Landscape and Urban Planning 159 (2017) 32–41

Contents lists available at ScienceDirect

Landscape and Urban Planning

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

Research paper

Initial conditions during Technosol implementation shape earthworms and ants diversity

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HIGHLIGHTS

- Technosols, made of backfills, provide habitats recolonized by soil macrofauna.
- Ants and earthworms communities were composed of few ubiquitous species.
- Their abundances increased with the age of Technosols with initial topsoil addition.
- Their abundances decreased with age without initial topsoil addition.
- Proportion of green spaces in the landscape does not affect diversity.

ARTICLE INFO

Article history:
Received 24 November 2015
Received in revised form 7 October 2016
Accepted 18 October 2016
Available online 22 November 2016

Keywords:
Urban soils
Technosols
Initial conditions
Age gradient
Soil
Management
Soil macrofauna

ABSTRACT

Soils in urban parks are mainly manmade and called Technosols. These Technosols are made of backfill with or without a topsoil addition, which may affect both the physicochemical properties of these soils and the success of soil fauna colonization. The effects of these initial soil management conditions on colonization dynamics of Technosols have not been evaluated yet.

To fill this gap, we sampled earthworms and ants in 20 Technosols covered by lawn and located in urban parks around Paris (France). We selected Technosols constructed with or without an initial addition of topsoil and distributed along an age gradient since construction ranging from 2 to 64 years. Surrounding greening index around Technosols, management practices and physicochemical soil properties have also been recorded.

Surprisingly, no significant differences were observed in the physicochemical properties of Technosols regardless of the absence/presence of topsoil. Communities were composed of few ubiquitous species, which could explain the lack of species richness response to any of our variables. Earthworm and ant abundances increased significantly along the age gradient only in Technosols with initial addition of topsoil. In Technosols, initial conditions apparently determine in part soil macrofauna.

Thanks to a close collaboration between scientist and managers, we highlighted that managers should add topsoil during the creation of Technosols in order to sustain abundance of ecosystem engineers and potentially the ecosystem services they provide.

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http://dx.doi.org/10.1016/j.landurbplan.2016.10.002
0169-2046/

1. Introduction

The surfaces covered by urban areas are expected to increase by 70% from 2000 to 2030 in Europe and will double by 2050, reaching 7% of emerged earth surfaces (UNFPA, 2011). Urbanization causes profound impacts on ecosystem functioning (Pickett et al., 2011) but the consequences for urban soil ecosystem processes are not well documented (De Kimpe and Morel, 2000; Pouyat et al., 2010) despite their importance in the delivery of ecosystem services (Morel, Chenu, & Lorenz, 2015). Urban soils can be highly heterogeneous and are mainly affected by human activities (Morel et al., 2015). The soils in urban parks contain a significant amount of recently excavated earth from deep soil horizons and other man made materials such as bricks or crushed stones (used as backfill) (IUSS Working Group WRB, 2006). Because of the importance of human disturbance in excavating this material, the soil of urban parks belongs to the Technosols Reference Soil Group (IUSS Working Group WRB, 2006). Their management is a growing concern (De Kimpe & Morel, 2000).

Currently, the demand to increase the number and the surface area of parks in cities is strong (Clergeau, 2007). This involves the construction of new Technosols as backfills from urban materials such as excavated deep soils or building pieces. In some cases, an initial input of organic matter, consisting in initial topsoil coverage on backfills, is added, which is supposed to help the development of the planted vegetation. However, topsoil is mainly retrieved from rural areas to urban areas (Cheverry & Gascuel, 2009), with high economic and environmental costs related to transportation and degradation of rural ecosystems. An alternative is to avoid topsoil coverage by planting vegetation directly on backfills. The impact of this initial management decision on soil biodiversity has never been addressed.

Soil macrofauna (animal organisms larger than 2 mm, Lavelle et al., 2006) is poorly understood (Decaëns, 2010) even though it provides numerous soil ecosystem services (Bardgett & van der Putten, 2014). Soil macrofauna contains two main ecosystem engineers (sensu Jones, Lawton, & Shachak, 1994): ants (Hexapoda Formicidae) and earthworms (Annelida Lumbricidae). They are involved in many ecosystems processes (Blouin et al., 2013; Lobry De Bruyn & Conacher, 1990) that affect in nutrient cycling, soil formation, soil structure maintenance, primary production, pollution remediation and water and climate regulation. However, their structure and function in urban soils remains poorly known (but see Pouyat et al., 2010; Vepsäläinen, Ikonen, & Koivula, 2008).

As reviewed by Walker, Wardle, Bardgett, & Clarkson (2010), many authors considered that initial abiotic conditions may affect soil properties and processes with soil fauna effects along an age gradient (chronosequence). Excavated deep soil lacks macrofauna and topsoil may lose them as a result of disturbance (Séré et al., 2008). These new initial conditions may affect the success of colonization by macrofauna. Colonization processes along an age gradient coupled with various initial conditions, which are also management decisions, have not been studied in Technosols. To fill this gap, we sampled earthworms and ants in Technosols with or without an initial addition of topsoil and along an age gradient from 2 to 64 years.

This study aims to identify factors influencing Technosols colonization by ants and earthworms and their community build-up by taking into account landscape properties such as the proximity of other greenspaces or roads and local (soil physicochemical characteristics and lawn management practices) that could affect species survival. We expected (H1) an increase of abundance/density and diversity along the age gradient, (H2) a stronger positive effect in Technosols with the initial presence of topsoil and (H3) a positive effect of the proximity of other greenspaces.

2. Material and methods

2.1. Study sites and sampling design

The study area is located in the Seine-Saint-Denis and Val-de-Marne districts, which are located around Paris city and are among the most urbanized districts of France, with urbanization rates around 60% (Fig. 1) and human densities around 6000 inhabs km^{-2} (IAU îDF, 2013). The climate is temperate and the substratum is mainly made of carbonated rocks of the Parisian Basin (France) from the Eocene (Antoni et al., 2013).

The sampling took place in urban parks managed by the Seine-Saint-Denis (Fig. 2) and Val-de-Marne (Fig. 3) districts. A single urban park is generally composed of a series of Technosols that are highly-heterogeneous in term of land use, vegetation type, age since construction, initial conditions and type of urban soils (Morel et al., 2015).We limited our study to recreational lawn (hereafter lawn) dominated by grasses (*Lolium perenne*, *Festuca spps and Poa spps*) and with past agricultural uses (as market gardens).

We sampled two types of initial conditions of Technosols, with or without facultative initial topsoil covering on mineral backfill, here after referred as topsoil presence/absence. We sampled 12 Technosols with initial topsoil and 8 without initial topsoil (20 Technosols overall). The age since construction varied between 2 and 64 years. This indirect measure of the colonization process, along a chronosequence, has been widely used in a post-mining reclamation context (Frouz et al., 2001; Hlava & Kopecký, 2013; Pižl, 2001) and more recently in urban soil context (Carpintero & Reyes-López, 2014; Smetak, Johnson-Maynard, & Lloyd, 2007). Data on age and type of topsoil is detailed in Table S1 in Supporting information. They were obtained by interviews with park managers and gardeners and were digitized in a GIS (Geographic Information System).

2.2. Macrofauna sampling and identification

Ants and earthworms were sampled in five subsamples per site/Technosol, according to an adaptation of the Tropical Soil Biodiversity and Fertility method (TSBF) (Anderson & Ingram, 1994; Lavelle, 1988). First retrieval of organisms at the soil surface was done by applying Formalin (0.4% dilution) twice on a 25 cm × n25 cm area during half an hour. After this step, a block of soil 15 cm deep was then dug up to be hand-sorted for retrieval of ants and earthworms of the subsurface. Ants and adult earthworms were identified to the species level using identification keys [respectively (Seifert, 2007) and (Bouché, 1972; Cuendet, 2001)].

The five subsamples per Technosol were distributed at each corner of a 10 × 10 m^{2}plus one in the middle of the square. Overall, 100 samples (20 sites × 5 samples per site) were collected. The sampling took place from 02 April to 10 May 2013, when most earthworms are active (Bouché, 1972).

2.3. Environmental parameters

2.3.1. Local scale

2.3.1.1. Soil physicochemical properties. We sampled soils (organo mineral horizon, between 0 and 15 cm) in each Technosol in order to characterize soil physicochemical properties at each sampling site. One soil sample was taken near each subsample (at 25 ± 5 cm) in order to avoid its contamination by formalin, collected with a 15 cm long − 7 cm diameter auger.

Particle size was measured without previous carbonate removal considering 3 classes of size (Fine <2 μm; Medium >2 μm and <20 μm; Coarse > 200 μm; NFX 31–107 without decarbonatation). Regarding the chemical properties, we measured: soil