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Research Paper

Mediterranean open habitat vegetation offers great potential for extensive green roof design

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HIGHLIGHTS

- Four vegetation types with distinct climatic, geographic and soil-related properties.
- 79% of the Mediterranean species list comprise a potential source for urban greening.
- Major life forms in NW European green roof list are hemicryptophytes (75.5%).
- Besides succulents, a mixture of different life forms is an interesting option.
- Annuals can improve green roof performance and should certainly be considered.

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ABSTRACT

Offering a wide array of benefits, green roofs have become an important tool for improving urban environmental quality mainly in regions with a temperate climate. However, green roofs seem to perform relatively bad in the Mediterranean, as plant species commonly used are often not adapted to cope with the additional stress factors associated with this climate. The habitat template hypothesis states that potential species can be found in habitats with similar conditions as on extensive green roofs. In this study, natural open habitats in southern France are described and variation in species composition in relation to environmental factors is analyzed. 372 local species recorded in 20 locations were grouped in four major vegetation types. These results are compared with a list of species commonly used on green roofs in NW Europe. 79% of the species found in these open habitats are currently not used on green roofs. Ten highly relevant plant traits for extensive green roofs were then used to screen the species found during the field work. 28 species scored highly in this screening procedure, indicating good potential. Annual species are currently rarely regarded for green roof purposes but in the habitat template context, this life form is an important part of Mediterranean vegetation and should be considered in green roof design. This research offers the ecological fundamental knowledge necessary for further selection and testing of species and final implementation into a successful green roof system.

1. Introduction

Urban regions are facing worldwide population and housing demand increases, causing a lot of environmental problems as building space becomes scarcer. New buildings replace green areas and make cities less attractive for living and working. In this respect, the application of green roofs or ecoroofs proved that, by transferring vegetation to the top of buildings, major urban problems can be reduced (cf. Oberndorfer et al., 2007). In terms of sustainability, extensive green roofs are preferred over the intensive ones. The former offer storm water control and thermal insulation without requiring substantial irrigation and maintenance. Furthermore, extensive green roofs have a shallow substrate (<20 cm) which makes them lightweight and suitable for wide application on new constructions and renovating old buildings (Oberndorfer et al., 2007). Although green roofs are manmade, they can be part of nature restoration and even potentially help counteracting the destruction of (semi)natural habitats if local or regional species are used (Francis & Lorimer, 2011; Oberndorfer et al., 2007). The multitude of ecological and economic benefits, along with some non-negligible factors like psychological and esthetic effects, makes green roofs an important tool for improving urban environmental quality.

An exponential rise of interest in and implementation of green roofs has been observed during the past decades particularly in

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temperate Europe and North-America (Dvorak & Volder, 2010; Köhler & Keeley, 2005; Williams, Rayner, & Raynor, 2010). In 2007, green roof coverage in Germany increased on average 13.5 million m^2 per year (cf. Oberndorfer et al., 2007). In France, extensive and semi-intensive green roof surface (substrate depth < 20 cm) reached 1 million m^2 in 2011, and is expected to rise to ca. 1.5 million m^2 in 2015 (Lassalle, 2012). Modern green roof technology is relatively recent and its origins lie in North- and Central Europe, with Germany as leading country. Research and experience has led to the development of the German FLL guidelines for the planning, construction and maintenance of green roofs (FLL, 2008), which serve as a model throughout the world. Implementation of these guidelines usually guarantees success in the temperate climate, but can pose problems in other ecoregions (Dvorak & Volder, 2010). In the Mediterranean area for example, plants often face severe water-stress as a cause of frequent elevated temperatures and extended summer drought (Benvenuti & Bacci, 2010). When plant species commonly used for green roof purposes are applied in the Mediterranean climate, they suffer from the additional stress factors, leading to poor green roof performance and therefore discouraging both industry and government to promote this innovative tool (Dvorak & Volder, 2010; Williams et al., 2010). Despite these problems, scientists showed that green roof advantages are also pronounced in the Mediterranean climate (cf. Fioretti, Palla, Lanza, & Principi, 2010), therefore rendering investigations to overcome the poor green roof performance very valuable. The incorporation of local or regional plant species can provide a solution to the problem, as they are more adapted to the Mediterranean climate (Oberndorfer et al., 2007). Evidence is provided that extensive green roofs mimic habitats found in nature, a concept which is described as the 'habitat template hypothesis' (Lundholm, 2006). These natural template habitats comprise mostly rocky environments, free draining dunes, open areas on very shallow substrates and limestone pavements. The Mediterranean region with its exceptional diversity of plant species (Médail & Quézel, 1997) contains a lot of these habitats, so we hypothesized that it should be possible to find drought-adapted, native plant species that could thrive on extensive green roofs.

In this study, we aimed at:

(1) Describing and classifying the vegetation of open habitats on very shallow, stony soils and analyzing the variation in species composition in relation to environmental factors. A literature research on old vegetation surveys will further complement the potential plant species in the region. This delivers us a potential plant species pool for further analysis.
(2) Comparing the resulting species list with a list of currently used green roof plant species in NW Europe and;
(3) highlighting the potential of the Mediterranean vegetation as a source of inspiration for development and improvement of extensive green roof design, by considering some major plant traits.

2. Methods

2.1. Vegetation description

2.1.1. Study area

As the Mediterranean region is considered a biodiversity hotspot (Médail & Quézel, 1997) with approximately 25,000 vascular plant species (ca. 7.8% of the number of species in the world), of which about 13,000 are endemic to this region (Quézel, 1985), it was impossible to include the whole Mediterranean basin in this project. Therefore, we focused on the southern part of France, more specifically the departments Hérault, Gard, Bouches-du-Rhône, Vaucluse and Drôme in the regions Languedoc-Roussillon and Provence-Alpes-Côte d'Azur (Fig. 1), with a plant species richness of approximately 5880 taxa. According to the plant repartition section of Tela Botanica, this number accounts for 50% of the total amount of taxa on French territory (Association TELA BOTANICA).

The Mediterranean region is classified as 'shrub or treelike pseudo steppe and open forest in less dry climates' (Unesco-FAO, 1969). The climate is considered as intermediate between cold temperate and dry tropical. Summer temperatures and the number of sun hours are high, e.g. average of 30 °C and 2835 sun hours a year in the Vaucluse region (Blondel, Aronson, Bodiou, & Boeuf, 2010). In general, summer drought lasts one to four months (Unesco-FAO, 1969) and precipitation is very irregular, with only a few intensive rainy days in summer, e.g. 80–90 mm in 12 days in Avignon, Vaucluse. On the contrary, rainfall is significantly higher in other seasons, with an average of 480 mm during winter, spring and autumn in Avignon (derived from the 'Local Climate Estimator' program and database New_LocClim v1.10 (FAO, 2005)). The whole region is very windy, with the '*mistral*' blowing from the north and the '*tramontane*' from the north-west, bringing glacial colds in winter and additional warmth in summer (Blondel et al., 2010; Filippi, 2008). The mountainous part in this region is dominated by coniferous forest but more to the Mediterranean sea, the vegetation changes in a mosaic of mixed forest (with amongst others *Pinus halepensis* and *Quercus ilex*), matorral such as *maquis* on acidic soils and *garrigue* on calcareous soils (David, 2006). The main blooming period of the vegetation occurs in spring. During summer drought, the aboveground part of many plants dies off, whereas the growth of evergreen shrubs just takes a halt. Altitudinal limits of the Mediterranean climate and flora and fauna is often situated at about 1000 m (Blamey & Grey-Wilson, 2004), although others (e.g. Blondel et al., 2010) do not recognize this limit. According to the latter, a good delimitation of the region should coincide with the 100 mm precipitation isohyets. We further describe our study area as (sub) Mediterranean.

2.1.2. Data collection

Given the specific conditions on extensive green roofs, only non-forest vegetation on shallow soils and limestone pavements in the (sub) Mediterranean part of France was considered. The departments under study contain many stony calcareous habitats with a great diversity of plant species (Appendix A). During the growing season of 2011 (April 22–June 6), 20 locations in an area of 190 × 130 km were visited (Fig. 1). Given the fact that local conditions on stony or rocky habitats may change over very short distances (Verrier, 1979), the vegetation was recorded in small plots of 1 m^2. Cover was estimated according to the decimal scale of Londo (1976). In total 253 plots were recorded with 12–20 plots per location. 372 species were found (species list: MEDVEG), with on average 18 species per plot. Some in situ measurements of vegetation-related variables included an estimation of the amount of bare soil (BS) and % cover of lichen and bryophytes (BL). In every plot, a number of environmental variables were recorded as well (Table 1). Altitude (A), geographic coordinates (WGS 84 reference system) and aspect were measured with a GPS navigator (Garmin eTrex Vista HCx, Garmin Ltd 2007). The two latter variables, together with slope (angle in degrees measured with a clinometer), where used to calculate the heat load (HL) of the plot (Eq. (1)) with the formula presented by McCune and Keon (2002).

$$\begin{aligned} \mathrm{HL} = {} & 0.339 + 0.808 \times \cos(\text{latitude}) \times \cos(\text{slope}) \\ & - 0.196 \times \sin(\text{latitude}) \times \sin(\text{slope}) \\ & - 0.482 \times \cos(\text{folded aspect}) \times \sin(\text{slope}) \end{aligned} \quad (1)$$

Folded aspect = $|180 - |\text{aspect} - 225||$