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Research Paper

Green roofs as habitats for wild plant species in urban landscapes: First insights from a large-scale sampling

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HIGHLIGHTS

- Green roofs act as habitats for native plants species in urban landscape.
- Substrate depth is the principal factor influencing colonizing plant diversity.
- Taxonomic and functional compositions are shaped by substrate depth and other local variables.

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ABSTRACT

The urban landscape is known to form a hostile matrix for wild plant communities because of its sealed infrastructure surfaces. However, green roofs can reduce this hostility by providing new spaces for wildlife directly on buildings. In this extensive study of 115 green roofs in northern France, we focused on wild plant communities and the variables that shaped their diversity and their taxonomic and functional compositions. A total of 176 colonizing vascular plant species were identified; 86% were natives, demonstrating that green roofs can serve as habitats for wild biodiversity despite their isolation in an urban landscape in three dimensions. Nonetheless, all types of green roofs were not equal, with the substrate depth playing a major role in the wild plant diversity. The taxonomic and functional compositions of the colonizing plant communities were also shaped by the substrate depth, green roof age, surface area, and height and maintenance intensity at the building scale. We did not detect any effect of the surrounding potential habitats at the landscape scale. The study of functional traits revealed that the wild plant communities are adapted to open xero-thermophilous conditions. This study led us to consider an ecological typology for green roofs referred to as stratum classification, which is based on the vegetal structures living and colonizing these anthropo-ecosystems. Wild roofs adapted to receive spontaneous species could play an interesting role in urban biodiversity dynamics if they continue to be developed at large scales in cities.

1. Introduction

Urban and suburban regions are increasing in area (UN World Urbanization Prospects, 2009). Indeed, in 2008, for the first time, over 50% of the global population was living in urban areas, and this percentage is predicted to increase to 70% by 2050. Therefore, urban areas may become among the most common habitats on Earth and the most common setting for human interactions with wild species (Pecarevic, Danoff-Burg, & Dunn, 2010). Although cities are very inhospitable sites for most wild species, according to some studies in conservation psychology, biodiversity serves important functions for the wellbeing of urbanites (Tzoulas et al., 2007). Furthermore, plants are among the taxa that are able to persist in highly anthropized environments: they are found even in very constructed elements, they can be highly diverse, and they are conspicuous and have an important ecological role due to their as the basis of the food chain.

For many reasons, including aesthetic value, food production, or hydric regulation, humans have long integrated plants into their buildings, particularly on rooftops (Oberndorfer et al., 2007). However, the rising concern expressed by urban dwellers regarding the impact of urbanization on the outskirts of cities and the need for biodiversity in these cities imposes a new challenge to scientists and urban planners: to reconcile urban expansion with the preservation of biodiversity and the services that biodiversity provides to humans (referred to as ecosystem services, Jim, 2004). Urban landscapes are mainly dominated by a hostile matrix

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composed of non-plant-containing structures, such as roads and buildings, which surround "islands" of vegetated spaces, referred to as green spaces, such as parks and gardens (Vergnes, Le Viol, & Clergeau, 2012). Despite this negative context, the variety of habitats created in some cities shelter a high diversity of species, providing opportunities for ordinary biodiversity and, occasionally, for the conservation of endangered species (Kowarik, 2011). If the challenge is to make a city permeable to species dispersion and welcoming to wildlife, it is necessary to enhance the quantity of green spaces and to reduce the hostility of the urban matrix. Green roofs can be a good tool to mitigate the inhospitality of urban areas because (i) unoccupied space is scarce in a dense city at the ground level, (ii) roofs generally represent more than 30% of the total surface of cities (Frazer, 2005), and (iii) following the principles of reconciliation ecology, their creation could also have a social role because they are bottom-up techniques that can be implemented directly by citizens or companies (Francis and Lorimer, 2011).

The greening of buildings is an active process of creating an "ecosystem" or "anthropo-ecosystem" on completely artificial and waterproof surfaces. In Switzerland, the potential of green roofs was studied for the conservation of the Northern Lapwing (*Vanellus vanellus*), which nests on rooftops. Baumann (2006) suggested that the settlement of ponds and diverse vegetal structures increases insect abundance, promoting the improved survival of Lapwing juveniles. In the UK, the preservation of the Black Redstart (*Phoenicurus ochruros*) involved the implementation of a new type of roof, recreating a birdlife environment in urban areas, i.e., brownfields (Grant, 2006). Kadas (2006) compared this new type, called brownroofs (or biodiverse roof), to sedum roofs, with a focus on invertebrate diversity, and Kadas, Gedge, and Gange (2008) showed that, by displaying more diverse microhabitats, brownroofs can provide better habitats for urban biodiversity than sedum roofs. Species of rare and endangered insects can also be observed on green buildings, justifying conservation goals in urban areas. In addition, green roofs with a particular vegetation type can create open areas in cities in which particular fauna can develop (Coffman & Waite, 2010; MacIvor & Lundholm, 2010; Madre, Vergnes, Machon, & Clergeau, 2013). Due to their small area, the role of green roofs in sheltering biodiversity would appear to be more important for organisms that need small vital areas, such as invertebrates or plants. Although the awareness of faunal communities is increasing, little is known about the potential for green roofs in the spread of wild plants in cities. Plants are the basic trophic level of such ecosystems, and wild species are particularly suited to urban faunal diversity.

Wild plants can spontaneously colonize green roofs and are thus maintained and spread within the urban landscape, as shown by the experimental study of Dunnett, Nagase, and Hallam (2008) in Sheffield, UK, in which 35 colonizing species were identified among the 15 planted species. Some 29 species were identified on experimental plots in Birmingham, UK (Olly, Bates, Sadler, & Mackay, 2011), and a floral assemblage study on two brownroofs in the same city reported 31 and 37 colonizing species, respectively (Bates, Sadler, & Mackay, 2013). Long-term studies have also been implemented in Berlin (Köhler & Poll, 2010), highlighting the importance of the substrate depth for the floral quality of green roofs and the spontaneous development of species on no-maintenance roofs. It has been reported that the ecosystem services (e.g., hydric and thermic regulation, carbon and pollutant sequestration, and life-quality improvement) associated with green roofs are enhanced when the plant species are a mixture of small shrubs, grasses, and sedums, each occupying complementary niches (Lundholm, MacIvor, MacDougall, & Ranalli, 2010). Wild plants could also have an interesting role in green roof ecosystems, as they are generally native and they could serve as a food chain basis for local phytophagous species and pollinators (Tonietto, Fant, Ascher, Ellis, & Larkin, 2011). However, the colonization of wild plant communities on green roofs remains poorly described, and there is a need for a spatial extensive survey on numerous sites to consider their potential role in urban biodiversity conservation.

In this study, we focused on a survey of the colonizing plant communities on 115 green roofs in northern France and addressed the following specific questions. (1) Which species colonize? (2) What are the factors that shape the communities? (3) What are the taxonomic and functional compositions of the communities? Lastly, we discuss our results and their impacts on the fields of urban greening and propose an ecological typology for green roofs.

2. Materials and methods

2.1. Sampling design

We obtained some sites in northern France from the databases of green roofing companies and other sources. A total of 115 sites were visited between April and June 2011 in the urban and suburban areas of several French cities (see Fig. 1). Each site was visited once for this comparative study, and the sites were visited from west to east. Spring 2011 was climatically characterized by an early drought (rainfall deficit) and temperatures above the seasonal norms.

We selected the sites according to the vegetation structures planted on the roof that refer to different technical solutions (i.e., moss/sedum plantings, herb plantings, and shrub plantings). Most of the green roofs belong to the "extensive" and "simple intensive" classes, according to the FLL guidelines (The Roof Greening Working Group, 2002). The cultivated species were planted in an artificial substrate, often a highly mineral substrate (pozzolana, beams, and

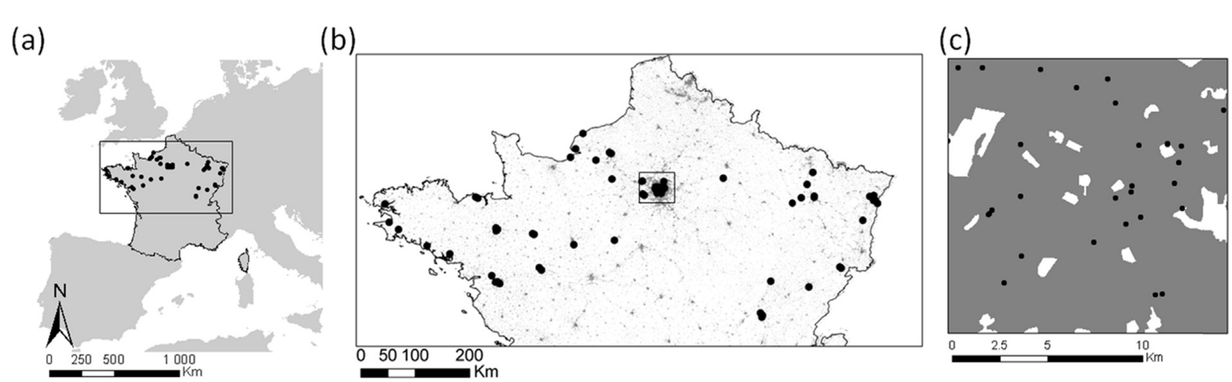

Fig. 1. Map of Central Europe (a), location of the sampled green roofs (b), and details of the city of Paris (c). (a) The land surface is represented in grey and the administrative limits of France in black; (b) the urban fabric is represented in grey; (c) the potential habitats are represented in white and the potential non-habitats in dark grey. In all maps, the sampled roofs are represented by black dots.