CLIMATE

NATURE-BASED SOLUTIONS FOR CLIMATE CHANGE IN PARIS REGION

OVERVIEW OF PROPOSITIONS FOR DISCUSSION AT THE COP21

CLIMATE :

NATURE-BASED SOLUTIONS FOR CLIMATE CHANGE MITIGATION AND ADAPTATION IN PARIS REGION

OVERVIEW OF PROPOSITIONS FOR DISCUSSION AT THE 21ST SESSION OF THE CONFERENCE OF THE PARTIES ON CLIMATE CHANGE (COP21)

SOLUTIONS FOR THE **PRESERVATION**, **SUSTAINABLE USE** AND **RESTORATION** OF ECOSYSTEMS AND BIODIVERSITY, WITH THE DUAL OBJECTIVE OF **MITIGATING** CLIMATE CHANGE AND **ADAPTING** PARIS REGION TO ITS EFFECTS.

CONTENTS

Acknowledgements
Natureparif would like to thank all those who participated in the symposium "Climate and Biodiversity: Nature-Based Solutions for Paris region" which was held on the 29th and 30th of September 2015. We would particularly like to thank Ludivine Conte, Charline Hue, Anaïs Kermagoret and Marine Kuperminc for the summary of information they provided as part of their MA in Ecology, Biodiversity and Evolution, and their thesis entitled "The place of biodiversity, ecologists and ecological engineering at the COP Climate Conference in Paris 2015".

Publication Director Liliane Pays
Edited by Marc Barra et Gilles Lecuir
Project coordinator Julie Collombat-Dubois
Editorial coordinator Ophélie Ricci
Graphic design by David Lopez (www.davidlopez.fr)
Cover Illustrations by Hervé Nallet
Impression Iropa Imprimerie
Published in Paris, Novembre 2015

INTRODUCTION

Today, climate change is an undeniable reality. Caused largely by human activities and the greenhouse gases emitted as a result, its effects vary greatly in both their nature and intensity. The consequences of climate change are already being felt through heatwaves, droughts and the emergence of new pathogens. The evolution of the problem has become a major cause of concern for both the scientific community and the public and private sector organisations trying to find solutions. It is in this context that in December 2015, the city of Paris will host the 21st Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change, also known as the COP21. This event with gather almost 50,000 representatives and delegates from 194 different countries, with the aim of establishing the first binding global agreement on climate change. An event of this nature carries a significant weight of expectation, particularly in regard to the strategies being proposed and adopted for climate change mitigation and adaptation (see insert, p.6).

Climate change in Paris region (Île-de-France) is only one aspect of a wider mutation; the region is also seeing unprecedented losses in biodiversity, and the two phenomena are inherently linked. Biodiversity is changing in reaction to the impacts of climate change and other pressures, while retroactions occur and can amplify the effects of climate change. Biodiversity itself can also act as reservoir of potential solutions - well-maintained ecosystems contribute to both the mitigation of climate change (by capturing and storing CO_2 from the atmosphere) and also help us adapt to its effects, which include the increased risk of storms, flooding, landslides and soil erosion.

It is with these considerations in mind that Natureparif, the agency for Nature and Biodiversity in Paris region, is working to propagate nature-based solutions concerning the preservation, restoration and creation of ecosystems in our local areas. These solutions may be applied in various contexts, in both urban and rural areas, enhancing the effects of other, more technical measures that may already have been put in place. Given the fact that these types of solutions have the potential to generate multiple benefits for biodiversity, climate and quality of life, they merit priority status within our overall regional strategy.

This booklet aims to explain and illustrate our interest in these solutions. Its contents draw upon the work of several different bodies, including Natureparif itself but also those who participated in the Natureparif / GIS Environment-Society / Seine-Normandie Water Agency symposium held on September 29th-30th 2015[1]. The recommendations drawn from this collaboration will serve as a basis for future reflection on the issue, but are by no means exhaustive.

Please help us build credible, efficient and ambitious solutions for climate and nature in Paris region!

Liliane Pays,
Paris region Councillor,
President of Natureparif

1. See the presentations from the Natureparif 2015 symposium: "Climate and Biodiversity: Nature, A Source of Solutions for Paris region", (in French) http://www.natureparif.fr/agir/colloques/1522-colloque-climat-biodiversite

WHAT IS THE RELATIONSHIP BETWEEN CLIMATE AND BIODIVERSITY?

Climate affects biodiversity...

Today, climate change is among the most significant threats to biodiversity (in addition to the impacts of human activity), and its effects are likely to grow in intensity over the coming decades (Leadley *et al.*, 2010). The direct consequences of climate change are seen in environmental modifications of varying intensity: overall rise in average air and sea temperatures, ocean acidification, melting ice caps, etc. (GIEC, 2014). On a more local scale, these changes will have an irrevocable effect on the biodiversity that shelters ecosystems, leading to the displacement of animal and plant species, certain types of habitat changing or disappearing, and physiological changes in the species that inhabit them. These kinds of impacts can be difficult to mitigate, as there is no way to precisely predict how a given species will react to such changes. A significant number of the most vulnerable species are already under severe threat from climate change.

Climate change has consequences for nature, and nature in turn influences climate change. © Creative Commons

...and biodiversity reacts to climate.

However, as with all natural phenomena, the effects of climate change are not unequivocal. In discussions on climate change, it is essential to consider the impact on biodiversity, but also how biodiversity may itself influence the climate, in both positive and negative ways. In effect, biodiversity that has been affected by climate change may react in such a way as to in turn influence its surrounding climate. There are several mechanisms by which this may occur: for example, when oceans acidify, populations of zooplankton are reduced. Zooplankton form the basis of the process by which oceans absorb CO_2. The lack of CO_2 absorption by the oceans leads to an increase in CO_2 in the atmosphere, which in turn affects the climate[1]. This interdependence adds a new dimension to climate negotiations, making it necessary to take into account the methods by which living organisms and ecosystems adapt (or fail to adapt) to climate change[2].

Zooplankton is an excellent example of the biological "feedback loop" between biodiversity and climate. © Creative Commons

1. View the findings of the GIEC – IPBES conference on the interactions between climate and biodiversity at: http://www.fondationbiodiversite.fr/fr/documents-frb/comprendre-la-biodiversite/videos/585-climat-et-biodiversite-rencontre-avec-des-experts-francais-du-giec-et-de-l-ipbes.html
2. View the latest ORÉE publication "Climate and Biodiversity: Challenges and Paths to Solutions" (in French) at http://www.oree.org/actualites-oree.html

CLIMATE CHANGE IS A REALITY IN PARIS REGION (ÎLE-DE-FRANCE)

Scenarios and forecasting models indicate a number of imminent changes for Paris region. According to Météo-France, climate change will result in an increase in overall global temperatures, an effect which will be particularly noticeable during the summer months (with increases in the numbers of very hot days, especially in built up areas affected by the phenomenon of Urban Heat Islands). This change in temperatures will also lead to reductions in air quality and a fall in the number of cold days in winter. In addition, annual rainfall will be lower, something that will also be particularly noticeable during the summer and in early autumn, leading to the prolongation of the dry mid-year period and an increase in droughts. Rainfall may also increase over the winter months, which in general terms could lead to increasingly intense meteorological activity (heavy storms, etc.). These underlying trends, which of course become more or less noticeable depending on the scenario, do not preclude the possibility of highly variable inter-annual patterns (with certain years seeing very harsh winters, for example).

The scenarios being presented also suggest consequences for ecosystems, such as the likely arrival of new pathogens and species that find the new conditions more amenable, as well as migrations and changes in ecological rhythms (including pollination, flowering, release of CO_2 from plant matter, biogeochemical cycles, etc.). While it is difficult to attribute the disappearance or decline of any particular regional species to climate change alone (aside from certain species of sub-mountainous flora which were, in any case, growing outside their normal biological range), it is this trend combined with other anthropogenic causes (such as urbanisation, the fragmentation of habitats by transport infrastructures, intensifying agricultural activity) that further weaken the health of ecosystems. The accumulation of these various impacts will severely effect biodiversity and dilute the benefits it brings to local residents.

Extreme climate activity such as torrential rain will occur more frequently, and with greater intensity. © M. Barra

WHICH CLIMATE STRATEGY SHOULD PARIS REGION ADOPT?

The strategy that has been adopted by the regional government is detailed in the Regional Climate Plan (Plan Régional pour le Climat, or PRC[1]), laid out and approved in 2011. The strategy builds on the notions generated by the Regional Air, Climate and Energy Scheme (Schéma Régional du Climat, de l'Air et de l'Energie d'Ile-de-France, or SRCAE), which was jointly developed by the state service's Regional and Interdepartmental Environment and Energy Group (Direction Régionale et Interdépartementale de l'Environnement et de l'énergie, or DRIEE), the Regional Council and the ADEME, and lists 24 actions and focus areas pertaining to both mitigation and adaptation. The regional priorities for mitigation of climate change focus on mobility, transport of merchandise, energy instability, agriculture, eco-construction and sustainable purchasing. While de-carbonisation of the regional economy and policies for greenhouse gas reduction remain priority issues, it is also necessary to prepare to adapt to effects that can no longer be prevented - as such, it has become particularly difficult to assess the effectiveness of mitigation measures in terms of overall CO_2 emissions. As the result of a globalised economy, large amounts of CO_2 emissions (and other environmental impacts) end up in other territories (often referred to as "imported" or "exported" emissions). The Climate Action Network (Réseau Action Climat, or RAC) points out that existing public policies pertaining to climate change are partly ineffective because they impact only a portion of a country's emissions (those which are directly emitted within its borders), and do not account for the levels of greenhouse gases emitted as a result of that country's consumption levels. This is the case, for example, with so-called "clean" transport and renewable energy, whose production can have serious effects on ecosystems outside Paris region (such as the manufacture of electrical batteries, or mining for rare materials used in the technology). Similarly, though insulation for buildings can be an effective solution for reducing the emissions from a given accommodation unit, the emissions produced during the manufacture of the insulating materials should not be overlooked. Policies pertaining to energy efficiency for accommodation units should therefore also aim to encourage the use of renewably-sourced insulation materials, produced as locally as possible in conditions that do not pose any threat to biodiversity. It is important to prioritise solutions that save CO_2 without generating disproportionate levels of emissions or damaging ecosystems in other areas.

WHAT DO WE MEAN BY MITIGATION AND ADAPTATION?

Mitigation and Adaptation are two of the main strategies for dealing with climate change, each complimenting the other. Mitigation aims to reduce the causes of climate change (such as the accumulation of Greenhouse gases in the atmosphere), while adaptation deals with adjusting existing systems in order to limit the effects of climate change. While the benefits of mitigation are global, those of adaptation are felt on a local level and according to regional specificities. Both aspects are essential, since even if significant mitigation efforts are made, climates will continue to change over the coming decades, thus making it necessary for societies to adapt to these oncoming changes.

Regarding adaptation to the effects of climate changes, proposals are notably focused on mitigating the impact of Urban Heat Islands and their knock-on effects on air quality, vulnerability of urban services and infrastructures, ecosystem resistance to damage, water quality and availability, the risk of flooding/drought and associated health risks. While the measures proposed in the PRC are varied, they share a common recognition of the significance of the link between climate and biodiversity, notably highlighting the need to "reinforce the robustness of our ecosystems." The RCP also points to biological solutions for adaptation, such as green city initiatives and ecological water management. Finally, the PRC is linked to the Regional Ecological Coherence Scheme (Schéma Régional de Cohérence Écologique, or SRCE), which aims to establish continuity in terms of the ecological measures being undertaken across the region (also referring to green and blue infrastructures), which is an essential strategy in terms of adapting to climate change.

Building on the work of the last few years, as well as evolving knowledge bases and practices, Natureparif suggests prioritising new solutions using natural methods, as well as extending integrated approaches linking Biodiversity and Climate issues within existing measures at every level, including the Territorial Climate/Energy Plans (Plans Climat Energie Territoriaux, or PCETs)[2].

1. ://www.iledefrance.fr/sites/default/files/mariane/RAPCR43-11RAP.pdf

2. View the Climate Action Network (RAC) report: Les émissions importées - Le passager clandestin du commerce mondial (Imported emissions: the stowaway of global commerce) - (http://www.rac-f.org/IMG/pdf/EMISSIONS-IMPORTEES_RAC-Ademe-Citepa.pdf)

WHAT ARE NATURE-BASED SOLUTIONS?

Various mitigation and adaptation strategies exist, combining a range of disciplines, technologies and approaches. Certain strategies, especially those pertaining to geo-engineering (trapping carbon in soil, construction of dykes and reservoirs to protect against flooding, etc.) focus on technological solutions to climate change, while others aim to use nature itself (revegetation initiatives in cities, restoring waterways and riverbanks, soil preservation, etc.). According to the International Union for Conservation of Nature (IUCN)[1], nature-based solutions are those which use ecosystems (and their inherent regulatory and productive systems) to combat climate change, aid global food supply and improve economic and social development. One of the key attractions of nature-based solutions is that they may be equally applicable to both mitigation and adaptation. They are useful both in terms of reclaiming nature and the establishment of practical climate services, all while incurring relatively little cost to local authorities. The possibilities for biodiversity-based solutions are varied and practically innumerable: they include options for every form of ecosystem and for various scales of action, whether aimed at mitigation or adaptation (improving biodiversity's ability to resist the effects of climate change). Natureparif actively support a more systematic and broad-scale approach to the development of these kinds of solutions, in accordance with local and area-specific contexts (urban, agricultural, forests, etc.).

Regarding mitigation

In 2002, the GIEC estimated that 370 billion tonnes of C02 could potentially be stored using biological mitigation methods - much more than we can avoid emitting using current technological means. It is therefore vital that we understand that the role of biodiversity is not simply aesthetic: in fact, biodiversity carries out important regulatory functions that we have tended to overlook, such as stability of gaseous exchanges and the proper functioning of the carbon and water cycles in a given area[2]. It is also possible to envisage "mixed" solutions combining elements of natural and technological methods, provided that physical structures do not impede natural processes.

THE GREEN INFRASTRUCTURE CONCEPT

The notion of "green infrastructure", as popularised by the European Commission, highlights the economic advantages of natural assets (flood zones, for example, are much less costly than dykes or levees when it comes to tackling the effects of flooding).

Green infrastructure attempts to reconcile ecological issues with the requirements of sustainable development during a time of economic crisis. It is an innovative conceptual framework for reconciling environmental concerns with human developments such as urbanisation, road construction and energy infrastructures, which too often damage and fragment our precious ecosystems. Nature-based solutions, whether focused on cities, water management, agricultural and forestry production or even energy, are much more economically viable than falling back upon traditional engineering, or "grey infrastructure." They also contribute to job creation and stimulate growth at a local level that is sustainable and non-outsourceable.

In France, the existing concepts of the "trame verte" and "trame bleue" (green and blue "frameworks") fall within this ideological framework, but their scope is often limited to creating connected ecological pathways, whereas the European idea applies the notion of green infrastructure to all aspects of nature, whether they are connected or not.

Regarding adaptation

By the same token, preserving biodiversity can reinforce a given environment's ability to deal with changing circumstances, especially in climate terms. It has now been demonstrated that high levels of diversity (both genetic and intra-species) give ecosystems greater long-term stability. This in turn renders them more capable of providing benefits for human populations. In effect, when faced with diverse threats to their existence, only diversified ecosystems are able to survive. This is due to the fact that a given population or group of species will find the changing circumstances suit them better than others, thus allowing the ecosystem to maintain itself. This is most notably the case in agricultural areas: while monocultures are fragile in the face of change, diversified cultures allow a system to absorb such changes and adapt. Biological diversity is akin to life insurance for environmental changes.

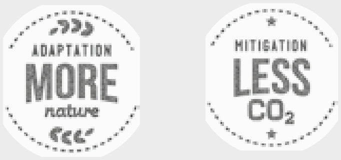
Other criteria than diversity may also come into play at different levels, including heterogeneity, connections between ecosystems and levels of self-regulation and maintenance. Most healthy ecosystems display a natural resilience to traumatic events, provided these are

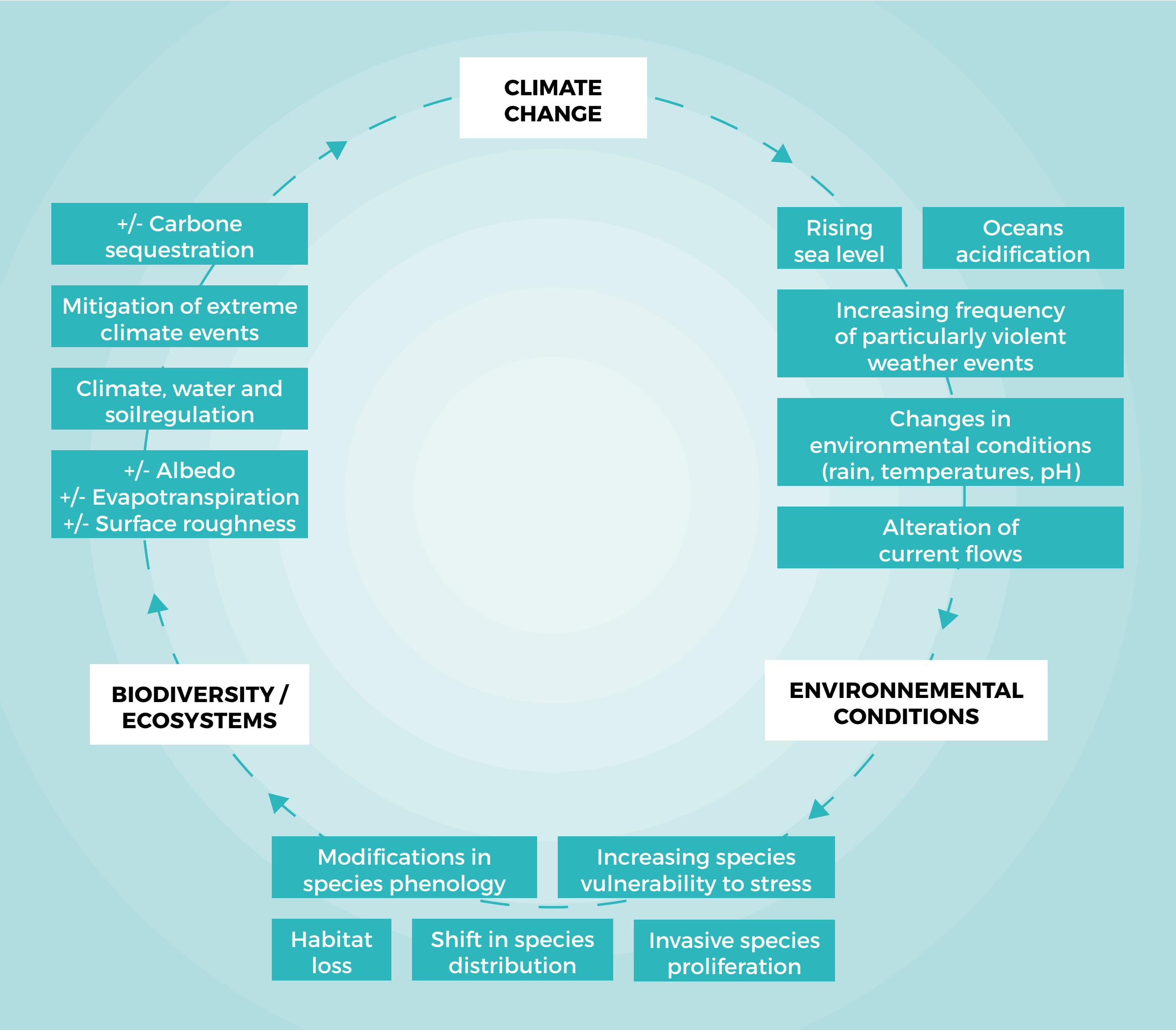
1. http://www.uicn.fr/COP-21-lancement-initiative-SFN.html
2. EU strategy prioritising nature-based solutions: http://ec.europa.eu/environment/nature/climatechange/pdf/EbA_EBM_CC_FinalReport.pdf

not overly drawn out or constantly repeated[1]. In practical terms, this means that it is useful to preserve any existing ecosystems that possess these characteristics, and to restore those that have lost them due to environmental degradation. New urban, agricultural and forest ecosystems may also be created in accordance with these fundamental principles. The increased presence of nature in both urban areas and in the countryside, notably in agricultural areas which are currently suffering serious declines in biodiversity, would have the effect of reinforcing the ability of these environments to withstand climate hazards.

The following pages outline some of the main solutions being proposed to meet the requirements of these dual strategies. Measures for mitigating and adapting to climate change are often one and the same - for example, a green roof acts as a carbon sink, and even contributes slightly to the building's insulation needs, but also plays a role in adaptation to the effects of climate change by slowing the flow of rainwater and reducing the effects of urban heat islands).

These will be denoted by the symbols opposite:

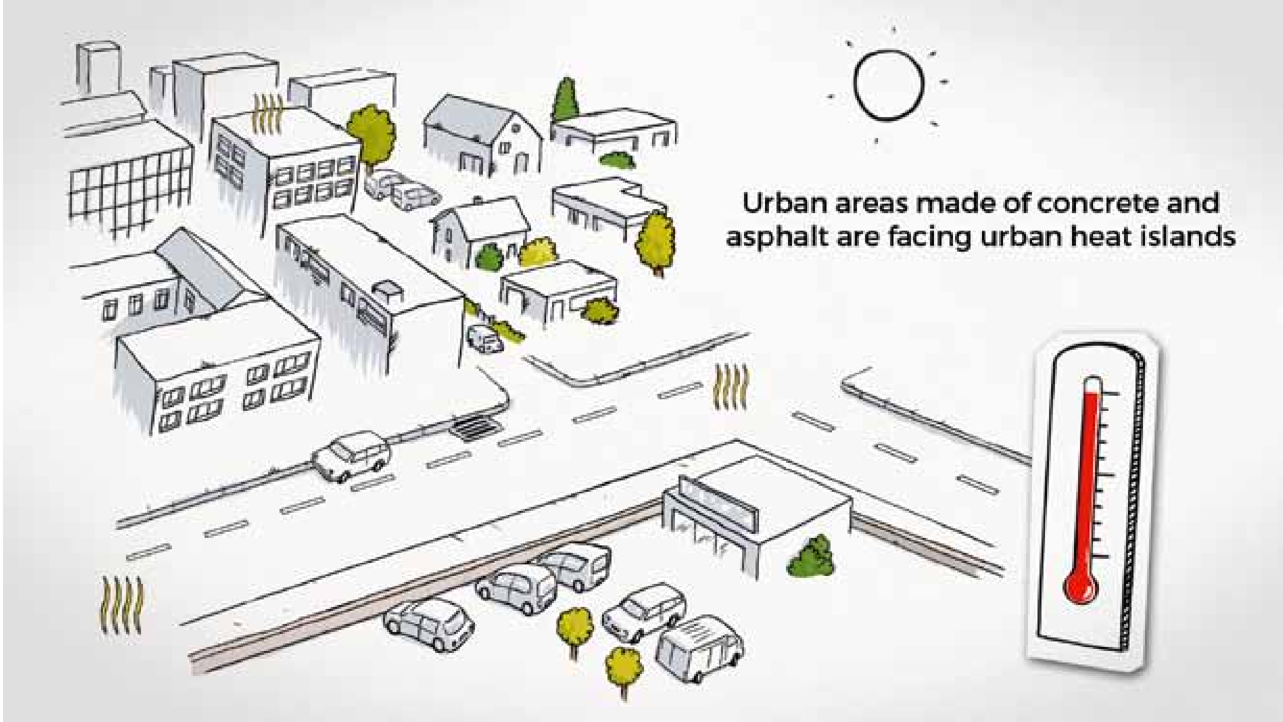




Feedback loop between climate change, environmental conditions and biodiversity. Adapted from GIEC and IPBES sources.

1. https://www.coe.int/t/dg4/majorhazards/ressources/pub/Ecosystem-DRR_fr.pdf

NATURE-BASED SOLUTIONS FOR **URBAN AREAS**



On a local level, urban areas affected by the Urban Heat Island (UHI) phenomenon are characterised by higher average temperatures than their surrounding areas (Oliveira *et al.*, 2014). The phenomenon is partly the result of the materials used in the construction of buildings. More globally, cities are known to emit significant quantities of greenhouse gases such as CO_2 and methane, as well as suspended particulate matter. On average, urban zones represent between 53 - 87% of global CO_2 emissions (GIEC), 2014).

As a result, cities are feeling the effects of climate change in the form of heat waves, reductions in air quality and the increased incidence of problems linked to extreme weather such as droughts and flooding. These impacts are all the more worrying in that they affect disproportionately large numbers of people due to the inherent population density in towns and cities. Global warming is therefore a major issue for towns and cities, in terms of both reducing the impact of climate change and adapting to the changes already being faced (Gómez-Baggethun *et al.*, 2013; Gill *et al.*, 2007). In the context of this realisation, a number of solutions are currently being put forward. Amongst them is the preservation and restoration of green spaces in towns and cities, proving popular because of the additional benefits offered in terms of public health and well-being (including oxygen production, carbon storage and particle filtration, recreational attributes and the generally positive use of public spaces). The solutions taking their cue from this idea are often much less costly than alternative measures, both in terms of initial investments and eventual management costs.

Greening streets, squares and roadsides in order to reduce the effects of Urban Heat Island (UHI) and improve water management

The presence of vegetation reduces temperatures by way of shade and evapotranspiration, particularly during the hottest months, and as such acts to mitigate the presence of urban heat islands (Gill *et al.*, 2007; Oberndorfer *et al.*, 2007). Plant life also contributes to improved air quality and diminishes the concentration of atmospheric CO_2 by photosynthesis (Azam *et al.*, 2012), as well as reducing concentrations of suspended particulate matter via the biological mechanisms of absorption and deposition to foliar surfaces (Azam *et al.*, 2012). All forms of vegetation are useful in this regard, from urban trees (whether isolated or not) to gardens, parks and large open spaces. Particular attention must be paid, however, to the choice of species (encouraging a mixture of local varieties and avoiding monospecific plantations in open ground, as well as eschewing species that may be allergenic or emit large amounts of volatile organic compounds), as well as how they are looked after (without the use of pesticides, non-intensive manual upkeep, etc.). However, refreshing the face of a city with plant life requires water in warmer months; a sensible, measured watering system drawn from trapped and stored rainwater may therefore be required.

A number of types of mineralised spaces can host vegetation. © G. Lecuir

Diversifying urban green spaces via the systematic application of ecological management methods, or "non-management"

Between recreational spaces, zones left to evolve naturally, urban forests, flower beds and meadows, as well as gardens and areas dedicated to urban agriculture, a wide range of nature-based solutions is available to towns and cities. In order to produce effects that are advantageous in terms of climate change, a certain system of responsible ecological upkeep must be observed for such spaces. This includes zero use of pesticides and chemical fertilizers, both of which are not only environmentally dangerous but also create greenhouse gas emissions in their manufacture. Mechanical maintenance should be prioritised (for sweeping, manual uprooting, pruning and trimming); trimming should be done once or twice a year and offcuts reused as mulch; the cutting height should be raised (10cm or greater) and frequency of grass mowing reduced. In some cases cutting and trimming should be avoided altogether, with spaces left to develop freely (wilderness areas are important reservoirs for urban biodiversity, complementing the role of large parks). Grazing has been proven to be an efficient method for maintaining green spaces, as the light impact of animals' footfall does not impede growth and their faeces also nourish the soil. Reclaimed green waste and residue from clippings and trimmings can be used for compost and in ramial chipped wood (RCW), which may be then be re-used in gardens. Finally, where the proliferation of invasive species has occurred, the optimum response appears to be increasing biodiversity and reducing fragmentation in order to give the ecosystem the capacity to self-regulate. Grazing is also an effective curative solution when dealing with certain invasive plant species.

Managing less can mean managing better! A "refuge zone" for flora and fauna, left to develop naturally in Nantes © G. Lecuir

✷ **Greening roofs and facades**, using systems with low ecological impact (such as climbing plants and roof meadows) rather than irrigated and industrialised systems, which are not proven to positively affect biodiversity or aid the fight against climate change

Vegetation projects for rooves and walls allow cities to reduce the effects of urban heat islands, as well as improving building insulation while restoring habitats and natural environments.

In order to ensure they engender positive effects for climate and biodiversity, planted or "green" rooves must be qualitatively designed. Depending on the situation and the roof's load-bearing capacity, ecologists recommend trying to reproduce a natural ground layer, adapting the composition of organic matter (mixing stones and local soil with +/- compost added) and targeting a structure and height that will allow the feature to store more CO_2 and rainwater as a means of tackling global warming (since more heat leads to more intense rainfall). It has been demonstrated that green rooves planted with a mixture of different species (both succulent and herbaceous) allows them to improve water retention during flooding and present better cooling properties during heatwaves (Dvorak *et al.*, 2010) than areas planted with sedum monocultures.

For walls, in most cases it is preferable (and often much less expensive) to prioritise the use of climbing plants, using and designing walls and facades as support structures for vegetation. In addition to their being easy to install, climbing plants create a microclimate around their host wall, regulating temperature and relative humidity. This also contributes to a reduction in the effects of UHIs during the summer months.

Walls without windows and gable walls can host climbing plants, which protect the building against extreme weather, cooling the air and providing a habitat for small animals. © M. Barra

✷ **Developing urban agriculture** in order to shorten food distribution channels and increase planted surface area in cities

When allowed to cohabit with wilder, more spontaneous forms of nature, urban agriculture shows real potential for reclaiming biodiversity in cities, in tandem with other measures such as revegetation of building surfaces and ecological green spaces, etc. Several experiments have confirmed that urban agriculture is capable of preserving genetic biodiversity through the choice of endemic plant varieties, and can host a variety of other species including wild pollinating animals. Well-thought out plant combinations can also breathe new life into damaged ground soil. On a broader scale, urban agriculture can also contribute to systems of blue and green infrastructure. However, in order to effectively shorten distribution channels, such activity must take into account the life cycles of the resources required (seeds, substrates, energy and water) in order to ensure they remain "ultra-local".

✷ **Create links between green spaces** through urban ecological corridors

In order to ensure that all living things are able to move around in urban environments, habitats and ecosystems have to be linked. In urban areas, green infrastructure can have many forms (green spaces, parks and gardens, temporary wilderness, trees and rows of trees, buildings with green surfaces, etc.), and each one can serve as a mini reservoir for biodiversity or a biological passageway or corridor. The functionality of green areas also depends on the use of applied management methods. It is for this reason that the abolition of pesticide use and the adoption of recommendations regarding ecological management methods are essential to their success[1]. It will be necessary to revise policy documents pertaining to urbanism, particularly in order to ensure that green and blue infrastructures are taken into account in the development of local urbanism strategies (plans locaux d'urbanisme, or PLUs)[2]; also essential is the establishment of systematic ecological diagnostic criteria[3] prior to the outset of any urban development project.

Urban agriculture is also a way of making use of spaces that are temporarily unused. The R-Urban project in Colombes. © G. Lecuir

1. Certification criteria for ecological management and green spaces, using the "ÉcoJardin" label for example, is an effective tool for supporting urban authorities in their reactions to climate change, as well as for external communication purposes: www.label-ecojardin.fr
2. View the guide: Prendre en compte le SRCE francilien dans les documents d'urbanisme (Taking SCRE guidelines into account in urban policy documents): www.natureparif.fr/srce
3. View the methodology for urban ecological diagnostics: www.methodo-deu.fr

✷ Replace impermeable surfaces (except for roadways) with natural surfaces and preserve soils integrity

Soils are the headquarters for a number of biogeochemical processes that are essential for climate change mitigation and adaptation. They are capable of storing large quantities of carbon (more so than surface vegetation) and, when kept intact, can also ensure the healthy functioning of local water cycles. In Paris region, ground surfaces are heavily artificialized: almost 20% compared to 2.77% nationally. More and more local councils are opting for solutions that limit soil compacting and the use of impervious ground surfaces. Certain towns such as Montreuil already apply imperviousness coefficients in their urbanisation projects, while others, such as Rennes, penalise the use of overly impervious surfaces in urban areas. Other areas favour the use of porous materials providing drainage in pedestrian or low-traffic areas, in order to facilitate the flow of water into the soil (drainage materials, non-cemented cobbles, cellular paving and grass paving). On a regional scale, impervious surfaces are a blight on the landscape - one that refuses to die out. Only financial measures discouraging construction on arable land and encouraging population density (taxes on empty accommodation units, financial support for increased density) will be capable of reversing the trend. Aside from halting urban expansion, eco-design measures for buildings and infrastructures, as well as methods for reversible construction that preserves underlying surfaces (buildings on stilts, for example) must also be developed.

✷ Identify surfaces that can be unpaved in cities in urban spaces (school yards, apartment buildings, roadways) in tandem with revegetation policies

When conservation is no longer enough, restoration becomes necessary. Urban areas in Paris region have high potential for natural development, provided they are able to transform impervious surfaces (concrete and asphalt) on a broad scale and in an organised manner. This would constitute a significant asset in terms of carbon capture and storage, restoring water cycles and increasing green surface area on the whole. Reducing imperviousness can be achieved in the public sphere, for example by creating new planted spaces along certain wide pavements, with the active participation of local inhabitants who want to be involved in the future upkeep of these new natural spaces. With the right public support, the private sector can also be made to adapt, for example via the application of a cap on percentage imperviousness (PIMP) for all construction, renovation or enlargement projects.

Reversing the imperviousness of concrete and asphalt surfaces is a key driver for rediscovering nature in cities. With local residents in Strasbourg. © H. Natt

✷ Encouraging natural water infiltration via natural ecosystems (rain gardens, pervious areas, ponds, limiting the risk of water runoff and flooding

Soil and surfaces in urban areas are often highly mineralised, preventing the natural flow of water cycles. Channelling and management of water also leads to vast infrastructure costs for local councils. Vegetation helps limit the harmful effects caused by extreme phenomena such as flooding; by intercepting water on the surface of the leaves, plants reduce the quantities of water that reach the soil. They also help to reduce water runoff thanks to the structural function of their roots, particularly in the case of trees. Revegetation measures should be applied in tandem with measures aiming to improve the quality of ground soil in cities, achieved via the reduction of artificial surfaces and reduced levels of compacting, in order to improve resistance of plant life and allow water to flow into the ground more freely. Rain gardens, swales, ponds and basins are some of the main examples of areas that can serve as water receptors. When heavy rain or flooding occurs, these areas act as expansion barriers, allowing the water to infiltrate the soil and return to groundwater tables. They also provide excellent habitats for common urban biodiversity.

Though concerns about the propagation of pathogens and mosquitoes may be legitimate, these kinds of natural wetlands are usually able to self-regulate via the presence of predatory species.

Car parks, pathways, and fire access areas are all spaces that can be developed without the use of impervious surfaces. © G. Lecuir

✷ **Encouraging phyto-purification of grey and black waters used in cities**, reducing the need for water treatment plants (which are costly and can damage surrounding soil)

In cities, the creation of wetlands can prove useful when it comes to managing rainwater, but also waste water; the process involved is known as phyto-purification. Whether independent or linked to existing water treatment facilities, phytopurification basins have been shown to be particularly effective in cleaning organic pollutants from waste water. Certain combinations of plants are particularly effective: phragmites (reeds), carex (sedges), bulrushes and duckweeds, for example. Apart from their ecological benefits, these wetlands help limit the number of trenches required for network passage. In addition, a phytopurification basin that is connected to other contrivances such as ponds or urban swales can contribute to the creation of a functional blue infrastructure. Where sewage is concerned, one option consists of directing the flow of sewage water towards anaerobic digestion plants that will produce biogas, a form of energy that may be used locally to heat homes (an ecological solution helping to mitigate climate change). In the right conditions (particularly depending on the space available) it is also possible to treat this kind of material by using stabilisation ponds and phyto-purification.

Natural purification avoids the heavy construction required for enlargement or renovation of waste water treatment facilities. © L. Pagès

✷ **Daylighting and restoring urban rivers,** restoring embankments, redirecting water flow

Operations aiming to restore and even reopen urban rivers are necessary in order to improve water quality in cities, reduce runoff and create new habitats. In Sarcelles, a town north of Paris, the restoration of the Petit Rosne has provided interesting perspectives in terms of how to go about this process. In Paris, the Espaces association has overseen the restoration of a portion of the banks of the river Seine using vegetation engineering techniques. Naturally-flowing rivers are not only advantageous for biodiversity, but also in terms of allowing species to move freely along their banks, which is a key element of adaptation to the effects of climate change.

The reopening and redirecting of subterranean urban rivers bring positive results in terms of water quality, reducing flood risk, preserving biodiversity and recreational access for citizens. © SIAH

✷ **Carrying out full carbon assessments** (covering the entire life cycle) **of solutions** being adopted for energy efficiency

Too often we focus on the reduction of greenhouse gases in a single aspect of building construction or equipment use, without considering the gases that are emitted in the sourcing of materials, as well as their manufacture, recycling and eventual destruction. We must learn to systematically include this "grey" energy when assessing our efforts to reduce greenhouse emissions. Beyond " grey energy ", we should also consider the impacts of materials on biodiversity on the entire value chain. This is what we call "grey biodiversity" or "embodied biodiversity". For stakeholders, reducing the impacts on "grey biodiversity" implies to support local production and certified sectors that are preserving biodiversity and ecosystems during production. It is also important to diversify building materials used in construction, for instance by using more bio-based materials from sustainable agriculture (see after).

✷ **Encouraging the use of organic insulation materials**

In terms of insulation, organically-sourced materials (produced via agriculture and forestry) form part of the solution for successful energy transition, while also favouring biodiversity. Choosing to use these materials reduces the carbon impact caused by conventional materials, which emit large amounts of CO_2. Opt instead for organically-sourced insulation (linen, hemp, recycled textiles, wood wool, etc.) over petrol-based materials (such as polystyrene or polyurethane).Plants such as hemp and linen have not only been proven to be technically viable for these purposes, but also fit in with forms of agriculture that respect biodiversity (crop rotations, reduced use of inputs, etc.). It is necessary to encourage the sub-industries that produce these materials, not forgetting that their use must be carefully considered in terms of specific local conditions.

Compressed straw has been proven to be an efficient, naturally-sourced building material and insulator. © M. Barra

✷ Encouraging the use of materials that make sense from the point of view of ecosystems (locally-sourced, where possible from renewable sources and produced according to rigorous specifications within the limits of local availability)

Paris region consumes more building materials than any other region in France (mostly in the form of aggregate used in the composition of mortar and concrete). Every year, 45% of required materials are imported from other regions, and even from abroad. This demand is continuing to rise: the Grand Paris (Greater Paris urban expansion) project has forecast the use of 4.7 million extra tonnes of aggregate, or 2.6 million cubic metres of concrete per year. The opening of new quarries, the concept of "interregional solidarity" and the use of marine aggregate are some of the areas being looked into by industry professionals to source this material; nevertheless, these measures are not capable of delivering the necessary quantities and will have negative impacts on natural environments. Solutions that will be beneficial both for climate change and biodiversity include: supporting the recycling and reuse of materials taken from demolition and redevelopment projects, and embracing production methods for raw materials with less environmental impact (renovated quarries for aggregates, managed forests for wood, agro-ecological systems such as polycultures/crop rotations/agroforestry for organic materials). In addition, prioritising use of eco-designed, non-processed materials will make them easier to recycle and retain their value without the need for industrial treatment. Finally, we must also minimise the quantities of materials used by choosing suitable architectural designs.

✷ Improving energy efficiency in construction via increased presence of vegetation on walls and rooves of new public buildings, as well as industrial and commercial properties

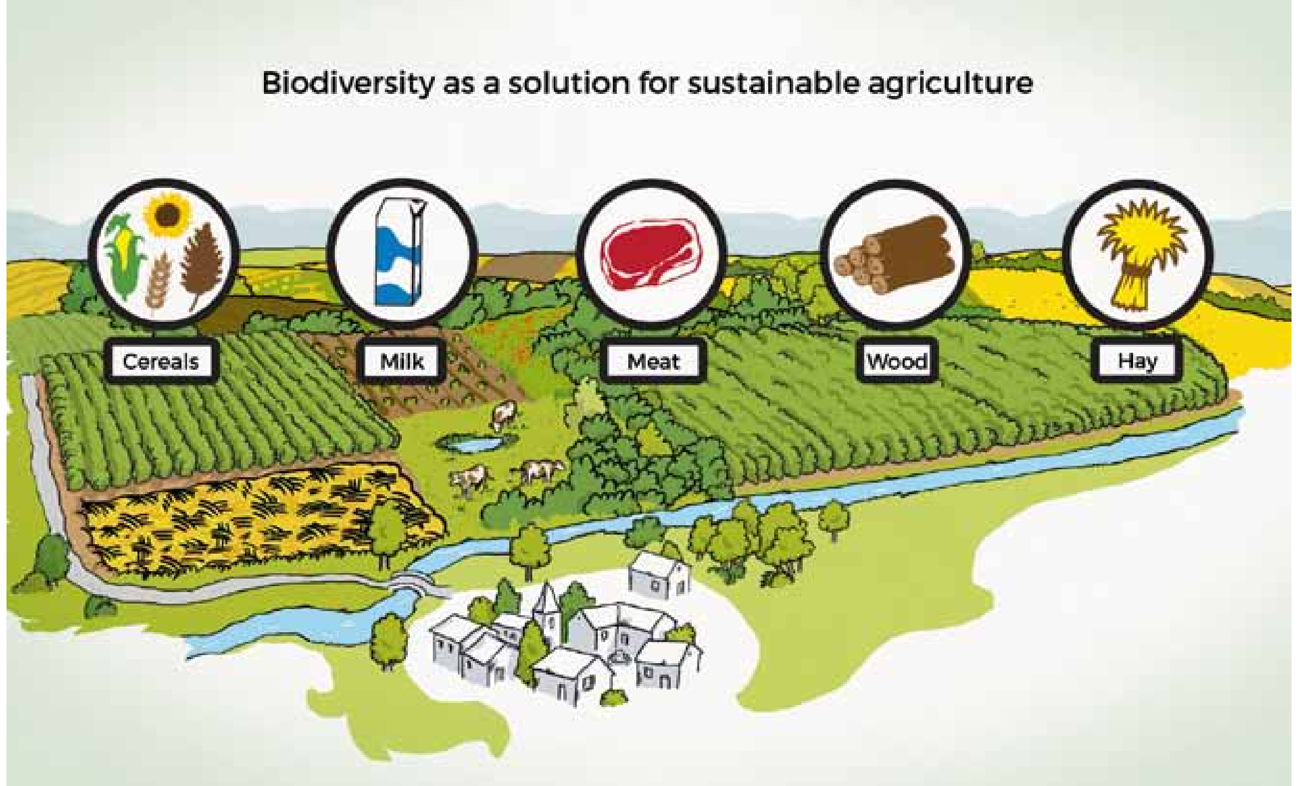
Sustainable construction should become an integral part of a wider vision that incorporates more than just energy efficiency. Nature-based solutions in construction can also bring positive effects in terms of climate change; this is the case for building vegetation schemes, which are an asset for reducing energy consumption and improving insulation. Rather than setting the two approaches against one another, they should be combined, following the example of buildings which have installed solar panels and plant beds, benefitting both objectives simultaneously.

✷ Intelligent Consumption

On an individual level, such as when we are required to establish or validate a public or private tender, we should choose projects with light carbon footprints, using as few non-renewable natural resources as possible and in conditions that do not harm the environment, produced as locally as possible and ensuring fair pay for the workers involved. Food production is a powerful field of action in this regard; on an individual basis consumers can opt to choose locally-grown organic produce, subscribing to a CSA (community-supported agriculture). On a collective level, the choices made by canteens and large-scale catering are also significant.

Combining solar energy and plant life brings mutual benefits: the vegetation cools the panels and increases their productivity, while they provide shade and habitat diversity for surrounding flora. © 2015 Green Roofers Ltd

NATURE-BASED SOLUTIONS FOR **AGRICULTURAL AREAS**



In France today, 20% of greenhouse gases are produced by agriculture; a figure to which we must add the emissions that result directly or indirectly from changes in soil use (CITEPA, 2014). Most of these emissions come from field fertilisation (NOx) and animal husbandry (CH_4, NOx). In Paris region, agriculture is responsible for "only" 7% of greenhouse emissions, or 3.5 million TEQ CO_2 (the national average is 20.5% of emissions). However, the region emits 3% of the nation's agricultural greenhouse gases from only 1.8% of the country's total farmland.

While it is responsible for a portion of greenhouse emissions, the agricultural industry is also feeling the effects of climate change (which is exacerbated by other agricultural factors such as changes in soil use and intensification of farming methods). These effects include lack of water, extreme weather, and increased temperatures in agricultural areas. The industry is also threatened by the movement of species, especially the pests that feed on crops. Intensified agricultural practice has also resulted in the extreme simplification of ecosystems, reducing biodiversity and leading to increased vulnerability to unforeseen threats (such as the emergence of pathogens and parasites that leave agricultural systems less resistant to climate change). In fact, intensive agricultural practices are based largely on reducing the number of cultivated species and genetic homogenisation within those species[1]. This kind of farming makes little use of the inherent ecological functions of natural ecosystems, which produce their own ecosystemic regulatory patterns, replacing them instead with chemical inputs (pesticides and fertilisers) and heavy mechanisation, all while limiting the growth of habitats that shelter animal life (hedges, ponds etc.). In Paris region, the agricultural landscape is mostly made up of large-scale farming operations (averaging 12 hectares per operation). According to Jean-Marc Meynard, INRA, this type of low-diversity agricultural specialisation, particularly in terms of cereal production, is accompanied by shortened and simplified rotation cycles.

Faced with the threefold challenge of reducing agricultural emissions, ensuring ecosystems are able to withstand the effects of climate change and retaining sufficient productivity, renewing links with biodiversity seems to be an essential strategy.

The strategies for adaptation outlined in scientific literature on the subject often aim to adapt crops to a changing climate (using genetically modified cultivars, carefully controlled growing conditions, technological

1. Papy F., Goldringer I., 2011. "Cultivating Biodiversity", http://www7.inra.fr/dpenv/pdf/C60Goldringer.pdf

innovation, improvements in irrigation, etc.). However, the scientific community has long held that it is possible to practice alternative agricultural methods based on the mechanisms already at work in natural ecosystems. This approach signals the emergence of major changes in farming practices, such as the reintroduction of high levels of genetic and special diversity, especially via crop mixing and rotation, the restoration of habitats capable of sheltering wild animals (hedges, trees, grassy riverbanks) and the reduction of ploughing and tilling intensity. Other methods include increased lifespans for temporary meadows, longer grazing times, areas that are permanently planted (with vines and orchards, for example) and finally reductions in the use of synthetic mineral fertilizers. While the region's agricultural landscape is largely shaped by the European Common Agricultural Policy (CAP), it remains within the scope of the regional council to support initiatives promoting a system of climate-smart agriculture that prioritises biodiversity. Various measures may be applied in this regard: organic farming, bio-dynamics, conservation of traditional species, permacultures, agroforestry, conservation agriculture, and many other concepts (globally referred to as agroecology) all signal the possibility of wide agricultural diversity, using methods inspired by nature in localised contexts.

Reintroducing genetic diversity, diversifying crop rotations, improved soil management and the conservation of landscapes are also significant assets in terms of rendering agricultural systems more resistant to the effects of climate change. © L. Pagès

✷ Encouraging diversified agroecology in Paris region

As opposed to intensive monocultures, the implementation of agro-ecological practices aims to maintain diversified and elongated crop rotations, alternating winter and spring crops with pulses and legumes. This style of farming also involves covering soil, at least before spring crops are planted (using residues from old crops or interspersed cover plants), a preference for mechanical weeding and organic methods in place of phytosanitary or herbicidal treatments. The presence of legumes facilitates nitrogen fixation in large crop rotations, which provides essential nitrogen compounds for other crops. When legumes are introduced, the organic matter of the soil becomes rich in forms of nitrogen that may be used by other types of crops (including wheat, rapeseed, and barley). Increasing the amount of farmland used for legumes therefore reduces the need for mineral fertilisation and saves energy (since the production of synthetic fertilisers requires large amounts of energy). Crop rotations also allow farmers to diversify production and respond to changing consumer needs. Faced with growing demand for raw materials produced by agricultural that are not destined for dietary uses (such as organic building materials, textile fibres, wood and biomass), diversifying agricultural processes appears to be a suitable response. This is, notably, something that has been forecast by the "Afterres2050"[1] scenario, based on the predicted needs of the French people in the year 2050 (and residents of Paris region area in its regional breakdown). Finally, water-saving irrigation measures are essential in order to deal with more severe and frequent droughts. In this regard, the choice of species to be cultivated and the patterns in which they are sown should be more tailored to local climates, even if this requires new agricultural policies in order to incentivise farmers.

✷ Reintroducing genetic and inter-species diversity in crop systems

In light of the future challenges faced by the agricultural industry (climate threats, input reduction, etc.), the increasing of inter-species diversity (polycultures, related crop types) and genetic diversity (multi-varietal crops) are effective methods of action. The benefits of increasing genetic diversity have been well proven, in particular for wheat and seeded meadows, controlling bio-threats, and maintaining wild biodiversity around crops, but also for production stability and maintaining balance among the species that are planted in mixed-crop areas. Other research has shown that growing several species and cultivars together increases biomass yields and reduces water requirements (Litrico *et al.*, 2015). In these cases, the various species involved are chosen for their ability to coexist and complement each other in terms of resource use. This practice is beneficial for the structure, quality and productivity of the soil and dependent biodiversity. In Paris region, combined cereal and legume crops have shown proven potential, but other combinations are undoubtedly waiting to be discovered over the course of further research and scientific advances. It is also recommended that farmers introduce cover crops, catch crops and grassy patches (Chenu *et al.*, 2014), since in meadow-type ecosystems carbon capture and storage increases along with diversity of species present in the area (Amiaud et Carrère, 2012; Huyghe et Litrico, 2008). However, storage levels also vary depending on how meadows are used. The technique of mixing crops has also been demonstrated to produce positive interactions in primary production, in cases where pulses and grasses were mixed (Kirwan *et al.*, 2007), where the introduction of "doses" of multi-speciality was shown to minimise attacks from bio-threats. This is also true for mixed varieties and genetic diversity within a given species.

Genetic diversity in seed plantations is essential in terms of adapting crops to the effects of climate change.
Mixed varieties of wheat cultures. © G. Lecuir

1. Afterres2050: un scénario soutenable pour l'agriculture et l'utilisation des terres en France à l'horizon 2050 (A sustainable scenario for agriculture and land use in France in 2050): http://www.solagro.org/site/393.html

✷ **Protecting specific habitats and conducive environments** (ditches, hedges, grassy patches, field edges, isolated trees and bushes, ponds and boggy patches)

The observance of increasing pest populations in large monocultural plantations also underlines the need for alternatives to chemical pesticides, which are proven to be ineffective in the long term. Among the nature-based solutions on offer is biological control, which involves dealing with pathogenic organisms via natural predation. Essentially, this involves re-establishing the function of natural food chains in agricultural plots. It is important to protect neighbouring habitats and zones set aside for biodiversity that are capable of sheltering these animal species, with the aim of re-establishing fundamental biological interactions (reproduction, suckling, predation, etc.). This agro-ecological infrastructure can consist of various types of habitat: grassy patches (providing they are large enough), field edges, trees, hedgerows, copses, thickets and bushes, riparian woodlands, drainage ditches, ponds and bog patches. It is interesting to note that the restoration of 60,000km worth of hedgerows in Paris region would enable the capture and storage and 75,000 extra tons of carbon each year (a single hedgerow stores an average of 125kg of carbon per metre per year). Hedgerows are not only useful in terms of farm biodiversity, but also provide habitats for a number of dependent species of birds and insects. They also serve as essential ecological pathways for the movement of species, which is a considerable asset in terms of climate change adaptation.

✷ **Preserving or re-establishing flood expansion zones** in rural areas, acting as "stoppers" to mitigate the effects of flooding

In recent years we have seen a decline in the amount of herbaceous areas in Paris region - they represent no more than 4% of useable farmland in the region. This is the case for flood-prone meadow wetlands, which are essential areas for biodiversity, carbon storage and climate adaptation, especially in terms of flood risk (as these types of meadows act as flood expansion zones). Such areas often constitute the last natural refuge for species that were not originally adapted for this kind of environment, such as the Corn Crake, which disappeared from Paris region in tandem with the decline of alluvial meadowland habitats. They are often replaced by plantations of poplar trees, in varying degrees of density but always with lower amounts of biodiversity. Finally, over the past several years there has been significant debate over the future of the Bassée, a natural area in the east part of the region. This area's role in controlling flooding in Paris region is well-noted, but a major development project is also being planned: this would involve channelling the course of the lower Seine and creating around ten artificial chambers capable of storing water during exceptionally high flooding. The project would impact greatly upon local biodiversity, which is an exceptional of the region's natural heritage. This example clearly demonstrates the difficulties that lie in reconciling varying challenges and objectives and the methods that must be implemented in order to achieve a common goal, such as protecting people and properties from flooding.

Hedgerows play a crucial role in controlling crop pest populations by sheltering their natural predators. © M. Zucca

Flood expansion zones will become more and more necessary in the future due to the impact of climate change. They will need to be expansively restored. © N. Flamand

✷ **Reinforcing carbon storage in soil and biomass** via adapted methods

Meadowlands can store as much carbon as forests (70 tonnes of carbon per hectare), compared to 43 tonnes/hectare for farmlands: it is therefore important to ensure that regional policies encourage the preservation of permanent meadowlands, whether used for grazing or not; this includes planning their restoration where necessary. In fact, we may note that in this context converting land for traditional meadowland growth would increase overall capacity for carbon storage. Results are negative when converting forests into crop land, but positive when converting crop land into meadowlands (for example, going from crop growth to permanent meadowlands = +0.49 carbon storage). According to Le Roux *et al.*, in order to maintain year-round biodiversity in farmlands, the area would have to consist of at least 20% semi-natural herbaceous lands (compared to an average of 11.6% in France overall). Achieving this ecological objective would restore 46,000 hectares of additional meadowlands, resulting in an extra 80,000 TEQ CO_2 being captured and stored every year. As is often the case, solutions aiming to improve biodiversity are the same that allow us to combat climate change.

Elsewhere, in order to store more carbon in soils and reduce erosion, it is recommended that farmers adopt crop management methods such as reduced ploughing combined with direct seeding and superficial tillage. Furthermore, ADEME[1] specifies that soil covering using intermediary crops should be encouraged during rotations, and that the spaces between vines and orchard rows should be kept grassy. Elongating the lifespan of temporary meadows is also recommended.

Improving biodiversity in soils increases their capacity to trap and store carbon. © L. Pagès

1. http://www.ademe.fr/sites/default/files/assets/documents/7886_sol-carbone-2p-bd.pdf

✷ **Reintroducing arboreal diversity** in crop cultures using agroforestry

Agroforestry works to reintegrate trees in or around crop fields and pasturelands. The presence of trees has several advantages, notably increasing primary production (Chenu *et al.*, 2014), which leads to more efficient carbon capture in soil and better retention due to reduced soil erosion (also limiting soil and river pollution). Moreover, agroforestry can vastly reduce the "standardisation" of rural areas by recreating a mosaic landscape of heterogeneous environments. The technique must always be applied with due awareness for local conditions, particularly in terms of the varieties of trees chosen (which may be further diversified within a given plot of land). The implementation of this particular agricultural practice does not imply any major change to production systems, but increases relative amounts of carbon stored in soil and adds to direct production (wood, biomass, etc.) Farm plots in which trees are present experience improved fertility (Boukcim, 2010) and levels of organic matter may increase by up to 50% (compared to control groups where no trees were present). The reintroduction of trees provides shelter, food sources and refuge for numerous auxiliary species (including pollinators and crawling insects), enabling biological control of pests and pathogens, thereby limiting the need for artificial agricultural inputs (Le Roux, 2008). Though currently underdeveloped in Paris region, applied agroforestry could capture between 1 and 4 extra tonnes of carbon per hectare per year, contributing significantly to the Regional Ecological Coherence Scheme (Schéma Régionale de Cohérence écologique, or SRCE) by reinforcing arboreal land patches in farmlands. Owing to their deep roots, trees also help regulate humidity in soils without pitting crops against one another, and therefore avoid saturation and overflow that may cause damage to the soil. Finally, agroforestry can help to diversify farmers' revenues, as trees are valued for timber, firewood and fruit production.

Returning trees to crop fields has several benefits for both climate change and biodiversity. © P. Monin / Bergerie de Villarceaux

✱ **Encouraging a return to husbandry in the valleys** of the Île-de France region and polyculture grazing

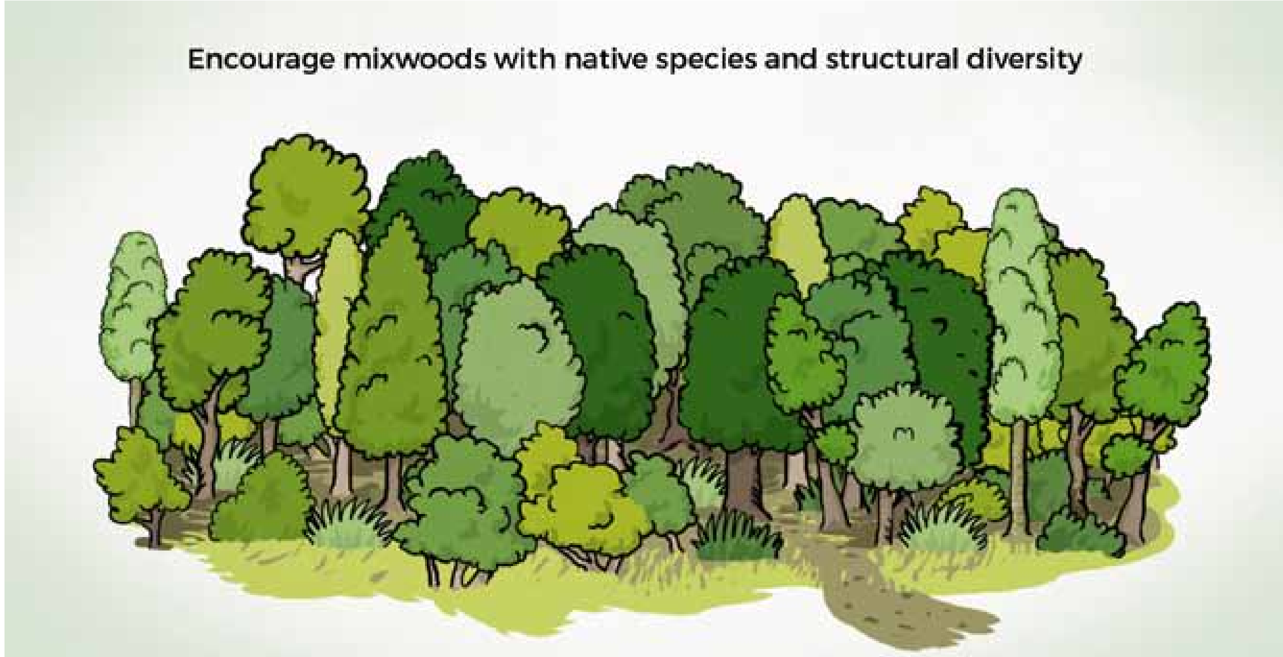
Livestock farming currently represents only 7% of agricultural activity in the region (Agreste, 2013), and yet animal farming (or grazing more generally, sometimes without food production objectives as in the case of horses and ponies, for example) can bring benefits for both climate change and biodiversity[1]. While livestock farming is often cited as a major source of greenhouses gases (especially methane), it is also a method for preserving the region's permanent meadowlands, which are essential for carbon storage (see p.23). Generating the desired effects for biodiversity and climate requires large livestock populations, so it is therefore important to accurately assess the capacities of each area and not to overload its ecosystem. In addition, grazing herbivorous animals benefits soil fertility (as their faeces are absorbed into the ground).

Mixing species and breeds (bovine, ovine, caprine and equine) helps to alleviate pressure on vegetation, as consumption habits vary between species. In the Paris region, a return to grazing and livestock farming in valley floors would be an improvement over poplar tree plantations. On the hillsides it would be possible to install temporary meadows, for harvest or grazing, in rotation with food crops. Orchard meadows are another possible choice, whereby grassy plains are planted with high fruit trees. The presence of the trees stabilises slopes, limits soil erosion, improves animals' quality of life, contributes to production diversification and, finally, acts as a shelter for certain wild species. Finally, in terms of maintaining production quality, initiatives of this kind could focus on raising breeds known to be suited to this kind of lifestyle due to their easy birthing and resistance to disease - examples include Salers cattle.

Extensive livestock farming has almost disappeared in Paris region, even though demand for its products is highest there. © RR

1. View the report: Élevage et biodiversité en Île-de-France, des synergies à encourager. Le cas des vallées franciliennes (Livestock farming and biodiversity in Paris region: positive synergies in the region's valleys): http://www.natureparif.fr/attachments/observatoire/rapports-etudes/elevage.pdf

NATURE-BASED SOLUTIONS FOR **FORESTS**



Forests are home to 65% of France's documented native species. They also play a key role in air and climate regulation. Forests are carbon sinks, contributing to both storage and fixation within living and deceased biomass. The amounts of carbon stored in forest ecosystems are difficult to quantify; they vary depending on climate, species present, and types of soil and land management programs in place. Nevertheless, researchers estimate that adult, temperate Boreal forests in the Northern Hemisphere store 2.4 tonnes of carbon per hectare per year[1]. The older a tree is, the more carbon it captures from the atmosphere so it can continue to grow, which confirms the benefits of preserving older forests and poplar plantations (Luyssaert *et al.*, 2008). Forest ecosystems in mainland France capture the equivalent of a third of the country's CO_2 emissions every year, or 32 million tonnes of carbon (MtC) per year. Carbon is stored in biomass (both elevated and subterranean) at a rate of 1,147 MtC for forests in mainland France, and in soil, which contains almost half the total stock, with 1074 MtC. As is the case with vegetation plantations, soil protection is an essential policy aspect in terms of protecting forests from the effects of climate change.

Wide-diameter trees absorb the largest amounts (in their trunks, branches, large roots, etc.) In forestry as in agriculture, solutions favouring biodiversity are also those which prioritise carbon storage and adaptation to climate change.

Forest environments therefore have high potential for mitigating, and adapting to, climate change caused by human activity.

However, forested areas, like other natural spaces, are already being affected by the impact of climate change. Though research is not yet complete or definitive, it is likely that climate change will push the biological range of certain plant species anywhere between 200 - 1200km to the North by the year 2100, which will have a knock-on effect on the biological diversity they help create. Droughts and forest fires are expected to become more intense and occur more frequently. The increase in atmospheric CO_2 could also lead to a rise in tree density, which in turn would lead to greater competition for light, impeding growth and reducing trees' capacity to capture and store CO_2. This would also have serious consequences for species living on the ground. Finally, the likely increase in the frequency and intensity of heavy storms raises the question of how forests will stand up to violent winds.

According to the DRIAAF, the amount of surface area covered by forest in Paris region is 23%, which in relative terms is not far off the national average of 26%. Despite its obvious urban character, Paris region remains as forested as many other French regions. Moreover, as in other parts of the country, forests are gaining ground despite being unevenly distributed across the region: a few very large forests (principally those of Fontainebleau and Rambouillet) stand out among highly dispersed areas of forested land around the rural areas of the wider region around Paris and its suburbs. Two thirds of forests in the region are

1. http://www.planetoscope.com/climat/co2

privately-owned, with this figure changing gradually from the central urban area outwards: in Paris and the immediately surrounding area, almost 90% of forests are publicly owned, a figure which diminishes considerably in outer regions.

It seems evident that forestry management (or sylviculture) practices (depending on the options chosen) can have an effect on a forest's ability to capture and store carbon and its overall biodiversity. Human intervention has profoundly modified climax vegetation, more so in terms of the upper stratum than of bushy or grassy flora. Forestry or sylviculture that uses thinning techniques (by simple felling or for timber production) has favoured species that will regrow from stumps (such as oak, hornbeam, teal and birch), to the detriment of beeches. Such methods also led to the widespread introduction of foreign species to the region, or those which had not spread far via natural means: these include deciduous species such as chestnut, and conifers such as Scots pine. Though forests in Paris region are not heavily farmed, scientists and forestry services are currently researching ways to ensure they are able to cope with these various challenges. Forests are also a source of interest for those hoping to increase forest cultivation for construction timber and wood fuel. Such policies should be required to prioritise management methods that respect biodiversity and climate change. As is the case with agriculture, it is apparent that solutions for mitigation and adaptation are often one and the same. According to researchers, forest managers should elongate forestry cycles, conserve dead wood and mulch, avoid vast felling and instead aim for careful and steady interventions, prioritising species variety and giving precedence to irregular treatments with continuous plant cover.

The Rosny-sur-Seine forest. © A. Muratet

✷ Promoting adaptive methods of forestry management that favour biodiversity

"Adaptive management" is an ambiguous term that may signify several things; for our purposes, it means practicing a form of forest management (which may also amount to non-management) that takes local, changing climate parameters into account and gives the forest the best possible chance of withstanding change and preserving itself in the long term. This type of adaptive management should also focus on forests' organic potential and diversity as a means of adaptation. According to Frédéric Gosselin, IRSTEA researcher, adaptive management should allow forest species to optimise their capacity for adaptation in the face of climate change. He recommends combining several forms of forest management: a mosaic of plantations covering all types of surface, young and old, exposed or shaded, with differing degrees of humidity and varying borders. This ranges from the ultra-natural (non-managed forests) to the most intensive forms of forest care, taking into account forest dynamics, conserving dead wood and biological ageing areas, limiting soil compacting, etc.

This type of approach could suit forests in Paris region. The frequent occurrence of natural regeneration in the forest ground layer helps preserve the genetic and intra-species potential of the plantation, and guarantees high levels of resistance to extreme circumstances (violent storms, fires etc.) as well as optimum capacity for adaptation to the effects of climate change.

According to Daniel Vallauri, Head of WWF forest program, if we are trying to maximize carbon storage in the forest ecosystem, elongating sylvicultural cycles is the optimum management choice. This can also help to optimise the production of quality timber, which is economically beneficial to the forest owner. In addition, forest plantations with multiple stratums are better for storing carbon, as lower levels can intercept carbon that is not captured by the soil. This structural complexity is generally more favourable for forest health, both in terms of resilience and biodiversity[1].

Finally, ADEME recommends not removing the upper biomass in its entirety, and leaving a portion of cuttings on the forest floor to preserve chemical and mineral fertility and reduce the risk of compacting, which contributes to increasing carbon stores. These warnings are all the more pertinent today as wood-energy development policies are being established with a real risk of over-exploiting forest resources. When it comes to felling, clearcutting is to be avoided, and researchers have highlighted the fact that reducing the density of felling operations to 8 trees/hectare would also be beneficial, both in terms of carbon capture and storage but also for existing biodiversity, maintaining a minimum distance of 35 metres between felled trees. Finally, trees whose diameter is above 100cm should not be felled, as they are capable of storing the largest quantities of carbon.

✷ Encouraging species variety in forests (mixwoods of native species and structural diversity)

Planting a hectare of temperate forest can store between 2 - 12 tonnes of carbon per year. Mixed populations are better able to adapt to changing circumstance, especially climate change (Legay *et al.*, 2007 and 2008). Moreover, mixing makes populations more resistant to both biotic and abiotic hazards (Dhôte *et al.*, 2005); this is due to their complex vertical structures, one effect of which is to allow roots to take hold at different levels and therefore make better use of water reserves in the soil. It is generally acknowledged by researchers and forest managers that greater diversity of tree varieties within a population makes the forest more resistant to drought in certain circumstances. All of these are reasons to adopt a "tree-by-tree" management approach, rather than viewing the plot as a whole.

✷ Preserving or increasing genetic diversity of forests species

According to François Lefèvre, a researcher at the National Agronomic Research Institute, (INRA), genetic diversity is the "fuel" that is necessary for adaptive forest evolution, whether achieved via natural or cultivated adaptation. Even within individual cultivars, genetic diversity allows more resistant individuals to emerge, in the same way as diversity within species helps prevent populations from disappearing when certain individual varieties are eliminated. These are the key factors behind the resistance of individual cultivars to climate change.

1. Rossi M., André J., Vallauri D., 2015. Movements of forest carbon. Food for thought in terms of wood value policies Lyon, Rapport REFORA, 40 pages. http://refora.online.fr/parutions/Rapport_carbone_forestier.pdf

✷ Preserving related environments of forests

Forests can shelter a multitude of other ecosystems, such as clearings, heaths and grasslands in dry or humid areas, meadows and even bodies of water (such as ponds and coastal wetlands), as well as streams, springs, and seepages. These areas contribute to the rich biological fabric of a forest and constitute "open" environments for various flora and fauna. They are also necessary for the reproductive cycles of many species of forest animals. These areas are also habitats for natural predators, which is beneficial for biological control.

Certain parts of the forest should be allowed to evolve naturally, without human intervention. © M. Zucca

✷ Leaving dead wood *in situ*, preserve biological refuges, old growth stands and preserving a framework of freely-evolving mature forests

It is essential to preserve a region-wide framework of mature wood, whether this consists of isolated trees (micro-habitat trees, dead trees, etc.), "biological ageing islands" (areas left to evolve naturally, as opposed to standard "ageing islands" in which trees are cut later in age/diameter than in common cultivation methods) or entire reservations. In order to be effective, these various parts of the freely-evolving mature wood framework must be connected from an ecological point of view (which is what we mean by the notion of a "corridor"). In Paris region, the policies for maintaining ageing islands affect 1,810 hectares of forest, which may be added to the total surface area classed as a biological reserve. Locally, certain private property forests have not used their forests for commercial purposes or hunting for several years, and these may also play a role (albeit non-statutory) as biological reserves or biological ageing islands, even if their longevity is not assured. These kinds of properties are estimated to occupy several hundred hectares in the Rambouillet forest.

According to Jean Claude Génot, ecologist in Vosges-du-Nord Regional Natural Park, it is important to preserve old-growth forests, but also to avoid managing them - instead leaving them to evolve naturally. For Génot, conservative management intended to increase biodiversity only serves to promote species that have been artificially maintained in open environments, leaving them much less diverse than true wilderness or wooded areas having evolved naturally over time. When evolving naturally, forests act as living laboratories for climate change adaptation. Finally, certain large areas of forest existing on slopes and hillsides, as well as on valley floors, should most definitely be preserved: these play a crucial role in protecting environments from the effects of water runoff and landslides.

✷ Reducing forest fragmentation and creating ecological corridors

Fragmentation of forest systems is emerging as a major concern, though the margins for error are probably more limited than those for intra-forest management. Despite the region's uniquely dense transport network, the level of countryside fragmentation of forest landscapes in Paris region is equal to the national figure (averaging 50 linear metres per hectare). This fragmentation is also due to the multiplicity of forest owners (⅔ of forests in the region are in private hands); at the same time, it is recognised that this system of ownership can be an asset, since many owners do not put their forests to commercial use, leaving them to evolve as conservation zones. In certain contexts, isolating large forested areas by way of large infrastructures and urbanisation prevents natural processes of emigration and immigration of species between forests, which are necessary to maintain populations (especially of fauna). Almost all the forests situated within 20km of Paris are completely enclaved; this statistic should lead us towards an improved appreciation of forest "frameworks" when writing urban policy documents, as well as reforesting operations aiming to establish functional forested corridors. In certain cases, the creation of natural passageways for fauna can prove to be an effective solution (road crossings), especially for larger mammals; such passageways must, however, be of sufficient size to operate successfully.

✷ Limiting poplar plantations

Monospecific poplar cultures pose problems for biodiversity, especially in alluvial valley areas, representing maximum biological simplification. Moreover, the damage done to European poplars by the various species of the Melampsora fungus is proof of monocultures' lack of resistance to environmental hazards (Pinon *et al.*, 1998). In Paris region, two sectors have been particularly damaged by poplar plantations: the Bassée and the Ourcq valley. These poplar plantations are home to only very low levels of biodiversity, and do not display the characteristics of a normal functional wetland. In the context of adapting to climate change, it is necessary to protect alluvial forests in tandem with extendible agricultural practices such as grazing in valley floors.

Fields of monospecific tree cultivars are vulnerable to external threats. © J. Birard

FOCUS: PRESERVING AND RESTORING WETLANDS AROUND URBAN, AGRICULTURAL AND FORESTED AREAS

In Paris region, wetlands represent around 2.8% of the region's surface area (compared to 5% nationally), including all wet woodlands found in valley floors and even poplar tree plantations (not counting poplars, the figure would drop to 2.1%). Over 50% of wetland areas have been lost in the last century, and a significant portion of those which have survived are formed around artificial bodies of water, often in old quarries. Wetlands are among the most vulnerable types of environments in terms of climate change, incurring damage and losing ground faster than any other kind of ecosystem (GIEC, 2007). And yet, in both urban and rural areas wetlands carry out essential natural functions including flood prevention, water purification and carbon storage.

Wetlands are also biodiversity reservoirs and important sites for the reproduction and nesting of a number of animal species. Preserving diversity in wetlands is a major concern in terms of both biodiversity and combatting climate change. Moreover, protecting wetlands is less costly than constructing dykes and levees. However, only wetlands in sound ecological health are capable of playing their role as a "natural sponge" for the effects of climate change.

Wetlands can be both sources and sinks for carbon. When functioning naturally, they generally act as carbon sinks: vegetation forms peat and the combination of the two is capable of storing carbon. When disturbed, however, they become carbon emitters. A study carried out within the scope of the national program for the study of wetlands (PNRZH) showed that carbon emissions varied from one peatbog to another: alkaline bogs produce more CO_2 than sphagnum (peat moss) blankets. In anaerobic conditions where particularly degraded peatlands are saturated with water, methane production may occur. In all cases, however, peatlands capture significant proportions of carbon and store it persistently (for several thousand years), preventing it from re-entering the carbon cycle and thus from contributing to global warming. Riparian forests are also able to trap carbon for relatively long periods of time in the oldest parts of their trees (trunks and branches). This carbon cannot return to the ecosystem for at least several decades, if not several hundred years.

For Paris region, the main challenge is preserving existing wetlands and related flood-prone areas (wetland meadows, riparian forests) of all sizes (especially ponds and marshy forests), as well as placing limits on overly intensive management of these areas: measures to be avoided include conversion to poplar plantations, commercial cultivation of alluvial forests, destruction of wood colonies and topsoil inversion of peatlands, digging of ponds that have become non-functioning, and the removal of dead wood. In addition, it should be noted that adherence to agroecological policies would allow us to reduce pollution and, at the same time, avoid putting undue stress on wetlands via unsustainable levels of water consumption

A flooded alluvial forest, the Refuge marsh in Lesches. © M. Zucca

1. http://www.econostrum.info/Des-zones-humides-pour-amortir-les-effets-du-rechauffement_a16832.html#ixzz3iW8aQBZ9
2. According to A. Schnitzler - http://www.snpn.com/IMG/pdf/ZHI_67.pdf

CONCLUSIONS

As we have seen, there exists a wide variety of "nature-based solutions" for mitigating climate change and adapting to its effects. Not all these ideas are at the same stage of maturity, nor equally easy to implement, but each of the solutions outlined in this dossier has been implemented at least once by a stakeholder in our local region.

Natural solutions have the advantage of being able to generate multiple social and environmental benefits, while at the same time requiring less public spending than solutions based on civil and traditional engineering.

While measures employing biodiversity bear undeniable appeal, the main impediment to their application resides in the means by which they must be implemented.

First of all, these measures require changes in the way we think as a society, requiring us to abandon habitual practices such as intensive agricultural methods and replacing them with systems that may seem less advantageous in the short term, even though they are much more beneficial overall. Another essential step forward is the distribution of scientific information among relevant parties, as well as opportunities for dialogue and confrontation between groups whose interests are divergent, through legitimate on an individual level.

Furthermore, we must remember that ecological engineering is a new science still in development, whose procedures we have not yet mastered. This kind of discipline requires scientific advances that will take time to achieve, despite the fact that the fight against climate change demands rapid responses.

Finally, these types of measures generate collective economies, reducing external interests rather than individual benefits.

In the context of the COP21, it is therefore important to combine elements of ecological engineering with traditional green technologies such as wind, solar and hydraulic power, in order to bring about real adaptation to climate change. However, the development of techniques for mitigation and adapting to global changes, particularly targeting carbon emissions, should avoid inviting a slew of projects that lack consultation or are limited to one sector, domain or type of stakeholder. In policy as in nature, diversity is the key to success.

OVERVIEW OF ADAPTATION AND MITIGATION MEASURES

METHODS	TECHNOLOGICAL SOLUTIONS	ECOLOGICAL SOLUTIONS
ADAPTATION		
COMBATTING THE EFFECTS OF URBAN HEAT ISLANDS	AC units Street watering	Revegetation of streets and buildings
COMBATTING THE RISK OF FLOODS AND HEAVY RAINS	Dykes and artificial runoffs	Restore functionality of urban water cycles bycreating ponds and basins to collect rainwater Adopt a program of demineralisation in urban surfaces (school playgrounds, apartment buildings, roadways) in tandem with revegetation policies
COMBATTING DROUGHT	Intensive watering Seed selection	Agricultural practices in accordance with local climate conditions
MITIGATION		
CARBON STORAGE	Carbon trapping using geo-engineering	Increasing amounts of biomass present in urban and rural areas Policies aiming to prevent the use of impervious ground surfaces
ENERGY EFFICIENCY IN HOMES	Insulation using classic petrol-based materials	Use of organic insulating materials Revegetation of buildings (rooves and facades)
REDUCING GREENHOUSE EMISSIONSIN URBAN AREAS	Green transport	Transport methods with reduced carbon footprints, using non-carbon energy sources and infrastructures conceived in accordance with SRCE policies
REDUCING GREENHOUSE EMISSIONS IN FARMLANDS	GMO, selective species growth	Reduced tillage Increasing biomass using cover crops and related crop choices Planting trees in or around crop fields (agroforestry)
RENEWABLE ENERGY	Renewable energies that have not been ecologically designed	Renewable energies whose component materials or processes have a reduced biospheric impact, organised in cooperation with local areas and authorities and working towards energy self-sufficiency in local regions.
CARBON STORAGE IN FORESTS	Species selectively-chosen for rapid growth	Conservation of older trees, Adaptive management prioritising biodiversity

NON-EXHAUSTIVE BIBLIOGRAPHY

Actes de la conférence " Climat et biodiversité : Rencontre avec les experts français de l'IPBES et du GIEC " - *http://www.fondation-biodiversite.fr/fr/interface-recherche-societe/societe-civile/decisions-publiques/international/ipbes/ipbes-rencontre-ipbes-giec-6-nov-2014.html*

Barbault, R., Weber ; J., 2010. Biodiversité et climat : le janus du changement global - *http://www.x-environnement.org/images/stories/jr/jr12/5-biodiversite-et-climat-barbault-weber.pdf*

Schéma Régional du Climat, de l'Air et de l'Energie d'Ile-de-France (SRCAE) - *http://www.srcae-idf.fr/IMG/pdf/SRCAE_-_Ile-de-France_version_decembre_2012_vdefinitive_avec_couverture_-_v20-12-2012_cle0b1cdf.pdf*

Plan Régional pour le climat d'Île-de-France - *http://www.iledefrance.fr/sites/default/files/mariane/RAPCR43-11RAP.pdf*

Réseau Action Climat France, Les émissions importées : le passager clandestin du commerce mondial - *http://www.rac-f.org/IMG/pdf/EMISSIONS-IMPORTEES_RAC-Ademe-Citepa.pdf*

Bruno Locatelli, Les synergies entre adaptation et atténuation en quelques mots - CIFOR : *http://www.cifor.org/fileadmin/fileupload/cobam/FRENCH-Definitions%26Conceptial-Framework.pdf*

Green infrastructure, European commission - *http://ec.europa.eu/environment/nature/info/pubs/docs/greeninfrastructure.pdf*

Bellard C., Bertelsmeier C., Leadley P., Thuiller W., Courchamp F., 2012. Impacts of climate change on the future of biodiversity - *http://max2.ese.u-psud.fr/epc/conservation/PDFs/Impacts.pdf*

IPCC, 2001. Climate change 2001: synthesis report. Cambridge University Press - *http://www.ipcc.ch/pdf/climate-changes-2001/synthesis-syr/english/front.pdf*

Le changement climatique à Paris, collectif, Météo-France et l'Agence parisienne du climat - *http://bibliotheque.meteo.fr/exl-php/util/documents/accede_document.php*

Rapport sur le climat de la France au 21e siècle Volume 4, G. Ouzeau, M. Déqué, M. Jouini, S. Planton, R. Vautard, sous la direction de

Jean Jouzel, Ministère de l'Écologie, du Développement durable et de l'Énergie - *http://www.developpement-durable.gouv.fr/IMG/pdf/ONERC_Climat_France_XXI_Volume_4.pdf*

T. Elmqvist *et al.* (eds.), Urbanization, Biodiversity and Ecosystem Services: Challenges 175 and Opportunities: A Global Assessment - *http://www.cbobook.org/pdf/Urbanization_biodiversity_and_ecosystem_services-challenges_and_opportunities_2013.pdf*

Villes et adaptation au changement climatique ; rapport au Premier ministre et au Parlement. Observatoire national sur les effets du réchauffement climatique. La Documentation française, Paris, 2010, 224 p - *http://www.developpement-durable.gouv.fr/IMG/pdf/ONERC_ville_et_adaptation.pdf*

Green Roofs as Urban Ecosystems: Ecological Structures,Functions, and Services (Oberndorfer *et al.* 2007) - *http://www.bioone.org/doi/pdf/10.1641/B571005*

J.M. Meynard, A. Messéan, A. Charlier, F. Charrier, M. Farès, M. Le Bail, M.B. Magrini, 2013. Freins et leviers à la diversification des cultures. Etude au niveau des exploitations agricoles et des filières. Rapport d'étude, INRA, 226 p. *http://agriculture.gouv.fr/la-diversification-des-cultures-comment-la-promouvoir*

Zucca M., Birard J. & Turcati L., 2013. Diagnostic de l'état de l'état de santé de la biodiversité en Île-de-France. Natureparif, Paris. 84 p. - *http://www.natureparif.fr/attachments/observatoire/Indicateurs/2013/Natureparif_diagnostic_biodiversite_WEB.pdf*

Ivan Prieto, Cyrille Violle, Philippe Barre, Jean Louis Durand, Marc Ghesquière, *et al.*. Complementary effects of species and genetic diversity on productivity and stability of sown grasslands. Nature Plants, 2015, 1 (4), pp.1-5 - *http://www.nature.com/articles/nplants201533*

DRIAAF, la foret francilienne - *http://driaaf.ile-de-france.agriculture.gouv.fr/IMG/pdf_foret_francilienne_DRIAFIledeFrance07_cle0ebbaa.pdf*

ADEME, Carbone organique des sols : l'énergie de l'agro-écologie, une solution pour le climat, Juillet 2014 - 27 p. - *http://www.ademe.fr/sites/default/files/assets/documents/7886_sol-carbone-2p-bd.pdf*

COP21 & Agroforesterie : Du nouveau sous le soleil avec l'agriculture du carbone, Association Française d'Agroforesterie - Juillet 2015 - *http://www.agroforesterie.fr/actualites/2015/documents/Agroforesterie-COP-21-du-nouveau-sous-le-soleil-avec-l-agriculture-du-carbone.pdf*

Luyssaert, S., *et al.*, Old-growth forests as global carbon sinks. Nature, 2008. 455(7210): p. 213-215 - *http://www.nature.com/nature/journal/v455/n7210/full/nature07276.html*

Natacha Massu, Guy Landmann, coord., 2011. Connaissance des impacts du changement climatique sur la biodiversité en France métropolitaine, synthèse de la bibliographie. Mars 2011. ECOFOR. 180 p. - *http://docs.gip-ecofor.org/libre/CCBio_SyntheseFinale_112011.pdf*

Rossi, M., Vallauri, D., 2013. Évaluer la naturalité. Guide pratique, version 1.2. WWF, Marseille, 154 pages - *http://www.foretsanciennes.fr/wp-content/uploads/Rossi-Vallauri-2013.pdf*

Lefèvre, F., Collin, E. (2008). Changement climatique, diversité génétique et adaptation des forêts. Forêt Méditerranéenne, 29 (2), 243-246 - *http://prodinra.inra.fr/record/20348*

Zones Humides Infos - n° 67 - 1er trimestre 2010. 2. ZH. Infos - *http://www.snpn.com/IMG/pdf/ZHI_67.pdf*

All Natureparif publications can be accessed at: *http://www.natureparif.fr/connaitre/publications*

Watch our latest video (5 minutes 33 seconds) - Climat: la nature source de solutions en Île-de-France at: *http://www.dailymotion.com/video/x37qhi8*

NATUREPARIF

A non-profit organisation as defined in the French law of 1901, Natureparif was created by Paris region with the support of the central government. Acting for nature and biodiversity in Paris region, its mission is to gather existing knowledge and information and distribute this information via appropriate channels.
The organisation also identifies regional action priorities and maintains an inventory of biodiversity preservation best practices, as well as working to ensure their widespread implementation.

www.natureparif.fr

AGENCE DE L'EAU SEINE-NORMANDIE
(SEINE NORMANDY WATER AGENCY)

The Seine-Normandie water agency is overseen by two government ministries: the Ministry of Ecology, Sustainable Development and Energy and the Ministry of Economy, Finance and Industry. Its purview is the Seine drainage basin and the coastal rivers of Normandy. Its primary objectives are the preservation of natural heritage and the streamlining of water management practices.

www.eau-seine-normandie.fr

GIS CLIMAT-ENVIRONNEMENT-SOCIÉTÉ

Created in March 2007, the GIS initiates, supports and coordinates interdisciplinary research pertaining to climate change and its impacts on society and the environment. Its work builds upon the expertise of a collective of research laboratories in Paris region, working primarily in the domains of climatology, hydrology, ecology, health and social sciences.

www.gisclimat.fr