republic of Congo • Indonesia • Malaysia • Papua, New Guinea	Forests (risk of use of forests for fuel wood in Africa) • Parks • Urban agriculture • Wetlands • Swales • Intensive green roofs • Green walls	
TROPICAL MONSOONAL	North and South America • West/Central Africa • Myanmar, Vietnam	Forests (risk of use of forests for fuel wood in Africa) • Parks • Urban agriculture • Wetlands • Swales • Intensive green roofs • Green walls	
SAVANNAH DRY WINTER	Brazil, Bolivia, Paraguay, Venezuela and North Mexico • Central Africa and Mozambique • South and East India • North Thailand, North Cambodia	Parks • Urban agriculture • Wetlands • Intensive and semi-intensive green roofs • Green walls	
COLD DESERT	Mongolia • West China • Uzbekistan	Urban and peri-urban forests (protection against dust storms) • Extensive green roofs	Parks • Wetlands • Green walls
HOT DESERT	North and South-West Africa • Ethiopia • Arabian Peninsula • Pakistan • Afghanistan • Iran	Extensive green roofs • Trees in cities	Forests (with some exceptions) Parks • Wetlands • Green walls
SEMI-ARID STEPPE	North Mexico • Angola, Zambia, Zimbabwe • Guinea, South Sudan, Central China, Mongolia	Parks • Urban agriculture • Wetlands (depollution) • Semi-intensive green roofs • Green facades	Forests • Green walls • Extensive green roofs
WARM WITH DRY SEASON	Maghreb coast • Azerbaijan, Turkey • North Chile • North India • South Europe	Parks • Forests • Urban agriculture • Wetlands • Extensive or semi-intensive green roofs • Green facades	
WARM WITHOUT DRY SEASON	North Argentina, Paraguay, Uruguay, South Chile • South Africa • Southeast China • New Caledonia	Parks • Forests • Urban agriculture • Wetlands • Semi-intensive green roofs • Green facades • Green walls	Green walls

** Some projects are not mentioned as their relevance for each type of climate will depend on the context.*

Furthermore, the territories of the projects comprise a set of physical constraints (water resources, type and use of the land, topography, etc.) and planning constraints and requirements (land pressure, need for housing, services, etc.) which need to be identified in order to be able to adapt to the local context and people's needs.

Correlation table between projects and the associated constraints

Constraints	Needs and levels of constraint		
	HIGH	**MEDIUM**	**LOW**
WATER RESOURCES	Parks (standard management) • Sports fields • Off-ground and direct urban agriculture • Ponds and wetlands • Intensive green roofs • Green walls • Depollution lagoons	Parks (differentiated management) • Hedges • Cemeteries • Trees (linear or isolated) • Semi-intensive green roofs • Green facades	Forests • Swales • Extensive green roofs
FOOTPRINT	Forests • Parks • Sports fields • Cemeteries • Direct urban agriculture • Large wetlands • Depollution lagoons	Swales • Hedges • Off-ground urban agriculture • Trees (linear or isolated) • Ponds	Green roofs (all types) • Green walls and facades
INVESTMENT COSTS	Sports fields • Urban agriculture in permanent greenhouses • Intensive and semi-intensive green roofs • Green walls	Swales • Cemeteries • Off-ground urban agriculture • Trees (linear or isolated) • Large wetlands • Extensive green roofs	Hedges • Green facades • Direct urban agriculture • Forests • Depollution lagoons • Ponds
MAINTENANCE AND INPUTS	Parks (standard management) • Sports fields • Cemeteries (standard management) • Off-ground and direct urban agriculture • Green walls	Forests • Parks (differentiated management) • Swales • Hedges • Cemeteries (differentiated management) • Trees (linear or isolated) • Ponds and wetlands • Intensive green roofs • Green facades • Depollution lagoons	Semi-intensive and extensive green roofs
VULNERABILITY TO ANTHROPOGENIC FREQUENTATION	Direct urban agriculture • Ponds and wetlands	Forests • Off-ground urban agriculture • Depollution lagoons	Swales • Hedges • Parks • Sports fields • Cemeteries • Trees (linear or isolated) • Intensive or semi-intensive green roofs • Green walls and facades

Municipal nursery installed in Teresina Botanical Park in Brazil. The level of the availability of local plants needs to be anticipated at the project design stage.
© Aurélie Ghueldre, Teresina, Brazil, 2020.

1.3. Protecting and promoting biodiversity at territories scale

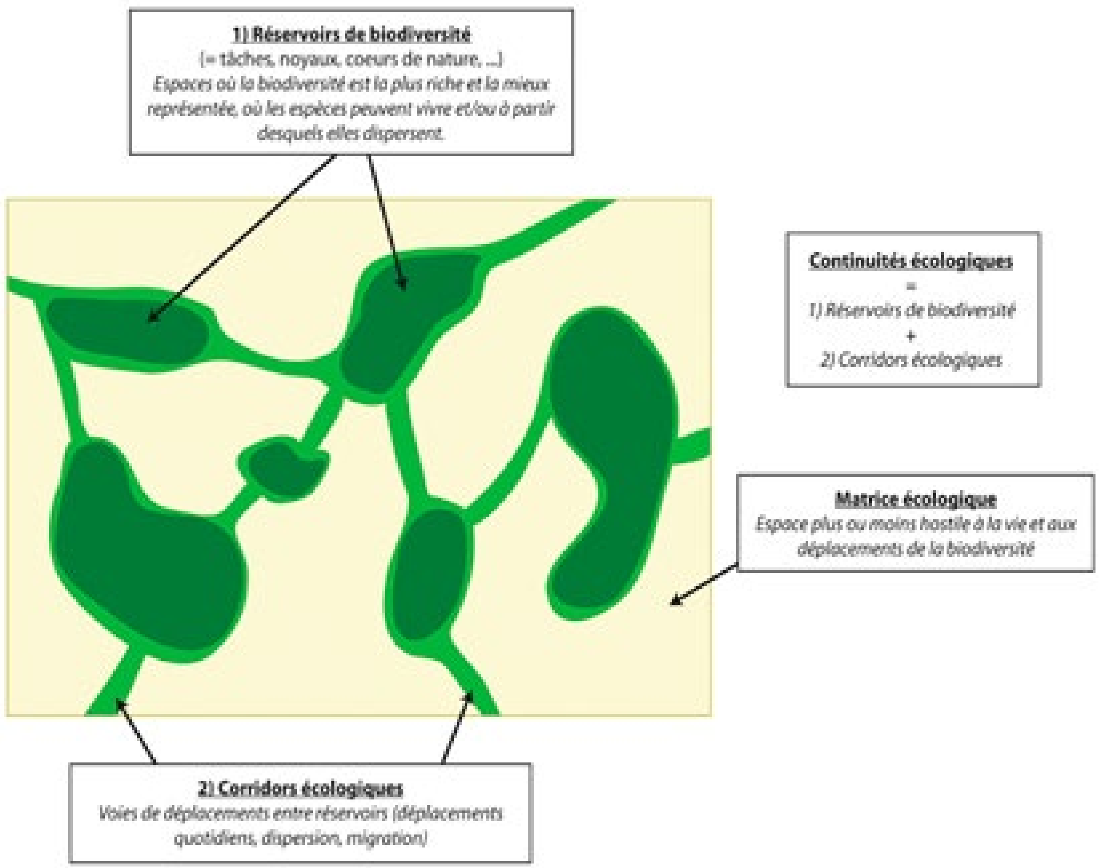
At urban areas level : promoting the coherence and continuity of ecosystems

The connection of biodiversity-friendly environments is essential for species. Indeed, the **genetic mixing, *i.e.* the mix of gene pools during reproduction, maintains the diversity of populations.** Similarly, animal species need connected spaces so that they can **move between the environments** in which they go through the various phases in their life cycles. The isolation of flora and fauna in restricted areas leads to a uniformization of the genes available, which reduces **the resilience of populations to disturbances.** The concepts of Green and Blue Corridors (GBC) integrate the need for connectivity, with a **distinction between biodiversity reservoirs (formed by habitats) and ecological corridors (allowing connectivity).** The elements outside the corridors can act as areas of extension in the form of secondary habitats, offering functions of refuge, nutrition or juvenile rearing.

METHOD SHEET

- From the territory to the city: connecting ecosystems

Explanatory diagram of biodiversity corridors and reservoirs forming ecological continuities
© UMS PatriNat

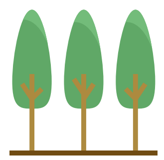


From the territory to the city: connecting ecosystems

While the connection of environments and habitats is necessary for species to go through their life cycles (food, reproduction, habitation, etc.), the urban environment tends to enclose habitats. Allowing the **permeability of cities to wildlife movements, the colonization of intra-urban natural spaces and opening up access for relict populations** present in the natural spaces are primary objectives. It involves restoring or maintaining connectivity between urban biodiversity reservoirs and the periurban and rural ecological spaces.

Think in terms of connectivity: urban ecological corridors

Corridors are a functional network composed of patches of habitats and ecological corridors, forming continuities of vegetation (green corridors) and water (blue corridors). While the French Grenelle Law of 12 July 2010 defines them by their nature as green infrastructure, the European Commission adopts a more functional vision and characterizes them as "a strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services". It is possible to extend the definition of corridors to other ecological continuities using this functional vision.



Green corridors

Ensure ecological continuities through corridors to allow flora and fauna to feed, shelter and reproduce (genetic mixing).

Blue corridors

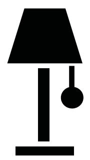
Maintain ecological and eco-landscape networks composed of watercourses and dependent adjacent wetlands.

Brown corridors

Support the role of soils in providing biomass and water filtration and regulation.

Gray corridors

Good air quality to limit the negative impacts on nature and humans (air pollution, cancer, respiratory allergies).



Black corridors

Adaptation of lighting to limit its impact on nature, without hindering the safety and comfort of urban activities.

Ensure the coherence of the network

Species require resources located in different habitats to go through their life cycles. Environments located near each other can be complementary and provide different resources, which may or may not be substitutable, and meet the various needs of species.

How to organize these corridors?
Connectivity is applied at **three main levels,** each of which must be in continuity with the others:

- The urban area, connected with the surrounding rural and periurban areas.
- The neighborhood, connected with the corridors of other neighborhoods and/or periurban and rural areas.
- The project, connected to the ecological corridors present locally or which serve as them.

What are these corridors based on?
These corridors are intended to be **part of the urban landscape,** showing the specific features of the territory and enhancing the built and non-built heritage. They also integrate both local and overall risk management (landslides, floods, etc.), social expectations and the variety of possible relations vis-à-vis these spaces.

What risks to anticipate and avoid when creating green infrastructure?

- **Fragmentation of land or its status:** a bias to the mobilization of key spaces and reduces their role in ecological continuities.
- Use of this infrastructure as a **support for urban sprawl** or, on the contrary, the **anthropogenic uses are not taken into account** in their design.
- **Sharp increase in the value of the surrounding land:** gentrification and eviction of socio-economic groups.
- **Limitation of these corridors exclusively to their social value** (succession of public parks) or ecological value (network of inaccessible corridors).

1.3.2 At cities and neighborhoods level : planning and integrating biodiversity in urban areas

The creation of habitats is the cornerstone of urban development for biodiversity. The World Bank defines habitat as a terrestrial, freshwater, or marine geographical unit or airway that supports assemblages of living organisms and their interactions with the nonliving environment[5]. Indeed, plant and animals species need non-artificialized spaces to have access to water resources and nutrients in order to go through their life cycles. While some artificial infrastructure can provide environments conducive to development (off-ground urban agriculture, insect hotels, etc.), **open ground plant ecosystems provide a number of ecosystem services and a number of areas of refuge for wildlife.**

METHOD SHEET

- Creating and structuring habitats for urban biodiversity

Cohabitation of periurban habitat and paddy fields on the Ha Giang plateau, classified as a Geopark since 2010 by UNESCO.
© Antoine Mougenot, Ha Giang Geopark, Vietnam, 2019.

Creating and structuring habitats for urban biodiversity

Transforming the urban space into habitat for biodiversity

What space is necessary for biodiversity?

It is estimated that **below 10% of vegetation in a city, the specific diversity is seriously threatened.** Areas of 50 hectares or more would be necessary to preserve the species the most sensitive to urban development.

If the residents of cities themselves are included among these sensitive species, it is interesting to note that WHO recommends for each resident the proximity of **a green space of a minimum of 0.5 ha less than a 5 minute walk away** (*i.e.* 300 to 500 m). The rehabilitation of certain previously inaccessible spaces can offer an opportunity for biodiversity.

In what form to introduce vegetation in cities?

For both parks and linear green spaces, it is important to structure the plant biodiversity spatially, temporally and functionally.

Spatial structuring: vertical (herbaceous, bushy and arborescent strata, from bushes to liana) and horizontal (importance of borders between the various strata to allow connectivity).

Temporal structuring: in the presence of seasonality, spread out the flowering/fruiting all year round through a varied selection of species and diversify the age classes of trees.

Functional structuring: reception, meeting or refuge spaces, selection of a range of plants to optimize the interest for wildlife (melliferous plants, etc.), enable the emergence of ecological functions in the territory and the diversity of functional responses (pest control, pollination, dispersion, etc.).

How to optimize the functions provided by habitats?

It is important to **complexify the structure of spaces and habitats** in order to adapt to climate change and achieve **a complex and optimal patchwork of several microecosystems** that meet a multitude of biological needs. The quality and diversity of green spaces are more important than for surrounding habitats in the urban presence of species, particularly for birds.

Adopt an action plan

At each stage of the action plan, **biodiversity needs to be integrated as a component and not as a constraint!**

ANTICIPATE	DEFINE	TRANSLATE	REALIZE
Spatialize sensitive areas Discuss with qualified partners Assess opportunities to create habitats and corridors Define indicators and reference bases	Green and blue corridors Limitation of urbanization Accessibility to nature Ecosystem services	In the development and planning documents Determine the species to protect Define the requirements	Maintain the project's coherence during the potential review of the objectives Raise awareness of maintenance and management practices

DID YOU KNOW?

In France, municipalities allocate on average **4 to 5%** of their budget to green spaces and **6 to 8%** to common services and water management (operation and investment). **95%** of this expenditure is financed by the municipal budgets.

Financing habitats for biodiversity

• Take advantage of the avoided costs through green infrastructure and NbS.
• Define projects for the medium to long term in order to optimize their ecological functions and role as environmental regulators.
• Diversify the sources of financing in a deteriorated situation for public finances, while assigning the responsibilities of each stakeholder ex ante.
• Develop arrangements and activities that generate revenue in order to reduce management costs (eco-tourism, urban agriculture, administrative incentives, regulations, etc.).

See Tool Sheet Proposing Nature-based Solutions in Urban Projects

To go further

- French bird protection association (LPO), "Fiche 13 : Stratification végétale", Technical Guide Biodiversity & Urban Landscape, U2B (Urban Planning, Buildings, Biodiversity) Program, 2016.
- Baseflore, database on weeds in crops in tropical environments.
- Norpac (subsidiary of Bouygues Construction), "Fiche technique : les corridors du quartier", Buildings and Positive Biodiversity (BPB) Guide, in partnership with the Institute for Sustainable and Responsible Development (IDDR) of Lille Catholic University, 2011.

Creating a green ecosystem

How to plan greening?

• Adapt the flora to the climate, soil and exposure of the territory concerned.
• Avoid homogenizing plant species (10% maximum of essences of the same species in a city to avoid the risk of epidemics).
• Gain cultural acceptance of the presence of spontaneous, appropriate and free vegetation, whose complementarity with the planted vegetation reduces the risk of parasitic infection (see Appendix Method n° 1).

How to organize greening?

• Rational use of horticultural species, which are less attractive for the fauna as they are selected for their estheticism and therefore produce less nectar and pollen
• Reduce the risks of genetic pollution by limiting flower meadows, which are attractive for bees but less so for the other pollinators, as well as imported species.

How to select vegetation to create and maintain local heritage?

- Identify nurseries with native species and use local channels.
- Use local species.
- i) Known and nutritionally appropriate for local wildlife.
- ii) That reduce the risk of genetic pollution.
- iii) That limit the introduction of invasive species.
- Include old varieties, which are more resistant to weather conditions.
- Encourage the conservation of urban and peri-urban flora and fauna.
- Choose shrubs or perennial plants for small beds and ground cover plants or herbaceous plants for large beds.

1 introduced plant species in 100 is invasive

Définitions

Herbaceous: any annual, biennial or perennial plant with no rigid stem.

Melliferous: plant producing good quantities and qualities of nectar and pollen, accessible to bees.

1.4. Meeting human needs through biodiversity

AFD's Sustainable Cities Strategy defines **three objectives** (Focus VIL 2018-2021): improve the quality of life of city dwellers, promote the sustainable development of territories and strengthen local stakeholders responsible for cities. The urban projects implemented by AFD develop infrastructure that has **socioeconomic and socioecological benefits for local communities.** The integration of biodiversity is in line with these key objectives and increases the benefits achieved. To do so, identifying the territory's ecological potential ensures consistency between the objectives and feasible activities.

1.4.1 The ecosystem services rendered by nature

Nature in cities provides **a number of ecosystem services,** such as for soil protection, improving air and water quality, and for climate change adaptation and mitigation.

The Millennium Ecosystem Assessment[6] classifies them in four categories:

- **Provisioning services,** which produce all the natural resources useful to humans.
- **Regulating services,** which stabilize the climate through ecosystems and ensure the quality of natural resources.
- **Cultural services,** spiritual, educational and religious contributions to human identity and well-being.
- **Supporting services** (or functions), necessary for the production of other services through their contributions to biogeochemical cycles and flows.

Explanatory diagram of the concept of Nature-based Solutions
© IUCN

1.4.2 Nature-based Solutions

Nature-based Solutions (NbS) provide **an alternative to traditional civil engineering** by taking advantage of these services. The International Union for the Conservation of Nature (IUCN) defines them as "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits".

Through their multifunctionality and adaptability to changes in their environment, they have a clear advantage over "gray" solutions. NbS are increasingly integrated into the principles of economic profitability: **while the cost of installing them is comparable to or even higher than conventional infrastructure, their longer lifespans and minimal maintenance costs often make it possible to generate long-term savings.**

DID YOU KNOW?

In New York, the **rehabilitation of wetlands** for wastewater treatment cost **$1.5 billion,** against almost **$5 billion** planned for the **installation of a wastewater treatment plant.**

They also offer **prospects for avoiding certain costs,** for example, related to the size of sanitation networks due to their action upstream (reduction of runoff, etc.).
NbS are often difficult to implement due to the low level of demand, the lack of technical knowledge on their implementation, and the time required to see the various benefits which make them interesting.

In this context, it is essential for the approach selected to **reflect the capacity of NbS to maintain or recreate ecological functions and provide the associated ecosystem services.** NbS systems that involve more systemic approaches able to **use public land** (public spaces) and **private land** (private plots) sometimes require **establishing regulations or public-private partnerships.**

TOOL SHEET

- Proposing Nature-based Solutions in urban projects

Proposing Nature-based Solutions in urban projects

NbS offer **alternatives to conventional technological or economic solutions,** based on ecological sciences. While they initially referred to green urban drainage systems (or "alternative stormwater management"), they now cover "actions to [...] address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (IUCN).

Typologies of NbS

There are several typologies of NbS, based on various concepts:

- **Ecological restoration:** recovery of a degraded, damaged or destroyed ecosystem to restore its capacity to provide an ecosystem service.
  Example: restoration of a watercourse to restore its capacity to filter water and habitat pollution
- **Ecological management:** use of the ecosystem services rendered by living beings (natural materials, organisms, etc.) to maintain an ecosystem.
  Example: use of eco-pastoralism to maintain public parks, differentiated management without plant protection products.
- **Green infrastructure:** network composed of natural or semi-natural areas strategically designed during the urban development.
  Example: green and blue corridors, connecting green spaces and wetlands.
- **Adaptation and mitigation based on ecosystems:** use of ecosystem services as part of a climate change adaptation and mitigation strategy, to increase the resilience of ecosystems and people and mitigate the impacts of climate change.
  Example: preparation of a municipal resilience plan, creation of cool islands and green belts for CO_2 storage.

Carbon storage (CO_2)		
DEVELOPMENT	LEVEL	IMPACT
Forest	City	+ + +
Private and community gardens	City	+
Street trees	City	+ +
Hedgerows and wasteland	City	+
Parks	City	+ +

Soil retention and erosion control		
DEVELOPMENT	LEVEL	IMPACT
Forest	Plot	+ + +
Parks	Plot	+ +
Private and community gardens	Plot	+

Ecological role and accommodating biodiversity		
DEVELOPMENT	LEVEL	IMPACT
Parks	Neighborhood	+ + +
Urban forest	Neighborhood	+ + +
Hedgerows and wasteland	Plot	+ + +
Private and community gardens	Plot	+ +
Street trees	Street	+
Swales and rain gardens	Street	+ +

Improving air quality		
DEVELOPMENT	LEVEL	IMPACT
Street trees	Street	+ +
Parks	Neighborhood	+ +
Forest	Neighborhood /City	+ + +
Green walls and facades	Street	+ +

Stormwater management (quality and runoff)		
DEVELOPMENT	LEVEL	IMPACT
Swales and rain gardens	Plot/Street	+ + +
Green roofs	Building	Neutral to + +
Street trees	Street	+
Parks	Neighborhood	+ + +
Forest	Neighborhood	+ + +
Private and community gardens	Plot	+ +
Wetlands	Plot	+ + +

Thermal comfort and reduction of urban heat islands		
DEVELOPMENT	LEVEL	IMPACT
Green roofs	Building	+ to + + depending on the substrate thickness
Green facades	Building/Street	+ +
Urban parks	Neighborhood	+ + +
Street trees	Building	+
Street trees	Street	+
Swales and rain gardens	Street	+ +
Green roofs	Plot	+

Development of built environment		
DEVELOPMENT	LEVEL	IMPACT
Green roofs	Plot	+
Green walls and facades	Plot	+
Parks	Neighborhood	+ +

Physical and mental health		
DEVELOPMENT	LEVEL	IMPACT
Parks	Neighborhood	+ + +
Urban forest	Neighborhood	+ + +
Street trees	Street	+
Green walls and facades	Street	+

Tourism		
DEVELOPMENT	LEVEL	IMPACT
Forest	City	+ +
Urban parks	City	+ + +

Reduction of acoustic intensity		
DEVELOPMENT	LEVEL	IMPACT
Green roofs	Building	+
Green walls and facades	Street	+
Hedgerows and wasteland	Plot	+

Performance of NbS and avoided costs

NbS are generally designed to provide essential human functions in urban areas: **the reduction of heat islands, stormwater management and the depollution of soil and water.** They make it possible to take action based on an approach that is preventive rather than curative and cross-cutting rather than segmented, in particular for the management of water and its quality (see Appendix Tools n° 1). The demonstration of this efficiency (cost/effectiveness ratio) is based on methods (cost-benefit or cost-effectiveness analyses which require a clear definition of the options available to provide the function expected), the objectives and the temporal study period.

The more detailed cost-benefit analyses are provided in the Technical Sheets by type of project. The cost-effectiveness analysis is useful for assessing the elements whose benefits are difficult to quantify in monetary terms, such as health, fresh water systems, extreme weather events and the services provided by biodiversity and ecosystems.

Socioeconomic benefits

NbS contribute to the Sustainable Development Goals defined by the Member States of the United Nations, in terms of reducing hunger around the world, access to clean water, the sustainability of cities and communities, the fight against climate change, and aquatic and terrestrial life (see Appendix Tools n° 2). As they mobilize ecological engineering techniques and expertise adapted to each territory, **jobs related to NbS generally cannot be relocated.** For example, the installation of NbS and the partici-patory development in an eco-neighborhood in Malmö have contributed to reducing the unemployment rate (see Appendix Tools n° 3).

The approach based on socioeconomic benefits makes it possible to measure the impact that the development of NbS has on the territory's economy.

The identification of the "demand" (technological, organizational or social innovation) addressed by the project makes it possible to determine the most appropriate NbS (see Appendix Tools n° 4).

Ecosystem services

Nature provides numerous and diverse ecosystem services (see Appendix Tools n° 5) and their destruction is extremely costly. The Economics of Land Degradation (ELD) Initiative estimates that worldwide, between 1997 and 2011, the costs of biodiversity loss, firstly due to changes in the use of land and, secondly, its degradation, caused the loss of ecosystem services valued at €3.5 trillion to €18.5 trillion per year and €5.5 trillion to €10.5 trillion per year, respectively[7].

Measuring the value of services

The value (direct and indirect use, or non-use) of ecosystem services can be measured on the basis of ecological, sociocultural and monetary criteria. The corresponding indicators provide discussion points for the negotiation with the counterparts (see Appendix Tools n° 6).

- The **ecological criteria** (naturality, integrity, fragility) mainly use energy and naturalist indicators, representing the flows of the environment and their value.
- The **sociocultural** criteria (therapeutic, pleasure, heritage value) are measured based on population surveys or an analysis of the history of the territory concerned, and the importance of the spiritual and religious dimensions, for example
- The **economic criteria** cover the estimates of the value determined by the market directly (price, production factors, etc.) and indirectly (avoided costs, replacement or substitution costs, hedonic prices). In addition, there are the survey methods (contingent or group estimation) and the benefit transfer method.

The monetary valuation must remain a complement to the estimation of the ecological, social and cultural values considered in the decision-making process and not replace it. The distribution of costs and benefits requires special attention: the stakeholders who benefit from an ecosystem service are not necessarily those who bear its cost.

To go further

- BAIG Saima P. & al., Cost and Benefits of Ecosystem Based Adaptation: The Case of the Philippines, UICN, Switzerland, 2016.
- Greentown, an online awareness-raising game developed by ThinkNature which demonstrates the benefits related to the use of NbS in an urban context.
- Climate-ADAPT, a resource on urban adaptation to climate change, a partnership between the European Commission and the European Environment Agency.
- I-Tree, a tool to quantify the benefits related to urban and periurban forestry.

1.4.3 Identifying and monitoring the potential of biodiversity and ecosystem services

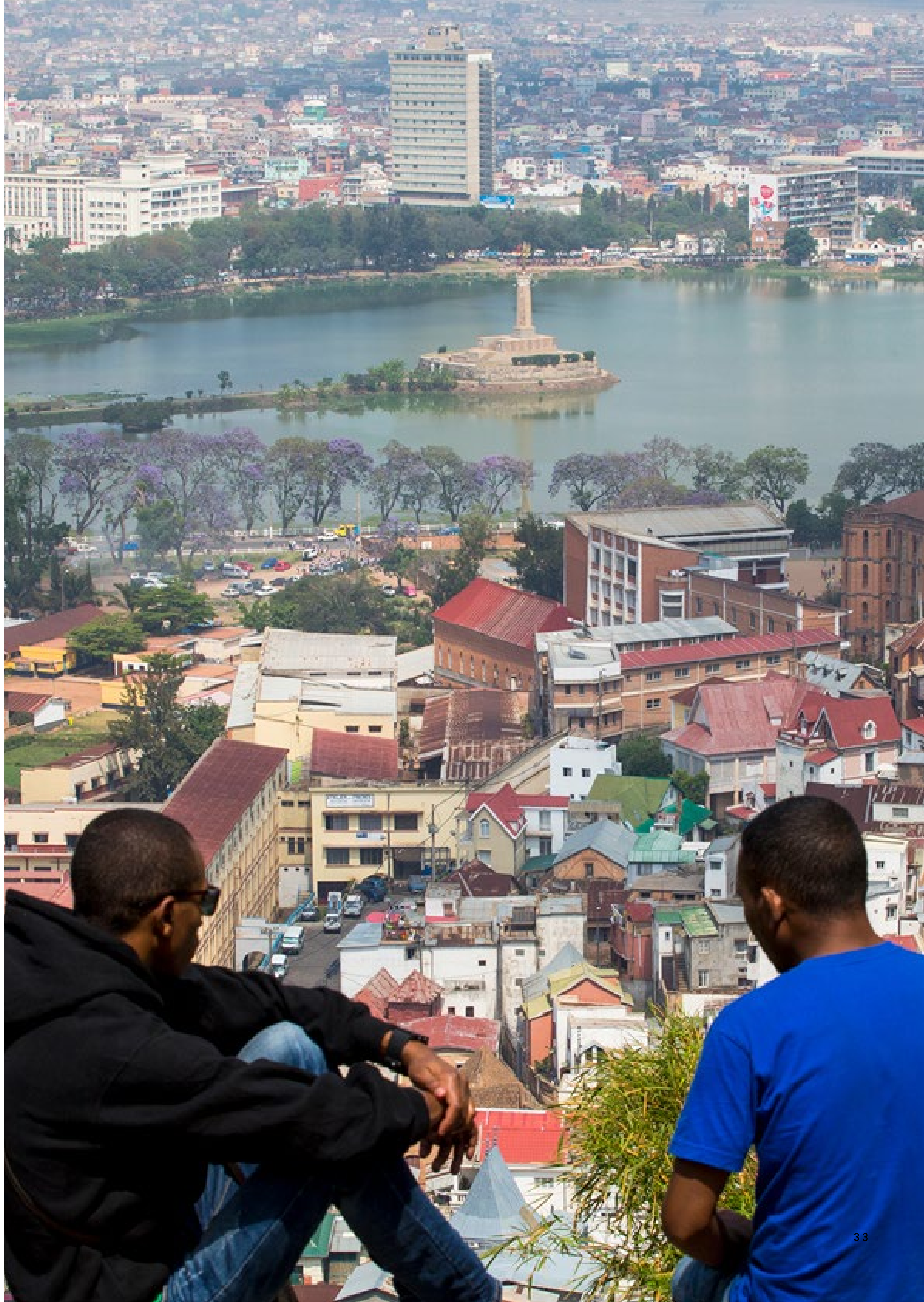
Each territory has its own sociocultural, economic and ecological context, which conditions and guides urban development. The use of tools, in the form of indexes and indicators, makes it possible to **identify and characterize the environment's biodiversity potential.** Furthermore, the indicators make it possible to **define the objectives in terms of biodiversity and the services it renders** for the population, and therefore to **identify the most appropriate ecological engineering solutions.** Finally, they are used during the impact assessment before the project and for its subsequent monitoring.

A characterization of the state of biodiversity at the level of the city makes it possible to define appropriate ecological objectives at the level of the project. This initial approach requires **implementing environmental assessment tools** to define the city's eco-potential. This notion characterizes the potential or probable level of biodiversity in a territory, the potential to express this biodiversity, and the value of the territory with regard to the ecology of the landscape. The use of indexes, in particular the Singapore Index, accounts for the biological diversity, which is a vast and largely unknown area, based on a limited number of easily observable entities.

Once the project has been completed, due to the dynamic nature of processes that degrade or increase biodiversity, it is often difficult to anticipate the intensity of the project's effects on the biodiversity reservoirs. While the project can have a negative impact on the territory's biodiversity, it can also create conditions conducive to the establishment of animal and plant species. It is therefore necessary to implement monitoring processes, based on matrixes of indicators adapted to the project and local context, to be able to detect variations in the environmental quality of the project and monitor local communities. This monitoring also makes it possible to value the project with regard to the Biodiversity Accounting Grid, as well as the Climate accounting under Climate-Biodiversity co-benefits.

TOOL SHEET

- Biodiversity indicators for urban territories and projects



Fragmented green spaces and Lake Anosy from uptown Antananarivo.
© AFD, Cyril le Tourneur d'Ison, Madagascar.

Biodiversity indicators for urban territories and projects

A biodiversity indicator is data, generally quantitative, which may be used to illustrate and inform about complex biodiversity-related phenomena in a simple manner, including the trends and progress over time[8]. Biodiversity cannot be restricted to a list of species and the indicators depend on the data available and the resources deployed. To make up for these limits, it is possible to use a consistent set of indicators or composite indicators associating qualitative and quantitative data, while avoiding an overload of information due to an excessive number of indicators.

In terms of biodiversity, a reflection and analysis framework generally used is the Driving Forces-Pressures-States-Impacts-Responses (DPSIR) framework. In this model, Driving Forces (D) put Pressures (P) on the environment, degrading its State (S) with Impacts (I) on society (in particular on the services rendered by ecosystems), leading it to formulate and implement Responses (R) able to address any other part of the system. The indicators may be applied to each of these stages in order to establish a diagnostic on the biodiversity management practices of the counterparts (see Appendix Tools n° 7).

Issues and objectives related to the use of indicators at the various stages of the project

© Based on *Nature as a Component of Urban Development Projects*, CEREMA, 2015.

DIAGNOSTIC OF THE ISSUES AND PROGRAMMING	Know the initial state, the issues and the remarkable spaces	Overall and local level, social demand
DESIGN AND CONSTRUCTION SITE	Work with the engineering team and organize the works	Define the spaces, compare alternatives and respect the biodiversity issues on the construction site
MANAGEMENT AND MONITORING	Manage the establishment of living beings, determine the success rate and generate good practices	Nature monitoring, changes in practices and awareness-raising

Indicators to adapt the project to the territory

Before the project: study the biodiversity status and its potential in the territory

The indicators can firstly be used prior to the design and development of the project, in order to define objectives adapted to the territorial context, regarding the biodiversity or the ecosystem services it renders. The ESGAP reference (under development) includes 22 indicators and provides a framework for issues related to knowledge about biodiversity at country level. The Singapore Index (see Appendix Tools n° 8) is a tool designed for the city level. It provides an assessment of urban biodiversity including an urban profile and 23 indicators measuring the city's native biodiversity, the ecosystem services and biodi-versity governance. This index, which will be renewed at regular intervals, can help local authorities benchmark their efforts to conserve urban biodiversity, implement urban biodiversity action plans and management programs, evaluate action plans and management programs, evaluate the results and discuss with international experts based on a common tool.

Compare the project alternatives based on biodiversity indicators

The capacity of urban vegetation to render ecosystem services can be quantified with a simplified model which includes an analysis of five main factors: the quantity of public and private green areas, the accessibility of green spaces, the environmental regulation capacity of the vegetation, the maintenance of ecological balances and the functional and esthetic developments.

This approach, which has been developed by Plante&Cité, can be applied to a plot that has already been built on (housing or offices), landscaped areas (accessible to the public) or, on a larger scale, to the territory, in order to assist the diagnostic of the various development projects. Indicators are associated with each of these levels and concern the five factors mentioned above (see Appendix Tools n° 9).

Project monitoring indicators

It is essential to implement tools and indicators to monitor the project's progress (performance indicators) and effective success (impact indicators) in order to measure the achievement of the targeted objectives. Ideally, an effective monitoring tool is simple and inexpensive, reflects the various project objectives, can be adapted over time and includes a monitoring of the project costs. It also comprises measures to interview users of the space in order to collect data and increase the acceptability of the project.

Monitoring indicators on the diversity of species once the project is completed

See Checklist for planning a biodiversity monitoring cycle for a project in Appendix Tools n° 10.

To determine the actual influence that the project's green developments have on biodiversity, the indicators ideally focus on monitoring species directly, rather than on influencing factors (connectivity, etc.). This type of indicator must account for:

- The wealth, *i.e.* the number of different entities represented.
- The equality between these entities in terms of population structure (number, presence of juveniles, etc.).
- The diversity, *i.e.* the distance between these entities in evolutionary terms (phylogenetic distance) or functional terms (ecological role).

The indicators selected can then be used to study a single parameter or they can be composite. They can provide information on the specific wealth (number of species present per unit of space), the specific abundance (number of individuals per unit of space), or weighted (in order to give more weight to information, such as rarity in terms of conservation or functional importance) or not weighted (see Appendix Tools n °11).

Indicators on functional diversity are preferable, as they reflect the diversity of the morphological, physiological and ecological characteristics within biological communities. This better accounts for the functioning of ecosystems than the other conventional measurements of biodiversity (such as phylogenetic diversity). These indicators can be complemented with tools based on a mapping analysis of satellite imagery (plant cover, ICU, etc.).

Monitoring the services rendered by biodiversity

Post-project, indicators can also be used to measure and approximate the ecosystem services rendered by vegetation in cities. Gaseous exchanges, which give plants the capacity to capture CO_2 and filter air pollutants, can thus be measured based on the density ratio of the vegetation/biomass.

Definitions

Phylogenetic distance: evolutionary distance between two individuals, taxa or groups.

Primary production: speed at which a given quantity of organic matter derived from mineral matter and energy input synthesizes in the biomass.

To go further

- Atlas of Municipal Biodiversity, a tool promoted in France and the French Overseas Territories to sensitize and mobilize elected officials, socioeconomic operators and citizens in terms of biodiversity.
- WERNER Florian et GALLO-ORSI Umberto, Biodiversity Monitoring for Natural Resources Management, Introductory Handbook, 2018.
- Biodi(V)strict Calculator®, comparison of the ecological potential before and after the project and identification of the impacts on biodiversity.
- CLERGEAU Philippe, PROVENDIER Damien, Grille pour l'évaluation de la biodiversité dans les projets urbains, Plante&Cité/DHUP, 2017. See Appendix Tools n° 13.

1.5. Assessing and managing a project's risks or negative impacts on biodiversity

A project's impacts can be seen in various contexts for biodiversity (wealth of protected species in environments, large migratory areas, etc.) and can be of varying intensities. If the project comprises risks for habitats/critical environments, it cannot be appraised as it is excluded from AFD's activities (see Exclusion List in Appendix 1). Otherwise, the risks are qualified based on the E&S classification. An "A" or "B+" classification for the project will lead to an Environmental and Social Impact Assessment (ESIA), which assesses the negative impacts of the project and the alternatives, while proposing appropriate measures in terms of avoidance and, otherwise, mitigation and/or compensation. A "B" classification leads to a limited ESIA, or Impact Notice, while there is no obligation to produce an ESIA with a "C" classification.

For each impact assessed, the ESIA will propose compensatory measures from the Avoid-Reduce-Compensate (ARC) sequences. This approach is based on the precautionary principle and prioritizes the mitigation measures. It is mentioned in the World Bank's Environmental and Social Standard n° 6 "Biodiversity Conservation and Sustainable Management of Living Natural Resources", which AFD refers to. The risk assessment is followed by the production of an Environmental and Social Management Plan (ESMP) which sets out the measures taken to reduce, manage and monitor these risks. These two documents require bibliographical and field studies (flora-fauna inventories), which may be difficult to carry out in contexts where it is not easy to mobilize local expertise. Furthermore, these processes require respecting key stages (on-site inventories at each season, etc.) in order to highlight all the potential impacts.

METHOD SHEET

- Biodiversity in impact assessment and management

A project's impacts on biodiversity can be structural, *i.e.* inherent to the project design. The creation of infrastructure can potentially affect the connectivity of spaces (disturbances created by street lighting, buildings on the routes of migratory species), can seal and pollute soils and can create obstacles for wildlife in the environment (large glass surfaces, street furniture that traps wildlife...). Furthermore, the project can lead to an unsustainable use of natural resources with an impact on a species and the entire ecosystem via the food web or other interspecific relations.

METHOD SHEET

- Risks for urban biodiversity

A project can have functional risks, *i.e.* related to the project implementation, operation and maintenance. During the construction phase, the species present on the site can be trapped, their habitats can be destroyed, and the site can be contaminated by alien or invasive species. These risks can be anticipated and mitigated through prior reflection on the practices of the construction site, and by taking into account the temporality of the life cycles of biodiversity. In some cases, the construction site can even offer the opportunity to create temporary biodiversity spaces and raise the awareness of stakeholders to the issues related to biodiversity on the site.

METHOD SHEET

- Biodiversity and construction sites

If the project's negative impacts on biodiversity cannot be avoided, and minimizing them nevertheless causes a net loss of biodiversity, the ARC sequence requires the implementation of on or off-site compensation measures. These measures can result in an ecological improvement in the degraded spaces, in order to develop, protect and conserve their biodiversity. Urban areas often have spaces with degraded ecological potential due to polluting activities and neglected wasteland. Theses spaces can be redeveloped ecologically or depolluted to make them attractive for flora and fauna. They can thereby be integrated into the project as a compensatory measure.

METHOD SHEET

- Restoration of the environment and on and off-site compensation

Biodiversity in impact assessment and management

The Environmental and Social Impact Assessment (ESIA) is an instrument to identify and quantify the potential environmental and social impacts (direct, indirect and cumulative) of a project, assess its alternatives and propose appropriate mitigation, management and monitoring measures. The Environmental and Social Management Plan (ESMP) sets out the measures taken during the operational phase to eliminate or reduce the negative environmental effects, and the actions required to implement these measures.

These two documents must also set out the legal framework of the operation, including national environmental regulations, the ratified international texts and the policies and standards of the donors involved[9]. AFD refers to the World Bank Group standards and has several tools on this issue to manage biodiversity-related risks in projects: a "Biodiversity and Ecosystem Services" Toolkit developed by the AES Division, a new rating grid developed by ADD, and reflection on national indicators conducted by IRS.

Biodiversity in the ESIA: key stages

Data collection

See management in Appendix Method n° 2, the checklist in Appendix Method n° 3, a Q/A in Appendix Method n° 4 and the resources and databases in Appendix Method n° 5.

- Scope of the study of the site (extended with the project's area of influence).
- Compliance with regulatory requirements in terms of methodology by AFD and the counterpart.
- Review of the literature specific to the biodiversity of the region and site.
- Field report: description of the methodology, time scale, relevance of the sampling method.
- Final report: description of habitats and ecosystem services, quantification of the specific abundance.
- Inclusion of stakeholders (experts, associations, communities, residents).
- Long-term monitoring to validate the relevance of the estimates and the effectiveness of the management plans (existing indicators, additional monitoring, etc.).
- Communication of the results (compliance with expectations, joint management of the follow-up action, sharing with stakeholders).

Analysis of the project's impact on biodiversity

See checklist in Appendix Method n° 6.

- Analysis of the alternatives to the project, at the minimum an alternative scenario or credible counterfactual, justifying the reasons for the choice of the project.
- Identification of the foreseeable positive and negative impacts (modification of habitats, wildlife mortality, etc.).
- Characterization of each impact (direct, indirect or cumulative, temporary or permanent, their scope and intensity).
- Evaluation of the consequences and risks related to the project (vulnerability of the biodiversity, net loss of biodiversity or not, probability of occurrence).

Definitions

Direct impacts: the immediate consequences of a project, in space and time, which may be structural (footprint, loss of species, damaged landscape) or functional (related to the project implementation, operation and maintenance: water pollution, waste, movement flows modified…).

Indirect impacts: cause-and-effect relationship originating from a direct effect, which may be a chain effect (spread of the impact through various compartments of the environment) or induced.

Cumulative effects: result of the cumulation and interaction of several direct and indirect effects generated by the project or by several separate projects.

All these impacts may be permanent or temporary!

Biodiversity in the ESMP

Impact mitigation measures:
Avoid-Reduce-Compensate (ARC) sequence
See Appendix Method n° 7 and the checklist in Appendix Method n° 8.

AVOID THE IMPACT

- Through the selection of the site.
- Through the design of the infrastructure.
- By taking into account the temporal logics of species, avoiding periods of vulnerability.

REDUCE THE EXTENT, INTENSITY AND DURATION OF THE IMPACTS ON BIODIVERSITY

See Method Sheets From the diagnostic to the project design and Biodiversity and construction sites

RESTORE ECOSYSTEMS IN ORDER TO TARGET NON-ASSISTANCE OVER TIME

- Take into account the topography and hydrology for the plant restoration.
- Use the genetic resources that were on the site before (seed banks, etc.).
- Implement quick-win projects to experimentally test the rehabilitation of the site.

OFFSET THE RESIDUAL IMPACTS ON AND OFF-SITE AS LONG AS NECESSARY

- Avoid losses: set up conservation projects in the event of a proven threat for biodiversity, create new protected areas, safeguard or actively support endangered protected areas.
- Restoration: set up conversation projects that aim to restore biodiversity by improving or actively creating habitats.

IDENTIFY AND TAKE SWIFT ACTION ON SITES WHERE A TEMPORARY LOSS OF BIODIVERSITY IS NOT AN OPTION (see Appendix Method n° 9)

See Method Sheet Restoration of the environment and on and off-site compensation

FAST FACT

- The **Avoid-Reduce-Compensate principle** aims to avoid any net loss of biodiversity. It is based on **3 consecutive stages,** in order of priority:
- Avoid impacts upstream.
- Reduce impacts during.
- Compensate residual impacts (and preferably with a net gain).

To go further

- Gullison Ted & al., Good Practices for the Collection of Biodiversity Baseline Data, Multilateral Financing Institutions Biodiversity Working Group & Cross-Sector Biodiversity Initiative, July 2015.
- Hardner Jared & al., Good Practices for Biodiversity Inclusive Impact Assessment and Management Planning, Multilateral Financing Institutions Biodiversity Working Group, juillet 2015.
- Environment, Climate and Social Office, Environmental and Social Standards, "Chapter 3: Biodiversity and Ecosystems", European Investment Bank, Luxembourg, May 2020, pp. 22-34.

Risks for urban biodiversity

Some human activities, particularly in urban areas, have well-known risks for the flora and fauna and ecosystems. Avoidance strategies involve identifying these risks and their impacts beforehand, in order to include "preventive" ecological principles in project design. It involves characterizing these risk factors and the technical solutions to mitigate the negative impacts.
Migratory birds are a prime example: most travel at night and navigate by using the stars. They are attracted by light and land at night in a place they are not familiar with. At dawn, they cannot see the glazed spaces and hit them. There are a wide range of solutions to reduce sources of risk, such as light pollution and glass surfaces.

Street lighting

RISKS FOR FLORA AND FAUNA

In a radius of about 700 m, street lighting attracts and traps birds and insects (1 billion insects die every night in Germany).
Modification of plant growth and organic biological rhythms, breaks in ecological corridors.

ISSUES

Energy saving, pedestrian safety, human health (stress, rest, melatonin-related diseases), road safety (drivers accelerate on roads with excessive lighting, increasing the accident rate).

GOOD PRACTICES ((see Appendix Method n° 10)

Creation/preservation of areas with low light pollution ("black corridors"):

- Prior study on the species affected, definition of the areas to light and lighting requirements.
- Adaptation of the systems, duration, intensity and orientation to ensure compliance with safety requirements, human comfort and the protection of wildlife.

Definitions

Food web: a series of interconnected food chains in an ecosystem through which energy and biomass circulate.

Integrated management: overall pest management which combines various forms of control and biological methods (introduction of predators, for example) or chemical methods, minimizing the use of synthetic pesticides.

Fires

RISKS FOR FLORA AND FAUNA

At the boundary between the natural environment and urban environment, fires can be a source of plant mortality and habitat destruction.

ISSUES

- The direct safety of humans
- Degradation of environments: rivers drying up in the dry season, soil depletion, acceleration of the desertification process, worsening runoff, increased soil erosion.

GOOD PRACTICES

Risk management policies in the city, with specific attention paid to the city/forest or city/periurban area interfaces and movement in forest or shrubland areas.

Traps for wildlife

RISKS FOR FLORA AND FAUNA

Pièges ou risques de collision avec des obstacles invisibles : fosses, trous et bassins à parois glissantes, clôtures hermétiques, barbelés ou câbles aériens.

ISSUES

Health safety and infrastructure protection.

GOOD PRACTICES

Developments providing exits for wildlife (slopes and materials/vegetation), hedgerows/railings or fences that are either slatted or have wide meshes, burying cables or materialization with colored strips (see Appendix Method n° 13).

Glass surfaces

RISKS FOR WILDLIFE

Collision with glass surfaces due to the transparency of the glazing and its reflections (see Appendix Method n° 11).

ISSUES

Natural lighting and energy savings, residents' privacy and comfort, enhancement and use of buildings.

GOOD PRACTICES (see Appendix Method n° 12)

Design aiming to create interplays of shadows, translucent rather than transparent effects, glass stamping, limit the reflection, materialize the edges...

Soil pollution

RISKS FOR FLORA AND FAUNA

- Degradation of habitats, diseases, air pollution and acute toxic effects on ecosystems with sudden imbalances in them (massive plant mortality).
- Reduction in plant growth.

ISSUES

- Human health: consumption of the contaminated vegetable products of ecosystems.
- Degradation of environments: risk of erosion or landslides, possible flooding and modification of the water cycle and microclimates.

GOOD PRACTICES

Elimination or reduction of sources of pollution; identification of polluted spaces; renaturing/restoration; depollution (via phytoremediation where appropriate), or another treatment or isolation technique adapted to the nature of the polluted soil.

Plant protection products

RISKS FOR FLORA AND FAUNA

Mortality due to non-selectivity in terms of the effects of plant protection products, development of resistance among invasive species and colonization of the environment, modification of food webs, concentration of chemicals in the treated plants.

ISSUES

Direct consequences for humans and their health, control of management and maintenance costs for green/public spaces.

GOOD PRACTICES

Control and integrated management practices (introduction of predators, use of pheromones during the reproduction period, etc.).

To go further

- ADEME, Diagnostic de l'éclairage public. Guide à la rédaction d'un cahier des charges d'aide à la décision, Collection Expertises, December 2012.
- General Council of Isère, Neutraliser les pièges mortels pour la faune sauvage, Grenoble, May 2010.
- Planning and Growth Management Department, Wildlife Strategy, City of Ottawa, April 2013.

Biodiversity and construction sites

The construction site is a critical space-time for operations in an existing environment. Its duration and scope modify the temporary or permanent nature of the impacts: it may cause disturbances and destruction or, conversely, become a temporary place of refuge for biodiversity. In both cases, anticipation is necessary, as it is always simpler, less expensive and less harmful for biodiversity to conserve existing ecosystems, rather than trying to repair them or compensate after the alteration. Consequently, beyond the design of the development itself, the management of the construction site can have specific impacts. They relate to the phasing of the works, the more or less invasive technical choices for the construction, the clearing and earthwork phases, the storage of materials and the management of the construction site waste. Regulatory frameworks can prevent certain risks.

Planning the construction site: the ecological planning phases

	ECOLOGICAL PLANNING PHASES OF THE CONSTRUCTION SITE	PROJECT PHASE
1	Characterization of the ecological quality of the site and its surroundings (protected habitats, etc.)	Possible ecological diagnostic
2	Preliminary analysis of the potential degradation and risks (invasive species – see Appendix Method n° 14 – breaks in ecological continuities, etc.) related to the construction site	ESIA
3	Identification of contractual and regulatory obligations applicable to the operation	ESIA
4	Definition of the environmental objectives and material and human resources to implement to achieve them	ESIA
5	Definition of avoidance and mitigation measures to implement: choice of the periods of works adapted to the biological rhythm of the species present (seasonality where appropriate), moving plants according to their annual development, cutting thickets outside the reproduction period of birds or other species, vigilance during the destruction of structures (old trees or old buildings, etc.), creation of temporary habitats to be considered, where appropriate, and phasing of the construction site	ESMP
6	Phasing of works in line with the previous phase	Pre-construction site
7	Implementation of an internal communication plan to facilitate ownership of the biodiversity issue by each stakeholder: awareness-raising and training for staff on the regulations and objectives (see Appendix Method n° 15)	Pre-construction site and construction site
8	Implementation of an external communication plan to promote the measures taken among residents (launch meetings, posters, communication)	Construction site
9	Implementation of a monitoring of the operations to ensure the effectiveness of the measures with regard to biodiversity conservation (indicators and keeping a record)	Post-construction site
10	Observation of the success of the measures and rectification of any errors	Post-construction site

Protecting biodiversity on the construction site

Maintain habitats and ecological continuity

The habitats present on the site (deadwood, hedgerows, groves, herbaceous areas and plant cover) must be conserved as much as possible, or moved (with the appropriate precautions). If the location of important flora is incompatible with the construction site, try to transplant certain plants present in the affected area and anticipate this operation with respect to the seasonality.

Reduce the risks of trapping wildlife

- Channel flows of terrestrial wildlife towards the exit of the construction site (doors opening outwards, guiding species with a funnel-shaped opening, etc.).
- Prevent refuge in precarious habitats and/or wildlife from being trapped (tarpaulin, creation of escape routes).
- Facilitate exit from the construction site.

Minimize the impact of the construction site

- Avoid the destruction of habitats or animal mortality: determine beforehand the areas for the passage of vehicles and storage of materials, so that there is an appropriate marking, and plan refuge areas on the edge of the construction site.
- Avoid temporary disturbances (light and sound pollution or vibrations).
- Preserve the soil: put layers of excavated or removed soil back in place, avoid degrading deep soils.

Definition

Ruderal species: plants which grow spontaneously in an anthropized environment.

Favor temporary biodiversity

Why?

The installation of "controlled" temporary local plant biodiversity makes it possible to avoid being faced with the establishment of species that have not been selected and will pose a problem in the long term (protected species, invasive alien species, ruderal species), subsequently leading to additional costs (derogation files, control and management…). When the area disappears, the construction site will have provided a temporary shelter for various species to live in (bees, bumble bees, butterflies, orthoptera, birds…), increasing their numbers which can colonize new environments.

In which cases?

The recommendations concern long-term construction sites (over six months between the deconstruction and reconstruction, for example) and sites intended to eventually be built on or developed.

See Appendix Method n° 16.

How?

Adapt to the period of latency and inaction before the construction site, to the species available depending on the geographical location, and the type of materials in place.
Example of temporary biomes and adapted biomes: temporary greening, pre-greening (on future permanent green spaces), areas of temporary humid rockeries (wasteland with little vegetation), piles of rocks, sand and rock platforms (sandy biomes without developed vegetation cover), sloughs (wetlands).

To go further

- Nord Nature Chico Mendès et LPO, EPF NPdC, Guide Biodiversité & chantiers. Comment concilier Nature et chantiers urbains ?, published by EGF.BTP, Paris, April 2019.
- Biodiversity Working Group of the National Federation of Public Works (FNTP), La Biodiversité sur les chantiers de Travaux Publics. Guide d'accompagnement et de sensibilisation, May 2017.

Restoration of the environment and on and off-site compensation

Compensation measures are part of the no net loss objective of the Avoid-Reduce-Compensate process. They aim to offset the significant direct or indirect negative effects of the project which it has not been possible to sufficiently reduce. If it is not possible to compensate for certain impacts in critical areas, the principle of ecological equivalence proposes to compensate the lost habitats with the rehabilitation of the same type of habitats. The compensation must also take into account the functional proximity of the measures in terms of the damaged site, hence the importance of ecological continuities.

Restoration of degraded ecosystems as a compensation mechanism

What is ecological restoration?

Ecological restoration is "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed"[10] and is an NbS. The objective is to put the ecosystem back on the trajectory it would have had without human intervention, regarding the ecological processes it renders (ecological functions, connectivities, etc.) – this is called rehabilitation –, but also its composition of species and the structures of plant and animal populations. It is an attempt to encompass the cultural and environmental trends from an ecological and socioeconomic perspective, rather than from a purely technical or development perspective. **Ecological engineering** is the scientific, technical and practical field which focuses on ecological restoration, by using natural materials, living organisms and their physico-chemical environment to resolve the technical problems related to human activities..

Graduation of compensation mechanisms depending on the project's impact

- **Restoration:** appropriate for marginally degraded ecosystems (see the nine attributes of a restored ecosystem in Appendix Method n° 17).
- **Reallocation** of initial ecosystems that are no longer viable: change in the trajectory of the ecosystem due to the technical infeasibility of returning it to its original trajectory
- **Renaturing:** necessary in situations where there is no other choice but to recreate natural schemes faced with completely anthropized environments.

High-potential field of action

Systemic restoration helps mitigate the effects of the risks of climate change and natural disasters and offers prospects for economic growth. In the USA, the restoration of environments provides over 126,000 jobs and generates some $10 billion annually[11].

Definitions

Trusteeship: a contract which allows an owner to temporarily transfer the ownership of their property to a third party that will manage it under the terms agreed to in the contract, for a duration of up to 99 years.

Real environmental obligations: under French law, a contract under which the owner of real estate sets up environmental protection (retention, conservation, management or restoration of elements of biodiversity or ecosystem services) attached to their property, for a duration of up to 99 years, which must be respected even if the property changes ownership.

Worldwide, degraded ecosystems cover an area equal to 20 times the territory of France.

Urban wasteland as privileged spaces for restoration

What is urban wasteland?

Natural wasteland results from the evolution of abandoned open spaces, leading to a heterogeneity of environments with high ecological potential due to the low level of human intervention. For example, in a highly urbanized territory such as the Hauts-de-Seine, the specific wealth of vegetation on urban wasteland accounts for 58% of the total specific wealth of the Department[12]. These spaces can fall under the category of damaged sites and their restoration/reallocation/renaturing provides a response to the objectives of controlling soil sealing and the need to recycle land in urban and periurban areas. Wasteland is generally made up of backfill, concrete slabs or contaminated natural soils. It accommodates non-native weeds (half of the plants identified on wasteland are from other parts of the world), adapted to thin nitrogen-rich substrates.

Why restore these spaces?

- Promote existing built heritage (industrial heritage, for example).
- Develop these economically unprofitable spaces, as they are unlikely to generate real estate revenue.
- Increase the social and cultural popularity of wasteland as a space of freedom and awareness-raising.
- Promote local economic and fiscal benefits by developing the surrounding areas of the restored spaces.
- Benefit from the ecosystem services they provide: greater wealth per m² and diversity of plants on them, as well as in forests (see Appendix Method n° 18).

Points requiring attention during the restoration of these spaces

- Control of land: the operator for the compensation must have control over the land in order to facilitate the implementation of activities and the long-term management of the land. Tools such as environmental trusteeship or the real environmental obligation can be used depending on the local regulatory context.
- Soil pollution and reconstitution: the techniques used must aim to improve the agronomic quality of the soils in place and implement approaches to manage health risks (no fruit trees or market gardening on polluted soils).
  See Appendix Method n° 19.
- Identify the local capacities and expertise: restoration requires the involvement of highly-skilled staff due to the complexity of managing an ecosystem.
- Include stakeholders: residents generally associate urban wasteland with neglected or poor neighborhoods. It is necessary to put ecological issues back at the center of the debate, while ensuring that the management of this wasteland can fit in with the social requirements of these neighborhoods.
- Integrate the concept of temporary biodiversity conservation via scalable urban wasteland.
- Implement a monitoring mechanism, if possible participatory, for the restoration processes.
- Mise en place d'un dispositif de suivi, si possible participatif, des processus de restauration.

To go further

- Natureparif, *Friches urbaines et Biodiversité*, produced by L. ARAQUE-GOY et al., Les Rencontres de Natureparif, Saint-Denis, 2012.
- Center of Ecological Engineering Resources, *Création de prairies biodiversifiées sur des sites urbains déconstruits et temporairement disponibles*, August 2019.
- GAUTHIER Cécile, *Contribution de la compensation écologique à un modèle écologique de renaturation des friches urbaines et péri-urbaines*, Humanité et biodiversité, Paris, September 2018.
- CDC Biodiversity and City of Sevran, *La friche Kodak : un espace naturel écologique en devenir*, Nature 2050, Paris.
- RALL Emily L., HAASE Dagmar, "Creative intervention in a dynamic city: A sustainability assessment of an interim use strategy for brownfields in Leipzig, Germany", Landscape and Urban Planning, vol. 100, Issue 3, 2011, pp. 189-201. URL : https://cutt.ly/ymMnqQL

See Appendix Method n° 20.

METHOD SHEET

1.6. Designing by, for and with biodiversity

The project design is a key stage where it is possible to look more closely at the link between the infrastructure developed and biodiversity. An ecological diagnostic can assess the site's potential in terms of developing biodiversity and guide the project design in its favor. This in-depth document uses information from the ESIA and flora/fauna inventory conducted previously. It can include other sources related to the physico-chemical parameters of the environment. The design is also the stage during which it is necessary to question the relevance of the program, the choice of the site and the most appropriate urban form. The construction, renovation, deconstruction and unsealing methods need to be considered. Indeed, urban spaces alternating "full and empty" spaces are highly favorable for biodiversity if they are designed to promote connectivity. Finally, the project's impact on natural resources can be limited by mobilizing local channels and know-how and through the choice of more eco-friendly building materials (full life cycle).

METHOD SHEET

- From the diagnostic to the project design

The implementation of "alternative or ecological" management practices in nature spaces in cities offers a number of benefits for biodiversity, but also for the residents and management services. This ecological management is based on a differentiated management of natural spaces, in order to maximize the diversity of habitats for biodiversity, as well as on a more preventive than curative approach. Mowing certain spaces less regularly saves money and prohibiting the use of plant protection products is beneficial for human health. However, this ecological management requires extensive planning in the form of a management diagnostic, which is sometimes included in the ecological diagnostic, in order to adapt the management to the use. Appropriate communication is required to prevent the feeling that these public spaces, which appear "wilder", have been abandoned. This management must also take health and safety issues for the residents into account.

METHOD SHEET

- Managing urban areas for biodiversity

The inclusion of local stakeholders, right from the planning stage, contributes to the success of the project and can improve the effectiveness of the process to integrate biodiversity in cities. The identification of the habits and expectations of residents, users and social groups in relation to the project, as well as their involvement in the project governance, limits conflicts over uses and the inconveniences related to the presence of flora and fauna in the city. Biodiversity-related issues sometimes have a conflicting relationship with the territory's socioeconomic issues (sealing related to the creation or rehabilitation of roads, precarious housing on wetlands or riverbanks...). Raising the awareness of local people to biodiversity issues ensures the coexistence of spaces and facilitates the acceptance of nature in the city. Furthermore, the stakeholders can be directly associated with the project implementation, in the context of participatory construction or management processes for nature spaces in the city. Finally, certain local stakeholders (indigenous communities, market gardeners, environmental associations...) have significant or even exclusive expertise in the use of biodiversity.

METHOD SHEET

- Stakeholders: consultation, inclusion and awareness-raising

From the diagnostic to the project design

What is an ecological diagnostic?

It involves a qualitative and quantitative assessment of biodiversity in a defined space, compared with the analysis of other relevant parameters: ecological continuities, pollution and soil condition, water and climate data, energy diagnostic, sociological and cultural context. It serves to make recommendations to the contracting authority, in order to improve the biodiversity potential of the project and highlight the developments to focus on. It is based on the resources in the ESIA (flora and fauna inventory, mapping, etc.) and takes into account the conclusions of the ESMP to provide input for the feasibility study.

See an example of the content of an ecological diagnostic in Appendix Method n° 21 and an example of an estimate for an ecological diagnostic in Appendix Method n° 22.

See Method Sheet Biodiversity in impact assessment and management.

Main stages of an ecological diagnostic
© Based on *Natureparif, Bâtir en favorisant la biodiversité. Un guide collectif à l'usage des professionnels publics et privés de la filière du bâtiment,* produced by BARRA Marc et al., 2012.

DATA FROM THE IMPACT ASSESSMENT

Collect existing data in the territory		
Territorial database, existing impact assessments	Regional and local context (protected species, immediate environment)	Existing reports, studies and inventories from nature associations

Inventory the flora, fauna and habitats	
Taxonomic inventories	Mapping of habitats

SUMMARY OF THE DATA FROM THE IMPACT ASSESSMENT AND DESK STUDY

Identify the ecological continuities	
Mapping of existing continuities (GIS)	Proposal for the creation or restoration of ecological continuities

ADDITIONAL DESK AND FIELD STUDIES

Study the soil		
Measure the pollution	Measure the compaction constraints	Assess the fertility

Analyze the environmental conditions		
Mapping of water network	Rainfall, sunshine, wind speeds and directions	Energy diagnostic

INCLUDED IN THE CONSULTATION PROCESSES

Conduct a sociological survey	
Survey, opinion poll and interviews	Cultural or archeological heritage

Project strategy: build, renovate or deconstruct?

Avoid new constructions: renovate and "undevelop"

Renovation makes it possible to avoid new soil sealing. It can be an opportunity to remove potentially obsolete artificial elements (beams and slabs, concrete infrastructure, channels and embankments) and integrate biodiversity-friendly elements (green roofs and facades, country hedges…). During the destruction of infrastructure (substandard housing, construction on a hazardous site, obsolete networks, etc.), it can be planned to "undevelop", *i.e.* deconstruct without rebuilding in the same place, in order to reopen ecological corridors and passageways for wildlife.

BASIC PRINCIPLES OF ECOLOGICAL DESIGN

- **Adapt the form, layout and construction principle** of buildings to the natural environment (topology, soil, vegetation, sunshine, rainfall…).
- **Minimize the footprint:** build on piers and stilts to reduce soil degradation and sealing and provide a place of refuge for wildlife.
- **Maximize the available free space:** limit the extension of underground or overhead networks, group together the easement tunnels for the passage of cables.
- **Develop roads, pedestrian areas and walkways with porous or semi-porous coatings** (open-joint paving and pavements, green paving slabs), as well as permeable surfaces (wood chip, gravel), or semi-permeable sand or stabilized coatings.
- **Green the built environment:** select local plant species, well-adapted to both the environmental conditions and their new substrate.
- **Maintain the water cycle:** drainage into the soil, via harvesting, reuse or infiltration systems for groundwater supply.
- **Ensure ecological continuities:** interconnection of green spaces, alignment of buildings on the basis of existing corridors, limit barriers and fences.
- **Strategically integrate spaces into the built environment** to accommodate bird populations (nesting boxes, porous walls and hollow untreated spaces accessible to plants), depending on the species observed during the diagnostic.
- **Plan gardens with varied uses:** urban agriculture, shared gardens, composting of green and food waste.
- **Use local resources and know-how:** diversify resources depending on the context, use raw materials that are eco-designed, biodegradable, unprocessed and untreated (plant fiber, stone, agro-materials). In the bid invitation phase, request a comparison of materials through an analysis of the life cycle.

Definition

Agro-materials: composite materials based on agro-resources, *i.e.* from agriculture and livestock farming (flaxseed, hemp, straw, wool…).

Managing urban areas for biodiversity

Ecological management encompasses a set of biodiversity-friendly practices. It requires a specific study, which is summarized in an ecological diagnostic, in order to adopt practices adapted to the area involved. It also addresses the issues of social acceptability, costs and implementation. It is often necessary to back up ecological management with an awareness-raising and communication campaign in terms of the "wilder" aspect of the vegetation, which is more or less well accepted depending on the local culture.

Conducting a management diagnostic

STAGES OF THE MANAGEMENT DIAGNOSTIC	KEY POINTS
Quantitative and descriptive inventory	Use: park, road, surroundings of a building, sports field, etc.
Mapping of spaces	List of the functions and services rendered
Qualitative description	Flora and fauna inventory Analysis of current management practices Use of field operators' expertise
Ecological study	Landscape qualities Historical, cultural and environmental values Current uses Frequentation rate Accessibility and regulation
Formulation of management objectives	Promote biodiversity Reduce pollution

Maintenance of green spaces

What practices to promote biodiversity?

Objectives: Apply a different management method to the different areas in a public space in order to diversify the potential habitats. This makes it possible to create potential refuge areas. It also fosters ecological continuities and potential reservoirs of predators and parasites of invasive plants or pests.

Various techniques can be implemented: from the least favorable to the most favorable for biodiversity: regular high mowing, late cutting, eco-pastoralism, free development and non-management (see Appen-dix Method n° 23).

What are the advantages of ecological management?

The main advantages of the implementation of ecological management are economic. Indeed, reducing mowing and not using plant protection products saves money. The Eco-Logical tool, developed by Veolia and the association *Noé*, identifies the savings achieved through the adoption of differentiated management practices (see Appen-dix Method n° 24).

What public/private co-management?

Draw on positive synergies in the management of public and private spaces, in order to take action against socioeconomic disruptions (budget cuts) and natural disruptions (drought, fires).

What approaches against weeds and invasive species?

For plant species

Preventive: use of compost rather than fertilizer, cover the soil (mulch, ground-cover plants and use of allelopathic plants), train staff in how to identify invasive plants.

Curative: biological control (natural predators, repel-lent or attractive plants, growing in rotation), bio-control, thermal or mechanical weeding, manual grubbing-up taking away the removal waste, etc.

For animal species

Do not use poisonous products. Favor the predation of these species (insectivorous birds, bats), use sexual confusion (pheromone traps or saturation of the environment with pheromones).

DID YOU KNOW?

In France, in 2011, **a third of people were not bothered by spontaneous urban vegetation, while a third considered it as an abandonment or negligence** by the manager[13].

Definitions

Spontaneous vegetation: vegetation which takes root and grows without human intervention on a site. It concerns roadsides, wasteland and any abandoned areas.

Weed: a plant which grows in a place without having been intentionally planted there. Some weeds can be invasive, *i.e.* they have a high capacity for colonization through rapid growth and/or reproduction.

Allelopathic species: species which produce one or several biochemical substances that affect the germination, growth, survival and reproduction of other organisms.

Zoonosis: diseases or infections transmissible from animals to humans.

Communicating on and managing the risks related to new practices

Communicating on and managing the risks related to new practices

- Communicate on the health and ecological interests of the transition to "zero phyto".
- Create biodiversity ambassadors in the technical management services who will spread the message of the interest of biodiversity.
- Raise the awareness of amateur gardeners, who are often the primary users of plant protec-tion products.
- Communicate on the persistence effects of plant protection products in the soil and water, but also the effects on health.

Managing user safety and the risks related to wildlife

For plant species: Surveillance of health risks (allergens or toxins…) and risks of accidents (dead trees, risks to homes).

For animal species: Surveillance of health risks that can cause zoonoses, management of degra-dation due to avifauna feces, auditory discomfort, mana-gement of uncontrolled outbreaks by com-plexifying ecosystems and maintaining the balance of environ-ments and, in certain cases, by sterili-zing males.

To go further

- Flandin Jonathan et Parisot Christophe, *Guide de gestion écologique des espaces collectifs publics et privés*, Natureparif, Ile-de-France, 2016.
- EcoLogiCal tool, ecological management calculator, developed by the association Noé and Veolia.

METHOD SHEET

Stakeholders: consultation, inclusion and awareness-raising

Why mobilize the stakeholders?

There are many different stakeholders with expertise that can be mobilized, in particular during the processes to identify the issues related to the territory and the project's impacts. If the project gives a place to biodiversity (public space), they can be involved in the project governance using different methods (information, consultation, co-design or co-implementation) and in the management or monitoring practices. Before setting out to change practices (such as the implementation of differentiated management), and given the **cultural specificities of each country in the relationship with nature and the landscape,** appropriate communication is essential (see Appendix Method n° 29).

Article 8 of the Convention on Biological Diversity promotes **respecting, preserving and maintaining knowledge, innovations and practices of indigenous and local communities** embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity.

Biodiversity and stakeholders during the project planning phase

Identifying and collecting information held by certain social groups

Indigenous communities have knowledge about biodiversity that is often more comprehensive and sometimes more precise than classic scientific sources, in particular about the ecological, economic, symbolic and cultural relations of biodiversity with the territory. Knowledge about these issues is related to the language: conservation programs in indigenous languages conserve and promote this knowledge.

Taking stakeholders into account: identifying the expectations and uses

The identification of sociotopes, *i.e.* the identification of the uses of spaces and the reasons for these uses, promotes urban planning that takes into account the basic needs of residents. For example, it makes it possible to identify the expectations and uses of citizens and residents and adapt the natural spaces in public spaces. This planning and design of spaces must also "leave room" for freer or unanticipated uses to avoid being too rigid with all the activities proposed. This ensures that there is a certain amount of flexibility and scalability in the uses.

How to prevent a conflict?

Conflicts related to public spaces (allocation, future, exclusive appropriation by a group or gender…) can be managed with information practices (awareness-raising, pedagogy, education), as well as by creating or strengthening biodiversity governance structures.

Biodiversity and stakeholders during the project design

Users and residents, citizens associations and nature protection associations can be involved to varying degrees. The contracting authority can decide to inform them, consult them (survey about a project already defined) or, ideally, organize a consultation on the issues, *i.e.* a dialogue in order to develop the project.

Consultation increases the involvement and interest of residents in biodiversity issues and allows them to more clearly understand the interest of the developments. At the minimum, information or consultation meetings make it possible to reconcile biodiversity issues and issues related to uses and safety. They also give residents the possibility of gaining a better understanding of the developments proposed, in particular those which are not open to the public for environmental reasons.

See consultation tools in Appendix Method n° 25 and advice on holding a consultation meeting in Appendix Method n° 26.

To go further

- Cerema, *Implication citoyenne et Nature en ville - Premiers enseignements issus de sept études de cas en France,* Collection Connaissances, 2016.
- Cerema, "Milieux humides, conflits d'usages et urbanisme : Prévenir et gérer les conflits d'usages liés aux milieux humides dans un contexte urbanisé", Nature in Cities, Sheet n° 4, Collection Connaissances, October 2019.

Biodiversity and stakeholders during the project implementation, management and monitoring

Involve citizens in the project: participatory construction and management

Participatory construction or maintenance make it possible to develop a collective commitment to a project and appropriate the space, while creating social cohesion and reducing management costs. The participatory management of green spaces can be based on citizen involvement that is either spontaneous or organized with the local authority. Communication through intermediary associations makes it possible to involve more citizens and avoid participants getting bored and dropping out.

Raise awareness of new environmentally-friendly management practices

Awareness-raising is a top-down approach, often initiated by the manager. It will maximize the ecological acceptance of the project and bring about changes in behavior. It can be related to the implementation of differentiated management or risks related to urban wildlife, and be based on the wealth and diversity of species in order to reach the public. It can change the practices of private stakeholders (individual gardeners or companies, for example) and gives citizens the means to learn about their local heritage. It is therefore important to define the target of the awareness-raising: children and maintenance staff are often receptive to the messages and act as intermediaries for knowledge.

See awareness-raising tools in Appendix Method n° 27.

Involve stakeholders in biodiversity monitoring

Participatory science is a form of scientific knowledge production which citizen stakeholders participate in as unpaid volunteers. Citizens who take part in it collect data on biodiversity in a structured way through a scientific protocol. This method can be applied for biodiversity monitoring in a park (following the implementation of new management methods, for example), city or region. It helps reconnect the public with nature (frequent monitoring of ordinary species in common habitats). The protocol that needs to be set up must be simple and standardized. The procedure must also be sustainable and subject to communication and frequent exchanges between the scientific world and the general public. These methods involve feedback through direct or online interviews. They are not well developed in developing countries.

See the benefits and risks of this type of program in Appendix Method n° 28

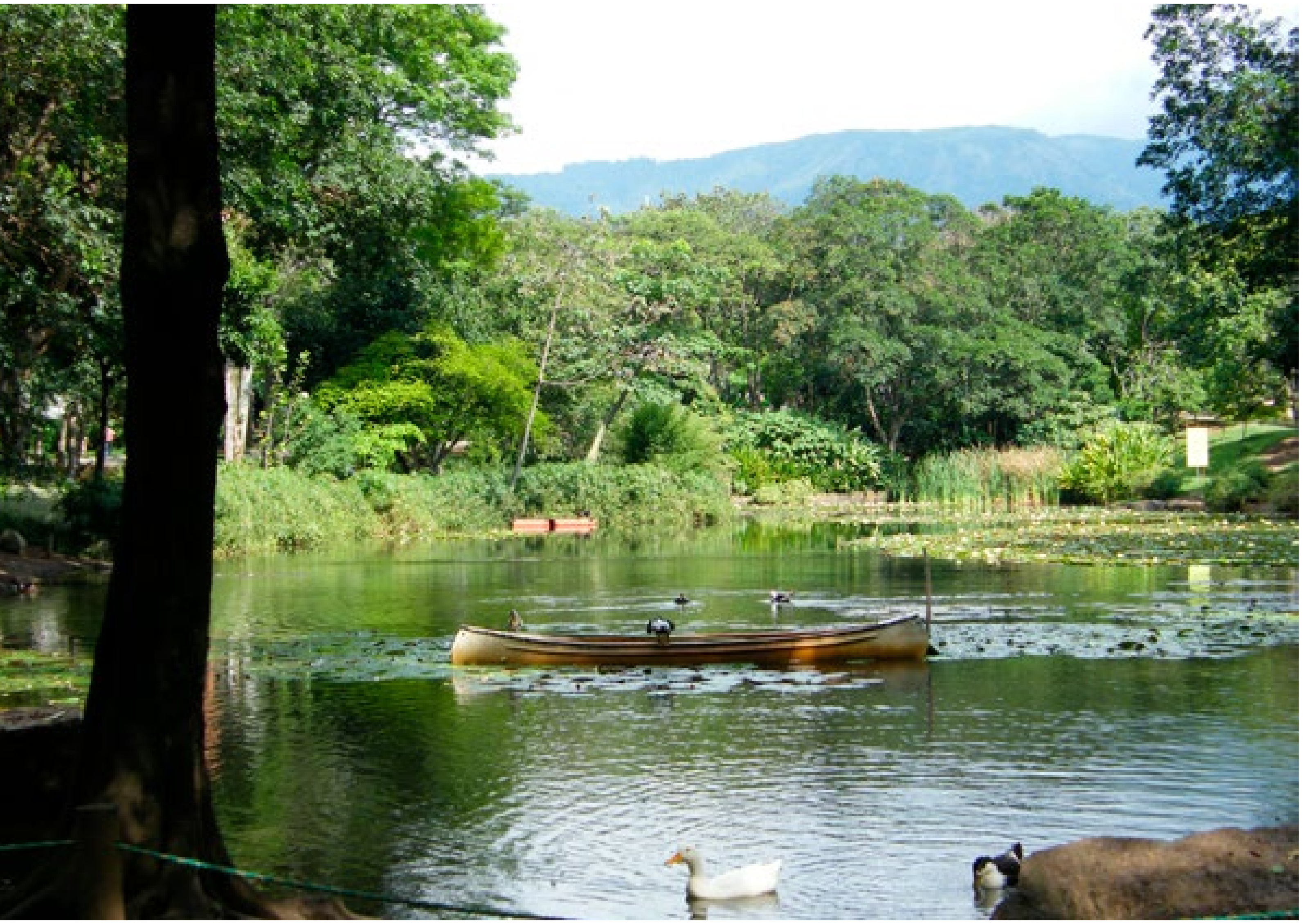
Implementing biodiversity in projects

©Antoine Mougenot, Xuom Chua, West lake, Hanoi, Vietnam, 2019.

2.1. Presentation of Technical Sheets

Each Technical Sheet addresses a **specific type of project.**
They present:

- The data from the cost-benefit analysis and/or the monetary assessment of their installation and maintenance.
- The ecosystem services that the developments or infrastructure render.
- The local mechanisms to develop or use to promote these practices.
- The socioeconomic benefits of the projects.
- The previous experience of AFD or outstanding projects.
- The points requiring attention when stakeholders are included.
- The presentation of qualified partners.
- Advice for the design, construction and maintenance.
- Potential indicators to use to monitor biodiversity in a project.



2.2. Developing urban green spaces

Projects to introduce or manage ecology in public or private spaces covered with vegetation are implemented in various geographical and climatic contexts. Depending on their functions, management practices vary to ensure they are **aligned with the appropriate level of requirement for the uses of these spaces by residents, the ecosystem services they render and the level of reception targeted for biodiversity.**

TECHNICAL SHEETS

Public parks

Public parks refer to green spaces for leisure (grassed, wooded, possibly planted with flowers, trees, ornamental shrubs and with water features). They are often equipped with pathways and furniture. More generally, they include spaces of a given size, which are usually accessible on foot or by bicycle and are safe for the users.

Urban and periurban forests

The concept of urban forests was invented in the late 20th century. It refers to a forest or woodland growing in an urban area. The term periurban forest is used more when it surrounds the city or its suburbs. It is different from urban parks through the focus on the "naturality" of the place. Some are preserved remains of natural forests, while others are the result of artificial plantations or woodlands that were already present before the expansion of the urban territory.

Green spaces for use

The urban environment can receive green spaces in limited and delineated areas, which are more or less accessible for the population. This very heterogeneous category includes green spaces used for stormwater management, green shoulder areas, as well as hedgerows and green urban furniture (except for trees).

Fragmented green spaces

Green spaces can be related to a specific use. For example, sports fields, golf courses and cemeteries are green spaces whose management and maintenance must be adapted to what they are used for. Private green spaces related to housing, or accompanying service uses, also contribute to the fragmented green space network.

Urban and periurban agriculture

Urban agriculture refers to agricultural practices on or off the ground which take place in urban or periurban spaces. They include market gardening and small-scale livestock farming practices, which are common in developing countries, fruit trees or sometimes even grain production.

Main public park for residents and environmental education.
© AFD, Medellin Botanical Park, Colombia, 2010

EQUATORIAL · TROPICAL MONSOONAL · SAVANNAH DRY WINTER · COLD DESERT · HOT DESERT · SEMI-ARID STEPPE · WARM WITH DRY SEASON · WARM WITHOUT DRY SEASON

Public parks

Open spaces are the most common environments in parks. They allow the public to occupy the space for multiple uses in a natural setting. The range of frequency in mowing and cutting, the cutting heights and periods of intervention lead to a differentiated management, which allows the recreational or ecological spaces to develop in space and time.

Costs & benefits

Increase in tax revenues	Job creation with low investment costs	Impact on health	Reduction of maintenance costs
In New York, $7 million of "surplus" tax revenues in 2006 due to rent increases (see Technical Appendix n° 1).	In France, €100,000 of investments support on average 1.4 jobs in a landscaping company, against 0.4 jobs in the rest of the economy (see Technical Appendix n° 2).	In the Netherlands, based on an average cost of €430 per asthma patient, savings on medical expenses attributable to a 10% increase in green spaces are estimated at €56 million a year[14].	In Fécamp, the differentiated management of green spaces has saved €5,000 a year on the budget for the purchase of plant protection products[15].

Potential ecosystem services

Ecosystem service provided	Detail of ecosystem services	Evaluation of ecosystem services
THERMAL REGULATION	*Cooling of the atmosphere*	Park 1 to 3°C cooler compared to urban blocks (see Technical Appendix n° 3). In sub-tropical areas with a mild climate (Mexico City, Mexico), the minimum temperatures are 3 to 4°C cooler in the park compared to the urban area
WATER MANAGEMENT	*Reduction of leakage rate* See Technical Appendix n° 4	15 to 20% reduction of the leakage rate by parks in Beijing (China), amounting to about €1.5 million a year
AIR PURIFICATION	*Absorption of gaseous pollutants by the stomata* See Technical Appendix n° 5	Reduction of the concentration of fine particles at ground level by 35%, of SO2 by 27%, and of NO2 by 21%
BASE FOR BIODIVERSITY	*Area of development for species* See Technical Appendixes n° 6, n° 7 and n° 8	Number of species proportional to the size of the park, great plant diversity and particular importance of urban parks for butterflies in tropical areas
HEALTH	*Reduces risks of obesity*	Physical activity promoted for all ages (see Technical Appendix n° 9)
	Increases life expectancy of elderly people	Life expectancy increased by 8 years for elderly people living near parks (see Technical Appendix n° 10)
	Reduces the prevalence of certain diseases See Technical Appendix n° 11	Reduction of 21% of coronary heart disease, 31% of anxiety disorders, and 20% of diabetes (for 10% to 90% of green spaces)
CARBON STO-RAGE	*Storage in herbaceous and shrub layers* See Technical Appendixes n° 12 and n° 13	Sequestration between 9.10 and 9.79 kg CO2eq per year (average value between 1985 and 2004) for all the parks in Florence In arid environments (Phoenix, USA), urban parks sequester about 3,630 tons of CO2 per year, for a value estimated at $283,000, *i.e.* a total storage estimated at over $4.5 million
ESTHETICISM	*Attraction of visitors for the presence of nature*	Varying expectations depending on the cultural contexts (wild, contemplative, structured, social, sport, etc.)

Local economic benefits

Increase in surrounding land prices and the attractiveness of the neighborhood (see Technical Appendixes n° 14a and n° 14b).

Ecotourism and attraction for urban parks (see Technical Appendix n° 15).

Employability of the sector (91,000 jobs in France), particularly for young people (12.5% of the sector).

Potential to recycle certain organic waste (see Technical Appendix n° 16).

Use of natural resources

Local land and adapted seeds traced of local origin (non-exogenous).

Inclusion of local stakeholders

Communication on the non-uniform aspect of the park (in particular on the permanent grassland).

Mowed areas maintained for borders to offer close-cropped spaces.

Involvement of residents and local associations (for elderly people, sport, etc.), medical professionals for outdoor equipment beneficial to health, and schools to promote the use of parks and gardens as learning and awareness-raising areas.

Monitoring indicators

Counting of the number and abundance of habitats, as well as the animal and plant species (see Technical Appendixes n° 17a and n° 17b).

Non-ecological indicators: development of the surface of parks by satellite, monitoring of the expenditure and maintenance cost of the park, as well as the number of visitors.

Local incentive mechanisms to develop

Implementation of "zero phyto" policies in the city, conservation of parks managed in a traditional way, use of former wasteland.

Design and context

Technical elements for the design and zoning (see Technical Appendix n° 18).

Use mixed design teams: landscapers, ecologists, ecological engineers…

Qualified partners

- Horticultural Regional Innovation and Technology Transfer Center (CRITT).
- National Union of Landscaping Companies.
- Landscaping agencies.

Project references

Tampines Eco-Green Park, Singapour.

Parc de l'île Saint-Germain, Hauts-de-Seine, France.

To go further

- Technical Guide Biodiversity and Urban Landscape, *"Fiche 14 : Pelouses et prairies"*, Urbanisme, Bâti & Biodiversité (U2B).
- Feedback on the creation of a park with an ecological design and management in a tropical country, IBRAHIM Roziya & al., *"Tropical urban parks in Kuala Lumpur, Malaysia : Challenging the attitudes of park management teams towards a more environmentally sustainable approach"*, Urban Forestry & Urban Greening, vol. 49, March 2020.

EQUATORIAL · TROPICAL MONSOONAL · SAVANNAH DRY WINTER · WARM WITH DRY SEASON · WARM WITHOUT DRY SEASON

Urban and periurban forests

Urban woodlands can be planted, relict or form a real forest: they consequently have **a variable ecological functionality.** A number of species go through their entire life cycles in these environments (reproduction, food, shelter, etc.) Their integration into the urban landscape requires **ensuring their multi-functional nature depending on the main uses** for local people.

Costs & benefits

Cost-benefit ratio See Technical Appendix n° 19	**Willingness to pay** See Technical Appendix n° 20	**Planting of an urban forest**	**Average costs and benefits of global urban forests** See Technical Appendix n° 21
In Chicago, ratio of 2.93 (lifespan of 30 years, 95,000 trees planted): - $21 million of investment and maintenance - $59 million of profits	In Florida, people would be willing to pay $1.59 to benefit from the shade and $3.95 for the good state of urban forests	In Paris, a project to plant 4 urban forests was announced by the Mayor Anne Hidalgo, at a cost ranging between €412 million and €1.016 billion[16]	Average cost/tree: $37.40 Average profit/tree: $44.34

Potential ecosystem services

Ecosystem service provided	Detail of ecosystem services	Evaluation of ecosystem services
THERMAL REGULATION	*Cooling of micro-climates* *See Technical Appendix n° 22*	Reduction of 3°C compared to non-forest areas and 1°C under the canopy
WATER MANAGEMENT	*Stormwater retention and filtration* *See Technical Appendix n° 23*	Runoff retention capacity of up to 44% of stormwater for certain species (eucalyptus, in Australia, for a precipitation of 14 mm/h), and water storage in the foliage of up to 1.16 mm of precipitation (summer lilac, native to China)
AIR PURIFICATION	*Fixation of pollution by the stomata* *See Technical Appendix n° 24*	12.5 kg/ha/year of pollution filtered, estimated at $67/ha for a foliage cover of 16%
	Carbon storage and sequestration	Between 22 and 59 kg sequestered on average per year per tree with a diameter of >45cm (variable depending on the biomes, see FAO Ex-Act tool)
SOUND INSULATION	*Reduction of sound level*	2 dB for shrub beds with a width of 5 m and 6 dB for a plantation with a width of 50 m[17]
BASE FOR BIODIVERSITY	*Specific diversity and wealth* *See Technical Appendix n° 25*	Between 120 and 215 plant species (45-50% native) in the urban forests of Canton (China)
	Habitats and connectivity *See Technical Appendix n° 26 and n° 27*	Presence of mammals in Ireland's urban forests Specific wealth multiplied by 1.6 through the presence of dead wood
HEALTH	*Effect of stress reduction*	Faster recovery (and fewer complications) for a patient hospitalized in a room with a view of a wooded area[18]
SOCIAL INTERACTIONS	*Recreation areas and creation of social cohesion*	For 9 visits per person per year, for a hedonic value of $1 per visit to a well-managed urban forest, the recreational value of urban forests would amount to roughly $2 billion in the USA[19]

Local economic benefits

Development of a timber industry, ecotourism, leisure activities (tree climbing, paintball).

Use of natural resources

Use local species (rare if possible) and promote integrated biological control.

See Technical Appendix n° 29.

Avoid treatment on dead trees (curettage, whitewash, cement, fillers, fungicide).

Inclusion of local stakeholders

Communicate on the presence of dead wood and make it acceptable:
• Create urban furniture (tables, benches).
• Create sculptures on stumps, candle trees and fallen trunks.
• Use majestic dead trees as totems.

Properly integrate the multifunctional management required by the uses of local people.

Minimize "disservices" and inconveniences for people (poisonous trees, allergenic pollen, presence of pest species, insecurity, risks of falling trees or branches).

See Technical Appendix n° 28.

Monitoring indicators

Canopy cover, specific wealth and diversity of plants, birds and insects, plant health, level of allergens present, increase in land value, speed of runoff, quality of runoff water.

See Technical Appendix n° 30.

Local incentive mechanisms to develop

Development of responsible forestry industries, introduction of payments for the right to use forests and fines in the event of non-compliance.

Design and context

Technical elements for the design and zoning (See Technical Appendix n° 31).

Choice of species depending on the geographical area (See Technical Appendix n° 32).

Use mixed design teams: forest engineers, ecologists, landscapers...

Qualified partners

- National Forestry Office (ONF), French Biodiversity Agency (OFB), Regional Biodiversity Agency in Île de France.
- Cities4forest (NGO).
- Landscaping agencies.

Project references

Otemachi neighborhood, Tokyo (Japan).
Achimota Forest, Accra (Ghana).

To go further

- Trees and Design Action Group, *Trees in Hard Landscapes: A Guide for Delivery*, 2014.
- CARTER Jane E., *The potential of urban forestry in developing countries : a concept paper*, FAO.
- RANDRUP Thomas B. & al., *Urban and peri-urban forestry and greening in West and Central Asia : experiences, constraints and prospects*, FAO, 2006.
- Tools: I-Tree et I-Tree eco, *Ex-Act for the CO_2 balance* (FAO).

Green spaces for use

Cemeteries have an **ecosystem structure similar to public parks,** although they are subject to much less human pressure (visits and need for maintenance). The specific wealth in these spaces is favored and enhanced by the diversity of potential habitats through a very heterogenous architecture with crevices. *Sports fields* are of little interest for flora and fauna. However, **the ecological management applied to these spaces and their surroundings can protect the soil and biodiversity** found there. The surroundings of these fields (hedgerows, grass strips…) can be **intermediary spaces** for biodiversity. Golf courses can be privileged spaces for biodiversity. The minor disturbance in these spaces and their diversity of habitats are beneficial for flora and fauna. *Private gardens* have high potential for biodiversity conservation, due to the large space they occupy in urban areas, particularly in big low-density cities. These spaces are very marked by human factors, such as the socioeconomic status of their owners and their conception of a green space.

Costs & benefits

Cost of the installation and maintenance of a sports field	Maintenance cost for a cemetery	Monetary valuation of the ecosystem services rendered by golf courses (Northern China, mild climate)
Between €120,000 and €180,000 for the installation and €4,000 for a natural field, against €400,000 to €500,000 for the installation and minor maintenance costs for a synthetic field	€0.4/m² for manual weeding, against €0.1/m² for weed control with plant protection products	Provision: €1,100/ha/year Regulation: €600/ha/year Water consumption: €970/ha/year Cost of creating an 18-hole golf course: between €3 million and €6 million (see Technical Appendix n° 33)

Potential ecosystem services

Ecosystem service provided	Detail of ecosystem services	Evaluation of ecosystem services
THERMAL REGULATION	***Decrease in temperature and reduction of heat islands*** *See Technical Appendix n° 34*	The presence of woody vegetation in tree stratum in private gardens reduces the air temperature by between 1 and 2°C compared to a garden with short vegetation (grass)
WATER MANAGEMENT	***Storage and reduction of runoff*** *See Technical Appendix n° 33*	Golf courses provide a stormwater storage service equivalent to €600/ha/year
AIR PURIFICATION	***Fixation of pollutants in the air***	Private gardens play an important role in the perceived air quality (see Technical Appendix n° 35)
BASE FOR BIODIVERSITY	***Specific wealth*** *See Technical Appendix n° 37 and n° 38*	Cemeteries contain a significant wealth of habitats and species (bats, birds, native plants and lichens) The size of private gardens is highly correlated with the specific wealth, mainly when the garden has no grass
	Habitats and connectivity *See Technical Appendix n° 36*	Attraction of cemeteries by avifauna (3 times more holes created by birds than in parks)
SOIL PROTECTION	***Reduction of risks of erosion***	Average reduction of soil erosion of between 2.9 and 3.7 t/ha/year
CARBON SEQUESTRATION	***Carbon storage in the vegetative system***	Golf course: sequestration of about 320 kg CO2eq/ha for Tees, Green or Rough and about 2,700 kg CO2eq/ha for trees (see Technical Appendix n° 33)
ESTHETICISM	***Calm areas and reconnection with nature*** *See Technical Appendix n° 39*	For 68% of residents, correlation between the beauty of a cemetery and the presence of vegetation Educational role, stress reduction and conservation of cultural heritage

Local economic benefits

Through participatory gardening, private gardens provide an environment for learning about horticulture, education in the adoption of healthy eating practices, and contribute to the fight against food insecurity.

Inclusion of local stakeholders

Private gardens:
See Technical Appendix n° 40
• Communication to reduce the homogenization effect between gardens.
• Encourage spontaneous vegetation, uncut hedges, compost, bases for reproduction for avifauna, dead wood, dry walls and wet areas.
• Favor porous separations for biodiversity between plots (hedges rather than fencing).

Cemeteries:
• Communication necessary on the presence of spontaneous vegetation in cemeteries.
• Take into account the cultural and spiritual expectations of the population.

Qualified partners

• *Cemeteries:* Regional Biodiversity Agency of Île de France, ecological cemetery in Niort, cities of Courbevoie and Rennes.

• *Sports fields:* Ecological Sports Fields Label, supported by the Ministries of Agriculture and the Environment.

To go further

- Flandin Jonathan, *Guide de conception et de gestion écologique des cimetières,* Natureparif, 2015.
- Ecological management of sports fields, A.M. PETROVIC, Managing Sports Fields to Reduce Environmental Impacts, *Acta Horticulturae,* 2014, pp. 405-412.

Monitoring indicators

Private gardens: bumble bees, avifauna.

Cemeteries: avifauna, bats, soil pollution.

Golf courses and sports fields: insects in the elements bordering the grounds, plant varieties on the grounds.

Non-ecological indicators: maintenance costs and consumption of water and plant protection products.

Local incentive mechanisms to develop

Private gardens: Support municipal environmental policies with the management of public gardens in order to transfer good practices to private owners through a top-down effect.

Cemeteries: Extend good practices (ban on plant protection products, maintenance of joints to prevent weeds from growing, etc.) to individuals and companies through the rules of the cemetery.

Design and context

Technical elements for the design and zoning. See Technical Appendixes n° 41a and n° 41b.

Project references

Maurice-Baquet and Jerzy-Popieluszko Stadiums, Guyancourt (France).
Natural cemetery in Souché, Niort (France).

EQUATORIAL TROPICAL MONSOONAL SAVANNAH DRY WINTER WARM WITHOUT DRY SEASON

Fragmented green spaces

Fragmented green spaces, such as rain gardens, swales and hedgerows, **act as bioretention areas and ecological connecters.** *Rain gardens* consist of a slight vegetated depression in which the runoff from roofs and paved areas is channeled. They make it possible to **manage flood risks related to stormwater runoff.** *A swale, or filter strip,* is in the form of a gentle slope which channels the water towards the bioretention areas, while **slowing down its flow and filtering stormwater.** *Hedgerows* **act as an ecological corridor and allow the establishment of auxiliary species** which can have various functions: pollinators (hymenoptera, butterflies), direct predators (chickadees, lacewings), parasitoids (ichneumons) and decomposers.

Costs & benefits

Investment and management costs avoided for runoff management projects	Comparison of installation and maintenance costs of runoff management methods (conventional/ecological)
Up to 30% of savings for a project integrating ecological stormwater management, with vegetated ditches and swales (See Technical Appendix n° 42)	Installation of a pipe: €20 to €60/ml Maintenance of a pipe for 30 years: €14/ml/year[20] Installation of a swale: €12/m³, €35/m³ for a ditch Greening of a swale: €1 to €2/ml and maintenance at €3/ml + €1.30/m²/year for mowing (€0.20/m²/year if late cutting)[21]

Potential ecosystem services

Ecosystem service provided	Detail of ecosystem services	Evaluation of ecosystem services
BASE FOR BIODIVERSITY	***Specific plant wealth*** *See* Technical Appendix n° 45	Swales are home to a variety of species up to 2 times higher than landscaped green spaces and 3 times higher than lawns Their specific diversity is up to 1.3 times higher than for green spaces and 1.6 times higher than lawns The berries of non-native species in hedgerows are suitable for virtually all bird species
WATER MANAGEMENT	***Water collection, infiltration and drainage*** *See* Technical Appendix n° 43	Rain garden: stormwater infiltration 30% higher compared to a traditional lawn Reduction of runoff by up to 94% by swales compared to asphalt and 75% compared to a road with drains[22]
	Wastewater treatment *See* Technical Appendix n° 44	Reduction of suspended matter (SM) of between 55 and 91% in swales, reduction of lead of between 17 and 76%, of zinc of between 63 and 93%, of dissolved organic carbon by 53 to 74%, or of up to 100% for swales with bark Rain gardens reduce nitrate and phosphorus pollution in stormwater by up to 60% if the substrate is partially made up of organic soil, instead of slate or sand
CARBON SEQUESTRATION	***Carbon storage in the vegetative system*** *See* Technical Appendix n° 46	Grassy swales can store 0.30 kg CO2eq/m²/year The presence of wood and shrubs doubles this amount

Inclusion of local stakeholders

Communication on the capacity of hedges to enclose private plots

Identification of appropriate species in order to privatize certain spaces (species with thorns, etc.), as well as potential disservices (allergens, invasive nature of species, unwanted shade)

Qualified partners

Regional Biodiversity Agency of Île de France
Landscaping agencies

Project references

Urban Community of Greater Nancy

Monitoring indicators

Swales and hedges: invertebrate species (hymenoptera, diptera, coleoptera and arachnids)

Specifically hedges: mammals and birds

Local incentive mechanisms to develop

Introduce the concepts of swales and stormwater bioretention elements in the Water Development and Management Master Plans (WDMMP)

Hedges: Creation of a local wood sector if multi-layered hedges are developed in public spaces

To go further

- Norpac (subsidiary of Bouygues Construction), *"Fiche technique : Gestion de l'eau à la parcelle : les noues et fossés", Guide Bâti et Biodiversité Positive (BBP)*, in partnership with the Institute for Sustainable and Responsible Development (IDDR) of Lille Catholic University, 2011.
- Design of stormwater retention swales, Gold Coast Planning Schema Policies, "13.4 Bioretention swales", Section n° 13 Water Sensitive Urban Design (WSUD) Guidelines, Policy n° 11, Our Living City, Australia, 2005.
- Choice of species for swales, HUNT William F. & al., "Plant Selection for Bioretention Systems and Stormwater Treatment Practices", Water science and Technology, 2015.
- Ecosystem services provided by each species able to integrate a hedge in a mild climate, BLANUSA Tijana & al., "Urban hedges: A review of plant species and cultivars for ecosystem service delivery in north-west Europe", Springer Briefs in Urban Forestry & Urban Greening, vol. 44, 2019.

Urban and periurban agriculture

Arboriculture, market gardening, livestock farming, horticulture… Urban and periurban agriculture (UPA) plays a prominent role in a number of developing economies, particularly in Africa. Faced with growing urbanization, its integration into urban dynamics provides opportunities in terms of food security (qualitative and quantitative), the reconversion of land and the preservation of the nature of soils. While urban agriculture is part of the creation of ecological corridors or the recovery of wasteland, it also has a buffer effect between inhabited spaces and natural spaces. Forms of virtuous agricultural practices (agroecology and permaculture) can provide ecosystem benefits and play a social, political and cultural role. Regenerative agriculture, which is based on the rehabilitation of the functional capacities of the soil, is a promising agricultural system in terms of the protection of biodiversity and yields to feed people.

Costs & benefits

Types of UPA See Technical Appendix n° 47	**Costs**	**Yield estimates**
SIMPLE AQUAPONICS	Installation, operation and maintenance: investment of €1,300/m²[23]	Basel, Switzerland: 16 t of vegetables and 4 t of fish a year for 1,000m²[24]
AGRO-ECOLOGY	Local and organic onion seeds in Mali: €5.34/100 gr Seeds produced by international firms: €9.15/100 gr	Average increase in yields of 80% in 57 developing countries[25]
GROWING IN CONTAINERS ON ROOFS	Initial investments of between $86,000 and $410,000 for a 2,000 m² market garden roof Manpower needs: 1.5 h/m²[26]	Growing in containers on roofs (Paris, France): 4.4-6.1 kg per m²
CREATION OF AGRICULTURAL AREA	Cost of depolluting urban wasteland, purchase price 15% compared to the development expenses, 8% of the cost price[27] Low transport costs, low cost of labor if participatory dimension	Return on investment in 5 years for wasteland converted into an urban farm in Versailles (France)[28] Potential source of tax revenues (rental of gardens)

Potential ecosystem services

Ecosystem service provided	**Detail of ecosystem services**	**Evaluation of ecosystem services**
	Plant production or animal farming	Production of food, medicinal plants, raw materials ▸ Brazzaville, Congo: urban horticulture accounts for 65% of the total vegetable supply[29]
SOIL MANAGEMENT	***Buffer effect***	Preservation and maintenance of buffer zones between anthropized and natural spaces (wetlands and flood-prone areas)
	Soil stabilization and erosion control	Preservation of agronomic potential and soil permeabilization, soil stabilization through the use of compost
BASE FOR BIODIVERSITY	***Diversity and continuity***	Contribution of agricultural biodiversity to the preservation and functional movement of species in cities (brown corridors)
WATER MANAGEMENT	***Water storage and release***	Regeneration of soil retention functions ▸ Antananarivo, Madagascar: storage of 850 km3 of water (*i.e.* 3 days of heavy rain) by a valley of 287 ha[30]
SOCIAL INTEREST AND WELL-BEING	***Cultural, spiritual and educational values***	Sacred nature of the Earth in certain cultures, enhancement of the urban landscape, educational dimension, reappropriation of traditional practices
	Health	Access to high-quality and healthy food, safety of practices without pesticides or agrotoxic products

Use of natural resources

- Biodynamic agriculture, permaculture and agroecology cultivation techniques:
- See Technical Appendix n° 48
- Regeneration of the biological properties of the soil (permeability, structure, bacteria, fertility, geochemical and water cycles). In the event of actual pollution or a high density, use of bases for cultivation (terraces, rooftops)
- Agronomic recovery of wastewater (raw water irrigation if the composition is favorable or irrigation with treated water), extensive inputs (vs intensive) and green waste (compost, guano, dung, manure, mulch)
- Conservation of the plant and cultural heritage and preservation of the genetic diversity cultivated (old varieties, auxiliary plants) through the provision of local seeds
- Interactions between livestock raising/horticulture and livestock feed from residues from vegetable crops

Management and maintenance: elimination or rational use of plant protection inputs and products; no-tillage or semi-direct techniques; fallow crop rotations and/or alternation with livestock farming; natural selection of adapted species and pathogen control (pests, weeds, diseases); development of wild vegetation on the edges of plots

Local economic benefits

- Development of agrotourism
- Seed autonomy and local fertilizer channels
- Revaluation of knowledge and know-how
- Financial empowerment of women farmers who bring about transformations through the diversification of their activities

Inclusion of local stakeholders

Consultation of groups of farmers' organizations and operators in family farming (women); formal and informal waste operators; local authorities (taxation, planning, transport…)

Monitoring indicators

Characterization of the contamination of urban land destined for market gardening and assessment of health risks (level of absorption of contaminants by the human body)

See Preparation of a Health Management Plan in Technical Appendix n° 50

Health status of the plot: nature inventories, analysis of the proportion of micro-environments created or maintained by agricultural activities (dead wood, mounds, ponds, ditches)

Water status: physico-chemical analysis of the water downstream from the plots or in the groundwater

Local incentive mechanisms to develop

Proactive policies: start-up aid, access to land for women and small-scale producers, tax incentives, urban market facilities, connection between the demand and supply for local agricultural products (catering, large retail outlets, etc.)

Scaling up and development of channels (processing, preservation, storage, distribution, direct sales)

Training programs for farmers in the self-management of their farms and rational practices

Design and context

- Agricultural diagnostic and integration of issues identified in the urban planning documents (See Technical Appendix n° 49)
- Redevelopment of urban wasteland with a low level of pollution into agricultural areas (See Technical Appendix n° 51)

Qualified partners

Urbalia, Saaltus, Natureparif, Cerema, Gret, Cirad, INRA, AgriSud International, Grdr, Essor

2.3. Linear or localized spaces

In the context of urban development, linear green spaces can interconnect localized spaces and thereby give animal species scope for mobility. Alignments of trees often make up a large part of the vegetation in city centers and provide a number of ecosystem services. Linear transport systems can alternatively either pose a threat to biodiversity, due to the fragmentation of habitats and the isolation of populations, or be an opportunity when they are designed as a component of the urban landscape and favor the permeability of pathways, for both pedestrians and wildlife.

TECHNICAL SHEETS

- **Trees in cities**

Urban trees can be spontaneous or introduced by humans. They contribute to the heritage of cities as they are part of a long-term cycle. They are more or less useful for biodiversity and provide a number of ecosystem services. However, they can also be an inconvenience or pose risks for the population if they do not take residents' expectations into account.

- **Highways and transport infrastructure**

Highways refer to all the traffic routes of the road network (roads, routes, streets, etc.) and include the roadway, destined for traffic, its shoulders and any central islands, as well as the spaces for pedestrians (impermeable or free pavements). In addition, rail infrastructure (railways, level crossings) are linear spaces which present both risks and opportunities for biodiversity.

Alignment trees and linear vegetation to complement public spaces in the city center.
© Antoine Mougenot, Tokyo, Japan, 2018.

Trees in cities

Trees, whether grouped or aligned, contribute to **improving ecological connectivity in cities and linking up the various centers of biodiversity** (natural spaces, parks and gardens). While isolated trees can be used by certain mobile species, alignment trees partly meet the needs of ecological connectivity. Dead wood is particularly interesting as habitat for saproxylophagous insects and often serves as a refuge for avifauna.

Costs & benefits

Average hedonic price for a tree	Economic evaluation of ecosystem services	Planting costs
In Portland, a tree with a canopy of 80 m² adds 3% ($8,870) to the sale price of a house, equivalent to a 12 m² extension[31]	Indiana, USA: $9.7 million for energy savings, $24.1 million for stormwater runoff, $2.8 million for the filtration capacity for particle pollutants and $1.1 million for the carbon sequestration capacity. Social and esthetic benefits estimated at $41 million on the adjacent properties[32]	Highways: €4,500 to €7,000 on average (creation of the hole, planting, border and finishing), with €300 to €400 for a tree about 10-years old Parks: more favorable soil, only requiring decompaction, with a total cost of €1,200[33]

Potential ecosystem services

Ecosystem service provided	Detail of ecosystem services	Evaluation of ecosystem services
THERMAL REGULATION	***Reduction of urban heat islands*** *See Technical Appendix n° 52*	Reduction of up to 3°C in the air temperature in streets planted with mature trees and of about 2°C in adjacent streets in Tel Aviv
	Buffer effect on micro-climates	In tropical cities, reduction of 2°C in the air temperatures and 20°C in the level measured on paved roads (See Technical Appendix n° 53)
WATER MANAGEMENT	***Rainwater storage and infiltration***	In 2009, in Orlando, the 68,000 trees studied intercepted over 900 million liters of rainwater, with a value estimated at $539,151 (See Technical Appendix n° 54)
AIR PURIFICATION	***Air filtration through the fixation of pollutants on leaves*** *See Technical Appendix n° 55*	In Guangzhou (China), in 2000, for 1,637 ha planted: 2.52 mg/month of SO2 are filtered in the air through dry deposition (€182), 4.00 mg of NO2 (€290) and 2.40 mg of suspended particles (€2,356)
SOUND INSULATION	***Capture of sound waves by the trunk and foliage***	Reduction of 4 to 12 dB of sound waves depending on the species (See Technical Appendix n° 56)
BASE FOR BIODIVERSITY	***Habitats and connectivities*** *See Technical Appendix n° 57*	Urban trees serve as habitats for bird species (0.25 individuals per native tree, and 0.08 per non-native tree)
HEALTH	***Shade and protection from UV radiation*** *See Technical Appendix n° 58*	Reduction of 15% to 30% of incident UV radiation under the canopy at street level and in residential complexes
INFRASTRUCTURE PROTECTION	***Reduced degradation from sunlight*** *See Technical Appendix n° 59*	After 12 years, the Pavement Condition Index stands at 0.5 for an unshaded pavement and 0.7 for a pavement shaded by a hackberry
CARBON STORAGE	***Sequestration and storage***	In New York, storage of 1,225,200 tons of carbon, with a net annual sequestration of 20,800 tons a year for 5 million trees (See Technical Appendix n° 60)
ESTHETICISM	***Landscape identity***	Creation of a landscape identity for residents and definition of a relationship with time and seasons in temperate zones

Local economic benefits

Increase in the value of properties and revenue from tourism

Use of natural resources

Land use:
Preserve the soil if it is of good quality or compensate for its poor quality through decompaction and the addition of local topsoil

Vulnerability of populations: Impose a maximum of 10% of identical species to avoid epidemics. Select local species rather than introduced species or cultivars full of pests. Use alternative techniques to destroy pests (such as integrated biological control). Select old varieties for orchards, if possible in aligned rows to safeguard the diversity of fruits and benefit from their resistance to diseases

Invasive species: Monitor invasive species on bare soil

Inclusion of local stakeholders

Communication on the interest of dead wood

Consideration of expectations of the role of urban trees (safety, collective use, etc.)

Identify local suppliers (nurseries, etc.)

Definitions

Saproxylophage: an organism that consumes decaying dead wood

Monitoring indicators

Wealth and specific diversity of plants, birds and insects

Quality of infiltration and drainage, temperatures

Increase in land value

Local incentive mechanisms to develop

Plantings sponsored by residents

Tax deduction for donations to associations (tree planting and maintenance programs such as WWF)

Design and context

Tree planting (See Technical Appendix n° 61)

Technical elements for the design, planting and maintenance (See Technical Appendix n° 62)

Choice of species depending on the geographical area, constraints of invasion (size of holes, presence of underground networks, exposure to wind, etc.)

See Technical Appendixes n° 63a and n° 63b

Qualified partners

- City of Orléans, CRITT Horticole, UPGE
- International partners: Trees for Cities, Trees.org
- Landscaping agencies

Project references

Parks and Tree Act, Singapore
Soweto Greening Project, Johannesburg (Afrique du Sud)
Urban tree forest of Mendoza, Argentine

To go further

- Trees and Design Action Group, *Trees in Hard Landscapes: A Guide for Delivery*, 2014.
- Technical Guide Biodiversity and Urban Landscape, *"Fiche 16 : L'arbre en ville"*, Urbanisme, Bâti & Biodiversité (U2B).
- Municipality of Orléans, *Charte orléanaise de l'Arbre Urbain*, Agenda 21 d'Orléans, 2011.

Highways and transport infrastructure

The development of linear highways and infrastructure for land transport (freeways, railways, roads, civil engineering structures, etc.) causes **a fragmentation of the landscape, ecosystems and habitats,** sometimes preventing flora and fauna from going through their life cycle. The movement of living beings must therefore be considered in a comprehensive manner, in order to **provide the best balance between the need to serve cities and connectivity between environments.** In addition to reflection on the routes, the combination of "dissuasive" ecological barriers can **minimize factors that disturb animal species,** such as noise and light pollution or risks of collision. Furthermore, when these developments and green spaces are designed taking into account the specificities of the environments and the species in them, they can **be corridors (penetrating) and/or act as a buffer (interface) between the urban ecosystem and natural areas.** The combination of strategies for urban mobility and planning for green and blue corridors can be a valuable driver for the development and spatial distribution of urban biodiversity.

Costs & benefits

Types of infrastructure	Development and maintenance costs
MAJOR ROADS	Wildlife passages (See Technical Appendix n° 64): ▸ Toad tunnel: €500 (50 cm concrete pipe) on any type of road (mammals and amphibians) ▸ Fauna tunnel: €30,000 to €50,000 (concrete structure 10 cm wide) Maintenance of green spaces and extensive management (streets, roads, avenues): €1.40/m² [34] Low-maintenance and low-water plants depending on the climates
URBAN ROAD SYSTEMS (PARKING LOTS, SIDEWALKS…)	*Permeable coatings (low-traffic areas or parking areas)* Hollow-core or grassed slabs: ▸ €20 to €22/m² for concrete "grass grids" ▸ €20 to €23/m² for concrete-grass slabs[35] Low maintenance costs

Potential ecosystem services

Ecosystem service provided	Detail of ecosystem services	Evaluation of ecosystem services
AIR MANAGEMENT	*Improvement in air quality*	Absorption of pollutants and particulate matter in the air by plants, in particular nitrogen and CO_2
ACOUSTIC REGULATION	*Noise abatement*	Plant coverings (vegetation, substrate) reduce the noise pollution generated by transport infrastructure The grassing of road systems reduces environmental noise by 6 decibels (or dB(a)) for tram traffic[36]
THERMAL REGULATION	*Reduction of urban heat islands*	A reduction of reflective mineral surfaces, combined with the greening of road systems, increases thermal comfort in the immediate environment
BASE FOR BIODIVERSITY	*Diversity and habitats*	40% of flora counted on the easement strips of the natural gas transmission network in Île-de-France and Eure-et-Loir between 2007 and 2009[37]
WATER MANAGEMENT	*Stormwater retention*	Restoration of the stormwater retention capacity of soils with permeable coverings and improved functionality of roads
SOCIAL INTEREST AND WELL-BEING	*Landscape enhancement*	Creation of a landscape continuum, improvement in the esthetics and living environment for residents

Use of natural resources

Management and maintenance:
• Reduction in mowing frequency and heights depending on the level of passage
• Promotion of free development; seasonal closure of certain roads depending on the migration processes of the target species
• Integration of issues related to forest roads (See Technical Appendix n° 67)

Inclusion of local stakeholders

Territorial consultation adapted to the infrastructure (local authorities concerned, State)

Consultation of local civil society stakeholders (naturalists, fishermen, hunters…)

Consultation of residents and specific users (disabled people, parents with pushchairs…)

Monitoring indicators

Long-term monitoring by an ecologist in the field: monitoring of invasive species and threats to them, mortality and collision

Monitoring of the appropriateness of management strategies in terms of the "species-habitats-infrastructure" context

Qualified partners

- ITTECOP Program, Infra Eco Network Europe
- Landscaping agencies, engineering firms, roads and utilities engineering firms, ecological engineers

Definitions

Green dependencies: green spaces bordering transport infrastructure, such as shoulders, embankments, central islands, roundabouts, lateral access roads, rest areas, etc.

Local incentive mechanisms to develop

Raising public awareness of biodiversity and the health of the environment: change mentalities about road maintenance in cities and notions of neatness (weeds, late cutting…).

Management companies and local authorities: training of employees, transfer of management to residents for certain spaces such as the bottom of walls, bases of trees

Design and context

Elements for zoning and routes (See Technical Appendix n° 65): importance of planning and diagnostic documents for the ecological continuities to safeguard

Roads: select permeable material to facilitate water infiltration depending on the uses and traffic (green hollow-core system, paving stones with or without joints, turf, etc.), replanting or grassing pavements, conservation of plant cover (See Technical Appendix n° 66)

Major transport infrastructure: methods to protect from noise, sound and light pollution (horns, orientation of lights towards the ground, etc.), deterrent devices (ultrasound, olfactory repellents, reflectors and mirrors) combined with the creation of passages for flora and fauna (ecoducts) adapted to local species, optimize the continuity of the original vegetation above or below roads (dead wood, stones, ditches)

Use mixed design teams: roads and utilities-transport engineers, landscapers, ecologists, urban planners…

Project references

Rehabilitation of a former urban railway, "High Line" - New York, (USA).

Wildlife underpass on the Narayanghat Highway, Mugling (Népal).

2.4. Biodiversity and water in cities

Aquatic environments are both **receptacles and bases for biodiversity,** as they provide ecological functions that are very important in the life cycles of various animal and plant species, including terrestrial species. They also offer many benefits to the city and its residents, in the form of ecosystem services such as **runoff management or improving air quality.** These interdependencies with water are especially marked in cities with rivers and coasts, or where there are wetlands.

TECHNICAL SHEETS

■ Urban watercourses

Rivers and riverbanks provide habitats for biodiversity and form structural ecological corridors for the entire urban ecological landscape. The ecosystem services they render (improvement in air and water quality, etc.) are directly related to their proper hydromorphological functioning, which first and foremost relies on the water cycle being respected. In addition to approaches at the level of watersheds (or the overall landscape), a wide range of ecological engineering techniques (local approach to the landscape) can be mobilized for the restoration of rivers and riverbanks, resilience to floods and accessibility for residents for more or less intense uses.

■ Ponds, basins and wetlands

Wetlands are "exploited or unexploited lands that are frequently permanently or temporarily flooded or filled with fresh, salt or brackish water, or whose vegetation, when it exists, is dominated by hygrophilous plants for at least part of the year". They cover about 6% of the world's land surface and are among the richest and most diversified ecosystems on Earth, as they are home to a great variety of animal and plant species. These spaces have traditionally been perceived as constraints in the development of cities which we wanted to be "out of the water" and are still threatened by urbanization. Yet they make an essential contribution to climate change mitigation and adaptation.

■ Biodiversity and coastal cities: risk management and ecological resilience

According to FAO, about three-quarters of the world's population live in areas within 60 km of the coast. Coastal, marine and estuary areas are home to a wealth of aquatic biodiversity which many geographical areas are dependent on nutritionally, touristically, economically, culturally and spiritually. These dynamic ecosystems continuously evolve with the coastline, which is itself subject to rising sea levels, erosion or, conversely, coastal accretion in estuaries with heavy silt deposits. Coral reefs are particularly interesting habitats for biodiversity, but they are often subject to degradation due to the discharge of pollutants or waste into the sea. A sustainable and regulated management of coastal ecosystems, combined with an understanding of the specific functioning of the urban environment (ports, seaside resorts, fishing…), can improve the resilience of cites to climate change and the living conditions of residents.

Linear park along the Barigüi River, alternating accessible banks and banks renatured to limit erosion and favor biodiversity.
© AFD, City of Curitiba, Brazil, 2018.

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Urban watercourses

Rivers, streams, creeks... Urban watercourses and their uses are **crucial health and economic issues in developing countries.** They are also blue corridors which **allow the movement and interaction of a variety of flora and fauna,** upstream and downstream from cities. Based on the natural functioning of these ecosystems, **the hydromorphological restoration of watercourses and their banks** can restore a number of ecological mechanisms, in particular in terms of the self-purification of water, the control of erosion and the management of hydrological extremes (rise in water levels, floods...).

Costs & benefits (See Technical Appendix n° 68)

The costs and benefits of a restoration project vary depending on the initial state and physical characteristics of the watercourse, how it is used, the restoration technique used, and the different urban planning components that need to be taken into account.

Cost difference for the restoration of banks (See Technical Appendix n° 69)	**Maintenance**	**Costs avoided by options for maintaining and creating habitats** (See Technical Appendix n° 70)	**Willingness to pay/contribute** (See Technical Appendix n° 71)
Conventional technique (steel sheet piling): €1,000 per linear meter Plant technique: €250 per linear meter	Dredging: €3 to €10/m^3	Construction of sub-banks: €230 to €3,150/unit Creation of aquatic vegetation: €6/m^2 Reconstitution of the formation of halophytes: €18,000 to €60,150/ha	25.5% of residents in Dhaka (Bangladesh) willing to contribute financially and 32.75% physically to the restoration of the Buriganga River (equivalent to a total of BDT 445.93 million, *i.e.* €4.4 billion)

Potential ecosystem services

Ecosystem service provided	**Detail of ecosystem services**	**Evaluation of ecosystem services**
SOIL MANAGEMENT	*Control of the erosion of banks*	Effective stabilization of banks by fascines and resistance to a flood of 300 W/m², 15 to 20 years after the installation (See Technical Appendix n° 72)
THERMAL REGULATION	*Albedo effect and evaporation*	Restoration of the Aygalades stream (project, Marseille, France): -3°C to -6°C compared to the current temperature (54 ha of urban surface cooled)
BASE FOR BIODIVERSITY	*Diversity of habitats and continuity*	600 fish (9 different species) in an obstacle-free watercourse, against less than 30 fish (4 different species) with obstacles[38]
SOCIAL, CULTURAL AND RELIGIOUS INTEREST	*Recreational, touristic and spiritual values*	250% increase in visitors to Ladywell Fields Park in London following the restoration of the river (IUCN) Contribution of water to mental health and well-being[39]
WATER MANAGEMENT[40]	*Water purification*	Purification function estimated at €251/ha/year
	Water retention and regulation of flood risks	Cost of €404/ha/year avoided by the flood regulation service from the expansion plains

Use of natural resources

Greening of the riparian forest:
• Integration of various layers of vegetation (herbaceous, shrubs and trees) to ensure the cohesion and protection of the surface
• Alternation of shade and light for a balanced development of the helophyte vegetation (semi-aquatic plants, avoiding invasions) and fight against eutrophication
• Favor deep-rooted trees for an effective absorption of pollutants (denitrification)

Management of the riparian forest (Non-intervention is a fully-fledged management option!):
• Stabilizing effects of dead wood depending on the position of the low-water channel and its presence provide a base for benthic fauna (fixed on the substrates or mobile at the bottom of the river)
• Recovery of sediments removed from the riverbed to reinforce banks
• Food for fish fauna from falls from the canopy (leaves, insects, droppings)
• Maintenance through holes and cutting to reduce the aerial apparatus for the benefit of the root apparatus and sustain stumps: cutting of non-native or erosive species, retention of trees of biological interest and focus on minority species or strata
• Favor maintenance of the vegetation outside the bird nesting or fish migration period

Local economic benefits

Exploitation of woody species from the riparian forest and flood silt

Positive impacts on agricultural production and activities based on the use of water

Revitalization of watercourses by developing leisure activities

Inclusion of local stakeholders

Involvement of local stakeholders in the approach: understanding of the development issues, consultation based on sharing the uses and participation in awareness-raising

Qualified partners

Water agencies (mainland France) and water offices (French Overseas Territories, excluding Mayotte), National Office for Water and Aquatic Environments (ONEMA), OFB, local authorities and water authorities, Waterways of France (VNF)

To go further

▸ Roland-Meynard Marlène & al., *Guides et protocoles de suivis d'opérations de restauration hydromorphologique en cours d'eau*, OFB, 2019.

Monitoring indicators

Evaluation of the biological quality of the watercourse depending on the aquatic flora (macrophytes, phytoplankton...), benthic invertebrate fauna (species which lives on the substrates in the depths of the water) and fish fauna

Design and context

Urban planning and hydraulic modeling (Water Management Master Plan, Flood Risk Prevention Plan)
See Technical Appendix n° 73

Technical elements for renaturing a watercourse and developing the banks
See Technical Appendix n° 74

Use mixed design teams: ecologists, landscapers, engineers, water engineers and hydrologists...

Project references

Cheonggyecheon, Seoul (South Korea)
Ravensbourne, London (UK)

Definitions

Riparian forest: woody vegetation (afforestation, riverine forest, etc.) located in direct proximity to a watercourse whose species composition depends on it

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Ponds, basins and wetlands

Wetlands are **natural or artificial parts of a territory** which are, or have been, permanently or temporarily flooded with water or waterlogged. They are identifiable by their hygrophilous vegetation and/or their hydromorphic soils. Wetlands are **extremely valuable reservoirs for biodiversity,** as they are often home to species with very limited ecological niches, *i.e.* with very specific environmental needs (resources, habitats, humidity).

There are:

- *Permanent ponds*, with water all year round due to a moderate evaporation, their depth and their surface.
- *Temporary ponds,* which are smaller and dry up in hot weather. They can be reduced to persistent puddles for several weeks. They are home to more specialized populations which need to complete their life cycle during the short period where there is water.

Costs & benefits

Savings in management costs for 4,000 m² for a center for gerontology (Lormont, France) See Technical Appendix n° 75	Maintenance of the aquatic part See Technical Appendix n° 76	Restoration cost for a wetland (France)
Conventional management: €2,800 Differentiated management: €2,155	Dredging: €3/m^3 in France	€19,000/ha[1] (including preliminary studies)[41]

Potential ecosystem services

Ecosystem service provided See Technical Appendix n° 77	Detail of ecosystem services	Evaluation of ecosystem services (in $/ha/year) Based on 200 case studies See Technical Appendix n° 78
THERMAL REGULATION	*Influence on the local climate*	135
WATER MANAGEMENT AND RESOURCES	*Retention and flood control*	465
	Filtration and purification	290
	Water supply	45
BASE FOR BIODIVERSITY	*Important biodiversity reservoir*	210
	Provision of habitats for reproduction	200
SOCIAL INTEREST	*Leisure, tourism and esthetic value*	1,350

To go further

- Cerema, *Milieux humides et aménagement urbain : dix expériences innovantes,* Collection Connaissances, 2015.
- Bordeaux Métropole Department of Nature & Agence Ter Team, *Guide zones humides. Comment intégrer les zones humides dans un projet urbain*, 55,000 Hectares for Nature project, March 2015.
- Use of the private ImpacTer model in the evaluation of the socioeconomic benefits of wetlands, CDC Biodiversité, "Socioeconomic Evaluation of Nature-based Solutions", Mission Économie de la Biodiversité, BIODIV'2050, n° 17, Paris, France, 2019.

Local economic benefits

Use of cutting waste for fertilizer (ramial chipped wood) and mowing waste for compost

Use of natural resources

Management of invasive species:
• Plants: prevention and early grubbing-up of shoots or mechanical removal, dredging, aquatic plant cutting with collection, net laying to avoid contamination downstream
• Animals: favor the predation of mosquitos by creating hedgerows and groves to attract amphibians and dragonflies

Natural seeding or use of local non-horticultural plants adapted to the conditions of the soil, sunshine and water requirement (possibly recovered in other ponds). "Zero phyto".
Keep the site away from areas with potential contaminations from pollutants or plant protection products

Inclusion of local stakeholders

Reconcile the uses of wetlands (visits and protection of habitats), organize the accessibility of the space, communicate on the presence of wetlands, involve the local community in the preservation (training of teams responsible for maintenance, organization of awareness-raising activities in partnership with associations, educational field trips, etc.)

Ensure public safety with shrub vegetation, which is cheaper and more esthetic than a safety barrier

Qualified partners

EauFrance, Resource Centers for Wetlands, Ifremer

Monitoring indicators

Air, water and soil quality

Number of species/surface units, number of endemic species

Gross and net primary production
See Technical Appendix n° 80

Local incentive mechanisms to develop

Use of wetlands in the ARC sequence
See Technical Appendix n° 79

Design and context

Technical elements for the design and zoning (See Technical Appendix n° 81)

Use mixed design teams: hydraulic engineers, landscapers, ecologists…

Project references

Yongning River Park, 2004, Taizhou (China)
Room for the River - H+N+S, 2006 (Netherlands)
Bishan Park – Studio Dreiseitl, 2012 (Singapore)

Définitions

Ramial chipped wood (RCW): uncomposted mixture of shredder residue from chipped wood, mainly from deciduous trees.

Hygrophilous vegetation: vegetation which requires a relatively high degree of humidity to develop well.

Hydromorphic soil: shows physical marks of regular water saturation.

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Biodiversity and coastal cities: risk management and ecological resilience

Urban sprawl, informal settlements and the human impact on coastal sites increase the vulnerability of these ecosystems, such as coral reefs, mangroves and beaches. A territorial diagnostic is necessary to determine the risks to these environments, their level of exposure and the state of the coastline, in order to guide the strategies to implement. Depending on the exposure and reversibility of the phenomena identified, the decisions may focus on reducing anthropogenic pressures, improving and strengthening the state of the coastline, or a preventive withdrawal through relocation. The use of biodiversity in these approaches can be profitable, for example, for fixing sand dunes with vegetation or stabilizing the coastline with the restoration of mangroves. Support for public policies, in particular for fisheries management, and the consideration of aquatic continuities across borders are drivers for operations. They can structure and ensure the sustainability of territorial planning and development projects for coastal cities.

Costs & benefits[42]

Cost difference in mangrove restoration	Benefits and avoided costs Voir Annexe Technique n° 82
Mangrove restoration: between \$200/ha (stop wood cutting, natural regeneration) and over \$200,000/ha (hydrological reconfiguration of the water flow and sediment deposits, manual planting of nursery-grown seedlings) 2 to 6 times < the cost of installing submerged dikes	Saving of \$9.8 billion a year around the world through mangrove restoration

Potential ecosystem services

Ecosystem service provided	Detail of ecosystem services	Evaluation of ecosystem services
SOIL MANAGEMENT	***Buffer effect*** See Technical Appendix n° 86	Reduction of flows of anthropogenic pollutants by dryland or wetland transitional areas between the aquatic and urban environments
	Soil stabilization and erosion control	Control of marine erosion by greening dune ridges
BASE FOR BIODIVERSITY	***Diversity of species and habitats*** See Technical Appendix n° 83	Restoration of nurseries and spawning areas useful to the life cycles of species, replenishment of a diversity of plant species favorable for birds and bats
CLIMATE	***Carbon sequestration***	Carbon storage estimated at between 1 and 6 g CO2eq/ha/year (at a depth of one meter in the ground[43]
WATER MANAGEMENT	***Floods and flood flows*** See Technical Appendix n° 83	Reduction of 13 to 66% of wave height by mangroves 100 m wide, 50 to 100% by mangroves 500 m wide[44]
	Water purification	Sediment retention and nutrient absorption by coastal wetlands such as mangroves. 2 to 22 ha of mangrove forests are necessary to organically filter the waste generated by one hectare of shrimp farming ponds[45]
SOCIAL AND CULTURAL INTEREST	***Recreational, tourism and spiritual values***	Emblematic interest of certain marine species, depending on the geographical areas and cultures, landscape continuity and enhancement of the natural heritage with educational walking trails

Local economic benefits

Development of an integrated forestry-fishing-aquaculture system: maintain the balance of coastal ecosystems, seek alternatives to local practices that are income-generating but too intensive

Inclusion of local stakeholders

Public-private partnership to take into account the different interests (ecological, social and environmental) and consultative groups: NGOs, committees of maritime professions, companies, religious organizations, citizens...

Creation of local and community management entities to involve the population in the preservation of coastal areas

Monitoring indicators

Monitoring of the rise in sea levels: measurement of peat surface elevation (mangroves and marshes)

Monitoring of the post-larval establishment of fish in the coastal habitat to measure its functionality

Analysis of the composition and diversity of aquatic flora and fauna

Local incentive mechanisms to develop

Integrated water management at the local and regional levels (watersheds, rivers, rainwater and runoff)

Reduction of pressure from pollution at the source: rational use of inputs (fertilizers and plant protection products) in agricultural activities, solid waste management and wastewater treatment sectors

Compensation and phased rehousing plan for residents in areas at risk when their restoration as buffer zones is the most reasonable option

Support and awareness-raising for citizens in terms of the fragility of coastal and aquatic ecosystems

Design and context

Attenuation of the magnitude and height of waves through the restauration of mangroves
See Technical Appendix n° 84

Restructuring of marine diversity and restoration of seabeds and shallow coastal areas: seagrass beds, reintroduction of algae and reconstitution of shelters conducive to the colonization of species, local nurseries

Coastal erosion control: selection of revegetation with specific endemic and native species (reinforcement of root systems)

Flexible management of sand dunes: windbreaks (wood slatted fences, nets made with vegetable fibers) or covering with plant debris to regulate the erosive capacity of the wind and reduce its speed; planting with a long and dense root network, resistant to silting
See Technical Appendix n° 85

Landscaping: creation of soft travel routes, restriction of motorized access or pedestrian-only, favor simple developments (reversibility, such as with stilts) and soil permeability

Qualified partners

Public operators: Coastal Agency, Water Agencies and Offices, ONEMA, OFB, local authorities and water authorities, Expedition MED, Ifremer

Engineering firms: Creocean, Suez, Egis Eau, Aquascop, Ecocean...

Project references

Restoration of the coast of L'Hermitage les Bains
(2018-2022) – Saint-Paul, Réunion

To go further

- UICN & WWF Germany, Tangled Roots and Changing Tides. Mangrove Governance for Conservation and Sustainable Use, 2020.
- FAO, "Gestion des plantations sur dunes", Arid Zone Forests and Forestry Working Paper, 2011.

2.3. Biodiversity and the built environment

When addressing the issue of the presence of biodiversity in cities, it is necessary to look at **the constructed matrix which characterizes the urban area: the built environment.** The link between the built environment and biodiversity is at the intersection of the issues of densification and urban sprawl and raises many questions. The responses required vary depending on the specific geographical, climatic and social characteristics of the project location.

▸ Should **a more compact urban model** be favored, to minimize urban sprawl and the use of natural resources?

▸ Up to **what threshold of urban density** do living conditions for people remain acceptable, while making it possible to accommodate biodiversity?

▸ How to **reconcile nature and architecture** in terms of construction systems, materials, functionality, comfort of use and urban forms?

The relationship between the artificial construction system and the environment in which it is established needs to be understood as a fully-fledged ecosystem. It calls for a **reconsideration of the spatial and architectural configurations of the city** at various levels.

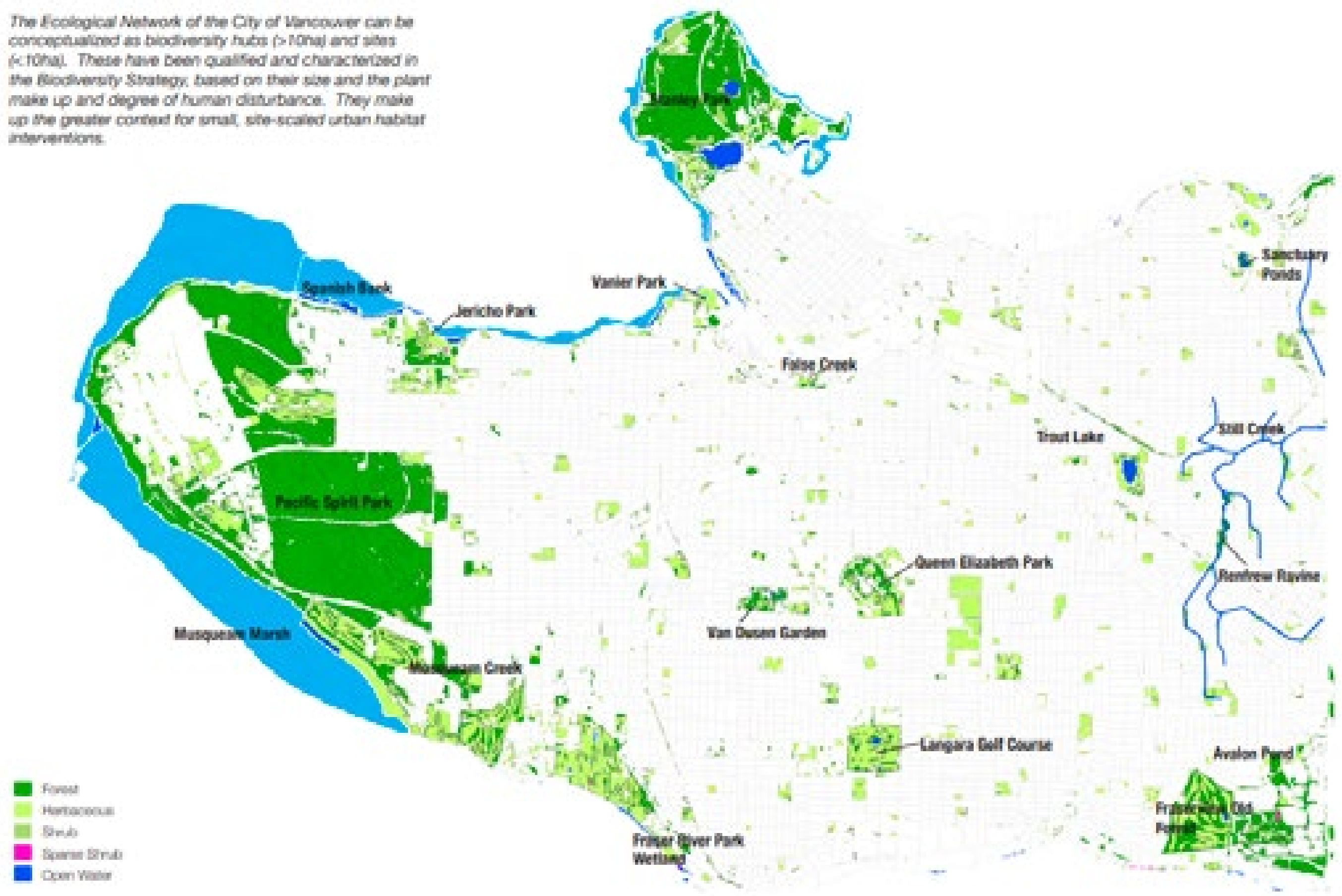
The "Bosco Vertical" towers of the architect Stefano Boeri in Milan. The integration of the equivalent of 1 ha of urban forest has led to an oversizing of the structure and substantial needs for materials.
© Boeri Studio, Milan, Italy.

At the level of the territory

The definition of a large-scale sustainable strategy should enable a better **understanding of the territorial development issues between natural and built spaces.** The planning documents, which spatialize the natural and protected areas and the other categories of green, forest, wetland, agricultural areas, etc., as well as the regulatory urban planning documents, for both cities and urban areas, are the main documents for defining the principles of balance and gradients between "natural" and human uses. For example, as part of its "Biodiversity" territorial strategy, the City of Vancouver has produced a mapping of the ecological continuities. This matrix has been conceptualized by biodiversity hubs (>10 ha) and sites (<10 ha) and provides a framework for defining the scale of construction or renovation projects for buildings and habitat, in relation to the lifestyles of the population and the biodiversity issues in the territory.

Mapping of ecological continuities in Vancouver (Canada)

© City of Vancouver, [Connecting to Nature in Vancouver's Urban Landscape](), Greenest City Scholar, 2014.



At the level of the neighborhood or block

This intermediary level seems to be the most relevant for **fully integrating the living world in reflection on the urban forms to favor.** As defined by the Foundation for Biodiversity Research (FRB), **urban forms** correspond to "types of organization of space, spatial configurations of buildings and specific layouts for public spaces", such as parks and green spaces. The various **urban typologies** (built or unbuilt land, arrangement of elements…) require varying levels of land use and fragmentation that are more or less biodiversity-friendly.

Typology of urban forms

© FLEGEAU, M., Formes urbaines et biodiversité, un état des connaissances, Foundation for Biodiversity Research (FRB), 2020. URL: https://cutt.ly/Sm4BawC

In dense urban areas, despite a weaker ecological performance (intensive population flows, etc.), urban configurations play a crucial role in maintaining ecological corridors between green spaces and the architectural structure of buildings (intermediary structures such as green roofs or walls, height of buildings favorable for certain species…).
Conversely, *in low-density urban areas,* the heterogeneity of land use and private green spaces, mainly in residential or suburban areas, more easily foster the diversity of species. They provide them with an intermediary space for movement between the city and natural spaces[46].

At the level of buildings

Buildings can also be a base for biodiversity and integrate eco-friendly and innovative construction methods in their design, in order to limit the direct and indirect impacts on the environment and climate.

Vernacular (or traditional) architecture refers to a type of construction adapted to cultural practices and a given environment, focusing on using the available resources. *Biomimetic architecture* works to come up with sustainable solutions in nature, based on the biological processes that govern it.

Bioclimatic architecture also has a specific objective of **improving people's living conditions through thermal comfort,** based on the characteristics of the territory concerned and techniques from other architectural methods. Indeed, **construction and housing** are ever more sophisticated (automated heat management, lighting, etc.) and **account for 40% of the energy consumption of OECD countries[47].**

THEY DID IT

To regulate new constructions or the rehabilitation of existing buildings in the Asian Chinatown quarter, the City of Vancouver in Canada has established **recommendations for passive construction[48],** as well as guidelines for urban development projects[49].
The recommendations in terms of uses, height (maximum 15.3 m), forms, density, the size of a block or orientation aim to **safeguard the historical and landscape identity of the built environment and promote natural ventilation or sun exposure processes, adapted to the climate and comfort of use.**

2.5. Biodiversity and the built environment

TECHNICAL SHEETS

Bioclimatic architecture

What contribution does biodiversity make to optimizing energy efficiency in buildings? How to promote the development of local channels for materials? For both new construction and the renovation of existing buildings, bioclimatic techniques and specific expertise draw on the living world to improve the resilience of cities and offer benefits in the form of ecosystem services. At the same time, man-made infrastructure can integrate in-ground structures adjoining the building or off-ground structures, which will serve as environments for the growth of plant populations and refuge for animal populations.

Green roofs and rooftops

Green roofs and rooftops are developments on flat roofs covered with vegetation, made up of layers of insulation and substrate with varying heights. There are various techniques to adapt the infrastructure to each climatic context, the configuration of the roof, etc. The integration of a green roof in a building is facilitated when it is planned ahead. Green roofs provide a large number of ecosystem services for residents and often add to the value of the building.

Green walls and facades

Under certain climate conditions, the plants may be arranged on vertical spaces, generally adjoined to walls. The term "green facades" is used when climbing plants cover the surface, while the concept of "green wall" refers to vertical ecosystems, often supported by an artificial structure. Both these techniques improve the thermal insulation of housing, but involve different installation costs and maintenance methods.

Bioclimatic architecture

While there are as many types of bioclimatic architecture as there are climates, they all consist in using local potential (natural resources, climate characteristics, labor, knowledge) to offer comfortable, energy-efficient and climate-resilient housing. In addition to the opportunities of creating habitats to accommodate flora and fauna, the built environment is thereby part of a passive construction approach, using NbS to favor thermal inertia and manage water and air quality. "Gray biodiversity" is a key concept here and extends the project analysis to the impacts of the building's life cycle (including the production, manufacturing, transport, use, maintenance, then recycling of the materials used) and the environment (in terms of the destruction of species and habitats, spatial fragmentation, genetic and landscape uniformity or, conversely, of positive impacts).

Costs & benefits

Costs of bioclimatic construction processes	Costs of outdoor developments	Estimate of avoided costs in the building's life cycle
Additional cost of 5 to 15% compared to a conventional construction[50] Cost of €150/m² with an additional cost estimated at 15% for the construction of a health center in Burkina Faso	*Greening of buildings:* €80 to €300 exclusive of tax/m², variable depending on the techniques *Shelters and nesting boxes:* €50 to €200/unit	Gray energy (energy required to produce material, from the design to the recycling and including the use): for an equivalent budget, the willingness of a contracting authority, developer and companies reduces the amount of gray energy of a construction by 30%. Profitability on the life cycle: 8 to 9% reduction of construction costs with a 7.5% increase in value[51].

Potential ecosystem services

Ecosystem service provided See Technical Appendix n° 87	Detail of ecosystem services	Evaluation of ecosystem services
AIR MANAGEMENT	*Improvement in air quality*	Natural ventilation or design to favor renewal in order to limit the use of air conditioning or HVAC (heating, ventilation, air conditioning)
CLIMATE REGULATION	*Thermal insulation/thermal inertia*	Reduction of energy needs to regulate the temperature of buildings
	Reduction of heat islands	The greening of the surroundings of the building can reduce solar radiation by 60 to 90%, limiting the reflectivity of the building and radiation
BASE FOR BIODIVERSITY	*Creation of habitats and ecological continuity*	The greening of the surroundings, rooftops, facades and centers of blocks ensures ecological continuities and the protection of certain species
WATER MANAGEMENT	*Stormwater management*	Regulation at the source of rainfall peaks, on-site infiltration and/or reuse of stormwater (watering, toilets...)
SOCIAL INTEREST AND WELL-BEING OF PEOPLE	*Recreational and cultural values*	Improved comfort, well-being of people and landscape quality of the site

Use of natural resources

Local biosourced materials: adapted to the climate, lower cost and appropriate manpower for the construction and maintenance
- Constructions in local stone for climates with strong daily temperature variations, wood for mountain climates and raw earth/sand to limit the risks of overheating
- Plant-based insulation of buildings (wool, flax, hemp, typha)
- Local reuse of construction waste

Local socioeconomic benefits

Creation of local added value:
- Directly by employment, the mobilization of traditional know-how and training to strengthen/disseminate it
- Indirectly *via* the development of material supply channels (hemp in France, for example)

Qualified partners

Urban Ecology Laboratory (tropical climate), NGO GERES, Ceebios, Cerway

Engineering firms: Nomadéis consulting firm, BioBuild Concept, Building for Climate, TERAO

Bioclimatic architecture agencies

Labels and certifications: Technical Appendix n° 92

To go further

- Mahoney Tables: a tool to analyze climate data and formulate recommendations
See Technical Appendix n° 90.
- See PEEB Facility (Program for Energy Efficiency in Buildings) and the technical assistance that can be mobilized in Technical Appendix n° 91.
- JOFFROY Thierry & al., *Architecture bioclimatique et efficacité énergétique des bâtiments au Sénégal*, 2017.
- HUET Severine & MERRELHO Thomas, Guidebook "Sustainable Design: Hot & Humid Climate", August 2018.

Design and context

Orientation and form of the building:

- Solar control: incidence of sunlight and simulation of sunshine, positioning of glass surfaces, positioning and type of surrounding vegetation (deciduous or evergreen), shading systems in buildings (inner courtyard in desert climates, etc.), energy storage and phase-shift redistribution
See Technical Appendix n° 88
- Ventilation: orientation in relation to the topography, prevailing winds, form and compactness of the building and passive air flow systems
See Technical Appendix n° 89
- Water management: air humidification in dry climates (fountains, humidity jars, vegetation), form of the roof, storage or drainage systems, infiltration systems and/or systems for reuse at the plot
- Accommodation of biodiversity: porosity of facades and non-smooth shell (development of climbing plants, habitats for fauna)

Inclusion of local stakeholders

Uses of the building: inform the occupants about the uses in line with the overall project reflection (choice of electrical or cooking appliances for the housing, for example)

Maintenance: understanding of the issues related to the maintenance of the equipment and adoption of reflexes for ventilation, the use of solar protection

Project references

Eastgate Building – Harare, Zimbabwe
Ecopavillon de Diamniado, Dakar

EQUATORIAL · TROPICAL MONSOONAL · SAVANNAH DRY WINTER · COLD DESERT · HOT DESERT · SEMI-ARID STEPPE · WARM WITH DRY SEASON · WARM WITHOUT DRY SEASON

Green roofs and rooftops

Green roofs are interesting due to the availability of flat surfaces in cities and the low level of competition over their use. There are **3 types:**

- **Intensive roofs,** with a heavy load and very thick (>30 cm), with major maintenance (irrigation, handling), high horticultural vegetation, sometimes accessible to the public.
- **Extensive roofs,** with a light load and maintenance (2/3 times a year), small plant range on a mineral base (3-12 cm), with a permanent and quasi-autonomous plant cover.

Costs & benefits See Technical Appendix n° 93

Types of roof	Lifespan (years)	Replacement ($/m²)	Installation ($/m²) and maintenance ($/m²/year)	Heating avoided ($/sqm. year)	Air-conditionning avoided ($/sqm.year)	Avoided costs of an increase in energy demand ($/m²/year)
EXTENSIVE GREEN	40-50	70-100	57	2.9	0.3	0.18
INTENSIVE GREEN	40-50	100-300	N/A	15	0.3	0.68
STANDARD	10-30	22	22	0.2	0	0

Potential ecosystem services

Ecosystem service provided	Detail of ecosystem services	Evaluation of ecosystem services	Monetary evaluation See Technical Appendix n° 98
THERMAL REGULATION	*Cooling of heat islands*	Up to -4°C in adjacent streets in Madrid (See Technical Appendix n° 94)	
	Thermal insulation of infrastructure *See Technical Appendix n° 95*	In summer, in Texas, -30°C compared to a standard roof, -5 to 6 °C compared to a cool roof/-167% of inflows in summer. During low temperatures (0°C), green roofs warmer by 2 to 5°C	
WATER MANAGEMENT	*Holding and retention See Technical Appendix n° 96*	Reduction of up to 600% of the leakage rate for a green roof compared to a standard roof	$1.44/m² to $45.82/m²*
	Filtration	Purification 75% Fe and CU in 15% of cases Cd: purification 90%[52]	
AIR PURIFICATION	*Collection and reduction of sources*	Temperature lowered hence reduction in the production of ozone and other pollutants	$521/ha/year to $839/ha/year*
BASE FOR BIODIVERSITY	*Pollination and accommodation of populations*	Populations of birds, bats, spiders and beetles	
ACOUSTIC COMFORT	*Sound absorption and diffusion by foliage*	Reduction of up to 10 dB for a 7 cm roof (See Technical Appendix n° 97)	1.6% to 4.3%*
ESTHETICISM AND WELL-BEING	*Stress reduction*	Increase in productivity and reduction in absences from work	11%* (recreational use)
CARBON STORAGE	*Pumping into the ground and plant apparatus*	162 g CO2eq/m² in the above-ground apparatus and 100 g CO_2eq/m² in the substrate, 5.7 kg/m²/year	$34/urban ha/ year*
FOOD	*Resilience of local agrosystems*	Short local production chain	$10/m²/month of harvest* on average

**Non-market benefits for all the residents of the neighborhood, derived from indirect assessments as a percentage of the value of the property or in value.*

Use of natural resources

Use local species and integrate local earth (enriched with green waste) in the substrate

Store and use the seed bank already collected from the soil, adapt species to water resources

Avoid inputs of non-renewable materials (peat) and use short circuits

Manage the fire risk with firewalls and the use of non-combustible materials

Design and context

Technical elements for the design and zoning See Technical Appendix n° 99

Choice of species depending on the geographical area See Technical Appendix n° 100

Qualified partners

CRITT Horticole, UMR 7356-CNRS, La Rochelle University, CSTB, ADIVET

Consulting firms: bioengineering, specialized landscaping agencies

Project references

The Muse - Bere Architects (London)

INFONAVIT National Workers' Housing Fund Institute roof (Mexico City)

Monitoring indicators

- Monitoring of the diversity (presence, identification and abundance) of plants, micro and macrofauna, avifauna
- Quality of the substrate and runoff water. Monitoring of consumption for heating and air conditioning, use, production

See Technical Appendix n° 101

Local incentive mechanisms to develop

Transfer of surface in the calculation of building rights

Increase in the ceiling on subsidized loans, tax credit, financial aid from territorial authorities

Reduction in the sanitation tax (in proportion to the volumes retained)

To go further

- Seine Saint-Denis Observatory of Urban Biodiversity et al., *Réaliser des toitures végétalisées favorables à la biodiversité*, 2011.
- Dunnett Nigel, Kingsbury Noel, *Planting Green Roofs and Living Walls*, Timber Press, April 2008.
- Norpac (subsidiary of Bouygues Construction), *"Fiche technique : Optimisation de la biodiversité sur les toitures végétalisées", Guide Bâti et Biodiversité Positive (BBP)*, in partnership with the Institute for Sustainable and Responsible Development (IDDR) of Lille Catholic University, 2011.
- On species adapted to semi-arid environments, Bousselot Jennifer, Schneider Amy, Fusco Mark, "Observations on the survival of 112 plant taxa on a green roof in a semi-arid climate", Denver Botanic Gardens Green Roof Research, 2014.

Green walls and facades

Green facades correspond to climbing (or descending) plants, which have attached themselves to the wall (or *via* a light support structure). Green walls (or living walls) are a module that is also raised parallel to the wall of the building, surfaced with a base for vegetation (fiber fixing the substrate), an irrigation system and the plants themselves.

Costs & benefits See Technical Appendixes n° 102a and n° 102b

Willingness to pay ($/ facade)	Installation (€/m²)	Maintenance (€/vertical m²/year)	Avoided air conditioning costs (€/m²/year)	Increase in rental value for the entire infrastructure (€/m²) See Technical Appendix n° 103
Southampton (UK): 21-56	Wall: 334 Facade: 87	Wall: 13 Facade: 0	12 (32 to 100% of costs)	12.5

Potential ecosystem services

Ecosystem service provided	Detail of ecosystem services	Evaluation of ecosystem services
THERMAL REGULATION	*Insulation and reduction of urban heat islands*	Reduction of up to 4°C during extreme heat days for green walls Increased effectiveness in dry climates
		Reduction of the cooling load: 68% for Brazil and 66% for Hong Kong for green walls (See Technical Appendix n° 104)
		Reduction of wind by up to 0.46 m/s, therefore lower convection for green facades and green walls (See Technical Appendix n° 105)
BASE FOR BIODIVERSITY	*Reduction of bird collisions*	
	Accommodation and refuge for species See Technical Appendix n° 107	Accommodation of insects for green walls and facades, accommodation of avifauna and terrestrial vertebrates for green walls
ACOUSTIC COMFORT	*Sound insulation* See Technical Appendix n° 108	Noise reduction of up to 15 dB and noise absorption coefficient of 0.4 (green wall on panels 6 cm thick) planted with curry (Helichrysum thianschanicum)
WATER MANAGEMENT	*Stormwater management*[53]	
CARBON STORAGE	*Storage in the plant apparatus*	Capture of between 0.44 and 3.18 kg CO2eq/m² (See Technical Appendix n° 109)
AIR PURIFICATION	*Absorption of particulate pollutants in the cuticle and stomata of leaves*	Reduction of molecules by 1.10^{11} cm2/second for a 100% green wall (See Technical Appendix n° 106)

Use of natural resources

Adapted local substrate: use sphagnum (mosses) which are not easily compacted, resist through their fibers and do not need to be weeded. Avoid felt-based systems

Local economic benefits

Less vandalism, better working environment

Local incentive mechanisms to develop

Set up tax reduction mechanisms

Inclusion of local stakeholders

Include stakeholders in the discussions and identification of risks based on the management and maintenance capacities, the presence of microfauna in the green walls (arachnids, insects)

Question the uses of the outside walls and facades and the property value for existing buildings

Design and context

Technical elements for the design and zoning See Technical Appendix n° 110

Comparison between green facades and walls See Technical Appendix n° 111

Monitoring indicators

Monitoring of the micro and macrofauna; plant status (longevity)

Non-ecological indicators: measure consumption (air conditioning and heating), maintenance costs (including water and nutrients)

Qualified partners

Horticultural Regional Innovation and Technology Transfer Center (CRITT)

Project references

Santalaia, Bogota (Colombia)
Oasia Hotel, Singapore

To go further

- Norpac (subsidiary of Bouygues Construction), Fiche Technique *"Murs et pieds de murs à bioversité positive"* *Guide Bâti et Biodiversité Positive (BBP)*, in partnership with the Institute for Sustainable and Responsible Development (IDDR) of Lille Catholic University, 2011.
- French Bird Protection Association (LPO), Technical Guide Biodiversity & Urban Landscape, U2B (Urban Planning, Buildings, Biodiversity) Program, 2016.
URL: https://cutt.ly/7Qv8iNb

2.6. Biodiversity, solid waste management and pollution

According to a World Bank report published in 2018, global waste production will increase by 70% by 2050[54]. With the growth in the population and urbanization, integrating biodiversity into solid waste management is a crucial aspect of the development of urban territories. While the priority of all waste management policies must be to organize the reduction at the source, then the reuse, recovery and, finally, the recycling of waste, an integrated and optimized management of the "ultimate" waste already produced, including through biodiversity, can contribute to **mitigating its impact on ecosystems and the health of local people. It can even be part of a virtuous dynamic for the living world.**

TECHNICAL SHEETS

- Biodiversity and landfills: Design and management of the site

  1. Integrating biodiversity in the landfill design
  2. Mobilizing NbS in landfill management

Landfills are today one of the solutions used for this solid waste which cannot be recycled upstream. The management of these sites can benefit from NbS, while offering opportunities for biodiversity conservation, protection and development in urban and periurban areas.

- Post-landfill biodiversity: rehabilitation of the site

When landfills cease to operate, their rehabilitation can offer a number of benefits in terms of restoring flora and fauna. The former landfill sites are turned into parks or nature reserves and can again foster the development of plant and animal species, while providing an attractive space for residents, although the uses after the closure are limited. Indeed, the air pollution and solid ground strongly influence the possible uses.

Botanical park for palm trees, developed on a former municipal landfill.
©The Open Wall, Palmetum Garden, Santa Cruz de Tenerife, Spain, 2017 // Flickr.

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Biodiversity and landfills: Design and management of the site

1 Integrating biodiversity in the landfill design

The unexploited spaces of a landfill (equipment storage buildings, natural spaces or covered cells) provide potential for maintaining or creating habitats for flora and fauna. Ponds, shrubs hedges, swales and grasslands are all green developments that pave the way for a balanced management of local ecological communities.

Potential benefits of integrating biodiversity

Ecosystem service provided	Detail of ecosystem services	Evaluation of ecosystem services
BASE FOR BIODIVERSITY	*Role of ecological corridor*	Establishment of species at every stage of their life cycle (migration, reproduction or nesting)
	Diversity and wealth of species	Accommodation of remarkable or endemic species. ▸ The landfill in Eteignières (Ardennes, France) is home to 70 bird species identified on the safeguarded water points, including about 20 threatened or endangered[55]
	Natural and semi-natural habitats	Wetlands (ponds, basins) allow amphibians/batrachia to reproduce and settle on the site Development of avifauna, presence of Odonata and reptiles
	Pollination	Value of the biotic pollination process estimated at €153 billion a year and at 9.5% of the value of global agricultural production[56] ▸ UK, 2008: accommodation of a diversity of pollinating insects (bees, beetles, bumble bees, butterflies, Syrphidae) comparable to a nearby nature reserve[57]
SOCIAL INTEREST	*Cultural and educational potential*	Creation of "biodiversity trails", recreational and educational routes
	Landscape enhancement	Landscape integration of the landfill and greater acceptance of the infrastructure by local people

Use of natural resources

Storage of excavated earth and reuse to green the site

Alternation maintained between fallow and operating areas to optimize the colonization of covered pits by wildlife

Inclusion of local stakeholders

Promote a joint management of the site with the expertise of a local environmental organization (counting, recognition of species) to anticipate the rehabilitation phase of the site after its closure (nature reserve, etc.)

Monitoring indicators

Response of bird and butterfly populations to changes in the environment and ecological factors conducive to their development

Qualified partners

Construction/Development: Sita Suez, Veolia, Vinci, Eiffage Génie Civil, Delta Déchets, Eurovia, Coved/Paprec, Tiru SA (subsidiary of EDF), Ortec Industries

Leachate treatment: Orelis Environnement, Ortec, Sita Bioénergies, Veolia Eau, Vinci Environnement, Vauché

Public organizations: ADEME

2 Mobilizing NbS in landfill management

Due to their capacity to fix pollutants, certain plant species can serve as a filtration tool for "leaching juice", also called leachate. Through the bacteria in plant root systems, phyto-purification can effectively purify and control these liquid effluents before their discharge. However, the use of NbS for biological treatment depends on a number of factors, such as the composition of the liquid discharges and the climatic and geological conditions (see Technical Appendix n° 112).

Importance of an appropriate treatment: the impact of leachate on biodiversity

RISKS TO HUMAN HEALTH	Through the infiltration into the soil and surface and groundwater, catchment (groundwater, watercourses) for the drinking water supply, then contamination by direct ingestion or by the irrigation of the food produced[58]
RISKS FOR FLORA AND FAUNA	Real consequences of leachate on the development of plant and animal species: ▸ In China, 2006: damage to the roots of barley corps by leachate concentration in the soil in areas near a landfill site[59] ▸ Circulation of plastic waste components (phtalates, bisphenols…) in leachate: impact on marine flora and fauna, increase in the mortality of copepods and fish, abnormal embryo-larval development[60]

Biological treatment of leachate: cost-effectiveness ratio

Installation and maintenance costs for treatment methods See Technical Appendix n° 115	Effectiveness and benefits of biological treatment. See Technical Appendix n° 116	Limits and options for combinations of biological processes
Biological treatment with tertiary phyto-purification: capacity of leachate treated of up to 59,000 m³/year, CAPEX of €4/m³ for 10 years, OPEX €7.5/m³ Standard by reverse osmosis: treatment capacity of up to 5,000 m³/year, CAPEX of €6/m³ for 10 years and OPEX €13/m³	Treatment efficiency of 95%, effective reduction of nitrogen parameters and organic matter, significant volume of capacity Dual function of the system: potential habitat for species Low energy input required: 5 to 20 kVA on average for a filtration system through reed beds[61]	Major footprint requiring an availability of land in the immediate proximity of the landfill Need to combine it with other biological processes (activated carbon) to comply with discharge standards

Design and context

Design (See Technical Appendixes n° 112 and n° 113): choice of the location of the landfill, ecological diagnostic of the site and analysis of the surrounding areas, anticipation and stabilization of the displacement of biodiversity before the implementation of the works

Management/treatment: principle of vertical and horizontal filtration by reed beds, physico-chemical characterization and estimation of the leachate flow rate based on the hydrograph and geological criteria of the site (See Technical Appendixes n° 117 and n° 118)

Local incentive mechanisms to develop

Reduction of fly-tipping and pollution: awareness-raising for local people on biodiversity issues, encouragement to reduce solid waste at the source

Definitions

Leachate: liquid flow emanating from the percolation of rainwater and liquids from the decomposition of buried waste. High concentration of pollutants and substances with ecotoxity potential.

To go further

- *Guide pratique sur la gestion des déchets ménagers et des sites d'enfouissement techniques dans les pays du Sud*, Francophone Institute of Energy and Environment (IEPF), 2005.
- Biodiversity Quality Index (BQI), by SITA France and the National Natural History Museum (MNHN): evaluation of the ecological quality of landfills during the operation phase (See Technical Appendix n° 114).
- LACASSIN Anaïs, *"Analyse de l'évolution des modes d'exploitation des ISDND en lien avec le développement des prétraitements organiques : exemples des sites de Castries (34), de Penol (38) et de Saint-Christophe-du-Ligneron (85)"*, Sciences de l'ingénieur, 2015.

Post-landfill biodiversity: rehabilitation of the site

The rehabilitation of a dump, either regulated (such as a landfill) or illegal, involves at a minimum the closure and securing of the site, with an appropriate cover, the collection of biogas (if any) and the stabilization of leachate flows. This rehabilitation can be optimized by a long-term ecological and landscape reintegration of the site operated as part of the dynamics of the urban ecosystem. However, the rehabilitation of a dump, which can be turned into a park, golf course or solar farm, is not suited to a multiplicity of uses. For example, agriculture must be avoided and criteria, such as the solidity of the ground and air pollution, guide the extent to which it may be used by the public.

Costs & benefits

Cost-benefit ratio of the levels of rehabilitation	Development costs ($ M)	Willingness to pay
Minimum securing operations: cost-benefit ratio of 0.48, net benefit of -$21.8 million Architectural rehabilitation: cost-benefit ratio ranging between 2.35 and 7.47 (depending on the intended uses), net benefit of $42.5 million to $53 million (See Technical Appendix n° 119) ▸ $125 million saved by using an ecological rather than conventional restoration method for the Jinkou landfill[62]	Variable depending on the desired use (public park, observatory, belvedere…): from $22.1 for a promenade with viewpoints to $39 for a full landscape integration (See Technical Appendix n° 119)	Willingness to pay estimated at $5.54 million a year for all the 440,000 households in favor of a rehabilitation of the Hiriya landfill (Israel) into a public park[63] Increase of $5,000 to $10,000 in the willingness to invest in property near a rehabilitated landfill[64]

Ecosystem services provided

Ecosystem service provided	Detail of the services	Evaluation of ecosystem services
SOIL MANAGEMENT	*Reduction of risks of erosion*	
BASE FOR BIODIVERSITY	*Habitats and diversity*	Attraction of birds which disperse seeds by planting trees and shrub hedges, natural reproduction level of plant species improved through secondary succession (20 new species, ¼ from wind dispersal)[65]
WATER MANAGEMENT	*Water retention*	Greening the cover of cells reduces water infiltration by increasing evapotranspiration and limits erosion
	Regulation of natural risks	Stabilization of the coast and sea level by restoring a wetland on the rehabilitated site of the Fresh Kills landfill (NYC)
SOCIAL INTEREST	*Education*	Awareness-raising and environmental education ▸ Creation of the Educational Wetland Area scheme by the Guadeloupe education authority following the development of an eco-educational trail on the former Morne-à-l'Eau landfill
	Recreational spaces	Public property with a high recreational value made available ▸ Over 2,000 visits during the first weeks when the Santa Cruz Palmetum (Tenerife, Spain) was opened to the public in the autumn of 2013
	Memory	To retain a record, in the long and very long term, of the former use of the site (landfill or illegal dump) in order to monitor and prevent health and environmental risks (reservoir of microplastics and other hazardous waste)

Use of natural resources

Mechanical weeding operations, selective mowing and grubbing-up to control the development of undesired plants and revitalize the herb layer

Optimization of costs by reusing local materials (inert waste and compost from green waste) to create a cover

Local economic benefits

• Ecotourism
• Development of a waste-to-energy channel with the recovery of biogas

Project references

Fresh Kills, New York (USA)
Santa Cruz Palmetum, Tenerife (Spain)

Qualified partners

Antea Group, ADEME, SEGE Biodiversité, bioengineering firms

To go further

▸ ADEME, *Remise en état des décharges Méthodes et Techniques, Connaître pour agir,* Waste and Soils Division, 2005. URL: https://cutt.ly/5QnwcYo

▸ Roccaro Paolo, Vagliasindi Federico G. A., Sustainable Remediation of a Closed Solid Waste Landfill Site: Development and Application of a Holistic Approach, AIDIC, vol. 35, 2013. URL : https://cutt.ly/lQnw3D8

Local incentive mechanisms to develop

Appropriate communication on the medium and long-term benefits of the project, as intangible for several decades

Involve the authorities at the landfill design stage in the possible transformation of the site at the end of its operation

Maintain the memory of the site and the associated risks (long-term pollution) *via* the developments, regulatory documents and awareness-raising among local people

Monitoring indicators

Regular analysis of groundwater and surface water

Annual monitoring of nutrient deficiencies of vegetation and of invasive species; wealth and diversity of species

Effectiveness of landscape reintegration through the increase in the property value of the surrounding housing

Design and context

Technical elements for the base cover of the landfill (See Technical Appendix n° 120)

Criteria for the creation of substrate conducive to greening (See Technical Appendix n° 121)

Flexible varieties of plant species for greening (See Technical Appendix n° 122)

2.7. Biodiversity mainstreaming in urban projects: inspiring feedback

FEEDBACK SHEETS

- *COLOMBIA*
  Barranquilla Development Plan 2020-2023
  "Soy Biodiverciudad": Promoting the ecological resilience of the Caribbean city
- *TOGO*
  Lomé Urban Environment Project (PEUL) - Phase II
  Development of the Aképé Landfill
- *INDIA*
  Smart Cities Program - CITIIS I
  Agartala Smart City Program: Restoration of the banks of the Haora River
- *BRAZIL*
  Curitiba Sustainable Urban Development Program
  Environmental recovery of the banks of the Barigüi River
- *MOROCCO*
  New Cities Program in Morocco
  Creation of the Zenata Eco-city: A new sustainable city model
- *BENIN*
  Porto-Novo, Green City (PNVV)
  Development and protection of the banks of the lagoon

Colombia

Brazil

Togo

Morocco

India

Benin

FEEDBACK SHEET

COLOMBIA, Barranquilla
Tropical climate

GENERAL INFORMATION

Sectors: sustainable cities, risk management

Financing tool: budget support loan (PrPP) with triggers and results matrix

Amount: €120 million

Beneficiaries: Municipality of Barranquilla

Allocation: November 2020

Project status: ongoing

PROJECT TIMELINE

April 2020
Publication of the Barranquilla Development Plan

May 2021
Signing of AFD financing agreement

2022
Objective of creating 50% of the eco-park

"Soy Biodiverciudad": Promoting the Ecological Resilience of the Caribbean City

GENERAL PROJECT CONTEXT

The fourth most populous city in Colombia, Barranquilla is located in the north of the country, at the mouth of the Magdalena River near the Caribbean Sea. Its hydrographical situation gives it **rich ecosystems (lagoons, mangrove swamps, deltas) which are today subject to risks of flooding, landslides and pollution through the development of backfill and illegal constructions.** While climate change exacerbates these phenomena (rising sea levels, erosion, urban heat islands), the Barranquilla Development Plan 2020-2023, which is led by the local authority, has a strategic focus on objectives for sustainable urban development and environmental protection and risk management.

This focus area is called Soy Biodiverciudad ("I am biodivercity") and provides for the creation of the eco-park at the Mallorquín lagoon, the main seafront in Barranquilla. The objective is to regulate the use of the lagoon area and limit the dangers of contamination related to industrial activities, while allowing the population to reappropriate the area. Similarly, it is planned to create and preserve an urban forest in the west of the city, in order to control urban sprawl and foster urban cooling, by making it a public green space. Based on annual investment and public policy objectives, this financing depends on a matrix of triggers, associated with actions and results.

POSITIVE ACTIONS FOR BIODIVERSITY

Environmental restoration of the Mallorquin lagoon and its mangroves

Under the project management of Barranquilla Verde, **the Plan to Recover and Clean Up the Mallorquín Lagoon and its 30 ha of mangroves and dry forest ecosystem** (out of 5.5 ha currently) should restore the functionality of the coastal ecosystem. The objective is to ensure the quality of the water and air and the city's resilience to risks of submersion and erosion. The objectives of the results matrix include **13,000 new mangrove seedlings a year (average from 2020 to 2022) and the classification of the lagoon as a protected area in the Colombian National Registry by 2022, combined with a management plan.**

A feasibility study was conducted on this site in 2020 for **the creation of an eco-park** in the lagoon area, mainly for recreational and educational purposes. The development plans are based on **soft infrastructure,** mainly above ground and floating, to ensure the reversibility of the constructions and minimize their footprint.

To address a hydrological imbalance in the bodies of water, sedimentation studies have identified the mechanisms and species responsible for the modification of the hydraulic dynamics. In the short term, **the implementation of biotreatment solutions should restore the sedimentary process and maintain populations of shellfish and fish,** whose habitats are affected by excess sedimentation. In the long term, the control of water quality and prevention will be coordinated with a **parallel project for the management of the city's wastewater and waste.**

A Center for Wildlife Surveillance and Development will be set up and comprise a team of specialized veterinarians. It will assist with the monitoring and integrated management of wild biodiversity and the ecosystem services rendered.

FEEDBACK SHEET

COLOMBIA, Barranquilla
Tropical climate

GENERAL INFORMATION

Sectors: sustainable cities, risk management

Financing tool: budget support loan (PrPP) with triggers and results matrix

Amount: €120 million

Beneficiaries: Municipality of Barranquilla

Allocation: November 2020

Project status: ongoing

Planting an urban forest: the Bosque Urbano de Miramar (BUM)

Covering a surface area of 33 ha, including 2.1 ha which will be developed, **the project to plant the Miramar urban forest** aims to give Barranquilla a new public green space. There were very few such spaces until now. There are many expected benefits: **natural buffer effect against noise pollution, reduction of urban heat islands, creation of habitats for local flora and fauna** (such as the semipalmated sandpiper, which migrates in the region every year) and an **improvement in air quality,** with an estimated 2,500 tons of CO_2 captured per year.

For this development, the objectives associated with the financing triggers set **the number of trees to plant at an average of 7,500 per year between 2020 and 2022.**

PARTNERS	
Contracting authority	Municipality of Barranquilla
Implementing agencies	Barranquilla Verde (public environmental institution) Agencia Distrital de Infraestructura (ADI)
ESTIMATED COSTS	
Environmental restoration of the Mallorquín lagoon area	
Creation of the eco-park	€19.5 million
Biological restoration of the quality of the bodies of water and mangroves	€325,000 a year until functional wastewater treatment is restored in the city
Bosque Urbano de Miramar (BUM)	
Total estimated cost of the development, including Urban and Landscape Planning (paths, tree planting, accessibility, irrigation system)	€6.4 million €2.01 million

MIRAMAR URBAN FOREST PLAN

FEEDBACK SHEET

TOGO, Lomé
Tropical monsoon climate

GENERAL INFORMATION ON PEUL

Sectors: urban development and sanitation – solid waste management

Financing tool:
PEUL 1: €8 million AFD grant, €3 million of EU co-financing and €3 million by BOAD
PEUL 2: co-financing by €10 million of grants from the EU and AFD, €9.15 million concessional loan from BOAD, FCFA 2 million of self-financing by the Municipality of Lomé
PEUL 3: €14 million AFD grant
PEUL 4: provisional €15 million AFD grant

TIMELINE OF PEUL

2007-2013 PEUL 1
2012-2018 PEUL 2
2019-2023 PEUL 3
2022 PEUL 4

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Lomé Urban Environment Project (PEUL) Phase II

Development of the Aképé Landfill

GENERAL PROJECT CONTEXT

While the population of the city of Greater Lomé is expected to count some 2.5 million urban dwellers by 2025, the project to strengthen public services and restructure the waste sector, which was launched in 2006, aims to **improve living conditions for residents from both a health and environmental perspective.**

The Lomé Urban Environment Project (PEUL) is based on four complementary phases, during which AFD is helping improve the technical, financial and institutional competences of the city in order to scale up solid waste management practices.

Phases 1 and 2 of PEUL involved reorganizing the urban waste collection and pre-collection sectors and **developing a new landfill in Aképé,** on the outskirts of Lomé (194 ha, including 80 ha currently in operation).

PEUL 3 follows on from these first phases. Its financing agreement was signed in 2019 and it aims to **environmentally and socially secure then rehabilitate the site of the former landfill in Agoè-Nyivé,** while continuing to assist the local authority with waste management.

A fourth phase, which is under appraisal, will also plan **the extension of the landfill**, based on lessons learned from the operation of existing cells, as well as the establishment of a Master Plan for waste collection and management in the District.

POSITIVE ACTIONS FOR BIODIVERSITY

Leachate treatment through a plant-based filtration basin

At the Aképé landfill, water from percolation in the mass of waste (or leachate) is captured through a gravity drainage system placed under the storage cells.

The leachate is transferred to the treatment plant to the south of the site and is initially treated by a lagoon equipped with aeration pumps (2,000 m³), which degrades the organic pollution and nitrogen through oxygenation.

A settling pond subsequently stores and homogenizes the raw leachate, while treating a fraction of the biomass produced in the aerated lagoon. Finally, **eight filtration basins with a vertical and horizontal flow, planted with reeds,** eliminate the suspended matter.

The lagoon basin is equipped with a geomembrane to ensure it is watertight. It uses the **purification properties of the reeds** to reduce the pollutant load of the leachate, prior to its discharge into the natural environment. At the same time, the lagoon also plays **a role in managing stormwater,** through its retention then infiltration into the soil. The choice of lagoon leachate treatment, which is based on a natural process, has enabled **savings on the installation and management costs.**

FEEDBACK SHEET

TOGO, Lomé
Tropical monsoon climate

FOCUS ON THE LANDFILL COMPONENT OF PEUL 2

Beneficiaries: Greater Lomé Autonomous District (DAGL), formerly Municipality of Lomé

Management of the landfill: Technical services of DAGL

TIMELINE OF PEUL 2

August 2011 Signing of financing agreement
April 2017 Start of the landfill construction works
Jan. 2018 Start of the landfill construction works

TECHNICAL AND OPERATIONAL ASPECTS OF THE LANDFILL

PARTNERS	
Contracting authority	Greater Lomé Autonomous District (DAGL)
Implementing agencies and technical assistance	ANTEA Group
COSTS	
Works	€17.5 million
Operation for 5 years	€11 million
Planting of reeds in the treatment basins	About €2,980

LESSONS LEARNED & AREAS FOR IMPROVEMENT

Optimization of the leachate treatment system to ensure its sustainability

It has been found that the **reed seedlings in the lagoons tended to die from asphyxiation.** There are many reasons for the degradation. They affect each other and need to be anticipated:

- Droughts lead to a **variation in the water supply of the lagoons.**
- The humidity of the buried waste fosters the production of concentrated leachate, which consequently has a higher pollutant load.
- The capacity of the aeration pumps in the first leachate circulation basin does not appear to be sufficiently adapted to the quantity and concentration of the effluent.

▸ The feasibility study for the fourth phase of PEUL, which is currently being conducted by SAFEGE-Suez Consulting with financing from CICLIA, is assessing the filtration potential of the lagoons, their adaptation to the size of the landfill and its extension, and is **considering the possibility of redeveloping the lagoon system.**

Spontaneous creation of a rainwater reservoir

During the landfill construction works, the extraction of clay soils led to the spontaneous creation of a water reservoir, through the accumulation of rainwater. This water network has turned out to be very useful in the event of fires in the mass of waste.

Colonization of the site by about 50 bird species

The many wetland areas on the landfill site, both intentional (lagoon areas) and unintentional (spontaneous water reservoir), have acted as a base for biodiversity by providing a habitat for avifauna. Indeed, **about 50 bird species were identified in Aképé in the spring of 2019.**

▸ To promote this biodiversity, PEUL 3 plans to **create an educational and ecotourism trail open to the public,** respecting safety standards with, for example, the creation of **marked trails, educational signs and observation posts.**

FEEDBACK SHEET

INDIA, Agartala
Oceanic climate

GENERAL INFORMATION

Sectors: sustainable urban development

Financing tool: sovereign loan, grants from the European Union and French Government

Amount: €100 million AFD loan, grants of €6 million from the EU and €1 million from France

Beneficiaries: Government of India

Allocation: November 2017

Project status: ongoing

TIMELINE OF PEUL

March 2018
Signing of AFD financing agreement

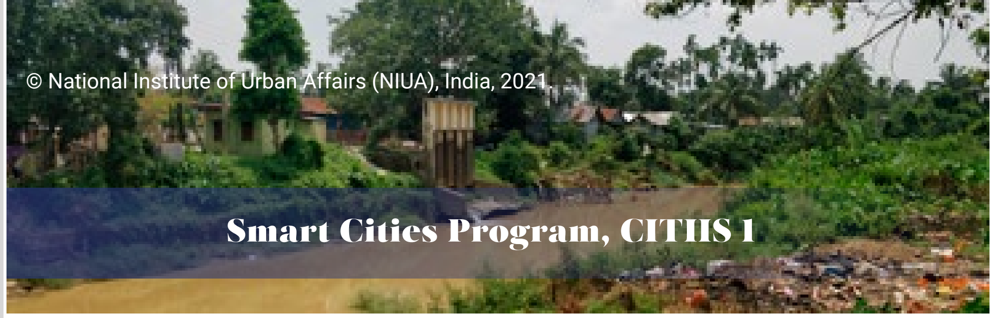
July 2018
Preparation of the launch of the call for projects

Dec. 2018
Selection of projects based on eligibility criteria

Feb. 2020
Maturation phase for the pilot project for organic horticulture in Agartala

By the end of 2021
Provisional start of the works for pilot project I

AFD AGENCE FRANÇAISE DE DÉVELOPPEMENT



Smart Cities Program, CITIIS I

"Agartala Smart City" Project: Restoration of the Banks of the Haora River

GENERAL PROJECT CONTEXT

In July 2018, the Indian Government launched the Smart Cities mission to improve living conditions for residents in 100 cities in the country. It is in this context that AFD is financing, alongside the National Institute of Urban Affairs (NIUA) and Ministry of Housing and Urban Affairs (MoHUA), **the CITIIS (City Investments to Innovate, Integrate and Sustain) program** in the form of a **national call for projects.** Sustainable mobility, public spaces, the digitalization of urban services and social innovation in precarious neighborhoods are among the themes of the program. **12 cities have been selected to benefit from financial and technical assistance** for the preparation and implementation of their sustainable urban development projects. Among the project eligibility criteria, the **contribution to biodiversity and sustainable natural resources management** has been an important consideration. An 18-month project **maturation phase** has improved the technical quality of the project, with the implementation of pilot projects, prior to the start of the **implementation phase** (between 18 and 30 months). The city of Agartala, capital of the State of Tripura in North-East India, has been selected with its project to **restore the banks of the Haora River,** which 60% of the population directly or indirectly depend on for their daily water needs. In a dense and polluted space, the main objectives are to restore the accessibility and attractiveness of the banks for the population, promote the collaborative development of organic farming areas, and increase the river's resilience to floods and risks of erosion.

POSITIVE ACTIONS FOR BIODIVERSITY

Pilot project I: Development of organic horticulture on the banks

While the development plan for the banks of the Haora River provides for several sequences for organic horticulture and floriculture, in early 2020, the city of Agartala launched a pilot project **on a 0.2 ha test site to confirm or refocus the design choices** for the overall project. Topo-graphical and flood modelling studies have made it possible to select the location of the horticultural project, based on its ideal exposure to the **natural resupply of nutrients and water during monsoons.**

With the municipality's heavy dependence on fruit and vegetable imports from the North of the region, **urban horticulture offers economic, ecological, cultural and tourism opportunities.** The horticultural area acts as a **visual interface between the urban fabric and the river,** but also with the population.

From a technical point of view, the horticultural plan provides for a construction on a slope, with the creation of terraces at each level. The objective is to **separate the crops and allow their rotation depending on their need for water and their seasonal relevance,** and maintain a **biannual rhythm to make the place attractive for local people** through public displays on the horticultural land.

The site is highly exposed to erosion and it is planned to secure it by **using reinforcements made of bamboo, a traditional local material,** and a shrub vegetation to help stabilize the soil and limit the risks.

FEEDBACK SHEET

INDIA, Agartala
Humid subtropical climate

PROJECT INFORMATION

Sectors: sustainable urban development, water management

Amount: a total of €11.1 million

Beneficiaries:
Municipality of Agartala

Project status: ongoing

AFD AGENCE FRANÇAISE DE DÉVELOPPEMENT

In situ ecological treatment to depollute the river's Nallah

Nallah are holes naturally formed by rainfall variations during the monsoon season and act as real drainage channels. However, domestic wastewater and the large amount of waste dumped in the Haora River have obstructed the water's self-purification capacity for decades. To optimize the depollution of the river and the costs of the scheme, **an in situ treatment combining phytoremediation and bioremediation** has been selected. The treatment system does not denature the initial structure of the river. It is based on sedimentation through the decantation of solid matter suspended in the water, then on **horizontal biofiltration through which plant roots degrade heavy metals.** Finally, **bacterial bioremediation stabilizes the treated water** and is favored by the supply of oxygen.

The process to depollute the river is based on natural mechanisms. It does not require any additional infrastructure and consumes very little energy.

PARTNERS	
Contracting authority	Municipality of Agartala
Implementing agencies	Tata Consulting Engineering Limited
COSTS	
• Horticulture (pilot project I) • CAPEX • OPEX and maintenance per year	€57,941 €56,183 €1,758
• In situ ecological treatment of wastewater by the Nallah (pilot project II) • CAPEX • OPEX and maintenance per year • Units cost of Nallah drains	€200,680 €133,785 €66,895 €988
BENEFITS	
Estimations of net profit generated by the project during the first 5 years (income/expenditure ratio), *including* estimations of the annual income generated by horticulture (based on pilot project I)	€189,815 (16.69 lakh) €63,600 (5.66 lakh)

PROJECT MASTER PLAN

FEEDBACK SHEET

BRAZIL, Curitiba
Oceanic climate

GENERAL INFORMATION

Sectors: sustainable cities, mobility and transport, biodiversity, climate

Financing tool: sovereign loan

Amount: €72.3 million (50% AFD loan and 50% Municipality of Curitiba), including €18.4 million for the Barigüi Linear Park component

Beneficiaries: Municipality of Curitiba

Allocation: December 2017

Project status: linear parks completed, public transport component ongoing

PROJECT TIMELINE

- *July 2011* Project start-up
- *March 2014* Opening of Guairacá Park (zone n° 1)
- *Sept. 2014* Opening of Mané Garrincha Park (zone n° 2)
- *June 2016* Opening of Cambuí Park (zone n° 3)
- *2018* Opening of Yberê Park (zone n° 4)

Environmental Recovery of the Banks of the Barigüi River

GENERAL PROJECT CONTEXT

Curitiba is the capital of Paraná State in the south of Brazil and has been one of the pioneering cities for sustainable development since the 1970s. Located in the Atlantic Forest, one of the world's 34 biodiversity hotspots, its wealth of flora and fauna is threatened by human activities and climate change. Aware of its plant heritage, for which the araucaria has become the symbol, the city has adopted a **proactive policy to mainstream biodiversity into its urban projects.** In this dynamic, since 2007, AFD has been helping the local authority **further its sustainable development policy** via a program with two components. Firstly, the program involves the extension of the municipality's public transport network with the development of a sixth Bus Rapid Transit line (BRT - Linhea Verde) covering 22 km. Secondly, **the recovery of the banks and natural spaces along the Barigüi River** which crosses the city over an area of 45 km. This second component is based on a green and blue corridor urban approach providing both ecological services and human uses. **The creation of four sequences of linear park** aims to **preserve the hydrographic and drainage system** and native flora and fauna, while offering recreational spaces to residents. At the same time, a rehousing plan has been implemented for 631 families living informally in flood-prone areas.

POSITIVE ACTIONS FOR BIODIVERSITY

Development of the Rio Barigüi Linear Park

The project to develop the Barigüi Linear Park, which is subdivided into three main sections from the north to the south, with a total length of 13.8 km, comprises the creation of four green spaces: Guairacá Park (140,000 m²), Mané Garrincha Park (120,000 m²), Cambuí Park (43,000 m²) and Yberê Park (238,000 m², including 86,500 m² for operations).
The design choices for these green spaces are based on the commitment to **restore the river's ecological functionalities.** Using local plant species, **the revegetation of the banks has stabilized the soils in order to control risks of erosion.** Rather than taking a defensive position, the sites have been designed to allow the submersion of certain areas of the riverbed, which are highly exposed to flooding during periods of rainfall or high water. **The development of this risk culture** is reflected in the landscape elements and equipment, which can voluntarily be flooded, and the choice of submersible street furniture and materials.
As an extension to the river, retention basins integrated into the landscape provide **a rainwater harvesting and drainage system,** while supplying natural wetlands, which are reservoirs for flora and fauna. Combined with the restoration of the riparian vegetation, *i.e.* the vegetation adjacent to the river, these wetlands **control the concentration of heat** through the direct and indirect evaporation of water and the shade.
Cambuí Park has been developed to create **a direct ecological connection with the riparian forest of Fazendinha.** This corridor allows species to move between urban and periurban areas.
These urban parks also have a **strong social and well-being function,** by offering people **cool and shaded spaces, suitable for a variety of sports and family activities,** or simply for contemplation. They are also easy to visit through the continuous linear paths for soft modes and the reflection on the management and safety of the parks.

FEEDBACK SHEET

BRAZIL, Curitiba
Oceanic climate

GENERAL INFORMATION

Sectors: sustainable cities, mobility and transport, biodiversity, climate

Financing tool: sovereign loan

Amount: €72.3 million (50% AFD loan and 50% Municipality of Curitiba), including €18.4 million for the Barigüi linear park component

Beneficiaries: Municipality of Curitiba

Allocation: December 2007

Project status: linear parks completed, public transport component ongoing

Structuring of the urban development policy integrating biodiversity issues

In addition, **an extensive environmental awareness-raising program, "Olho d'Agua",** has been conducted among residents and schools. Finally, between 2015 and 2017, the city carried out **a Water Depollution Program (WDP)** in order to **measure the water quality and identify the sources of pollution** in the Rio Barigüi watershed. The Water Resources Department of the Municipal Secretariat of the Environment was thus able to deploy connection campaigns for sanitary wastewater, verify their effects on water quality and identify the negative points that still need to be addressed.
The actions financed are more generally part of **the long-term dynamic of the "Viva Barigüi" program** launched in 2007 **to strengthen the ecological diversity and hydrological quality of the watershed** which irrigates Curitiba and its suburbs.
AFD has been assisting the Municipality with the South Barigüi sequence since 2020, in the "Caximba" working-class neighborhood, which is affected by floods. The project is pursuing the objectives of ecological continuities and is organized based on a large submersible park covering the flood plain of the river (free of informal constructions) and the construction of new housing and facilities in the upper part of the neighborhood. This is allowing residents to stay on the site and is ensuring their safety.

PARTNERS	
Contracting authority	Municipality of Curitiba Secretariat of the Environment (SMMA)
Implementing agencies – recovery of the river banks	IPPUC (Institute for Research and Planning of Curitiba)
COSTS	
Development of the Rio Barigüi Linear Park (total €18.4 million, including 50% AFD)	
Works	€12.96 million
Studies and supervision	€3.61 million
Land and rehousing	€1.026 billion
"Olho d'Agua" participatory environmental program and WDP	€820,000 *incl.* €340,000 "Olho d'Agua" *incl.* €480,000 WDP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FEEDBACK SHEET

MOROCCO, Zenata
Mediterranean climate

GENERAL INFORMATION

Sectors: sustainable cities, climate

Financing tool: non-sovereign loan

Amount: €150 million by AFD, co-financing by the European Investment Bank (EIB) and €4.3 million European Union grant

Beneficiaries: Zenata Development Company (SAZ)

Allocation: March 2013

Project status: ongoing

PROJECT TIMELINE

June 2015
Signing of AFD financing agreement

2016-2017
Development works on the retention basins and coastal area

Creation of the Zenata Eco-City: a New Sustainable City Model

GENERAL PROJECT CONTEXT

In its National Territorial Development Plan (SNAT) established in 2000, Morocco stated its ambition of creating 12 new cities by 2020 as part of its sustainable urban development. The project for the new city of Zenata is located between Casablanca and Rabat in the north-east of Morocco. It aims to promote the integrated and controlled urban development of Greater Casablanca, which has been under demographic pressure for several decades. The region is faced with new urban issues, with spatial and socioeconomic imbalances resulting in a major lack of housing, services and facilities for the middle classes. The eco-city project has been planned in several phases over a 30-year period and aims to offer these emerging classes a quality living environment and services for health, education, employment and leisure activities. With a 5 km-long coastline, the city's coastal areas will be protected and not built on.

This new urban center covers an area of 1,860 ha and has been devised using an ecodesign approach, as it aims to limit its impacts on the environment throughout its life cycle. The project is labelled Ecocity and has led to the creation of a reference base for urban action.

The initial land reserves are made up of both private and public properties occupied by makeshift homes, sheds and informal warehouses. The project firstly includes a rehousing plan for the families concerned and, secondly, the integration of some of them in the planned residential lots.

POSITIVE ACTIONS FOR BIODIVERSITY

Bioclimatic design and optimization of natural resources

The urban programming of Zenata has been devised to create a bioclimatic city and is based on **optimizing natural resources,** particularly air. Airflow studies on natural ventilation have been conducted in the various urban areas to guide the choices for the development of the urban fabric. Consequently, based on Morocco's specific climate characteristics, **a diagonal air corridor will effectively cool the city by creating cool areas.** The natural aeration of the city, mainly by sea winds, should **regulate the humidity in winter and the temperature should decrease by 2 to 3 degrees in summer.** Based on a multi-scale approach, both in the city and in the residential blocks, the orientation of the future structures built has been decided according to the topography of the site and the network of green spaces. The **14 "living units" built are therefore structured by 470 ha of green spaces and contribute to urban cooling.**

The choice of bioclimatic architecture uses low-tech and eco-friendly urban design methods, based on the natural functioning of ecosystems, and reduces human impacts on the environment.

FEEDBACK SHEET

MOROCCO, Zenata
Mediterranean climate

GENERAL INFORMATION

Sectors: sustainable cities, climate

Financing tool:
non-sovereign loan

Amount: €150 million by AFD, co-financing by the European Investment Bank (EIB) and €4.3 million European Union grant

Beneficiaries: Zenata Development Company (SAZ)

Allocation: March 2013

Project status: ongoing

Development of the coast and integrated water management

In November 2019, the engineering firm SETEC Maroc/SETEC HYDRATEC conducted **an analysis of the hydro-sedimentary functioning and a modelling of the risks of submersions and erosion,** in order to define the protection plan for the dune ridge in Zenata. The understanding of the dynamics of the coast led to a programming of retention basins to a**ct as a "buffer" between the sea and the urban environment.** The stormwater drainage function of these wetlands is structured at both the level of the plots and the city. It is made possible by **using the natural slope of the site for gravity drainage to the ocean and groundwater recharge through the infiltration capacities of the soil.**

The developments to protect the dune ridge will use endemic halophytic species adapted to the environment to **help stabilize and restructure the dunes.**

PARTNERS	
Urban planning firm – air corridor	Reichen & Robert
Contracting authority – design and overall development of the eco-city	Zenata Development Company (SAZ) Ad hoc subsidiary of the Caisse de Dépôt et de Gestion (CDG)
Engineering firm – hydro-sedimentary studies on the dune ridge	SETEC Maroc – SETEC HYDRATEC
ESTIMATED COSTS	
Estimation of the overall project investment cost	€725 million
Estimation of the cost for the development of the dune area	€4.63 million

URBAN PROGRAMMING AND MICRO-CLIMATES IN ZENATA

© Zenata Development Company (SAZ).

FEEDBACK SHEET

BENIN, Porto-Novo
Temperate equatorial climate

GENERAL INFORMATION

Sectors: sustainable cities, climate

Financing tool: grant

Amount: €8 million by AFD, €1.2 million by FFEM, €0.3 million of technical assistance from Greater Lyon and the Urban Community of Cergy Pontoise

Beneficiaries: Municipality of Porto-Novo

Allocation: 2013 for FFEM, 2015 for AFD

Project status: ongoing

PROJECT TIMELINE

Dec. 2015
Signing of AFD financing agreement

July 2019 - Feb. 2021
Vulnerability study on the eligible territory

Nov. 2022
Estimated reception of the development works on the promenade

Development and Protection of the Banks of the Lagoon

GENERAL PROJECT CONTEXT

The administrative capital of Benin, Porto-Novo is located on the coastal strip in the south-east of the country and is made up of a number of natural areas and wetlands. The city has been experiencing uncontrolled spatial development in urban and periurban areas for several years, in a context of weak economic growth. Urban sprawl and the creation of vulnerable informal settlements in lagoon areas expose ecosystems to strong anthropogenic pressure, leading to coastal erosion and increased flood risks during seasons with heavy rain. The "Porto-Novo, Green City" (PNVV) project, which is jointly led by AFD and FFEM, aims to **support the design of a sustainable urban development strategy for the territory,** address the issues of climate change adaptation by **preserving the lagoon area classified RAMSAR,** and promote sustainable income-generating activities for local operators (organic agriculture, fish farming, market gardening).

POSITIVE ACTIONS FOR BIODIVERSITY

Integrating ecosystems in the preparation of the city of Porto-Novo's Sustainable Urban Development Plan

Based on a structural approach, one of the project's main objectives is to **define the strategic directions for the sustainable development** of Porto-Novo for 2035, in particular **with regard to the specific nature of its ecosystems.** To do so, the vulnerability study on the territory at the level of the city, which was conducted between 2019 and 2021 by the SGI-Expertise Plurielle Group, is the reference document for the **integration of the biological balance of wetlands and natural areas, with extremely vulnerable biotopes, into the urban planning tools.** It mainly involves hydrological and hydraulic modelling, combined with a mapping of flood-prone areas, which will serve as a basis to strengthen what already exists and guide the recommendations for the city's long-term spatial development, depending on the sensitive areas identified.

Development of the "Cent Pas" pedestrian promenade along the east bank of the lagoon

The east bank of the lagoon is located on the edge of the Porto-Novo plateau and is the focus of **a project to develop a 19 km-long promenade.** Only a few sections will be subject to works in the context of this financing. In consultation with the populations concerned, preliminary design studies (PDS) will make it possible to decide which sections to give priority to.

The enhancement of the lagoon landscape through **tree planting and the development of community uses and recreational spaces** is part of an approach to reconcile residents with this remarkable ecosystem. It also aims to **limit the urbanization of this sensitive area.** An educational trail will raise awareness of the wealth of this lagoon heritage and its positive impacts on the quality of life of the population.

In addition to its socioecological base, the project offers **design choices which aim to strengthen and respect what already exists.** Among these choices, **the simple nature of the developments and local materials used,** as well as **the notion of the reversibility of the spaces developed on the environments** (installations raised on stilts), guide the project implementation. The planting of the banks with **targeted and local plant species** will play a key role as a buffer for the delimitation of non-build zones and in stormwater management through swales and ditches.

FEEDBACK SHEET

BENIN, Porto-Novo
Temperate equatorial climate

GENERAL INFORMATION

Sectors: sustainable cities, climate

Financing tool: grant

Amount: €8 million by AFD, €1.2 million by FFEM, €0.3 million of technical assistance from Greater Lyon and the Urban Community of Cergy Pontoise

Beneficiaries: Municipality of Porto-Novo

Allocation: 2013 for FFEM, 2015 for AFD

Project status: ongoing

PARTNERS	
Contracting authority	Project Management Unit (PMU) of the Municipality of Porto-Novo
Social and environmental implementing agency	Urbaconsulting
Implementing agency – Territorial planning	Urbaplan – Transitec – Studio 2AP Group
Implementing agency – Development of the promenade	URAM International
COSTS	
Preparation of the sustainable territorial development strategy	
Vulnerability study on the territory at the level of the city	€570,000
Environmental and anthropological study	€140,000
including sociological representations and an inventory of wetland biodiversity	€100,000
Preservation and enhancement of the lagoon area	
Development of the promenade along the banks	€1.6 million
Training and adaptation measures for integrated organic production	€30,000

MAP OF THE PROJECT SELECTED: "THE CONNECTED PROMENADE"

Appendix

©AFD, Cyril le Tourneur d'Ison, Manjakaray neighborhood, Madagascar, 2016.

Appendix 1: Extract from AFD Group's Exclusion List for biodiversity

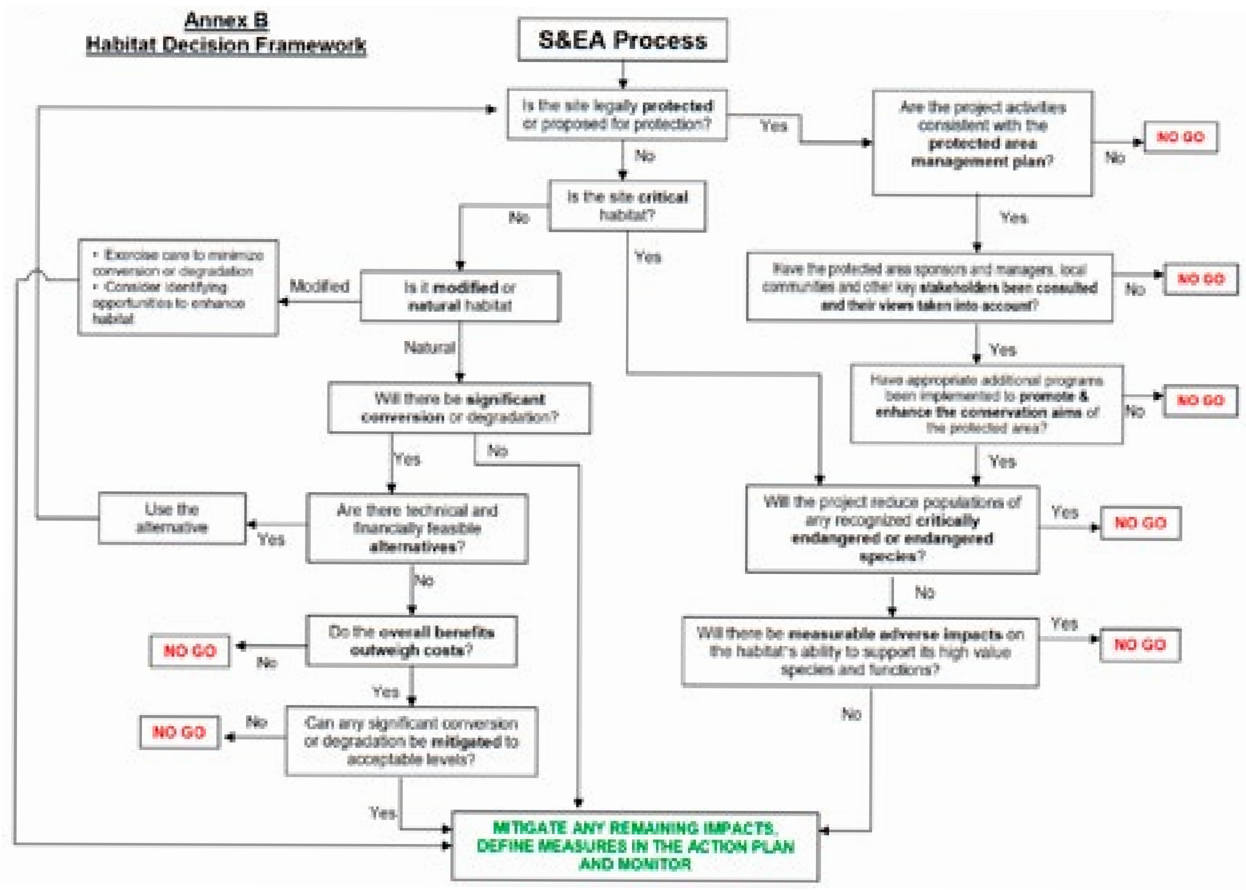
In foreign countries, AFD's Corporate Social Responsibility Plan (applicable to Proparco) states that AFD may not appraise projects that cause a net loss of biodiversity in critical habitats. These habitats are defined as follows:

- Spaces with high biodiversity value.
- Spaces with a particular importance for endemic species or whose geographical range is limited.
- Critical sites for the survival of migratory species.
- Spaces welcoming a significant number of individuals from congregatory species.
- Spaces presenting unique assemblages of species or containing species which are associated according to key evolution processes or which fulfil key ecosystem services.
- Territories with socially, economically or culturally significant biodiversity for local communities. Primary forests or high conservation value forests must also be considered as critical habitats.
- It is also impossible to finance the production or use of pesticides and herbicides.

The International Finance Corporation, an arm of the World Bank, has developed a diagram to establish the type of activities that cannot be financed by organizations that follow its guidelines.

Decision framework relating to habitats included in Recommendation 6 which accompanies Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources

© International Finance Corporation (IFC), ***Guidance Notes: Performance Standards on Environmental and Social Sustainability,*** 1 January 2012, World Bank Group. URL: https://cutt.ly/qQeBxpS



Appendix 2: Databases and online resources

Level	Resources	URL	Comments
PROTECTED AREAS	International Union for the Conservation of Nature and United Nations Environment Programme	www.protectedplanet.net	Extensive database on terrestrial and marine protected areas
	United Nations Educational, Scientific and Cultural Organization (UNESCO) List of World Heritage sites	https://whc.unesco.org/en/list/	UNESCO World Heritage Sites
	World Network of Biosphere Reserves	www.unesco.org/new/en/natural-sciences/	www.unesco.org/new/en/naturalsciences/
	The Ramsar Convention on Wetlands	www.ramsar.org	Wetlands on the RAMSAR list
	Association for Southeast Asian Nations Heritage Parks	https://environment.asean.org/awgncb/	Areas of particular importance for biodiversity for Member States of the Association for Southeast Asian Nations
	Natura 2000 Sites	https://ec.europa.eu/environment/nature/natura2000/index_en.htm	European network of areas protected by the 1992 Habitats Directive and 1979 Birds Directive
	Protected Areas Data	https://maps.usgs.gov/padus/	Inventory of protected areas in the USA
SENSITIVE AREAS FOR BIODIVERSITY	Endemic birds	https://www.ibat-alliance.org/	Spatial data on diverse critical habitats
	Important areas for birds		Conservation status of species
	Key areas for biodiversity		Conservation status of species and habitats in North, Central and South America
	Alliance for Zero Extinction		Free data on the specific distribution
	Biodiversity hotspots		Specific plant distribution in America and Oceania
	Large unspoilt landscapes		Vegetation from all over the world allowing the study of habitats
DISTRIBUTION OF SPECIES	IUCN list of endangered species	www.iucnredlist.org	Database on fish
	NatureServe conservation database of species and ecosystems	www.natureserve.org	Online tools for ecosystem assessments
	Global Biodiversity Information Biodiversity Data Facility	www.gbif.org	Technical tool for the in situ assessment of ecosystem services
	The Botanical Information and Ecology Network	https://biendata.org/	Specific plant distribution in America and Oceania
	Spatial Analysis of Local Vegetation Inventories Across Scales	www.salvias.net/pages/	Vegetation from all over the world allowing the study of habitats
	A Global Information System on Fishes	www.fishbase.org	Database on fish
ECOSYSTEM SERVICE	Artificial Intelligence for Ecosystem Services	www.ariesonline.org	Online tools for ecosystem assessments
	Toolkit for Ecosystem Service Site-based Assessment	www.aries.integratedmodelling.org/	Technical tool for the in situ assessment of ecosystem services

Appendix 3: Signatory countries to the Convention on Biological Diversity of Rio de Janeiro (CBD, 5 June 1992)

Country	Signature	Ratification, Adhesion(a), Acceptance(A), Approval(AA), Succession(d)
AFGHANISTAN	12 June 1992	19 Sept. 2002
ALBANIA		5 Jan. 1994 a
ALGERIA	13 June 1992	14 Aug. 1995
ANDORRA		4 Feb. 2015 a
ANGOLA	12 June 1992	1 April 1998
ANTIGUA AND BARBUDA	5 June 1992	9 March 1993
ARGENTINA	12 June 1992	22 Nov. 1994
ARMENIA	13 June 1992	14 May 1993 A
AUSTRALIA	5 June 1992	18 June 1993
AUSTRIA	13 June 1992	18 Aug. 1994
AZERBAIJAN	12 June 1992	3 Aug. 2000 AA
BAHAMAS	12 June 1992	2 Sept. 1993
BAHRAIN	9 June 1992	30 Aug. 1996
BANGLADESH	5 June 1992	3 May 1994
BARBADOS	12 June 1992	10 Dec. 1993
BELARUS	11 June 1992	8 Sept. 1993
BELGIUM	5 June 1992	22 Nov. 1996
BELIZE	13 June 1992	30 Dec. 1993
BENIN	13 June 1992	30 June 1994
BHUTAN	11 June 1992	25 Aug. 1995
BOLIVIA (PLURINATIONAL STATE OF)	13 June 1992	3 Oct. 1994
BOSNIA AND HERZEGOVINA		26 Aug. 2002 a
BOTSWANA	8 June 1992	12 Oct. 1995
BRAZIL	5 June 1992	28 Feb. 1994
BRUNEI DARUSSALAM		28 April 2008 a
BULGARIA	12 June 1992	17 April 1996
BURKINA FASO	12 June 1992	2 Sept. 1993
BURUNDI	11 June 1992	15 April 1997
CABO VERDE	12 June 1992	29 March 1995
CAMBODIA		9 Feb. 1995 a
CAMEROON	14 June 1992	19 Oct. 1994
CANADA	11 June 1992	4 Dec. 1992
CENTRAL AFRICAN REPUBLIC	13 June 1992	15 March 1995
CHAD	12 June 1992	7 June 1994

Country	Signature	Ratification, Adhesion(a), Acceptance(A), Approval(AA), Succession(d)
CHILE	13 June 1992	9 Sept. 1994
CHINA	11 June 1992	5 Jan. 1993
COLOMBIA	12 June 1992	28 Nov. 1994
COMOROS	11 June 1992	29 Sept. 1994
CONGO	11 June 1992	1 Aug. 1996
COOK ISLANDS	12 June 1992	20 April 1993
COSTA RICA	13 June 1992	26 Aug. 1994
CÔTE D'IVOIRE	10 June 1992	29 Nov. 1994
CROATIA	11 June 1992	7 Oct. 1996
CUBA	12 June 1992	8 March 1994
CYPRUS	12 June 1992	10 July 1996
CZECH REPUBLIC	4 June 1993	3 Dec. 1993 AA
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA	11 June 1992	26 Oct. 1994 AA
DEMOCRATIC REPUBLIC OF CONGO	11 June 1992	3 Dec. 1994
DENMARK	12 June 1992	21 Dec. 1993
DJIBOUTI	13 June 1992	1 Sept. 1994
DOMINICA		6 April 1994 a
DOMINICAN REPUBLIC	13 June 1992	25 Nov. 1996
ECUADOR	9 June 1992	23 Feb. 1993
EGYPT	9 June 1992	2 June 1994
EL SALVADOR	13 June 1992	8 Sept. 1994
EQUATORIAL GUINEA		6 Dec. 1994 a
ERITREA		21 March 1996 a
ESTONIA	12 June 1992	27 July 1994
ESWATINI	12 June 1992	9 Nov. 1994
ETHIOPIA	10 June 1992	5 April 1994
EUROPEAN UNION	13 June 1992	21 Dec. 1993 AA
FIJI	9 Oct. 1992	25 Feb. 1993
FINLAND	5 June 1992	27 July 1994 A
FRANCE	13 June 1992	1 July 1994
GABON	12 June 1992	14 March 1997
GAMBIA	12 June 1992	10 June 1994
GEORGIA		2 June 1994 a

Appendix 3: Signatory countries to the Convention on Biological Diversity of Rio de Janeiro (CBD, 5 June 1992)

Country	Signature	Ratification, Adhesion(a), Acceptance(A), Approval(AA), Succession(d)
GERMANY	12 June 1992	21 Dec. 1993
GHANA	12 June 1992	29 Aug. 1994
GRANADA	3 Dec. 1992	11 Aug. 1994
GREECE	12 June 1992	4 Aug. 1994
GUATEMALA	13 June 1992	10 July 1995
GUIANA	13 June 1992	29 Aug. 1994
GUINEA	12 June 1992	7 May 1993
GUINEA-BISSAU	12 June 1992	27 Oct. 1995
HAITI	13 June 1992	25 Sept. 1996
HONDURAS	13 June 1992	31 July 1995
HUNGARY	13 June 1992	24 Feb. 1994
ICELAND	10 June 1992	12 Sept. 1994
INDIA	5 June 1992	18 Feb. 1994
INDONESIA	5 June 1992	23 Aug. 1994
IRAN (ISLAMIC REPUBLIC OF)	14 June 1992	6 Aug. 1996
IRAQ		28 July 2009 a
IRELAND	13 June 1992	22 March 1996
ISRAEL	11 June 1992	7 Aug. 1995
ITALY	5 June 1992	15 April 1994
JAMAICA	11 June 1992	6 Jan. 1995
JAPAN	13 June 1992	28 May 1993 A
JORDAN	11 June 1992	12 Nov. 1993
KAZAKHSTAN	9 June 1992	6 Sept. 1994
KENYA	11 June 1992	26 July 1994
KIRIBATI		16 Aug. 1994 a
KUWAIT	9 June 1992	2 Aug. 2002
KYRGYZSTAN		6 Aug. 1996 a
LAO PEOPLE'S DEMOCRATIC REPUBLIC		20 Sept. 1996 a
LATVIA	11 June 1992	14 Dec. 1995
LEBANON	12 June 1992	15 Dec. 1994
LESOTHO	11 June 1992	10 Jan. 1995
LIBERIA	12 June 1992	8 Nov. 2000
LIBYA	29 June 1992	12 July 2001
LIECHTENSTEIN	5 June 1992	19 Nov. 1997

Appendix 3: Signatory countries to the Convention on Biological Diversity of Rio de Janeiro (CBD, 5 June 1992)

Country	Signature	Ratification, Adhesion(a), Acceptance(A), Approval(AA), Succession(d)
LITHUANIA	11 June 1992	1 Feb. 1996
LUXEMBOURG	9 June 1992	9 May 1994
MADAGASCAR	8 June 1992	4 March 1996
MALAWI	10 June 1992	2 Feb. 1994
MALAYSIA	12 June 1992	24 June 1994
MALDIVES	12 June 1992	9 Nov. 1992
MALI	30 Sept. 1992	29 March 1995
MALTA	12 June 1992	29 Dec. 2000
MARSHALL	12 June 1992	8 Oct. 1992
MAURITANIA	12 June 1992	16 Aug. 1996
MAURITIUS	10 June 1992	4 Sept. 1992
MEXICO	13 June 1992	11 March 1993
MICRONESIA (FEDERATED STATES OF)	12 June 1992	20 June 1994
MONACO	11 June 1992	20 Nov. 1992
MONGOLIA	12 June 1992	30 Sept. 1993
MONTENEGRO		23 Oct. 2006 d
MOROCCO	13 June 1992	Aug. 1995
MOZAMBIQUE	12 June 1992	25 Aug. 1995
MYANMAR	11 June 1992	25 Nov. 1994
NAMIBIA	12 June 1992	16 May 1997
NAURU	5 June 1992	11 Nov. 1993
NEPAL	12 June 1992	23 Nov. 1993
NETHERLANDS	5 June 1992	12 July 1994 A
NEW ZEALAND	12 June 1992	16 Sept. 1993
NICARAGUA	13 June 1992	20 Nov. 1995
NIGER	11 June 1992	25 July 1995
NIGERIA	13 June 1992	29 Aug. 1994
NIUE		28 Feb. 1996 a
NORTH MACEDONIA		2 Dec. 1997 a
NORWAY	9 June 1992	9 July 1993
OMAN	10 June 1992	8 Feb. 1995
PAKISTAN	5 June 1992	26 July 1994
PALAU		6 Jan. 1999 a
PANAMA	13 June 1992	17 Jan. 1995

Appendix 3: Signatory countries to the Convention on Biological Diversity of Rio de Janeiro (CBD, 5 June 1992)

Country	Signature	Ratification, Adhesion(a), Acceptance(A), Approval(AA), Succession(d)
PAPUA NEW GUINEA	13 June 1992	16 March 1993
PARAGUAY	12 June 1992	24 Feb. 1994
PERU	12 June 1992	7 June 1993
PHILIPPINES	12 June 1992	8 Oct. 1993
POLAND	5 June 1992	18 Jan. 1996
PORTUGAL	13 June 1992	21 Dec. 1993
QATAR	11 June 1992	21 Aug. 1996
REPUBLIC OF KOREA	13 June 1992	3 Oct. 1994
REPUBLIC OF MOLDOVA	5 June 1992	20 Oct. 1995
ROMANIA	5 June 1992	17 Aug. 1994
RUSSIAN FEDERATION	13 June 1992	5 April 1995
RWANDA	10 June 1992	29 May 1996
SAINT KITTS AND NEVIS	12 June 1992	7 Jan. 1993
SAINT VINCENT AND THE GRENADINES		3 June 1996 a
SAINTE LUCIA		28 July 1993 a
SAMOA	12 June 1992	9 Feb. 1994
SAN MARINO	10 June 1992	28 Oct. 1994
SAO TOME AND PRINCIPE	12 June 1992	29 Sept. 1999
SAUDI ARABIA		3 Oct. 2001 a
SENEGAL	13 June 1992	17 Oct. 1994
SIERRA LEONE		12 Dec. 1994 a
SINGAPORE	10 March 1993	21 Dec. 1995
SLOVAKIA	19 May 1993	25 Aug. 1994 AA
SLOVENIA	13 June 1992	9 July 1996
SOLOMON ISLANDS	13 June 1992	3 Oct. 1995
SOMALIA		11 Sept. 2009 a
SOUTH AFRICA	4 June 1993	2 Nov. 1995
SOUTH SUDAN		17 Feb. 2014 a
SPAIN	13 June 1992	21 Dec. 1993
SRI LANKA	10 June 1992	23 March 1994
STATE OF PALESTINE		2 Jan. 2015 a
SUDAN	9 June 1992	30 Oct. 1995
SURINAME	13 June 1992	12 Jan. 1996

Appendix 3: Signatory countries to the Convention on Biological Diversity of Rio de Janeiro (CBD, 5 June 1992)

Country	Signature	Ratification, Adhesion(a), Acceptance(A), Approval(AA), Succession(d)
SWEDEN	8 June 1992	16 Dec. 1993
SWITZERLAND	12 June 1992	21 Nov. 1994
SYRIAN ARAB REPUBLIC	3 May 1993	4 Jan. 1996
TAJIKISTAN		29 Oct. 1997 a
THAILAND	12 June 1992	31 Oct. 2003
TIMOR-LESTE		10 Oct. 2006 a
TOGO	12 June 1992	4 Oct. 1995 A
TONGA		19 May 1998 a
TRINIDAD AND TOBAGO	11 June 1992	1 Aug. 1996
TUNISIA	13 June 1992	15 July 1993
TURKEY	11 June 1992	14 Feb. 1997
TURKMENISTAN		18 Sept. 1996 a
TUVALU	8 June 1992	20 Dec. 2002
UGANDA	12 June 1992	8 Sept. 1993
UKRAINE	11 June 1992	7 Feb. 1995
UNITED ARAB EMIRATES	11 June 1992	10 Feb. 2000
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND	12 June 1992	3 June 1994
UNITED REPUBLIC OF TANZANIA	12 June 1992	8 March 1996
UNITED STATES OF AMERICA	4 June 1993	
URUGUAY	9 June 1992	5 Nov. 1993
UZBEKISTAN		19 July 1995 a
VANUATU	9 June 1992	25 March 1993
VENEZUELA (BOLIVARIAN REPUBLIC OF)	12 June 1992	13 Sept. 1994
VIETNAM	28 May 1993	16 Nov. 1994
YEMEN	12 June 1992	21 Feb. 1996
ZAMBIA	11 June 1992	28 May 1993
ZIMBABWE	12 June 1992	11 Nov. 1994

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Notes

Notes

Towards a World in Common

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