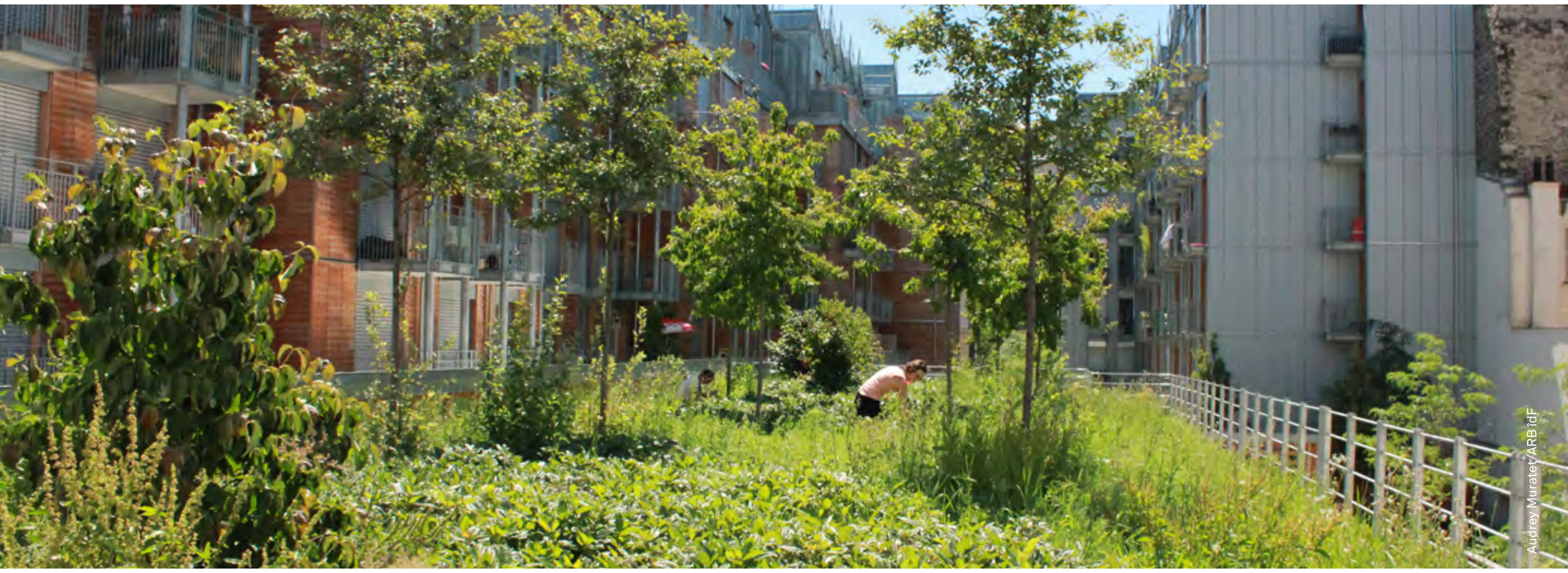
NOTE RAPIDE

L'INSTITUT PARIS REGION #44



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BIODIVERSITY

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GREEN ROOFS: AN ASSESSMENT OF ECOLOGICAL BENEFITS IN THE PARIS REGION

36
GREEN ROOFS STUDIED

400
PLANT SPECIES

611
INVERTEBRATE SPECIES IDENTIFIED

BETWEEN 2017 AND 2019, THE AGENCE RÉGIONALE DE LA BIODIVERSITÉ (ARB ÎDF) AND ITS PARTNERS STUDIED 36 GREEN ROOFS IN THE PARIS REGION IN ORDER TO ASSESS THE BENEFITS OF THESE NEW URBAN ECOSYSTEMS. BIODIVERSITY, RAINWATER RETENTION AND COOLING ARE EXAMPLES OF THE ECOSYSTEM SERVICES PROVIDED BY THE MAIN TYPES OF GREEN ROOFS ASSESSED.

Green roofs have existed for thousands of years, especially in Scandinavian countries. In France, their development has accelerated since the 2000s in relation to the development of urban ecology policies. Urban developers and architects see in these novel ecosystems a way of making cities more attractive to biodiversity. Green roofs can be helpful in dense urban areas with few green spaces to cope with the consequences of climate change (heat islands, rainwater management, etc.). Extensive green roofs are the most popular because they are lightweight, easy to install and require little maintenance. Since the 2000s, other types of green roofs have been implemented based on knowledge of urban ecology. Studies of green roofs began only recently, and their ability to respond to a range of environmental challenges remains uncertain. Carried out between 2017 and 2019, the GROOVES study (Green ROOfs Verified Ecosystem Services) selected 36 roofs in Paris and its inner suburbs. Professionals recognise three categories of green roofs, mainly depending on the depth of the soil : the study focuses on 18 extensive roofs (0 – 15 cm soil depth), 6 semi-intensive roofs (15 - 30 cm) and 8 intensive roofs (over 30 cm). There are also 4 "wildroofs", a fourth type that denotes non-planted roofs on which plants grow spontaneously. The study assessed several parameters including flora, fauna, fungi, soil bacteria and other ecological functions. This work aims to provide new scientific insights as well as guidelines on the design and management of green roofs.

This research has demonstrated the influence of design principles on biodiversity and ecosystem services provided by green roofs.

Green roofs lend themselves to large-scale scientific field studies as they are relatively small, available in large numbers, and embody several distinct design approaches. ARB îdF is applying this

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Front page
This intensive roof atop a Paris Habitat residential building near the Place de la République in Paris, with its diverse plant strata, is one of the most efficient in terms of rainwater retention, with a capacity of almost 178 litres per square metre.

"GROOVES" ASSESSMENT PROTOCOLS

Between May and July over a period of three years, naturalists and ecologists carried out a range of different assessment protocols for biodiversity and ecosystem services, including several citizen science programmes[1]:
- **Vascular plants** (plants with stems, leaves and roots): "Vigie-Flore" protocol, one survey per year, 10 quadrats per rooftop
- **Bryophytes** (mosses and lichens): exhaustive inventory of species, one survey in three years
- **Invertebrates** (insects, spiders, molluscs, etc.): visual census, transect sampling and sweep net for 10 minutes, two surveys per year
- **Pollinators:** photographic monitoring of pollinating insects ("SPIPOLL" protocol), six surveys per year
- **Soil:** ten extraction points, samples analysed in lab (physics, chemistry, microbiology, environmental DNA), one survey in three years
- **Water retention:** maximum water capacity, one survey in three years
- **Cooling:** measurement of evapotranspiration on 14 rooftops, two surveys in three years

GENERAL INFORMATION

- 36 rooftops in Paris and its inner suburbs.
- On public and private buildings 2.7 - 30 metres tall.
- Green areas between 91 and 2,980 sq.m..
- Most are recent constructions (0 - 15 years). The oldest is the roof of the Mozinor distribution centre (1975) in Montreuil. The newest is that of the Seine Musicale in Boulogne-Billancourt (2017).
- Most of the rooftops are not accessible to the public, although two are accessible to school groups for educational purposes.

innovative methodology of ecological assessment to other urban ecosystems such as urban farming plots (the "BiSEAU" project), cemeteries (the "COOL" project) and an urban flood expansion area (the "ZEBU" project), which aim to assess biodiversity and ecosystem services more effectively.

A LEVEL OF BIODIVERSITY ON ROOFTOPS THAT IS UNCOMMON IN URBAN ENVIRONMENTS

In total, about 400 plant species were observed on the 36 rooftops studied. In order to compare this with other urban green spaces, the "Vigie-Flore" protocol was carried out: 292 species of vascular plant were observed, 70% of which are spontaneous (spread by the wind or animals). Among the most frequently observed species are sedums, which are often used on green roofs. Rare species were also recorded, such as the yellow serradella *(Ornithopus compressus)* and the orange bird's foot *(Ornithopus pinnatus)*. These observations confirm the role played by green roofs in providing habitat for varied, and sometimes rare, plants in urban areas. The distinction between spontaneous and planted specimens provides extra information that improves our understanding of the ecology of rooftops and their ability to host urban biodiversity.

611 species of invertebrate belonging to a diverse range of taxonomic groups have been recorded on these rooftops, in particular isopods (woodlice), myriapods (millipedes) and springtails (tiny creatures that live in the soil and whose atypical morphology sets them apart from insects). The latter are primarily detritivores and help to recycle organic matter. Higher up the trophic chain, phytophagous insects are well represented: beetles, orthoptera (crickets and grasshoppers) and hemiptera (bugs, aphids and cicadas). As a consequence of this diversity, numerous predatory arthropods are also present, along with spiders, hymenoptera (the order of insects that includes bees, wasps, ants and hornets) and several beetles.

If we compare rooftop data with data collected from ground-level green spaces using the same citizen science protocols, it turns out that rooftops on average host fewer pollinators but are home to as many plants as are found in brownfields and urban parks. This diversity is very variable. Extensive rooftops, which have a substrate that is essentially composed of mineral substances and/or is rather shallow, host a range of organisms that is less rich than that found on semi-intensive and intensive roofs. These two categories of roofs host a range of pollinators comparable to those in other urban green spaces. There are sometimes even more plant species than in ground-level green spaces.

Some design parameters help to increase biodiversity, such as the quality and depth of the roof substrate and the height of the building (3 storeys), but plant diversity doesn't increase anymore beyond this height. Plant diversity increases in proportion to substrate depth up to 25 cm, while the diversity of pollinators continues to increase beyond this threshold. The composition of the substrate also plays an important role in the establishment of diverse flora: substrate containing 10% clay and around 60% sand allows maximum species diversity.

Although they host fewer species, extensive roofs and wildroofs are of no less interest: they feature

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1. In hot weather, sedums turn red on the extensive roof of Le Périscope, a residential building in the 13th arrondissement of Paris.

2. Even 20 metres from the ground, plants are capable of colonising rooftops. 32 species flourish spontaneously on this semi-intensive rooftop belonging to Paris Habitat in the 19th arrondissement: one of the richest in the selected sample.

3. Built in 2017, the intensive roof of La Seine Musicale, in Boulogne-Billancourt has already been spontaneously colonised by 22 plant species and 65 species of invertebrate including the Bordeaux cricket, which is rare in the region.

4. This wildroof on top of the GTM Bâtiment building in Nanterre hosts only spontaneous vegetation. Such roofs are sometimes home to non-indigenous species: here we see the evening primrose, originally from North America and introduced circa 1614.

combinations of plants that thrive on dry, sandy soil and host Mediterranean, continental and North American species. Invertebrate populations found on extensive roofs are different from those seen on intensive roofs. Semi-intensive rooftops seem to be somewhere between the two, offering an intermediate habitat with respect to the other categories.

Comparable disparities in terms of species populations are observed between roofs and ground-level environments. If we compare the invertebrate species that are commonly found on roofs with those in urban areas across the Paris region using the regional wildlife observation database Cettia, we can distinguish three groups of species: "roofophiles" that are usually scarce in urban areas but very common on rooftops, such as *Runcinia grammica* (a species of spider), *Nysius graminicola* (a type of seed bug) and *Lygus pratensis* (the common meadow bug); "versatile" species that are common to both roof and ground, such as the firebug *(Pyrrhocoris apterus),* the European garden spider *(Araneus diadematus)* and the southern green shield bug *(Nezara viridula);* and "roofophobes" that are uncommon on rooftops but common down below, such as the nursery web spider *(Pisaura mirabilis),* the mottled shield bug *(Rhaphigaster nebulosa)* and the dock bug *(Coreus marginatus).*

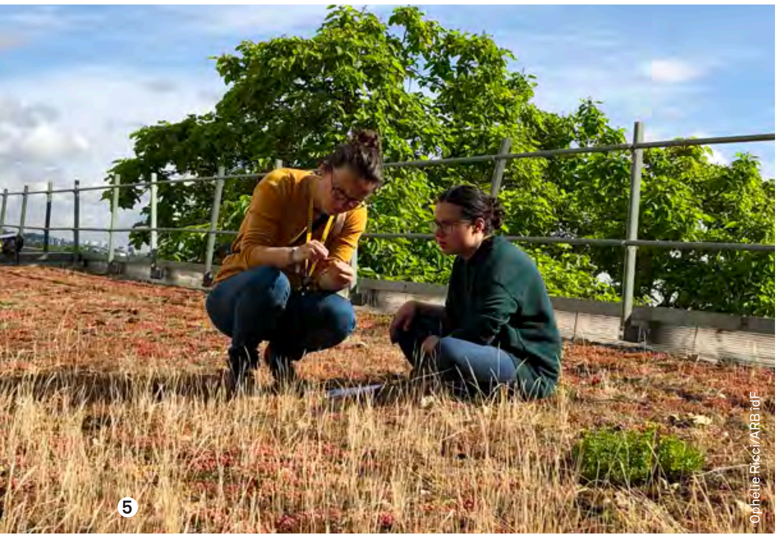
ECOSYSTEM SERVICES PROVIDED BY GREEN ROOFS

Rainwater retention

Laboratory analysis of substrates has given us a better understanding of the water storage potential of rooftops. There is some variation, mainly due to the type, depth and particle size of the substrate. The least absorbent roof retains 6 litres per square metre with a substrate depth of 3.5 cm, while the most absorbent is able to retain 532 L/sq.m. with a substrate 100 cm deep. To obtain a more detailed insight into this variation in water retention potential, the data was processed using the Faveur model[2], which makes it possible to integrate a number of variables into the water retention (vegetation, depth of substrate, climate, etc.) but does not include roofs with a substrate depth of more than 30 cm: the values were thus calculated for 26 of the roofs in the sample. The model confirms the observed trend, with values ranging from 200 to 500 L/sq.m. of runoff retained per roof per year. As for the maximum amount of rainwater captured by the substrate and consumed by the plants each time it rains, there are also large variations between the least absorbent roofs (4L/sq.m.) and the most absorbent ones (92 L/sq.m.). Although all the roofs are able to retain water when it rains, only 5 of the 26 are able to regulate a ten-year average rainfall of 48 mm in 4 hours. The latter have substrates consisting of "agricultural soil" and are almost 30 cm deep. The Faveur model suggests that for high water retention capacity the threshold substrate depth is about 30 cm, and between 10 and 30 cm for average water retention. These results may be useful for local authorities in the framework of their climate change adaptation strategies, helping in particular to anticipate rainwater management needs on the scale of local planning schemes.

Contribution to urban cooling

To assess the cooling potential of green roofs, evapotranspiration (water transferred from the substrate to the atmosphere via plant transpiration) in 14 of the selected roofs was measured by the CEREMA (Centre d'Etudes et d'Expertise sur les Risques, l'Environnement, la Mobilité et l'Aménagement) in summer and autumn. Summer measurements varied from 7 watts per square metre (low evapotranspiration and thus low cooling potential) and 190 W/sq.m. (much higher evapotranspiration). Only 6 of the 14 roofs studied had evapotranspiration values above 100 W/sq.m.; they would thus be able to cool the roof surface but not the space beyond it. The results seem to confirm the importance of substrate depth and type of



vegetation. These measurements are nonetheless influenced by local microclimatic conditions (shade, cloud, wind, etc.) and can vary widely. Last but not least, evapotranspiration is by its very nature dependent upon the availability of water in the substrate and could thus be lower in prolonged periods of hot weather or drought. On the scale of the city, the contribution of roof-based vegetation to urban cooling appears to be minimal compared to other ground-level areas (rows of trees, wooded areas, etc.).

Soil quality

Known as a “supporting” ecosystem service, soil quality has a major influence on biodiversity. Most green roof substrates cannot be compared to true soil. Their origin and composition vary greatly, from topsoil removed from natural or agricultural land to substrates created using materials from different sources (mineral components– crushed brick, clinker, perlite, etc. – mixed with an organic component – agricultural soil, compost, backfill, etc.).

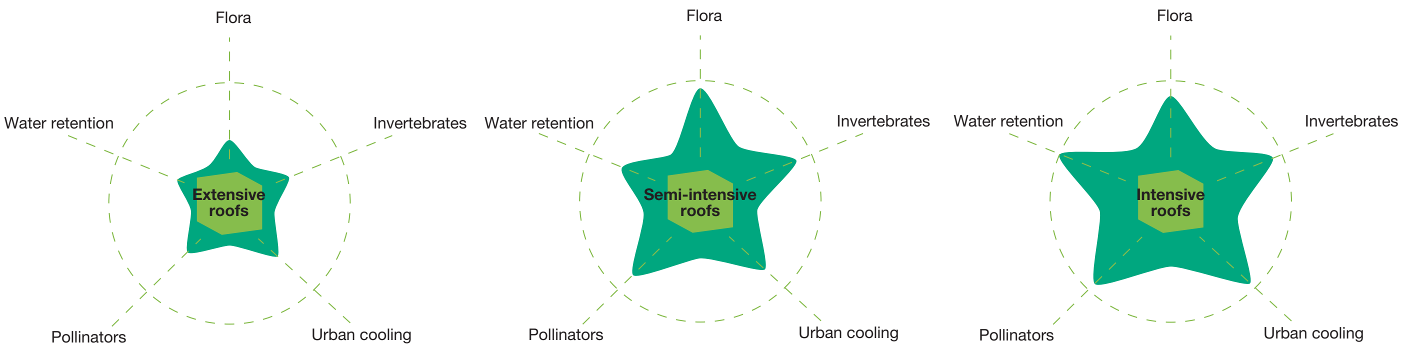
The concentration of metallic trace elements (MTEs) such as copper, lead and cadmium in roof substrates has been analysed. Although most roofs are not significantly contaminated, some reveal proportions of lead and zinc that exceed risk levels. It is very difficult, if not impossible, to trace the source of such pollution: it may come from substrates contaminated before being placed on the roof or from atmospheric deposits accumulated over the years. Measuring MTEs can nonetheless by very useful for building managers to avoid risk of contamination when rooftops are accessible to the public – in schools, for instance – or during maintenance.

Microbiological analysis was carried out by the INRAE, the National Research Institute for Agriculture, Food and the Environment in Dijon, based on microbial DNA. The results show that green roofs are environments that promote the development of microbial communities (bacteria and fungi), both in terms of quantity (biomass) and quality (diversity). Average levels of microbial

5. Audrey Muratet and Amandine Gallois are doing the Vigie-Flore protocol on this rooftop in Antony.

6. The semi-intensive greenroof on the top of GTM bâtiment building in Nanterre flourish during spring.

Comparison of efficiency of ecosystem services provided by roofs according to their typology



Extensive roofs are shown to be on average 50% less efficient than semi-intensive and intensive roofs in providing the services that were evaluated.

7. A Mining Bee *(Andrena sp.)* pollinating a flower of the Common Yarrow *(Achillea millefolium).* One example of the solitary bees found on rooftops.

8. Some sedum and fungi species on the top of Fontane's school in Courbevoie.

abundance and diversity on rooftops are higher than those reported on a national scale in "natural" soils using the RMQS[3] benchmark. On average, calculated biomass is 129.4 µg DNA/g soil on roofs: more than double the average level measured with the RMQS benchmark (59.2 µg ADN/g soil). High levels of organic carbon observed on these roofs (via the addition of fresh materials such as compost) may explain these high values. However these analyses remain difficult to interpret and show that rooftops are environments that are too specific to be assessed using standard agronomic indicators.

WHAT CAN WE LEARN FROM THE STUDY? HOW CAN GREEN ROOFS BE IMPROVED?

Towards low-tech ecological design

Clearly we cannot expect green roofs to provide the whole range of ecosystem services at the same time, be it in terms of biodiversity, rainwater management, urban cooling or pollination. It is, however, possible to design and manage them in such a way as to optimise some of their functions, depending on their location and the goals set by local authorities.

Our study shows, as is often the case in ecology, that there is no "perfect recipe" but that recommendations vary according to the group of species under consideration, the criteria under analysis, the geographical location, and so on. Where substrate depth is concerned, we see that plant diversity stops increasing when the soil is about 30 cm deep, while pollinator diversity continues to increase beyond that threshold. "Mixed" or "agricultural" substrate about 30 cm deep containing at least 10% clay and 60% sand will be more likely to support varied flora and more able to retain rainwater. Despite their poorer performance in terms of ecosystem services, extensive roofs host a kind of biodiversity that is unfamiliar in urban environments and can thus complement other rooftop typologies.

The observations made during the project also showed that some design approaches rely on a number of man-made components (plastic geotextile planters, non-biodegradable membranes or felt, plastic netting, built-in watering systems, etc.) whose usefulness is questionable. Of the 36 roofs studied, 13 do not include man-made components, which confirms that it is possible to restrict the use of potentially energy-guzzling manufactured materials that can leave lasting traces: we observed a significant amount of plastic debris left behind when systems deteriorate, sometimes on very recent roofs. This aspect must not be neglected, especially as these man-made components add to the cost of green roofs. The way plants are packaged also involves industrial processes that tend to standardise products for sale (e.g. plants packed in pot trays or sold as pre-grown rolls). New design approaches inspired by landscaping techniques and ecological engineering could be applied: creating dry grassland, meadows or sandy environments, choosing local species adapted to climate conditions, planting wild seeds collected nearby, etc. Last but not least, wildroofs require no planting at all: plants grow on them spontaneously from seed carried by the wind or by animals.

Increased demand for green roofs – and consequently for substrate – raises the issue of production methods. This is the case in particular for roofs using agricultural soil. This is usually topsoil stripped from fertile land: a process that adversely affects soil sustainability. Using upcycled substrates (excavated soil from building sites or mixtures of salvaged soil, crushed materials and compost) is a way of reducing the ecological footprint of green roofs in the future.

Management practices that need to evolve

Green roofs may be managed to check water-proofing, to remove unwanted ligneous plants or to bring them in line with aesthetic expectations.

Frequent interventions are unnecessary: weeding once or a few times a year is enough to maintain the roof over time. Choosing plant species adapted to the conditions allows to get rid of this obligation while saving water. Over-intensive management may have a negative impact on plant diversity and lead to excessive soil compaction. Regular watering is similarly unnecessary: although some roofs are designed for aesthetic purposes, accepting variations in colour and appearance as the seasons go by is another way of looking at nature.

Allowing spontaneous vegetation to complete its life cycle is essential for pollinators and other invertebrates, as is ensuring that there are a variety of strata (i.e. plants of different heights). Moreover, a dense, well-developed herbaceous stratum (plants 0 - 50 cm tall) increases a roof's capacity for evapotranspiration and rainwater retention. Other options exist to make roofs attractive to biodiversity, for example varying soil depth and types of substrate or diversifying plant cover. Micro-habitats (dead wood, dry stones, hollow stems, bare sandy substrate for wild bees, etc.) are a good way of attracting pollinators and other invertebrates to rooftops as long as they are combined with the appropriate plants.

Some see green roofs as mere greenwashing, others as a great way for buildings to host wildlife. The GROOVES study confirms that these special environments can serve as alternative habitats that complement other types of urban green space. But the current trend for planted buildings must not be used as a green alibi for planning projects that contribute to land take. Their use is only acceptable when it complements a frugal land use strategy that aims to preserve natural land and to promote rewilding on all scales. ■

Marc Barra and **Hemminki Johan**, ecologists
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1. The Spipoll and Vigie-Flore protocols were developed during the Vigie Nature programmes.
2. Outil Fonctionnel pour l'estimAtion de l'impact des toitures Végétalisées sur le ruissellement Urbain (functional tool for assessing the impact of green roofs on urban runoff).
3. Réseau de Mesures de la Qualité des Sols (soil quality measurement network).

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