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Original article

# Plant functional traits and diversity in sand dune ecosystems across different biogeographic regions

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ABSTRACT

Plant species of a functional group respond similarly to environmental pressures and may be expected to act similarly on ecosystem processes and habitat properties. However, feasibility and applicability of functional groups in ecosystems across very different climatic regions have not yet been studied. In our approach we specified the functional groups in sand dune ecosystems of the Mediterranean, Hyrcanian and Irano-Turanian phytogeographic regions. We examined whether functional groups are more influenced by region or rather by habitat characteristics, and identified trait syndromes associated with common habitat types in sand dunes (mobile dunes, stabilized dunes, salt marshes, semi-wet sands, disturbed habitats). A database of 14 traits, 309 species and 314 relevés was examined and trait-species, trait-plot and species-plot matrices were built. Cluster analysis revealed similar plant functional groups in sand dune ecosystems across regions of very different species composition and climate. Specifically, our study showed that plant traits in sand dune ecosystems are grouped reflecting habitat affiliation rather than region and species pool. Environmental factors and constraints such as sand mobility, soil salinity, water availability, nutrient status and disturbance are more important for the occurrence and distribution of plant functional groups than regional belonging. Each habitat is shown to be equipped with specific functional groups and can be described by specific sets of traits. In restoration ecology the completeness of functional groups and traits in a site may serve as a guideline for maintaining or restoring the habitat.



## 1. Introduction

Plant functional traits efficiently support the study of ecological systems as they allow to explain and generalize the ecosystem by making use of a limited number of functional groups rather than dealing with a large number of species (Díaz Barradas et al., 1999; Petchey, 2004; Grime et al., 1997). Plant traits are useful to better understand plant and ecosystem function (Díaz and Cabido, 2001; Helsen et al., 2012), for predicting vegetation changes (Lavorel and Garnier, 2002) and for nature conservation (Poschlod et al., 2003; Kooyman and Rossetto, 2008). They are particularly suitable for large-scale studies with different environmental conditions and for comparing regions with no or few species in common (Dupré and Ehrlén, 2002; Díaz et al., 2007a; Tecco et al., 2010).

There is a wide range of studies using plant traits, dealing with different scales and numerous though non-exhaustive aspects of ecosystems, including land use (Díaz et al., 1999; Verheyen et al., 2003; Quétier et al., 2007), grazing (Klimešova et al., 2008; Díaz et al., 2007), fire (Lloret and Vilà, 2003; Keeley et al., 2011), community dynamics (Yablon, 2013; Pillar et al., 2013), climate change (Box, 1996; Díaz and Cabido, 1997), ecosystem services (de Bello et al., 2010) and phylogenetic structure and evolution (Kraft and Ackerly, 2010; Pillar and Duarte, 2010). Surprisingly few studies deal with functional groups without *a priori* classification. García-Mora et al. (1999) and Gallego-Fernández and Martínez (2011), for instance, defined functional groups in the coastal vegetation of SW Spain and Mexico, respectively, by using functional trait classification. Some researchers classified functional traits to study responses to disturbance (Lavorel et al., 1999) or for predicting the landscape dynamics (Noble and Gitay, 1996) but functional classification did not become a common method in ecological studies. It has been argued that regionally defined functional groups might not function at global scale (Bugmann, 1996). Noble and Gitay (1996) emphasized that functional classification is context-dependent and that universal functional groups may thus not be

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expected to occur. However, repeatable patterns of functional traits have been observed by some researchers (Wright et al., 2004; Sasaki et al., 2011) suggesting that functional groups may be applicable across regions. As functional groups comprise species with similar response to environmental pressures and similar effects on ecosystem processes (Díaz et al., 2001; Harrington et al., 2010), it may be expected that they are formed rather by habitat filters and niche similarities (Cornwell et al., 2006; Lebrija-Trejos et al., 2010; Maire et al., 2012) than by the biogeographic region. For instance, Díaz et al. (2001) showed that in two regions with different floras similar combinations of traits were associated with grazing. Such studies across different regions are needed to assess the feasibility and repeatability of functional groups.

Despite increasing attention to functional traits the knowledge of functional groups in specific ecosystems such as sand dunes is limited (García-Mora et al., 1999; Gallego-Fernández and Martínez, 2011). Sand dunes, whether coastal or inland, are known as stress-prone habitats distributed worldwide in different climatic and biogeographic regions. Regardless of their differences in species composition, sand dune ecosystems are well adapted to cope with extreme stress such as of water deficiency, salinity and lack of soil and nutrients, and with disturbances through wind erosion and sand burial. The special adaptations of psammophytes to sand ecosystems are well reflected in their traits (Danin, 1996; Maun, 2009) and can be applied for studying dune vegetation at larger scale by defining groups of species with similar functionality for the ecosystem. Similar habitats and vegetation zonation in sand dunes all over the world (Doing, 1985; Acosta et al., 2009) suggest their azonal character. We chose sand dune ecosystems reflecting extreme environmental conditions to explore the adaptation strategies of plants in three regions very different in climate and phytogeography. We aim to identify functional groups of plants in various common habitats of sand dune ecosystems (both inland and coastal) via classification. Easily measurable traits have been selected to study the ecological response of plants to the environmental pressures in the habitats of the three regions. We specifically ask the following questions: Are there specific groups of species with similar traits in sand dune ecosystems across different biogeographical regions? Are plant functional groups more influenced by the habitat types and their local properties than by the climatic region in which the plants occur? If yes, which functional groups and trait syndromes (groups of consistently co-occurring traits that express adaptation to environmental characteristics) are associated with particular habitats in sand dune systems?

We hypothesized that there are widely applicable plant species traits determined by habitat characteristics and niches in sand dune ecosystems, and that the adaptive response of plants to the environment in a certain habitat is similar across biogeographical regions.

### 1.1. Study area

Sand dune ecosystems in three regions have been studied: Mediterranean, Hyrcanian, and Irano-Turanian (Fig. 1). The regions are very different in climate, phytogeography and species composition but are all furnished with a similar set of psammophytic habitat types.

Mediterranean region: NE Greece, ca. 300 km along the North Aegean coast from south of Katerini (40° 09′ N, 22° 33′ E) via Thessaloniki eastward to Porto Lagos (40° 54′ N, 25° 23′ E); The area is characterized by Mediterranean climate with hot, dry summers and wet and cool, but almost frost-free winters; mean monthly temperatures vary between 6 °C (January) and 25–27 °C (July); mean annual rainfall is 400–600 mm (Hellenic National Meteorological Service). The soil consists of fine quartz sands in dunes mixed with coarse sands and gravels in the stabilized dunes. Although not represented throughout, the vegetation zonation of sandy coasts includes drift lines (Euphorbion peplidis), mobile dunes (Ammophilion), stabilized hind dunes (Crucianellion maritimae) (Sýkora et al., 2003) and associated salt marshes (Salicornietalia fruticosae).

Hyrcanian region: NE Iran, SE Caspian Sea shore, Miankaleh Biosphere Reserve (36° 48–55′ N, 53° 25′–54° 02′ E), with 50 km of semi-natural coastline, and two other sites westward along the Caspian Sea (36° 49′ N, 53° 8′ E & 36° 39′ N, 52° 22′ E). The area has a warm humid climate with rainy summers and mild winters; mean annual temperature and rainfall are 17.9 °C and 789 mm, respectively (based on the nearest meteorological station in Sari). The coldest month is January with a mean temperature of 8.7 °C and the warmest is August with 28 °C. The soils and vegetation zonation resemble that of the Mediterranean coasts but the plant community composition differs.

Irano-Turanian region: Central Iran, southern shore of the Namak Lake (Daryacheh-ye Namak) in the Maranjab Desert (34° 9–19′ N, 51° 30–56′ E); large saline playa surrounded by halophytic communities and sand dunes. The area is characterized by continental climate with low precipitation, hot and dry summer and cold winter; annual temperature is 19 °C and the annual precipitation is 136 mm. Mean monthly temperatures vary between 5 °C (January) and 33 °C (July). The vegetation zonation differs from the coastal dunes in species composition and by the absence of drift lines.

## 2. Methods

### 2.1. Data collection

The field data were collected during the summers 2011 and 2012 in sand ecosystems of the Mediterranean, Hyrcanian and Irano-Turanian region. The vascular plant composition and cover-abundance were sampled in plots of 25 $m^2$. Five common and widespread habitat types in sand dunes were defined based on Devillers and Devillers-Terschuren (1996; see also e.g. Doing, 1985; Danin, 1996; Maun, 2009), comprising herbaceous and subshrub vegetation. We distinguished in each region (in brackets the corresponding EUNIS habitat type codes as in http://eunis.eea.europa.eu/habitats.jsp and plot numbers): 1. mobile dunes (B1.3, X35; 114 relevés); 2. stabilized dunes (B1.4; 46); 3. salt marshes (A2.5, D6.1; 95); 4. semi-wet sands (B1.8; 38) and 5. disturbed habitats (B1.1, H5.6; 21). In total, 314 relevés were collected: 161 relevés in the Mediterranean, 62 in the Hyrcanian and 91 in the Irano-Turanian region. Plant nomenclature follows Flora Iranica (Rechinger, 1963–2012) for Iran, and Dimopoulos et al. (2013) for Greece.

Fourteen easily measurable categorical traits applicable for sand dune environments were chosen (Table 1). Categorical traits can be measured or obtained from the literature especially for areas without established trait databases. They also facilitate repeating and comparing the approach in other areas. The traits were selected from different parts of plants to better reflect the adaptive response patterns of species to the environment (Cornelissen et al., 2003). For standardization, the protocol for functional traits (Pérez-Harguindeguy et al., 2013) was followed. The observed species were assigned to the traits based on the given attributes in Table 1. Original trait information was obtained mainly from specimens collected and field observation, but also from floras (Rechinger, 1963–2012) and other resources (especially for plant strategies and regenerative traits Grime, 2001; Grime et al., 2007; Klotz et al., 2002).