Landscape and Urban Planning 131 (2014) 27–35

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

# Potential contributions of green spaces at business sites to the ecological network in an urban agglomeration: The case of the Ile-de-France region, France

Hortense Serret[a,*], Richard Raymond[b], Jean-Christophe Foltête[c], Philippe Clergeau[a], Laurent Simon[b], Nathalie Machon[a]

[a] UMR 7204 CNRS-MNHN-UPMC, Centre d'Ecologie et des Sciences de la Conservation, Muséum national d'Histoire naturelle, 61 rue Buffon, 75005 Paris, France
[b] UMR 7733 CNRS, Université Paris 1 Panthéon-Sorbonne, 2 rue Valette, 75005 Paris, France
[c] UMR 6049 CNRS – Université de Franche-Comté, ThéMA, 32 rue Mégevand, 25030 Besançon, France

## HIGHLIGHTS

- The area dedicated to business activity in the Ile-de-France region increased by 42% in 30 years.
- These increases occurred mainly at the interface between urban and rural sectors.
- Green spaces at business sites spanned 8700 ha in IdF, i.e., 8% of the total urban green spaces.
- GSBS contribute significantly to regional connectivity essentially in suburban sector.
- GSBS represent 23% of the patches contributing the most in terms of stepping stones for mobile species.

## ARTICLE INFO

*Article history:*
Received 27 January 2014
Received in revised form 9 July 2014
Accepted 11 July 2014
Available online 14 August 2014

*Keywords:*
Urban area
Connectivity
Business site
Graph theory
Urban green spaces

## ABSTRACT

For several decades, the sprawling of urbanisation has resulted in the loss of natural habitats and in landscape fragmentation and thus represents one of the main causes of the erosion of biodiversity. Green spaces in urban areas help maintain ecological connectivity and provide ecosystem services to citizens. The impact of urban green spaces on the conservation of biodiversity and their contribution to ecological networks in urban areas have been studied. However, little is known about the area occupied by green spaces at business sites (GSBS) or about their organisation within the urban matrix and their possible contribution to the maintenance of functional connectivity at local and regional scales.

This study analysed the evolution in the dynamics and locations of business sites over the past 30 years in the Ile-de-France region. Cartographic data allowed us to identify GSBS which spanned 8700 ha and represented 8% of the urban green spaces forming the herbaceous network. Using a graph theoretic modelling approach, we quantified the potential contribution of GSBS to regional connectivity. We demonstrated that GSBS did not add to connectivity in terms of total area but rather through the density of the links that these sites shared with other green spaces or via their strategic position in the network, i.e., their capacity to serve as stepping stones. The contribution of GSBS was greatest in suburban and pericentral sectors, where most business activities have been developed in the past 30 years and land resources remain available for green space development.



## 1. Introduction

More than half of humanity lives in cities today, and the global urban population is expected to increase by 72% by 2050, from 3.6 billion in 2011 to 6.3 billion in 2050 (United Nations, 2012). According to predictions of the United Nations, in thirty years, the global urban population will likely be the same as the total global population of 2002.

* Corresponding author. Tel.: +33 658005816.
*E-mail addresses:* hortense.serret@gmail.com (H. Serret), ric_raymond@yahoo.com (R. Raymond), jean-christophe.foltete@univ-fcomte.fr (J.-C. Foltête), clergeau@mnhn.fr (P. Clergeau), laurent.simon@univ-paris1.fr (L. Simon), machon@mnhn.fr (N. Machon).

http://dx.doi.org/10.1016/j.landurbplan.2014.07.003
0169-2046/

The level of urbanisation, i.e., the percentage of the global population living in urban areas, is expected to reach 67% in 2050 and to rise from 78% to 86% in developed countries (United Nations, 2012). The number of megacities with more than 10 million inhabitants will increase from 23 in 2011 to 37 in 2025 and will account for almost 14% of the global urban population. Urban areas are sprawling in different configurations (Makse, Havlin, & Stanley, 1995) and transforming landscapes along an urban-rural gradient (McKinney, 2002).

The presence of green spaces in cities presents many advantages to citizens. Links between health and well-being and the presence of nature in urban green spaces are now well established (Dean, van Dooren, & Weinstein, 2011; Maller, Townsend, Pryor, Brown, & St Leger, 2006; Sijtsma, de Vries, van Hinsberg, & Diederiks, 2012; Takano et al., 2002; Tzoulas et al., 2007). The provision of ecosystem services by urban green spaces has been an important issue in urban planning and public policy for some years (Carpenter, 2013; Chiesura, 2004).

Artificial surfaces often replace natural habitats; as a result, the spaces available to wildlife are decreasing and becoming more distant from each other. Landscape fragmentation due to urbanisation and human disturbances such as the introduction of exotic species, the pollution of the soil and air and the compaction of the soil are driving a loss of species diversity and a rise in generalist species along urban gradients; this phenomenon has been demonstrated in birds (Clergeau, Croci, Jokimaki, Kaisanlahti-Jokimaki, & Dinnetti, 2006), butterflies (Ramírez Restrepo & Halffter, 2013), plants and other animal species (McKinney, 2006, 2008).

As urban areas grow, green spaces in urban landscapes become crucial for creating and preserving an effective network of habitats for the remaining species. For several years, ecologists have studied the contribution of different types of urban green spaces to biodiversity, for example backyard habitats (Rudd, Vala, & Schaefer, 2002). Green spaces represent a tool to reduce the loss of biodiversity by maintaining gene flow among populations (Kong, Yin, Nakagoshi, & Zong, 2010). The efficiency of a green network in an urban area is linked to the density of green spaces, the location of these spaces in the urban matrix (Kong et al., 2010; Sandström, Angelsta, & Mikusiński, 2006), the management of these spaces (Gaston, Smith, Thompson, & Warren, 2005; Loram, Warren, Thompson, & Gaston, 2011; Teillac-Deschamps et al., 2009) and the connectivity between them (Vergnes, Le Viol, & Clergeau, 2012). Urban green spaces networks also called 'greenways' have become an essential tool for preserving biodiversity in cities. Fabos (1995) and Ahern (1995) reported that they were useful for the planning, management and design of sustainable landscapes; since then, a large body of literature has emerged describing the innovation of greenways and the value of their ability to contribute to the preservation of biodiversity while serving the needs of urban residents (Bryant, 2006; Conine, Xiang, Young, & Whitley, 2003).

In cities, most animal and plant species are found in green spaces such as public gardens (Shwartz, Muratet, Simon, & Julliard, 2013), domestic gardens (Cameron et al., 2012; Davies et al., 2009; Gaston et al., 2005; Smith, Thompson, Hodgson, Warren, & Gaston, 2006) or wastelands (Muratet et al., 2008; Politi Bertoncini, Machon, Pavoine, & Muratet, 2012).

Despite the fact that their number and cumulative area may be important at the scale of the urban agglomeration, green spaces at business sites, i.e., 'places where people work' (Snep, WallisDeVries, & Opdam, 2011), have been poorly studied. From a social point of view, aesthetic issues related to business districts have been analysed (de Vries, de Groot, & Boers, 2012); however, no studies have discussed the ecological function of these green spaces. Only one study, conducted in the Netherlands by Snep et al. (2011), has focused on the importance of green spaces at business sites in large cities for the conservation of biodiversity, particularly for endangered butterfly populations.

The objective of our study was to assess the role that green spaces at business sites could play in a network of urban green spaces; more specifically, we analysed the role of the size, configuration and location of the sites within the general green infrastructures of the agglomeration. The study was conducted in the Ile-de-France region, i.e., the administrative region centred on the city of Paris and the most urbanised region in France.

The first part of our study describes the development of areas dedicated to business activities over the last thirty years and the type of urban sectors where business activities have increased the most. Thereafter, we define 'green spaces at business sites' (GSBS) and analyse their size and spatial organisation within different urban sectors. The second part of our study determines how GSBS participate in the network of urban green spaces, i.e., their potential contribution to urban ecological connectivity. Different methodological approaches have been developed to measure connectivity (Calabrese & Fagan, 2004; Kool, Moilanen, & Treml, 2013). Urban and Keitt (2001) described the importance of graph-based landscape modelling; since then, this tool has represented a useful approach for quantifying landscape connectivity (Foltête, Girardet, & Clauzel, 2014; Galpern, Manseau, & Fall, 2011; Minor & Urban, 2008) that can be used in our study to model the connectivity of the urban green space network. In our model, nodes of the graph represent patches of green spaces (parks, domestic gardens, vacant areas or green spaces at business sites); the links connecting these spaces represent the paths by which species can potentially move between patches. From this network structure, several metrics have been calculated at different levels to assess levels of landscape connectivity (Foltête, Clauzel, & Vuidel, 2012; Rayfield, Fortin, & Fall, 2011).

Three aspects of the contribution of GSBS to the urban green space network are evaluated: (1) their contribution to the total surface of green spaces, (2) their level of connectivity with other types of green spaces and (3) their location within the networks.

## 2. Materials and methods

### 2.1. Study sites

We first studied green spaces at business sites (GSBS) at the Parisian region scale (France). The Parisian region is called Ile-de-France (IdF). Then, we focused on a smaller zone for the graph modelling that we call "focus area" as represented by the dashed lines in Fig. 1. IdF has 11.8 million inhabitants (19% of the French population) and spans a total area of 12,000 $km^2$. Over 700,000 companies, most of which are in the service sector, are located in IdF; these companies employ a total of 5.4 million people. IdF produces 29% of the national gross domestic product and is the top economic region in France. The region consists of agricultural land (56%), forests (23%), built-up areas (16%) and open green spaces such as private and public parks and gardens or vacant lots (5%) (Architecture and Urbanism Institute of Paris Region (AUIPR), 2008). Each district of the region can be classified according to its degree of urbanisation (Clergeau, 2011), i.e., the proportion of land that consists of artificial areas (e.g., buildings, roads, courtyards and car parks). This proportion can be used to classify each district as belonging to an urban centre (more than 36% artificial), a pericentral sector (between 20% and 36% artificial), a suburban sector (between 8% and 20% artificial) or a periurban sector outside of the city (less than 8% artificial) (Fig. 1).