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LONG DATABASE REPORT ECOINFORMATICS

Vegetation Database of the Gran Paradiso National Park: a new tool for the oldest national park in Italy

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Abstract

National parks play a key role in biodiversity conservation, but the vegetation data collected within them often remain fragmented, heterogeneous, or difficult to access. Structured vegetation databases are therefore essential for transforming historical and contemporary records into accessible resources for environmental management, scientific research, and future monitoring initiatives. Here we present the Vegetation Database of the Gran Paradiso National Park, Italy's first national park, registered in GIVD under the ID EU-IT-025. The park is a hotspot of alpine biodiversity, harbouring over 1,100 vascular plant species, including more than 80 alpine endemic species. The database integrates decades of botanical research. This comprehends vegetation surveys derived from different research projects based on different sampling methods, including a subset of permanent plots. To ensure consistency and interoperability, records were georeferenced and harmonised. The database includes 1,203 vegetation plots, associated metadata, and 853 recorded taxa, largely from high-elevation environments above 2,000 m a.s.l. More than 100 species are of conservation concern, and nearly 7% are alpine endemics. Most plots (89%) were assigned to EUNIS habitat categories, with grasslands as the dominant type. The database is accessible through a dedicated web application, facilitating data exploration and supporting its use in conservation planning, habitat assessment, and future vegetation monitoring.

Taxonomic references: Bartolucci et al. (2024) for native vascular plants, Galasso et al. (2024) for alien vascular plants, Aleffi et al. (2023) for bryophytes.

Keywords

Alpine vegetation, biodiversity conservation, EUNIS habitat, Gran Paradiso National Park, Italy, vegetation database

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GIVD Fact Sheet

GIVD Database ID: EU-IT-025			**Last update:** 2026-10-21
Vegetation Database of the Gran Paradiso National Park		**Web address:**	
Database manager(s): Andrea Mainetti (andrea.mainetti@pngp.it); Gianmaria Bonari (gianmaria.bonari@unisi.it)			
Owner: Ente Parco Nazionale Gran Paradiso			
Scope: To create the Vegetation Database of the Gran Paradiso National Park, Italy.			
Abstract: The database contains all the records from vegetation plots performed between 1970 to 2023 in the Gran Paradiso National Park area. The plots are conducted in different habitats, with a focus on high-elevation environments. All the records are implemented with various measurements, including plot-level variables and EUNIS habitat classification (v.2025-10-03).			
Availability: free upon request		**Online upload:** no	**Online search:** no
Database format(s): TURBOVEG, Excel		**Export format(s):** TURBOVEG, Excel, CSV file	
Plot type(s): normal plots		**Plot-size range (m²):** 0.625 to 400	
Non-overlapping plots: 1203	**Estimate of existing plots:** 1203	**Completeness:** 100%	**Status:** ongoing capture
Total no. of plot observations: 1203	**Number of sources (biblioreferences, data collectors):** 0		**Valid taxa:** 853
Countries (%): IT: 100			
Formations: Forest: 4% = Terrestrial: 4% // Non Forest: 96% = Terrestrial: 96%			
Guilds: all vascular plants: 1%; only trees and shrubs: 95%; bryophytes (terricolous or aquatic): 4%			
Plot size categories (%): < 1 m2: 4%; 1-10 m2: 22%; 10-100 m2: 72%; 100-1000 m2: 2%; 1000-10000 m2: 0%; >= 10000 m2: 0%; unknown: 0%;			
Environmental data (%): altitude: 100; slope aspect: 88; slope inclination: 100; microrelief: 0; surface cover other than plants (open soil, litter, bare rock etc.): 59; other soil attributes: 0; soil pH: 0; land use categories: 0; soil depth: 0			
Performance measure(s): cover: 100%			
Geographic localisation: GPS coordinates (precision 25 m or less): 98%; point coordinates less precise than GPS, up to 1 km: 2%			
Sampling periods: 1920-1929: 0%; 1930-1939: 0%; 1940-1949: 0%; 1950-1959: 0%; 1960-1969: 0%; 1970-1979: 2%; 1980-1989: 0%; 1990-1999: 0%; 2000-2009: 21%; 2010-2019: 43%; after 2020: 34%			
Information as of 2026-10-21; further details and future updates available from http://www.givd.info/ID/EU-IT-025			

Introduction

National parks have a unique responsibility in preserving biodiversity, not only by protecting representative habitats and species, but also by facilitating the collection, preservation, and integration of ecological data. Through long-term observation and research, protected areas can act as reference sites for detecting environmental changes and testing conservation strategies (Urbano et al. 2024). In this context, structured vegetation databases are essential tools for supporting biodiversity conservation and environmental management (Capotorti et al. 2012). By organising large volumes of ecological information in a systematic and accessible way, these resources provide a solid foundation for conservation planning, habitat mapping, adaptive management, long-term monitoring, and scientific research (Franklin et al. 2014). They also offer common ground for dialogue between researchers, park managers, and stakeholders (Lindenmayer and Likens 2009), while playing a crucial role in understanding ecosystem dynamics, identifying conservation priorities, and evaluating changes in habitat structure and composition over time (Schaminée et al. 2009).

Vegetation databases are not merely repositories of botanical knowledge, but dynamic tools that can be updated, expanded, and applied across a wide range of conservation and planning contexts. Their value increases when local and regional datasets are integrated into broader networks operating across multiple spatial scales. Such networks form a hierarchical system ranging from national repositories of phytosociological relevés (Landucci et al. 2012), to supranational initiatives addressing biogeographical questions across borders (Bonari et al. 2019), and further to continental (EVA; Chytrý et al. 2016) and global archives (sPlot; Bruelheide et al. 2019). This integration enables large-scale analyses of vegetation diversity and, together with plant trait and phylogenetic data, supports the exploration of macroecological patterns of functional and taxonomic diversity worldwide. The growing adoption of open access principles (Sabatini et al. 2021) and the development of interactive platforms, such as EVA-MAP (Mertel et al. 2025), have further improved the accessibility and usability of these data.

Despite this growing integration at continental and global scales, alpine and high-mountain ecosystems remain underrepresented in large plot-based datasets (Orusa and Borgogno Mondino 2021). This gap is particularly relevant because high-quality and well-documented vegetation data from mountain areas are essential for detecting ecological responses to ongoing global change. Mountain ecosystems are highly sensitive to climatic and environmental shifts, and their adequate representation in vegetation databases is therefore crucial for understanding biodiversity patterns, assessing habitat changes, and informing conservation strategies across spatial scales.

This underrepresentation is closely linked to the way vegetation data have historically been collected, stored, and preserved. A substantial amount of vegetation plot data has remained largely inaccessible to the broader scientific community, often confined to private archives, unpublished reports, local project datasets, paper records, or obsolete digital media. This issue is particularly significant for historical vegetation data collected within protected areas and national parks. While the risk of data loss is not necessarily higher, the value of such historical information is arguably greater in these contexts, given their roles as long-term reference sites and guiding conservation management (Easterday et al. 2018). Without active interventions, these datasets may become increasingly difficult to retrieve or interpret, as metadata are progressively lost, misplaced, or discarded. As a result, a significant percentage of historical data from recent decades are thought to have already been lost or rendered unusable (Wood et al. 2025). Making such databases widely accessible not only prevents the loss of valuable historical information but also contributes to the recognition of field botanists (Bonari 2025). In addition, it supports ecological research by enabling scientists to analyse biodiversity patterns and assess the impacts of global environmental change across multiple spatial scales.

Beyond the risk of data loss, a further challenge concerns the fragmentation and heterogeneity of vegetation surveys within protected areas. Historical and contemporary surveys are often compartmentalised across separate short-term projects, each employing its own sampling design, data structure, and classification scheme (Urbano et al. 2024). This lack of standardisation tends to produce datasets that are difficult to compare, analyse in parallel, or integrate into coherent temporal assessments without substantial preliminary processing (Stendardi et al. 2023; Urbano et al. 2024). Even within a single protected area, different vegetation mapping campaigns may apply divergent classifications, requiring careful manual curation to reconcile detailed locally defined vegetation typologies into broader and functionally comparable categories (Stendardi et al. 2023). Addressing these interconnected challenges is particularly important for alpine protected areas, where the effects of global change are occurring faster than in other environments, and where historical data are therefore particularly valuable in providing the baseline information to reliably assess change over time.

In this context, the Gran Paradiso National Park provides an ideal case study for developing a structured vegetation database aimed at improving the representation of alpine vegetation within wider national, continental, and global networks. The park represents a territory of major importance for conservation and monitoring, as well as a hotspot of alpine biodiversity. It preserves a unique ecosystem characterised by the coexistence of alpine endemic, Mediterranean-montane, and arctic-alpine floristic elements. The origins of its protection date back to 1856, when the area was first established as a Royal Hunting Reserve to prevent the extinction of the Alpine ibex (*Capra ibex* L., 1758). It was subsequently established as Italy's first national park by royal decree in 1922.

The park is characterised by high environmental heterogeneity driven by strong elevational, climatic, and geomorphological gradients. This variability supports a wide range of habitats, including wetlands, rocky environments, grasslands, shrublands, and forests, each contributing to the overall ecological diversity of the area. Wet habitats, although often localised, sustain specialised plant communities, while extensive rocky terrains and alpine grasslands host highly adapted and endemic species. Forest ecosystems, composed of both broadleaf and coniferous stands, occupy a relatively small area of the park but further increase landscape diversity. Together, these elements create a heterogeneous mosaic that supports high species richness and reinforces the conservation value of the area.

More than 1,100 vascular plant species have been recorded within the park, including over 80 alpine endemics (Bertolli et al. 2024). Beyond these endemic species, numerous species are of high conservation interest, and many are protected under regional, national, and European legislation. The park also hosts 36 Natura 2000 habitats, further underlining the importance of systematic vegetation data collection and management within this protected area (Gran Paradiso National Park 2022; Ministry of the Environment and Energy Security 2026).

This paper presents a vegetation database developed by the Gran Paradiso National Park, Italy, which brings together detailed information on vegetation types across the park's territory, aiming to make the vegetation data collected over time publicly available. This database includes only vegetation data directly produced by or for the park across its territory. Additional data on the park's territory and its surroundings exist from other sources (e.g. Wiesner et al. 2015; Klopsch et al. 2025) but have not been incorporated in the database. The database has been registered in the Global Index of Vegetation-Plot Databases under the code EU-IT-025 (GIVD; Dengler et al. 2011), ensuring its visibility and accessibility to the vegetation science community.

Study area

The Gran Paradiso National Park (GPNP) is located in the Graian Alps of north-western Italy and covers approximately 71,000 ha across the administrative regions of Aosta Valley to the north and Piedmont to the south (45°30'N, 7°18'E). The park is characterised by a marked elevational gradient, ranging from a minimum elevation of 800 m a.s.l. to 4,061 m a.s.l. at the summit of Gran Paradiso (Figure 1).

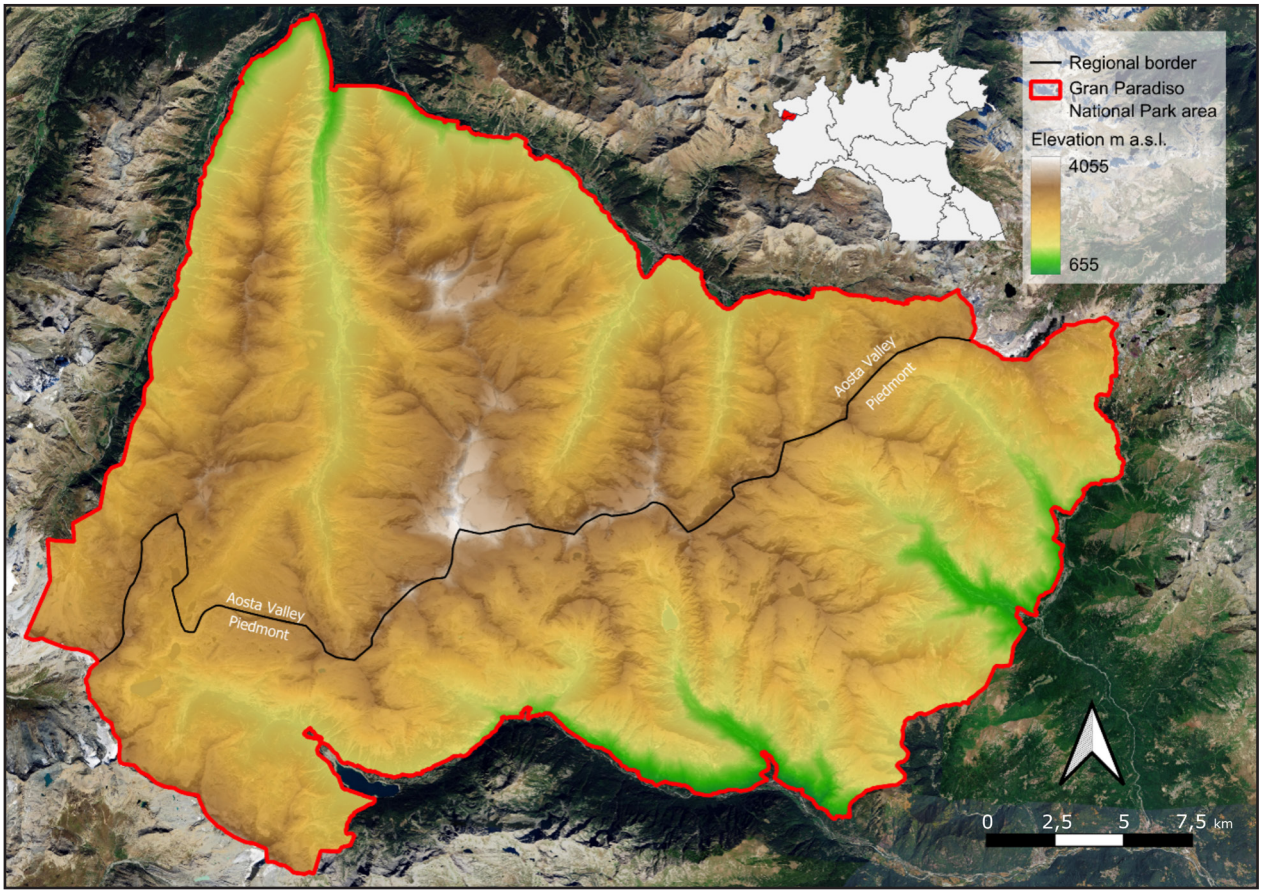


Figure 1. Location of the Gran Paradiso National Park (Italy), shown in red on a 5 m resolution Digital Elevation Model (DEM). The regional boundary between Aosta Valley and Piedmont is shown in black.

This topographic complexity generates steep thermal and precipitation gradients, extending from the deciduous forest belt to the nival zone (Baumann et al. 2016; Stendardi et al. 2023). The climate varies across the park. On the Aosta Valley side, it is typically intra-alpine, with relatively continental conditions characterised by cold, snowy winters and cool summers. By contrast, the Piedmont side is more humid and less continental (Poussin et al. 2019; Morgese et al. 2024). Annual precipitation varies substantially with elevation, aspect, and valley orientation, typically ranging from 900 mm to over 1,200 mm on the Piedmont side, while values in Aosta Valley are approximately 1.5 times lower. In sheltered rain-shadow areas, such as the Cogne valley floor, annual precipitation can drop to as low as 700 mm at an elevation of 1,700 m a.s.l. (Mercalli 2003).

Geologically, the park belongs to the Internal Crystalline Massifs of the Penninic Domain. It is predominantly composed of orthogneiss, known as the "Gran Paradiso Gneiss", and schists, with significant areas of calcschists and, to a lesser extent, ophiolites, mainly serpentinites. These lithological differences strongly influence substrate conditions and exert a selective effect on the lithophilous flora (Tiberti et al. 2010).

The landscape has been shaped by intense Pleistocene glaciations, which produced a mosaic of glacial cirques, moraines, and glaciers. As of 2024, 57 glaciers were recorded within the park (Mosso and Tortorelli 2025), contributing to the current geomorphological and habitat heterogeneity.

Vegetation is structured along a marked elevational gradient, with a gradual transition from montane to nival communities. At lower elevations, between 800 and 1,500 m a.s.l., forest composition differs markedly between the two sides of the park. The Piedmont side is dominated by mixed forests of *Fagus sylvatica*, *Castanea sativa*, *Picea abies*, and *Pinus sylvestris*, whereas the Aosta Valley side is characterised by mixed *Acer pseudoplatanus*, *Tilia platyphyllos*, *Fraxinus excelsior* forests, often with the early occurrence of *Larix decidua*.

Between 1,500 and 2,300 m a.s.l., these forests transition to coniferous woodlands characterised by *Larix decidua* and *Pinus cembra*, especially on the Aosta Valley side. On acidic substrates, these woodlands are often accompanied by a well-developed ericaceous shrub layer, including *Rhododendron ferrugineum* and *Vaccinium* spp. Above the treeline, between 2,300 and 2,800 m a.s.l., vegetation is largely composed of alpine grasslands, ranging from acidophilous communities dominated by *Carex curvula* to calcicolous assemblages with *Sesleria caerulea* and *Carex sempervirens*. Above 2,800 m a.s.l., the nival belt is characterised by discontinuous pioneer vegetation colonising screes and rocky outcrops, supporting highly specialised taxa and a notable endemic component (Aeschimann et al. 2011).

Data gathering

The database was compiled through the integration of multiple sources spanning several decades of botanical research and fieldwork conducted within the Gran Paradiso National Park. Data acquisition relied primarily on structured field surveys, complemented by the validation of historical records. Furthermore, the database includes data collected within the framework of various research projects and conservation programmes implemented in the park. These initiatives focused on plant diversity, habitat mapping, land-use dynamics, and the ecological effects of climate change, providing a valuable diachronic perspective. Notably, some of these projects involved long-term monitoring programs, such as the proglacial flora monitoring (Nota et al. 2025), which contributed a key subset of permanent plots to the database. The dataset, therefore, comprises vegetation data gathered via several established study methods.

Specifically, vegetation data were collected using different methodologies, including: i) traditional phytosociological relevés based on different scales, such as the Braun-Blanquet scale (Braun-Blanquet 1932) and its modified version by Brusa et al. (2017), the Pignatti scale (Pignatti 1952), and visual percentage cover estimates from 1 to 100% (Kennedy and Addison 1987); ii) pin-point method based on grids of 16 m^2 (289 pins) and 25 m^2 (441 pins) (Levy and Madden 1933); and iii) linear surveys, with lengths of 12.5 m, 20 m, and 25 m (Daget and Poissonet 1971) for high-precision abundance estimation integrated with the list of occasional species (Pittarello et al. 2018; Mainetti et al. 2023). These data were harmonised by converting the different abundance-dominance scales used in the surveys into a percentage cover value, to ensure internal consistency, interoperability, and applicability for conservation planning, ecological analysis, and future monitoring initiatives. For pin-point derived data specifically, species relative abundance was calculated as the proportion of total vegetation contacts. This value was then scaled to the total herbaceous cover recorded in the corresponding plot, converting raw contact frequencies into cover estimates comparable with those obtained from other methods. Details regarding the various scales and their respective conversion methodologies are available in Suppl. material 1.

These surveys involved the systematic description of plant communities, estimation of cover for biotic components (e.g. herbs, trees, shrubs, bryophytes) and abiotic elements (e.g. rocks, sand, litter), as well as the recording of ecological parameters such as elevation, slope, and aspect for each plot. All records were georeferenced either directly in the field using GPS or through localisation and digitisation of historical records.

Data record

The database consists of interrelated parts providing a comprehensive overview of the vegetation plots recorded in the Gran Paradiso National Park and their associated ecological, biogeographic, and conservation related attributes. Data is managed using Turboveg 3 (v.3.9.8.; Hennekens 2015). All fields, values, and their definitions are provided in Suppl. material 2.

Species information

Each entry in the database represents a single, unique plant taxon documented through direct field surveys. For each taxon, the dataset provides a unique identifier ("id_taxa") corresponding to the ID used in the Park's botanical database and linked nomenclaturally to the Italian checklists of native and alien vascular flora (Bartolucci et al. 2024; Galasso et al. 2024) and to the national checklist of bryophytes (Aleffi et al. 2023). This identifier serves as the primary key to ensure interoperability and seamless integration between the different files and the park's broader databases and herbaria collections.

To facilitate both field-to-database traceability and international comparability, the taxonomic information is structured as follows:

i) Field name ("taxon"): The original identification recorded during primary data collection, maintained to allow back-verification with original field sheets;
ii) Accepted name ("current_name"): The current taxonomically valid name, standardised according to Bartolucci et al. (2024) for native vascular plants; Galasso et al. (2024) for alien vascular plants; and Aleffi et al. (2023) for bryophytes;
iii) EUNIS ESy species name ("esy"): The nomenclature specifically aligned with the EUNIS Expert System version v.2025-10-03 (Chytrý et al. 2020) to improve the accuracy of automated vegetation classification.

The database further reports the ecological and phytogeographical status of each taxon, including the regional status for the Aosta Valley and Piedmont sectors of the park, distinguishing between native and alien species. Finally, the conservation status is documented by cross-referencing regional, national, and international frameworks. This includes protection under Aosta Valley Regional Law no. 45/2009 and Piedmont Regional Law no. 32/1982, inclusion in the National Red List (Rossi et al. 2020a, 2020b), and listing within the Annexes of the Habitats Directive (92/43/EEC).

Species occurrences

The occurrence data are organised in a species-by-relevé matrix. In addition to the percentage cover, each matrix entry retains critical metadata to ensure data integrity and interoperability. These include the unique taxon identifier ("id_taxa") and botanical family, as well as the dual nomenclature (original field name and the updated accepted name), ensuring a clear taxonomic trail. The vegetation

layer (stratum) in which each species was recorded (e.g. tree, shrub, herbaceous, moss) is also specified, providing a multi-layered representation of community structure. Taxa recorded in multiple vegetation layers (e.g. *Acer pseudoplatanus*, *Betula pendula*, *Corylus avellana*, *Fagus sylvatica*, *Fraxinus excelsior*, and *Larix decidua* appearing simultaneously in tree and herbaceous layers) are treated as distinct entries in the occurrence table, while any redundant occurrence was cross-checked and reconciled during the data cleaning phase.

Vegetation-plot metadata

The metadata table includes all recorded vegetation plots and provides a comprehensive spatial and temporal characterisation of the sampling effort. The spatial distribution (Figure 2) reflects the specific objectives of various research projects and is partially influenced by the complex topography and accessibility of certain alpine sectors. The dataset spans a broad temporal range, from 1970 to 2023. Annual variations in the number of recorded plots are associated with the intermittent availability of research funding and the timeline of specific floristic monitoring programmes within the park. Data collected in 2024, 2025, and 2026 are not yet included in the database as they are still undergoing revision, species identification, and digitisation. Furthermore, plot sizes vary from 0.625 m^2 to 400 m^2; these dimensions were selected based on the specific vegetation type and the established survey protocols for different vegetation structures (Ellenberg and Mueller-Dombois 1974; Chytrý and Otýpková 2003). Plot size also reflects the specific objectives of the projects conducted within the park (Mainetti et al. 2023). Each entry in this table corresponds to a single plot and includes the information reported in Table 1.

EUNIS classification

To ensure international comparability and facilitate ecological interpretation, each plot was classified into a habitat type according to the EUNIS (European Nature Information System) classification framework using an expert system (v. 2025-10-03; Chytrý et al. 2020). To automate the assignment of vegetation plots to high-level habitat categories, we employed a standardised R-based expert system following the general concept and algorithmic framework for formalised vegetation classification proposed by Bruelheide et al. (2019).

Data visualisation

To make the database more accessible and to provide an overview of the data, we developed a ShinyApp (Chang et al. 2025), available at https://comunellod.shinyapps.io/gran_paradiso_national_park_vegetation_database/, where users can visualise the data in a dynamic and user-friendly

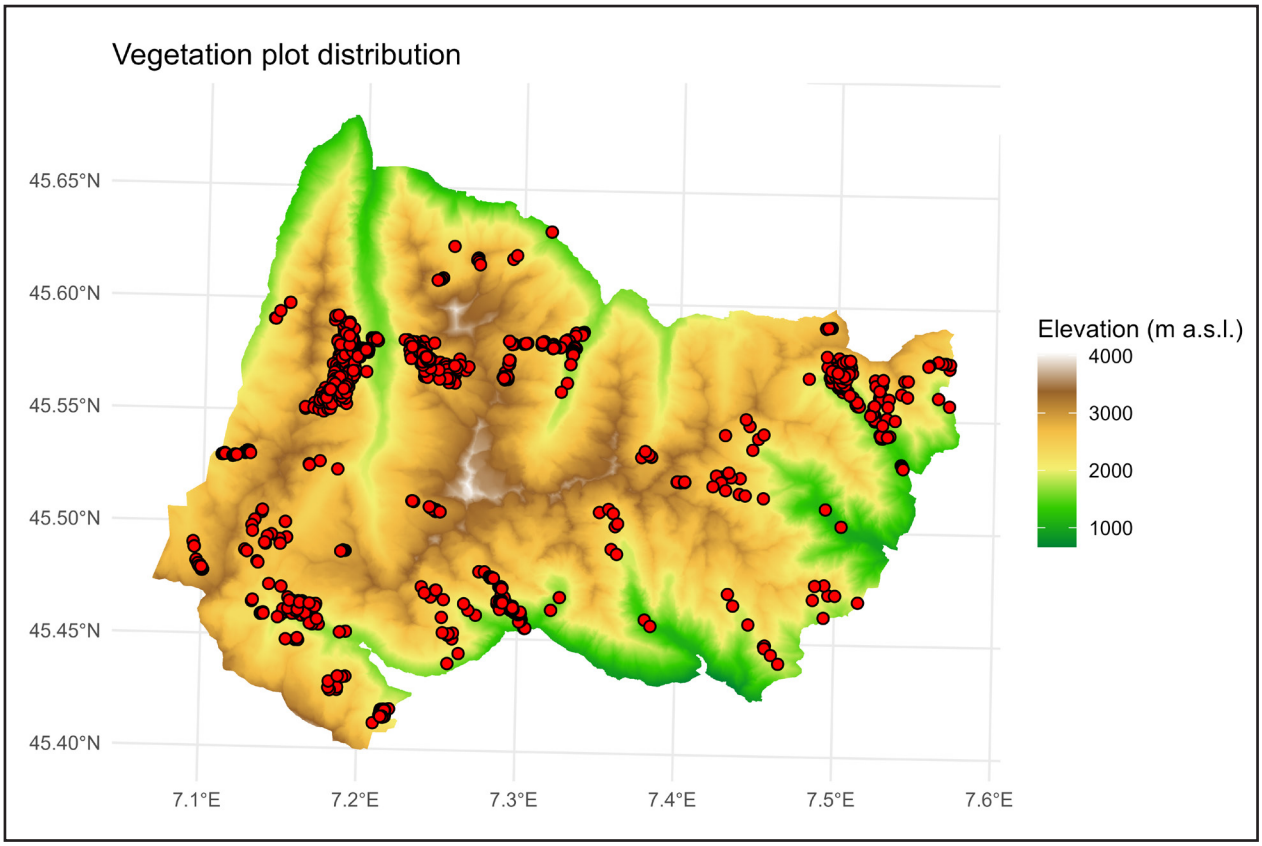


Figure 2. Spatial distribution of vegetation plots within Gran Paradiso National Park (Italy). Each point represents a single georeferenced vegetation plot.

Table 1. Overview of the vegetation plot database structure. The table summarises the main data categories included, listing for each category the variables recorded and providing a brief description of the content.

Category	Variable (unit)	Description
Temporal and spatial identification	Sampling date	Exact sampling date (day, month, year) and geographic coordinates recorded using high-precision GPS instruments and digital mapping applications
	Latitude (°)	
	Longitude (°)	
Topographic and physiographic data	Elevation (m a.s.l.)	Elevation derived from a 5 m resolution Digital Terrain Model using QGIS; slope and aspect measured in the field
	Slope (°)	
	Aspect (N, S, E, W)	
Substrate and abiotic features	Lithology	Detailed characterisation of substrate and estimated percentage cover of abiotic components
	Bare soil cover (%)	
	Rock cover (%)	
	Debris (%)	
	Sand (%)	
	Silt (%)	
	Water (%)	
Biotic structure and macro-habitat classification	Vegetation layer cover (%)	Estimated cover of vegetation layers (e.g. tree, shrubs, herbaceous, moss) and classification into macro-habitats (e.g. alpine grasslands, screes)
	Macro-habitat type	
Logistical metadata	Primary investigator	Administrative information, qualitative notes and taxonomic group recorded (i.e. vascular plants, bryophytes, lichens) for each survey
	Project ID	
	Field remarks	
	Taxonomic group recorded	

manner (Figure 3). The app provides an interactive map of the study area, where users can explore the data using several filters, including EUNIS habitat type, year and elevation ranges, survey method, and a geographic filter to select a specific area. Users can also overlay different map layers, such as Digital Elevation Model (DEM), and park, valleys and regional boundaries. Additional information about each plot is provided when it is selected through a pop-up window. This shows the EUNIS habitat code and its description, both linking to the corresponding FloraVeg.EU (Chytrý et al. 2024) habitat page, as well as the plot ID, elevation, geographic coordinates (Latitude and Longitude), and year. The plot ID is itself a link that, when selected, opens a second pop-up window containing further metadata, including authors, site attributes (area, slope, aspect, and lithology), survey method, percentage of biotic and abiotic cover, number of species, vascular plants and bryophyte counts, and other fields (see Suppl. material 2).

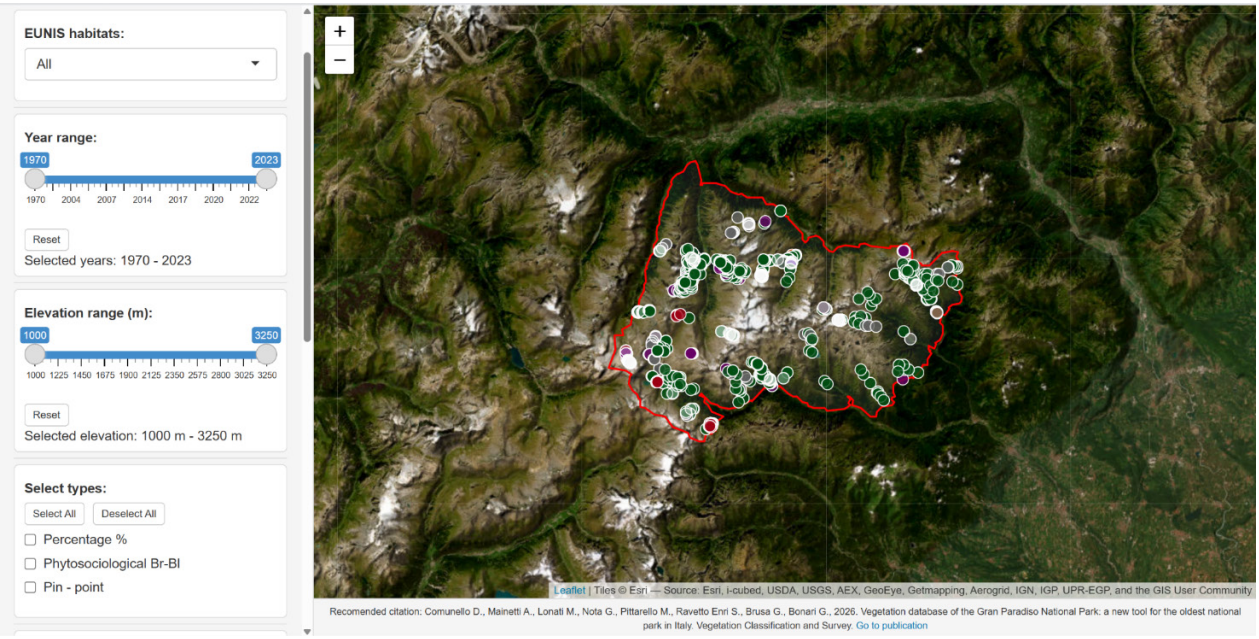


Figure 3. View of the web application developed to visualise the Vegetation Database of the Gran Paradiso National Park (https://comunellod.shinyapps.io/gran_paradiso_national_park_vegetation_database/). The interface allows users to explore vegetation plots and associated information through interactive filters.

Results

Overall, the database comprises 1,203 plots, including 66 permanent plots. Most plots were located above 2,000 m a.s.l. (N = 953), indicating a clear focus on alpine vegetation (Figure 4A). None of these plots had previously been deposited in any vegetation database. Of the total, 1,184 plots had coordinates collected via GPS, with a precision of 5 m, while 19 plots were geolocated through digitisation with a precision of 100 m. Most surveys followed a pin-point approach (Figure 4B) and plot sizes were predominantly 4, 25, and 50 m^2 (Figure 4C). The temporal distribution of sampling highlights two main peaks: 2004, with 219 plots, and 2013 with 285 plots, representing the years with the highest number of surveys conducted (Figure 4D). From 2019 to 2023, the sampling effort remained similar, with the number of surveys carried out each year ranging from 63 to 175.

The database includes 853 taxa, consisting of 809 vascular plants and 44 bryophytes. Of the more than 1,100 vascular plant species known for the study area, the lower number recorded here reflects some gaps. In particular, tree species are underrepresented, as forest habitats were marginally surveyed. Similarly, ruderal species are scarcely represented, since no plots were conducted in urban environments. Of the taxa included in the database, 63 (7% of the total) are classified as endemics of the Alps or even only the Western Alps, highlighting the high biogeographical value of the survey area. Overall, 107 species are currently assigned to at least one conservation category. Several taxa fall under multiple protection frameworks simultaneously (Figure 5A). For example, *Arnica montana*, *Artemisia genipi*, and *Trifolium saxatile* are listed under regional legislation, included in the National Red List, and reported in the Habitats Directive 92/43/EEC. At the regional level, 99 species are protected by specific legislation: 79 under Aosta Valley Regional Law no. 45/2009 and 35 under Piedmont Regional Law no. 32/1982, with 15 species shared between the two frameworks. At the national scale, 24 species are included in the National Red List, covering different categories, including Least Concern (LC), Near Threatened (NT), and Endangered (EN), while approximately half of them are classified as Data Deficient (DD). Finally, 10 species are of community concern and are listed in the Habitats Directive (92/43/EEC) under annexes II, IV, and V (Figure 5B).

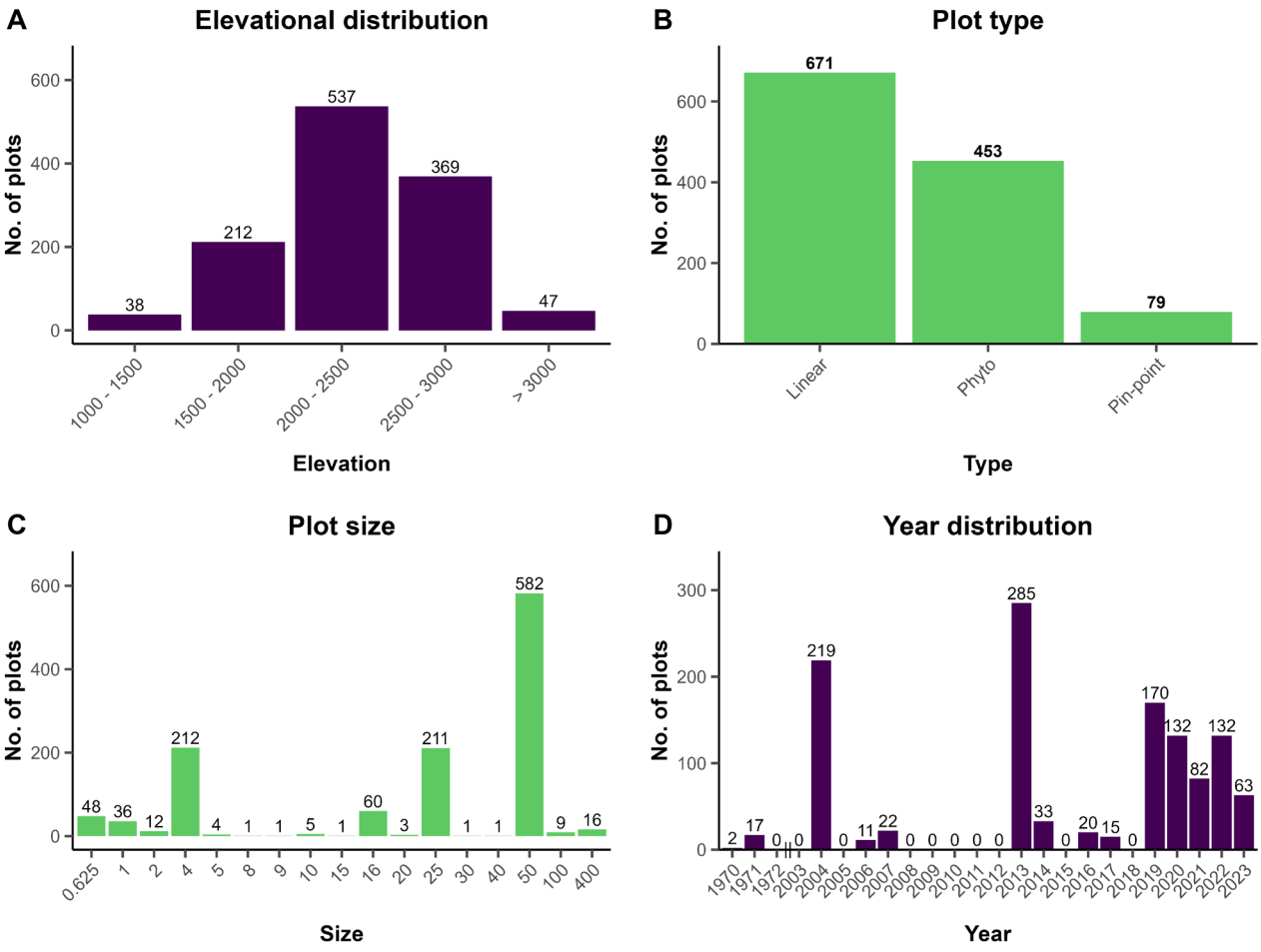


Figure 4. Overview of vegetation plots within Gran Paradiso National Park. A) Elevational distribution of the plot across classes (m a.s.l.); B) Distribution of the different types of vegetation plots, Linear = linear survey, Phyto = traditional phytosociological relevés based on different scales (Percentage cover, Braun-Blanquet and its modified versions, and the Pignatti scale), Pin-point = pin-point method; C) Distribution of the different plot sizes; D) Temporal distribution showing the years in which surveys were conducted.

The vast majority of the plots were classified as 'Grasslands and lands dominated by forbs, mosses, or lichens' (code R; $n = 837$), with more than half assigned to 'Alpine and subalpine grasslands' (code R4; $n = 423$) (Figure 6). 'Wetlands' (code Q; $n = 74$) and 'Inland habitats with no or little soil and sparse vegetation' (code U; $n = 66$) followed, with smaller contributions from 'Heathlands, scrub and tundra', 'Forests and other wooded land', 'Inland waters', and 'Vegetated man-made habitats'. Finally, 131 vegetation plots remained unclassified, primarily due to lack of diagnostic species cover and the presence of transitional vegetation types that did not reach the membership thresholds required by the expert system. Overall, this classification reflects the high-elevation character of the Gran Paradiso National Park, with a dominance of open alpine habitats.

Reuse potential

The Vegetation Database of the Gran Paradiso National Park provides a reusable reference for ecological research, conservation planning, habitat assessment, and long-term monitoring from montane to nival environments. Although primarily focused on vegetation, the database can also support broader ecological applications, as vegetation strongly influences habitat structure, resource availability, microclimatic conditions, landscape dynamics, and soil processes. For this reason, the dataset may provide valuable environmental information for integrated conservation strategies targeting faunal taxa, as well as for studies on landscape evolution, habitat suitability, and soil stability.

While most of the database originates from projects not specifically designed for long-term monitoring and should therefore be regarded primarily as a historical vegetation archive, these data could still serve as a valuable starting point for future monitoring initiatives. Concurrently, the subset of 66 permanent plots already enables direct temporal comparisons, supporting targeted analyses of specific habitat dynamics.

For the scientific community, this resource offers detailed information on alpine vegetation composition, structural heterogeneity, and habitat distribution. By consolidating decades of field surveys into a standardised and validated framework, the database provides a robust baseline for phytosociological research, vegetation classification, ecological comparison, and supporting future ecosystem monitoring. This is particularly relevant in sensitive mountain environments, where the combined effects of climate change and land-use change are rapidly reshaping high-elevation ecosystems.

The availability of georeferenced, harmonised, and validated data also increases the potential for reuse in large-scale comparative studies. The database contributes to regional, national, and international vegetation-plot networks, improving the representation of alpine ecosystems in broader analyses of biodiversity patterns, habitat change, and vegetation responses to global environmental change.

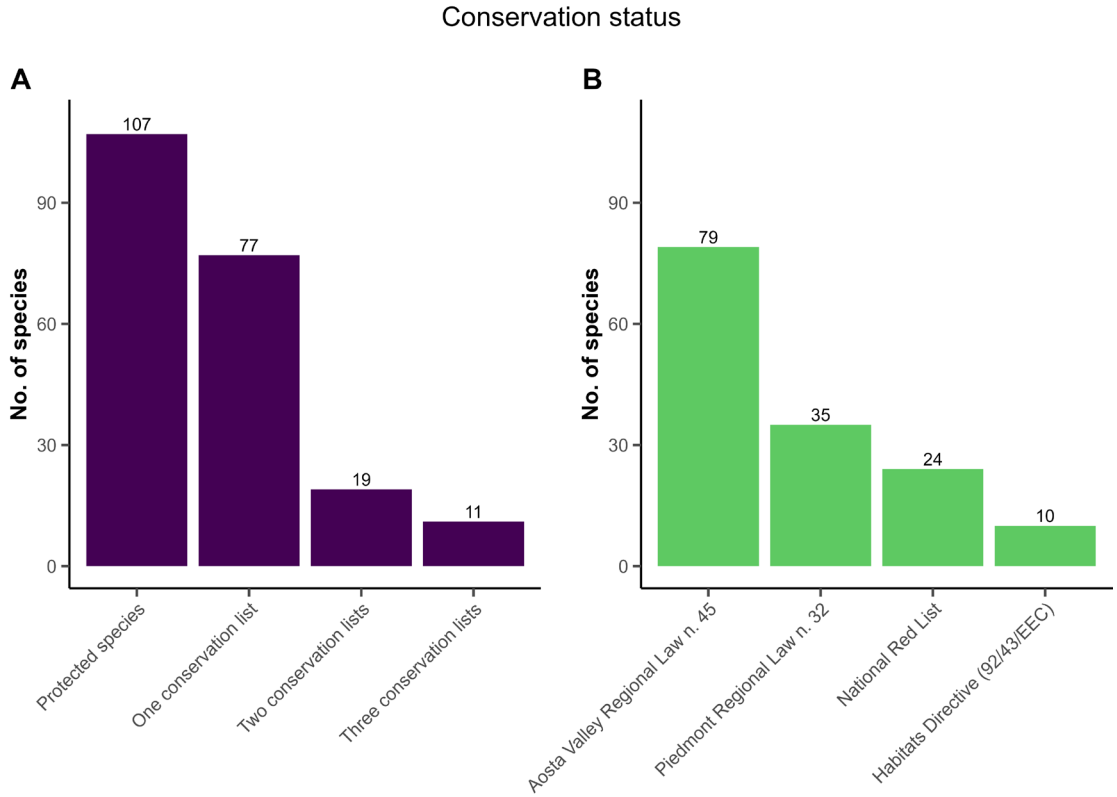


Figure 5. Conservation status of documented taxa. A) Total number of species with conservation status and the number of species included in multiple conservation lists simultaneously; B) Number of species found within each specific conservation framework.

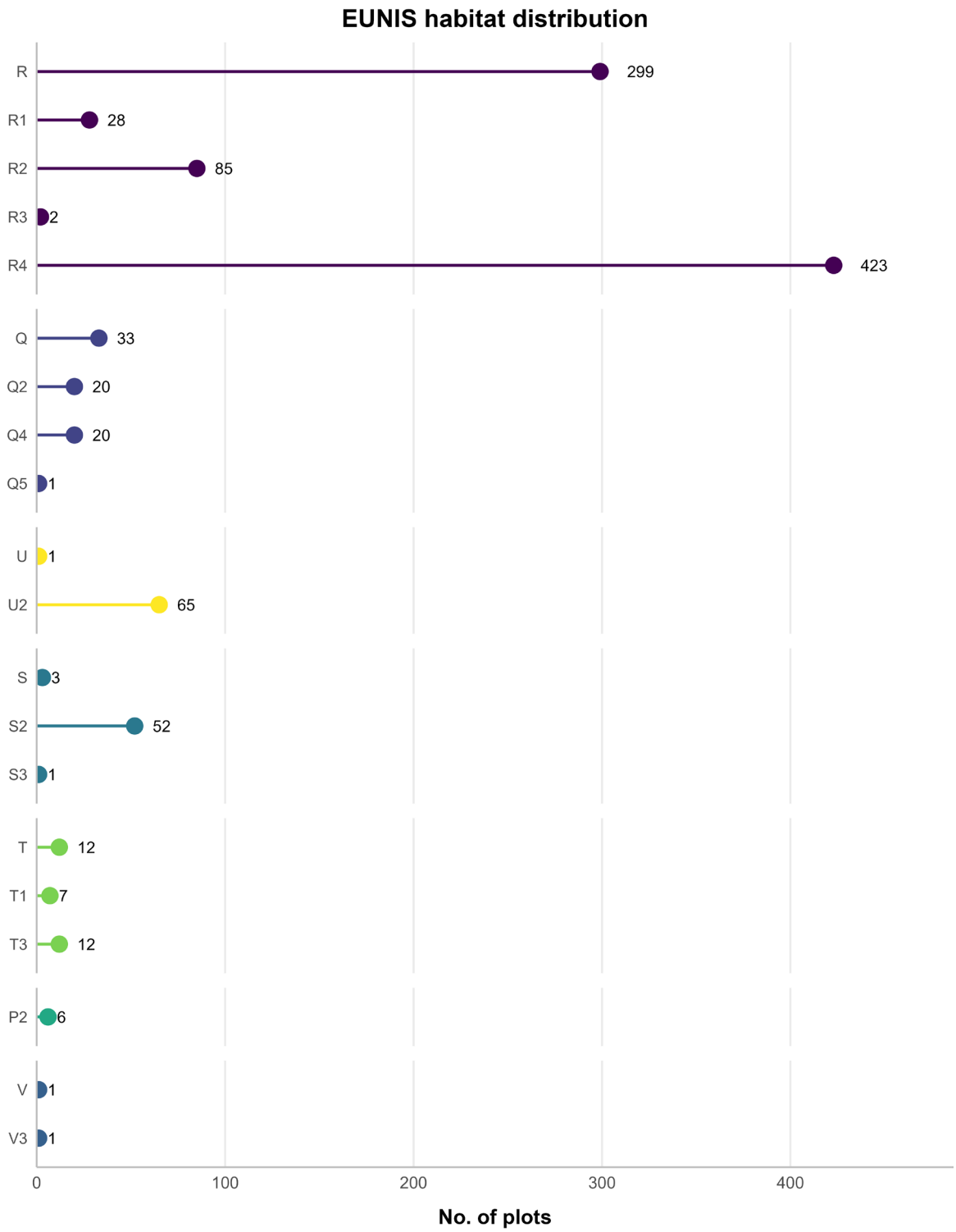


Figure 6. Distribution of vegetation plots by EUNIS habitat category. The figure reports the number of plots assigned to each EUNIS macro-category and their breakdown into subcategories. Counts represent the number of plots classified at each hierarchical level and therefore are not cumulative. R = 'Grasslands and lands dominated by forbs, mosses or lichens'; Q = 'Wetlands'; U = 'Inland habitats with no or little soil and mostly with sparse vegetation'; S = 'Heathlands, scrub and tundra'; T = 'Forests and other wooded land'; P = 'Inland waters'; V = 'Vegetated man-made habitats'.

Finally, the dataset represents a strategic resource for park managers, stakeholders, land-use planners, and local or regional administrations. By providing access to systematically organised vegetation data, it can support environmental impact assessments, habitat mapping, conservation planning, and the development of sustainable land-use policies. In this way, the database helps bridge scientific research and applied environmental management, supporting decisions that balance biodiversity conservation with socio-economic needs.

Future perspectives

This database is intended to be a dynamic resource that will be continuously updated and refined through the integration of new vegetation data collected within the Gran Paradiso National Park. Future efforts will focus particularly on improving the representation of currently under-sampled habitats, such as forests and other wooded land and inland waters, thereby increasing the completeness and representativeness of the dataset.

Looking ahead, the continued development of this resource will support tracking vegetation dynamics over time and contribute to a more comprehensive understanding of ecosystem trajectories in high-elevation environments. By highlighting current knowledge gaps, the database will also help guide future survey efforts and promote a more balanced coverage of habitats across the park.

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References

Aeschimann D, Rasolofo N, Theurillat JP (2011) Analyse de la flore des Alpes. II: Biodiversité et chorologie. Candollea 66: 225–253. https://doi.org/10.15553/c2011v662a1

Aleffi M, Cogoni A, Poponessi S (2023) An updated checklist of the bryophytes of Italy, including the Republic of San Marino and Vatican City State. Plant Biosystems 157: 1259–1307. https://doi.org/10.1080/11263504.2023.2284136

Bartolucci F, Peruzzi L, Galasso G, Alessandrini A, Ardenghi NMG, Bacchetta G, Banfi E, Barberis G, Bernardo L, … Conti F (2024) A second update to the checklist of the vascular flora native to Italy. Plant Biosystems 158: 219–296. https://doi.org/10.1080/11263504.2024.2320126

Baumann E, Weiser F, Chiarucci A, Jentsch A, Dengler J (2016) Diversity and functional composition of alpine grasslands along an elevational transect in the Gran Paradiso National Park (NW Italy). Tuexenia 36: 337–358. https://doi.org/10.14471/2016.36.015

Bertolli A, Adorni M, Alessandrini A, Andreatta S, Ardenghi NMG, Argenti C, Bona E, Bovio M, Dellavedova R, … Wilhalm T (2024) Flora endemica nel Nord Italia. Athesia; Fondazione Museo Civico Rovereto. Athesia Buch, Bolzano, IT.

Bonari G, Knollová I, Vlčková P, Xystrakis F, Çoban S, Sağlam C, Didukh YP, Hennekens SM, Acosta ATR, … Chytrý M (2019) CircumMed Pine Forest Database: An electronic archive for Mediterranean and Submediterranean pine forest vegetation data. Phytocoenologia 49: 311–318. https://doi.org/10.1127/phyto/2019/0311

Bonari G (2025) Who identified the plants? Reclaiming plant identification expertise in vegetation science. Applied Vegetation Science 28: e70046. https://doi.org/10.1111/avsc.70046

Braun-Blanquet J (1932) Plant sociology: The study of plant communities. McGraw-Hill, New York, US.

Bruelheide H, Dengler J, Jiménez-Alfaro B, Purschke O, Hennekens SM, Chytrý M, Pillar VD, Jansen F, Kattge J, … Zverev A (2019) sPlot – A new tool for global vegetation analyses. Journal of Vegetation Science 30: 161–186. https://doi.org/10.1111/jvs.12710

Brusa G, Cerabolini BEL, Dalle Fratte M, De Molli C (2017) Protocollo operativo per il monitoraggio regionale degli habitat di interesse comunitario in Lombardia (Versione 1.1). Università degli Studi dell'Insubria – Fondazione Lombardia per l'Ambiente.

Capotorti G, Zavattero L, Anzellotti I, Burrascano S, Frondoni R, Marchetti M, Marignani M, Smiraglia D, Blasi C (2012) Do national parks play an active role in conserving the natural capital of Italy? Plant Biosystems 146: 258–265. https://doi.org/10.1080/11263504.2012.695298

Chang W, Cheng J, Allaire J, Sievert C, Schloerke B, Xie Y, Allen J, McPherson J, Dipert A, Borges B (2025) shiny: Web application framework for R. R package version 1.11.1. https://CRAN.R-project.org/package=shiny

Chytrý M, Otýpková Z (2003) Plot sizes used for phytosociological sampling of European vegetation. Journal of Vegetation Science 14: 563–570. https://doi.org/10.1111/j.1654-1103.2003.tb02183.x

Chytrý M, Hennekens SM, Jiménez-Alfaro B, Knollová I, Dengler J, Jansen F, Landucci F, Schaminée JHJ, Aćić S, … Yamalov S (2016) European Vegetation Archive (EVA): An integrated database of European vegetation plots. Applied Vegetation Science 19: 173–180. https://doi.org/10.1111/avsc.12191

Chytrý M, Tichý L, Hennekens SM, Knollová I, Janssen JAM, Rodwell JS, Peterka T, Marcenò C, Landucci F, … Schaminée JHJ (2020) EUNIS Habitat Classification: Expert system, characteristic species combinations and distribution maps of European habitats. Applied Vegetation Science 23: 648–675. https://doi.org/10.1111/avsc.12519

Chytrý M, Řezníčková M, Novotný P, Holubová D, Preislerová Z, Attorre F, Biurrun I, Blažek P, Bonari G, … Axmanová I (2024) FloraVeg. EU—An online database of European vegetation, habitats and flora. Applied Vegetation Science 27: e12798. https://doi.org/10.1111/avsc.12798

Daget P, Poissonet J (1971) Une méthode d'analyse phytologique des prairies: Critères d'application. Annales Agronomiques 22: 5–41.

Dengler J, Jansen F, Glöckler F, Peet RK, De Cáceres M, Chytrý M, Ewald J, Oldeland J, Lopez-Gonzalez G, … Spencer N (2011) The Global Index of Vegetation-Plot Databases (GIVD): a new resource for vegetation science. Journal of Vegetation Science 22: 582–597. https://doi.org/10.1111/j.1654-1103.2011.01265.x

Easterday K, Paulson T, DasMohapatra P, Alagona P, Feirer S, Kelly M (2018) From the field to the cloud: a review of three approaches to sharing historical data from field stations using principles from data science. Frontiers in Environmental Science 6: Article 88. https://doi.org/10.3389/fenvs.2018.00088

Ellenberg D, Mueller-Dombois D (1974) Aims and methods of vegetation ecology. Wiley, New York, US, 547 pp.

Franklin J, Regan HM, Syphard AD (2014) Linking spatially explicit species distribution and population models to plan for the persistence of plant species under global change. Environmental Conservation 41: 97–109. https://doi.org/10.1017/S0376892913000453

Galasso G, Conti F, Peruzzi L, Alessandrini A, Ardenghi NMG, Bacchetta G, Banfi E, Barberis G, Bernardo L, … Bartolucci F (2024) A second update to the checklist of the vascular flora alien to Italy. Plant Biosystems 158: 297–340. https://doi.org/10.1080/11263504.2024.2320129

Gran Paradiso National Park (2022) Checklist. https://www.pngp.it/natura-e-ricerca/conservazione-e-ricerca/checklists [accessed 10 Mar 2026]

Hennekens SM (2015) Turboveg v.3 – a gateway to EVA and other databases. In: Chytrý M, Zelený D, Hettenbergerová E (Eds) 58th Annual Symposium of the International Association for Vegetation Science: understanding broad-scale vegetation patterns – abstracts. Masaryk University, Brno, CZ, 152–152.

Kennedy KA, Addison PA (1987) Some considerations for the use of visual estimates of plant cover in biomonitoring. Journal of Ecology 75: 151–157. https://doi.org/10.2307/2260541

Klopsch C, Terracina N, Dengler J, Adulhak S, Argagno O, Becker T, Becker U, Berastegi A, Biurrun I, … Vynokurov D (2025) The GrassPlot dataset EU-R sampled during the 18th EDGG Field Workshop 2024 in the south-western inner-alpine valleys in France and Italy. Palaearctic Grasslands 63: 27–35. https://doi.org/10.21570/EDGG.PG.63.27-35

Landucci F, Acosta ATR, Agrillo E, Attorre F, Biondi E, Cambria VE, Chiarucci A, Del Vico E, De Sanctis M, … Venanzoni R (2012) VegItaly: The Italian collaborative project for a national vegetation database. Plant Biosystems 146: 756–763. https://doi.org/10.1080/11263504.2012.740093

Levy EB, Madden EA (1933) The point method of pasture analysis. New Zealand Journal of Agriculture 46: 267–279.

Lindenmayer DB, Likens GE (2009) Adaptive monitoring: A new paradigm for long-term research and monitoring. Trends in Ecology & Evolution 24: 482–486. https://doi.org/10.1016/j.tree.2009.03.005

Mainetti A, Ravetto Enri S, Pittarello M, Lombardi G, Lonati M (2023) Main ecological and environmental factors affecting forage yield and quality in alpine summer pastures (NW Italy, Gran Paradiso National Park). Grass and Forage Science 78: 254–267. https://doi.org/10.1111/gfs.12609

Mercalli L (2003) Atlante climatico della Valle d'Aosta. Torino: Società Meteorologica Subalpina. Torino, IT, 405 pp.

Mertel A, Knollová I, Chytrý M (2025) EVA-MAP: An online application to visualize European vegetation data. IAVS Bulletin 2025(3): 22–25. https://doi.org/10.21570/BUL-202503-8

Ministry of the Environment and Energy Security (2026) Schede e cartografie. https://www.mase.gov.it/portale/web/guest/schede-e-cartografie [accessed 9 Mar 2026]

Morgese S, Casale F, Movedi E, Confalonieri R, Bocchiola D (2024) Modelling the effects of potential climate change on the dynamics of multi-species mountain pastures: A case study in Gran Paradiso National Park, Italy. Agricultural Systems 217: 103942. https://doi.org/10.1016/j.agsy.2024.103942

Mosso PG, Tortorelli M [Eds] (2025) Oltre i ghiacciai. Crisi climatica e nuovi equilibri nel Parco Nazionale Gran Paradiso. Franco Cosimo Panini, Modena, IT.

Nota G, Ravetto Enri S, Lonati M, Mainetti A (2025) Faster than expected: 5-year re-surveys reveal accelerating plant colonization in two proglacial forelands of the Gran Paradiso National Park (NW Italian Alps). Botanical Journal of the Linnean Society 207: 266–278. https://doi.org/10.1093/botlinnean/boae043

Orusa T, Borgogno Mondino E (2021) Exploring short-term climate change effects on rangelands and broad-leaved forests by free satellite data in Aosta Valley (Northwest Italy). Climate 9: 47. https://doi.org/10.3390/cli9030047

Pignatti S (1952) Introduzione allo studio fitosociologico della pianura veneta orientale con particolare riguardo alla vegetazione litoranea. Archivio Botanico 28: 265–329.

Pittarello M, Lonati M, Gorlier A, Perotti E, Probo M, Lombardi G (2018) Plant diversity and pastoral value in alpine pastures are maximized at different nutrient indicator values. Ecological Indicators 85: 518–524. https://doi.org/10.1016/j.ecolind.2017.10.064

Poussin C, Guigoz Y, Palazzi E, Terzago S, Chatenoux B, Giuliani G (2019) Snow cover evolution in the Gran Paradiso National Park, Italian Alps, using the Earth Observation Data Cube. Data 4: Article 138. https://doi.org/10.3390/data4040138

Rossi G, Orsenigo S, Gargano D, Montagnani C, Peruzzi L, Fenu G, Abeli T, Alessandrini A, Astuti G, … Blasi C (2020a) Lista rossa della flora italiana. 1. Specie non endemiche. Roma: Comitato Italiano IUCN e Ministero dell'Ambiente e della Tutela del Territorio e del Mare.

Rossi G, Orsenigo S, Gargano D, Montagnani C, Peruzzi L, Fenu G, Abeli T, Alessandrini A, Astuti G, … Blasi C (2020b) Lista rossa della flora Italiana. 2. Endemiti e altre specie minacciate. Roma: Comitato Italiano IUCN e Ministero dell'Ambiente e della Tutela del Territorio e del Mare.

Sabatini FM, Lenoir J, Hattab T, Arnst EA, Chytrý M, Dengler J, De Ruffray P, Hennekens SM, Jandt U, … Bruelheide H (2021) sPlotOpen – An environmentally balanced, open-access, global dataset of vegetation plots. Global Ecology and Biogeography 30: 1740–1764. https://doi.org/10.1111/geb.13346

Schaminée JHJ, Hennekens SM, Chytrý M, Rodwell JS (2009) Vegetation-plot data and databases in Europe: An overview. Preslia 81: 173–185.

Stendardi L, Dibari C, Bassignana M, Bindi M, Brilli L, Choler P, Cremonese E, Filippa G, Piccot A, Argenti G (2023) Pasture areas in the Gran Paradiso National Park. Journal of Maps 19: 2120835. https://doi.org/10.1080/17445647.2022.2120835

Tiberti R, Tartari GA, Marchetto A (2010) Geomorphology and hydrochemistry of alpine lakes in the Gran Paradiso National Park, Italy. Journal of Limnology 69: 242–256. https://doi.org/10.4081/jlimnol.2010.242

Urbano F, Viterbi R, Pedrotti L, Vettorazzo E, Movalli C, Corlatti L (2024) Enhancing biodiversity conservation and monitoring in protected areas through efficient data management. Environmental Monitoring and Assessment 196: Article 12. https://doi.org/10.1007/s10661-023-11851-0

Wiesner L, Baumann E, Weiser F, Beierkuhnlein C, Jentsch A, Dengler J (2015) Scale-dependent species diversity in two contrasting dry grassland types of an inner alpine dry valley (Cogne, Aosta Valley, Italy). Bulletin of the Eurasian Dry Grassland Group 29: 10–17.

Wood CM, Metzger MJ, Bunce RGH (2025) Protecting the Bunce legacy: lessons learned from safeguarding long-term ecological survey datasets in Great Britain. Environmental Management 75: 1872–1885. https://doi.org/10.1007/s00267-025-02175-5

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Artificial Intelligence (AI) use

Large language models (LLMs) were used to check spelling and improve the readability of the manuscript. The authors carefully reviewed and verified all outputs and took full responsibility for the content of the manuscript.

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Author contributions

DC wrote the text with major contributions from AM and GBo. AM, ML, GN, MP, SRE, and GBr collected and harmonised the data. DC analysed the data and prepared the figures. All authors commented on the manuscript.

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Data availability

The data is nested in the CircumMed database and CircumMed Resurvey database (GIVD: EU-00-026) with semi-restricted access regime. Data will be available in EVA and sPlot through CircumMed after its next update planned at the beginning of 2027. In addition, data can be directly requested to the Park administration and to the VegItaly Management Committee for national projects.

Supplementary material

Supplementary material 1
Scales conversion methodologies (.pdf)
Link: https://doi.org/10.3897/VCS.196748.suppl1

Supplementary material 2
Database fields (.xlsx)
Link: https://doi.org/10.3897/VCS.196748.suppl2