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DATA ARTICLE

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MEDIS—A comprehensive spatial database on Mediterranean islands for biogeographical and evolutionary research

Francesco Santi[1] | Riccardo Testolin[1] | Piero Zannini[1,2,3] | Michele Di Musciano[1,4] | Virginia Micci[1] | Lorenzo Ricci[4] | Riccardo Guarino[5] | Gianluigi Bacchetta[6] | José María Fernández-Palacios[7] | Mauro Fois[6] | Konstantinos Kougioumoutzis[8] | Kadir Boğaç Kunt[9,10] | Federico Lucchi[11] | Frédéric Médail[12] | Toni Nikolić[13] | Rüdiger Otto[14] | Salvatore Pasta[15] | Maria Panitsa[9] | Konstantinos Proios[16] | Spyros Sfenthourakis[17] | Stylianos M. Simaiakis[18] | Claudio A. Tranne[11] | Kostas A. Triantis[16] | Alessandro Chiarucci[1]

Correspondence
Michele Di Musciano, Department of Life, Health & Environmental Science, University of L'Aquila, Piazzale Salvatore Tommasi 1, 67100 L'Aquila, Italy.
Email: michele.dimusciano@univaq.it

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Abstract

Motivation: The intrinsic characteristics of islands make them a unique study system for the investigation of ecological and evolutionary dynamics. The Mediterranean Basin, an island-rich biodiversity hotspot, still lacks a comprehensive spatial database for these geographic features. This study presents the first comprehensive spatial database of all Mediterranean islands larger than 0.01 km^2, aiding ecological investigations and interdisciplinary research.

Main types of variable contained: The MEDIS spatial database offers detailed information on 39 geographic, climatic, ecological and land-use variables, including island area, perimeter, isolation metrics, climatic space, terrain data, land cover, palaeogeography, road networks and geological information, providing a multifaceted view of each island's characteristics.

Spatial location and grain: The study encompasses 2217 islands in the Mediterranean Basin larger than 0.01 km^2. The spatial grain of the datasets on which the selected variables are based varies from 10 m (ESA WorldCover) to 1 km (CHELSA-BIOCLIM+).

Time period and grain: The spatial database incorporates data from various sources, each with its own timeframe, such as the Global Shoreline Vector from 2014 Landsat imagery and the WorldCover dataset from 2021. Historical data like the Paleocoastlines GIS dataset offer insights into island configurations during the Last Glacial Maximum.

Major taxa and level of measurement: While not focusing on specific taxa, the study lays the foundation for comprehensive research on Mediterranean islands, facilitating comparisons and investigations into the distribution of native, endemic or alien species. The level of measurement is extensive, encompassing a wide range of variables and providing polygonal features rather than centroids' coordinates.

Francesco Santi, Riccardo Testolin, and Piero Zannini contributed equally to this study.

For affiliations refer to page 6.

KEYWORDS
biodiversity hotspot, biogeography, conservation biology, ecological dynamics, endemism, evolutionary research, GeoJSON, island ecology, Mediterranean islands, spatial database

1 | INTRODUCTION

The intrinsic features of islands, such as their natural boundaries and isolation, make them unique environments for studying ecological and evolutionary dynamics (Mac Arthur & Wilson, 1963, 1967; Warren et al., 2015; Whittaker et al., 2017, 2023). Islands serve as natural laboratories, being simplified systems where processes like species interactions, colonization, evolution and extinction can be more easily investigated. Research on island ecosystems and biotas shaped our understanding of fundamental concepts in biogeography, ecology, evolution and conservation biology. Remarkably, the theory of island biogeography by Mac Arthur and Wilson (1963, 1967) has revolutionized our understanding of species diversity and distribution patterns. Island research also contributed to the study of evolutionary theory, highlighting processes like adaptive radiation and the emergence of unique island biotas, and providing insights into biogeographical patterns of species diversity (Whittaker et al., 2023).

Island systems worldwide harbour a significant proportion of global biodiversity, accounting for approximately 20% of all known species, despite covering only about 7% of the Earth's landmass (Fernández-Palacios et al., 2021). A distinguishing feature of island biotas is the pronounced presence of endemic taxa—organisms exclusive to certain regions, especially prevalent in remote archipelagos (Whittaker et al., 2017) and oceanic islands (Fernández-Palacios, 2016). However, islands have been disproportionately affected by extinctions over time, making them a crucial target of conservation efforts (Fernández-Palacios et al., 2021).

The Mediterranean Basin is renowned for its abundance of islands, making it one of the most island-rich regions in the world (Médail, 2017, 2022). Moreover, the Mediterranean Basin is regarded as a global hotspot of biodiversity (Médail & Myers, 2004) and its islands host the majority of the gap species in the EU (Spiliopoulou et al., 2023), i.e., those species whose distribution is not included in any protected area. While the exact number of islands in this area remains uncertain, estimates suggest that there are between 5000 (see Vogiatzakis et al., 2016) and>10,000 islands and islets (see Médail, 2022; Sfenthourakis & Triantis, 2017), depending on definitions and area thresholds. Yet, only 157 of these islands are larger than 10 km^2 (Médail, 2017), while most of them are very small in size. Most of the Mediterranean islands have a continental origin, with only a few originating from volcanic activity. Furthermore, the largest islands, i.e., Sicily, Sardinia, Corsica, Cyprus and Crete, host high mountains (>1800 m above sea level), which often act as climatic refugia (Steinbauer et al., 2016).

Mediterranean islands have been the subject of a plethora of studies investigating various taxa and ecological topics (see Médail, 2022). Researchers focused on the biodiversity and the ecological dynamics of these islands, analysing the patterns of their unique flora and fauna and determining their underlying drivers (Bonardi et al., 2022; Fattorini, 2006; Fattorini et al., 2017; Médail, 2022; Özden et al., 2008; Sfenthourakis & Triantis, 2017; Testolin et al., 2023). Other studies encompassing particularly well-surveyed islands explored changes in plant species composition across two centuries, likely one of the longest timeframe for studies of island biogeography (Chiarucci et al., 2017). Despite the wealth of research conducted, a comprehensive geospatial layer encompassing all Mediterranean islands is still lacking. Bonardi et al. (2022), by reporting the distribution of the reptile fauna, contributed to addressing this gap by providing essential data, such as geographic coordinates, area and elevation, for 1815 Mediterranean islands.

In this paper, we present the first comprehensive geospatial database of all Mediterranean islands larger than 0.01 km^2. Alongside the geometries, we provide a wide range of variables for each island with the aim of assisting biogeographical and evolutionary research in the area. By providing the aforementioned geospatial database, we aim to support ecological investigations as well as interdisciplinary research exploring economic, environmental and social issues.

2 | METHODS

2.1 | Island identification

The construction of the spatial database was based on the Global Shoreline Vector (GSV; Sayre et al., 2019), a global vector-based depiction of shorelines and islands at 30 m resolution, derived from 2014 Landsat satellite imagery. We retrieved all the GSV island polygons found in the Mediterranean Basin, here defined as the portion of sea bounded by the Gibraltar and Bosporus Straits. We checked all polygons for geographical consistency by using satellite imagery (Google, n.d.), fixing them in case of discrepancies (e.g. islands fused together and reclaimed land mistakenly identified as natural landforms) or adding new polygons in case of missing islands. We chose a 0.01 km^2 threshold to distinguish islets from islands and excluded the former to avoid potential errors in boundary identification. For the same reason, we also removed lagoon and estuary islands, which are inherently variable in their shape and extent. Finally, we checked island names already provided in the GSV, and named all the unnamed islands when the information was available.

The aforementioned spatial operations were all performed with QGIS v. 3.10 (QGIS Development Team, 2019).

2.2 | Data retrieval

After consolidating the island polygons, we extracted information regarding climate, morphology, land cover, palaeogeography and road networks. Climate data were derived from CHELSA-BIOCLIM+ V2.1 (Brun et al., 2022), a high-resolution (30 arc second) global climate dataset (Karger et al., 2017), and used to provide information on the climatic space occupied by the islands. Climatic rasters were accessed using the 'ClimDatDownloadR' package (Jentsch et al., 2024) in R (R Core Team, 2023). Terrain data were derived from the NASA Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM; Farr et al., 2007) at a resolution of 1 arc-second (approximately 30 m). Climatic and terrain factors are key proxies or direct drivers of biodiversity and can thus assist the interpretation of its patterns on island systems (Kreft & Jetz, 2007; Weigelt et al., 2013). Land cover information was extracted from the European Space Agency (ESA) WorldCover dataset (Zanaga et al., 2022). This provides a global land cover map (11 land cover classes) for 2021 at 10 m resolution based on Sentinel-1 and Sentinel-2 data. Data on land cover are key to understanding observed biodiversity patterns as it provide information on the state of terrestrial environments and the threats to their conservation. Information on the spatial configuration (i.e. area and isolation) of Mediterranean islands during the Last Glacial Maximum (LGM, c. 20,000 years BP) was indeed obtained from the Paleocoastlines GIS dataset (Zickel et al., 2016), which provides 23 vector layers with sea level configuration in different time periods during the last 140,000 years for central and southern Europe, Near East and North Africa. The spatial configuration of islands in the past has been found related to current plant, land snail, butterfly and reptile diversity (Hammoud et al., 2021; Norder et al., 2019; Weigelt et al., 2016) and can therefore assist the interpretation of observed biogeographical patterns. Finally, road networks were retrieved using data from OpenStreetMap (OSM; OpenStreetMap, 2017) accessed with the 'osmdata' package in R (Padgham et al., 2017). OSM is a global open-access, citizen science mapping project, freely accessible and continuously updated by its contributors. Roads have multiple effects on wildlife population dynamics (Fahrig & Rytwinski, 2009) and habitat fragmentation (Laurance et al., 2009; Trombulak & Frissell, 2000) and contribute to enhancing human pressure on ecosystems (Kati et al., 2020).

2.3 | Variable extraction

Based on the above-mentioned datasets, we retrieved a set of descriptors for all island polygons.

Concerning geographic and topographic variables, we calculated the area and the perimeter values for each island and categorized them according to their size for data visualization purposes (small islands: 0.01 km^2 < area ≤ 1 km^2; medium islands: 1 km^2 < area ≤ 100 km^2; and large islands: area > 100 km^2).

As for isolation metrics, we included distance from the mainland, distance from the closest island and distance from the closest larger island, as well as to the closest 10 times, 100 times and 1000 times larger island. To calculate distances, we employed the *st_distance()* function from the 'sf' package (Pebesma, 2018) in R.

We also processed island configuration during LGM, using the palaeocoastline −120 m layer (Zickel et al., 2016), retrieving the island ID (or the mainland) to which each island belonged and the planar area of the former island.

As far as climate is concerned, we derived the mean and standard deviation values for the following variables from the CHELSA-BIOCLIM+ dataset: mean annual air temperature (bio1), temperature seasonality (bio4), annual range of air temperature (bio7), annual precipitation amount (bio12) and precipitation seasonality (bio15). Data were extracted with the *exactextract()* function from 'exactextractr' R package (Baston, 2022).

Starting from the SRTM DEM data, for each polygon, we calculated mean, maximum and standard deviation values for elevation, as well as mean and standard deviation values, respectively, for the terrain ruggedness index (TRI; Riley et al., 1999) and the topographic position index (TPI; Weiss, 2001). The TRI calculates the overall change in elevation between a grid cell and its eight surrounding grid cells, providing a rapid and objective measure of terrain heterogeneity (Riley et al., 1999). The TPI indicates the difference in elevation between a selected cell and the mean value of the neighbouring ones. Thus, TPI enables distinguishing different topographic features, such as peaks, plains and canyons.

We also calculated a set of variables linked to human impact on islands. We derived the linear extent and density of major roads per island using OSM data, as well as that of all road types excluding local roads in residential areas and hiking trails. As for major roads, we only included those tagged as motorway, primary, secondary and tertiary, as well as those linking these types. For the length and density of all roads, we also included unclassified roads and tracks (e.g. forest roads). ESA WorldCover was the source to calculate the percentage covered by croplands and built-up areas, as well as the number and evenness (Pielou index; Pielou, 1975) of land cover types. Terrain and land cover indexes were calculated using Google Earth Engine (Gorelick et al., 2017).

Finally, we added geological information about those islands which are entirely volcanic.

2.4 | Data structure

The database is provided in GeoJSON and GeoPackage format, with reference system ETRS89-extended/LAEA Europe (EPSG: 3035). A complete list of all the variables can be consulted in Table S1.

3 | RESULTS

The MEDIS spatial database is made up of 2217 islands larger than 0.01 km^2 and provides information on 39 geographic, climatic, ecological and land-use variables (Figure 1a; Table S1). Greece and

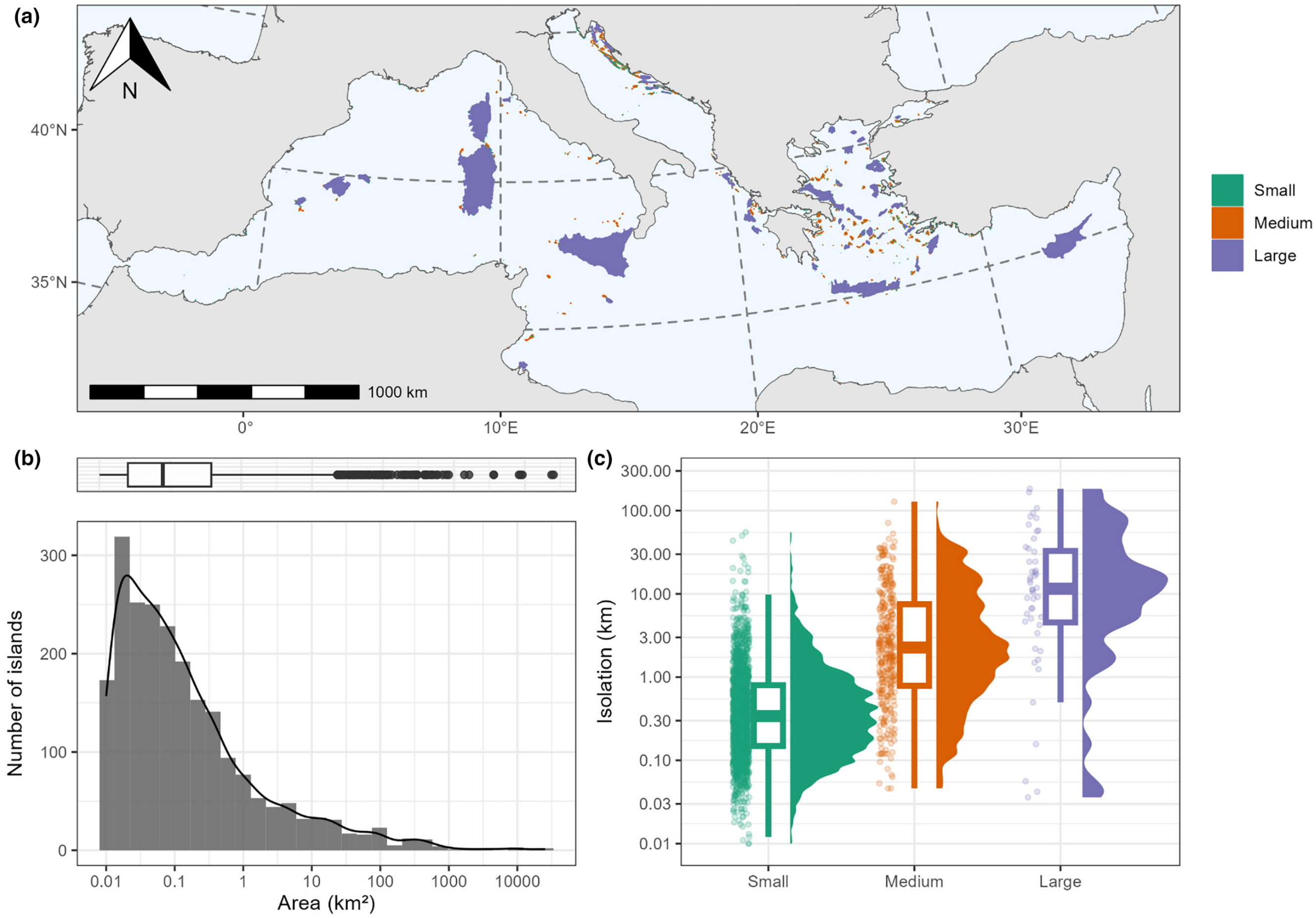

FIGURE 1 (a) Map showing the Mediterranean Basin and the polygons makingup the MEDIS spatial database. Islands are coloured according to their size: small islands are smaller than 1 km^2 but larger than 0.01 km^2, medium islands are smaller than 100 km^2 and large islands are larger than 100 km^2. Note that small islands are not visible at this resolution. (b) Distribution of island size in km^2 on a logarithmic scale. (c) Distribution of island isolation in km on a logarithmic scale by island size class. Here, isolation is defined as the lowest value for each island between distance from mainland and distance from the nearest larger island.

Croatia are the two countries with the highest number of islands, with 871 (39%) and 629 (28%), respectively, while in terms of area, Italy has the greatest amount of islands (49%), followed by Greece (25%) and Cyprus (9%).

The distribution of island area is highly left skewed, showing a dominance of small islands (Figure 1b). Most of the islands belong to the small size class (83%), followed by medium (15%) and large ones (2%). For 2209 islands, we provided a name featured in national or local maps, archives or documents.

Isolation, indicated as the minimum value between either the coast-to-coast distance to the mainland or that to the closest larger island, increases from smaller to larger islands (Figure 1c).

The climatic space occupied by the 2217 islands is quite large (Figure 2), ranging from 13.3 to 21.4°C in mean annual temperature and from 150 to 2900 mm of cumulative annual rainfall. Whereas the database has a broad coverage on most of the variables, data about roads were only available for 266 islands (12%). Differences in road length are obviously linked to island class size (Figure 3a), while road density appears to be higher in smaller islands (Figure 3d). On average, large islands have higher percentages of cropland and built-up cover fractions than smaller ones (Figure 3b,e, respectively); however, smaller islands showed substantially higher variation of these values. The number of land cover types ranges from 1 to 7 per island and it increases with island size (Figure 3c). Land cover evenness (Figure 3f), however, has similar median value across different island sizes, but the variability range decreases with increasing area.

4 | DISCUSSION

The MEDIS spatial database here presented is a freely available source providing data on 2217 Mediterranean islands larger than 0.01 km^2, with the aim of assisting ecological and biogeographical research within a global biodiversity hotspot (Médail, 2022; Vogiatzakis et al., 2016). This effort represents a conspicuous development of the work carried out by Bonardi et al. (2022) for 1815 Mediterranean islands, both in terms of geographical completeness and detail (polygonal features are provided rather than island centroids) and in the scope of the associated variables, which cover a wide range of natural and anthropogenic features.

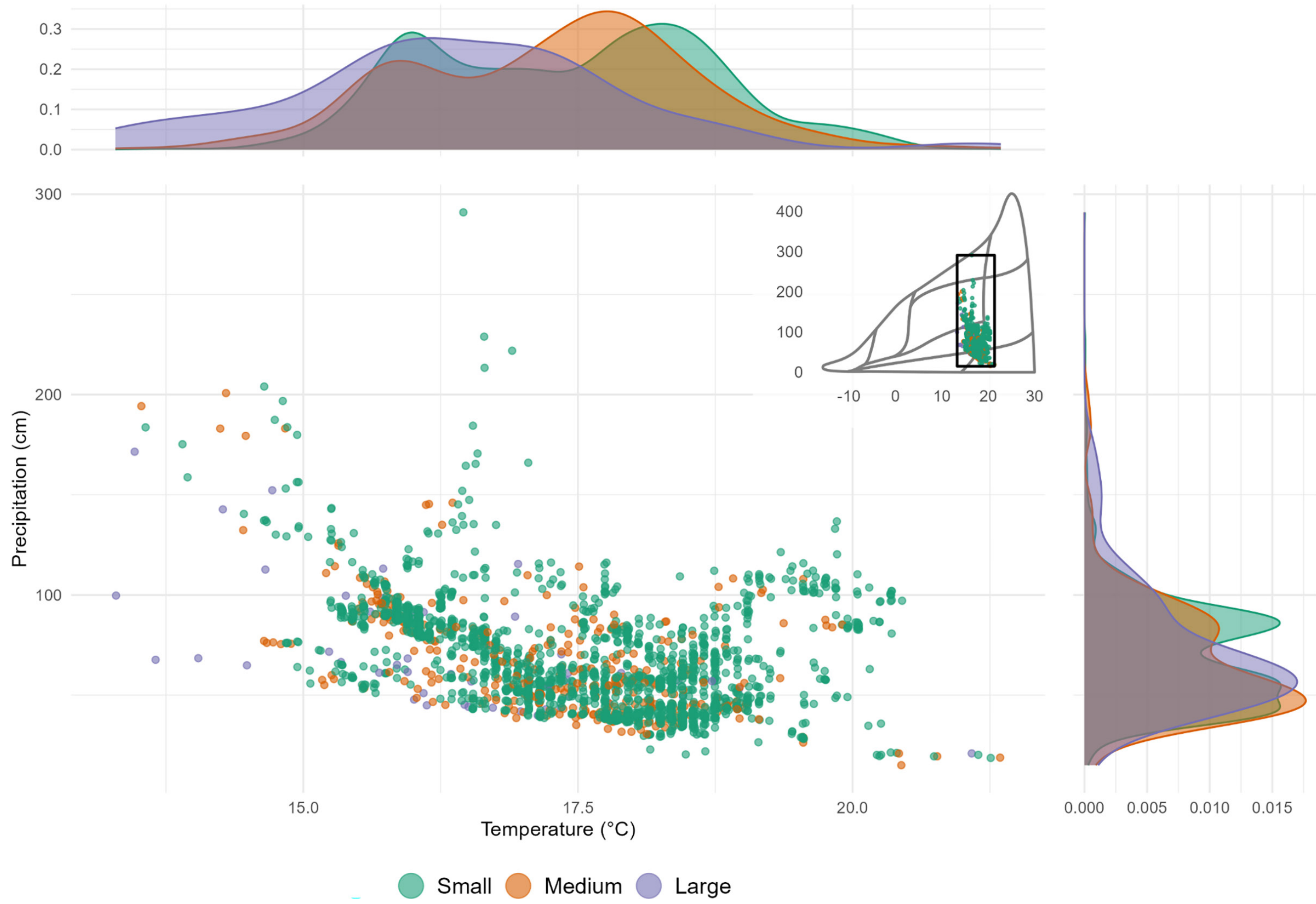

FIGURE 2 Distribution of mean annual temperature and annual precipitation for each island, shown by island size class. Marginal plots show distributions for each group. The inset panel shows the islands' climatic space in a Whittaker's plot.

The data provided in MEDIS can stimulate the development of research projects on the entirety of Mediterranean islands, allowing a common reference for island name, size, elevation and other bioclimatic variables. This information can facilitate seamless retrieval of topographical and bioclimatic data to be used for biogeographical or ecological comparisons across Mediterranean regions, such as the biogeographical relations within a given taxon (see, e.g. Fattorini, 2002), the investigation of island origin (continental vs. oceanic), habitat, landscape and climate effects on biodiversity, the distribution of native, endemic or alien species (see, e.g. Fois et al., 2020) or the comparison of species–area relationships across different Mediterranean archipelagos (see, e.g. Chiarucci et al., 2021).

Despite our effort to provide a complete spatial database, some features will require further investigation. First, we were not able to identify the names of eight islands. Secondly, the assessment of island road networks, crucial to the analysis of human impacts on islands and the risk of invasion by alien species (see, e.g. Bacaro et al., 2015; Fois et al., 2020), is still largely incomplete. In the present work, we were able to retrieve data for only 266 islands (12%). While this low value may be linked to the absence of infrastructure on many small or protected islands, it also confirms the lack of data for the smallest islands and some overlooked regions (Meijer et al., 2018). Future, ad hoc studies involving the manual or machine-learning-assisted identification of roads in the study area are required to fill this gap and identify those islands that have been spared from infrastructural development. Indeed, roadless area is an important indicator of the conservation value of terrestrial environments (Ibisch et al., 2016) and this aspect can be particularly important on islands. Indeed, entirely protected, infrastructure-free island ecosystems, can host important biodiversity features. As an example, the island of Montecristo (Italy) hosts the oldest known individuals of *Quercus ilex* (Filibeck et al., 2023), while the Palm Islands Nature Reserve (Lebanon) is home to the residual populations of several threatened endemic plant species, as well as an important shelter for threatened sea turtles and migratory birds (Lakkis & Sabour, 2007). Finally, the climate variables provided here could bear some incongruences, given the presence of fine-scale influential factors (e.g. topography), not accounted for in global climate datasets (Patiño et al., 2023). Therefore, such variables should be interpreted as a general indication of the islands' bioclimate. For small-scale studies on Mediterranean islands, we recommend a thorough check of the congruence of climate data, e.g., by downscaling (see some application examples for Azores islands and Canary islands in Ferreira et al., 2016; Patiño et al., 2023).

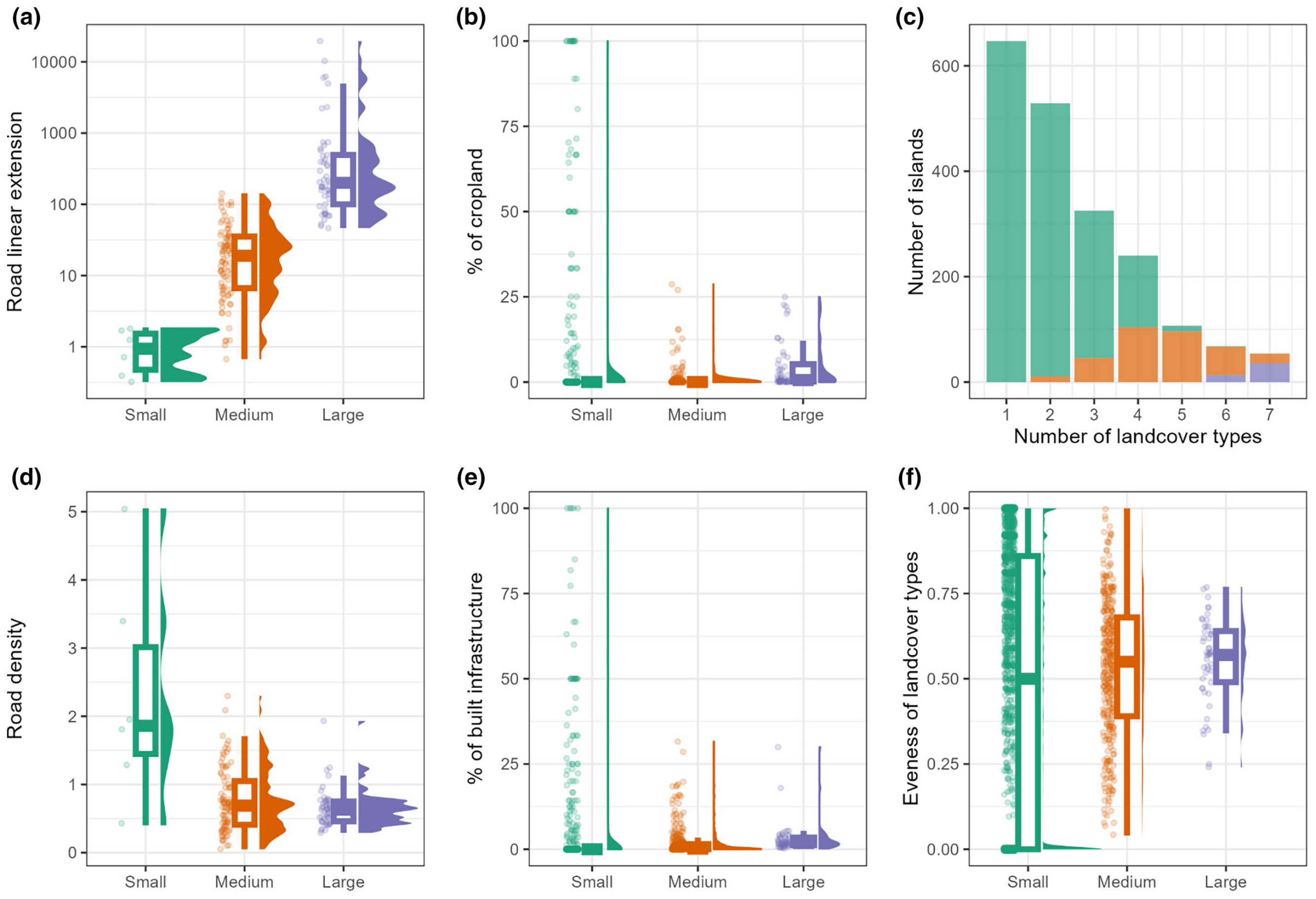

FIGURE 3 Distribution of human-related variables by island size class. (a) Road linear extension in km on a logarithmic scale. (b) Percentage of cropland areas. (c) Number of land cover types. (d) Roads density. (e) Percentage of built-up infrastructure areas. (f) Pielou's evenness of land cover types.

AUTHOR CONTRIBUTIONS

PZ and AC conceived the original idea. PZ, RT, VM, MDM, LR and FS elaborated on the product and produced the database. PZ, RT, MDM and FS prepared the first manuscript, RG, GB, JMF-P, MF, KK, KBK, FL, FM, TN, RO, SP, MP, KP, SS, SMS, CAT and KAT contributed with data for specific islands and/or regions. FS, RT and MDM reviewed the final manuscript and elaborated the last version of the dataset. AC coordinated the project.

AFFILIATIONS

[1]BIOME Lab, Department of Biological, Geological and Environmental Sciences, Alma Mater Studiorum, University of Bologna, Bologna, Italy
[2]Plant Data – Interuniversity Research Centre for Plant Biodiversity and Big Data, Department of Biological, Geological and Environmental Sciences, University of Bologna, Bologna, Italy
[3]LifeWatch Italy, Lecce, Italy
[4]Department of Life, Health & Environmental Science, University of L'Aquila, L'Aquila, Italy
[5]Department STEBICEF, University of Palermo, Palermo, Italy
[6]Department of Life and Environmental Sciences, Center for the Conservation of Biodiversity (CCB), University of Cagliari, Cagliari, Italy
[7]Island Ecology and Biogeography Group, Instituto Universitario de Enfermedades Tropicales y Salud Pública de Canarias, Universidad de La Laguna, San Cristóbal de La Laguna, Spain
[8]Department of Biology, University of Patras, Patras, Greece
[9]Zoological Collection, Cyprus Wildlife Research Institute, Taşkent, Cyprus
[10]Department of Biology, Faculty of Engineering and Natural Science, TR-71451, Kırıkkale University, Kırıkkale, Yahşihan, Turkey, Yahşihan, Kırıkkale, Turkey
[11]Department of Biological, Geological and Environmental Sciences, Alma Mater Studiorum, University of Bologna, Bologna, Italy
[12]Institut méditerranéen de biodiversité et d'écologie Marine et Continentale (IMBE), Aix Marseille Université, Avignon University, CNRS, IRD, Aix-en-Provence Cedex 4, France
[13]Department of Botany, Division of Biology, Faculty of Science, University of Zagreb, Zagreb, Croatia
[14]Department of Botany, Ecology and Plant Physiology, University of La Laguna, San Cristóbal de La Laguna, Spain
[15]Italian National Research Council (CNR), Institute of BioSciences and Bioresources (IBBR), Unit of Palermo, Palermo, Italy
[16]Faculty of Biology, Department of Ecology and Taxonomy, National and Kapodistrian University of Athens, Athens, Greece
[17]Department of Biological Sciences, University of Cyprus, Lefkosia, Cyprus
[18]Natural History Museum of Crete, University of Crete, Crete, Greece

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The dataset and the R codes can be accessed at https://doi.org/10.5061/dryad.b8gtht7k5.

ORCID

Michele Di Musciano https://orcid.org/0000-0002-3130-7270
Konstantinos Proios https://orcid.org/0000-0001-7545-5892
Alessandro Chiarucci https://orcid.org/0000-0003-1160-235X

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BIOSKETCH

This data paper is the product of an international research network, focused on the study of the biodiversity of Mediterranean islands and caring for their conservation.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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