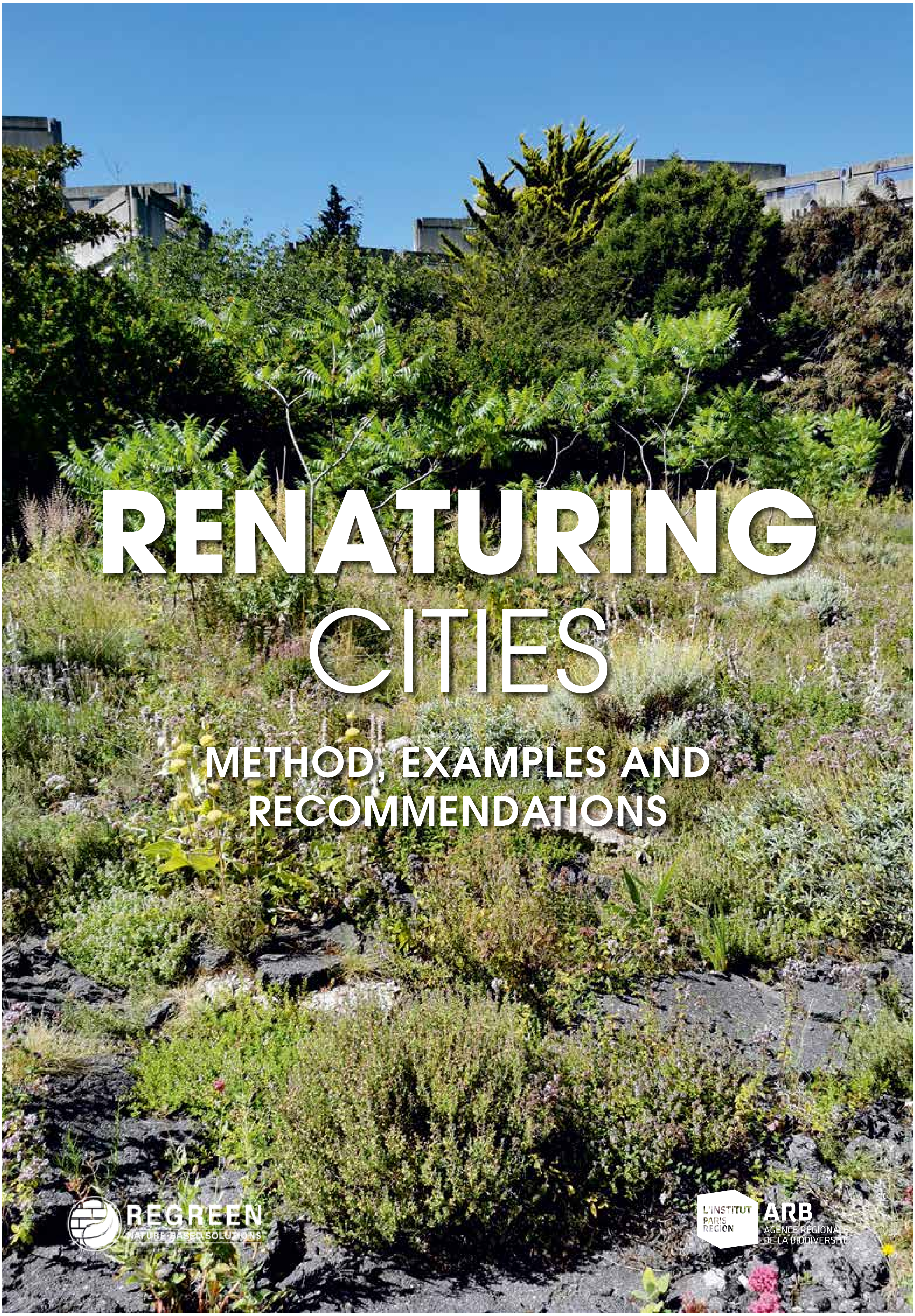

RENATURING CITIES

METHOD, EXAMPLES AND RECOMMENDATIONS

REGREEN
NATURE-BASED SOLUTIONS

L'INSTITUT PARIS REGION

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This guide is part of the European project titled Horizon 2020 REGREEN [1] on nature-based solutions in urban environments. The term "nature-based solutions" refers to initiatives aimed at the conservation, management and restoration of ecosystems. Their aim is to attenuate climate change (e.g. via carbon capture and storage) and to facilitate adaptation to climate change (e.g. via protection against storms, flooding and landslides). These solutions have proved their effectiveness and can complement or replace the grey infrastructure traditionally used in regional development. The advantage of nature-based solutions is that they are multi-functional whereas grey solutions only solve one problem at a time. As well as benefiting climate and biodiversity, they have the advantage of helping to improve the living environment and health of city-dwellers at lower cost to local authorities. Nature-based solutions apply to all environments on all scales (farmland, woodland, aquatic and urban environments) and help enhance the resilience of local regions to global change. Renaturing is a way of rolling out nature-based solutions in areas that have been subject to land take and ground sealing..

PREAMBLE

The Paris Region (l'Île-de-France), the most densely populated and urbanised Region in France, has a natural heritage that is all too often overlooked. This is characterised by a diverse range of habitats: fertile farmland, outstanding woodland, wetlands and rivers. However, the Paris Region has experienced profound transformations relating to its economic and demographic development over the past century which have affected its natural environment. Its wildlife has been significantly affected by these changes, with a marked decline in many populations and the disappearance of some species.

The Regional Council has launched a number of initiatives relating to the challenges of biodiversity including the Plan Vert call for projects which aims to increase the area of green spaces and improve their accessibility; the call for expression of interest on urban brownfield sites; and the "100 îlots de fraîcheur" project, whose aim is to limit urban sprawl, to encourage urban renewal and to set up local heatwave management strategies. These initiatives form part of the regional biodiversity strategy for 2020-2030.

To take us further forward, the current Regional Master Plan is being revised with a view to achieving Zero Net Land Take, Zero Net Emissions and Zero Waste (the circular economy). Because renaturing sealed areas is a way of bringing much-needed nature back into our cities, the President of the Regional Council has asked me, with the help of the Agence Régionale de la Biodiversité en Île-de-France, to begin working on a new tool to speed up the restoration of degraded areas, to make our urban areas better able to host biodiversity, and to articulate public policies focusing on the protection of natural spaces across the Paris Region.

Renaturing, of course, means replanting, recreating habitats and hosting wildlife; but it also means reinforcing green and blue grids, re-establishing ecosystems and restoring ecological functions. While ecological restoration has proven its worth in natural environments, many questions remain concerning the renaturing of urban areas: how can we identify sectors with high renaturing potential within a given area? How can we put together strategies that respond to ecological and climate-related emergencies? What knowledge and methods need to be mobilised in order to carry out a renaturing project successfully?

The Agence Régionale de la Biodiversité en Île-de-France attempts to answer these questions in this book, which is intended to be an inspiring technical guide to support concrete regional renaturing strategies and projects.

Sophie DESCHIENS,
President of the Agence Régionale de la Biodiversité en Île-de-France, President of Île-de-France Nature, Regional Councillor in charge of regional circular economy and animal welfare initiatives.

PREFACE

Of course, renaturing cities is a good idea - but why, how, where and when? Everyone involved in or affected by urban development asks these questions, from city-dwellers to political decision-makers. Answers do exist, most of the time, whether based on science or concrete experience, but they are seldom gathered together in one place and connected to one another.

It's now a cliché to say that only systemic, multi-goal, multi-scale vision and initiatives will allow us to restore the major natural balances that shape our lives and even determine our survival. Taking action with this in mind is the urgent challenge we face. This book, which skilfully combines scientific knowledge, practical methodologies and field reports, helps us to do this.

The book provides urban practitioners with a digest of what needs to be known about the current ecological crisis in urban contexts, in particular the decline of biodiversity, climate change and soil degradation. Through the concept of ecological engineering, it covers the main principles that make it possible to achieve qualitative zero net land take goals. It also provides access to a simple method for rolling out a coherent long-term renaturing plan in different urban areas. Last but not least, it suggests how projects can be adapted to local conditions and shared with local communities.

Renaturing the city means more than just making it greener. It means committing to building a new relationship with the world around us that is radically different from the one that has prevailed until now. This book shows us, with great clarity, how this is possible.

Luc Abbadie, Professor of Ecology and Director of the Institute of Environmental Transition at the Sorbonne

Cities and towns across Europe experience strong population growth, and with more people follow an increase in artificial, sealed surfaces for new roads, pathways, squares, buildings and other infrastructure. In fact, sealed surfaces grow proportionately more in our cities and towns than the number of urban dwellers. Although most European cities lack a compensation strategy to recover the loss of vegetation and green infrastructure resulting in a continued loss in existing green urban areas and canopy cover, promising developments are underway to counter this development. Paris region is one of the front runners with the Master Plan (SDRIFE) to reach no net land take by 2030 and the creation of the Agency "Île-de-France Nature" to facilitate and financially support depavement and renaturing in 145 cities. Also, the upcoming EU Nature Restoration Law lays out requirements to stop the continued loss and increase the amount of urban green infrastructure and canopy from 2030 in European cities and towns.

Renaturing cities – methods, examples and recommendations provides much needed insights and guidance on just how to depave and develop high quality urban nature in European cities. With more and better-connected high-quality urban nature, be it through more street trees, green verges, raingardens, green walls, parks or roof gardens, our cities can become climate resilient, biodiverse, healthy and liveable places.

Marianne Zandersen, REGREEN Coordinator & Senior Researcher, Department of Environmental Science at Aarhus University.

INTRODUCTION

The loss of soil functions and ecosystem services is one of the major environmental challenges Europe is facing. Despite a reduction in the last decade, land take in EU28 still amounted to 539 km²/year between 2012-2018. Since the mid-1950s, the total surface area of cities in the EU has increased by 78% while the population has grown by just 33%. Population growth can also drive land take, but built-up areas are expanding more quickly than populations are growing. Urban sprawl often continues even where populations are decreasing. In France, the rate of land take in France is the highest in Europe, occurring 4 times faster than population growth. This phenomenon is now foremost among the drivers of rapid climate change and the erosion of biodiversity.

To address this global problem, the European Commission has proposed in the EU Environment Action Programme to 2020 (7th EAP) to achieve 'no net land take' by 2050. Sealing agricultural land and open spaces should be avoided as far as possible and the focus should be on building on land that has already been sealed. In France, the national objective dubbed *Zéro Artificialisation Nette* (Net Zero Land Take) marks a turning point in strategies designed to slow urban sprawl as it places the emphasis on urban renewal and densification. It also introduces a renaturing goal that involves "giving back to nature" an amount of land equivalent to that consumed by urban growth. For example, unused land could be returned to cultivation or renaturalised so that it can once again provide the ecosystem services of unsealed soils. The implementation of the Net Zero Land Take goal, however necessary it may be, may nevertheless result in even greater urban densification in cities that are already suffering from climate change and dwindling biodiversity. Moreover, the estimated cost and complexity of a renaturing operation above all presuppose the avoidance of any additional land take.

In this context, slowing urban growth and renaturing urban environments have become key strategies. They are all the more relevant as biodiversity is declining significantly in urban areas, the effects of climate change (runoff, flooding, urban heat islands, etc.) are intensifying and the health and wellbeing of city-dwellers are deteriorating. Renaturing makes it possible to adapt cities to climate change and to make them more permeable to wildlife by developing nature-based solutions. Our cities are full of areas that have been concreted or asphalted over and where nature could return and flourish. The Paris Region, especially the Greater Paris area, is particularly affected by the consequences of urbanisation and density. The purpose of this guide is to propose a method that will help local authorities to target urban areas where renaturing represents a key strategy to restore biodiversity, adapt to climate change and improve people's health. Based on feedback from respondents in the field, it provides recommendations on how to implement projects in the best possible conditions.


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WHAT IS RENATURING?

The term renaturing encompasses many different approaches and visions whose terms are constantly evolving within the scientific community. The word, for which it would be pointless to attempt to give a single, universally accepted definition, refers to the general idea of "returning ecosystems that have been degraded, damaged or destroyed by human activity to their natural or semi-natural state" (*SER, 2004*). Originally associated with the restoration of degraded natural areas, the concept has been gaining ground in the urban environment since the advent of the Net Zero Land Take goal. It remains open to different interpretations depending on the stakeholders involved, be they ecologists, developers, planners, or landscapers. It thus seems vital to return to the source of this idea and the different approaches it encompasses. Understanding the goals of renaturing facilitates dialogue between urban stakeholders and makes it possible to propose a common interpretive framework for the implementation of these kinds of projects.

APPROACHES AND MEANINGS

SPONTANEOUS REGENERATION

Renaturing is traditionally associated with processes by which nature returns to an area that has been subjected to land take or anthropic disturbance. Simply putting an end to human interference allows the environment to be recolonised in a passive or spontaneous way. This process has been described as leading to a state of "ferality": in other words, ecosystems return to the wild state when human exploitation ceases (*Génot & Schnitzler, 2012*). Ferality is close to the idea of rewilding, which means the recolonisation of an environment by wildlife (with or without human intervention) when anthropic activities have been abandoned or halted.

This type of renaturing, which allows nature to take its course, relies on elements already present in or near the area (*Grubb & Hopkins, 1986; Powers et al, 2009*) and thus involves no financial or environmental cost. Moreover, renatured ecosystems function as open-air laboratories, adapting over time to new uses and climate change. This type of renaturing is especially useful when the project can take place over a long period of time and when ecological connectivity is

In France, the idea of rewilding is defended and implemented in particular by the Association pour la Protection des Animaux Sauvages (ASPAS) at the 490-hectare wildlife reserve in the Vercors Natural Park [2], and recently by the Association Francis Hallé pour la Forêt Primaire, which is involved in a 70,000-hectare rewilding project in the Vosges mountains [3].

Set up in 2021, Coordination Libre Evolution, which groups together four wildlife protection organisations, supports the idea that protected wildernesses should account for 10% of the total area of metropolitan France by 2030 [4]. The naturalists Gilbert Cochet and Béatrice Kremer-Cochet, who specialise in rewilding, have published *Europe réensauvagée. Vers un nouveau monde* (Actes Sud, 2020), which, supported by experimental findings, demonstrates the value of these wildernesses in restoring biodiversity. In an article on planetary ecological boundaries, researchers recommend restoring 23.9 million sq.km., equivalent to 18.1% of the biosphere, to preserve the integrity of biodiversity and the functionalities associated with it (*DeClerck et al, 2021*).

According to Edward O. Wilson, a scientist renowned all over the world for his work on biodiversity, half of the planet would have to be left wild to halt mass extinction. In France, «heavily protected" areas classified as "*aires protégées réglementaires*" (natural reserves, areas at the heart of national parks, biological reserves, areas covered by official protection orders) only accounted for 1.8% of the country in 2019 [5]. They represent a mere 0.59% of the Paris Region [6].

sufficient to allow animal and plant species to recolonise the site (*Prach et al, 2015*; Chazdon & Guariguata, 2016). In certain cases, it can even be used in significantly disturbed areas such as abandoned quarries or mines, although the process is then slower (*Prach & Hobbs*, *2008*). Unfortunately, passive renaturing is still undervalued, and the challenges associated with it are sometimes understated. Renatured areas are all too often seen as degraded and earmarked for development.

Brownfield sites as biodiversity reserves

In urban areas, the idea of spontaneous colonisation is still uncommon as it is often associated with neglect and abandonment. This type of trajectory can, however, already be observed in urban brownfield sites, although the latter are sometimes perceived negatively. Several scientists have shown that sites that have been allowed to become overgrown have real potential for the conservation of urban biodiversity (*Bonthoux et al, 2014*). In the Paris Region, the diversity of plants, birds and butterflies in brownfield sites is higher than in any other "natural" urban areas (parks, gardens, cemeteries, and so on) (*Baude et al, 2011*). Because they do not harbour exactly the same species as managed areas, brownfield sites also act as a refuge for so-called "urban avoiders" (Great mullein, Welted Thistle, whitethroat, wall lizard), which struggle to adapt to urban conditions. Last but not least, these freely evolving environments also contribute to the ecological continuity of local areas by allowing species to travel across the urban matrix (*Muratet et al, 2019*).

This process of spontaneous colonisation has been studied in particular detail in Germany via the work of Ingo Kowarik on spontaneous urban woodland in Berlin. Some of the city's emblematic parks are the result of this process, for example the *Natur-Park Schöneberg* Südgelande, which is the result of renaturing a former railway marshalling yard. This 18-hectare area remained inaccessible for almost 50 years before opening to the public in 2000. Existing trees have been retained with no additional planting. Maintenance is minimal and restricted to the footpaths. An inventory in the 2010s identified 366 different species of ferns and flowering plants, 49 species of mushroom, 49 bird species, 14 grasshopper and cricket species, 57 spider species and 95 bee species, 60 of which are endangered [10].

ARE BROWNFIELD SITES JUST LAND RIPE FOR DEVELOPMENT?

Recently, several initiatives involving identifying and evaluating brownfield sites have been launched, including Cartofriches (Cerema) [7] and the Bénéfriches guide (ADEME) [8]. A survey by the Institut Paris Region has listed 2,700 brownfield sites covering almost 4,200 hectares across the Paris Region. These initiatives aim to help local authorities to envision several modes of use for such sites and highlight how they can contribute to urban renewal.

Although certain brownfield sites, such as those that are heavily sealed, are ripe for densification, others have become fully-fledged natural areas boasting significant levels of biodiversity. Still others provide the final opportunity to recreate natural areas in highly urbanised zones.

Improved understanding of brownfield sites, especially via ecological inventories, is thus essential before any intervention or planning is carried out. Still too readily seen as "areas awaiting development", recognising their status as natural areas should form part of an ambitious regional renaturing policy. Similarly, any brownfield redevelopment project, however "green" it is (turning them into parks, gardens, urban farms, etc.), can ultimately lead to the destruction of natural assets and diminish the ecological potential of such areas, whereas leaving them unmanaged and free to evolve guarantees greater biological diversity.

Brownfield sites are an example of spontaneous renaturing without human intervention ©École d'Urbanisme in Paris [9]

In 2000, the Natur-Park Südgelände in Berlin opened to the public after almost 50 years of unhindered evolution. ©City of Berlin

THE ECOLOGY OF RESTORATION AND ECOLOGICAL ENGINEERING

In most cases, renaturing involves human intervention, however minimal. This is referred to as ecological restoration, a discipline formally established in the 1980s with the creation of the *Society for Ecological Restoration* in the USA. This group of scientists defines ecological restoration as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed in order to re-establish the former ecosystem with respect to its specific composition, its ecological functions, the ability of the physical environment to support living organisms and its connectivity with the surrounding landscape. In recent years, ecological restoration has developed in particular in natural, especially aquatic environments (rivers and wetlands) but has also been used to restore sites and soils contaminated by former industrial activity (*Tobias et al, 2018*).

Ecological restoration initiatives can take very varied forms and involve varying degrees of human intervention. While some interventions require heavy equipment (construction site machinery, etc.), others use alternatives to traditional civil engineering. This is true of ecological engineering, which leverages a wide range of expertise and tools based on living organisms and an understanding of the mechanisms that govern ecosystems. According to the researchers who initiated the movement, ecological engineering is broadly defined as "*the management of environments and the design of sustainable, adaptable, multi-functional developments inspired by, or based on, the mechanisms that govern ecological systems (self-organisation, diversity, heterogeneous structures, resilience)*" (*Abbadie et al, 2015*). Ecological engineering is applied in the context of the rehabilitation of damaged ecosystems; the restoration of functional communities; the reintroduction of species; the treatment of pollution using living organisms; the restoration and reinforcement of ecosystem services; and the design of new materials that minimise the destruction of the environment.

One of the objectives of ecological engineering is to limit the use of non-renewable resources and inputs, instead using renewable natural resources with low ecological impacts. Ecological engineers use an array of techniques inspired by the living world. For instance, it is possible to use species referred to as ecosystem engineers, whose presence and activity alone significantly modify their environment (mycorrhizae, earthworms, phytoremedial plants, harvester ants, beavers, rustic herbivores, etc.).

Ecological restoration has been particularly developed within the framework of the rehabilitation of aquatic environments (rivers and wetlands), here the Bièvre restored at Igny © Hervé CARDINAL, SIAVB

REFERENCE STATES IN RESTORATION ECOLOGY

Restoration ecology uses the notion of the reference state, which means establishing the condition a site was in before it was damaged. This method of defining an initial state is often used in projects aimed at the restoration of natural or semi-natural ecosystems, but it is difficult if not impossible to carry out in urban environments. Renaturing in urban settings more often involves rehabilitation, reclamation or natural regeneration without necessarily aiming to return to an original state whose very existence is open to debate within the scientific community. However, it is always interesting to carry out historical research in the early stages of a restoration project and to seek to restore certain functions of the target ecosystem (if not its biotic integrity), as is the case with renaturing operations focusing on former wetlands, streams that have been channelled or covered over, relictual woodland, former meadows, or riverbanks that have deteriorated over time. Where reassignment and natural regeneration are concerned, no historical references are required as renaturing leads to a new ecosystem with different functions and a different structure.

Unlike civil engineering, ecological engineering has a small ecological footprint and takes its cue from the context in which it is applied, providing greater chances of success. However, restoration initiatives usually combine civil and ecological engineering, given that they often rely on the prior decontamination of the sites concerned and require the destruction of man-made structures such as buildings, concrete infrastructure, channels, embankments, dams and so on.

RENATURING IN URBAN AREAS

BEYOND GREENING

In urban settings, renaturing is still often perceived as an approach to landscaping (*Pech, 2017*) whose main aim is to create a green decor that makes the city more attractive. In France, this kind of greening developed under the influence of formal landscaping whose legacy has been a highly controlled ornamental approach to nature focusing mainly on plants and ignoring other species as well as ecological functionality.

What's the difference between greening and renaturing?

Unlike ecological engineering, greening often takes place with no connection to the climatic or geographical context, uses ill-adapted horticultural species and requires numerous inputs (topsoil, fertiliser, energy, irrigation, etc.), which means that these areas are not self-sufficient and are reliant on intensive management. Greening operations often start from scratch by eliminating existing vegetation and replacing the existing soil with topsoil—which is becoming scarce in agricultural environments. Greening is often organised on the scale of the site alone whereas renaturing considers a range of different scales, following the principles of landscape ecology. The archetypes of greening are, for example, the French-style formal garden, lawns, monospecific planting, modular living walls, raised planters, flower meadows sown with non-local species, etc.

A concept that doesn't stop at vegetation

Fads and fashions also affect wildlife, as shown by the number of beehives seen in densely populated urban areas. This can be compared to a breeding method and can lead to an excessively high density of domestic honeybees (*Apis mellifera*), to the detriment of populations of wild pollinating insects which have to compete for access to floral resources (*Ropars et al, 2017*). "Saving the bees" above all requires protecting or restoring a diverse range of habitats suitable for pollinators (urban meadows, hedgerows, soil environments, etc.).

Generally speaking, artificial solutions such as wildlife homes, although very popular, can potentially become ecological traps, especially for certain birds (*Schwartz, 2020*). Similarly, insect hotels can be out of synch with the needs of the target species and insufficient thought goes into ensuring their connectivity. Because of this, while these initiatives have undeniable educational value, they are not effective means of restoring biodiversity.

On the other hand, renaturing through ecological engineering relies on knowledge of ecology and considers all levels of biodiversity (genetic, specific and ecological). Its main aim is not to embellish the environment; instead, it seeks the ecological function that most closely corresponds to natural systems, focusing on well-adapted fauna and flora and taking species requirements into account, using the fewest possible resources and minimising future management interventions.

Encouraging wild bees in urban areas, 70% of which nest underground, requires preserving or restoring their habitat rather than providing substitute shelters. Above: a halictid bee in its nest. ©Gilles Lecuir/ARB ÎdF

Blandscaping or standardising nature in urban areas

Growing interest for nature in urban settings thus goes hand in hand with a form of standardization, as evidenced by the increasing numbers of beehives and insect hotels (*Fortel et al, 2014*), "ready-to-use" planting systems for buildings and attractively marketed urban micro-forests. This phenomenon, which researchers have dubbed "blandscaping" (*Connop, 2018*), corresponds to installations that use the same design methods and the same species and which are often "cut-and-pasted" from urban areas across the globe. These solutions are generally developed industrially in order to meet marketing requirements, in the form of standardised or ready-to-use products.
But ecology functions according to local realities. While it is necessary to constitute supply chains (for seeds, seedlings, materials, etc.), approaches that aim to bring nature into urban areas and renaturing projects can only be designed on a case-by-case basis, taking account of local characteristics. They are incompatible with industrial development, which inevitably leads to standardisation. Applying the principles of ecological engineering would avoid this pitfall by proposing unique solutions whose design focuses on species requirements, life cycles and intrinsic needs (habitat area, connectivity, complexity of trophic networks) and by using local resources (salvaged soil, wild seeds collected nearby, species already present on site, etc.). In France, the Végétal local® brand, which offers wildflower species adapted to different regions, has opened the way for projects that adopt this approach.

Some greening systems, such as these pre-cultivated sedum mats for green roofs, are often «copied and pasted» from one city to another.
©Marc Barra

MIYAWAKI FORESTS: RENATURING OR JUST A FAD?

In the past few years, urban micro-forests called "Miyawaki forests" have been springing up all over Europe. The method involves creating dense plantations of various tree species (3 - 7 trees per square metre) in an area generally smaller than 1 hectare. They were originally inspired by spontaneous growth dynamics observed in forests. Supported by a well-rehearsed spiel that is more electoral slogan than science, these new forests are said to "grow ten times faster", "host 20 times more biodiversity" and are "30 times denser" than natural woodland [11]. They are hugely popular among local councils and communities.
Proposed as a miracle solution for biodiversity and urban renewal, they are nonetheless criticised by the scientific community. Where the claim of being "30 times denser" is concerned, one of the few studies made on the subject in Europe shows a mortality rate of between 61 and 84% (*Schirone et al, 2011*). Moreover, in addition to the resources this method requires (watering, uprooting unwanted seedlings, etc.), species selection depends entirely on competitiveness, not resilience, in particular to episodes of drought.
While this type of operation may have its place in the array of initiatives involving nature in urban areas, it cannot be standardised. Such operations must be anchored in their local context, and can thus take a variety of forms: hedgerows, coppices, extensions to relictual woodland, or simply allowing wild urban woodland to develop, which requires no human intervention and costs nothing. We must bear in mind that biodiversity cannot be measured in terms of the number of trees that have been rapidly planted. A mature forest requires old forest soil, takes a long time to develop (over 200 years) and hosts maximum biodiversity (lichens, fungi, insects) at its old-growth and senescent stages (*Génot & Schnitzler, 2020*).
Last but not least, the initial state of the soil is significant: a soil that is contaminated or in poor condition can restrict plant development. Where renaturing is preceded by desealing, one must not forget the important of plant succession, especially the development of pioneering plants and the part they play in restoring degraded soils (see p. 83).

From greening to ecological engineering

Many landscape designers, such as Michel Clément, have opened up a new era where the world of landscaping and the world of scientific ecology meet. They rely on landscape ecology, which takes the scale of the landscape into consideration in the spatial organisation of ecosystems, considering its composition and configuration as key elements that influence ecological processes (*Bourgeois, 2015 ; Burel et Baudry, 1999*). It uses different methods and models to study past, present and future forms of the landscape, and has contributed to both ecological knowledge and the implementation of ecological connectivity in cities. Urban ecology cannot do without landscape ecology as the disciplines are necessarily complementary in the framework of urban renaturing projects.

An increasing number of restoration projects are approached on the scale of the broader landscape rather than that of the individual habitat, taking account of the fact that species need to move, feed and reproduce in such a way that they maintain essential genetic intermingling between populations. These approaches involve, for example, restoring green and blue grids by reconnecting isolated environments in the landscape matrix. In practice, the boundary between landscape design and urban ecology is gradually becoming blurred: the choice of plants is no longer only determined by aesthetic criteria, instead focusing on local species and taking interactions with wildlife, soil and local conditions into account. Conversely, ecologists, who are sometimes very theory-oriented, are relying more and more heavily on the skills and expertise of landscape designers.

ECOLOGICAL ENGINEERING IN URBAN SETTINGS

In recent years ecological engineering has significantly developed in cities, in particular, in France, under the name plant-based engineering techniques ("genie vegetal" in French), which comprises an array of techniques based on the use of plants and their structural functions (as stabilisers, anchors, etc.) to combat soil erosion, to stabilise embankments, or to restore riverbanks, rivers or urban wetlands. In these kinds of operations, vegetation does not merely play a supplementary role (that of "greening"); instead, plants are perceived as living construction materials in their own right, which can be used alone or in association with inert materials (*Schiechtl, 1992*). The use of ecology can take a variety of forms in cities and serve a range of applications designed to restore ecological functionalities or entirely renature degraded environments: using plants to purify greywater (phytopurification) or to capture urban pollutants; flood management; reducing urban heat islands; and so on. In any case, biodiversity is central to these operations: it is both a means and an end where renaturing is concerned.

The principles of ecological engineering can thus be applied to a multitude of urban projects, whether they involve renaturing or the management or creation of new ecosystems. New techniques combining ecological and civil engineering have also emerged, in particular regarding the restoration of soils containing materials left over from demolition programmes ("technosoils"). Although some human intervention is required, ecological engineering is often synonymous with active renaturing. The principles and steps involved in implementing ecological engineering in the framework of a renaturing project are laid out in part 3.

Ecological engineering techniques used to restore riverbanks in order to protect them from erosion, stabilise them and allow them to regenerate. ©Gilles Lecuir

Combined approaches

The different approaches to renaturing in natural and urban environments are not incompatible; on the contrary, they can complement one another within an area or on a single site, for example applying natural regeneration goals in some sectors and human-assisted restoration in others. Whether renaturing is passive or active, all these approaches converge towards the natural process of ecosystem recovery though they differ in terms of how much human intervention is involved. In all cases, they require continuous adaptive management and close monitoring until the ecosystem has recovered. Objectives vary from one project to the next: we can attempt to restore all the components of biodiversity, from genes to species to landscapes; we can focus on the functionality of ecosystems, in other words not only the functions that are necessary for ecosystems to work but also the functions that provide humans with "ecosystem services" (Millennium ecosystem assessment, 2005) ; we can also try to make ecosystems "wilder". The final goal is to restore ecological functionality, to make environments better able to maintain themselves and to ensure that natural carbon, water and nitrogen cycles are functional by mimicking the characteristics of natural systems.

DESEALING IS NOT RENATURING

Renaturing is often confused with desealing, which involves restoring the permeability of topsoil, often using porous drainage pavements. Though an essential factor, desealing alone is not sufficient to restore the soil's ecological functions, however. The use of permeable surface materials has developed significantly in recent years, sometimes to the detriment of open ground (e.g. school playgrounds, spaces around trees). Their use should be limited to roadways, paths and parking areas whose use is incompatible with permanent planting.

Alternative rainwater management systems have encouraged town councils to partially deseal and plant certain areas, mostly using landscaping (planted ditches, floodable gardens). While several studies confirm the value of these solutions in terms of biodiversity, their design and maintenance can nevertheless be improved to enhance their ecological credentials and to initiate a return to open-ground solutions (*Barra, 2020*), via soil restructuring initiatives (decompaction, creating soil horizons, soil amendment, etc.). Off-ground installations (green roofs, urban vegetable gardens in containers, planted areas on slabs, modular green walls, etc.), which can contribute to more effective stormwater management, do not belong to the category of renatured areas.

Drainage pavements or permeable asphalt, which are genuinely useful on certain surfaces to improve stormwater management, are not examples of renaturing. ©Gilles Lecuir (up) ©Commune de Narbonne (down)

	DESEALING	GREENING	RENATURING
Goals and purposes	Restoring the water cycle by making the soil permeable, limiting runoff and flooding.	Using plants to make the urban environment more attractive, ornamentation.	Restoring ecological functionalities, creating viable habitats in relation to the green and blue grid, water management, adapting to climate change.
Associated skills and professions	Engineers, hydrologists	Landscape architects	Ecologists, engineers, naturalists, eco-landscapers
Scales considered	Site, runoff zone or catchment	Site or landscape	Nested scales with respect to the landscape and ecological networks
Monitoring	Relating to the quality and dynamics of water	Not systematic	Evaluation of biodiversity before and after using standardised protocols
3 levels of biodiversity considered	Not included in goals, but increasingly frequent in rainwater management solutions.	Not systematic, often plant-focused.	Gene flows, species and ecological interactions considered.
Examples of application	Alternative systems for managing rainwater, permeable surfaces	Swales, flowerbeds, raised containers	Marshland, meadows, green and blue grids, creation of habitats focusing on the needs of species
Adapted to local environmental context?	Yes, in relation to the water cycle	Not necessarily (inappropriate choice of species, massive input), but often take the social context into account	Prior ecological analysis, coherent species selection within the desired ecological trajectory, soil surveys.
Management	Extensive to intensive	Extensive to intensive	Extensive to free natural evolution

TABLE 1. Comparison between desealing, greening and renaturing.

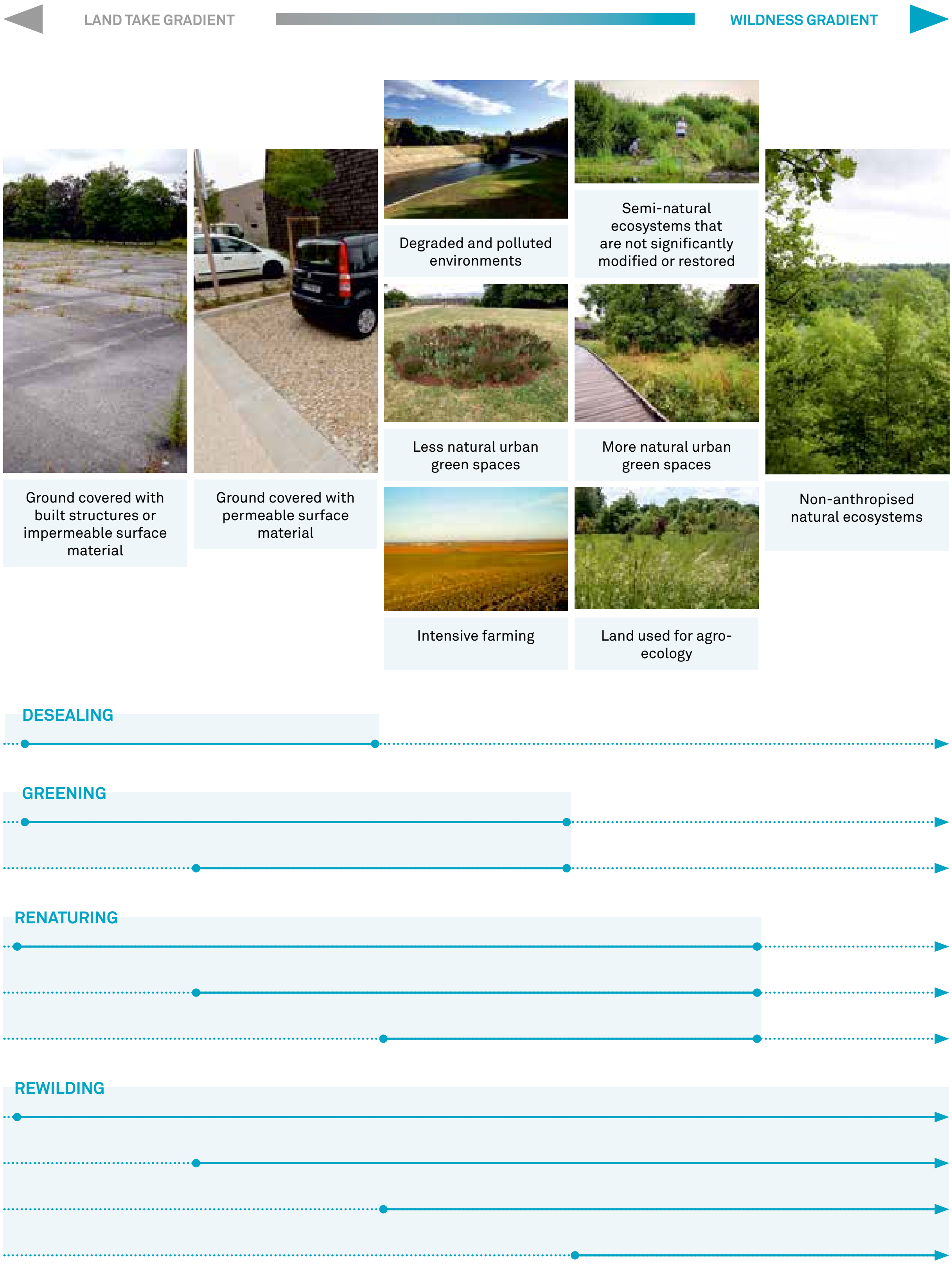


FIGURE 1. Classification of areas using a “land take – wildness gradient” depending on desealing, greening, renaturing and rewilding operations.

URBAN SOILS: A KEY CHALLENGE

Although soil is home to 25% of the world's terrestrial biodiversity (*IPBES, 2019*), it is still poorly understood and has long been neglected and seen as a mere physical medium. The soil is, however, a fully-fledged component of biodiversity, providing a habitat for countless living organisms (microfauna, mesofauna and macrofauna) and acting as a medium for fundamental ecological processes such as biogeochemical cycles and the water cycle. Renaturing cannot be implemented without considering the state of the soil and its ecological functionality.
Urban soils are in most cases significantly modified and degraded (pollution, compaction, disturbed soil horizons) or even rendered impermeable when they are covered with non-porous materials (roads, car parks, etc.) or by a building. Sealing prevents water from entering the soil and compromises its function as a medium for plants. Urban soils are also generally contaminated with heavy metals and hydrocarbons. In the Paris Region, soil concentrations of cadmium, lead and copper content are 8 times higher in urban woodland than in rural woodland (*Foti, 2017*). In cities, soils are also fragmented by infrastructure, which breaks up ecological continuity and partially or totally isolates biodiversity reservoirs.
Renaturing in urban environments has to focus on restoring soil functions rather than replacing them. Today, most planting projects in urban environments use topsoil removed from farmland or volcanic soil. This is a major problem that merely transfers impacts to other environments. To put an end to this "soil-trafficking", more and more actors are choosing to reuse urban by-products (compost from green waste, crushed concrete or brick, excavated earth) collected on site. These circular economy approaches can be combined with techniques of ecological engineering (reintroduction of earthworms, mycorrhization, inoculation of micro-organisms). The restoration of fertile soils or "technosoils" has been the focus of several recent research programmes and seems to be a viable solution for urban renaturing in the future. Renaturing must also focus on restoring continuity between soil compartments, both vertically and horizontally ("brown grid").

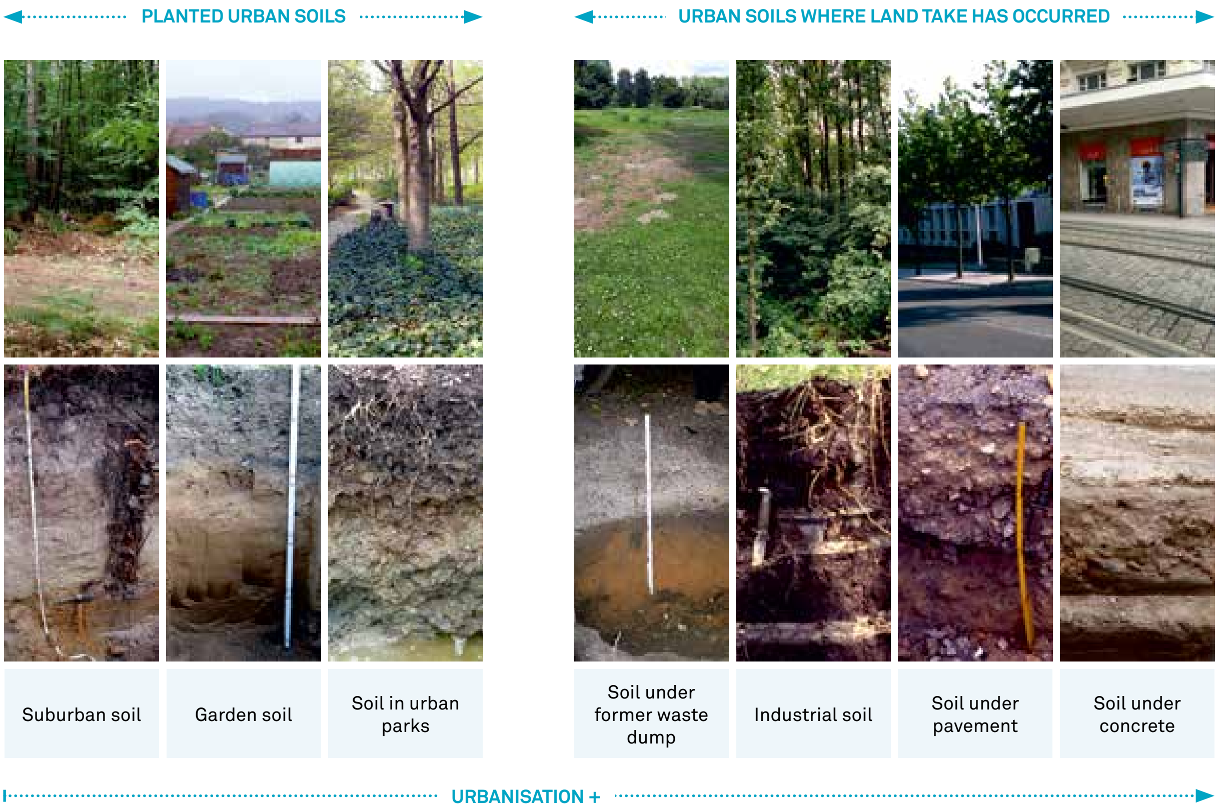


FIGURE 2. Profiles of planted soils and soils where land take has occurred, with increased urbanisation from suburban areas towards town centres. ©Christophe Ducommun, Jean-Pierre Rossignol and Laure Vidal-Beaudet (Beaudet & Rossignol, 2018)

"OPEN GROUND": A NOTION THAT IS HARD TO DEFINE BUT ESSENTIAL FOR RENATURING

More and more local authorities in France are seeking to improve representation of soil-related issues in their planning documents and are taking an interest in protecting what is termed "la pleine terre", which may be translated approximately as "open ground" or "natural soil" (planter en pleine terre means to plant directly in the ground and not in a pot or container). The notion of open ground does not have a universally accepted definition, nor is there scientific consensus regarding its precise meaning. A study carried out by the Paris Region Institute (*Cocquières et al, 2021*) looked at 25 local urban development plans and highlighted the fact that no definition of open ground was provided in 20% of the documents. Where such a definition was provided, local authorities used different criteria to define what open ground means, such as «[the soil's] ability to let water in, the absence of constructions on and under the surface (though the presence of underground utility networks does not necessarily disqualify it), or its ability to provide a medium for plants». Such attempts at definition reflect how difficult it is to establish a binary classification given the significant variability of urban soils. Because of this, it seems more appropriate to talk in terms of an "open ground gradient", referring to several criteria including surface covering, vertical continuity and depth, horizontal continuity (the "brown grid"), physical, chemical and biological soil quality, compaction and permeability.

Surface covering (paving/sealing)

An obvious distinction can be made between sealed urban soils and soils that are not sealed or paved. This is not, however, sufficient to qualify a soil as an open ground.

Vertical continuity and depth

For pedologists (soil ecology specialists) it is tempting to equate open ground areas with natural soils where there is continuity between soil horizons[1] and the water table or the geological subsoil. However, this situation hardly ever arises in densely built-up urban areas, where the subsoil is occupied by utility networks, tunnels, underground transport networks, sewers, car parks, basements, etc.). An overly strict definition would risk excluding degraded or modified soil that can be rapidly restored and requires protection. An excessively loose definition (accepting, for example, shallow soil depth) risks encouraging developers to lay out green spaces on concrete plazas.
Nevertheless, in certain city-centre areas already cluttered with underground networks and where deep soil continuity no longer exists, shallow soil could be tolerated (although strictly speaking this does not qualify as "open ground"). However, this presupposes considering the depth and volume required for plant growth, especially for trees. It is first necessary to fully understand the rooting strategies of trees, which vary from species to species: taproots, lateral roots and oblique roots (*Atger and Edelin, 1994*). This approach, which we call "partial open ground", must be strictly limited to areas where it is no longer possible to ensure topsoil and subsoil continuity. Under no circumstances should it encourage the creation of slab-based urban spaces.

1. Pedologists in France have defined over 70 types of horizons (called "reference horizons"), which are listed in the *Référenciel Pédologique* (Pédologique, R, 2008). A distinction is generally made between: the organic horizon (Horizon O) which results from the transformation of plant debris that accumulates on the surface of the soil into organic material; Horizon A, which contains both organic and non-organic material and is the result of the work of living organisms in the soil (worms and insects); Horizon B, enriched with a range of organic and non-organic materials (clay, iron, organic material, calcium carbonate, etc.) resulting from the transformation of primary minerals from the bedrock; Horizon C is the substratum of weathered bedrock; and Horizon R or M is the layer of bedrock (R for hard rock (granite, sandstone, limestone) and M for loose material (sand, marl, etc.)).

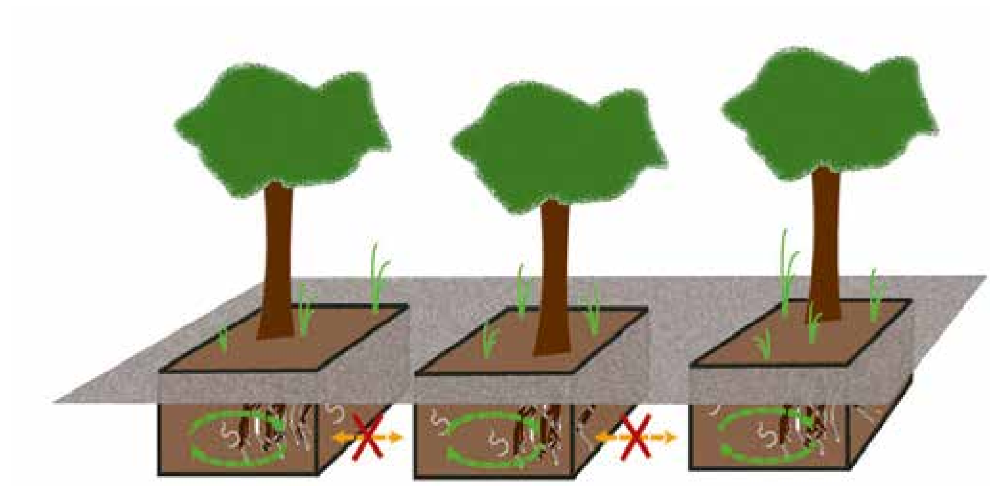


FIGURE 3. Urban soil fragmentation. © Romain Sordello (after Chalot, 2016) [12]

Horizontal continuity or "brown grid"

The "brown grid" is a concept based on the model of the Green and Blue Grid applied to connectivity between soils. Pedologists refer to "lateral horizons" stretching from a metre to a kilometre. Species present in the soil also need to move from one place to another (*Mathieu, 2015*) in order to complete their life cycle, to reproduce, to escape occasional changes in their environment, to recolonise an area after an episode of mortality, etc [12]. These species may be earthworms, ground beetles, springtails, ants or moles. The notion of a brown grid is connected to that of open ground insofar as it aims to reduce elements that cause soil fragmentation (concrete tanks, drainage networks, etc.). The idea of the "brown grid" also refers to the anchoring requirements of plants and interactions between root networks that facilitate exchanges between them (thanks to mycelial filaments) or with soil-borne organisms. In cities, certain areas where the soil is fragmented are no longer considered to be open ground, especially places where there are isolated trees planted in individual trenches, compared to areas where rows of trees stand in adjacent trenches sharing the same mass of soil. The volume of such trenches in urban environments is seldom more than 4-9 cubic metres though it can be up to 12 or even 24 cu.m. when financial resources allow (*Gouedard, 2014*). Using brown grids to ensure soil continuity would increase the volume of soil available for trees and facilitate rainwater permeation.

The physical, chemical and biological quality of the soil

Another dimension concerns the biological quality of the soil relative to its level of biodiversity. Several thousand animal species and several tens or even hundreds of thousands of bacterial and fungal species cohabit in just a few square metres of soil or humus (debris decomposing on the surface), all to a very shallow depth (sometimes less than a metre). In urban areas, several indicators can be used to assess the state of soil fauna and define the ecological quality of the soil (see p.82). Degraded soils of low ecological quality or whose horizons have deteriorated may nevertheless be restored and referred to as "degraded open ground".

Permeability

This last dimension concerns the permeability of soils to rainwater: open ground must allow water to seep down to the water table (except in special cases such as naturally less permeable clay soils). Depending on the compaction constraints to which urban soils may be subject, this criterion could make it possible to distinguish open-ground soils that have retained satisfactory permeability from degraded open-ground soils that require restoration action.

Towards a definition of an "open-ground gradient"

Considering these five criteria makes it possible to distinguish several degrees of open ground: open ground in the strictest sense (natural urban soils); degraded open ground (compacted soil, soil with destructured horizons, polluted soil) requiring restoration work; partial open ground (tolerance of minimum depth in dense urban areas where some infrastructures are already present); and absence of open ground (areas entirely covered in infrastructures). This classification is offered as an indication. This type of approach requires in-depth knowledge of the soil and the use of cartographic tools to evaluate the state of the soil with regard to this gradient. This would help to improve representation of the soil in planning documents and facilitate soil protection or renaturing using objective criteria.

	OPEN GROUND	DEGRADED OPEN GROUND	PARTIAL OPEN GROUND	ABSENCE OF OPEN GROUND
Vertical continuity	Provided down to bedrock/water table	Provided, although horizons may have been altered	Minimum depth defined according to depth and volume of soil required by trees	Not provided
Permeability	Reference permeability according to soil type	Low permeability, high compaction constraints	Permeability possible if surface not compacted	Zero soil permeability
Horizontal conti-nuity (brown grid)	Provided across the site	Not necessarily provided	Not necessarily provided	Not provided
Surface covering	No covering	No covering	No covering	Impermeable or permeable covering
Theoretical physical, chemical and biological quality	High (to be confirmed by analysis)	Low to high (to be confirmed by analysis)	Low to high (to be confirmed by analysis)	Zero
Type of planning-re-lated action	To be maintained and protected	To be restored and protected	To be defined only in areas where underground infrastructures are present	Surface ripe for renaturing

TABLE 2. Overview of types of “open ground”.

THE NEED TO RENATURE SEALED GROUND

Scientific and technical literature on renaturing sealed areas is still very patchy. From 2016 to 2019, the European programme SOS4LIFE [14] listed European soil protection and desealing initiatives [15] and made recommendations on soil evaluation and monitoring [16]. Several initiatives have been implemented in Europe, especially in the framework of compensatory measures (*Adobati et al, 2020*). Depending on the local authority concerned, desealing operations may or may not be coupled with renaturing programmes.

Belgium, Italy, Germany, Denmark, France: desealing / renaturing projects on the rise

Such approaches have also been adopted in Wallonia, Belgium (2005), with the application of the Net Zero Land Take goal set by the European Union in 2016. In 2021, the Wallon government launched a call for projects for the creation of urban parks. Seventeen towns were earmarked and will share a budget of 12.1 million euros to create 45 hectares of new green spaces after desealing. In Flanders, the government financed some twenty "experimental desealing gardens" as part of a call for projects in 2019. The funding (5 million euros) was set aside for the removal of concrete, asphalt and certain buildings and the landscaping of the freed-up space.

Germany also has significant experience in this field with several desealing projects at regional level (Bade-Wurtemberg) and local level (Stuttgart and Berlin). In the 2000s, after the Elbe burst its banks, Dresden City Council defined a planning goal, which stipulates that built plots designed for housing and roads cannot account for more than 40% of total urban space. To achieve this, the council has created a "soil compensation account". In return, new projects on unbuilt plots must implement desealing measures in unused or abandoned areas. This public policy has given rise to a range of interventions including demolition, restoring rivers, rehabilitating contaminated

Our cities are full of areas that have been needlessly concreted or asphalted over and where nature could return and flourish. ©Marc Barra

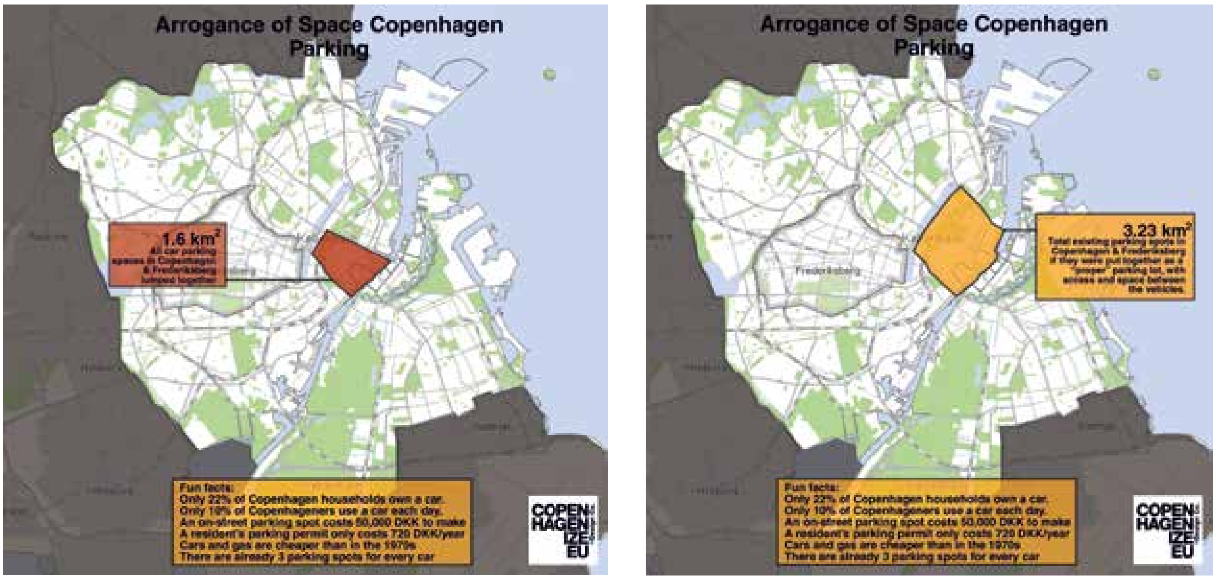


FIGURE 4. Graphic showing how much space is allocated to car parking in Copenhagen
©Copenhagenize.com by Mikael Colville-Andersen

waste ground, destroying farm buildings and removing asphalt from cycle lanes and footpaths in green corridors and green spaces. Since 2010, an average of about 4 hectares of land has been desealed annually.
In urban areas, experiments involving the renaturing of sealed land have often taken place in the framework of rehabilitation projects for brownfield sites (*Atkinson et al, 2014*). The region of Emilia-Romagna in Italy introduced the concept of "incongruous buildings" in 2002, giving councils the opportunity to remove these "environmental detractors" that have a negative impact on ecology and the landscape (*Stanghellini, 2010*). Other Italian regions have since taken similar steps, although with different objectives. Liguria, for example, has made it possible to demolish buildings to reduce exposure to flood risk and avoid the presence of human activities near rivers.
In Berlin, the local government has rolled out a strategy to identify desealable sites as part of the federal Zero Net Land Take programme. This strategy, titled Potential for the Removal of Impervious Soil Coverage 2020, is similar to the Net Zero Land Take programme rolled out in France and offsets new land take by renaturing sealed areas. It is part of a Soil Quality Atlas developed as a decision-making tool for the city's planners [17]. A survey carried out among council staff and the Forestry Department in Berlin has made it possible to create a database identifying potentially desealable zones. The study went further by classifying each site according to the feasibility and priority of renaturing initiatives. In 2020, of the 179 sites identified, 31 have already been completely desealed and 14 partially desealed.
In Denmark, a cycling association has estimated how much space is taken up by parking spaces and car parks in Copenhagen (Figure 4.). Placed side by side, parking spots would occupy a surface area of 1.6 square kilometres. If they were made into a single parking lot with spaces between the cars, it would cover 3.23 square kilometres. This work highlights the amount of available sealed areas in cities and the need for tools to characterise them.
In France, several recent projects have focused on the potential of desealing and/or renaturing, with complementary approaches. In 2019, Cerema helped the Communauté d'Agglomération du Grand Narbonne to construct a method for calculating desealable areas [18]. In the Paris Region in 2021, DRIEAT tasked Cerema Ile-de-France with developing a methodology for identifying the renaturing potential of the Paris urban area, helping to establish an operational strategy of resilience and adaptation to climate change [19]. ADEME is also managing the DésiVille research project with a view to creating a tool to facilitate desealing and a catalogue of solutions applicable in urban areas.
In parallel with these programmes, numerous initiatives are emerging at local authority level in the framework of calls for projects or local council initiatives (planting permits, participatory budgets, ad hoc renaturing operations). Initiatives take various forms: some focus only on desealing in the framework of rainwater management strategies, while others couple desealing with renaturing. In Rennes, a project in progress run by AUDIAR aims to produce a map of desealable areas in connection with the DEPAVE movement initiated in the USA and Canada (see p. 101). In Strasbourg, in the framework of the "Strasbourg ça pousse" programme, significant funding is set aside exclusively for the removal of hardscape from public areas (see p. 102). Recently, the *département* of Loire-Atlantique set up a support programme for desealing and renaturing projects which excludes off-ground structures [20].

#2

IDENTIFYING AREAS **WITH HIGH RENATURING POTENTIAL**

METHODOLOGY

The method developed in this guide focuses on desealed spaces where renaturing will improve a region's ecological credentials. They might be oversized car parks, school playgrounds, courtyards of buildings, concrete riverbanks, residual public space that has been needlessly asphalted over and that remains unused, industrial sites, business parks, shopping precincts, etc. Local authorities first need to identify their potential.

Three key challenges make it possible to locate these urban areas:

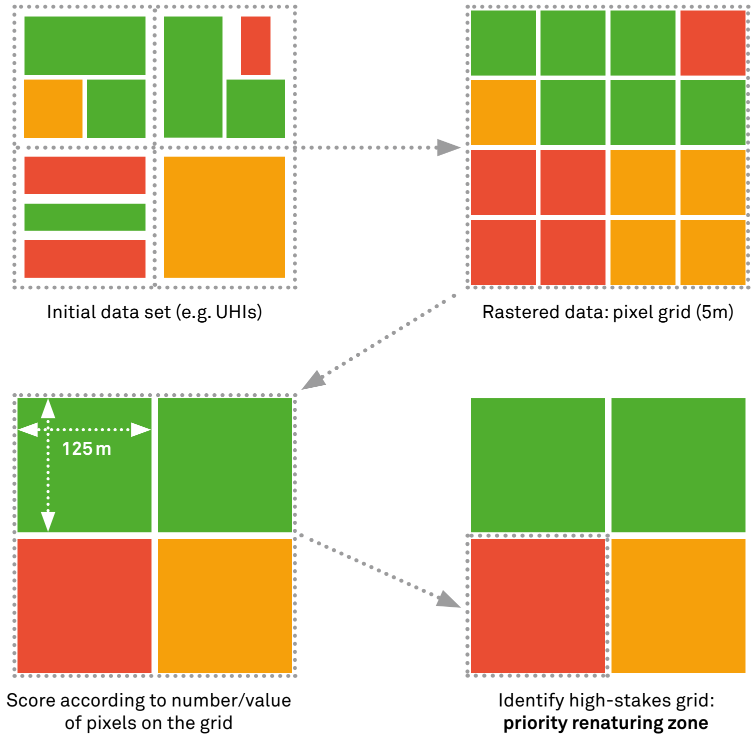
- Restoring biodiversity in target areas that are deficient in terms of biodiversity, by studying the size of green spaces; the percentage of plant cover; and the presence of rare habitats.
- Adapting to climate change in target areas exposed to climate risk: river flooding, runoff and urban heat islands (UHIs).
- Improving health and the living environment in target areas that are vulnerable because of lack of green spaces, air pollution and health problems relating to UHIs.

In order to carry out this analysis, the Paris Region was divided into 125 m x 125 m cells (cell size compatible with the data and studies of the Paris Region Institute). For each challenge (biodiversity, climate change and health), criteria were selected based on advice from experts and available data on the region.
The state of each cell is analysed and converted into a score. For example, a cell exposed more or less significantly to air pollution is given a score that reflects this. A score is thus attributed to each criterion, and then an overall score is given to each challenge. The attribution of overall scores corresponds to the sum total of individual scores for criteria, and the criteria are not weighted in any way. The thresholds that make it possible to attribute scores were based on studies and bibliographical summaries as well as interviews with experts. The results are summarised on pages 32, 50 and 63.
Once the different criteria have been analysed and the overall score attributed, the cells for which the stakes are highest are identified. These are chosen according to their score (a low score reflects high stakes) and according to how many of them there are (having too many cells might highlight an entire area and prevent prioritisation). This first step makes it possible to identify sectors where potential for renaturing is high, but it does not pinpoint sealed sites that could be renatured. To do this, potentially desealable / renaturable sites (school playgrounds, car parks, areas of waste ground, public squares, etc.) were listed based on the land use classification guidelines laid out in the *Mode d'Occupation du Sol* (MOS) published by the Paris Region Institute (see p.27).

The Paris Region (Île-de-France) is an area located in north-central France. It includes the city of Paris and 1,275 municipalities around the capital. The Paris Region is the most populated area in France (12 million inhabitants, 20% of the French population concentrated in only 2% of the country: 1,022 inhabitants per sq.km.). 23% of the region is covered by urban areas (including 16% totally sealed). Outlying areas remain largely rural with agricultural landscapes (51% - mainly intensive open fields) and forests (24 %).

STEP 1

ANALYSIS OF REGIONAL RENATURING CHALLENGES



STEP 2

IDENTIFY UNSEALED SITES WITH RENATURING POTENTIAL ACCORDING TO PREDEFINED TYPOLOGY


Pavements with lines of trees separated by asphalt/paving

Unused parking

Concrete sports grounds

Disused roadways

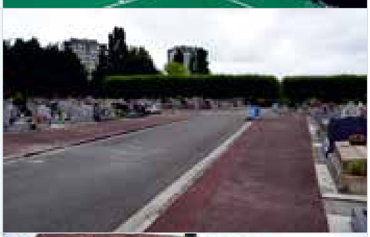
FIGURE 5. Method of spatial analysis

TYPOLOGY OF POTENTIALLY RENATURABLE SEALED AREAS

A typology of sealed areas to be located

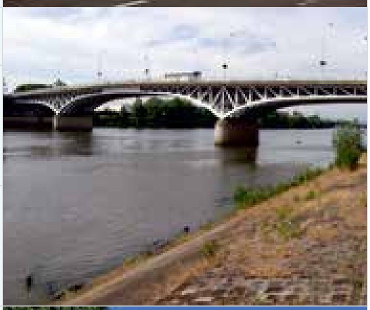
The typology used here, based on the Land Use Classification Guidelines published by the Paris Region Institute, identifies urban areas containing easily renaturable sealed surfaces (without requiring the demolition of existing buildings). The list is based on available data and is not exhaustive: for example, small areas such as the space at the foot of a wall or the space between two trees planted in trenches cannot be located using this method. It nevertheless targets both small and large areas, making it possible to work on a regional or sub-regional scale.

TABLE 3. Typology of potentially renaturable sealed areas based on Paris Region Institute Land Use Classification Guidelines

TYPOLOGY: LEVEL OF DETAIL 1	TYPOLOGY: LEVEL OF DETAIL 2	TYPOLOGY: LEVEL OF DETAIL 3	
OPEN SPACES WHERE LAND TAKE HAS OCCURRED	Public squares	Public squares (pavement, asphalted path, plaza)	
	Urban green spaces	Parks or gardens (associated car parks, roads, asphalted paths)	
	Open spaces intended for sport	Open-air sports grounds (associated car parks, unused sports grounds, areas around sports grounds that are in use)	
		Large-scale sports facilities: golf courses, racecourses (associated car parks, concrete slabs)	
	Cemeteries	Cemeteries (concrete slabs, asphalted paths, associated car parks)	
	Vacant lots/ waste ground	Brownfield sites (concrete slabs, disused buildings)	
		Disused facilities: stations, airports, factories (concrete slabs, disused buildings)	

HOUSING	Collective housing	Residential buildings (inner courtyards, concrete slabs, unused car parks, pavements)	
	Other	Prisons (yards, areas around sports grounds, car parks)	
ROADS	Associated structures	Roundabouts	
		Cul-de-sacs	
		Central reservations	
	Roads	Unused or underused roads and paths	
	Disused roads	Disused roads, roadsides, concrete roadways.	
	Pavements (= sidewalks)	Pavement > 1,40m	
		Pavement with row of trees	

TRANSPORT	Roads	Roads over 25 metres wide (urban freeways, disused roads)	
	Car parks	Ground-level car parks (circulation areas, areas separating parking spots, parking spots)	
	Stations	Stations (car park, square)	
		Edges of tracks	
	Railways	Disused tracks	
FACILOITIES	Schools and colleges	Primary schools (playgrounds, edges of sports grounds)	
		Secondary schools (playgrounds, edges of sports grounds)	
		Higher education (edges of sports grounds)	
	Hospitals and clinics	Hospitals, clinics (car parks, concrete slabs, plazas)	
	Public facilities	Town halls (squares, car parks)	
		Conference and exhibition centres (concrete slabs, car parks)	
		Cultural/Leisure venues: museums, castles, etc. (car parks)	

ACTIVITIES	Economic and industrial	Large industrial facilities (dilapidated areas, car parks, pavements)	
		Business parks (dilapidated areas, car parks, pavements)	
	Shopping	Shopping centres (car parks, pavements, squares)	
WATER COURSES	Covered rivers	Covered rivers	
	Rivers	Riverbanks	
		Asphalted paths	
	Canals	Banks	
		Artificial riverbeds	
		Asphalted paths	

Public squares ©Camille Gosselin/ L'Institut Paris Region. Urban green spaces ©Vincent Gollain/ L'Institut Paris Region. Open spaces set aside for sport ©Pierre-Yves Brunaud/L'Institut Paris Region. Collective and other housing, roads ©Barnabé Duplan-Ival / L'Institut Paris Region. Stations ©Frédéric Larose/ L'Institut Paris Region. Railways ©Paul Lecroart / Institut Paris Region. Schools ©Jean-Claude Pattacini/ Urba Images/L'Institut Paris Region. Health facilities ©Anca Duguet/ L'Institut Paris Region. Public buildings ©Corinne Legenne/ L'Institut Paris Region. Shops ©Pierre-Yves Brunaud/L'Institut Paris Region. Rivers ©Elisabeth Bordes-Pages/ L'Institut Paris Region. Canals (artificial waterways) ©Vincent Gollain/ L'Institut Paris Region. Cemeteries, waste ground, associated structures, roads, disused roads, pavements, abandoned car parks and industrial/business areas ©ARB îdF.

RENATURING TO RESTORE BIODIVERSITY

In the Paris Region, although urban environments account for less than a quarter (23%) of the total surface area, their density is much greater than in other regions (1,022 inhabitants per sq.km). Since the 2000s, biodiversity had declined sharply in towns and cities. In the Paris Region, the abundance of butterflies has fallen 33% and that of birds has fallen 20% in urban areas (*Muratet et al, 2016*). In addition to species decline, the urban environment has also witnessed a process of homogenisation favouring generalist species (e.g. wood pigeons and magpies) to the detriment of specialist species (e.g. swallows and swifts). The population abundance of these specialist birds adapted to buildings fell by 41% between 2004 and 2017 (*Muratet et al, 2016*).

To identify the urban areas to be renatured in order to restore biodiversity, it is important first to locate zones where biodiversity is lowest and where renaturing would offer high ecological gains. Our methodology relies on several criteria drawn from scientific literature and is inspired in particular by Making Nature's City (*Spotswood et al, 2019*). In accordance with the data available on the Paris Region, 3 criteria were selected: planted surface areas; percentage of plant cover; and the presence of rare habitats.

ECOLOGICAL NETWORKS AND CONNECTIVITY

Ecological connectivity is a key factor in maintaining and preserving biodiversity in urban environments (*Shanahan et al, 2011*). It allows species to move from place to place (which is essential for survival and reproduction), increases genetic intermingling between populations and ensures the adaptation and resilience of ecosystems.

In the absence of precise data on a regional scale, it has not been possible to include this criterion in the method. However, local authorities can fine-tune the method by incorporating their own data on ecological continuities in their areas.

The Environment92 association has produced a map of vegetation in urban areas based on very high-definition aerial photographs taken in the *département* of Hauts-de-Seine. In order to show areas of ecological continuity, graph theory was used as an assessment tool for urban biodiversity in the area studied. The connectivity of ecological networks was studied, based on 4 species (European hedgehog, *Myotis bechsteinii* (a species of bat), great tit and meadow brown butterfly). This work provides a more detailed overview of urban areas to be renatured with a view to improving the connectivity of ecological networks. It could be built into the methodology for a more precise approach to spaces earmarked for renaturing in order to foster biodiversity.

CRITERIA FOR LOCATING PRIORITY AREAS

Continuous planted areas

The size of planted areas is one of the main factors that determine biodiversity in urban settings. The larger a habitat[2], patch[3] or biodiversity reservoir is, the more likely it is to be home to a diverse range of species (*Strohbach et al, 2013*). In a study of 75 cities, researchers have shown that to support biodiversity adapted to the urban environment, the minimum size of a habitat is 4.4 ha. Where more sensitive species that usually stay away from cities are concerned (so-called "urban avoiders"), this rises to 53.3 ha (*Beninde, 2015*). On the basis of this information, the following types of areas have been identified in urban environments:

- Micro-patches: planted areas less than 4.4 ha;
- Patches: planted areas measuring 4.4 - 53.3 ha;
- "Areas of special regional interest" [*réservoirs d'intérêt regional*]: planted areas larger than 53.3 ha.

For this criterion, the score was applied in the following way: the presence of a micro-patch in a cell gives it a score of 1, a patch gives it a score of 2 and an area of special regional interest earns it 3 points. If there are no green spaces at all, it scores 0. Where 2 green spaces of different sizes are present in the same cell, only the most promising one is taken into account.

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2. In ecology, a habitat is a set of characteristics and natural resources that constitute an environment allowing a species population to live and reproduce there. A single habitat can meet the needs of several different species. Diverse interconnected habitats form an ecosystem that allows numerous species to thrive and move around.
3. In ecology, a patch is a relatively uniform space that differs from its surroundings. Parks and areas of grass within a built-up area can be considered as patches.

CRITERIA	THRESHOLDS	SCORE	SOURCE
Thresholds	Absent	0	*Vega & Küffer, 2021; Spotswood et al, 2019; Beninde et al, 2015*
	Surface area ≤ 4.4 ha	1	
	4.4 ha <surface area < 53.3 ha	2	
	Surface area ≥ 53.3 ha	3	
Plant cover (%)	Plant cover < 25 %	0	*Threlfall et al, 2017; Szulczewska et al, 2014*
	25 % ≤ Plant cover < 45 %	1	
	Plant cover ≥ 45 %	2	
Rare habitats	None	0	
	Notable trees	1	*Spotswood* et al, *2019 ; Stagoll* et al, *2012 ; Le Roux* et al, *2015*
	Ponds	1	*Spotswood et al, 2019; Ramsar Convention on Wetlands, 2018; Oertli and Parris, 2019; Alikhani et al, 2021*
	Wetlands	2	

TABLE 4. Criteria, thresholds and bibliographical resources used to identify areas of low biodiversity.

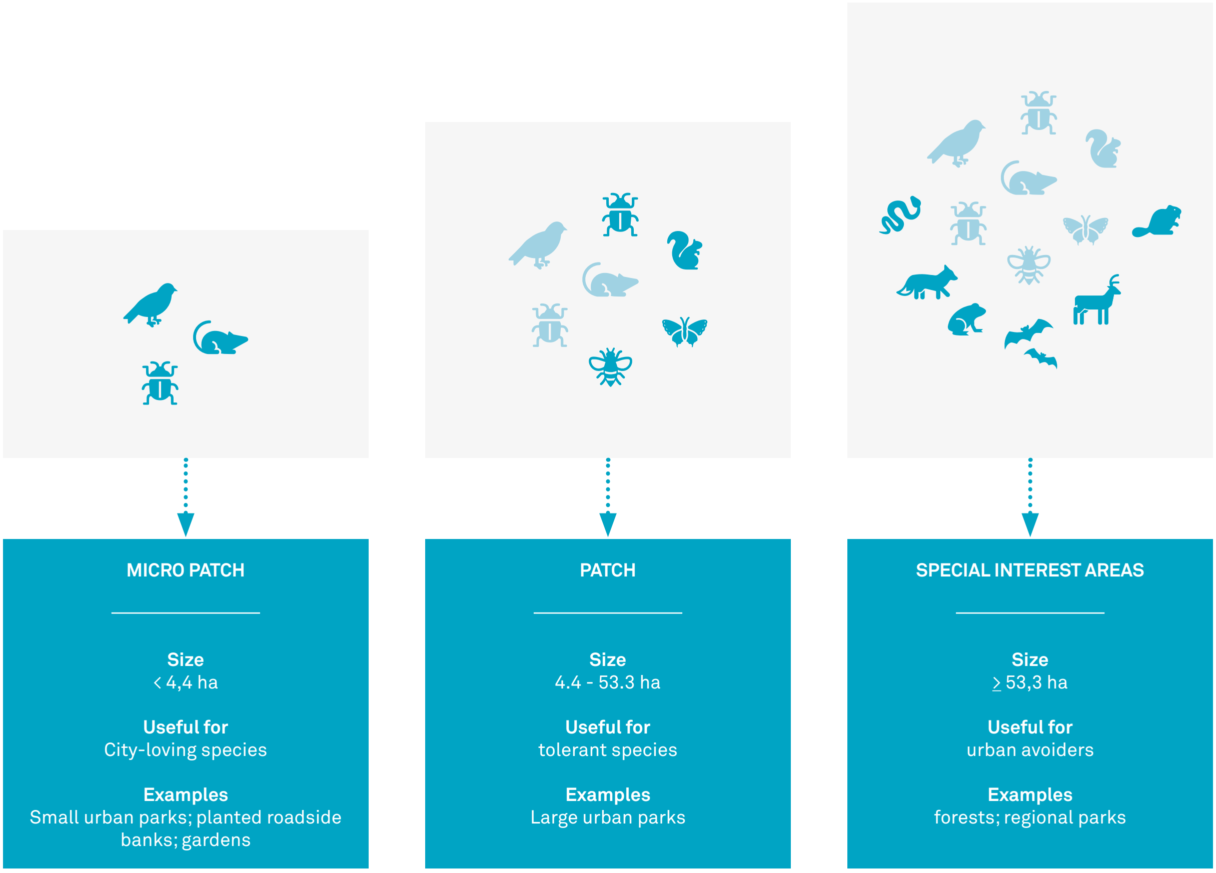


FIGURE 6. Illustration of connection between size of habitat and specific diversity

GOING FURTHER

Although not included in the analysis, private gardens contribute to the green grid (*Riboulot-Chetrit, 2015*) and can serve as refuges and stop-off points for many species, especially if they are ecologically managed (*Goddard et al, 2010*).

Adding this data, as well as an ecological quality index for urban green spaces (based on species diversity, plant strata, management methods, etc.) would make it possible to fine-tune the ecological analysis of an area.

Plant cover in the urban matrix[4]

Several studies have highlighted the importance of plant cover and its positive effect on the number of species present in urban areas (*Aronson et al, 2014*). While urban environments are made up of built-up areas with little greenery, they also feature many planted areas (rows of trees, hedges, gardens, waste ground, riverbanks, cemeteries, etc.) that can provide habitats for numerous species. These spaces can be looked at by analysing satellite images that show the surface area occupied by plant cover. It is generally accepted that the more highly developed plant cover is in a particular area, the more able that area will be to host biodiversity (*Threlfall et al, 2017*).
The difficulty lies in the definition of a threshold above which plant cover begins to offer optimum conditions for biodiversity. In a Polish study (*Szulczewska et al, 2014*), researchers suggest that a minimum of 45% of

4. The urban matrix is here considered to be the set of elements that make up the urban landscape (buildings, roads, etc.), within which can be found patches of greenery that lend themselves to biodiversity. Landscape ecologists also refer to the landscape's ecological matrix, which means the dominant feature of the landscape characterised by a more or less uniform occupation of the land (forest matrix, hedgerow matrix, field matrix, etc.), and in which habitat patches can be discerned.

spaces covered in vegetation (RBVA index[5]) is necessary to provide environmental stability on the scale of the local area. Taking this hypothesis into account, 3 thresholds were selected for our study: a score of 0 for cells where plant cover is less than 25% of the total area; a score of 1 for plant cover of 25% to less than 45%, and a score of 2 for areas that have 45% plant cover or more.

Habitats that are rare in urban settings

Some habitats able to host a high level of biological diversity or specialised species are rarely found in urban areas: for example, wetlands or old trees are ecological niches in which many cohorts of species can thrive. Wetlands (including ponds, lakes, streams, rivers and marshland) play a vital role in terms of the ecological services they provide and also as habitats for many different species (*Stagoll et al, 2012; Hill et al, 2017*). Wetlands (including ponds, lakes, streams/rivers and marshes) play an important role not only in terms of their ecological functions but also in terms of the quality of their habitats (amphibians, odonata, avifauna) (Ramsar Convention on wetlands, 2018; IPBES, 2019). In urban areas, these habitats also offer a refuge for more specialised and even rare species (*Oertli et Parris, 2019; Alikhani et al, 2021*).
Large old trees also play an essential role in conserving biodiversity in urban environments (*Stagoll et al, 2012*): they host more species than smaller trees and offer more diverse habitats due to their age (holes, dead wood, etc.). They are sometimes the only habitats for very specialised species such as saproxylic insects. In response to the decline of old trees in towns, an Australian study recommends preserving old specimens as a priority and protecting them 40% longer than the currently tolerated lifespan (*Le Roux et al, 2014*). In urban settings, the lifespan of a tree is generally 40-60 years (*Peyrat, 2014*).
The absence of such "rare" habitats in an area can reflect a "biodiversity deficiency" that could be remedied via a renaturing strategy. The method analyses the presence or absence of 3 types of habitats: notable trees[6], ponds and other wetland areas (inshore marshes, peat bogs, lakes, humid meadows and marshy woodlands, natural/semi-natural riverbanks). A score of 1 is given to cells with one or more notable trees; a score of 1 to areas with at least one pond; a score of 2 to cells where there is another wetland area. A single cell can accumulate several scores.
Towns can host other habitats of high ecological value that could be called "rare", such as ponds, wetlands and old trees. They also include dry grassland, moorland, meadows, pioneer zones, etc. If spatial data exists at subregional level, for example from inventories of local biodiversity, it can be added to the method and used to fine-tune the analysis.

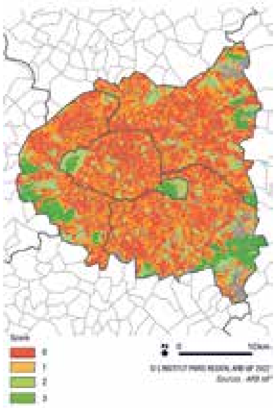
5. The study uses the RBVA or Ratio of Biologically Vital Areas, which means the percentage of areas covered in vegetation across a neighbourhood. Different levels of RBVA were compared on the basis of species inventories and calculations of climate-related parameters.

6. Notable trees are trees that have been identified for their outstanding features (beauty, age and/or size). Although old trees are not always labelled "notable", most of those that have high potential for biodiversity. The data used here comes from notable trees in the Paris Region. Data at sub-regional level would provide this study with an added level of detail.

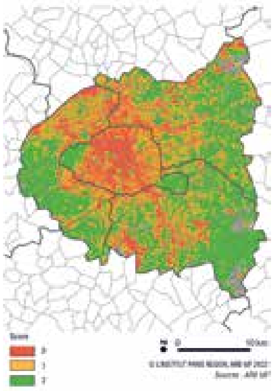

©Gilles Lecuir

WHERE SHOULD RENATURING TAKE PLACE IN ORDER TO RESTORE BIODIVERSITY?

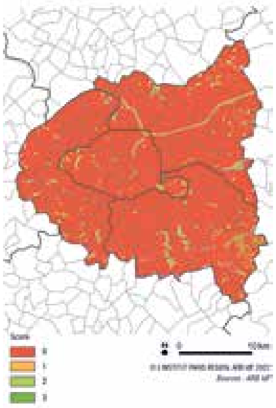
In keeping with the method detailed p.25, low-scoring cells (with a score between 0 and 1) were defined as priority renaturing zones. Spatial analysis reveals that the urban zones with least biodiversity are in the city of Paris. Where the inner suburbs are concerned, the least favourable zones are generally close to Paris and thus correspond to areas that come under pressure from urbanisation and densification, which have adversely affected biodiversity.



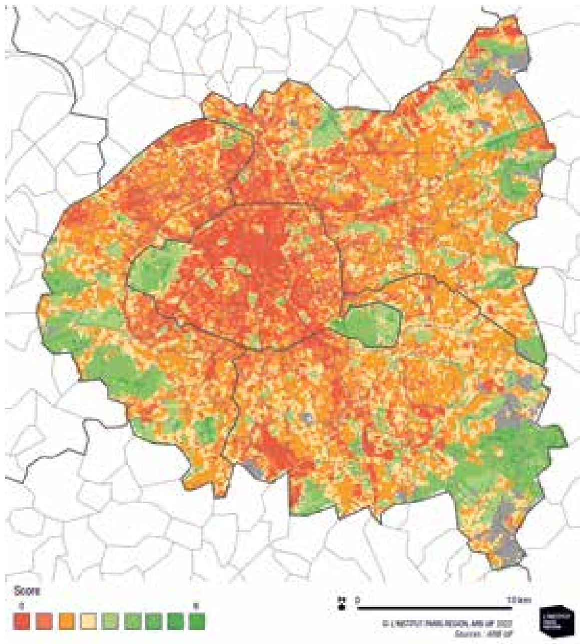
Surface area of planted areas



Plant cover



Rare habitats

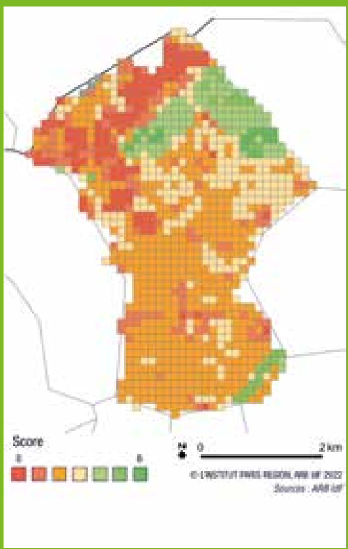


Overall map representing the “Restoring Biodiversity” challenge

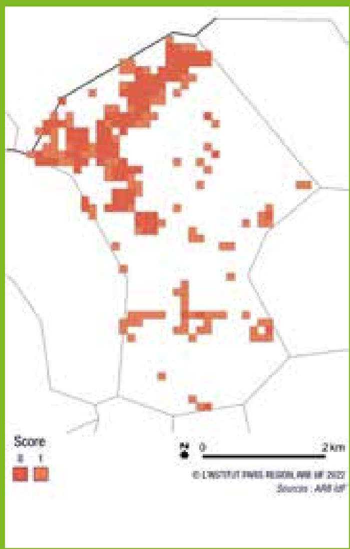
FIGURE 8. Cartographic results of the study of biodiversity criteria and overall map of biodiversity shortfalls corresponding to the sum of scores (on the right). The results shown here only concern Paris and its inner suburbs

EXAMPLE OF APPLICATION IN AULNAY-SOUS-BOIS

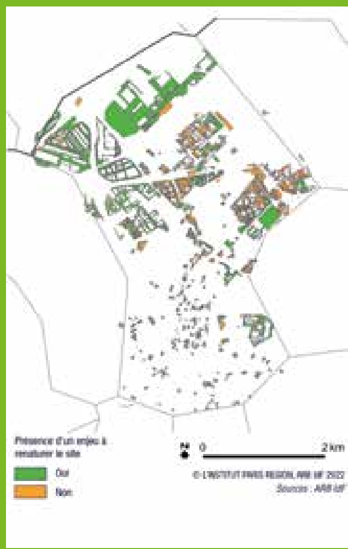
Aulnay-sous-Bois is a town in the *département* of Seine-Saint-Denis in the northeast suburbs of Paris. Analysis (Figure 9.) reveals a total of 264 cells badly lacking in biodiversity (score 0 or 1). Where the rest of the area is concerned, 144 cells suggest good overall quality in terms of biodiversity (score 6, 7 or 8). These correspond to the Parc du Sausset and the Parc Robert-Ballanger (parks in the northeast and northwest of the area) and the banks of the Canal de l'Ourcq (southwest). 747 cells score 4 or 5, which cannot be interpreted as reflecting high quality but does not make these high-stakes areas either.



Overall analysis of the challenge of restoring biodiversity



Identifying priority renaturing zones



Locating potentially desealable and renaturable sites

FIGURE 9. Identification des sites désimperméabilisables dans les secteurs à fort enjeu de renaturation pour la biodiversité sur la commune d'Aulnay-sous-Bois (93).

EXAMPLE OF INTERPRETATION IN THE NORTHERN SECTOR

Renaturing needs are concentrated mainly in the northeast of the area, which corresponds to a heavily sealed industrial zone. In terms of biodiversity, this zone has especially high potential as it is adjacent to the Parc du Sausset (in the northeast of the area), which is remarkable for its biodiversity, has been awarded the Natura 2000 label, and has been identified as a biodiversity reservoir in the SRCE (regional ecological plan).

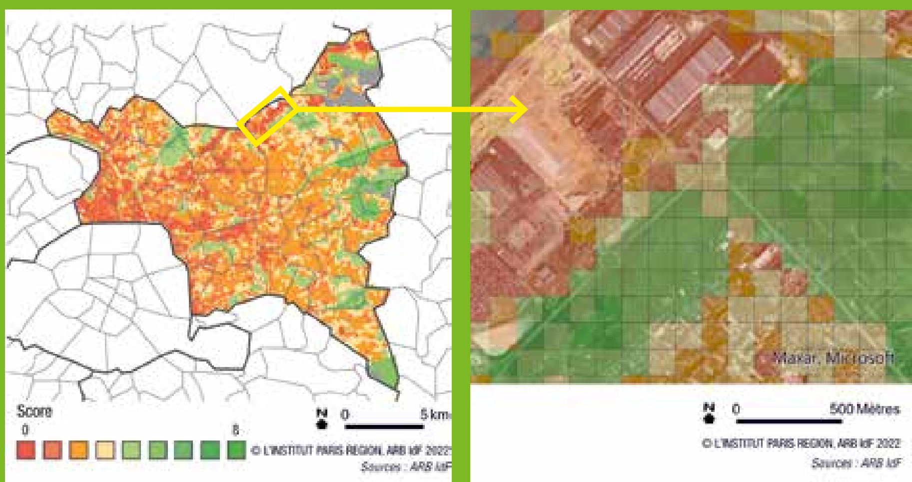


FIGURE 10. Map of areas lacking in biodiversity and example of interpretation for the northern sector of Aulnay-sous-Bois.

FEEDBACK AND RECOMMENDATIONS

Any renaturing initiative, irrespective of its location, can help to improve biodiversity. However, the benefits can be more or less extensive according to the location of the project. It is thus necessary to contextualise renaturing initiatives and not make general assumptions based on the restoration of a single type of habitat. What can be beneficial to one location might turn out to be inefficient and inappropriate elsewhere. With respect to the criteria selected for this approach, several types of recommendations can be made, in particular:

- Extending a biodiversity reservoir, a patch or an area of ecological interest whose size is considered insufficient.
- Re-establishing connections between existing biodiversity patches and reservoirs.
- (Re)creating a habitat or ecological niche for fragile species in urban environments or a community of target species.
- Facilitating the free evolution or restoration of a brownfield dynamic.

Renaturing to create and/or increase the size of habitats

Focusing on extending existing planted areas can help to expand natural spaces in urban environments, in relation to the thresholds presented on p.32. The areas to be desealed will be smaller and the newly renatured area will directly benefit species already present in the park or planted area that has been enlarged. Given that there is an existing natural area nearby, the chances of recolonisation will be higher and better suited to so-called "passive" renaturing. Extending an existing natural area may also target the conservation of a specific group of species, based on knowledge of their ecological niche (see appendix 1).

FIELD REPORT 1

REHABILITATION OF THE KODAK FACTORY (ÎLE-DE-FRANCE)

In brief: rehabilitation of a brownfield site to turn it into an area of high ecological value.

Since the demolition and decontamination work at the Kodak factory in Sevran ended, the 13- hectare site has been left untouched, allowing a range of species to reclaim it as their home. In 2015, based on the results of naturalist inventories, the town council decided to preserve the Kodak brownfield site without further intervention: its various environments, coupled with its size and location, make it into a refuge for urban biodiversity and provide an opportunity to reinforce the ecological continuity of a highly urbanised area. In 2017, CDC Biodiversité and Sevran Town Council adopted a plan for the management of the site in the framework of the Nature 2050 programme [21].

The former Kodak industrial brownfield was demolished and replaced by a park with a wide variety of habitats ©CDC Biodiversity

KEY TAKEAWAYS

- Biodiversity is richer in brownfield sites than in managed parks and gardens because it is able to develop freely.
- Brownfield sites can function as networks and exchanges for seeds and species. Sites larger than 2,500 m² could foster inter-site species exchange, reduce the risk of extinction for plant populations, and supply seeds that could colonise other sites. (*Muratet et al, 2007*)

This document sets out objectives for maintaining existing habitats and recommends allowing spontaneous evolution in some areas. Among other things it recommends proceeding with the ecological restoration of several wetlands; allowing some areas of grassland to recover spontaneously; allowing 3 hectares of woodland to evolve freely; and setting up scientific monitoring programmes to assess the impact and relevance of each management approach.

FIELD REPORT 2

RENATURING BROWNFIELD SITES (HAUTS-DE-FRANCE)

In brief: renaturing brownfield sites adopting a naturalist approach resulting in the classification of one of the sites as a natural area in the local planning protocol.

In the Hauts-de-France region, the Etablissement Public Foncier (EPF: public land developer) has for several years been renaturing brownfield sites. Initiated by the development body's resident ecologist Guillaume Lemoine, several projects have been launched with the aim of creating temporary or permanent natural areas, guided by a naturalist approach primarily targeting flora and insect populations.

Lens-Van Pelt (3.5 ha) is a site formerly occupied by factories which were demolished by the EPF with a view to urban densification. Over 10 years later, the state of the economy, in particular the property market, had changed and EPF decided instead to create a natural heartland in line with the Regional Forestry Plan, whose target was “1 million trees for Hauts-de-France». The renaturing work made it possible to plant an urban forest of local species, to create a variety of different woodland environments, and to restore dry grassland and habitats for xerothermophilous species. Habitats for chiroptera and sand loving hymenoptera were created using materials available on site. A discovery trail was laid out to allow residents to explore the newly created ecosystems. Once the project was completed, Lens City Council modified its local planning protocol to classify the site as a natural area and protect it from any form of urbanisation. The EPF regularly carries out wildlife inventories to follow up on the evolution and success of the renaturing initiative.

On the Houplines-Hâcot-Colombier site (2.5 ha), the intervention of the EPF has revitalised the «bord de Lys» industrial belt in the *communes* of Hazebrouck and Houplines. 12 hectares of land are awaiting the development of a new district that will replace a string of brownfields. Meanwhile, the Hâcot-Colombier site is being temporarily renatured and used for urban agriculture (vegetables and herbs). The EPF has restored the soil and set up biomass cultivation to supply local green spaces with straw mulch. Discussions were initiated with the different stakeholders before the project began in order to define the agricultural trajectory of this “urban third place”. Partners specialising in social and therapeutic integration, compost producers and gardeners worked together to outline a programme coordinated on behalf of the local council by the Compagnie des Tiers-Lieux. Renaturing entails demolition work, dealing with concentrated sources of pollution and maintaining a wooded area within the demolition zone to create a future green space before construction work begins. To improve the agronomic quality of the soil, the EPF has sown fabaceous plants, green fertilisers (phacelia) and flower meadows as well as growing hemp to produce biomass that supplies local green spaces with mulch. The latter represents an “economical” way to use an area awaiting development and makes it possible to test technical aspects of hemp growing in urban settings. The remainder of the EPF programme might involve growing complementary crops, setting up a network of hedgerows to produce biomass, or creating a nursery of local trees to supply the entire region

On the Roubaix-GTI Sodifac site (2.2 ha), timeframes for reviewing local planning protocols and carrying out consultations with developers mean that the land will still be available for several years. As well as “standard” operations to increase biodiversity, improve the living environment and limit urban heat islands, mixtures of cereals and legumes (lucerne and vetch) have been planted to test the value of these areas awaiting development as suppliers of biomass to the city's methanation plant and reduce its reliance on fossil fuels without competing with food crops. A technical partnership with the Lille Agricultural College (JUNIA -ISA) made it possible to determine which combinations to test, to assess the agronomic quality of the soil and to monitor possible contamination of the crops produced. At this stage, the EPF carried out

Temporary flower meadow on the Houplines site ©EPF Hauts-de-France

KEY TAKEAWAYS

- Sites awaiting development can be temporarily renatured, making it possible to test ecological restoration methods or to experiment with local production (nurseries, cultivated plots, biomass, etc.).
- Discussion with residents and stakeholders makes it possible to develop locally relevant projects.
- The approach of EPF Hauts-de-France stands out for its understanding of ecological challenges and its ability to make biodiversity into an asset where other developers see it as a liability (because of the presence of protected species and unwanted temporary modes of use).

demolition and decontamination work on the site, sowed flower meadows for biodiversity and planted various crop combinations. A similar project is underway on the Lille-Hellemmes-Québecor site (1.5/2 ha), also involving the demolition of a former factory (a concrete and metal recycling works). Most of the trees present on site have been retained, and an on-site nursery has been created to preserve trees and shrubs that had to be uprooted.

Improving or restoring ecological continuity

Making it easier for species to move from place to place increases genetic mixing between populations and maintains dynamic, adaptable and resilient ecosystems. Renaturing in urban areas can also help to reinforce ecological connectivity and restore green, blue, brown or black grids. Carefully chosen sites can resolve lack of continuity between adjacent habitats, enlarge an existing corridor or create an extra habitat that acts as a stepping stone. The varied range of recreated habitats and the management methods adopted will also be decisive factors in ensuring the functionality of the different grids. The proposed methodology offers an initial approach to sectors where renaturing could improve ecological connectivity, although further studies must be carried out locally to maximise the likelihood of success for the target species and grids concerned.

FIELD REPORT 3

RENATURING BROWNFIELD SITES IN THE MAUBEUGE-VAL DE SAMBRE AREA (HAUTS-DE-FRANCE)

In brief: renaturing brownfield sites to reinforce the green and blue grid.

In a context of large-scale deindustrialisation, the *communauté d'agglomération* (administrative area) of Maubeuge-Val de Sambre, along with several non-profit and institutional partners, has committed itself to renaturing its brownfield sites. These are mostly sites that have been decontaminated, desealed, restored and returned to nature so that wildlife can establish itself spontaneously. This approach is even more interesting because the local authority first identified and mapped out these sites to craft a renaturing strategy that can reinforce ecological continuities across the area. For example, the former HK Porter site, which used to be a steelworks manufacturing train carriages and locomotives, is now officially an ecological corridor forming part of the Val de Sambre green and blue grid scheme. This site, which mainly consists of a wetland and a woodland left to develop freely, also has several areas of pioneer grassland where swathes of a heritage plant, the round-leaved wintergreen (Pyrola rotundifolia), have become established. On the site of a former power station (Pantegnies), desealing and restoration work has made it possible to recreate both a marsh and wet meadows. This site is now officially classified as a biodiversity reservoir as part of the Val de Sambre green and blue grid plan, and as a regional natural reserve.

Transforming the former HK Porter factory site, which closed 25 years ago, into an ecological corridor called "Les Portes des Marpiniaux".
©CAUE Nord

KEY TAKEAWAYS

- Once these areas have been renatured, local authorities can classify them as "Zone N" [Zone Naturelle] in planning documents so that the sites are protected.
- In 2014 ADEME, the French ecological transition agency, published a guide for local authorities and developers on biodiversity awareness and the transformation of contaminated brownfield sites. In 2018, the association Humanité & Biodiversité also published a collection of articles on renaturing urban and suburban brownfield sites. Renaturing projects on former brownfield sites can retain the spirit of the original factory, which the local community often fondly remembers.

FIELD REPORT 4

DEMOLITION: AN OPPORTUNITY FOR RENATURING (USA)

In brief: study in Cleveland of the potential of demolishing buildings on vacant land to increase urban biodiversity.

In the United States, the city of Cleveland (Ohio) has undergone an industrial and demographic crisis leading to the closure of many factories. Between 2006 and 2010, the city's housing department demolished 5,152 buildings (factories and individual houses), leading to a significant increase of vacant lots. Today, the city has almost 1,400 hectares of wasteland, a large part of which belongs to the municipality. This unprecedented situation has become an opportunity to reimagine the city and study the role of these spaces for urban biodiversity. In a prospective study, several scenarios were proposed to give new uses to the sites freed from construction, such as urban agriculture, water management through natural spaces (nature-based solutions), the creation of green spaces for the population or the development of renewable energies [22].
Between 2013 and 2019, researchers studied the role of these vacant lots as potential habitats for pollinating insects (*Gardiner et al, 2013; Turo and Gardiner, 2019*). Forty plots were surveyed. Despite their small size, all plots supported large and diverse populations of wild bees. A total of 107 species were inventoried, most of which were native, representing approximately 20% of the total bee species found in Ohio. This research shows that soil newly freed from building cover can become a host site for biodiversity within a few years. The researchers' observations confirmed the importance of pioneer and spontaneous vegetation for wild bees, as well as intentionally planted species for pollinators. On a landscape scale, the combination of these vacant lots and their networked functioning is an important factor in maintaining bee communities. While the deconstruction of buildings is still infrequent in the city and difficult to implement, the case of Cleveland offers an unprecedented example of de-densification of the city and reconstitution of a network of wastelands actively participating in the urban green grid.

KEY TAKEAWAYS

- In certain contexts of urban decline, the demolition of buildings and infrastructure can maket it possible to renature many sealed areas and reconstitute ecological networks.
- Restoring ecological continuities in urban environments may involve reconnecting isolated habitat patches, extending existing patches or ecological corridors, or creating "stepping stones"* between habitats within the urban matrix.
- The Florilèges-prairies protocol helps to improve our understanding of the impact of management practices on the ecological quality of meadows, as well as the dynamic that drives the evolution of these environments thanks to a standardised method for monitoring the flora of urban meadows [24]. Managers are provided with several tools: a booklet explaining the protocol, field notes, and a plant identification guide.

* "Stepping stones" refers here to a discontinuous ecological corridor made up of a series of intermediate habitat patches or refuges (permanent ponds, coppices in cultivated fields, etc.)

Demolition in Cleveland. ©Turo and Gardiner, 2020 [23]

FIELD REPORT 5

RESTORING AN URBAN RIVER AND CREATING A NETWORK OF PONDS (GRAND EST)

In brief: restoration of a river and creation of a corridor for green toads.

In the 2000s, the Eurométropole de Strasbourg undertook to resolve an ecological discontinuity identified in its green and blue grid plan. The project had three aims: to renature the river Ostwaldergraben, which was in poor ecological condition; to create a corridor for the green toad (*Bufo viridis*) between two wetland areas located upstream and downstream; and to create new breeding grounds for the toads. Several projects were carried out. In 2012 and 2015. Soil contaminated with chrome was extensively removed and contaminated river mud was removed from the natural environment. The floodplain was made narrower and remeandered to energise its flow, and the earth levees along the Ostwaldergraben were removed to physically reconnect the floodplain with the riverbed. To resolve the ecological discontinuity identified under the Ostwald road bridge, a wildlife underpass was installed to enable animals to cross under the bridge without getting wet. A network of ponds was also created along the river, further reinforcing the ecological corridor. Several wildlife inventories have since demonstrated how effective the initiative has been, with green toads colonizing the site and breeding there the same year the work was carried out.

Spontaneous recolonisation of flora in and around the renatured Ostwaldergraben. ©Rémy Gentner

KEY TAKEAWAYS

- As the notion of connectivity is hard to define and varies from one species to the next, it is possible to rely on average values recorded in scientific studies that can be applied to several groups of species. For example, several studies indicate that a green space located over 300 metres away from another is “disconnected” for butterflies (*Shwartz et al, 2013*), plants (Muratet et al, 2008) and birds (*Hostetler & Holling, 2004*).
- In natural environments, the wider and more continuous corridors are, the more efficient they are and the more likely they are to host numerous species (*Ford et al, 2020*). This principle can also be applied in urban settings by giving preference to wide corridors, for example along watercourses or linear infrastructure. The appropriate size of the corridors varies, however, according to the species being targeted, making it necessary to carry out a preliminary study.
- When urban morphology does not allow the creation of corridors, the presence of numerous interconnected natural areas may be an efficient alternative. A Swiss study shows that areas smaller than 20 sq.m. can provide habitats for several species. Continuity between such areas must be maintained by ensuring they are no more than 50 - 200 metres apart, especially in densely populated areas where large green spaces are scarce (*Vega & Küffer, 2021*).

FIELD REPORT 6

RENATURING RIVERBANKS VIA PLANT-BASED ENGINEERING TECHNIQUES (ÎLE-DE-FRANCE)

In brief: renaturing and managing the banks of the Seine by a social and work integration association.

The heart of the Paris Region has miles of artificial riverbanks (riprap, concrete dykes, sheet piling), especially along the Seine. The decline of natural riverbanks has led to a loss of wildlife habitats. Since 1995, the association Espaces [25] has been renaturing the banks of the Seine to restore ecological corridors and the functions of these ecosystems (i.e. regulating the physical, chemical and hydromorphological quality of streams and rivers).
The association uses ecological engineering techniques such as spiling (willow wands woven between upright posts) and planting beds of bog plants to limit riverbank erosion and restore habitats. In some areas, reedbeds or planted rafts have been used. In total, 575 metres of riverbank and 300 metres of embankments have been restored around the île Saint Germain using plant-based engineering techniques. These initiatives improve water quality by increasing phytopurification, boost species diversity (in the 1970s the Seine was home to only four species of fish; today there are about thirty) and protect threatened birds such as kingfishers.

Willow spiling by Association Espaces on the Île Saint-Germain at Issy-les- Moulineaux to stabilise and replant the riverbank.
©Association Espaces

KEY TAKEAWAYS

- Plant-based engineering techniques provide solutions that limit soil erosion. Thanks to its network of roots, the plant stratum protects the soil from subsidence, rain and wind. In riverbank restoration projects, spiling is often followed by sowing adapted plants or planting willow cuttings.
- Renaturing urban riverbanks helps to slow down the flow of the river, to purify the water, to trap sediments and to regulate water temperature.
- While the advantages of natural rivers for biodiversity are undeniable, they also allow species to move along riverbanks as they adapt to climate change.

FIELD REPORT 7A

RENATURING TO RESTORE BROWN GRIDS (NORMANDY)

In brief: desealing and renaturing a row of trees to improve rainwater management and restore a brown grid.

To improve rainwater management and attenuate the phenomenon of urban heat islands, many local councils have been regreening public areas and desealing pavements. In 2020 Caen City Council launched an ambitious desealing and planting programme for rows of trees along pavements and roads and removed 4 hectares of asphalt in 2023. The first stage of the work removed almost 5,000 sq.m. of asphalt from several rows of trees. As well as planting, the aim is to restore a continuum of soil ("brown grid") so that surface vegetation (herbaceous plants, trees and shrubs) can benefit from this subterranean continuity not only to share nutrients via their roots but also to interact with the fungal network. Desealing is also an opportunity to plant up the soil around the feet of trees and improve connectivity for plants and insects along rows of trees. To date, a total of about 2 hectares of ground has been renatured around the feet of rows of trees.

The street named after the Norman painter Eugène Boudin became much greener in 2021 when part of the asphalt was removed.
©Ville de Caen

FIELD REPORT 7B

RENATURING TO RECONSTITUTE BROWN GRIDS (SWITZERLAND)

In brief: modifying planting trenches for rows of trees.

As well as dealing with asphalt on the surface, it may also be useful to restore the brown grid at a deeper level by removing or reconfiguring individual planting trenches and creating contiguous trenches for the trees. In the framework of the NOS-TREES project (2016-2018), the Canton of Geneva produced a summary of best practices for planting new trees and encourages digging contiguous trenches that are big enough to allow large trees to achieve their potential (ideally 15-100 cu.m. of trench per large tree) to replace smaller individual trenches. This work has shown that the trees are healthier and grow more quickly when individual trenches are not used. It recommends plantings with complex structures (i.e., small and large trees planted at the same time) and combinations of different species with trees planted close to one another in high-quality contiguous trenches [26].

Renaturing to diversify habitats in the urban matrix

In some cases, renaturing may make it possible to create viable new habitats by targeting specific cohorts or by focusing renaturing on a specific area (urban meadows, woodland, thermophiles, sandy soil, etc.). In all cases, habitat diversification creates a range of different living conditions able to host a wide range of species with different ecological requirements. This work must take place on the scale of the entire administrative area, but it can also be relevant at site level if a range of different habitats is provided. For example, diverse plant strata (herbaceous plants, shrubs and trees) will provide a range of different habitats (*Brunbjerg et al, 2018*). In other cases, it is possible to implement an approach focusing on one or more communities of species in order to prioritise certain groups or a particular environment.

An experiment in Geneva shows that trees are healthier and grow much faster when individual trenches are not used.
© L. Chabbey, M. Schaller, P. Boivin, HEPIA, Genève

KEY TAKEAWAYS

- Setting up brown grids providing soil continuity makes it possible to increase the volume of earth available to tree roots and to facilitate rainwater infiltration. Brown grids allow trees to connect at root level and to exchange nutrients and information.
- Species present in the soil also need to move around (*Mathieu, 2015*) to complete their life cycles, to reproduce, to escape occasional changes in their environment, to recolonise an area following an episode of mortality, etc.
- Desealing and greening the areas at the foot of trees may improve colonisation by wild plants, which either spread continuously or non-continuously in the form of "stepping stones" (*Pellegrini et al, 2014*).

FIELD REPORT 8

RENATURING A CEMETERY IN VERSAILLES TO IMPROVE CONDITIONS FOR WILDLIFE (ÎLE-DE-FRANCE)

In brief: renaturing various sealed areas of a cemetery (paths and spaces between graves), planting local species and setting up a monitoring programme via participatory science protocols.

In France, cemeteries are very stark environments with little room for spontaneous flora, of which users often disapprove. Rows of marble gravestones and concrete crypts criss-crossed by schist or gravel paths occupy most of the space, to the detriment of vegetation. Herbicides have long been the most practical solution for weed control. With increased anxiety relating to biocides and the prohibition of certain pesticides pursuant to the Labbé Act of 2019, local councils are increasingly inclined to reduce or halt the use of pesticides and to renature cemeteries.
This is the case in Versailles, which in 2009 halted the use of such chemicals in four cemeteries with a total surface area of 18.5 hectares. In the Les Gonards cemetery, the council has renatured several areas where there was no greenery to make the place more wildlife-friendly. Some of the main paths have been desealed, as have the smaller paths and spaces between the graves. Work has been carried out to create areas of open meadow, to plant a range of local species and to monitor wildlife via the Propage and Florilèges Prairies participatory protocols (see p. 99).
These operations have also improved acceptance of ecological management techniques by actively communicating with residents. The Versailles cemeteries were awarded the EcoJardin label in 2012, reflecting the quality of their ecological management approach.

The first cemetery to receive the Ec oJardin label (2012), Les Gonards has become an integral part of the urban green grid ©Marie Wagner

KEY TAKEAWAYS

- The management of renatured areas is equally essential for restoring and enriching biodiversity. The idea is to adopt an ecological management method or even an unmanaged approach. This decision will depend on the site in question and must go hand in hand with appropriate communication. Not communicating on management practices can result in rejection by residents.
- Scientific monitoring makes it possible to assess your renaturing project and the impact of its management plan on species. It is possible to set up simplified protocols that do not require extensive naturalist skills, such as those offered by the French Natural History Museum in its participatory science programme "Vigie Nature" (see p. 99).

FIELD REPORT 9

RENATURING SOIL HABITATS FOR POLLINATORS IN LILLE (HAUTS-DE-FRANCE)

In brief: creating a network of nesting sites to aid conservation of wild bees.

In 2010, Lille City Council became aware of the huge diversity of its wild pollinators thanks to an inventory of wild bees in the Parc de la Citadelle carried out that year. Since then, almost 120 bee taxons have been identified across the city. This group of insects includes species that depend not only on very specific flora but also on special soil qualities. This refers to soil with sparse vegetation that is often poor and heats up quickly (mesotrophic or even oligotrophic soil, loamy, clay or sandy soil, etc.) to reproduce. As well as developing diversified meadows rich in fabaceous plants and increasing areas of host plants for target bee species (goat willow (*Salix caprea*), the red bartsia (*Odontites vernus*), the purple loosestrife (*Lythrum salicaria*), etc.), the council created a network of nesting sites for species associated with sandy, sandy-and-loamy and clay soils (all oligotrophic and sparsely planted). This network of sites was distributed according to the latest populations identified and mapped onto the main green grid. In total, restoration of these habitats was carried out on eight sites, with volumes of soil ranging from 4 to 20 cu.m. suitable for the plant species necessary for these ground-nesting bees to complete their life cycles (*Odontites rubra, Echium vulgare, Lytrhum salicaria, saules divers, Reseda sp., Lysimachia vulgaris*, etc).

Monitoring the project confirmed the success of these solutions for hymenoptera including bees such as *Andrena vaga* and *Colettes hederae* and several species of ground wasp. Minimum maintenance is planned to remove certain grasses as local rainfall has a high nitrogen content. This initiative draws on in-depth naturalist knowledge and focuses on the ecological needs of wild bee species, the majority of which (70%) are ground-nesting.

Yohan Tison, an ecologist working for Lille City Council, standing in front of a bank restored to provide a home for ground-nesting bees.
©Denis Lagache, Association Les Blongios

KEY TAKEAWAYS

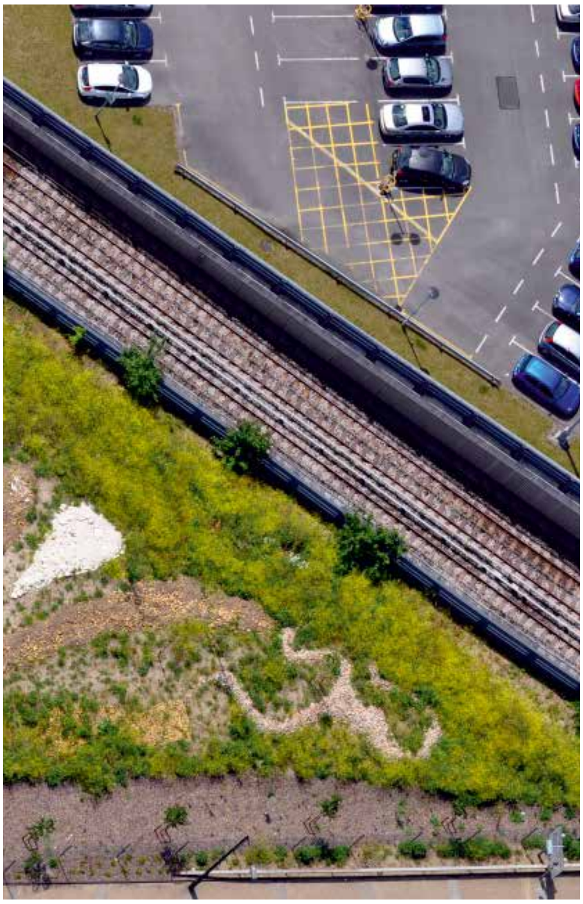
- This initiative relies on extensive naturalist knowledge and focuses on the ecological needs of wild bee species, the majority of which (70%) nest in the ground.
- To limit competition between domestic bees and wild bees in Lille, no new beehives have been set up in sectors earmarked for boosting wild bee populations.
- All new planting programmes, whether to bring wildflowers into the city or when adding new features to the area, involve selecting plants that are of local origin, locally produced, and recognised as good bee hosts and providers of nectar and pollen.

FIELD REPORT 10

LONDON'S "BEETLE BUMP" (UK)

In brief: renaturing project aimed at recreating the habitat of a species whose former home had been destroyed.

In the UK, the restoration of a habitat for the bombardier beetle (Brachinus sclopeta) is a remarkable example of renaturing focused on a single species. The beetle was associated with brownfield sites in London's Docklands in the East Thames corridor, and its last known habitat had to de destroyed to make way for development. In the framework of compensatory measures supported by Buglife (the Invertebrate Conservation Trust) and the University of East London, discussions led to the creation of the Beetle Bump, a renaturing project that mimics the characteristics of a brownfield site and reproduces the beetle's habitat. The operation involved bringing in a mixture of recycled aggregates poor in nutrients and sowing wildflowers typical of brownfield sites in the region (*Connop et al, 2018*). The bombardier beetles rescued from the construction site were moved to the Beetle Bump. Inventories over the ensuing years have demonstrated the quality of the habitat for the beetles and also for other species. In her PhD thesis, the British researcher Caroline Nash proposes similar restoration methods inspired by habitats found in brownfield sites. This "eco-mimicry" approach focusing on communities of species and their habitats seeks to foster change in current landscaping practices (*Nash, 2017*).



Aerial photo of the Beetle Bump habitat creation at the University of East London, Docklands Campus
©Stuart Connop – Sustainability Research Institute

The Beetle Bump (Brachinus sclopeta)
© Stuart Connop – Sustainability Research Institute

KEY TAKEAWAYS

- It is possible to restore habitats targeting a single species or community of species. In this case, it is advisable to enlist the help of naturalist or ecologist organisations.
- Renaturing only makes sense if the restored environments are long-lasting. To ensure that they are, local authorities have a range of tools at their disposal, from land purchase to regulatory protection via their planning protocols.

RENATURING TO FACILITATE ADAPTATION TO CLIMATE CHANGE

The consequences of climate change are already visible in the Paris Region: higher average temperatures (an average increase of about 2°C since 1950), more frequent heatwaves, less frequent cold snaps and sub-zero temperatures, summer droughts and more intense rainfall (*Vautard et al, 2021*). The frequency, intensity and duration of extreme events (heatwaves, flooding, etc.) have increased. Surface sealing and the preponderance of concrete and stone in cities accelerate the effects of climate change, from rainwater runoff to urban temperatures up to 10°C higher than in rural areas during heatwaves. Although strategies exist to adapt to the effects of climate change, the emphasis should be on nature-based solutions due to their co-benefits in terms of biodiversity and quality of life. Renaturing operations in sealed urban areas can meet these needs by reclaiming natural spaces that mitigate the effects of runoff, reduce flood risk and combat heat islands.
To pinpoint the areas most vulnerable to climate change and maximise the efficiency of renaturing with this aim in mind, exposure to the effects of urban heat islands (UHIs), runoff and river flooding have been analysed.

CRITERIA FOR PINPOINTING PRIORITY ZONES

Exposure to the effects of urban heat islands (UHIs)

In urban areas, sealed surfaces and buildings absorb and reflect the sun's rays, heating the surrounding air. This is one of the many factors contributing to the urban heat island (UHI) effect, resulting in higher temperatures in dense urban areas than in rural areas. The difference in temperature between densely populated areas in the centre of Paris and the Bois de Boulogne and Vincennes is around 4°C in standard summer conditions (summer 2000) but can be much greater in times of extreme heat: 8°C in 2015 and 10°C in 2003 [27]. This phenomenon has many harmful effects on health and wellbeing, energy consumption (air conditioning) and biodiversity (hydric stress and increase in species mortality).
Exposure to UHIs was analysed using the indicator "Aléa jour" [daytime hazard] produced in the framework of the project titled "Adapter l'Île-de-France à la cha-

CRITERIAS	THRESHOLDS	SCORE	SOURCE
Exposure to effects of UHIs	High	0	*Cordeau, 2017*
	Medium	1	
	Low	2	
	Cooling	3	
Exposure to runoff	High	0	*Paris Region Institute*
	Medium	1	
	Low	2	
Exposure to flood risk	High	0	*Paris Region Institute*
	Medium	1	
	Low	2	

TABLE 5. Criteria, thresholds and bibliographical resources used to identify urban areas that are most vulnerable to climate change

leur urbaine"/"Adapting the Paris Region to urban heat" (*Cordeau, 2017*). The effect of UHIs represents a hazard, reflecting the likelihood that heatwaves will worsen locally. The "Aléa jour" indicator is calculated from parameters that generate UHIs: soil sealing, number of built surfaces, ventilation, thermal properties of materials and shade from trees.
According to these parameters, an area will have either potential for the hazard to worsen (increasing the effect of the heatwave) or lessen (e.g., in the case of urban cooling islands). In the framework of the analysis carried out here, a score of 0 is attributed to a cell with a high potential for worsening, a score of 1 for medium potential for worsening, a score of 2 for low potential for worsening and a score of 3 for cooling potential.

Exposure to runoff risk

Runoff in urban environments is likely to occur more frequently due to increasingly heavy rainfall; it consequently amplifies the effect of land take. As well as increasing the risk of flooding, runoff also affects the water quality in rivers and streams. During heavy rain, drainage networks can be saturated and runoff mixes with sewage. Overloading the system that carries sewage to the purification plant can cause polluted water to overflow into natural environments from stormwater overflows, even when rainfall is of average intensity [34].
Exposure to runoff has been studied based on the runoff index established by the Paris Region Institute. This index compares different datasets such as land use surveys (split into three categories: heavily sealed areas; moderately sealed areas; lightly sealed areas) and the risk of heavy runoff due to local topography (studied by applying three categories of slopes: steep, moderate and gentle). For further details, please see appendix 3).
The values associated with each category are summarised in the table below. Cumulative values are reclassified to obtain a score of 0 to 2 (values in bold) reflecting exposure to runoff risk depending on the slope and the degree of ground sealing. A score is then attributed to the cells according to the principal risk: high exposure to runoff scores 0, medium exposure 1 and low exposure 2.

In urban settings, runoff is increased by ground sealing.©Nicolas Hannetel / Agence de l'Eau Seine-Normandie

SLOPE / SEALING	STEEP (= 0)	MODERATE (= 1)	GENTLE (= 2)
HEAVY (= 0)	0 → 0	1 → 0	2 → 1
MODERATE (= 1)	1 → 0	2 → 1	3 → 2
LIGHT (= 2)	2 → 1	3 → 2	4 → 2

TABLE 6. Cross table analysing exposure to runoff depending on slope and degree of sealing

Exposure to flood risk

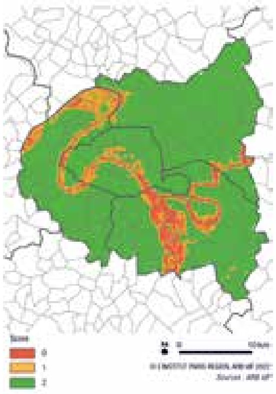
Rises in water level are natural phenomena that may result in flooding. Flooding is a major risk in France, with almost 17 million people exposed to the risk of rivers bursting their banks [28]. Increasingly heavy rainfall associated with climate change will amplify this phenomenon (according to some scenarios, a 20% increase in heavy rainfall events is expected by the end of the century) (*Coppola et al, 2021; Soubeyroux, 2020*).
Rising water levels and flooding are not only due to rainfall but also to the adaptation of catchments, the management of streams and rivers, land use and ground sealing. To study the cumulative impacts of land take and flood risk, different datasets were compared. Land occupation was divided into three categories: unbuilt areas; open built areas (parks, cemeteries, etc.); and densely built-up areas (housing, business parks, etc.). Flood risk is studied via three categories of hazard: low; high; and very high (for further details, please see appendix 4).
The values associated with each category are summarised in the table below, then reclassified to obtain a score from 0 to 2 (values in bold). This provides information reflecting exposure to flood risk depending on land occupation and potential intensity of flooding. A score is then attributed to the cells according to the principal risk in the cell: high exposure to floods earns a score of 0, moderate exposure 1 and low exposure 2. Table 7; Cross table analysing exposure to flood risk depending on land use and potential intensity of flooding.

HAZARD / TYPE OF AREA	STEEP (=0)	MODERATE (=1)	GENTLE (=2)
UNBUILT (= 3)	5 → 2	4 → 2	3 → 2
OPEN (= 1)	3 → 2	2 → 1	1 → 0
DENSE (= 2)	2 → 1	1 → 0	0 → 0

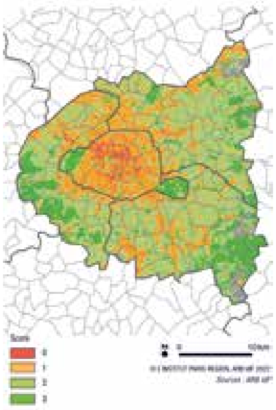
TABLE 7. Cross table analysing exposure to flood risk depending on land use and potential intensity of flooding.

WHERE SHOULD RENATURING TAKE PLACE TO HELP A REGION ADAPT TO CLIMATE CHANGE?

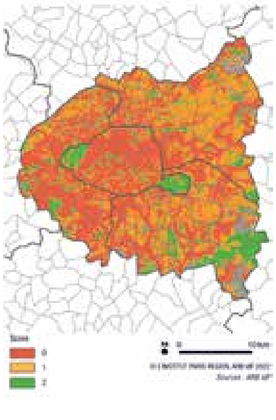
Following the method described p.25, low-scoring cells (0 - 3) were defined as priority renaturing zones. Applied to the perimeter of the inner suburbs, the analysis shows that the urban areas most exposed to the effects of climate change are in Paris itself, but also more broadly along the Seine and the Marne, where urbanisation leads to high exposure to flood risk. As far as the *départements* of the inner suburbs are concerned, exposure decreases the further one gets from dense urban areas.



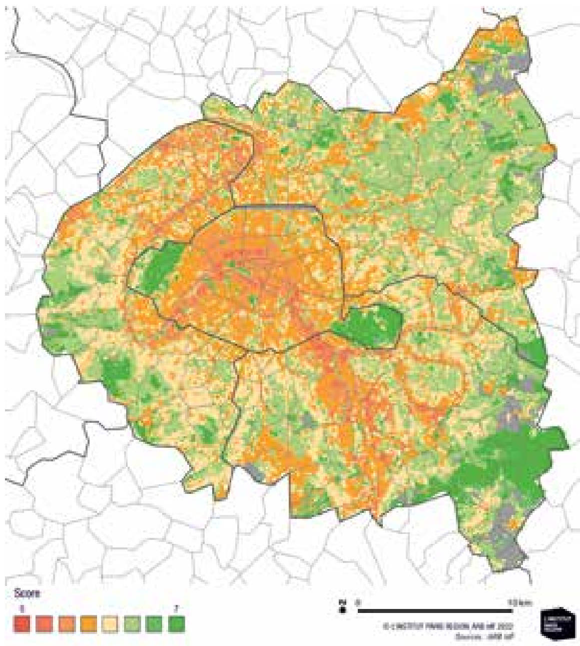
Exposure to flood risk



Exposure to UHI



Exposure to runoff risk

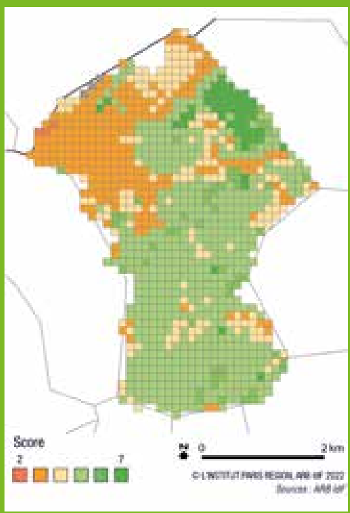


Overall map of exposure
to the effects of climate change

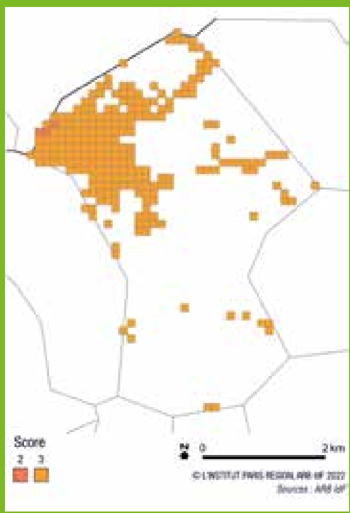
FIGURE 11. Cartographic results of the study of chosen criteria (left) and overall map of exposure to effects of climate change, corresponding to the sum of criteria scores (right). Results shown here only concern Paris and its inner suburbs.

EXAMPLE OF HOW THE METHODOLOGY WAS APPLIED TO THE TOWN OF AULNAY-SOUS-BOIS

The analysis reveals a total of 280 cells highly exposed to the effects of climate change (scoring 2 or 3). Renaturing needs are concentrated in the northwest of the area, which corresponds to an extensively sealed industrial zone exposed to runoff and UHIs. As for the rest of the area, 748 cells have low exposure (scoring 4 or 5). 127 cells have very low exposure (scoring 6 or 7) and are low priority for renaturing projects targeting adaptation to climate change



Overall analysis of the "Adaptation to Climate Change" challenge



Identification of priority renaturing zones

Location of potentially desealable and renaturable sites

FIGURE 12. Identification of desealable sites in sectors highly exposed to climate change in Aulnay-sous-Bois (Paris Region, *département* of Seine-Saint-Denis).

EXAMPLE OF INTERPRETATION OF RESULTS FOR IVRY-SUR-SEINE

Spatial analysis for Ivry-sur-Seine reveals a heavily sealed urban area, which is also a floodable area and thus highly exposed to risks of flooding and runoff. The degree of sealing also causes a significant UHI effect. Renaturing would not only protect existing infrastructure from flood risk, it would also limit the impact of heatwaves (with efficiency depending on the size of the renaturing programme).

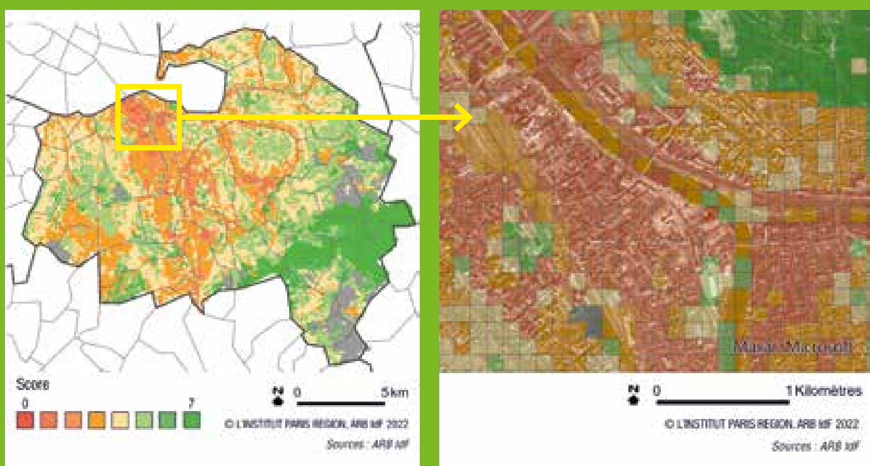


FIGURE 13. Map of exposure to climate risk in Ivry-sur-Seine

FEEDBACK AND RECOMMENDATIONS

In terms of adaptation to climate change, renaturing can target several trajectories depending on the area concerned to respond to one or more types of vulnerability that have been identified. Several types of recommendations can be formulated, for example:

Restoring and remeandering urban rivers and renaturing riverbanks

Restoring floodplains and other buffer zones to cope with overflow (wetland meadows, networks of ponds, lakes, alluvial woodland)

Increasing the number of alternative rainwater management systems in previously sealed areas (floodable gardens and parks, networks of ponds, lakes, rain gardens, planted swales, etc.)

Increasing the density of tree and plant cover in paved streets, in popular public squares and along roads.

Renaturing to create floodplains and manage flood risk

In France, most watercourses have been altered by human interventions (rectification, embankment, channelling, covering) which have adversely affected their functionality, leading to an increase in flood risk during heavy rainfall. In parallel, most wetlands and marshes acting as rainwater storage areas in or near towns and cities have been drained or sealed. Rivers are often deprived of their annexes (floodable meadows and floodplains) which used to act as overflows during storms. For example, in the inner suburbs of Paris, the areas surrounding major riverbeds are almost all urbanised, compared to 30% in the outer suburbs.

Renaturing existing watercourses, remeandering them, or in some cases restoring them entirely, can improve their flow and increase their storage capacity. Ecosystems associated with rivers such as riparian woodland also help to maintain riverbanks and slow down river flow. Faced with increased risk of flooding, more and more local authorities are planning to restore floodable wetlands next to large rivers and to restore urban watercourses.

FIELD REPORT 11

THE VIGNOIS FLOODPLAIN (ÎLE-DE-FRANCE)

In brief: creation of a biodiversity-friendly floodplain.

The Vignois site in Gonesse is one of the most successful examples of a nature-based solution explicitly designed to manage flood risk and provide benefits for biodiversity. The operation carried out by the SIAH (Syndicat Intercommunal d'Aménagement Hydraulique) in 2019 involved creating a 12-hectare wetland with a storage capacity of 55,000 cubic metres to protect the area from flooding when the River Croult

Permanent and temporary wetlands on the Le Vignois site, which has become a floodplain © SIAH Croult et Petit Rosne

breaks its banks and due to rainwater runoff.
Co-construction by ecologists, landscape designers and planners made it possible to design different hydrological regimes and diverse habitats such as meadows, reedbeds, willow groves and copses. Several wetlands and lakes are interconnected. The site is not lit at night to maintain a "dark corridor" for birds and bats. In terms of vegetation, some species have been planted but the existing trees have been protected and spontaneous vegetation is accepted. Although the main goal is flood management, this wetland also offers a range of habitats for biodiversity.

Since 2020, biodiversity monitoring (based on standard protocols from participatory science programmes allowing comparison over time) has been carried out on several taxons (moths, dragonflies, orthoptera, pollinators, reptiles, amphibians, plants, birds, bats and small mammals such as hedgehogs, squirrels, rats, hares). After three years, early results confirm that the restoration of wetlands has a significant impact on biodiversity as well as adaptation to climate change. While the Le Vignois site was originally fallow farmland, similar operations on sealed sites are possible with even greater benefits.

KEY TAKEAWAYS

- Il It is important to involve residents at an early stage of the project as acceptance of the presence of water in urban areas cannot be taken for granted. Preconceived ideas relating to cleanliness, or the presence of mosquitoes need to be lifted before the project goes ahead.
- The creation of wetlands can be planned on several different scales to interconnect restored wetlands, facilitating species movement and reinforcing the blue grid.
- On larger sites it is advisable to create diverse habitats (meadows, reedbeds, copses) offering a range of ecological niches for different taxonomic groups.
- Post-project monitoring should assess the project's impact on biodiversity and improve knowledge of renaturing in urban settings.

FIELD REPORT 12

RENATURING AND LANDSCAPE MODIFICATION AT THE PRÉS DE VAUX BROWNFIELD SITE IN BESANÇON (BOURGOGNE-FRANCHE-COMTÉ)

In brief: conversion of a brownfield site causing a heat island and flood risk into a 5-hectare park that will help combat both risks while offering a recreational area for the population.

Les Prés de Vaux is a brownfield site that was abandoned 30 years ago. Nestling in a bend of the River Doubs near Besançon city centre, it is in a flood zone and is highly contaminated due to its industrial past. The ground is totally impervious due to buildings and ground sealing. The site is not only a significant heat island near the city centre; it also significantly increases flood risk should the Doubs burst its banks. Besançon City Council purchased part of the land to demolish the buildings and convert the site into a 5-hectare park. The aims are to deseal and restore natural environments to reduce the heat island effect and restore a floodplain upstream of the city centre; to create a cultural trail highlighting the history of the site in response to requests from the local community; to diversify environments by systematically applying ecological or passive management approaches. The flood expansion area has been re-established upstream of the city centre; a cultural trail retracing the history of the site has been created in response to requests from residents, and some of the buildings bearing witness to its industrial past are being converted into premises for sports clubs.
Demolition began after wildlife analysis was carried out. The riparian woodland and desealed areas will be planted and nature will be left to take its course. Plantings and seed sowing will merely speed up the natural recolonisation of the park. The seeds were collected by council staff in surrounding natural areas (riverbanks, hillsides, etc.). Specific combinations have been put together according to the different environments to be restored. Many environments have poor, shallow soil that encourages the growth of pioneer flora making it possible to see the different phases of the site's transformation. Special care will be taken to avoid the appearance of invasive exotic species during and after the work. Some buildings will be retained and used for leisure activities. Special gardens will be laid out to make the transition between restored areas and areas left untouched to preserve the memory of the site's history. The principle of these gardens is to encourage natural recolonisation on concrete slabs on which buildings used to stand and former circulation roads.
In total, over 2.5 ha will be desealed, including 1.8 ha. given over to the creation of natural environments. The creation of new habitats (dry grassland, ordinary grassland, dense shrubs, planted swales and water collection basins, etc.) and the implementation of ecological management methods will make it possible to create refuges for biodiversity.

The Prés de Vaux brownfield site in Besançon, located on a bend in the River Doubs. © Gwendoline Grandin

KEY TAKEAWAYS

- Reusing earth and rubble from the site itself avoids having to transport material (creating CO_2 emissions) and transferring impacts to other sites where exported material would be stored or from which topsoil would be removed.
- Restoration work can combine the two types of renaturing: passive and active. For reseeding, local species should be used. It is possible to mix seeds harvested from natural areas around the site, while being careful not to «plunder» these areas, which could limit their own capacity for future regeneration.
- Keeping poor soil can be an option to encourage pioneer plants or plants specific to such soils. Many remarkable or poorly conserved plant species only grow in this kind of environment.

FIELD REPORT 13

AGGLOPOLYS FLOODPLAIN (CENTRE VAL-DE-LOIRE)

In brief: gradual de-densification of a 60-hectare district to create not only a floodplain to help manage flood risk but also functional natural and agricultural areas.

In keeping with its flood risk prevention plan, for almost seventeen years Agglopolys, the *communauté d'agglomération* (area council) of Blois, has been recreating a floodplain for the River Loire in a district called La Bouillie. Located on the south bank of the Loire, the 60-hectare district is being gradually de-urbanised. A *zone d'aménagement différé* (gradual development zone) has been designated, giving Agglopolys the opportunity to purchase buildings and houses on sale before demolishing them so that the sites can be restored.

Since 2004, 132 buildings have been purchased and demolished out of 143 that have been identified. Various surveys carried out on the area's history, landscape, ecology, hydrology, etc. have made it possible to plan La Bouillie's future use. As well as managing river flooding, the project aims to restore functional natural areas (shrubland, meadows, hedgerows, wetlands) and agricultural areas (farms, public or non-profit orchards, allotments). The new area will also be an attractive place to walk, reconnecting residents with the River Loire, the River Cosson and the forest of Russy. Far from being set in stone, this programme forms the basis for debates and discussions to which all local stakeholders can contribute. Workshops and public consultations were held in 2021 to improve participation and foster appropriation by the local community.

The La Bouillie district to be de-urbanised in order to restore a floodplain. © *Agglopolys*

KEY TAKEAWAYS

- To manage the risk of flooding, it is possible to implement a gradual land purchase scheme to carry out de-densification projects that will eventually make it possible to restore a floodplain.
- If the site is large enough, a range of areas can be restored: some for biodiversity (meadows, woodland, wetlands) and others for farmers and residents (orchards run by community associations, allotments).

FIELD REPORT 14

RESTORING THE PETIT ROSNE IN SARCELLES (ÎLE-DE-FRANCE)

In brief: restoring a channelled and covered river to manage flooding due to runoff while offering new habitats for biodiversity and a place for residents to enjoy.

In 1992, the centre of Sarcelles found itself under 1.50 metres of water following heavy storms. The Petit Rosne, shrouded in concrete, could only overflow when its water level rose. After several years of surveys, the Syndicat mixte d'Aménagement Hydraulique du Croult et du Petit Rosne (SIAH), in partnership with Sarcelles Town Council, decided to open up a stretch of this forgotten river. Work began in 2014 with the aim of controlling flood risk and restoring nature in this urban area. Along a 165-metre stretch, a new riverbed was dug, the banks were reinforced and planted using ecological engineering techniques for part of the project. Despite the lack of available space and the high degree of urbanisation in the area, the Petit Rosne has returned to its original course and a number of added amenities have made the site completely accessible.

As the river had been covered over and flowed along a concrete tunnel, no prior inventory of the watercourse could be carried out. A ground-level wildlife inventory was nevertheless carried out in 2010 before the work began. This highlighted the potential for an area of wet woodland at right angles to the new meander. The existing woodland was thus retained, both for its value as a landscape feature and for its ecological potential. A post-project wildlife inventory was carried out in 2017/2018, laying the foundations for a long-term monitoring programme including fish, bats, moths, birds and plants. Water quality was also measured upstream and downstream in 2018. A few months after the project was completed, the first aquatic species (sticklebacks and aquatic macro-invertebrates) were observed.

A poll was carried out among users of this stretch of river in March/April 2018 to assess public perceptions at each stage of the project: initiation, restoration work and day-to-day management. The poll shows that a return to nature in urban areas requires awareness on the part of residents and that more extensive communication in the initial stages, during the work and post-project would have resulted in better acceptance of the "wildness" of the site (unmown grassy banks, diversity of plant species, etc.). Since that time, the SIAH has made consulting with residents a strategic plank of its operations. Opening up the river is nonetheless part of a dynamic of local reappropriation that is to continue with the creation of educational gardens on the riverside.


Before and after opening up the river in a densely built-up area of Sarcelles. © SIAH Croult et Petit Rosne

KEY TAKEAWAYS

- The restoration of the watercourse, which was entirely concreted over, requires a great deal of civil and ecological engineering expertise.
- The creation of a diversified hydromorphological profile (sinuosity, flow velocities, sunshine, shade) ensures varied opportunities for nesting, feeding and reproduction for various species that are dependent on the aquatic environment
- The management of the renatured site must be anticipated as early as possible, both in terms of its technical aspects (maintaining vegetation, monitoring biodiversity) and its social aspects (safety, waste management, communication with residents). Co-construction with the population facilitates the acceptance of wetland renaturation projects.

Renaturing to limit runoff

On the initiative of water boards, planted areas are increasingly being used as an alternative method of managing rainwater. These techniques have the advantage of being close to the natural water cycle, relying on natural soil infiltration, the creation of multiple planted areas and the rehabilitation of wetlands and rivers. They protect the quality and quantity of water-related resources (reducing the amount of polluted water released into the environment and naturally recharging water tables) and reduce the risk of flooding and runoff.

Several towns in the Paris Region are gradually replacing grey infrastructure (concrete tanks, artificial basins) with rainwater management solutions and floodable green spaces. Several publications have shown that these solutions have the potential to provide a habitat for biodiversity (*Monberg et al, 2019*). However, certain developments are little more than landscaping. Specialists have also stressed the need to improve the design and operation of rainwater management systems (improving structural diversity and irregularities on riverbanks, lighter mowing, etc.) so that they have a positive impact on biodiversity (*Oertli et al, 2019*). These solutions must consider the need for species that live in these environments to move by encouraging the removal of uncrossable barriers (fences, etc.) that prevent connectivity with other wetlands or green spaces (*Ahn et al, 2019*). More effective partnerships between landscapers and urban ecologists might help to adjust design and management practices and achieve more efficient biodiversity conservation.

As the methodology outlined in this guide shows, local authorities have a very large amount of sealed and paved areas at their disposal which could be desealed and planted to manage rainwater in sectors subject to runoff. A range of different solutions exist on all scales. Improved water management primarily requires the presence of trees, which are able to store large amounts of rainwater. Improving rainwater management involves restoring receptor environments such as wetlands and ensuring the presence of trees, which are able to store large amounts of water, although this storage capacity varies between species and increases with the size and age of the tree.

FIELD REPORT 15

MOVING FROM GREY INFRASTRUCTURE TO ALTERNATIVE RAINWATER MANAGEMENT (ÎLE-DE-FRANCE)

In brief: floodable green spaces to replace underground water tanks in the *département* of Seine-Saint-Denis

Renaturing in urban environments can make it possible to replace grey infrastructure with ecosystems able to manage rainwater and runoff. Alternative rainwater management solutions such as planted swales, ditches, basins and floodable parks are increasingly being used by local councils (*Monberg et al, 2019*). Since the early 1990s, the *département* of Seine-Saint-Denis has focused on managing rainwater at source to relieve saturated drainage systems during heavy rain. In several towns, the council has created multi-functional landscaping that responds to the question of rainwater management while improving the living environment and fostering biodiversity in sectors where green spaces are often few and far between.

Created between 2002 and 2006, the *zone d'aménagement concerté* (ZAC: priority development area) of Clos Saint Vincent in Noisy-le-Grand was designed to manage rainwater in the open air, making the public park multi-functional. The "artists' garden", covering 2 hectares, is floodable and receives runoff from the park and neighbouring rooftops. In heavy rain, the garden is able to retain 570 cu.m. of water, and raised walkways allow visitors to move across the garden when it is submerged. The garden and surrounding amenities make it possible to avoid ground sealing and to control rainwater runoff while bringing water back into urban space as a visual feature.

Renaturing to combat heat island effects

Natural spaces in urban areas help to reflect the Sun's rays, unlike most concrete surfaces which directly absorb the Sun's energy and turn it into heat. Numerous scientific studies confirm the role of vegetation in reducing urban temperatures through shade

and evapotranspiration, especially during the hottest months, thus reducing the urban heat island effect (*Bowler et al, 2010*).
The size and composition of green spaces are also important factors that influence both the cooling effect and how far it extends. A study carried out in London points out that areas of 5 to 15 hectares have a cooling effect of 0.6 to 1 degree that can be measured 180 – 330 metres beyond the study site (*Monteiro et al, 2016*), which is not the case for areas smaller than 0.5 ha where effects on the surroundings are negligible. The ADEME (French Energy and Environment Agency) summary titled "Planning with Nature in Urban Areas" [29] details this correlation and states that "*Inside a park, the difference in temperature compared to built-up areas is significant and varies in particular in proportion to surface area: 2.5°C in a 20-hectare park and 1°C in a 10-hectare park in Valencia; 2°C in a 50-hectare park and 3°C in a 200-hectare park in Berlin.*"

Creation of a floodable parks in the Clos Saint-Vincent district of Noisy-le-Grand ©Département de Seine-Saint-Denis

KEY TAKEAWAYS

- For these installations to be effective in terms of water absorption, it is important that they should remain covered in vegetation and that the soil should not be compacted. The height of the vegetation and the presence of multiple plant strata slow down rainwater before it reaches the ground, giving it more time to be absorbed.
- Temporary wetland areas are as valuable as permanent ones and host different groups of species. It is essential to share information about the specific characteristics of such habitats.
- Overintensive management applied to these areas often has a negative impact on biodiversity. Researchers suggest drastically reducing management interventions (especially mowing) to allow flora to thrive. Close mowing around the edges of lakes is disastrous for invertebrates.
- It is necessary to avoid trampling and keep vehicles off areas that facilitate water infiltration (for example by ensuring that they are covered in dense shrubs).

FIELD REPORT 16

THE TIERCE FORÊT IN AUBERVILLIERS (ÎLE-DE-FRANCE)

In brief: transforming a residents' car park into a recreational area designed to combat the UHI effect.

The Tierce Forêt ("Third Forest") project involved renaturing a car park and sealed plaza in front of a building in Aubervilliers. Its aim was to improve the living environment for residents of the building and to reduce the particularly high heat island effect on the site. The project grew from the idea of turning the car park in front of the building, a hostel for young workers, into a cross between a park and a square for the use of residents and employees. Soil analysis assessed the agronomic, physical, chemical and biological quality of the existing soil, sparking a conversation on how on-site restoration techniques could avoid the need to bring in topsoil from elsewhere.

The soil was restored using decompacted soil from the site, demolition materials and compost. To restore the water cycle, the sealed areas were replaced by permeable ground covering, including the heavy vehicle access road that had to be retained to allow the fire brigade to access the building. A rainwater reservoir was built using clay soil to avoid the use of in-ground concrete structures. To avoid the use of plastics, the new drains are made of terracotta. The reservoir is a useful source of water for the trees and extends the cooling effect in periods of drought. Where the planting strategy is concerned, solar irradiance measurements guided the choice of areas to be planted. The idea was to have a large canopy where the surrounding buildings provide the least shade. The species planted are local and selected for their ability to resist urban conditions. The roots were also mycorrhized to help the plants to absorb water and minerals from the soil. Last but not least, a meteorological station was installed to monitor the efficiency of the project. Early studies show an average temperature reduction of 2°C under the canopy, with perceived temperature said to be up to 6°C lower than before.

Replacing a car park with a cool island. © FIELDWORK Archi

KEY TAKEAWAYS

- Using excavated earth and demolition rubble from the site itself to reconstruct the soil reduces the ecological footprint of the operation.
- Preliminary surveys (heat mapping, soil analysis) provide vital information for effective renaturing.
- Setting up monitoring programmes makes it possible to assess how successful the project has been in reducing temperatures and the UHI effect, and to make adjustments where necessary.
- An oak tree can store up to 200 of water per day, most of which is released through transpiration in gaseous form. An American study has shown that the trees in New York City help to reduce runoff of about 2 million cubic metres of rainwater per year, equivalent to 4.6 million dollars annually (*Nowak et al, 2018*).

RENATURING TO IMPROVE HEALTH AND THE LIVING ENVIRONMENT

Ground sealing affects health and wellbeing: it is an aggravating factor, if not the cause, of phenomena such as flooding and UHIs, which have many negative impacts on health. For example, UHIs cause excess deaths during heatwaves and have indirect effects such as increasing the concentration of atmospheric pollutants.
A review of the scientific literature carried out by Plante & Cité has identified over 300 publications showing the benefits of natural spaces on physical and mental health (*Meyer-Grandbastien et al, 2021*). Renaturing urban environments is thus a way of improving the living environment and well-being of city-dwellers. To identify areas that might be desealed as a priority, vulnerability to UHI effects, air pollution and scarcity of green spaces were studied.

CRITERIA FOR LOCATING PRIORITY AREAS

Vulnerability to UHI effect

UHIs cause a significant number of excess deaths in periods of extreme heat. Night rest and recovery are affected, and the risk of death is twice as high among people exposed to heat, especially at night and when a heatwave lasts a week or longer. This risk increases when other individual factors (existing health issues, age, income, etc.) or factors relating to the environment of the dwelling (located under a roof, located in a district affected by UHIs, limited access for doctors or emergency services, etc.) are added.
Vulnerability to the effects of UHIs was analysed using the "Vulnerability"[7] indicator in the project titled "Adapting the Paris Region to Urban Heat" (*Cordeau, 2017*) carried out by the Paris Region Institute. The principle of vulnerability involves several notions: exposure of an area and a community to a hazard (here the UHI effect); the sensitivity and fragility of the exposed population; and its ability to cope with the hazard by anticipating it, reacting to it or withstanding it. Where UHIs are concerned, vulnerability thus depends not only on exposure to the hazard (high, moderate or low), but also sensitivity (e.g., because of age) and ability to cope (e.g., if a cool island exists). In the framework of the study carried out here, high vulnerability gives the cell a score of 0, moderate vulnerability scores 1 and low vulnerability scores 2.

7 This indicator is calculated on the basis of the "hazard" indicator (cf. chapter 2.4.1.1), a "sensitivity" indicator (presence of a nursing home, proportion of the population sensitive because of age, density of housing occupation, etc.) and a "coping" indicator (lack of public green spaces; proximity to hospital A&E, proportion of low-income households, etc.). Vulnerability at night was taken into account as this is when the UHI effect is most pronounced.

CRITERIA	THRESHOLDS	SCORE	SOURCE
Vulnerability to UHI effect	High	0	*Cordeau, 2017 ; Pascal* et al, *2021 ; Basagaña* et al, *2011 ; Urban green spaces and health, 2016*
	Medium	1	
	Low	2	
Air pollution (concentration of PM2.5 µg/m³/year)	≥ 15	0	*Articles R221-1 à R 221-3 du Code de l'Environnement ; World Health Organization, 2006*
	≥ 10 et < 15	1	
	≥ 5 et < 10	2	
	< 5	3	
Lack of green spaces	High	0	*Cox et al, 2017 ; Szulczewska et al, 2014*
	Medium	1	
	Low	2	

TABLE 8. Criteria, thresholds and bibliographical resources used to identify urban areas where health risks are greatest

Air pollution

Air pollution was analysed on the basis of particulate concentrations known as PM2.5, in other words particles whose diameter is 2.5 microns (µm). These particles have many sources, but the residential sector and road traffic are the two main culprits in the Paris Region [30]. In France, there are 48,000 premature deaths annually due to particles whose diameter is less than 2.5 µm in the open air [31]. PM2.5 concentrations were chosen to assess air quality because they pose a significant health risk (*Pascal et al, 2016*) and because research on plant-based air decontamination has mainly been carried out on this type of particle (*Prigioniero et al, 2021; Selmi, 2016*).
The data used comes from the association Airparif and corresponds to the average PM2.5 concentration in 2014 - 2018. For the attribution of scores, the thresholds were chosen on the basis of goals set at the *Grenelle de l'Environnement* (15µg/m³/year) and WHO recommendations (5µg/m³/year with an intermediate threshold of 10µg/m³/year) [32].
On the basis of the above objectives, the cells score 0 points for areas where the concentration is 15 µg/m³/ear or more, 1 point where it is less than 15 µg/m³/ear but higher than 10 µg/m³/year, 2 points where it is lower than 10µg/m³/year but higher than 5µg/m³/year, and 3 points where it is lower than 5µg/m³/year.

Lack of green spaces

Several studies have shown the health benefits of nature in urban areas. The presence of natural spaces helps to reduce anxiety (*Hystad et al, 2019*) and depression (*Beute et al, 2020*); to improve mood (*Sonntag-Öström et al, 2014*); and to improve attention span and concentration (*Kaplan et Kaplan, 1989*). Although no further proof of the health benefits of nature is needed (*Meyer-Grandbastienet al, 2021; Plante & Cité, 2021*; [33]), additional research is required to improve understanding of the direct and indirect links between nature and health.
Several research projects have also succeeded in highlighting thresholds above which positive effects on health are observed. In 2017, an American study has shown that cases of stress and anxiety could be reduced by 17% or 25% if plant cover exceeded 20% or 30% respectively (*Cox et al, 2017*) within a 250-metre radius of where people live. A Polish study recommends a minimum of 45% plant cover or aquatic environments (*Szulczewska et al, 2014*) in residential neighbourhoods to ensure adequate air cooling, permeability to rainwater and evapotranspiration during heatwaves.
To characterise a lack of natural space, 2 components were studied: (i) lack of green spaces open to residents and (ii) a vegetation index (established on the basis of plant cover).
(i) The study of the lack of public green spaces was

VEGETATION INDEX	
Plant cover	Value
Cover < 30%	0
30% ≤ Cover < 45%	1
Cover ≤ 45%	2

PUBLIC GREEN SPACES	
Type of deficiency	Value
Both	0
Lack of spaces	1
Lack of access	1
None	2

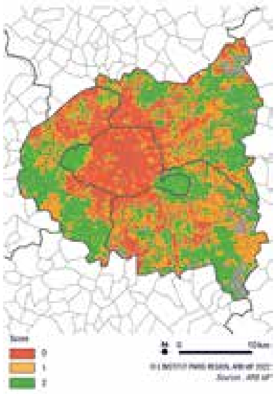
TABLE 9. Attribution of scores for the 2 components studied (vegetation index and access to public green spaces).

LACK OF PUBLIC GREEN SPACES / VEGETATION INDEX	BOTH (= 0)	LACK OF SPACE (= 1)	LACK OF ACCESS (= 1)	NONE (= 2)
Low (= 0)	0 → 0	1 → 0	1 → 0	2 → 1
Moderate (= 1)	1 → 0	2 → 1	2 → 1	3 → 2
High (= 2)	2 → 1	3 → 2	3 → 2	4 → 2

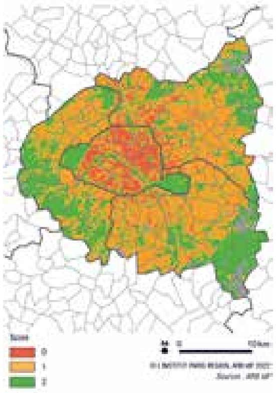
TABLE 10. Table combining (i) lack of public green spaces and (ii) vegetation index

based on data from the study carried out by the Paris Region Institute as part of the 2017 Green Plan (appendix 5), which distinguishes three types of deficient zones: zones lacking in accessibility; zones lacking both green spaces and accessibility; and zones that lack neither.
(ii) The vegetation index was studied according to thresholds highlighted in the research quoted above.

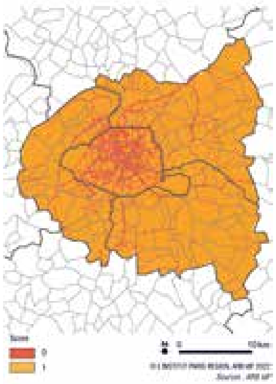
Adding together the two components (lack of public green spaces + vegetation index) makes it possible to distinguish areas with significant deficiencies from non-deficient areas. The final score is reclassified so that it is between 0 and 2 (value in bold). A score is then attributed to the cells according to lack of natural spaces: significant deficiency scores 0, moderate deficiency 1, and low deficiency 2.



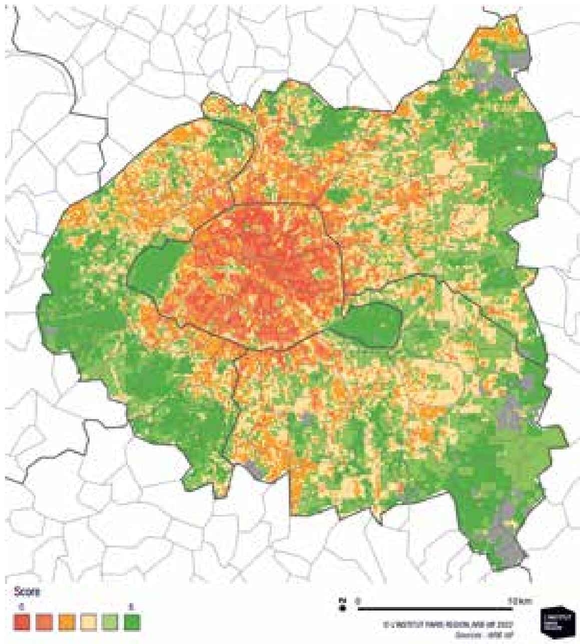
Lack of green spaces



Vulnerability to UHI



Exposure to air pollution by PM.2.5



Overall map of risk to health and wellbeing

FIGURE 14. Cartographic results of the study of chosen criteria (left) and overall map of the health/living environment of the population in terms of the criteria studied here, corresponding to the sum of criteria scores (right). The results shown only concern Paris and its inner suburbs.

WHERE SHOULD RENATURING TAKE PLACE TO IMPROVE HEALTH AND THE LIVING ENVIRONMENT?

In keeping with the method detailed p.XX, cells with a score from 0 to 2 were defined as priority renaturing zones. Cartographic analysis reveals that urban areas where health risks are greatest are in Paris and its immediate suburbs. It seems that the risks studied increase with densification: the denser an area is, the less green spaces it has and the higher UHI effects and levels of vehicular pollutants will be. As far as PM2.5 pollution is concerned, it is important to note that no zone complies with the WHO recommendation of 5µg/cu.m./year, and only a few areas in the outer suburbs are below the threshold of 10µg/cu.m./year. It should also be remembered that the analysis only took account of factors on which renaturing operations might have a beneficial effect (creating a cooling island; reducing deficiency in green spaces; helping to reduce atmospheric pollution). The results cannot be extrapolated to other studies concerning public well-being as additional information would be required (on pollutants other than PM2.5, standard of living criteria, etc.).

FEEDBACK AND RECOMMENDATIONS

For a renaturing project to improve health and the living environment, it is important first to know its aims (improving air quality, combating UHIs, improving wellbeing, etc.). Although increasing the number of natural spaces will be of obvious benefit to the living environment, their ecological quality must not be neglected. More significant benefits concerning mental health have recently been attributed to lightly managed natural areas (with less mowing and no pruning) (*Clark et al, 2014*). Other studies have highlighted the importance of biological components in recreational areas. For example, the number of visual interactions with birds is thought to be linked to lower levels of stress (*Cox et al, 2017*). With a view to improving all aspects of health (physical, mental and social), several recommendations can be made, in particular:

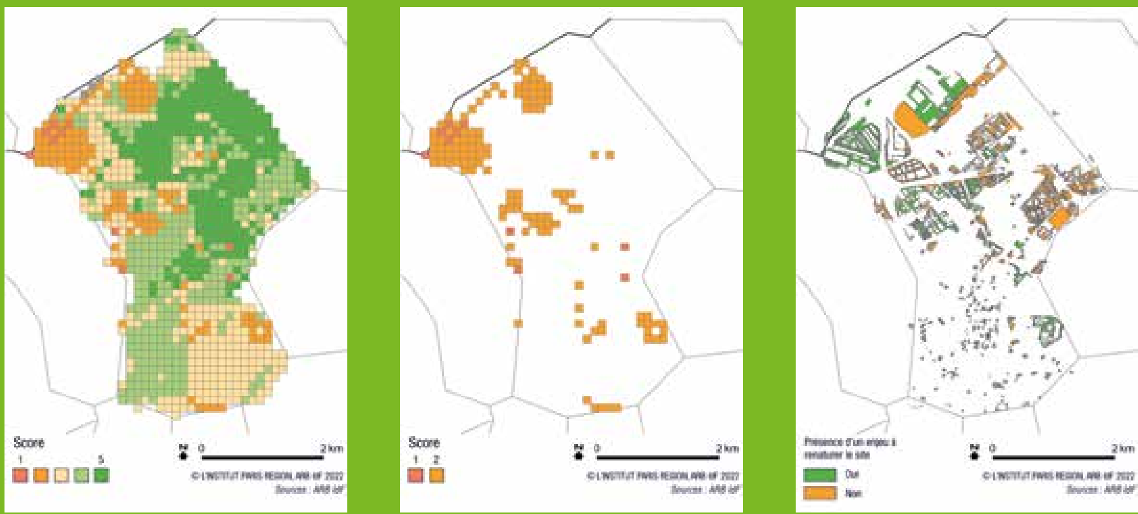
- Offer more natural spaces and remedy deficiencies in the areas concerned.
- Reduce the number of concrete surfaces, which absorb heat, instead placing the emphasis on vegetation.
- Create a canopy capable of providing shade and promoting evapotranspiration to reduce the UHI effect.
- Use species able to fix atmospheric pollutants to improve air quality.
- Use participatory approaches making citizens into agents of change and fostering social interactions.

Renaturing to improve temperature comfort in urban areas

Natural areas can help to improve temperature comfort in cities, especially during heatwaves. They reflect sunlight, avoiding the accumulation and release of heat. In summer, depending on the tree species, the canopy only allows 10% - 30% of sunlight to get through, providing shade and reducing perceived temperatures. Plants are also the source of evapotranspiration, which combines evaporation (water contained in the soil and bodies of water is released in gaseous form) and transpiration (water contained in the leaves is exuded to maintain the temperature of the plant). Evapotranspiration thus cools the air thanks to the release of a large quantity of water vapour. However, for vegetation to cool a city, it must have water available to it in very hot weather. Frugal watering using collected and stored rainwater may thus be necessary. The benefits provided by natural spaces on UHI and temperatures are, however, highly localised. More renaturing projects must be rolled out to maximise their effects. Also, the type of vegetation needs to be considered: multi-strata urban woodland is more efficient than hay meadows at improving temperature comfort, for example.

EXAMPLE OF HOW THE METHODOLOGY WAS APPLIED IN THE TOWN OF AULNAY-SOUS-BOIS

The results reveal a total of 162 cells exposed to health risks or with a degraded living environment (score: 1 or 2). These are scattered across the area and risks are mainly due to a lack of green spaces and/or the vulnerability of the population to UHI effects. The 993 remaining cells do not suggest especially high risks relating to the criteria studied here (score: 3 - 5).



Overall analysis, "Health and Living Environment" challenge

Identification of priority renaturing zones

Location of potentially desealable and renaturable sites

FIGURE 15. Identification of desealable sites in high-stakes areas to improve health and/or the living environment in Aulnay-sous-Bois (Paris Region, *département* of Seine-Saint-Denis).

EXAMPLE OF INTERPRETATION, CITY OF PARIS

The city of Paris is an area highly deficient in green spaces. The map (Figure 16) highlights an extensively sealed urban area in the city centre, which is thus highly exposed to air pollution and UHI effects. The degree of densification also causes a deficiency in green spaces, except in areas adjacent to parks. Renaturing these types of areas would make it possible to tackle the lack of green spaces, to limit the heat island effect, and, to a lesser extent, to reduce atmospheric pollution (which can only be drastically reduced via measures aimed at directly curtailing pollutant emissions).

FIGURE 16. Map of risks to health and wellbeing in Paris

FIELD REPORT 17

REHABILITATION OF THE RUE GARIBALDI IN LYON (AUVERGNE-RHÔNE-ALPES)

In brief: transformation of a major city-centre road into a planted parkway to improve urban temperature comfort.

As part of its climate plan, the Lyon Metropolitan Council is greening urban space to reduce the effects of urban heat islands. This was the aim when a 3-kilometre stretch of the Rue Garibaldi, a major traffic artery, was turned into a shaded parkway. The first stage, carried out between 2014 and 2016, retained over 80 existing trees and planted 150 new trees, shrubs and herbaceous plants of different species responding to ecological and aesthetic criteria. One of the special features of the project is the way it has turned road tunnels into rainwater storage reservoirs. In periods of extreme heat, evapotranspiration, which cools the air, no longer occurs. Giving trees stored rainwater kick-starts evapotranspiration to cool the city. According to several measurement campaigns carried out on the Rue Garibaldi, the trees brought temperatures down an average of 1.78°C to 2.33°C in August 2016 and 2017. As for perceived temperatures, the difference between planted and unplanted areas was up to 10°C.

Experiencing the cooling properties of vegetation on the renatured Rue Garibaldi in Lyon. © Laurence Danière

KEY TAKEAWAYS

- Vegetation, especially trees, offers shaded areas that filter direct sunlight and provide higher levels of temperature comfort.
- Retaining existing trees should be the primary objective of any strategy aimed at developing the urban canopy.
- The mechanism of cooling through evapotranspiration, which complements the effect of shade, depends on the availability of water for the plants. Collecting and storing water makes it available during heatwaves and avoids having to use potable water.

FIELD REPORT 18

GREENING THE BASE OF THE RAMPARTS IN AVIGNON (PROVENCE-ALPES-CÔTE D'AZUR)

In brief: desealing 1,900 parking spaces along the ramparts that were causing an urban heat island, turning them into meadows to improve residents' wellbeing.

The ramparts surrounding the old city of Avignon are on the UNESCO World Heritage list and are one of the city's major emblems. Until 2010, the outer façades were lined with parking spaces that formed a heat island in summer. Desealing 1,900 parking spaces made way for meadows at the base of the ramparts. They are planted with a variety of species adapted to full sunlight or half-shade and to the Mediterranean context. The work was also an opportunity to provide access to a shaded promenade for pedestrians and cyclists. Moreover, the project shows that it is possible to carry out such initiatives next to listed historic monuments and to comply with the demands of the historic buildings inspectorate.

Greenery at the base of the ramparts after desealing the parking spaces © Cécile Vo Van/Cerema

KEY TAKEAWAYS

- Particular care must be taken over the choice of plant species. Giving preference to local species means that they will be better adapted to the local climate and able to withstand heatwaves even without watering.
- Renaturing is not incompatible with listed historic monuments. It is possible to accommodate the demands of the historic building inspectorate/heritage commission, etc. and to achieve a result that showcases the existing historic site.

Creating new spaces to improve air quality

Plants help to improve air quality, reducing the concentration of atmospheric CO_2 by photosynthesis and of suspended particles which are absorbed and deposited on the surface of leaves (*Litschke et Kuttler, 2008*). In 2020, Bruxelles Environnement carried out a study to summarise scientific knowledge of the impact of urban vegetation on residents' exposure to atmospheric pollutants, noise and extreme heat. The summary confirms that in general, trees are most efficient in this regard, followed by shrubs and herbaceous plants. Conifers are generally better at filtering particulate pollution (as they offer a larger surface of interaction) and the adsorption of volatile organic compounds. They are also effective all year round as they do not lose their leaves in winter, with a few exceptions. Deciduous trees deliver the best results in terms of absorbing gaseous pollutants (NO_2 and O_3 in particular). Also, rough-leaved plants can absorb more pollutants than smooth-leaved ones (*Sæbø et al, 2012*).

The ability of vegetation to reduce local pollution depends on numerous other factors such as the nature of the pollutants, weather conditions and the position of the plants with respect to the local source of pollution (*Baldauf et al, 2008*). Applied to 4 critical zones in terms of air pollution, Bruxelles Environnement estimated that maximum greening scenarios would provide a reduction of 5 to 10% in local concentrations of NO_2. However, the study confirms that nature-based solutions are generally insufficient to reduce atmospheric pollution significatively and that measures taken to reduce pollutant emissions at source must remain a priority [34]. Renaturing operations for car parks and roadside parking areas can also be seen as a way of reducing the presence of cars in urban environments and thus helping to improve air quality.

FIELD REPORT 19

DISMANTLING AN URBAN HIGHWAY IN SEOUL (SOUTH KOREA)

In brief: dismantling a 10-lane road (leaving only 4 lanes) to form a 5-km parkway and restore a river.

In 2005, the city of Seoul launched a major project to restore the River Cheonggyecheon which flowed beneath a 10-lane road with a 4-lane highway above. The project had several objectives. Its primary aim was to improve the living environment and health of residents by reducing the atmospheric pollution and noise created by 170,000 vehicles every day. The highway was dismantled and only 4 of the original 10 lanes were retained to leave space for the restored River Cheonggyecheon and footpaths along its banks. Today the river flows through a parkway stretching over 5 kilometres that attracts 60,000 pedestrians every day.

Several scientists have monitored the benefits, underlining the value of the project in terms of flood protection. Between the pre-restoration work in 2003 and the end of 2008, the number of plant species rose from 62 to 308, fish from 4 to 25, birds from 6 to 36, aquatic invertebrates from 5 à 53, insects from 15 to 192, mammals from 2 to 4 and amphibians from 4 to 8 (*Revkin, 2009; Kim et al, 2009*). The project has also helped reduce the urban heat island effect, with temperatures along the river 3.3° to 5.9 °C cooler than on a parallel road a few hundred metres away. This is due to the removal of the highway, the cooling effect of the river, the increased amount of vegetation and higher wind speed along the corridor. In terms of air quality, measurements have confirmed a 35 % reduction in fine particulates, which have fallen from 74 to 48 micrograms per cubic metre. Before the restoration work, residents were twice as likely to suffer from respiratory illness than those living elsewhere in the city. Despite the project's environmental performance, scientists have highlighted conflict between the City Council and a coalition of NGOs around different approaches to renaturing. The NGOs criticise the lack of ecological authenticity in the restored stream (*Cho, 2010*), while others regret the artificial way vegetation is surrounded on all sides by concrete (*Lévy, 2015*). The project nonetheless provides unique intelligence on dismantling infrastructure to restore a river and its immediate surroundings.

The Cheonggyecheon restoration project was centred on revitalising the Cheonggyecheon Stream that had been covered for decades by a highway overpass ©Global Designing Cities Initiative

KEY TAKEAWAYS

- Renaturing roadways is an opportunity to limit the presence of cars in urban areas and thus to reduce pollutant emissions. It is also a way of making room for pedestrians and encouraging activities that are known to improve health. Although vital, walking has been largely overlooked in French public transport policy despite being the leading means of transport in the Paris Region. Giving pedestrians more space in urban areas is also a way of responding to challenges relating to public health, the climate and the living environment [35].
- The ability of plants to absorb pollutants depends on several factors such as chosen species, air flow, concentration of pollutants, position of plants, etc. (*Pugh et al, 2012*). In all scenarios, their ability to absorb pollutants is relatively low and cannot justify failing to reduce emissions at source.

FIELD REPORT 20

FIGHTING AIR POLLUTION WITH TREES (GRAND EST)

In brief: a test site for air pollution in Metz as part of the SESAME study carried out by the CEREMA.

SESAME (Services EcoSystémiques rendus par les Arbres, Modulés selon l'Essence/Ecosystem Services provided by Trees, Modulated according to Species) is an innovative project run by the City of Metz, Metz Métropole and the CEREMA. The study originated in research carried out by Metz City Council since 2015 into how nature-based solutions, especially trees and shrubs, can respond to a number of issues relating to climate change, biodiversity and air quality. SESAME identifies the ecosystem services provided by 85 species of trees and shrubs in terms of air quality, support for biodiversity, local climate regulation, carbon sequestration, the living environment and adaptation to climate change. It also takes into account risk of allergies, the production of volatile organic compounds, and physical constraints (size, root system, etc.). The study resulted in the creation of an operational tool designed for the Council and planners, helping to select plant species for any green space project according to a typology of landscapes identified in the region and making it possible to adapt to constraints and leverage opportunities. The study continues with the analysis of 250 further species of trees, shrubs and climbing plants and the investigation of new services and constraints.

The City of Metz climate plan includes large-scale tree planting (20,000 trees to be planted by 2030). The trees will be selected according to the results of the study, the combination and diversity of species being essential recommendations for any planting project. A SESAME test site was created at the intersection of Boulevard de Guyenne and Boulevard Solidarité, very busy roads used by 4,000 to 9,000 vehicles daily. ATMO Grand Est, an officially endorsed association that monitors air quality, has been asked to assess the site and to determine the potential impact of vegetation on air quality and thus the health of residents. Pollutants measured as part of the study are nitrogen dioxide (NO_2) and particles whose diameter is less than 10 µm (PM10), mainly due to road traffic. Of the 18 species selected, some absorb pollutants (for example the European nettle tree) and others foster biodiversity (e.g., the common elder). Sensors will be put in place on the site and the area opposite to compare the impact of plants on air quality and biodiversity. Measurement campaigns will be carried out every two years to check the potential impact of the planted species on air quality by comparing concentrations measured near traffic, a few dozen metres away, and with no plant barrier nearby.

Planting trees on the SESAME test site in Metz. 14 species were selected for their ability to absorb pollutants and host local wildlife. © City of Metz

KEY TAKEAWAYS

- Plants can trap air pollutants, either because they absorb them (gaseous pollutants) or because pollutants are deposited on their surface (fine particles).
- The effect of plants on air quality is limited but real (*Selmi et al, 2016*). It requires developing the "urban forest" (*Chrétien, 2019*).
- The example of the Strasbourg Eurométropole shows that trees can eliminate 0.03% of CO_2, 7% of PM10, 1.5% of PM2.5 and 0.5% of SO_2 (*Selmi et al, 2016*).
- The SESAME study provides a table showing the performance of 85 tree species in terms of regulating gaseous pollution in particular [36].

Renaturing projects by and for the local community

Health is closely connected to the quality of the living environment and access to natural areas. Providing more room for nature in urban areas, in terms of both quantity and quality, is a way of actively improving wellbeing. This is supported by a high level of demand from the community and expressed in successful initiatives such as "planting permits", participatory budgets and the creation of allotments.
Renaturing urban areas is also a way of combating what sociologists and ecologists call "the extinction of experience" (*Miller, 2005*). Over recent years, interdisciplinary research on the subject, for example the work of Anne-Caroline Prévot at the Centre of Ecology and Conservation Sciences at the Muséum National d'Histoire Naturelle, has shown the need to maintain nature in urban areas to provide residents with opportunities to come into contact with biodiversity [37]. It is through observation and day-to-day experience of flora and fauna that people develop a concern for, and an interest in, wildlife. You protect what you know. These experiences can be enriched by designing areas that are particularly effective at hosting biodiversity. Experiences with biodiversity also contribute to human wellbeing (*Fuller et al, 2007*).

FIELD REPORT 21

WILD GARDEN ON THE SITE OF A FORMER CAR PARK IN AUBERVILLIERS (ÎLE-DE-FRANCE)

In brief: destroying a disused car park to transform it into a rock garden and improve the living environment.

La Maladrerie is a housing estate built in the 1980s in Aubervilliers, a town in the *département* of Seine-Saint-Denis. The edge of the estate overlooked a car park that had been disused for several years. To improve the living environment, Wagon Landscaping and the artist Sylvie Da Costa, who lives in the estate, commissioned by the Aubervilliers Town Council Housing Office, worked for 5 days to create the garden. First the Council broke up the surface of the car park, leaving the rubble in place to create a 1,600 sq.m. "rock garden" that is a cross between an area of waste ground and a botanical garden. Soil was brought in, and 150 species of perennials, shrubs and young trees were planted to kick-start a process of recolonisation. A total of 2,000 plants were introduced, chosen for their ability to adapt to uneven ground and requiring little maintenance. The Jardin des Joyeux is maintained as little as possible to preserve its rough, rocky appearance with asphalt peeking through the vegetation. Five years after the preparatory work, much of the broken asphalt has been overgrown. Wagon Landscaping managed the entire project, including the construction work. The garden requires minimum maintenance and no watering. Aubervilliers Council has organised several open days inviting residents to discover the project and the new on-going ecosystem.

Concrete crushing and planting on a former parking lot in the city of Aubervilliers, France ©Wagon landscaping

KEY TAKEAWAYS

- Ecological management or passive management can be used in all urban areas. Communicating with the local community and showing how projects benefit nature facilitates acceptance.
- It is possible to recreate the right conditions for recolonisation, even on previously sealed ground

FIELD REPORT 22

TRANSFORMATION OF A FORMER AERODROME IN FRANKFURT (GERMANY)

In brief: transformation of an airport into a multi-use public park featuring sports amenities, footpaths, educational workshops for schools, and spontaneous recolonisation by flora and fauna.

Ten years after the former aerodrome closed, the City of Frankfurt purchased 7 hectares of land and turned it into a new natural area open to the public. There were three aims: to guarantee and reinforce spontaneous natural recolonisation; to create a recreational area for residents; and to keep the budget low. Several buildings have thus been retained to recall the history of the site and are now used as artists' studios and cafés. A third of the former runway has also been kept to cater for one of the uses identified for the site: safe from traffic, the runway is ideal for cycling, rollerblading and skateboarding.

In all, 3 hectares of runway and car parks have been dismantled. Instead of being removed, the asphalt has been crushed and left on the ground, offering cavities that can be colonised by animals and plants. The size of the chunks varies from place to place: they get smaller as you move further away from the buildings. This makes it possible to visualise natural recolonisation thanks to a desealing gradient that echoes ecological succession. Concrete is still a strong presence near the buildings, then come rocky environments, meadows, copses, and finally spontaneous woodland representing the climax of the process (the final step in ecological succession).

Today the former aerodrome has become not only a place to walk and engage in leisure activities but also an educational area. Regular events are scheduled for residents and schools focusing on plant identification, amphibian-spotting, birdwatching, and so on). The project recalls the famous Berlin Tempelhof airport, which also became an urban park in 2007 after part of its surface was desealed. Airports, like large industrial parks or railway stations, occupy significant areas of land that can be transformed into new natural spaces.

The former runway has been retained to be used as a cycle path and to facilitate observation of the natural environment.
©Stefan Cop

KEY TAKEAWAYS

- For brownfield rehabilitation projects, it is important to study the current use of the site in order to develop projects that closely respond to local community expectations.
- Renatured sites are new educational areas that can be used to raise awareness of conservation and biodiversity issues.

FIELD REPORT 23

RENATURING AN OLD ROAD IN SAINT-JACQUES DE LA LANDE (BRITTANY)

In brief: desealing and passive renaturing of a stretch of road as part of a new ecological park.

Initiated in 2004, the development of the Saint-Jacques de la Lande Ecological Park, near Rennes in Brittany, now offers 45 hectares of relaxation and leisure areas and footpaths. In addition, the park manages rainwater from the new city centre. Streams planted with phragmites and planted ditches direct the water to a basin, then to a reed bed where phytoremediation takes place.
The operation has also made it possible to deseal an old road. Led by the council and a landscape architect, the operation consisted of crushing the asphalt and keeping it in place to avoid generating waste. The principle adopted is a passive ecological restoration: the crushed blocks of asphalt constitute seed traps and habitats for the development of pioneer vegetation. A team of researchers and students from Agrocampus Ouest is monitoring the flora, lichens and insects in this freely evolving space. After a few months, opportunistic observations have confirmed the presence of reptiles (vipers, lizards), for which these rocky environments are the characteristic habitat.
By combining ecological and artistic approaches, this project succeeds in involving the local population in the restoration project. It is reminiscent of the rewilding of Berlin Tempelhof and Frankfurt Bonames airports in the late 2010s, and brings together ecologists and landscape architects in a shared approach.

Crushed asphalt gives way to spontaneous vegetation on an old road in Saint Jacques de la Lande. © Yann Laurent

KEY TAKEAWAYS

- Broken asphalt can be kept in place to create a new type of habitat (like a rocky environment) suitable for certain groups of species such as reptiles: grass snakes, vipers, wall lizards.
- Renatured areas can be stage-managed to give them an artistic dimension as well as a scientific one. Bringing together art and ecology is a way of encouraging local people to make projects their own.

FIELD REPORT 24

THE "TRANSFORMER" IN SAINT NICOLAS DE REDON (PAYS DE LA LOIRE)

In brief: renaturing a brownfield site via several community projects making it possible to experiment with renaturing methods while organising a range of public events.

A 5.5-hectare brownfield site in Saint-Nicolas de Redon (Loire-Atlantique) was regularly flooded when the River Vilaine overflowed. In 2001, the *Département* of Loire-Atlantique and the town council asked students at the Ecole Supérieure du Paysage in Versailles to carry out a landscape survey reflecting upon the future use of the site. Their central proposal was to renature the site, drawing inspiration from Antoine Lavoisier's famous phrase "Nothing is lost, nothing is created, everything is transformed". Only pollutant materials were removed from the site; the rest was left in place, repurposed or used as a medium for plant recolonisation. The experimental and participatory projects led residents to form associations in order to continue with the renaturing and management of the site. In response to these successes, the Loire-Atlantique Council purchased the site in 2005 as part of its "Sensitive Natural Areas" policy and signed an agreement with the association "Les Amis du Transformateur" [38] in order to: (i) manage and renature the site, (ii) create the right conditions for opening the site to the public, (iii) collect and share information on the experiments carried out on the site.

Le Transformateur offers a range of different spaces (hangars, concrete slabs, unbuilt areas where bumps have been created using infill, herbaceous environments, wetlands, etc.), which have inspired ideas for future uses of the site and renaturing projects. A range of experiments have been carried out since 2006:

- Desealing to form gaps and micro-ditches that make it easier for plants to lift and overgrow chunks of concrete.
- Participatory projects involving re-creating woodland, hedgerows, vegetable gardens and orchards. These projects have made it possible to pass on rural know-how such as pleaching, canework and using materials salvaged on site.
- Using Nantaise cattle to graze the meadows.
- Artworks showcasing the identity of the site: Land Art made with demolition materials, street art festival (murals on the buildings).

Le Transformateur in Saint Nicolas de Redon is a low-cost brownfield renaturing project carried out by local residents.
©Christian Baudu – Scopidrone

- Activities and outings: nature rambles, historic visits, cookery workshops, taking part in management or planting projects, art exhibitions, etc.

In 2015, the "Bosquito" experiment was launched on the Transformateur site, with the help of 28 volunteers. 1,000 square metres of concrete and asphalt surface covering were replaced by organic amendments and straw mulch to create a future copse [39]. The design and technical aspects of copses make them into models for the reintroduction of trees in urban areas.
Scientific monitoring has revealed the presence of several species of interest on the site, including bee orchids and Gallic pinks. Very hardy plants such as bryophytes and sedums also suggest that plants are taking over the site once more. In terms of animal life, the site hosts several species of bats (common pipistrelle and Kuhl's pipistrelle) and birds (black kite), which use it a transit point between the River Vilaine and the surrounding woodland and meadows. This illustrates how an industrial site can be spontaneously recolonised by wildlife.

KEY TAKEAWAYS

- Residents, via associations, can make decisions, organise renaturing programmes, manage the site, and organise events to share information about the project.
- An exemplary approach in terms of reusing earth and rubble that makes it possible to reduce the financial and ecological costs of demolition, exportation of materials, decontamination and waste treatment and storage.
- The renatured site enjoys long-term protection because the *département* acquired the land as part of its "Sensitive Natural Areas" programme, but other tools exist to protect renatured spaces (in France: "Zone N" classification, protected woodland listed in planning documents.

POTENTIAL OF RENATURING IN THE PARIS REGION

The methodology presented in this guide makes it possible to estimate the amount of potentially desealable and renaturable land. This can be calculated at the level of the commune (town or village), the *département* (sub-regional administrative area) and the Paris Region. As an example, calculations and data visualisation have been carried out on the commune of Aulnay-Sous-Bois.

Renaturing potential of Aulnay-sous-Bois

Renaturable area depending on the number of challenges

On the scale of the *commune*, the method makes it possible to estimate that there is a total of 256.66 hectares of potentially renaturable sites, including:

- 16.92 hectares which are not associated with renaturing challenges. These are sites that have been identified thanks to the *Mode d'Occupation des Sols* (MOS), a tool that determines the evolution of land use based on the analysis of aerial and satellite photographs, but which are not located within priority renaturing zones (i.e., in low-scoring cells).
- 71.87 hectares which are only concerned by a single renaturing challenge, which means they are located within an area that qualifies as a priority zone because it is subject to only one of the challenges studied (biodiversity, climate change or living environment).
- 84.26 hectares located in priority areas that are subject to two challenges (e.g., biodiversity and climate change, or climate change and living environment).
- 83.61 hectares located in areas that are subject to all three challenges (5.17% of the *commune*).

Renaturable area according to type of challenge

It is also possible to look at renaturable areas according to the type of challenge they face (rather than the number of challenges). Areas thus obtained will be larger than those obtained by looking at the number of challenges. As an example, the 228.24 hectares that are potentially renaturable to foster biodiversity include not only sites that are subject to a biodiversity challenge and no other challenges, but also sites subject to a biodiversity challenge associated with another challenge (biodiversity+climate change or biodiversity+health/living environment) as well as sites facing all 3 challenges. This makes it possible to evaluate the surface area of sites that could be renatured with a view to fostering biodiversity.

Renaturing potential in the Paris Region

However, estimations of this potential are to be viewed with caution as they rely on sets of data from automated studies based on aerial photography and satellite views. Some sites considered to be sealed are not always sealed in reality. For example, building courtyards and the areas surrounding them are automatically considered to be sealed, whereas this is not necessarily the case. Conversely, some rows of trees where the ground is sealed, abandoned buildings, oversized pavements and roadside parking spaces have not been pinpointed in this initial approach and are thus not taken into account at this stage. Last but not least, it must be remembered that the feasibility of renaturing operations has not been assessed. These limitations confirm the importance of an on-site verification process set up by the local authority and based on the methodology.

FIGURE 17. Map identifying sealed surfaces that are potentially desealable depending on what is at stake in Aulnay-sous-Bois

CHALLENGE	POTENTIAL AREA (HA)	% OF COMMUNE
RENATURABLE AREA PER TYPE OF CHALLENGE		
Biodiversity	228,24	14,12
Climate change	158,26	9,79
Health and the living environment	104,74	6,48
RENATURABLE AREA IN TERMS OF NUMBER OF CHALLENGES		
No major challenge	16,92	1,05
1 challenge identified	71,87	4,45
2 challenges identified	84,26	5,21
3 challenges identified	83,61	5,17
Total area	256,66 ha	15,88 %

TABLE 11. Sealed areas that are potentially desealable depending on what is at stake in Aulnay-sous-Bois

CHALLENGE	POTENTIAL AREA (HA)	% OF PARIS REGION
RENATURABLE AREA PER CHALLENGE		
Biodiversity	15 139,52	1,26
Climate Change	14 872,52	1,24
Health/Living env.	10 373,42	0,86
RENATURABLE AREA IN TERMS OF NUMBER OF CHALLENGES		
0 major challenge	10 385,10	0,86
1 challenge	6918,48	0,58
2 challenges	6214,94	0,52
3 challenges	7016,79	0,58
Total area	30 535,31 ha	2,54 %

TABLE 12. Sealed areas that are potentially desealable depending on what is at stake in the Paris Region

©Sous les Pavés / Centre d'écologie urbaine de Montréal

#3

SUCCESSFUL RENATURING STEP BY STEP

The third part of this guide offers a few general recommendations for each step of a successful project: planning, implementation, monitoring and assessment, as well as long-term maintenance. Before anything else, it is necessary to put together a multi-disciplinary team to design and manage the different operations. Ideally this would involve council departments, renaturing specialists, research organisations, local associations and, if possible, members of the community affected by the project. Bringing together a panel of stakeholders at the beginning of the project makes it possible to consider a broad spectrum of points of view and thus to ensure that the different steps run smoothly. Ecological skills are fundamental and must be identified before the project begins.

PRIORITISING PROJECTS AND ASSESSING FEASIBILITY

The methodology proposed on page 25 is based on the principle that the benefits of renaturing will be greater if they target adaptation to climate change, restoring biodiversity or improving the living environment. The spatial analytical tool presented in this guide also allows local authorities to prioritise their actions, but it does not make it possible to assess feasibility. The technical difficulty associated with renaturing depends on a number of parameters. In the framework of its strategy for the restoration of sealed areas, the City of Berlin relies on 4 criteria to help it prioritise its actions.

The status of the land

Privately owned sites will need to be purchased, and this can be time-consuming. It is important to prioritise renaturing projects on publicly owned sites. In parallel the local authority can come up with ways of incentivising, funding or supporting private owners willing to renature sealed areas (planting permits, water board subsidies, etc.).

Technical work

The more technical the work is, the more difficult and costly it will be. On 2 sites of the same size, a project requiring the demolition of large-scale infrastructure or buildings will be more difficult to carry out than “simply” desealing the surface of an area (a car park, a square, etc.).

	HIGH PRIORITY	MEDIUM PRIORITY	LOW PRIORITY
Land status	Public		Private
Demolition	Little or no demolition	Demolition of small structures	Demolition of large structures (buildings)
Desealable area on site	Entire surface	Several separate areas	A few small, very isolated areas
Project timeframe	1 – 2 years	About 5 years	More than 5 years

TABLE 13. Criteria used by the city of Berlin for assessing the feasibility of a renaturing project on a sealed site

Area to be desealed

This criterion aims to estimate the total surface area that can be desealed and renatured on the site. A site whose whole surface can be desealed is of greater interest than a site where it is only possible to depave small, isolated areas.

Project timeframe

It is possible to prioritise projects according to the time they will take and give priority to those that can be rapidly implemented (in 1 - 2 years) rather than those that can only be completed in the medium term (about 5 years) or long term (over 5 years).

PRIOR ANALYSIS

Local and historic context

Before beginning a project, a historical research phase may be useful to determine an anterior or reference state for the site, if this is known. It can take the form of archive research at local government offices or consultation with residents (as well as studying street names and old maps).

Major pollution

Major pollution arising from the former use of the site, especially by substances able to migrate such as hydrocarbons and heavy metals (lead, zinc, copper, etc.), can be studied first by investigating how the site was occupied in the past. This type of study can lead to the creation of a map of areas of presumed pollution where studies and surveys may be carried out. Where analysis highlights the presence of soil pollution (see page 84), the project must be adapted accordingly. Some analyses may reveal polluted soil on which urban farming projects cannot take place, or pollution that requires the project to be adapted to prevent pollutants seeping into aquifers.

Water table depth

From a hydrological point of view, the level of the water table must be studied. Desealing can pose a risk of chronic or accidental contamination of subterranean water [40] as well as a risk of rising water table levels during heavy rain, especially if the water table is very shallow.
However, the presence of shallow groundwater can also be an advantage in some contexts, such as the restoration of wetlands. The highest level of a given water table is defined by a hydrogeological survey using historic data (geological databases and archives, data obtained from operators, etc.), sometimes with the addition of a local district survey or a survey using piezometric devices.

Risks connected to soil type and bedrock

The mechanical behaviour of certain soils can limit or halt infiltration and compromise renaturing (risk of dissolution and collapse of gypsum-rich soils [41] ; shrinkage and swelling of clay soils; karstic or fissured soils). These phenomena must be studied to characterise their presence or absence on the site to be renatured. The risks mentioned here must be considered in cases where the renaturing project aims to create an infiltration zone (floodable green space, rain garden, flood expansion zone), but they will not necessarily prevent a desealing/renaturing project from going ahead.

Ecological evaluation of the site

Once the research phase is complete, it is also necessary to assess the initial ecological state of the site to find out what species are present, the state of the soil, and the landscape in which the project will be carried out. This analysis must be adapted to the location and size of the site, and must at least include inventories of fauna, flora and habitats, soil analyses, and a study of ecological continuity within the scope of the project. It may be carried out by freelance ecologists and naturalists or specialist organisations or associations. Although the sites targeted by renaturing are generally significantly degraded, some species may have established themselves and their presence may help determine the renaturing trajectory to be adopted. Moreover, wildlife surveys generally cover a wider area than the site itself to gain a better understanding of the environment in which it lies and opt for a project which is ecologically meaningful on the scale of the broader landscape. If the project covers several sites, surveys should be carried out in each of them. Ecological evaluation must, if possible, be based on standard, easily applicable protocols. In France, participatory science programmes offered by Vigie Nature (page 99) are very useful for long-term monitoring.

IMPLEMENTATION

DISMANTLING INFRASTRUCTURE AND DESEALING

As far as sealed areas are concerned, the crucial step is to remove the ground covering be it concrete, tarmac or asphalt. This step is not always sufficient to strip the ground completely as artificial layers such as gravel or clinker may remain below ground and will need to be extracted.
This step requires specialist contractors although some collective initiatives use local volunteers. However, the latter option generally applies to smaller areas and must be carried out in an appropriate legal framework in compliance with health and safety regulations.

Carrying out waste analysis before the project starts makes it possible to identify opportunities for reuse, recycling and repurposing ground covering as part of a circular economy approach. Several specialist contractors offer these kinds of services although some types of bitumen cannot be recycled or reused. In this case, to avoid taking broken material to rubbish dumps it can be retained on site to create a rocky environment where nature can be allowed to take its course.
It is nonetheless important to differentiate concrete, which is a “mineral” material, from bitumen, asphalt, etc. which are produced by the petrochemicals industry and may pose contamination risks. The harmlessness of materials left over after desealing must thus be established before experimenting with reuse.

Desealing a car park in Aubervilliers. ©Wagon Landscaping

Cost and benefits of renaturing

According to France Stratégie (*Fosse et al, 2019*), the average cost of desealing is between 60 and 270 euros per square metre: these are significant costs that can be offset by savings made thanks to rainwater management and the direct and indirect benefits that a new natural area provides. In the town of Douai (in the Nord *département* in northern France), where 25% of public space is managed using alternative techniques, it is estimated that a saving of 1 million euros per year is made (30-40%) compared to traditional methods (*Herin & Dennin, 2016*). Moreover, water agencies offer desealing subsidies via calls for projects that can fund up to 80% of the work.

PHYSICAL QUALITY			
Texture: silt, clay, sand. **Granulometrics**: coarse elements.	**Structure**: penetrometer (permeability), spade test (physical condition of soil), slake test (cohesion of soil aggregates).	Auger profile (0-20 cm).	Soil colour.
CHEMICAL QUALITY			
Organic carbon, nitrogen (N), phosphorus (P).	Soil biochemistry, pH.	**Contaminants** : metallic trace elements, hydrocarbons, pesticides.	
BIOLOGICAL QUALITY			
Organic matter in the soil.	Plant cover indicators.	Soil fauna indicators.	Micro-organism indicators.
Measurement of biological activity of soil: litter bag method [42]. **Organic contaminants:** pesticides, polycyclic aromatic hydrocarbons	**Description of cover:** perennials and annuals vs spontaneous and planted. Study of root systems. Species providing bio-indication of environment and contamination	**Megafauna:** traces of activity (burrow, modification of soil and litter, etc.). **Macrofauna:** earthworm abundance and diversity (participatory worm observatory [43]), observation of worm casts); capturing soil fauna (Barber trap, JardiBiodiv protocol [44]); cover board gastropod trap) **Mesofauna:** springtails; mites; annelid worms **Microfauna:** nematodes atodes.	**Microbial biomass:** density and taxonomic diversity of bacteria and fungi (metagenomic). **Microbial activity:** enzymatic activity, mineralisation, soil respiration.

TABLE 14W. Main indicators for evaluating physical, chemical and biological soil quality (Source: AgrInnov project, indicators for evaluating biological soil quality)

RESTORING THE SOIL

Once its impermeable covering has been stripped away, urban soil will nevertheless have suffered significant damage. To assess the condition of soil on site, samples must be taken with a soil auger in different spots and sent to a specialist laboratory for bio-physico-chemical analysis. This preparatory analysis is a key step before planning different renaturing options. Table 13 summarise the main indicators used to assess soil condition.

The results of physical, chemical and biological analyses will serve as the starting point for soil restoration. Involving soil specialists is essential to interpret the different parameters and propose solutions appropriate to the restoration of soil functions.

Infiltration capacity

Depending on its infiltration capacity, a soil will lend itself more or less readily to different types of projects. An impermeable soil may be an asset in the framework of a blue grid restoration project, for example with a view to creating a network of temporary ponds. In the case of permeable soils, there may be a risk of water table pollution if the latter is high, but it also provides the opportunity for managing runoff at source, which limits the accumulation of pollutants. This type of test can be carried out using an infiltrometer, a device that measures the hydraulic conductivity of the soil. An alternative is to make shallow holes, fill them with water, and measure how quickly it is absorbed.

STUDYING POLLUTION WITH A VIEW TO FOOD PRODUCTION

When part of the renatured site is to be set aside for food production, additional tests must be carried out to ensure there are no pollutants that could be dangerous for consumers. In the light of the increasing popularity of projects that include urban farming, researchers at INRAE and AgroParisTech have developed an approach called REFUGE (Risques En Fermes Urbaines – Gestion et Evaluation/Risks in Urban Farms – Management and Assessment) to help people running this kind of project [45]. It involves first characterising the danger and then carrying out a risk assessment if the danger turns out to be present. Characterisation involves not only a historical research phase; it also involves analysis of soil destined to be used for agronomic purposes (including chemical analysis, at a cost of 90 to 150 euros per soil sample, as well as agronomic analysis costing 100 euros per sample). Details of the protocol are available in the REFUGE guide "Caractérisation de la contamination des sols urban destinés à la culture maraîchère et évaluation des risques sanitaires" (Barbillon et al, 2019).

It is still possible to grow certain plants in polluted soil given their low capacity for accumulating pollutants [47]. Some local authorities provide lists of species it is advisable or unadvisable to grow depending on the condition of the soil. The Paris suburb of Montreuil carried out analyses on plants for three years, which led to the implementation of a management plan encouraging people to grow plants that do not concentrate pollutants (cabbages, onions, fruit vegetables, fruit trees) and to a by-law in 2012 which prohibits the distribution of certain high-risk plants in the "Peach Wall" area of the town (a historic area where peach trees are grown against long walls)[48].

Protection of "peach walls" in Montreuil (93). This programme encourages agriculture and the creation of micro-farms with the help of local community initiatives. ©Gwendoline Grandin/ARB ÎdF

Working with contaminated soil

As far as soil contamination is concerned, and beyond standard analyses (heavy metals, organic pollution e.g., hydrocarbons), it may be useful to know about the historic condition of a site. A historic urban inventory aims to collect information on past (or still present) activities on the site with a potential for contamination. This makes it possible to incorporate the issue of pollution at the project planning and definition stage. In addition, it is possible to use bio-indicators to monitor toxicity to living organisms. Chemical analyses provide no information on the bioavailability of contaminants, their potential transfer and their level of toxicity to species, either alone or as parts of pollutant "cocktails" (synergistic/antagonistic effects). ADEME has produced a guide on the use of bio-indicators to measure biodiversity and soil functions and to evaluate soil contamination to develop relevant renaturing strategies and to monitor soil quality [48].

Decontamination

More and more ground decontamination techniques have emerged in recent years. They depend on the type of pollutant (heavy metals, hydrocarbons, chemicals, etc.) and on the nature of the soil and surfaces to be dealt with. Unlike civil engineering techniques (replacement, physical/chemical processes, etc.), ecological engineering techniques aim to limit energy costs arising from soil excavation, transport and infill with imported soil, instead opting for on-site restoration. To do this, the properties of certain micro-organisms such as bacteria and fungi (bioremediation) or of plant species (phytoremediation) can be used to decontaminate soil.

Example of a phytoremediation garden: the Peuple de l'Herbe Park in Carrières sous Poissy. ©Atelier d'Ecology Urbaine

Phytoremediation: decontaminating soil using plants

Phytoremediation comprises an array of techniques using the properties of plants and their microbial flora to decontaminate environments (ground, air and water). These techniques are based on the ability of plants to extract, transform, stabilise or accumulate toxic elements (respectively termed phytoextraction, phytodegradation, phytovolatilisation, phytostabilisation and phytosequestration), whose origin is often anthropic. Phytoremediation has turned out to be very useful for the decontamination of large areas where pollution levels are quite low.
In 2011 - 2015, the Atelier d'Ecologie Urbaine created 3 phytoremediation gardens each covering 400 square metres in the Parc du Peuple de l'Herbe, Carrières Sous Poissy. Two techniques have been applied: an 'ex situ' technique with specially constructed planted boxes receiving relatively contaminated materials (metals, aromatic hydrocarbons, volatile compounds) and an 'in situ' technique for soils with low-level contamination from aliphatic hydrocarbons based on appropriate planting. The typology of vegetation and strata that are used plays a part in the production of biomass and thus affects extraction capacities. It also impacts decontamination depth: 0.3 m for brassicas; 1 m for leguminous plants; 2.5 m for willows; 5 m for poplars). Here are the plants chosen on the basis of expected decontamination potential for each phytoremediation garden:

- The "in situ agri-forest garden" was created to fix metallic trace elements (MTEs) and hydrocarbons. Vegetation comprises a shrub coppice with several species of willow and a herbaceous stratum consisting of Fabaceae (leguminous plants are effective at degrading hydrocarbons).
- The "ex situ metal-extracting meadow" designed to extract MTEs. Here, brassicas have been used. Other experiments on the Plaine de Chanteloup near the Parc du Peuple de l'Herbe have shown that Miscanthus (silvergrass) seems to be effective at dealing with heavy metals.
- The "in situ agro-forest garden" was planted in an acidic environment to deal with MTEs and volatile halogenated compounds. It comprises willows coppiced in short rotation to extract pollutants stored in the biomass and a herbaceous strata of "acidic moorland" consisting of heather and gorse. The willows offer interesting prospects for dealing with heavy metals as they can accumulate cadmium, lead, nickel, zinc and copper in their roots, stems and leaves—up to several hundred mg/kg depending on the species.

The gardens have been regularly monitored since 2016, in terms of soil chemistry, plant biochemistry and the hydrochemistry of leached materials collected from a drain. In addition to these chemical tests, flora and pedology were monitored, making it possible to inventory the plants present in the gardens (both planted and spontaneous plants) and to observe the evolution of the restored soils. Recommendations were made on additional plantings and plant and soil management (mulching and incorporation of organic matter) [49].

An effective but still underused approach

Phytoremediation is still seldom used in urban settings, although reluctance is fading as more examples appear. In addition to feasibility issues and doubts regarding its effectiveness, legislation on polluted sites and soils and the time required for treatment, which is often incompatible with real estate development projects, were factors that dissuaded project leaders from using the method. In the US, in Canada, in the UK and in Northern Europe, however, phytoremediation is a preferred technique to treat contaminated sites (brownfields, military zones, etc.). Several projects have been launched in France and the method is making progress in the light of scientific results proving its effectiveness. Although the method requires monitoring and maintenance, it is less costly than the excavation, transportation and burial of contaminated earth. It can be up to ten times cheaper than traditional methods (*Chevrier, 2013*). Phytoremediation can be a financial argument in particular when the pollution to be dealt with covers a large area.
Several plants have been found to be effective in dealing with soil pollution, especially willows such as Salix viminalis, a shrub with an extensive root system whose roots, stems and leaves are able to sequester large quantities of metals. As for herbaceous species, *Lolium arundinaceum* (tall fescue) also has an extensive root system that supports microbial flora responsible for biodegradation. Depending on the pollution, combinations of plants may be used: Buxaceae are effective for nickel contamination, sunflowers for cesium, strontium and uranium, Arabidopsis for mercury, and tobacco and mustard for zinc, cadmium and lead.

Decompaction

As well as decontamination, it may be necessary to restore soil in order to make it ecologically functional once more, even if it differs from its original state in terms of structure and functions.
Urban soils that have been concreted over are subject to numerous impairments including compaction, which reduces the porosity necessary for the circulation of water, gases and nutrients vital for plants to function and grow. Good porosity is necessary for root penetration and also affects water circulation and retention capacities. Decompaction work may be carried out depending on the size of the site and the intensity and depth of the compaction. It is possible to use mechanical means (garden forks, broadforks, decompaction devices and machinery) or biological solutions. For example, some organisms such as earthworms or plants (i.e., their roots) can improve soil porosity. However, these techniques using living

organisms take several years to work: 1 to 2 years to restore porosity in the first 20 centimetres of soil and over 10 years to get down to a depth of 30 to 50 cm. To shorten these timeframes, mechanical action may be necessary using decompactors and pseudo-ploughing tools that can work the soil to a depth of 20 or even 35 cm. [50]. In Switzerland, a study carried out on three former industrial sites confirms that it is technically possible to restore sealed soils and reintroduce quality vegetation, although compaction is often a factor that limits the success of renaturing (*Tobias et al, 2018*).

Soil engineering species

Whether it be to improve the structure of the soil or kick-start its biological activity, it is possible to use so-called "ecosystem engineers" (earthworms, ants, etc.). This principle relies on their bioturbation capacities, in other words the phenomenon by which organisms manage to restructure the soil or transfer nutrients or chemicals into it. Earthworms, according to species, are burrowers and diggers and also allow other species to take refuge naturally in freshly worked soil. The introduction of engineering species as part of a renaturing initiative entails carefully selecting species or communities of species and obtaining the advice of soil specialists. This selection must be based on prior analysis of soil condition to ensure that the introduced species can survive in the degraded environment.

Plants also act upon soil structure with their roots and affect soil fertility and colonisation by other organisms. Improving soil porosity will depend on the morphology of the root system (the shape, diameter and length) of the planted species. Plants with taproots (dandelions, burdocks, trees, etc.) affect the soil to a greater depth, while those with fasciculate roots (Poaceae) have a greater impact on the surface where they form a densely matted root network. Combining species with different root systems will help structure the soil both on the surface and deeper

There are three main categories of earthworms, each with its own ecological characteristics. Epigeic earthworms live on the surface; endogeic earthworms are important soil stabilisers; and anecic earthworms play a key role in distributing organic matter through the soil. ©Maxime Zucca/ARB ÎdF down. It is possible to combine varied local species so that they complement one another in the way they affect soil structure.

Vegetation also directly influences soil fertility via airborne litter, root exudates and the ability of certain species to fix airborne nitrogen in the soil. This is the case with fabaceous or leguminous plants such as lucerne, clover, vetch, Spanish lentil, etc. Also, plants (or mainly their roots) modify their abiotic environment (temperature, humidity, pH, oxygen pressure) and biotic environment by releasing exudates into the rhizosphere[8]. These compounds feed a specific range of microbiota. Plants thus control the abundance, diversity and activity of microorganisms involved in processes such as the mineralisation of organic matter and nitrification.

Restoring the soil using urban by-products: “technosoils”

One technique that has long been used for the creation of green spaces is bringing in topsoil extracted from a natural or agricultural area. This technique is, however, ecologically counterproductive as it delocalises the impacts of land take on farmland as well as generating CO_2 emissions due to transportation. In 2008, the Plante et Cité association estimated that 3 million cubic metres of topsoil had been used in France for urban purposes (*Vidal-Beaudet, 2018*).

To avoid bringing in topsoil, innovative soil construction processes using urban waste have emerged in research programmes. The Soil and Environment Laboratory in Nancy is pioneering research into technosoils using waste and by-products present in an area to restore functional soils degraded by the steel industry. Part of a circular economy approach, this technique relies on recycling materials available on site positioned in layers or functional horizons (*Fabbri et al, 2021*). It combines a mineral substrate (non-contaminated excavated earth, concrete, railway ballast, rubble, etc.) with an organic substrate (crushed green waste, slurry from sewage farms, compost, street sweepings, etc.).

8. The part of the soil that immediately surrounds roots. This section of the soil is shaped and influenced by both roots and the micro-organisms associated with them

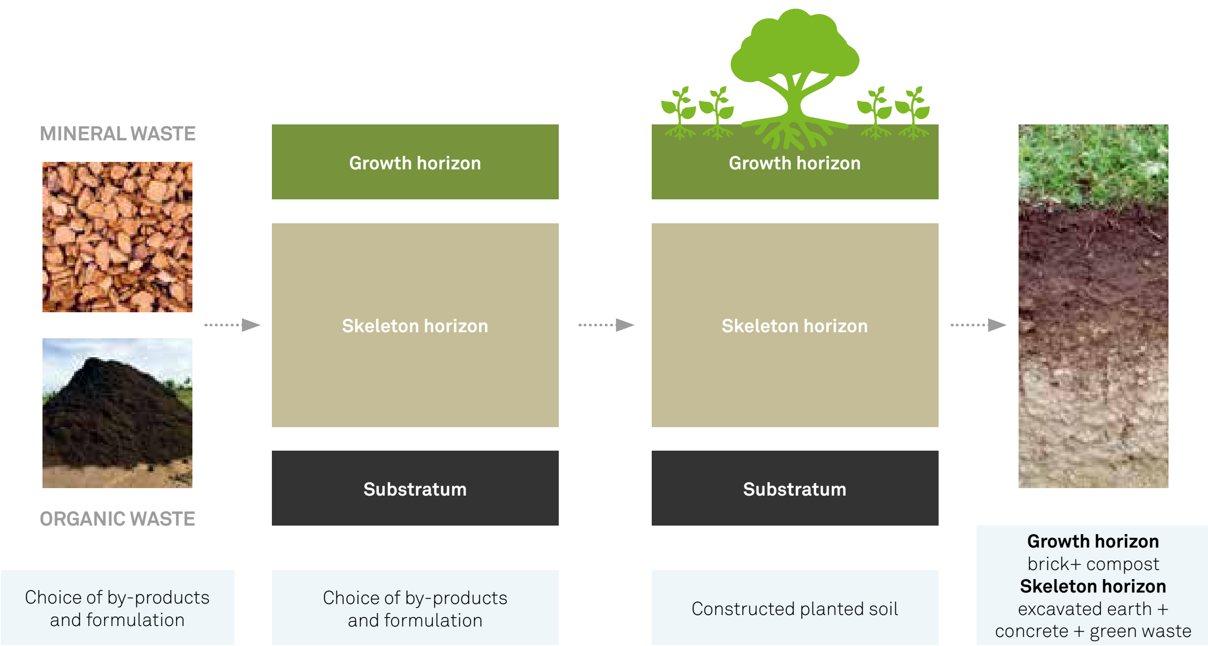


FIGURE 18. Soil construction process uses in the Siterre programme. Example of soil profile developed for areas of trees planted in rows.
© Plante & Cité, Institut Agro Rennes-Angers, Université de Lorraine, Ifsttar, BRGM, Rittmo Agroenvironnement, Valterra DR, Luc Durand Travaux Publics, ACTeon

BRINGING IN EARTH IS NOT ALWAYS NECESSARY

Italian researchers have put forward the hypothesis that the fertility of desealed urban soil will increase without the addition of exogenous topsoil. They compared desealed plots with and without added topsoil. Both sites were planted with 2 species of shrubs and irrigated. Soil fertility was analysed using chemical indicators (total carbon and organic materials) and biological indicators (biological quality index and microbial activity). The results show that desealed soils with no added topsoil can rapidly increase both their fertility and their functional and biological stability. (*Maienza et al, 2021*).

POOR SOIL IN RENATURING PROJECTS

It is important to remember that soil fertility is not the ultimate aim of all renaturing projects. Many herbaceous formations (grassland, meadows, etc.) are only found on nutrient-poor soils in environments that host extremely rich biodiversity. They are also environments that provide habitats for thermophilous species such as reptiles. In more urban contexts, as the GROOVES study carried out by ARB îdF on green roofs shows, these special ecosystems with poor soil are no less valuable in terms of biodiversity. Their special composition resembles nothing else in urban areas and there may be original combinations such as planted and spontaneous species and dry sandy grassland of local and more distant origin (*Barra & Johan, 2021*).

Technosoils and ecosystem services

Research has shown that these "constructed anthroposoils"[9] or "technosoils" are able to provide ecosystem services in a comparable way to natural soil, and that phenomena attributed to pedogenesis such as aggregation, decarbonisation, root colonisation and microbial activity can be rapidly observed (*Hafeez et al, 2012*). As far as carbon storage is concerned, even if the total amount stored is lower in constructed soil, the store of organic carbon remains four times higher in technosoil than in the natural soils studied (*Séré, 2018*).

One study estimates that after four years, technosoils are able to function in a similar way to natural meadows (in terms of production of plant biomass and decomposition) (*Cortet et al, 2014 ; Yilmaz et al, 2017*). Inventories show that the main groups of soil organisms can be observed in technosoils, be they micro-organisms, decomposers or engineer species (*Cortet et al, 2014*).

9. Soils constructed or significantly modified by humans

FIGURE 19. How the horizons of a technosoil evolve over time. ©Schwartz, G. Séré, Université de Lorraine

COMPARISON OF SOIL REHABILITATION TECHNIQUES

As part of the Bio-TUBES project (2016-2019) funded by Valorhiz with support from BRGM and Elisol Environnement, researchers carried out experiments comparing 3 soil restoration techniques: zero intervention (control site); decompaction coupled with ecological engineering; and technosoils combined with ecological engineering. After 30 months, the results showed the positive effect of rehabilitation measures on carbon storage, fertility and water retention functions compared to the control site. As for the "medium for biodiversity" function, all the sites demonstrated an interesting dynamic of recolonisation. These early results also underline the fact that with a limited number of physical, chemical and biological parameters it is possible to observe ecological functions performed by soils following the implementation of distinct technical solutions.

One of the experimental sites 5 months after implementing different soil rehabilitation strategies. © Valorhiz

THE "DESSERT" PROJECT

To improve understanding of urban soils, the DESSERT project (Désimperméabilisation des Sols, Services Ecosystémiques et Résilience des Territoires/Soil desealing, ecosystem services and regional resilience) was launched in 2021. This research programme aims to improve understanding of the behaviour of desealed soils, to improve knowledge of soil refunctionalisation after desealing, to create a typology of desealing approaches, to measure their effectiveness and to monitor them to optimise desealing processes on experimental sites. A thesis due to be completed in 2024 focuses on creating an inventory of practices, making observations on how desealed soils function and characterising the functions and services provided by these environments [51]. The project is funded by ADEME in the framework of the MODEVALURBA call for projects and coordinated by the University of Lorraine/INRAE (LSE Laboratoire Sols et Environnement)..

Trench under asphalt in Angers.
©Robin Dagois / Plante & Cité

A project for recycling demolition waste in the Paris Region

In the Paris Region, a partnership between the *département* of Seine-Saint-Denis, the ECT Group (soil recycling and upcycling) and the University of Paris-Est Créteil has tested the recovery of locally produced demolition waste and green waste to reconstitute fertile soils (*Pruvost, 2018*). On an experimental 4,000 m² site in Villeneuve-sous-Dammartin, 26 experimental plots were set up, corresponding to the three types of use to be tested: park and garden meadows, avenue trees and agricultural uses. Soils made up of sterile components (fill, alluvium, silt) were prepared with and without compost (10% of the total volume) for the three vegetation types. Mixtures with and without crushed concrete aggregate were also tested for the tree-planting plots. A four-year observation period showed that the compost used was responsible for the death of some trees, but that combined with concrete it greatly increased their growth rate and colonisation by macrofauna. In the meadows, the addition of compost increased biomass production and altered the composition of the plant community, favouring competitive species but not macrofauna. It is therefore possible to improve the primary productivity of new ecosystems by manipulating the composition of material mixtures while avoiding the dominance of certain species, in order to maintain diverse communities [52].

RENATURING DEGRADED SITES USING PLANT COMMUNITIES

Renaturing an anthropised site entails restoring plant communities, either through natural regeneration or through assisted recolonisation. It is actually more a question of a plant community, interacting with its environment and other species, than of individual plants. This approach requires precise knowledge of the ecosystems to be restored or created.

Colonisation by spontaneous flora: letting nature take its course

These days, natural processes are seldom allowed to express themselves in urban settings and interventionism is the rule. However, when nature is allowed to evolve spontaneously over time, natural dynamics are established, becoming more complex and structured and leading to functional, resilient ecosystems. This type of renaturing makes it possible to observe the dynamics of plant communities via ecological succession.
This succession is characterised by the height of the plant cover which increases over time. Most habitats tend to evolve naturally towards woodland in our latitudes. The process begins with pioneer species, which are the first to colonise poor, degraded or polluted soil. Their action over time modifies the soil structure physically (root action) and chemically (accumulation of litter), thus favouring their replacement by species that prefer to establish themselves on already colonised soil. After the pioneer plants, providing the shelter needed for future trees.

Waste ground in Strasbourg colonised by buddleia. ©Gilles Lecuir/ARB ÎdF

The role of pioneer plants in soil rehabilitation

Pioneer plants are the first plants to establish themselves on a degraded site. They are generally considered to be "weeds" although their role in preparing the soil is essential. They are able to colonise unstable environments poor in organic matter where climate conditions are tough (absence of water, intense heat, etc.) (*Sarasin, 2011*). In urban environments, they are generally annuals belonging to Amaranthaceae, Brassicaceae or Papaveraceae families (*Muratet et al, 2017*). As these plants modify the environment, they are gradually replaced by perennial species that are less specialised or more demanding. Using these species is of special interest in the framework of spontaneous ecological restoration programmes, and they can also be used to actively restore highly degraded environments. For example, they are recommended in the context of reforestation to initiate, amplify and accelerate the early plant colonisation process.

Invasive exotic species

When a renaturing project is carried out, the destabilising effects of the work may lead to the development of invasive exotic species. The presence of such species is closely connected to the instability of the

FACILITATING PLANTS

Facilitation is a mechanism by which an organism is able to modify the conditions of its environment so that the latter can host another organism that would otherwise be unable to thrive there (*Thiffault et al, 2017*). A facilitating plant, also called a nurse plant, speeds up the growth of other species by providing them with a refuge and improving the availability of resources. This refuge can offer protection from predators and from sources of environmental stress such as exposure to sunlight, drought, heat or cold. Pioneer plants can act as facilitating plants, though other species that arrive later on in the ecological succession process can also be used. For example, in tropical areas, planting tree ferns facilitates forest regeneration mechanisms (*Rivière et al, 2008*). In the Mediterranean context, a study has shown that planting previously mycorrhized species of lavender and thyme boosts the development of woodland plants and improves soil quality (*Hafidi et al, 2013*). Facilitation plays an essential role in degraded environments, in difficult conditions, for secondary species, and more broadly for the colonisation of new habitats and renaturing.

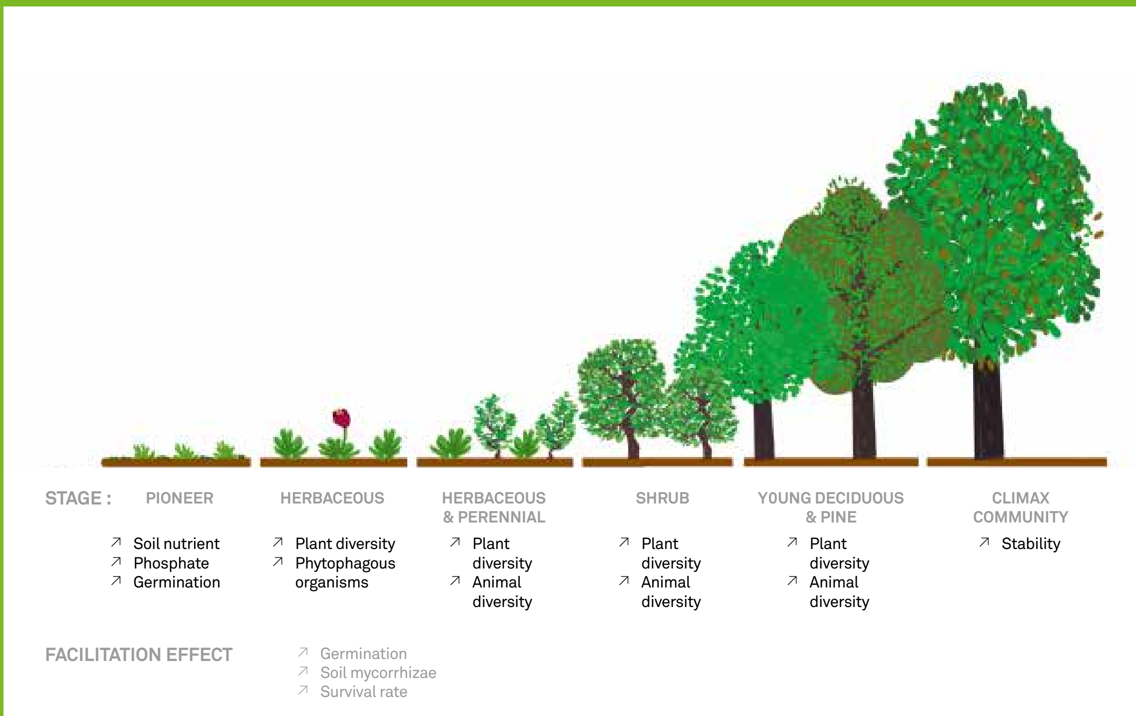


FIGURE 20. Effects of facilitation on the stages of ecological succession. Source: inspired by Chapin et al, 1994

environment, and it may be necessary to take action to avoid unwanted colonisation and dispersal. In this case, it is necessary to monitor the evolution of the site and even uproot young shoots to avoid single-species colonisation (e.g., buddleia). In the case of renaturing by planting, certain ecological engineering techniques now make it possible to integrate this variable, for example by maintaining sufficient planting density to create competition that inhibits the development of invasive exotic species such as Japanese knotweed or giant hogweed. Certain abandoned sealed areas may now already be colonised by these species. If so, prior treatment may be required to avoid the spread of residual plants during subsequent renaturing phases.

Spontaneous colonisation as part of renaturing

Passive renaturing does not mean "doing nothing"; it entails closely observing the first steps of spontaneous colonisation. Such observation can influence the direction the ecosystem to be restored should take (*Ravot et al, 2020*). Experimenting with spontaneous colonisation in cities can help scientists understand the value of these kinds of processes specific to urban ecosystems. Observation, and the information it can provide, is a key factor in renaturing projects as it results in more holistic scientific knowledge.

Assisted recolonisation: a leg-up for ecosystems

In some cases, the self-repair process for ecosystems can be accelerated by using plant-based engineering, whether it be sowing facilitating species or heavier work involving transferring whole patches of ground from nearby ecosystems. Though various methods can be used for sowing or planting a renaturing site, they have to be carried out on an ad hoc basis. Before the renaturing project begins, the following must be considered: the aim of the intervention (accelerating a process of spontaneous recolonisation, obtaining the most complete cohort of species for the environment to be rehabilitated, combating soil erosion, etc.), the typology of the host site (surface area, soil type, ecological connectivity, etc.), the type of technique to be used (sowing, hay, plug plants), available equipment and labour, as well as economic aspects and the management plan for the site after sowing.

PASSIVE RENATURING OF THE BANKS OF THE SÉLUNE

As part of the project that involved dismantling two large dams on the River Sélune, a coastal river that flows into the Bay of Mont-Saint-Michel, a scientific programme to monitor the renaturing of the river was set up. This pilot project combines passive restoration (spontaneous plant colonisation) and active restoration (removing the dams; gradual draining; creating banks; excavating the riverbed). Scientists focused on the vegetation that colonised the alluvium of the former dam reservoir. In the space of two and a half years, the results show that spontaneous vegetation typical of riverbanks has established itself and helps to maintain the banks. These results confirm how relevant and effective passive renaturing operations are. Plant communities will be monitored in the long term via a valley observatory, making it possible to decide between civil engineering and passive restoration in future projects. (*Ravot et al, 2020*).

Spontaneous renaturing on the banks of the Sélune, two years after gradually draining the old dams and reshaping the banks. ©Charlotte Ravot

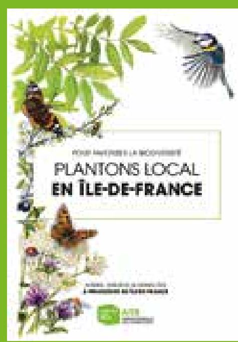
Restoring with locally sourced seeds

Locally sourced plants are increasingly being used in renaturing projects. These native species have the advantage of being better adapted to current ecological conditions and have a level of genetic diversity that provides the best guarantee of adaptation to climate change. Choosing native species also ensures that the entire cohort of accompanying species (entomofauna, soil invertebrates, symbiotic bacterial and fungal flora), which are vital to their ecosystem, will also establish themselves. They will have a better chance of long-term survival and of carrying out their complete vegetative cycle, unlike commercial species. It is possible to buy locally sourced plants from certain nurseries and suppliers. The *Végétal local* label [53] was created with this in mind. It is a collective brand rooted in the desire of green space project leaders and managers to use wild plants collected in their region. It was created in 2015 at the initiative of the Fédération des Conservatoires Botaniques Nationaux (FCBN), Plante & Cité and Afac-Agroforesteries, and is the property of the Office Français de la Biodiversité (OFB). The *Végétal local* label makes it possible to guarantee the local provenance of wildflowers, trees or shrubs in a given ecological region (11 bio-regions have thus been designated in metropolitan France), with local genetic diversity and regularly replenished seed stocks. In some cases, it is also possible to select seeds by harvesting wild seeds or hay directly in their natural environment close to the renaturing site.

CREATING A LOCAL SEED OPERATION IN BESANÇON (GRAND EST)

For several years the City of Besançon has been committed to conserving biodiversity, especially urban pollinators. To increase the presence of local species and provide a habitat for them, the City chose to develop production skills and structures (greenhouses and the municipal orangery) to create a supply stream providing locally collected wild seeds. The operation has been organised in close connection with the Conservatoire de Botanique and the Conservatoire des Espaces Naturels in Franche-Comté. The City's three gardeners and botanists are now in charge of harvesting the seeds and creating mixtures adapted to the City's ecological plan. The seeds are used in municipal flowerbeds and sown in the grassed-over part of the tramway. In 2017, 20 species were harvested in this way (creeping thyme, dianthus, sanfoin, etc.).

THE "PLANTONS LOCAL" GUIDE



ARB îdF has published a guide to help increase the proportion of indigenous plants in public and private areas. It provides lists of species that are best adapted to the Paris Region's environmental conditions for the creation of meadows, hedges, shrubberies, wooded areas, etc.

The species presented in the guide...

...foster interactions with fauna: plants host larvae and caterpillars and flowers attract adult insects (butterflies, hoverflies, bumblebees, honeybees, etc.), fruit attracts birds and mammals, and so on

...are adapted to the local climate and to the natural or impaired soils of the region, as well as to human management...are offered under the "Végétal local" label.

EXAMPLE OF MEADOW RESTORATION

The hay-spreading technique was tested in 2006 on the Crau plain to reintroduce species specific to dry grassland and increase the specific diversity of post-agricultural disused land. The initiative was unusual in that as well as mowing to a height of 20 cm, the resulting hay was then collected using a leaf vacuum. The hay was kept dry over the summer and then, after the first autumn showers, strewn on the ground. To encourage germination and limit seed loss, the soil was first harrowed. The quadrates were watered before and after spreading, and wire mesh was laid over the area to prevent the seeds from being blown away. This technique turned out to be very effective. Two years later, the diversity of plants in the quadrates had increased significantly and many steppe plants had returned (thyme, oats, pimpernel, sage, etc.).

Harvesting plants and seeds

Hay transfer
One of the techniques used in ecological restoration to rehabilitate plant communities is hay transfer (*Jaunatre et al, 2014*, [54]). This technique involves mowing a species-rich meadow in an area near the project. The resulting hay can be spread either immediately on the site (green hay) or after a period of storage (dry hay). It is spread over dug and decompacted soil on the renaturing site. As it dries, the hay releases its mature seeds, which then germinate in the target area. Ideally, the operation should be repeated several times during the fructification period. As the phenology of meadow plants varies, it may be necessary to choose a window of opportunity that makes it possible to harvest the required plants. The transfer of mulch or cut branches resulting from site management work is also possible (*Lemoine, 2016*).

Sod transplant
This technique involves extracting vegetation and soil in large sods or small plugs and transferring them to the site under restoration. Plant cover is thus restored in record time. The technique makes it possible to replant seedlings, mosses and soil micro-organisms as well as flora from seed-rich micro-ecosystems. To ensure success, it is advisable to dig up about twenty centimetres of soil, though if the source site is to be entirely destroyed sods 30 - 50 cm deep may be extracted. As this technique degrades the “donor ecosystem”, it should only be used when the source habitat is threatened with destruction (due to urbanisation).

Mycorrhization

A mycorrhiza is the product of co-evolution between a microscopic fungus and a root. This association brings plants many advantages: improved access to nutrients and water, protection against pathogenic organisms, better resistance to environmental stress, etc. For example, it has been shown that mycorrhizal fungi (in non-disturbed ecosystems) improve growth compared to non-mycorrhized plants (*Plenchette et al, 1983*).
Controlled mycorrhization involves “artificially” restoring the symbiotic relationship between fungi and roots. Though it is used in particular in farming, it can also be valuable in restoration projects in urban environments (*Henry et al, 2021*).
Mycorrhization is best done at the moment of planting, especially if the plant has exposed roots (e.g. trees and shrubs), which means the product containing the fungus can be applied directly to the roots. Otherwise, it is possible to mix the product with the soil. This process is used by landscapers and soil suppliers to boost soil fertility and accelerate plant growth. In addition to this productivist approach, it is possible to use mycorrhization to lastingly improve soil functions. Plante & Cité, in partnership with INRA in Nancy, carried out a study in 2009 to assess the mycorrhizal status of roots [55].

Mycelium (white) of an ectomycorrhizal fungus associated with roots ©André-Ph. D. Picard

HAY TRANSFER: A TECHNIQUE NOT RESTRICTED TO NATURAL ENVIRONMENTS

Built in 2014 and designed by architects Chartier-Dalix, the Ecole des Sciences et de la Biodiversité in Boulogne-Billancourt is one of the most successful examples of green architecture in the Paris Region. Its single tiered façade and its living roof are the result of a partnership between the architects and the ecologist Aurélien Huguet. The depth of the roof substrate varies between 30 cm and 1 m, making it possible to create a range of habitats from a meadow to an urban "micro-forest". In 2020 the architects decided to renovate the meadow to increase its potential for biodiversity using ecological engineering techniques. The main aim was to increase the diversity of perennial flowering local species typical of old meadows. The project team identified areas of dry grassland in the park of Marly-le-Roi. With the agreement of the park authorities, a plot was identified as an "ideal donor" due to its exceptional floristic diversity and compatibility with conditions on the roof in Boulogne. In June and July, seeds were collected by hand from the earliest flowering species (meadow sage, erect brome, quaking grass) before the area was entirely hand mown. The harvested seeds and hay were spread out on the rooftop. The operation was monitored to evaluate its success and to fine-tune practices where necessary. One year later, floristic evolution indices showed the appearance of eleven flower species from the donor meadow, as well as several new insect species.

Hand mowing in the Marly Royal Park to reseed the roof of the Ecole de Sciences et de la Biodiversity in Boulogne-Billancourt.
©Sophie Deramond (down) © Aurélien Huguet (up)

CREATING HABITATS FOR BIODIVERSITY

Although renaturing needs to be context-specific and cannot be generalised by referring to a single type of habitat, some principles can be applied more or less everywhere when implementing renaturing projects. Depending on the project, it is advisable to:

- Diversify plant strata (moss layer, herbaceous layer, shrub layer, trees), species and environments (meadows, copses, hedges, ponds, banks, stones, etc.), to offer species different conditions to which they may adapt. The aim should be to create a variety of different areas.
- Create additional micro-habitats for species, such as piles of rocks, dead wood or water (a pond for example).
- Avoid using artificial barriers (walls and fences), which significantly hinder species migration and fragment the landscape. If it is necessary to protect a site (e.g. to avoid trampling), fencing should allow small animals to pass through.
- Restore habitats specific to a cohort of species instead of setting up hives, nesting boxes, insect hotels and so on.
- Limit the ecological footprint of materials by using those already on site and by avoiding man-made materials (geotextile membranes, plastic trays, etc.).

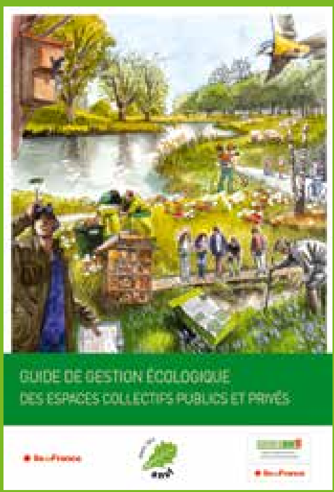
MANAGING RENATURED AREAS

The many ways in which renatured areas are used and their value for communities often mean that they must be managed in one way or another. However, natural areas in urban environments are often maintained too intensively, to the detriment of the biological cycle of species and the free development of wildlife. Designing biodiversity-friendly areas requires tailored ecological management approaches—or even allowing the environment to develop freely. Ecological management requires finding a compromise between the relatively strict and constrained maintenance of municipal parks and gardens and the conservation of nature reserves. Combining the two can foster biodiversity while at the same time responding to users' needs and expectations. This approach can be minimalistic by reducing trees and shrubs pruning, while some areas can be left unmanaged. It can just involve making the site accessible and providing footpaths for recreational activities. In some cases, raised boardwalks can allow people to visit the site without disturbing wildlife.

If the aim is to maintain a target species or community, management approaches can be tailored to their specific characteristics. This will depend on the group of environments targeted (removing ligneous species to focus on herbaceous vegetation, grazing to keep an area open, maintaining areas of bare earth for pollinators, bringing in dead wood, etc.). In the case of wetlands, it may be necessary to protect ponds or reedbeds to keep the environment in good condition. In any case, specialists should always be consulted in order to keep human intervention to the bare minimum.

A site allowed to develop freely: part of the Épinay-sur-Seine ecological reserve. ©Marc Barra

SUPPORT FOR TRANSITION TO ECOLOGICAL MANAGEMENT



ARB îdF and the ANVL (Association des Naturalistes de la Vallée du Loing et du Massif de Fontainebleau) have published a practical guide to ecological management. Many guides have already been published on the subject, but they tend to concentrate on one particular theme (water pollution, weeding, etc.). This book deals with cross-sectional subjects such as local biodiversity, greenhouse gas emissions and the effects different practices can have on humans. It does not replace more specialist guides, which deal with a broader range of issues and provide a more detailed description of methods relating to a particular theme. It should also be borne in mind that techniques evolve very rapidly [56]. In addition, the EcoJardin label was created in 2012 by Plante & Cité to meet growing demand from public bodies and private companies to move towards the ecological management of their green spaces [57].

MONITORING AND INDICATORS

Monitoring is necessary to assess the success of a renaturing project or fine-tune management approaches. As well as monitoring biodiversity, many parameters can be assessed over several years such as soil quality, ecological services (cooling, permeation, air quality), ecological connectivity, community acceptance, etc. Monitoring should be seen as a way of communicating around projects and a way of convincing decision-makers of their relevance. There is no "monitoring model" applicable to all restored sites: it depends on the individual project (surface area, environments restored, objectives, budget, in-house skills, etc.).
Where wildlife monitoring is concerned, it is advisable to refer to a standard protocol[10] making it possible to compare the site with similar areas across the region and the country [58]. Participatory science programmes offered by Vigie Nature are especially useful to carry out this kind of long-term monitoring. Coupled with support and/or mediation from a local association, participatory sciences are also a good way of sharing the results of a renaturing project with the local community. It is advisable to target taxonomic groups that make sense in relation to the site and the restored ecosystem. It is possible to enlist the aid of naturalist or ecological associations to put in place a follow-up plan and help carry out certain inventories when in-house skills are lacking.

10 This means a protocol that is precisely defined in a reference document and is applicable by different operators in several regions. This type of protocol makes it possible to monitor projects on a large scale over long periods. Standard protocols used in participatory science programmes make it possible, for example, to respond to key questions on ordinary biodiversity.

TARGET GROUP	PROTOCOL	TYPE OF ENVIRONMENT	TIME SPENT	LEVEL OF KNOWLEDGE
RHOPALOCERA (BUTTERFLIES)	STERF	Open environments	Minimum 4 hours per year per site	Naturalist
	Propage	Open environments	Minimum 3 x 10 mins per year on a site (June to August)	Green space manager
	Opération Papillons	Open environments	Once a year (March to October)	For everyone
BIRDS	STOC and / or EPOC	All	Once a year (March to June)	Naturalist
	SHOC (common birds in winter)	All	Once a year (December to January)	Naturalist
	Oiseaux des jardins (garden birds)	Private gardens; parks	All year round	For everyone
DRAGONFLIES	STELI	Aquatic environments	Once a year (March to October)	Naturalist / Green space manager
FLORA	Vigie-Flore (common plants)	All	Once a year (April to August)	Naturalist
	Sauvage de ma rue (street flora)	Urban (street)	All year round	For everyone
	Florilège, (urban meadows)	Open environments	Once a year (June to July)	Green space manager
	sTREEts (flora at the foot of trees)	Urban (foot of trees)	Once a year (April to June)	Naturalist
BATS	Vigie-Chiro (bats)	all	Twice a year (June to September)	Naturalist
INSECT POLLINATORS	SPIPOLL	Species in flower, all environments	All year round, time spent variable	For everyone

TABLE 15. Biodiversity monitoring protocols proposed by Vigie-Nature. Non-exhaustive list.
For more information on protocols, see webography [59 ; 60])

COMMUNITY ENGAGEMENT

The ecological crisis, in the form of climate change and the erosion of biodiversity, often causes an individual feeling of powerlessness. Taking part in a desealing and renaturing project allows members of the community to get actively involved and shows them that they can have a genuine impact on their day-to-day environment. It's also a way of getting them to re-appropriate public space and to change their way of thinking about the city in response to new aspirations. Convincing people that a project is of value, making it acceptable, creating multiple ambassadors…there are many good reasons to involve residents in renaturing projects. Moreover, renaturing requires different levels of engagement. These include improving communication, involving people in carrying out analyses, looking for sealed areas that could be renatured, the co-construction of the project, active participation in the on-site work, and naturalist monitoring.

Whatever the renaturing project, it is vital to communicate, inform and involve people at every stage. Often forgotten or neglected, communication generally begins after the first steps have been taken or the first responses formulated. It must begin before this to prepare residents, users, local government officials and agents for the changes to come and use all available means to share the information as widely as possible (newsletters, social media, workshops, etc.). This is even more essential in the framework of a passive renaturing project involving passive management. Communication focusing on the benefits in terms of biodiversity, health, improving the living environment and risk management will allow the local community to appropriate the renatured sites and understand how useful they are. There are many different means of information, consultation and participation available; here are just a few to inspire future projects:

Debates, workshops and talks to raise awareness of what is at stake in a desealing/renaturing project and share scientific knowledge

Communication tools can take the form of public meetings, articles in the local press and on social media, or a dedicated website

Polls (questionnaires or one-to-one interviews) can be organised to collect opinions and ideas; project co-construction workshops can be set up; the local community can be invited to take part in on-site work; and residents can be encouraged to take part in wildlife monitoring via participatory science programmes.

The "Oasis" playground at the Émeriau nursery school in Paris. ©Théo Ménivard, CAUE Paris

Desealing school playgrounds: the OASIS programme

More and more local authorities are desealing and planting school playgrounds. These areas, which when originally built comprised a concrete slab and a few isolated trees, have a lot to offer in both educational and environmental terms. Renaturing them has numerous benefits: reconnecting with nature, educating children about the environment, a more equitable distribution of space, combating urban heat islands, etc.

While in some schools the work is limited to rainwater management (replacing the ground covering with a permeable alternative), more and more authorities are choosing to transform playgrounds into planted areas. As well as direct benefits to wellbeing and health, these areas are ideal settings for education about nature, particularly via participatory science initiatives[11]. The set of recommendations produced as part of the Paris City Council's OASIS programme provides a wealth of information on how to deseal playgrounds and on how to involve the educational community in their design, which is essential to the success of such projects [61].

11 The Vigie-Nature École programme run by the Muséum National d'Histoire Naturelle offers protocols adapted for schools: https://www.vigienature-ecole.fr/

Desealing the l'Ille playground. ©RM

Pull up a parking lot: participatory depaving

Several depaving initiatives have emerged in Canada and the USA. Since 2005, the "Depave" collective in Portland, Oregon has been engaging in depaving initiatives with the slogan "From Parking Lots to Paradise". This initiative has inspired a similar approach in Canada titled "Sous les pavés" run by the Montreal Urban Ecology Center [62]. This participatory urbanism project aims to depave public and community spaces collectively and by hand and create planted areas. Local citizens are involved throughout the process: finding the site, organising co-construction workshops, green-lighting the final project, depaving and planting, and finally inaugurating the redeveloped site. Selected areas are between 100 and 300 square metres. The site is first prepared by specialist contractors who pre-cut the asphalt, which can then be carried away by hand or in wheelbarrows and thrown in a dumpster.

The DEPAVE movement exported to Rennes

Audiar, the planning agency in Rennes, has supported local strategies with the project titled "Depave, la ville perméable" (Depave, the permeable city). Inspired by DEPAVE in North America, a Metropolitan Council think tank analysed the idea of desealing public spaces in order to improve practices and create a shared culture. Two projects for public space and a school were analysed. Visits and workshops made it possible to share current practices and questions so that issues relating to water and biodiversity were fully taken into account. The worked helped to inform the Metropolitan Council's public space planning guide, which provides a new reference framework for future projects. "Depave, la ville permeable" also includes a partnership with an academic research laboratory (LETG Rennes) which aims to use remote sensing technology to identify and monitor impermeable materials in the urban fabric (work in progress).

Strasbourg ça pousse: a community public space gardening programme

Since 2017, the City of Strasbourg has been offering the local community the opportunity to take part in a public space gardening programme. The base of trees, pavements and the façades of buildings all provide opportunities to bring greenery into the city, to develop areas able to host biodiversity and to improve rainwater infiltration, either alone, with neighbours or in front of shops. Organised around a single online urban gardening platform, in 2020 the initiative included no less than 160 projects on city pavements (700 sq.m. desealed), 50 flowerbeds at the base of trees and numerous planters installed with the help of local shopkeepers [63]. A guide to help project leaders decide what to plant was published in 2020. Ideas for improvement are currently being discussed: improved consultation procedures, a plant donation programme and several other changes are planned to improve understanding of the initiative and make it more accessible to the community at large.

Participatory depaving and planting during a "Sous les paves" operation. ©Martin Matteau, free authorisation for use provided by the Center for Urban Ecology in Montreal. "Sous les paves" has published a guide to running participatory desealing projects. Tools and activities are suggested for each phase of the project

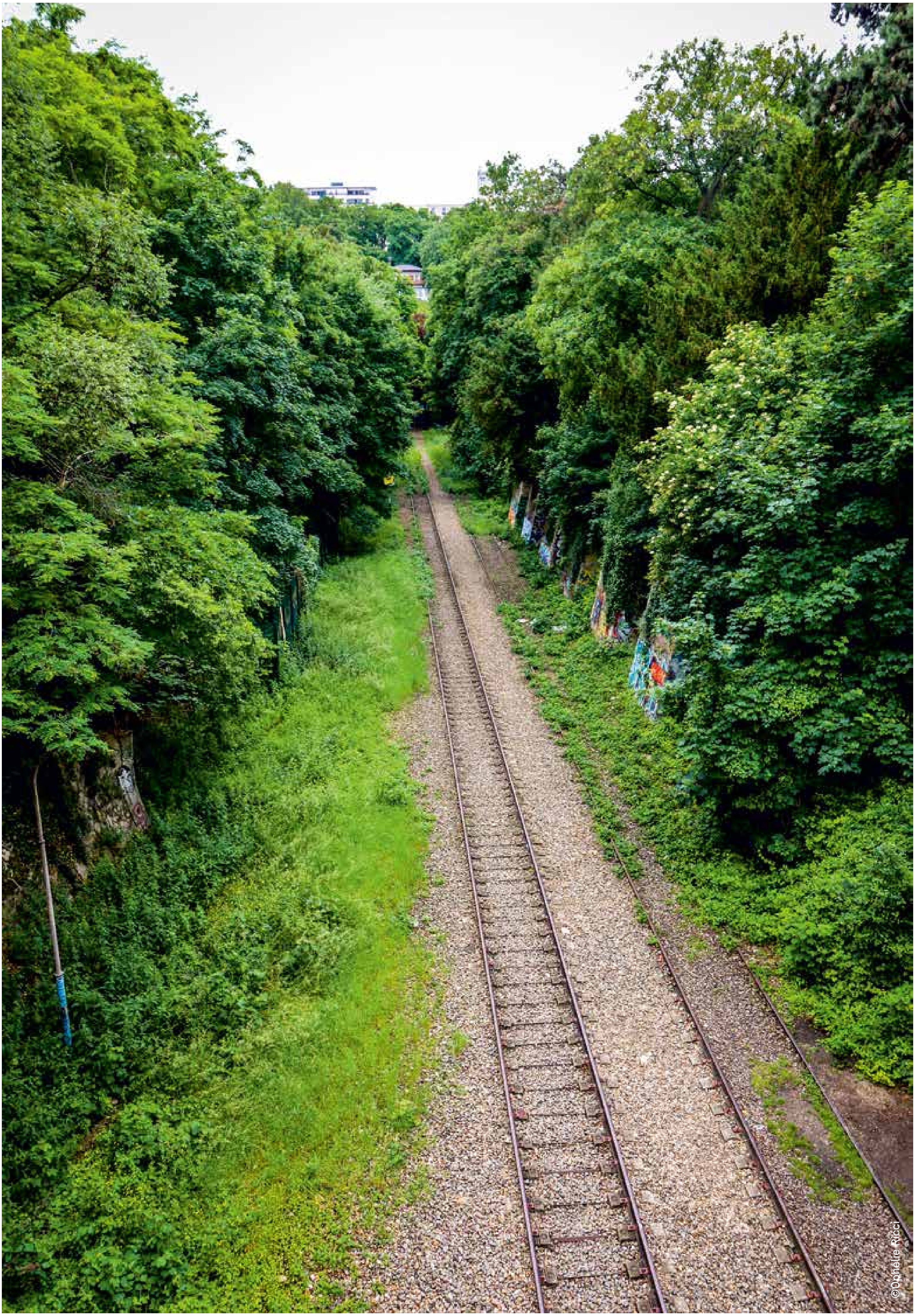
Any new public space planting initiative must be authorised by the City Council and the Metropolitan Council. Projects must also comply with "zero pesticide" and "locally sourced planting" protocols. ©Alban Hefti/ Strasbourg Eurométrople

PROTECTION OF RENATURED SITES

Renaturing only makes sense if restored environments continue to thrive in the long term. In France, natural spaces are protected in the following ways:
Public bodies can purchase land to protect it. This approach is often adopted in areas threatened with urbanisation. Regulatory protection controls or prohibits human activities that may harm wildlife and ecosystems (e.g., biotope protection laws, biological reserves and listed sites, planning regulations).

Contractual protection involves delegating the management of a natural area in the framework of a convention for a specified period.
These approaches are complementary and may be used in tandem to provide reinforced protection. Local authorities have several tools at their disposal that can easily be implemented to protect natural spaces in urban environments, often termed "ordinary nature" (nature ordinaire).

The Repainville natural urban park in Rouen covers an area of 10 hectares. Once earmarked for urbanisation, the partially renatured site has been classified "Zone N" (protected natural area) in the city's urban planning masterplan. ©Marc Barra/ARB ÎdF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CONCLUSION

The climate and biodiversity crises we are currently facing are not set in stone and can be halted. More than ever before they invite us to collectively rethink our lifestyles and the way we design and manage our cities. Until now, urbanisation has tended to involve simply covering the ground with roads and buildings. In France, the average rate of land take was 27,638 hectares per year in 2009-2019 (*Bocquet, 2021*). This unsustainable dynamic cries out for structural reform, both to slow urban sprawl and to repair the errors of the past. A new pact between nature and the city seems possible provided we come up with more frugal development methods, improve the protection of ecosystems and speed up the renaturing of degraded or sealed environments.

Many cities have to cope with excessive density and lack of greenery. The idea of compact cities and densification is now being re-examined in favour of small and medium-sized towns (Faburel et al, 2020). While 75% of the French population lives in urban areas, a vast majority are in favour of nature returning to the city, in particular to improve the living environment. The benefits of nature in the city no longer need demonstrating, whether they concern adaptation to climate change (water management, cooling), public health (air quality, recreational areas) or supporting numerous species whose abundance has significantly declined in recent years. Once again, these observations militate in favour of renaturing urban environments.

Ecological engineering and research into ecological restoration have made it possible to garner a significant amount of knowledge and expertise that can be leveraged in order to begin such restoration in cities. As many projects testify, renaturing sealed soils has already proven its worth and past projects can provide inspiring feedback. However, ecological restoration in urban settings is quite a recent development. This guide aims to disseminate knowledge on the subject, to help public bodies elaborate strategies, and to encourage sharing and experimentation.

Renaturing is also an invitation to strengthen connections between urban stakeholders, which are still too tenuous. Urbanists, developers, councillors and technicians must more than ever turn to ecologists and naturalists as they think about tomorrow's cities and initiate a kind of renaturing that is able to provide effective ecological and climatic responses. Urban design must also open up to the community, which must be placed at the heart of urban policies. Convincing people and making projects acceptable to them, reappropriating the public domain, making use of ambassadors and adopting inventive approaches are all ways of motivating members of the community to take part in renaturing our towns and cities.

KEY POINTS TO REMEMBER

1

Renaturing means **returning ecosystems that have been degraded or destroyed by human activity to a natural or semi-natural state.** It can be passive (allowing nature to take its course) or active (ecological engineering). It concerns a wide range of environments.

2

Renaturing involves restoring "open ground" and living soils. Desealing, which aims to make the ground permeable, is necessary but not sufficient. Although off-ground solutions in urban settings (e.g. green roofs) offer genuine benefits, they do not constitute renaturing.

3

Greening, unlike renaturing, refers to plant-focused approaches whose aim is essentially aesthetic. **Renaturing relies on knowledge of ecology and awareness of all levels of biodiversity** (genetic, specific and ecological).

4

URBANISATION CONSUMED

539 sq.km. OF LAND PER YEAR IN EUROPE

BETWEEN 2012 AND 2018.

It must be a priority to avoid new land take by working within the framework of the existing urban fabric and by making every effort to protect natural spaces.

5

Implementing Zero Net Land Take requires a complex strategy that aims (a) **to reduce urban sprawl** by encouraging renewal and densification and (b) **to restore areas consumed by urbanisation** with the help of renaturing projects.

6

Densification must not take place to the detriment of small wild areas in towns and gardens or planted areas of waste ground, whose ecological value has been proven.

7

Although the Paris Region is responsible for "only" 5% of land take in France while being home to 20% of its population, it is also the country's **most urbanised region**. Renaturing should make it possible to reverse previous land take: the challenge is to carry out ecological restoration in urban areas and to increase the amount of wild space they provide.

8

Renaturing should **focus on sealed surfaces** (car parks, public squares, etc.) to maximise ecological benefits.

9

The notion of "open ground" (pleine terre) refers to several soil-related criteria: ground covering material, vertical continuity, horizontal continuity (the brown grid), physical, chemical and biological quality and permeability.

10

The REGREEN method highlights priority renaturing zones in the Paris Region in order to locate potentially renaturable sites and to measure their renaturing potential.

11

REGREEN has identified **30,535.31 hectares of potentially renaturable sites,** equivalent to

2.54%
OF THE PARIS REGION

12

Sites where renaturing would bring benefits relating to **all 3 key challenges** (biodiversity, climate change, health) represent a total of **7,016.79 hectares**.

13

Ecological analysis is required prior to any renaturing project. This comprises inventories of flora, fauna and habitats, soil analysis and ecological continuity surveys within the scope of the project.

14

Phytoremediation means using plants to decontaminate the soil. The effectiveness of the technique has been proven, although it is quite time-consuming. It is also **up to ten times cheaper** than standard decontamination methods.

15

"Technosoils" are soils constructed from materials seen as urban waste (concrete, rubble, railway ballast). They provide ecosystem services similar to those afforded by natural soils: carbon storage, decomposition of organic matter, etc. The use of new techniques such as technosoils would avoid importing natural soil from elsewhere, which merely transfer the impacts of land take.

16

Appropriate management of a renatured site is as important as the renaturing process itself. An intensively managed renatured site cannot fully express its potential, unlike an ecologically managed or unmanaged site.

17

Involving the community in renaturing projects helps residents to accept them and make them their own, ensuring their long-term success. Communication is even more vital for projects where the renatured site is left unmanaged, to relieve people's preconceptions.

18

There are **numerous legal tools that make it possible to ensure the long-term survival of a renaturing project**: land control, regulatory procedures and contractually delegating site management are ways of ensuring that renatured sites are not built over a few years later.

CONCEPTS AND **DEFINITIONS**

This glossary aims to define certain key terms in the light of knowledge available in scientific literature and to provide additional clarification.

BIO-INDICATOR

An organism (animal, plant, bacteria, fungus) or group of organisms whose presence or condition provides information on the quality of the environment. According to the aim of the project, several types of bio-indicators can be distinguished (*Argillier et al, 2008*): diagnostic bio-indicators, which make it possible to measure modifications linked to human activities and compare them to less disturbed ecosystems; goal-related bio-indicators, which make it possible to determine whether goals have been achieved; and early warning bio-indicators, which warn of the existence of environmental intoxication processes before more severe effects appear in the ecosystem.

BROWNFIELD SITE *see* WASTE GROUND

DESEALING (ALSO DEPAVING)

Making the surface of the soil permeable again. Desealing belongs to an array of alternative rainwater management methods and techniques that favour permeation and at-source rainwater storage. It is a necessary but not sufficient condition for the restoration of ecological soil functions. Using porous ground covering materials (e.g., permeable paving or surfacing materials) is not the same as complete renaturing.

ECOLOGICAL RESTORATION

Partially or totally restoring the functions of an environment or landscape, particularly their soil functions, and returning them to a natural or semi-natural state. (Might also be referred to as "land take reversal". The standard French term is *désartificialisation*).

ECOLOGICAL ENGINEERING

"The management of environments and the design of sustainable, adaptative, multifunctional solutions inspired by, or based on, the mechanisms that govern ecological systems (self-organisation, diversity, heterogeneous structures, resilience)." (*Abbadie et al, 2015*). Ecological engineers are involved in rehabilitating degraded ecosystems, restoring functional communities, reintroducing species and creating sustainable new ecosystems valuable to humans and the biosphere. Ecological engineering means "managing projects that are implemented and managed [...] in such a way as to support the resilience of ecosystems" (*Journal Officiel*, 18/08/2015 1). Renaturing, when it does not happen spontaneously, makes use of the expertise and techniques of ecological engineering.

ECOLOGICAL GRIDS

In 2007, the Grenelle de l'Environnement recognised habitat fragmentation as one of the causes of biodiversity decline. This awareness resulted in the launch of a new policy supported by the Ministry of Ecology, Sustainable Development and Energy, called the "Green and Blue Grid". The concept of "grids" is connected to the aim of maintaining or restoring networks that allow animal and plant species to move around and carry out the different stages of their life cycles. The Green and Blue Grid policy is also based on concepts belonging to landscape ecology (*Keitt et al, 1997; Henein & Merriam, 1990; Pulliam, 1988; Forman & Baudry, 1984*). Biodiversity reservoirs are environments where wildlife can live and reproduce, whereas corridors allow species to move between these sites. Green and Blue Grid policy is applied at regional level in Schémas Régionaux de Cohérence Écologique (SRCEs: regional ecological coherence Plan) and at sub-regional level in planning documents, natural park charters, etc. Scientists are now suggesting new grids concerning other spaces inhabited by biodiversity—the air, the ground surface and the soil—for example the "black grid" (used by nocturnal species), the "brown grid" (soil-dwelling species), and the "aerial grid" (used by winged species) (*Sordello, 2021*).

ECOSYSTEM SERVICES

This notion emerged in the 1980s among naturalists engaged in conservation programmes. It developed significantly in the late 1990s thanks to the work of the economists Robert Costanza (*Costanza et al, 1997*) and John Daly (*Daly, 1997*), but it really gained

1 JORF du 18 aout 2015 : https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000031047578

momentum following the publication of the Millennium Ecosystem Assessment in 2005. It refers to the benefits that human societies gain from functioning ecosystems. These services are generally divided into four main categories:

- Provisioning services: the "products" of ecosystems (timber, fish, pollen, access to water, etc.)
- Regulating services: benefits provided by properly functioning ecosystems (protection or limitation of damage during floods, pollination, CO_2 storage, limiting effects of climate change, water purification, etc.)
- Cultural services: intangible benefits arising from our relationship with an ecosystem (recreation, education, etc.)
- Supporting services: services necessary for the production of all the other services, ensuring that ecosystems function properly (soil formation, biogeochemical cycle, primary production, etc.)

This concept should be used with caution and may arouse criticism by helping to establish a utilitarian (or even monetarist) approach while taking insufficient account of divergent visions and values relating to nature. Protecting biodiversity and managing ecosystem services are two separate processes that do not necessarily match. Biodiversity may offer multiple ecosystem services (carbon storage, landscape quality, water retention, etc.), but it cannot be reduced to categories of services alone. Such an approach might lead to poor practices focusing on one or several services while ignoring the integrity of ecosystems (monocultures for carbon sequestration, the overdevelopment of beehives to the detriment of wild pollinators, etc.). It is important to remember that biodiversity protection primarily involves ethical considerations in which utilitarian parameters have no place. Rather than asking "why protect biodiversity?", an ethical approach makes us ask "why destroy it?" (*Sarrazin et Lecomte, 2016*)

ENGINEER SPECIES

A species whose presence and activity significantly modifies its environment (e.g., beaver, earthworm). The concept of ecosystem engineers was suggested in 1994 by Clive Jones. It refers to organisms that modifies their environment so much that they have a significant effect on species around them. There are two types of ecosystem engineers: autogenic engineers, which are organisms that modify the environment by their mere presence (e.g., a tree that intercepts light and thus creates special conditions for the photosynthesis of nearby plants) and allogenic engineers whose activity modifies their environment. The beaver is the simplest example; the woodpecker, which allows fungus or other birds to use the holes it makes in trees, is another. In ecological engineering, engineer organisms are extremely valuable tools for renaturing environments.

FACILITATING SPECIES

A species whose presence allows or improves the development of other species. A facilitating or "nurse" plant will facilitate the establishment and growth of other species by providing them with a refuge. This refuge can offer protection not only from predators but also from sources of environmental stress such as sunlight, drought, heat or cold.

FERALITY

The act of returning to the wild state after being domesticated. It may refer to an animal or plant, or to an entire ecosystem as Schnitzler and Génot suggest (2012). This concept is close to that of rewilding.

GREEN SPACE

The notion of green space belongs to the lexicon of urban and landscape planning. In urban areas, green spaces are areas that are not yet built on and which are given over to plants (including trees). They may be areas of woodland or used for farming purposes.

LANDSCAPE ECOLOGY

A discipline of ecology that entails studying ecological processes on the scale of the landscape, considering its composition and configuration as key elements that influence these processes. One of the key concepts of this discipline is landscape connectivity, which highlights the importance of ecological networks in population dynamics (*Bourgeois, 2015*). The principles of landscape ecology have to be mobilised in the framework of a renaturing project to ensure that it is coherent with respect to the other spatial scales as well as its local environment.

LAND TAKE (artificialisation in French)

Land take is the result of anthropisation, whose final stage is ground sealing. Providing a definition of land take is complicated and requires considering numerous dimensions, including soil condition, biodiversity and landscape. Scientific and regulatory definitions often diverge. In France, before the Climate and Resilience Act was passed in August 2021, artificialisation was defined in the broad sense as "the consumption of agricultural, wooded and natural areas". The 2021 Act introduced a new definition referring to "lasting deterioration of some or all of the ecological functions of a soil, in particular its biological, hydric and climatic functions, as well as its agronomic function via its occupation or use". This is closer to the definition proposed by ecologists, who consider that there are several degrees of artificialisation, the ultimate stage being sealing due to building or asphalting/concreting over. This nonetheless involves being able to assess the condition and functions of the soil using specific measuring and monitoring tools. In urban settings, the wide variety of soils and the many gradients of ecological quality in green spaces make the boundary between *espace artificialisé* and *espace non artificialisé* (areas where land take has/has not occurred) difficult to define.

NATURALNESS *see* WILDNESS

PIONEER SPECIES

The first species that colonise or recolonise a given environment. This may be a newly created environment (a wall, an area of waste ground, a patch of desealed ground, etc.) or a recently disturbed one (infill, an urban building site, an area of felled trees, a landslide, an area where topsoil has been removed, etc.). Pioneers are the first species to appear at the beginning of ecological succession.

PLANT ENGINEERING

Implementing techniques using plants and their mechanical and/or biological properties for: controlling, stabilising and managing eroded soils; restoring, rehabilitating or renaturing degraded environments, including incorporating solutions into the landscape; and phytorehabilitation or phytoremediation (decontamination of soil and water using plants) (*Rey et al, 2015*).

REHABILITATION (ALSO REFUNCTIONALISATION)

This means creating an ecosystem that is structurally and functionally identical to the one that existed before a disturbance (*Séré, 2007*). Its composition, however (i.e., its specific diversity and abundance) differs from that of the initial ecosystem.

RENATURING

In the broadest sense, renaturing means returning ecosystems that have been degraded, damaged or destroyed by human activity to a natural or semi-natural state. It is synonymous with ecological restoration and can be either active or passive. Active renaturing involves actions that initiate or accelerate the self-repair of the ecosystem in question. Passive renaturing, used where damage is less severe, allows natural processes to restore the ecosystem. Renaturing can be used for both natural and semi-natural ecosystems. The Net Zero Land Take goal sees renaturing as a way of offsetting or reversing land take, defining it as the set of processes that make it possible to restore disturbed land to its initial natural state.

RESILIENCE / NATURAL REGENERATION

The word resilience comes from the Latin verb *resiliare* which means "to spring back". In ecology, the term is used to refer to how an organism, a species (taxon) or an ecosystem is able to withstand major or minor disturbances (natural or industrial disasters, etc.) and return to its normal way of functioning. Resilience generally depends on the diversity and complexity of ecosystems and on the genetic heritage of individuals. When the concept is applied to a country or area, it is used to assess social vulnerability to environmental and economic risks so that the area can better defend itself against external hazards. It denotes the stability of an ecosystem and how fast it is able to return to a stable state after a disturbance (*Triplet, 2021*). "Natural regeneration" refers to the ability of an ecosystem to restore itself spontaneously following a disturbance that might have led to its total or partial destruction; it is thus synonymous with resilience. Renaturing projects whose aim is spontaneous recolonisation leverage resilience.

REWILDING

This can refer either to the reintroduction of species that disappeared centuries or millennia ago or to the absence of human intervention in a given area (also known as natural regeneration). In cases aiming at a total lack of human intervention, all activities that impinge on nature are prohibited and the site is not managed. Humans are not entirely excluded, however, and visitors may be allowed providing they use specially laid out paths and observation points. Rewilding is synonymous with the "free evolution" of nature. A "freely evolving" area is an area governed by natural processes. It is made up of habitats that are large enough for natural processes to function. It is unmodified (or not significantly modified) and is subject to no intrusive or extractive human activity, permanent dwelling, infrastructure or visual disturbance [64].

SEALING (ALSO "PAVING")

Permanently covering the ground with a man-made non-permeable material (asphalt or concrete, for example), especially for the construction of buildings and roads.

URBAN ADAPTER

A species that tends to shun the urban environment or which disappears when urbanisation leads to loss of habitat, lack of resources necessary for survival, or disturbance. Species that need a large distribution area are often affected by urbanisation, such as some birds of prey and mammals. Some species manage to eke out an existence in the urban environment, without really benefiting from it. These are known as "tolerant species".

URBAN ECOLOGY

A sub-discipline of ecology that studies urban ecosystems and seeks to understand the dynamics, evolution and characteristics of biodiversity in cities, towns and villages. Urban ecology is part of a multi-disciplinary approach that attempts to understand interactions between humans and wildlife in urban areas. It draws from the natural and social sciences such as sociology, demography, geography, economics and anthropology. The roots of urban ecology go back to the 1950s with the Berlin School of Urban Ecology (Sukopp) and the Chicago School of Urban Ecology (Park, Burgess & McKenzie). Urban ecology is expanding, bringing together ecologists and key urban stakeholders (planners, landscape designers, architects), and aims to develop methods and solutions to help build wildlife-friendly cities. Written by the ecologists Audrey Muratet and François Chiron and illustrated by the photographer Myr Muratet, the *Manual of Urban Ecology* (2019) presents up-to-date knowledge on how nature functions in urban settings.

URBAN EXPLOITER

A species highly dependent on humans for food and shelter or that has found ecological conditions in urban areas to be close to its original environment (e.g., ivy-leaved toadflax, common pigeon, magpie) (*Muratet et al, 2019*)

URBANISATION

The growing concentration of the population in urban centres. The word "metropolitanisation" refers to the same process but from a more economic, political and symbolic perspective, suggesting the highest levels of the organisation of urban systems.

WASTE GROUND

There is no generally agreed definition of what constitutes waste ground. Areas of waste ground vary greatly due to their history, their characteristics and the broader environments they form part of. They might be former industrial sites (in which case they are called brownfield sites). Waste ground inspires varied and contradictory reactions. A local resident, a planner, a local councillor, an ecologist, an anthropologist and a photographer will all have different ways of seeing waste ground. Also, waste ground is not frozen in time; it is constantly changing, which makes it even harder to define. But all areas of waste ground have one thing in common: the idea of abandonment and neglect. They are places where humans have stopped doing something, and where nature gradually returns. Although abandoned, these spaces are far from being uninhabited. Wildlife freely returns to them, and they host an array of natural habitats, each corresponding to a stage in ecological succession, starting with bare earth and ending with woodland. Diversity of environments and an absence of management make patches of waste ground into hotbeds of biodiversity. Unlike parks and gardens in urban areas, waste ground hosts so-called "urban avoiders". It provides not only a refuge for biodiversity but also a stopoff point for species within the urban matrix (the "green and blue grids"). In French, the equivalent of the term "[an area of] waste ground" is une friche, and a brownfield site is *une friche industrielle*.

WILD/ LOCAL/ INDIGENOUS SPECIES

A species whose presence in an ecosystem or area is the result of a natural process, without human intervention. The use of wild plants collected in their natural surroundings is relevant to operations whose aim is to restore the ecological functionality of environments. Wild and local plants (collected sustainably in the biogeographical area) benefit from long-term co-evolution with local flora and fauna, and thus contribute to how the ecosystems with which they are associated function. Conversely, horticultural species are plants that have undergone selection to create ornamental varieties. They are selected for their aesthetic appeal and generally possess little genetic diversity, making them more vulnerable to exterior factors (weather conditions, pathogens, etc.) than local species.

WILDNESS, NATURALNESS, WILDERNESS

A wilderness is an area that has been subject to little or no disturbance or degradation from humans: it is a virgin or almost virgin area. Wildness (or "naturalness") refers to the biophysical integrity and spontaneity of a natural area and the spatial and temporal continuities that exist within it (*Guetté et al, 2018*). The concept of wildness can be used to define certain (sometimes antagonistic) qualities of an area, which is referred to as more or less "wild" or "natural". In urban settings, it may be useful to distinguish "non-wild" green spaces (lawns, flower gardens), which are of low ecological quality, from "wild" green spaces (waste ground, unmanaged or abandoned areas), which are closer to true natural areas or wildernesses.

APPENDIX

APPENDIX 1

EXAMPLES OF MINIMUM AREAS NECESSARY FOR MAINTAINING CERTAIN TAXONOMIC GROUPS

SPECIES	CONTINUOUS AREA REQUIRED FOR URBANOPHILES	SOURCES
Birds	5 ha	*Beninde et al, 2015*
Frogs and toads	3 ha	*Drinnan, 2005*
Flora and fungi	2 ha	*Drinnan, 2005*
Pollinators	8 ha	*Hinners et al, 2012*
Beetles	8 ha	*Salder et al, 2006*

SPECIES	CONTINUOUS AREA REQUIRED FOR "URBAN AVOIDERS"	SOURCES
Birds	46 ha	*Beninde et al, 2015*
Frogs and toads	50 to 72.5 ha	*Drinnan, 2005*
Pollinators	20 ha	*Hinners et al, 2012*
Reptiles	50 ha	*Vignoli et al, 2009*

ANNEXE 2

DETAILS OF RUNOFF RISK EXPOSURE STUDY (1)

Degrees of sealing are grouped into 3 categories: high, medium and low. Gradients (slopes) are also grouped into 3 categories: high (over 7%); medium (3 - 7%); low (less than 3%). Values are then assigned to each category so that the data can be compared. Highly sealed areas score 0, areas with a low degree of sealing score 1 and areas where sealing is low-level score 2. Areas with a steep gradient score 0, those with a medium gradient score 1 and those with a low gradient score 2. These values are then compared and summarised in the table below. Cumulative values are reclassified so that they stand between 0 and 2 (value on the right in the table), making it possible to obtain information reflecting the runoff risk exposure depending on gradient and degree of sealing.
Cells are then given the score associated with the main type of risk they face. High exposure to runoff scores 0, medium exposure scores 1 and low exposure scores 2.

SEALING LEVEL	VALUES
High	0
Medium	1
Low	2

GRADIENT	VALUES
High	0
Medium	1
Low	2

GRADIENT / SEALING LEVEL	HIGH (= 0)	MEDIUM (= 1)	LOW (= 2)
High (= 0)	0 →0	1 →0	2 →1
Medium (= 1)	1 →0	2 →1	3 →2
Low (= 2)	2 →1	3 →2	4 →2

Crosstable analysing exposure to runoff risk depending on gradient and degree of sealing

APPENDIX 3

DETAILS OF RUNOFF EXPOSURE RISK STUDY (2)

Areas were divided into 3 categories: unbuilt areas; open built-up areas (e.g. parks, cemeteries); densely built-up areas (e.g. residential areas, business parks). Flood risk was divided into 3 risk categories: low (less that 1 m of floodwater or slow-flowing); high (1 - 2 m); very high (over 2 m, or between 1 and 2 m fast-flowing). As for the rest of the methodology, values were assigned to different types of area and to different types of risk so that their cumulative impacts could be studied. Unbuilt areas score 3, open built-up areas 1 and densely built-up areas 0. Low to medium risk scores 2, high risk 1 and very high risk 0.

These values are then compared and presented in the table below. Cumulative values are reclassified to range between 0 and 2 (value on the right of the table). This provides information reflecting the exposure to flood risk depending on the type of area and the potential intensity of the flooding. A score is then assigned to the 125 m cells depending on the main risk level in each cell.
The cells then get a score associated with the level of risk they face. High exposure to flooding scores 0, medium exposure 1 and low exposure 2.

TYPE OF AREA	VALUES
Unbuilt	3
Open	1
Dense	0

FLOOD RISK	VALUES
Low to medium	2
High	1
Very high	0

RISK / TYPE OF AREA	LOW/MEDIUM (=2)	HIGH (= 1)	VERY HIGH (= 0)
Unbuilt (=3)	5 → 2	4 → 2	3 → 2
Open (=1)	3 → 2	2 → 1	1 → 0
Dense (=0)	2 → 1	1 → 0	0 → 0

Crosstable showing flood risk according to area type and potential intensity of flooding

APPENDIX 4

LACK OF PUBLIC GREEN SPACES AND NATURAL AREAS

Lack of public green spaces and natural areas in terms of ratio, the indicator used in the framework of the 2017 *Plan vert regional* (regional plan for the creation of new green spaces), is equal to 1 if the sliding ratio of available public green spaces and natural areas is less than 10 sq.m. per inhabitant and 0 in all other cases. The sliding ratio of public green spaces and natural areas is equal to the ratio of the total area of green spaces and natural areas in 2019 with respect to the 2016 population within a 9 sq.km. radius of cell 500 (it is 0 if the total population is zero).

Lack of public green spaces and natural areas in terms of accessibility, an indicator also used in the framework of the 2017 *Plan vert regional*, is equal to 1 if the micro-cells of the road network in the cell are on average:

- over 150 metres from a green space or natural area open to the public measuring less than one hectare;
- over 300 metres from an area measuring 1 - 10 ha (or a strip 300 m - 1 km long);
- over 600 metres from an area measuring 10 - 30 ha (or a strip 1 - 5 km long) ;
- over 1,200 metres from an area measuring over 30 ha (or a strip over 5 km long).

It is equal to 0 in all other cases. Note that these distances were calculated not as the crow flies but reflect the distance covered on foot and detours made necessary by the presence of built-up areas or the location of park entrances.

APPENDIX 5

DETAILS OF THE STUDY ON LACK OF GREEN SPACES

The study on the lack of public green spaces was carried out by the Paris Region Institute as part of the 2017 *Plan vert*. It distinguishes zones lacking in green spaces, zones lacking in accessibility, zones lacking in both and zones lacking in neither. A score of 0 was assigned to non-deficient cells; a score of 1 to cells lacking one aspect; and a score of 2 to cells lacking both.
To describe the vegetation index, cells with plant cover of < 30 % scored 0; those with ≥ 30 % and ≤ 45 % scored 1; and those with ≥ 45% scored 2.

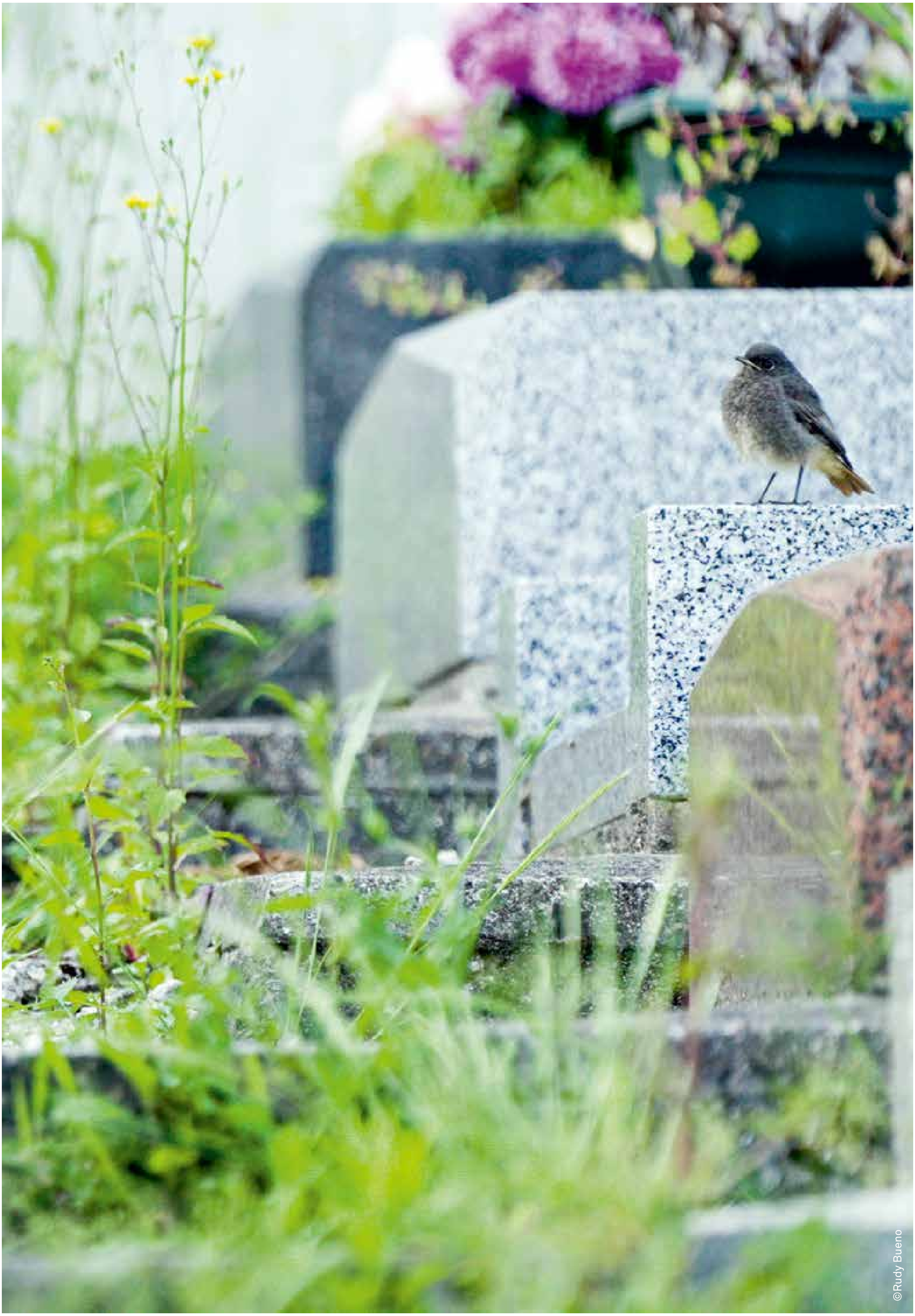
PUBLIC GREEN SPACES	
TYPE OF DEFICIENCY	SCORE
Both	0
Green spaces	1
Accessibility	1
Neither	2

VEGETATION INDEX	
PLANT COVER	SCORE
Plant cover < 30%	0
30% ≤ Plant cover < 45%	1
Plant cover ≥ 45%	2

LACK OF PUBLIC GREEN SPACES / VEGETATION INDEX	BOTH (=0)	LACK OF SPACES (=1)	LACK OF ACCES-SIBILITY (=1)	NEITHER (=2)
Low (=0)	0 → 0	1 → 0	1 → 0	2 → 1
Medium (=1)	1 → 0	2 → 1	2 → 1	3 → 2
High (=2)	2 → 1	3 → 2	3 → 2	4 → 2

Crosstable showing (i) lack of public green spaces and (ii) vegetation index

Combining the two components (lack of public green spaces and vegetation index) makes it possible to differentiate less deficient areas from highly deficient ones. The final cumulative score is reclassified so that it ranges from 0 to 2 (score on the right of the table). A score is then assigned to the cells depending on the lack of natural areas: high deficiency scores 0, medium deficiency 1 and low deficiency 2.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RENATURING CITIES

Method, examples and recommendations

Renaturing urban environments is a major challenge, whether its aim is to implement a zero net land take strategy in a particular administrative area or to make towns and cities more permeable to wildlife, greener and more pleasant to live in. The method presented in this guide is intended to help public bodies identify priority renaturing areas based on three key objectives: restoring biodiversity, adapting to climate change and improving health and the living environment. It also includes numerous field reports and interpretive aids to ensure that renaturing projects are based on the latest scientific knowledge.

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