

REVIEW ARTICLE

Uruguay's Online Flora: A new resource connecting science, society, and conservation

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Abstract Floras and botanical collections are essential tools for understanding plant diversity, promoting its conservation, and supporting a wide range of scientific applications. Uruguay, located in the biodiverse grassland region of southern South America, has had only an incomplete Flora, the most comprehensive of which was published more than a century ago. We review the country's flora and the history of its study, and introduce the new Flora Uruguay Online (FUO; <https://florauruguay.org>), which when completed will provide a comprehensive record of all vascular plant species, including information on their distribution, morphological, ecological, and phenological characteristics. This online Flora presently contains information on 182 families, 1053 genera, and 3112 species, 85.4% of which are native to Uruguay and 2.2% endemic. Although Uruguay accounts for only 25% of the surface area of the

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Río de la Plata Grasslands, it contains over 60% of their species and more than 50% of their endemic taxa, reflecting its core geographical position. Uruguay's flora faces increasing pressure from land-use change, habitat fragmentation, and invasive species. FOU provides critical support for addressing these challenges, offering systematic botanical data for basic and applied research, conservation, sustainable uses, and land management, including practical applications such as the identification of toxic plants affecting livestock production. We highlight key features of FOU with its research-enabling tools for the exploration of Uruguay's botanical richness by scientists, as well as by policymakers, educators, conservationists, and citizens. These features include its accessibility, interactivity, multiple filters (e.g., geographic regions, ecological characteristics, conservation status, or specific species attributes), rich graphics, and multiple sources of data inputs tied to herbarium specimens.

Keywords biodiversity; botanical history; *campos*; citizen science; collections; endemism; grasslands; Pampean province; South America

■ INTRODUCTION TO URUGUAY'S FLORA: HISTORY, COMPOSITION, AND THREATS

A Flora is a scientific resource that compiles essential information—typically including names, descriptions, and identification keys—about the plants of a specific geographic area and is designed to offer a comprehensive and accessible reference that spares users the need to consult dispersed and often hard-to-find taxonomic literature (Davis & Heywood, 1963; Heywood, 1984; Frodin, 2001; Knapp, 2008). Since the sixteenth century, botanists have produced Floras that have laid the groundwork for understanding plant diversity and significantly advanced scientific progress in this field (Frodin, 2001). Floras are pillars of biodiversity research, providing indispensable tools to address questions of great scientific relevance (Funk, 2006; Miller & al., 2015) and to establish objective criteria for conservation policies (Forest & al., 2007; Nic Lughadha & al., 2018; Wagensommer, 2023). These foundational works underpin the generation of applied knowledge across numerous fields and also inform public policy on land use and management. Closely tied to Floras, botanical collections in herbaria represent the primary source of information on plants (Funk, 2003; Lavoie, 2013; Nualart & al., 2017; Soltis, 2017; López & Sassone, 2019). They document change by preserving the history of our planet, trace our interaction with nature, and help decipher the future of biodiversity (Crisci & Katinas, 2017).

Floras have gained increasing relevance in the twenty-first century, as demonstrated by the rise of digital platforms and global efforts such as the World Flora Online initiative (Borsch & al., 2020; <https://www.worldfloraonline.org/>), which aims to compile a comprehensive Flora of all known plant species. That initiative emerged as one of the likely outcomes of the Global Strategy for Plant Conservation, adopted under the Convention on Biological Diversity (CBD)—to which Uruguay is a signatory (<https://www.impo.com.uy/bases/leyes/16408-1993>)—which called for improved access to information on plant diversity as a basis for conservation and sustainable use. In South America, there are national and collaborative efforts at digital regional Floras, such as the Flora Argentina (<http://www.floraargentina.edu.ar/>), Flora del Cono Sur (<http://conosur.floraargentina.edu.ar/>), and the Flora e Função do Brasil (BFG, 2021; <https://reflora.jbrj.gov.br/>). Digital Floras allow for continuous updates

(Martellos, 2012) and provide access to underlying documentation (i.e., specimen records) and other added value (e.g., mapping). One notable example of how such tools are used, that transcends both geographic and political boundaries, is the study by Andrade & al. (2018), who analyzed species richness in the Río de la Plata Grasslands (RPGL). Their work stands out for assembling the first taxonomically verified, region-wide vascular plant checklist for this extensive temperate grassland system, enabling cross-border comparisons and establishing a critical baseline for future biogeographic and conservation research. In a global context of documented biodiversity loss driven by various components of global change (Cardinale & al., 2012; Díaz & al., 2019; IPBES, 2019; Pereira & al., 2020; WWF, 2024), it is critical to have a reliable source of information on national biodiversity and its distribution. This knowledge is essential for making informed decisions about sustainable land use, especially in regions such as Uruguay, where environmental heterogeneity and localized biodiversity patterns play a significant role.

Situated in southeastern South America (30°S–35°S), Uruguay is a country of moderate size (176,215 km²) and relatively uniform, low-elevation topography (0–513 m). Its climate is warm-temperate, humid, and markedly seasonal with limited regional variation (Kottek & al., 2006; Castaño & al., 2011; Rossado & al., 2024). Bioclimatically, Uruguay occupies a transitional zone between the humid subtropics to the north and the cooler, drier temperate regions to the south. This intermediate location supports predominantly temperate grasslands (*campos*), which form part of the extensive RPGL, one of the largest grassland regions in the world, including parts of Argentina and Brazil (Soriano & al., 1992; Oyarzabal & al., 2019).

The remarkable biological diversity of the RPGL is underscored by the record of 63 vascular plant species in a single 1 × 1 m plot of shallow-soil grassland in southern Uruguay (Pañella & al., 2020), and 56 species in a comparable plot in adjacent areas of Rio Grande do Sul, Brazil (Menezes & al., 2018; Menezes & al., 2022). Grasslands dominate the Uruguayan landscape, while native forests and shrublands are primarily restricted to riparian corridors, hills, and ravines (Toranza & al., 2019; Bergamin & al., 2024). Although forests cover only ~6% of the national territory (Betancourt, 2021), their distribution amid extensive grasslands creates a complex biogeographic mosaic. Floristically, the country

belongs to the Pampean biogeographic province, with strong affinities to the Paranaense province in the north, and influences of the Atlantic and Chaco provinces in the east and west respectively (Cabrera & Willink, 1973; Brussa & Grela, 2007; Haretche & al., 2012). Consistent with this setting, recent phylogenetic evidence indicates that most angiosperm lineages occurring in the RPGL have diverged relatively recently, coinciding with biogeographic transitions from neighboring regions into the Pampa domain. Moreover, lineages resulting from *in situ* diversification within the region also appear to be of recent origin, particularly within the last 5 million years (Baez-Lizarazo & al., 2024).

The presence of southern or eastern distributional limits for many plant species in Uruguay (Brussa & Grela, 2007; Haretche & al., 2012; Pérez-Quesada & Brazeiro, 2013; Toranza & al., 2024) promotes genetic differentiation among plant populations, as documented in species such as *Eugenia uniflora* L. (Myrtaceae; Turchetto-Zolet & al., 2016), *Feijoa sellowiana* (O.Berg) O.Berg (Myrtaceae; Rivas & al., 2024), *Ilex paraguariensis* A.St.-Hil. (Aquifoliaceae; Hernández, 2019), and *Turnera sidoides* L. (Passifloraceae; Speranza & al., 2007). In several cases, this differentiation has been interpreted as an adaptive response to past climatic fluctuations (particularly during the Quaternary) and the establishment of climatic refugia and long-term genetic isolation (Speranza & al., 2007; Jolochin, 2016; Moreno & al., 2018; Hernández, 2019). Uruguay appears to be an area harboring marginal populations of several species especially susceptible to climatic fluctuations, which underscores the importance of understanding and systematically recording the evolution of the country's plant diversity in light of climate change projections. These patterns of genetic differentiation and paleoclimatic adaptation emphasize not only the scientific value of Uruguay's flora, but also the critical need for comprehensive, well-documented biodiversity data. Despite some progress, access to biodiversity data on Uruguay, such as from herbarium collections, remains very limited. Initiatives such as Biodiversidata, the Uruguayan Biodiversity Data Consortium, have sought to promote data openness through digitalization, standardization, and publication (Grattarola & al., 2019, 2020). Nevertheless, significant challenges persist, making it difficult for national research institutions, museums, and government agencies to manage and provide digital, open-access data (Grattarola & Pincheira-Donoso, 2019; Grattarola & al., 2024).

Uruguay's biodiversity is endangered by human activities. Recent studies have documented the harmful effects of native-habitat destruction (Tiscornia & al., 2014; Brazeiro & al., 2020; Ríos & al., 2022; Mello & al., 2023) and invasions by non-native species (Sosa & al., 2018; Romero & al., 2021; Brazeiro & al., 2024; Guido & al., 2024). These studies emphasized the need for well-documented knowledge on local diversity to develop effective conservation and management plans. In response to these needs, the Flora Uruguay Online (FUO) project was developed by Uruguayan botanists with contributions from international specialists. This paper

provides an overview of Uruguay's vascular flora (Marchesi & al., 2025), formally introduces the FUO project, and outlines its development stages. The platform is publicly accessible at <https://florauruguay.org>.

Main contributors to the study of Uruguayan flora. —

The earliest records of plants in Uruguay date back to observations made in the eighteenth and nineteenth centuries by European explorers such as Jeanne Baret (1740–1807), Philibert Commerson (1727–1773), Augustin de Saint-Hilaire (1779–1853), Friedrich Sellow (1789–1831), John Tweedie (1775–1862), Arsène Isabelle (1806–1888), Alcide D'Orbigny (1802–1857), Adelberto von Chamisso (1781–1838), Joseph Hooker (1817–1911), and Charles Darwin (1809–1882), who had access to Uruguayan plants (Arechavaleta, 1898–1911; Ridley, 2010). One of the most influential and essential regional publications of this period was *Flora Brasiliensis*, coordinated by Carl Martius, in which over 100 taxa are based on type material collected in Uruguay and many other species now recorded for the country were first described or illustrated (Martius, 1840–1906). Building on this foundational work, generations of Uruguayan botanists developed a strong tradition of botanical exploration, species documentation, and herbaria development (Fig. 1). These national contributors have played a central role in advancing knowledge of the country's flora and are highlighted in the brief profiles that follow.

Dámaso Antonio Larrañaga (1771–1848), a prominent figure in Uruguayan history and culture, is considered the country's first scientific authority (Fig. 2A) and was one of the most important scientists in South America at the time. A self-taught naturalist, he worked in various fields including zoology, paleontology, and botany, and made a lasting contribution by assembling a valuable herbarium of native plants, enriched by expeditions across the country. He identified around 1000 species for the country, prepared more than 900 plant descriptions, and produced the first botanical illustrations made in Uruguay (Fig. 2B) (Larrañaga, 1922–1924). He maintained correspondence with prominent European naturalists including Auguste de Saint-Hilaire, who described Larrañaga as the most distinguished naturalist I have met in the Americas (“le naturaliste le plus distingué que j’aie rencontré en Amérique”; Saint-Hilaire, 1829: 144). In 1837, Larrañaga chaired a commission tasked with organizing a library and a national museum of natural history, and his collections partly formed the foundation of the institution's holdings. His scientific legacy was diminished by the loss of his herbarium and because his research was not published during his lifetime—likely due to the onset of blindness in 1825 (Klappenbach, 2004). Larrañaga's writings were published posthumously (Larrañaga, 1922–1924), which led to the near-total loss of nomenclatural authorship credit for the species he had described (Del Puerto, 1969; Klappenbach, 1997).

Ernesto José Gibert (1818–1886) was a French naturalist who emigrated to Montevideo, Uruguay in 1851 for political reasons and devoted himself to teaching (Fig. 3A). In his spare time, he assembled a significant herbarium that became the

first major plant collection in the country. His most notable publication is *Enumeratio plantarum sponte nascentium agro Montevidensi* (Gibert, 1873), which presents a list of 1178 species of vascular plants and some bryophytes, based on literature records and specimens from his herbarium. Although it lacks illustrations and descriptions, this work is considered the first floristic treatment for Uruguay in the form of a catalogue (Herter, 1930a; Fernández Saldaña, 1945; Del Puerto, 1969; Alonso Paz & Bassagoda, 2011).

José Arechavaleta (1838–1912) was born in Spain and emigrated to Uruguay at the age of 17 (Fig. 3B). He trained as a pharmacist and worked for many years as a university professor and researcher in the field of medical botany, focusing on chemistry and microbiology. A self-taught naturalist, he began his academic studies in entomology under the guidance of Gibert, but later turned to botany and began collecting plants in 1863. He served as director of the National Museum of Natural History in Montevideo and founded the *Anales del Museo Nacional*. Among his works, *Las gramíneas uruguayas* (Arechavaleta, 1894–1897) stands out, but his principal contribution is *Flora Uruguaya* (Arechavaleta, 1898–1911), which includes descriptions of over a thousand plant species, many of them new to science. Although

incomplete, Arechavaleta's *Flora Uruguaya* has remained, until now, the most comprehensive and detailed treatment of the country's plants (Caviglia, 1938; Cordero, 1939; Fernández Saldaña, 1945; Del Puerto, 1969).

Mariano Balbino Berro (1838–1918) retired from a political career in 1894 and dedicated himself to the study of natural sciences, especially botany (Fig. 3C). He collected plants across the country and ultimately assembled one of the most complete, well-documented, and best-preserved Uruguayan herbaria that contains over 9000 specimens. He documented the practical uses of plants, particularly forage species. His work *Las gramíneas de Vera* (Berro, 1906) is among his most notable, wherein he described and classified forage species according to their nutritional quality. Berro's collections resulted in the citation of numerous taxa for the first time in Uruguay, and also contributed to the description of many species new to science by other researchers, some of which were named in his honor (Villegas Suárez, 1975).

Cornelius Osten (1863–1936) was born in Germany and became a key figure in Uruguayan botany (Fig. 3D). Although his professional life was focused on business, he developed an early interest in botany and dedicated much of his resources to expanding his plant collection and acquiring botanical

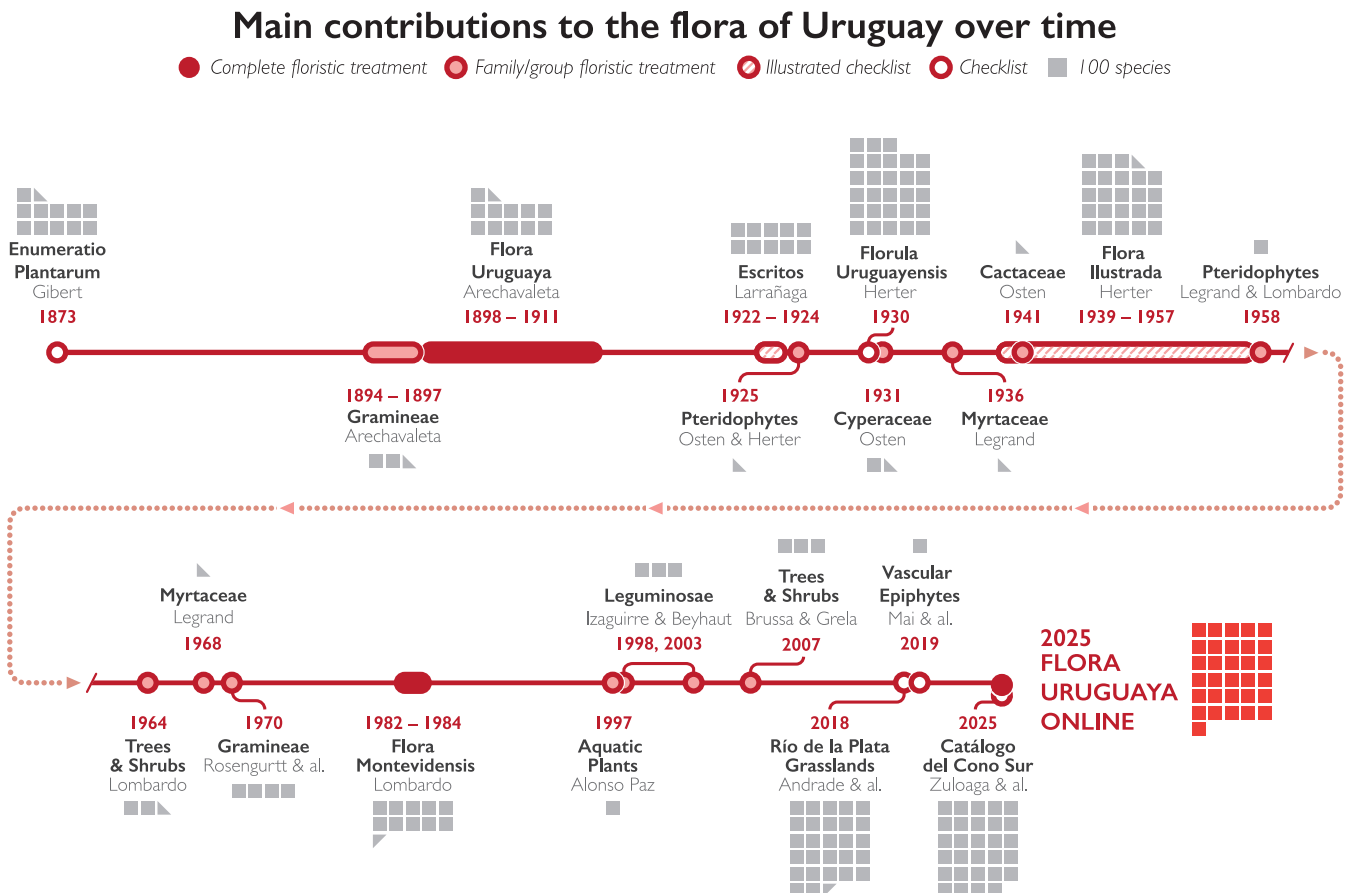


Fig. 1. Timeline of the main contributions to the flora of Uruguay. The infographic shows national or resident authors, categorized by type of contribution and the approximate number of species treated.

publications. Osten stood out for his rigor and commitment to scientific work, which was notable on Cactaceae (Osten, 1941) and Cyperaceae (Osten, 1931), and also included ferns (Osten & Herter, 1925). One of his greatest legacies was the donation of his herbarium to the National Museum of Natural History, shortly before his death. Containing around 28,000 specimens, this herbarium is among the most valuable for the study of Uruguayan and regional plants, as it also includes many collections from Argentina and Paraguay (Legrand, 1936a; Alonso Paz & Bassagoda, 2011).

Guillermo Herter (1884–1958) emigrated from Germany to Uruguay in 1907 to teach at the recently established School of Agronomy (Fig. 3E), using his extensive academic background in medicine and natural sciences from European universities. Herter played a fundamental role in the creation of the Botanical Research Section of the Institute of Higher Studies, and in 1934 he founded the *Revista Sudamericana de Botánica*. His taxonomic work resulted in many new species and combinations in several plant families and genera. He also authored numerous publications in his series *Estudios Botánicos en la Región Uruguaya*, including the influential *Florula Uruguayensis* (Herter, 1930a; 1939–1943; 1949–1956; 1952–1957), where he presented a list of more than 2700 plant species found in the country, with illustrations for most of them. He had a strong interest in ecosystem conservation, especially to protect the now endangered palm savannas of Castillos in eastern Uruguay (Herter, 1930b; Legrand, 1959; Schulkin, 1982; Alonso Paz, 2002).

Diego Legrand (1901–1982) was initially trained in the humanities before turning to natural sciences as a self-taught

scholar (Fig. 3F). In 1938, he was appointed deputy director (later serving as director) of the National Museum of Natural History, where he made significant contributions, especially in the herbarium and in the publication of the *Flora ilustrada del Uruguay* series (Legrand & Lombardo, 1958). He made notable contributions to the systematics of *Portulaca* L. (Legrand, 1942, 1953, 1962a) and Myrtaceae of Uruguay and of tropical America (Legrand, 1936b, 1961, 1962b, 1968) and published new species and taxonomic combinations (Legrand & Chebataroff, 1943, 1944; Klappenbach & Philippi, 1987). His fieldwork was hindered by health problems, and he worked primarily with herbarium material received from Argentina and Brazil. The genus *Legrandia* Kausel (Myrtaceae), endemic to central Chile, is named in his honor.

Atilio Lombardo (1902–1984) was a central figure in twentieth-century Uruguayan botany and was closely associated with the Montevideo Botanical Garden and Museum (Fig. 3G). With an early interest in plants this self-taught botanist began to collect in 1918 and assembled a herbarium of native and cultivated species, which is now preserved at the Botanical Garden. He served as its director (1940–1974), which allowed him to shape its scientific and educational mission. Lombardo's research focused on medicinal plants, cultivated species, and native flora. He published numerous works, especially aimed at general audiences (Lombardo, 1969), which were often illustrated with his own drawings. Highlights include his revision of cultivated *Eucalyptus* L'Her. species in Uruguay (Helguera & Lombardo, 1953), a work on medicinal plants (González & al., 1940), and his books *Flora*



Fig. 2. A, Dámaso Antonio Larrañaga (1771–1848), Uruguayan naturalist who made the first botanical observations on the flora of Uruguay; B, Drawing by Larrañaga of *Tarenaya trachycarpa* (Klotzsch ex Eichler) Soares Neto & Roalson (Cleomaceae), one of the earliest (likely produced between 1809–1824) plant illustrations made in the country. — Images courtesy of Archivo General de la Nación, Uruguay.

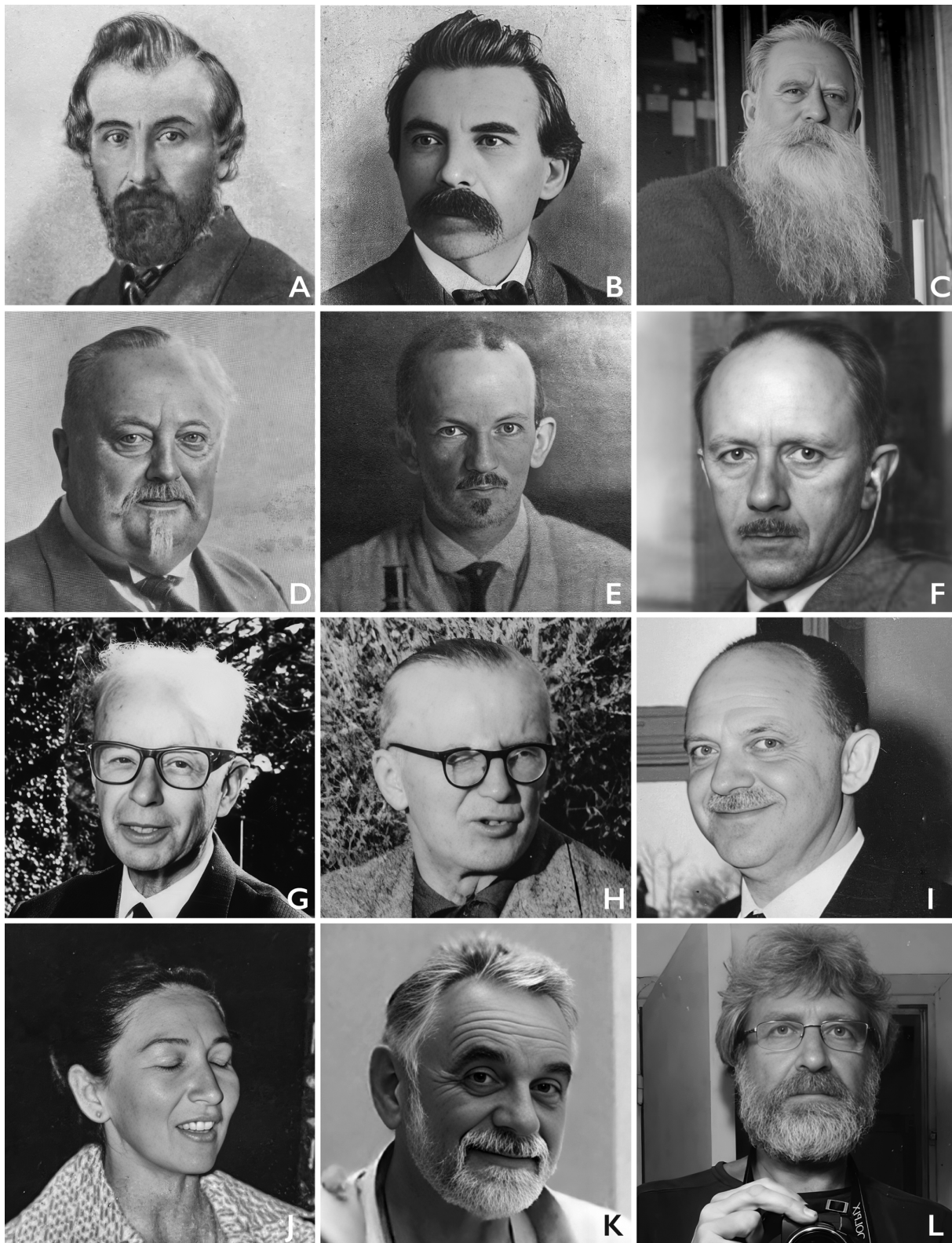


Fig. 3. Major contributors to Uruguayan botany. **A**, Ernest Gibert (1818–1886); **B**, José Arechavaleta (1838–1912); **C**, Mariano Berro (1838–1918); **D**, Cornelius Osten (1863–1936); **E**, Guillermo Herter (1884–1958); **F**, Diego Legrand (1901–1982); **G**, Atilio Lombardo (1902–1984); **H**, Jorge Chebataroff (1909–1984); **I**, Bernardo Rosengurt (1916–1985); **J**, Blanca Arrillaga (1917–2011); **K**, Orfeo Crosa (1938–2021); **L**, Eduardo Alonso Paz (1953–2016). — Photos: A–E, I & J, Courtesy of Laboratorio de Botánica, Facultad de Agronomía, Universidad de la República; F–H, courtesy of Carlos A. Brussa; K, courtesy of Marcelo Guerra (Universidade Federal de Pernambuco); L, courtesy of María Julia Bassagoda.

arborea y arborescente del Uruguay (Lombardo, 1946, 1964). *Flora Montevidensis* (Lombardo, 1982–1984), with keys, descriptions and illustrations for over 1000 species may be his most important floristic contribution. Lombardo's legacy endures both through his writings and studies as well as through his mentorship of several contemporary botanical researchers (Marchesi, 1985).

Jorge Chebataroff (1909–1984) was a professor and wide-ranging researcher in botany as well as geography, geology, geomorphology, and biogeography (Fig. 3H). He developed an interest in plants through his association with contemporaries such as Herter, Rosengurt, and Legrand, who accompanied him on his first field trips and helped him identify collections. Chebataroff explored the country extensively, reporting more than 60 species new to the flora and one new to science (Legrand & Chebataroff, 1943, 1944; Chebataroff, 1942a, 1946, 1981) and assembling a collection of over 12,000 specimens. His most significant contributions were in phytogeography, due to his integrative understanding of the relationships among flora, vegetation, geology, and geography (Chebataroff, 1936, 1938, 1952, 1960, 1974; Talice & Chebataroff, 1969). Chebataroff was the first to propose the existence of a Uruguayense Phytogeographic Province (Chebataroff, 1942b), which he distinguished from the Argentine Pampean Province. He also published several studies classifying the plant associations of the Uruguayense Province, emphasizing the relationship between environmental conditions and species distribution (Alonso Paz, 2002; Brussa, 2002).

Bernardo Rosengurt (1916–1985), a graduate of the School of Agronomy in 1939, served as a university professor and eventually became chair of botany and dean of that school (Fig. 3I). His academic and scientific career focused on the ecology, biology, and productivity of native species in Uruguay's natural grasslands. Between 1938 and 1946, he published a series of contributions titled “Estudios sobre praderas naturales del Uruguay” (Gallinal & al., 1938; Rosengurt & al., 1939; Rosengurt, 1943, 1944, 1946), notable as some of the few comprehensive studies of Uruguayan terrestrial plant communities at the time. Rosengurt subsequently focused on the taxonomic study of grasses, and his *Gramineas uruguayas*, published in collaboration with Blanca Arrillaga and Primavera Izaguirre (Rosengurt & al., 1970), combined taxonomic and agronomic knowledge. His collection of approximately 20,000 specimens formed the basis of the MVFA herbarium, which now bears his name in his honor. He was a pioneer in biodiversity conservation in Uruguay, launching efforts in the early 1980s to collect native grasses and establish a seed bank at the School of Agronomy. Rosengurt also mentored students, which was especially relevant at a time when botany was poorly promoted in Uruguay (Roig & al., 1986; Krapovickas, 1987).

Blanca Arrillaga (1917–2011) earned her degree from the School of Chemistry at the Universidad de la República (Fig. 3J). In 1951, she joined the Department of Botany at that school as a professor, and later also taught at the Schools of

Agronomy and Sciences. Throughout her career, she made valuable contributions to MVFA by carrying out collecting expeditions across the country. Her scientific work focused on the anatomical and taxonomic study of the Uruguayan flora (Arrillaga, 1968), especially for understanding the country's grasses (Rosengurt & Arrillaga, 1961, 1963, 1964; Rosengurt & al., 1968a,b, 1970, 1982). She also investigated Anacardiaceae (Arrillaga & al., 1973) and Polygalaceae (Arrillaga & Bigo de Grosso, 1980), and studied toxic plants harmful to humans and animals, as well as the use of plants in traditional medicine (Arrillaga, 1969, 1977; Arrillaga & Moyna, 1977).

Orfeo Crosa (1938–2021), associate professor of genetics at the School of Agronomy, Universidad de la República, was a central figure in the development of plant cytogenetics and biosystematics in Uruguay (Fig. 3K). He began his academic career in 1959 and, after a forced interruption during the dictatorship, resumed his position in 1985, dedicating himself to teaching, research, and student training in plant genetics. His research focused on subfamily Allioideae of Amaryllidaceae, with particular attention to the South American genera *Ipheion* Raf., *Leucocoryne* Lindl., and *Nothoscordum* Kunth (Crosa, 1975a,b, 2004; Souza & al., 2009, 2010, 2012, 2015, 2016a,b, 2019). He conducted extensive fieldwork and assembled a living collection of cultivated specimens, which supported a substantial body of work in taxonomy, cytogenetics, and morphology, including species descriptions and systematic revisions. His legacy lies not only in advancing the understanding of South American flora but also in his enduring impact as a mentor to botanists and geneticists in Uruguay and the region.

Eduardo Alonso Paz (1953–2016) was a botany professor at the School of Chemistry of the Universidad de la República (Fig. 3L), curator of its herbarium (MVFQ), and an associate researcher at the National Museum of Natural History. A biologist by training, he expanded knowledge of the country's flora and plant communities, covering various taxonomic groups, with an emphasis on coastal forest formations (Alonso Paz & Bassagoda, 1999, 2002) and wetland plants (Alonso Paz, 1997). Several of his contributions were carried out in collaboration with his life partner, María Julia Bassagoda, with whom he described *Chiropetalum puntaloberense* Alonso Paz & Bassagoda, a Uruguayan endemic (Euphorbiaceae; Alonso Paz & Bassagoda, 2009). He also worked in ethnobotany, notably authoring the book *Yuyos: Uso racional de las plantas medicinales* (Alonso Paz & al., 1992), among other publications (Marchiori, 2016).

Primavera Izaguirre (b. 1932) is a prominent Uruguayan botanist, a graduate and later professor of the School of Agronomy at the Universidad de la República, and a member of the first generation of women to enter this field (Fig. 4). She began her career at the Laboratory of Botany at the School of Agronomy, working alongside Bernardo Rosengurt and focusing on grass taxonomy. Together with Rosengurt and Arrillaga, she co-authored *Gramineas uruguayas* (Rosengurt & al., 1970). She added anatomical studies to traditional morphological approaches, and was a pioneer in the development

of plant embryology in Uruguay. In the 1990s, she initiated studies on the legumes of Uruguay, culminating in the publication of *Las Leguminosas del Uruguay y regiones vecinas* (Izaguirre & Beyhaut, 1998, 2003). In parallel, she became a key authority on the Orchidaceae of Uruguay (Izaguirre, 1972, 1973, 1985, 2010, 2013). Over her career, she conducted extensive expeditions that strengthened MVFA collections.

Co-author here Eduardo Marchesi (b. 1943) has played a foundational role in the study of Uruguayan flora. A contemporary of many of the botanists profiled above, Marchesi was invited by Rosengurt to organize the MVFA herbarium, an endeavor through which he developed a deep, firsthand understanding of the national flora. His meticulous work led to many publications (Marchesi, 1964, 1965, 1968, 1969, 1972, 1975, 1979, 1984, 1987) that then laid the groundwork for a comprehensive manuscript that would, decades later, become the starting point of FUO. Marchesi also trained a generation of botanists and his contributions form a vital link between earlier botanical efforts and the development of this initiative.

Since Marchesi's initial efforts, a new generation of researchers has emerged and revitalized the study of Uruguay's flora (Alonso Paz & Marchesi, 1988; Alonso Paz, 1989;



Fig. 4. Primavera Izaguirre (b. 1932), pioneer of Uruguayan botany and specialist on grasses and legumes. Her scientific and teaching legacy has shaped generations, especially paving the way for women in the discipline. — Photo courtesy of Laboratorio de Botánica, Facultad de Agronomía, Universidad de la República.

Brussa & Grela, 2007; Zuloaga & al., 2008, 2025; Bonifacino & al., 2009, 2020; Haretche & al., 2012; Trujillo & al., 2014, 2022; Valtierra & Bonifacino, 2014; Mai & al., 2016, 2019; Andrade & al., 2018; Rossado & al., 2018, 2024; González & Keller, 2020; Köhler & Majure, 2020; Köhler & al., 2020; Deble & al., 2021; Valtierra & al., 2021, 2023; Batista & al., 2023; Mailhos & al., 2023, 2025; Izaguirre & al., 2024). Yet despite the efforts of the botanists enumerated here, Uruguay has remained one of the few South American countries without a modern Flora project to comprehensively document its biodiversity. The country's most recent but partial Flora dates back over 100 years (Arechavaleta, 1898–1911). The launch of FUO marks the beginning of a new era by enabling detailed, systematic, and openly accessible knowledge of Uruguay's flora and biodiversity.

Synopsis of Uruguay's flora. — Uruguay's vascular flora comprises 3112 species distributed across 1053 genera and 182 families. The ten most diverse families account for 53.3% of all species (1658 spp.), with Compositae (426 spp.), Gramineae (419 spp.), and Leguminosae (253 spp.) leading in species richness (Fig. 5). This pattern closely resembles that observed in the adjacent grasslands of southern Rio Grande do Sul, Brazil (Boldrini, 2009; Andrade & al., 2023). A similar dominance of these families has also been reported for Argentina—a country largely covered by grasslands and arid lands—underscoring the floristic continuity across the Southern Cone (Zuloaga & al., 1999). The most diverse genera in descending order are *Baccharis* L. (Compositae; 51 spp.) and *Paspalum* L. (Gramineae; 46 spp.), *Cyperus* L. (Cyperaceae; 43 spp.), *Mimosa* L. (Leguminosae; 41 spp.), *Solanum* L. (Solanaceae) and *Nassella* (Trin.) É.Desv. (Gramineae) (25 spp. each), *Senecio* L. (Compositae) and *Oxalis* L. (Oxalidaceae) (24 spp. each), *Eleocharis* R.Br. (Cyperaceae), *Euphorbia* L. (Euphorbiaceae) and *Rhynchospora* Vahl (Cyperaceae) (23 spp. each). Of the total number of vascular plant species, 85.4% (2657 spp.) are native and 14.6% (455 spp.) are exotic (Fig. 6). Among the native species, 69 are endemic to Uruguay, and 167 are considered regional endemics (i.e., species whose distribution includes Uruguay and marginally extends into adjacent geographic provinces; Figs. 6, 7) that form part of the Uruguayan region (Rio Grande do Sul in Brazil, and the Argentine provinces of Entre Ríos, Corrientes, and Buenos Aires). The 69 species endemic to Uruguay are distributed among 24 families, although this diversity is unevenly concentrated: Compositae (13 spp.), Gramineae (10 spp.), and Iridaceae (5 spp.) together account for 40.6% of the total, while the remaining 41 species are scattered across 21 other families. Similarly, the regional endemics are found in 25 families, with 4 families—Gramineae (25 spp.), Leguminosae (23 spp.), Iridaceae (22 spp.), and Compositae (12 spp.)—concentrating nearly 49.1% of all species, despite representing only 16% of the families involved. This concentration of both national and regional endemics reflects the abundance of open habitats

such as grasslands, where these families typically occur (Figs. 7, 8).

As to life forms, Uruguay's flora is dominated by herbaceous species, that account for 76.0% (2367 spp.) of the total and is consistent with the widespread RPGL ecosystem (Soriano & al., 1992; Andrade & al., 2018, 2023). Shrubs and suffrutices make up 15.8% (491 spp.), while trees represent only 5.1% (158 spp.). The remaining 3.1% consists of woody climbers (96 spp.; Fig. 6). Although the country covers only about 25% of the RPGL area, it harbors over 60% of the region's recorded species diversity. Moreover, 53.4% of the species reported as endemic to the RPGL occur in Uruguay (Andrade & al., 2018), underscoring the country's central role in the conservation of this floristic heritage. The distribution of species diversity aligns with the dominant vegetation types in Uruguay, with the majority of species (1977 spp.) occurring in grassland communities (Figs. 6, 9). However, a significant proportion occur in forests (999 spp.), which are relatively evenly distributed throughout the country (Figs. 6, 10).

Land-use change and biological invasions as threats to the flora. — Biodiversity in Uruguay faces multiple pressures that compromise the ecological integrity of its ecosystems and have endangered several species (Fig. 11). Among the primary threats are land-use changes driven by the expansion of intensive-production systems such as plantation forestry and food crops, as well as overgrazing for livestock production. These activities replace natural communities and fragment habitats, which is particularly damaging in ecologically heterogeneous and floristically rich areas like hill and ridge zones (Tiscornia & al., 2014; Baeza & Paruelo, 2020; Brazeiro & al., 2020; Guido & al., 2025; MapBiomias, 2025). Increasing urbanization in coastal regions exerts intense pressure on those fragile and ecologically sensitive habitats (e.g., Castiñeira Latorre & al., 2013; Puppo & al., 2020; Mai & al., 2022). These processes underscore the urgent need for integrated conservation policies that consider the specific ecological features of each environment alongside the socioeconomic dynamics that influence them. In addition, an increasing threat is posed by invasive alien species such as *Gleditsia triacanthos* L. (Leguminosae), *Ligustrum lucidum* W.T.Aiton (Oleaceae), and *Pittosporum undulatum* Vent. (Pittosporaceae) in forest ecosystems, and *Acacia longifolia* (Andrews) Willd. (Leguminosae), *Coleostephus myconis* (L.) Rchb.f. (Compositae), *Cynodon dactylon* (L.) Pers. (Gramineae), *Eragrostis plana* Nees (Gramineae), *Pinus* spp. (Pinaceae), *Senecio madagascariensis* Poir. (Compositae), and *Ulex europaeus* L. (Leguminosae) in

grasslands (Masciadri & al., 2010; Brazeiro & al., 2024; Guido & al., 2024). In this context, FUO provides a critical tool for conservation planning and management by offering detailed, up-to-date information on species distributions, habitats, and ecological settings—an essential foundation for developing informed responses to these environmental threats.

■ URUGUAY'S ONLINE FLORA PORTAL

General description of the portal. — FUO is a modern and versatile tool designed to document, organize, and disseminate knowledge about the country's plant diversity and further encourage its study and conservation. It offers a broad and accessible user experience, enabling the exploration of Uruguay's botanical richness through multiple filters, such as specific species attributes, geographic regions, ecological characteristics, or conservation status. Furthermore, the portal is richly illustrated with high-quality photographs and includes detailed distribution and diversity maps, facilitating both scientific study and broader public engagement with Uruguay's plant diversity.

FUO is a collaborative initiative that brings together institutions in Uruguay committed to the study and conservation of the country's biodiversity. Originally conceived and developed by the School of Agronomy of the Universidad de la República—which continues to coordinate and lead its implementation—the project was launched in 2023 and quickly expanded in scope over the course of two years. Participating institutions include the Universidad de la República through the Schools of Agronomy, Sciences, and Chemistry, and the Regional Eastern University Center; the Montevideo City Government, through its Botanical Garden; the Ministry of Education and Culture, represented by the National Museum of Natural History and the Clemente Estable Institute of Biological Research; and the Ministry of the Environment. A key asset from the outset was the availability of the unpublished extensive conspectus of the Flora by E.H. Marchesi organized by family with keys to genera and species, along with other data including distribution and phenology. In the early design of the database architecture that supports the platform we focused on developing a solid taxonomic and nomenclatural framework with a structure capable of accommodating diverse types of information—such as names, synonyms, taxonomic concepts, and distribution data—while maintaining consistency and allowing for future growth. Having this architecture in place from the beginning was important to facilitate communication with developers, guide interface design, and

Fig. 5. Taxonomic diversity of the Uruguayan flora at the family level, following the APG IV (2016) and PPG I (2016) classification systems. The infographic organizes plant families according to their placement within major evolutionary clades or grades, each represented by a distinct color. Each family is depicted as a circle, with its size proportional to the number of species it contains. The number inside (or next to) each circle serves as a key that corresponds to the family name listed at the bottom of the graphic. For the key, within each clade or grade, families are grouped alphabetically by orders and within each order, families are listed by decreasing species richness. To the right of each family name are indicated the number of **genera/species** recorded in the Flora.

FLORA OF URUGUAY: species origin, habit, and habitat diversity

Using FUO to document broad ecological trends

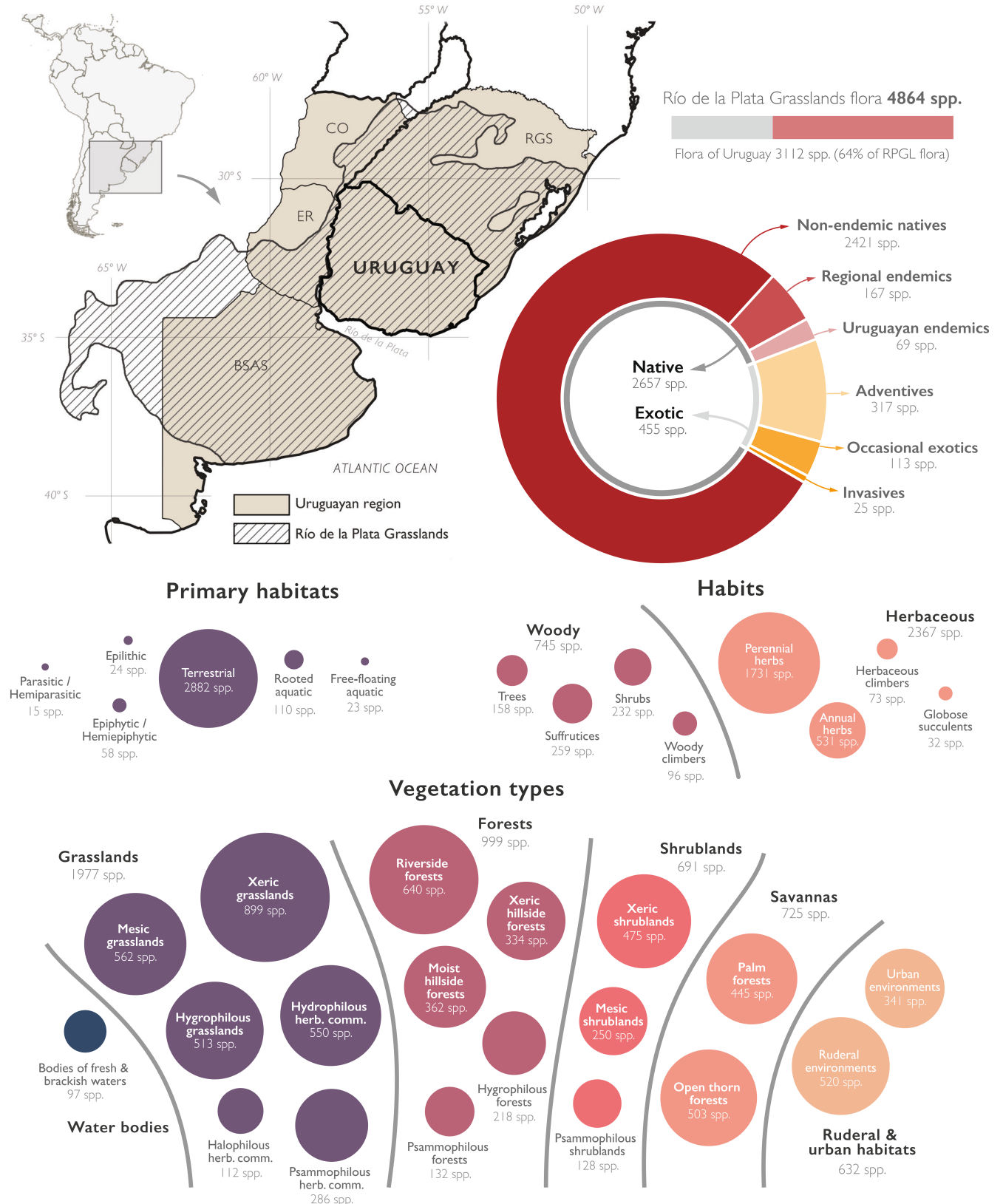


Fig. 6. Caption on next page.

ensure the platform's technical feasibility. From the beginning, collaboration was central—not only from an academic standpoint but also for funding. The project was supported by a combination of small grants obtained specifically for its development and by the contributions of colleagues who shared resources from their research projects. While the core contributors are Uruguayan botanists, the project also benefits from a long list of international collaborators who have provided specialist content for their respective plant groups. Just as crucial was the active engagement with all national institutions involved in botanical research and conservation. This close interaction fostered a collective sense of ownership and identity—perhaps a unique advantage of working in a small, highly connected country. As we examined digital Floras from around the world, we focused on the most effective features that would serve our needs and answered: What would we want to see in a national Flora and what kinds of questions should it address? Through months of discussion, iteration, and close collaboration with software developers, these reflections took shape in the platform we are now launching as FUO.

At the time of release (October, 2025), FUO includes a complete list of taxa based on current knowledge, although the amount of information associated with each species varies among groups. While the correct names for all accepted taxa known to occur in the country have been included, synonyms are being progressively added as the project advances. Data on growth form, habitat, and ecological setting are currently available for all species. Our goal is to complete the full development of the portal by 2030, at which point we aim for all species to be illustrated and linked to at least one digitized specimen, for all national herbaria to be fully integrated into the database, and for morphological descriptions and identification keys to be available for all genera and a significant number of species. By that stage, we also expect all relevant synonyms to be incorporated for all taxa. Users will be able to monitor the platform's progress in a dedicated section that tracks the available data for each plant family. Beyond that initial target date, we envision this platform as a collective and continuously evolving work—designed so that future generations of taxonomists can continue to enrich this legacy and keep alive the exploration, understanding, and appreciation of Uruguay's flora.

About the emblem of FUO. – *Schlechtendalia luzulifolia* Less. serves as the emblem of FUO, chosen for both scientific and symbolic reasons (Fig. 12). It belongs to the Compositae, the most diverse plant family in the country, and

represents an early-diverging lineage (Barnadesieae) restricted to southern South America. Importantly, the species is most abundant in Uruguay, making the country the core area of its geographic distribution. Finally, the radiant appearance of its capitulum evokes the image of the sun found in the national flag, offering a subtle yet powerful reference to national identity and underscoring the link between biodiversity and cultural heritage.

Key features of the portal. — FUO is presented as an innovative and robust tool for accessing, exploring, and analyzing the country's vascular flora. Its design offers multiple functionalities tailored to different types of users and purposes by combining scientific depth, user-friendliness, and openness.

(a) *Comprehensive coverage.* – FUO includes detailed descriptions, photographs, distribution maps, and ecological information on Uruguay's vascular plants.

(b) *Powerful search and exploration engine.* – FUO's advanced search allows users to combine multiple filtering criteria (i.e., family, genus, or species; vegetation types in which species occur, plant traits such as habit and habitat, phenological data; and precise geographic definitions based on political boundaries or custom coordinate ranges). Search results can be downloaded in CSV format, facilitating further analysis and use in other platforms. FUO's flexible query system allows users to interact with data in various ways, such as generating custom species lists, visualizing distribution patterns on interactive maps, and accessing information on conservation status, ecology, and uses.

(c) *Open access and collaboration.* – FUO is open-access and encourages citizen science through the iNaturalist platform (<https://www.inaturalist.org>) contributions, allowing users to submit observations, report new records, and participate in species identification challenges—promoting a collaborative approach to biodiversity documentation. In addition, FUO is linked to the Uruguayan node of GBIF.

(d) *Continuous updates.* – FUO will be continuously updated through the support of the researchers who envisioned, designed, and built it. Updates will include not only the addition of new herbarium records, images, and data, but also the ongoing taxonomic re-evaluation of all entities.

(e) *Bilingual platform.* – The portal is available in both Spanish and English, ensuring its national and international accessibility. This facilitates the global dissemination of information on Uruguay's flora and promotes scientific collaboration across linguistic boundaries.

(f) *Technical framework.* – The site was developed using a robust structure based on MySQL (<https://mysql.com>) and

Fig. 6. Origin, growth form, habitat, and vegetation types where species occur. “Regional endemics” are defined here as species with distributions restricted to a broader region that includes Uruguay, as well as the provinces of Buenos Aires, Corrientes, and Entre Ríos in Argentina, and the state of Rio Grande do Sul in Brazil (strictly Uruguayan endemics were excluded from this category to allow for separate analysis). Species values per vegetation type represent initial estimates subject to refinement as the Flora is updated; for broader vegetation categories, species occurring in more than one subtype are counted only once to avoid duplication. Area of the Río de la Plata Grasslands (RPGL) follows Soriano & al. (1992); species counts for this area are based on Andrade & al. (2018). ER: Entre Ríos Province (Argentina), COR: Corrientes Province (Argentina), BSAS: Buenos Aires Province (Argentina), RGS: Rio Grande do Sul State (Brazil).

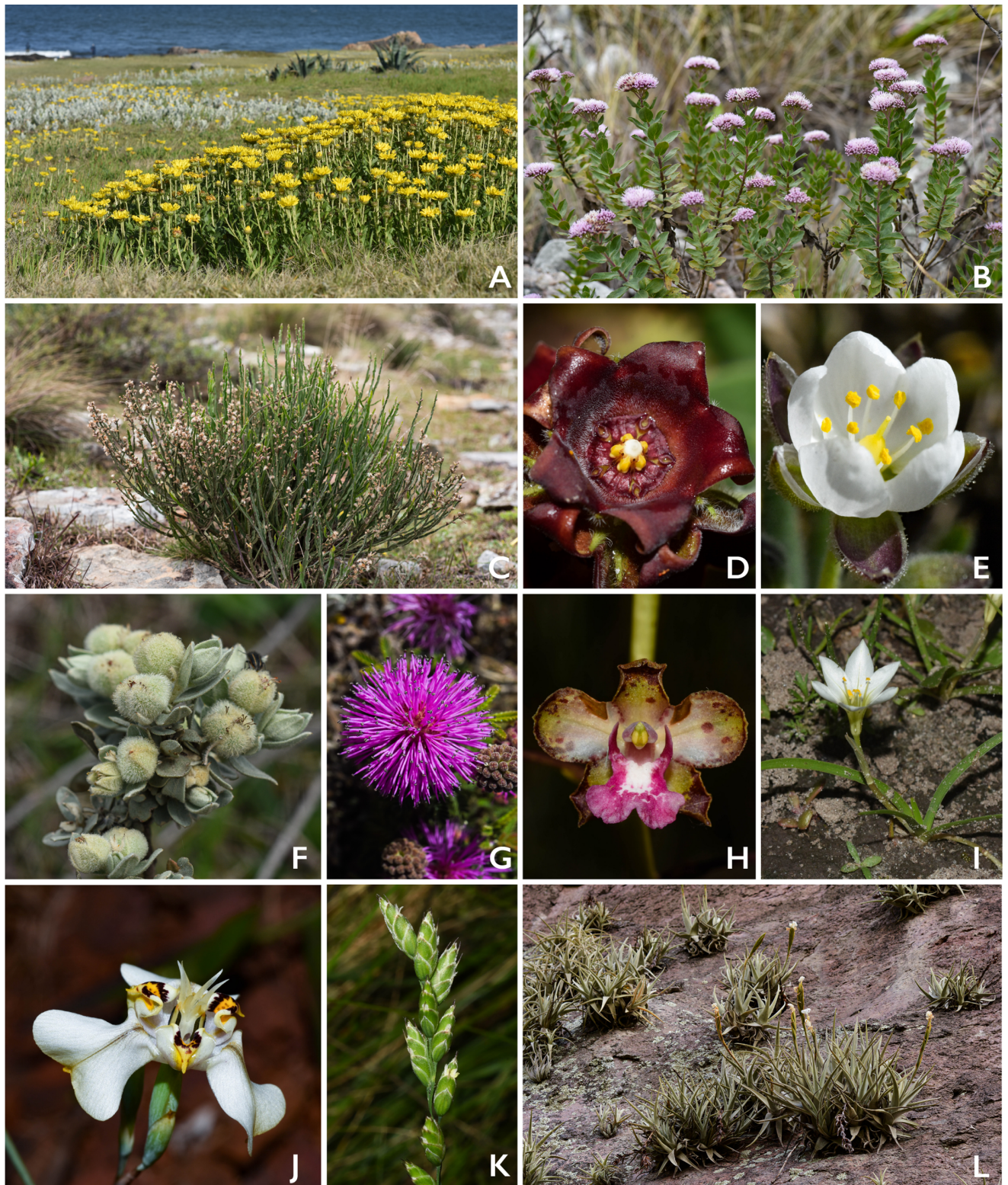


Fig. 7. Endemic species, either strictly national (EN) or regional (ER). **A**, *Grindelia orientalis* Adr.Bartoli & al. (Compositae, Astereae; EN); **B**, *Grazielia brevipetiolata* (Sch.Bip. ex Baker) R.M.King & H.Rob. (Compositae, Eupatorieae; EN); **C**, *Baccharis rectilata* Valt. & al. (Compositae, Astereae; EN); **D**, *Oxypetalum nigricans* (Decne.) Liede & Meve (Apocynaceae; EN); **E**, *Spergularia rupestris* Cambess. (Caryophyllaceae; EN); **F**, *Croton chamaepitys* Baill. (Euphorbiaceae; EN); **G**, *Mimosa burkartii* Marchesi (Leguminosae; ER); **H**, *Cyrtopodium izaguirreae* Andrés González & J.A.N.Bat. (Orchidaceae; EN); **I**, *Ipheion tweedeanum* (Baker) Traub (Amaryllidaceae; ER); **J**, *Cypella osteniana* Beauverd (Iridaceae; EN); **K**, *Erianthecium bulbosum* Parodi (Gramineae; ER); **L**, *Tillandsia arequitae* (André) André ex Mez (Bromeliaceae; EN). — Photos: A–C & F, J. Mauricio Bonifacino; D, E & G–K, Ary Mailhos; L, Andrés Rossado.



Fig. 8. Caption on next page.

PHP (<https://php.net>), with a user-friendly control panel that simplifies both maintenance and technical support, despite the specificity and complexity of the taxonomic content it handles. While it is a *sui generis* development tailored to the particular needs of the national Flora, its modular architecture and use of standard technologies ensure that maintenance remains accessible to technical teams with general expertise in web-based application development. Furthermore, all recorded data are atomized, which not only improves internal organization but also allows for easy and efficient integration with other databases, supporting interoperability and projection across diverse scientific and technical environments.

(g) *Contribution to international commitments.* – FUO supports Uruguay's commitments under the CBD by facilitating access to nationally curated plant diversity data. It contributes to global goals related to conservation, sustainable use, and informed environmental policy, including several targets assumed by the country under the Kunming–Montreal Global Biodiversity Framework (<https://www.cbd.int/gbf>), especially for the voluntary additional action 21b of the updated Global Strategy for Plant Conservation (GSPC), which has been adopted by the CBD Conference of the Parties (COP) 16 in 2024.

Integrating taxonomy, collections, and geography: The three pillars of FUO. — The architecture of the FUO portal is built on three interconnected pillars that organize and give meaning to the information: (a) taxonomic information, (b) botanical collections, and (c) the geographic distribution of plants. Together, they form a comprehensive platform that integrates scientific knowledge, natural heritage, and open access to information.

(a) *Taxonomic information.* — This information is organized within a hierarchical taxonomic structure, following the Angiosperm Phylogeny Group IV (APG IV, 2016) and the Pteridophyte Phylogeny Group I (PPG I, 2016), and covering ranks from order to infraspecific categories. Each taxon includes **Basic nomenclatural data**, including place of publication, links to original descriptions, and type specimens where available; **Taxonomic status** (e.g., accepted name, synonyms), with cross-references to international databases such as IPNI and WFO; **Origin and conservation status**, indicating whether the species is native or exotic (adventives, occasional exotics, and invasives), and including national conservation status

(Marchesi & al., 2013) and endemism where applicable; **Ecological characteristics**, including plant type, growth form, habitat, associated vegetation types, and, where relevant, flowering and fruiting periods; **Morphological descriptions**, initially focused on the family level and gradually extended to other taxonomic ranks; **High-resolution images**, illustrating each taxon with photographs of live plants, habitats, herbarium specimens, and, in some cases, microscopic details for complex groups (e.g., Gramineae and Cyperaceae); **Identification keys**, in the form of dichotomous and matrix-based tools using the LUCID platform (<https://lucidcentral.org>), allow users to determine plant identity based on morphological, vegetative, and reproductive traits. Keys are linked to the corresponding taxa and are also compiled in a dedicated section for ease of access. All information can be downloaded in PDF format or as spreadsheets, allowing users to manipulate and analyze the data according to their needs (Fig. 13).

(b) *Botanical collections.* — FUO compiles information from specimens collected in Uruguay and deposited in the country's five main botanical collections, which together house ~275,000 specimens: the Bernardo Rosengurt Herbarium (MVFA), with ~100,000 specimens; the National Museum of Natural History Herbarium (MVM), with ~100,000 specimens; the Montevideo Botanical Garden Herbarium (MVJB), with ~60,000 specimens; the Eduardo Alonso Paz Herbarium (MVFQ), with ~10,000 specimens; and the School of Sciences Herbarium (MVHC), with ~5,000 specimens. FUO extracts label data from each specimen, and in cases where geographic coordinates are not available, approximate georeferencing is performed using label and database information, with the result clearly indicated as an estimate (Chapman & Wiczorek, 2020). Specimen phenology (i.e., whether it bears flowers, fruits, or both) is also recorded. Digitization and databasing remain limited for national herbaria, and to date, ~15,000 specimens have been digitized, and ~1,000 high-resolution images have been generated, each representing a different species. FUO organizes these data and will virtually unify Uruguay's five main botanical collections as digitization projects progress and will enable customized queries to generate specimen lists based on multiple criteria. FUO recognizes the contributions of numerous digitizers by including their names among the collaborators of the Flora project (Enright & Smith, 2025).

Fig. 8. Common or ecologically important species in the Uruguayan flora. **A**, *Paspalum flavescens* (Roseng. & al.) P.R.Speranza & G.H.Rua (Gramineae, Paspaleae): *Paspalum* L. is the second most diverse genus in the flora and ubiquitous across all grasslands in Uruguay; **B**, *Nassella neesiana* (Trin. & Rupr.) Barkworth (Gramineae, Stipeae): tribe Stipeae represents an ecologically important component in many grasslands; **C**, *Bothriochloa laguroides* (DC.) Herter (Gramineae, Andropogoneae): a common species in Uruguayan grasslands, representing the Andropogoneae, a floristically rich group that also plays a major role in grassland ecosystems; **D**, *Cyperus aggregatus* (Willd.) Endl. (Cyperaceae): Cyperaceae is the fourth most diverse family and ecologically ubiquitous; **E**, *Acanthostyles buniifolius* (Hook. & Arn.) R.M.King & H.Rob. (Compositae, Eupatorieae): perhaps the most common shrub in the country, representative of Uruguay's most diverse family; **F**, *Trifolium polymorphum* Poir. (Leguminosae): the third most diverse family, this species is a frequent grassland component; **G**, *Baccharis dracunculifolia* DC. (Compositae, Astereae): another common shrub, belonging to the most diverse genus in Uruguay; **H**, *Eryngium eburneum* Decne. ex Hérinçq (Apiaceae): *Eryngium* spp. are abundant and impart a distinctive character to many Uruguayan grasslands; **I**, *Blepharocalyx salicifolius* (Kunth) O.Berg (Myrtaceae): Myrtaceae is the most diverse woody family and ubiquitous in native forests; **J**, *Scutia buxifolia* Reissek. (Rhamnaceae): likely the most frequent species across all forest types in Uruguay; **K**, *Amorpha decurtata* (Link) Salino & T.E.Almeida (Thelypteridaceae): most ferns are restricted to forested environments; Thelypteridaceae is the second most diverse family among pteridophytes. — Photos: A–C & E–J, J. Mauricio Bonifacino; D, Ary Mailhos; K, Carlos A. Brussa.



Fig. 9. Dominant herbaceous and shrubby vegetation types in Uruguay. **A**, Grasslands: the most characteristic vegetation type of Uruguay, shown here in the north of the country, where they are best preserved. These grasslands develop on mostly shallow basalt-derived soils; **B**, Halophytic herbaceous vegetation: occurs in river mouths opening into the Río de la Plata, and important components of wetland or flood-prone zones; **C**, Psammophilous herbaceous vegetation: occurs on dunes and sandy soils, among the most threatened vegetation types due to coastal urban expansion along the Río de la Plata and the Atlantic coast; **D**, Xerophytic shrublands dominated by *Baccharis aliena* (Spreng.) Joch.Müll. (Compositae, Astereae): shrublands are the second most extensive vegetation type after grasslands and are largely dominated by Compositae species. — Photos: A–D, J. Mauricio Bonifacino.

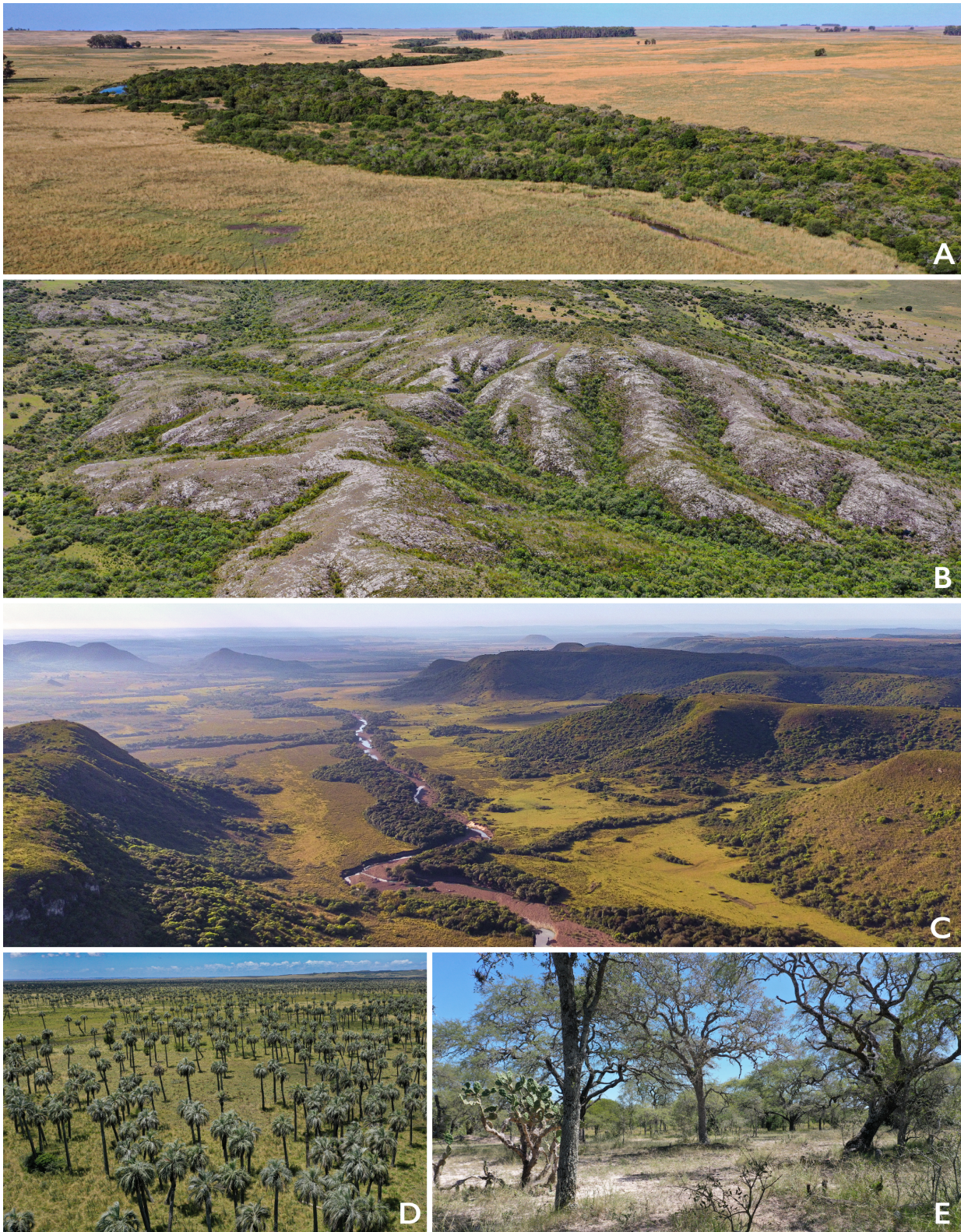


Fig. 10. Dominant forest types in Uruguay. **A**, Riverside forest: Uruguay has a dense network of waterways, along which forest vegetation forms one of the landscape's most distinctive features; **B**, Xeric hillside forests: occurs on slopes of hills forming a network of low mountain ranges across the country; **C**, Moist hillside forests: in northern Uruguay, particularly where sandstone and basalt meet, deep gullies host one of the most diverse and lush forest types in the country; **D**, *Butia odorata* (Barb.Rodr.) Noblick palm savannas: this species forms tightly packed clusters in eastern Uruguay; **E**, Open thorn savannas, marking the presence of Chaco biogeographic elements into Uruguay. — Photos: A–E, J. Mauricio Bonifacino.

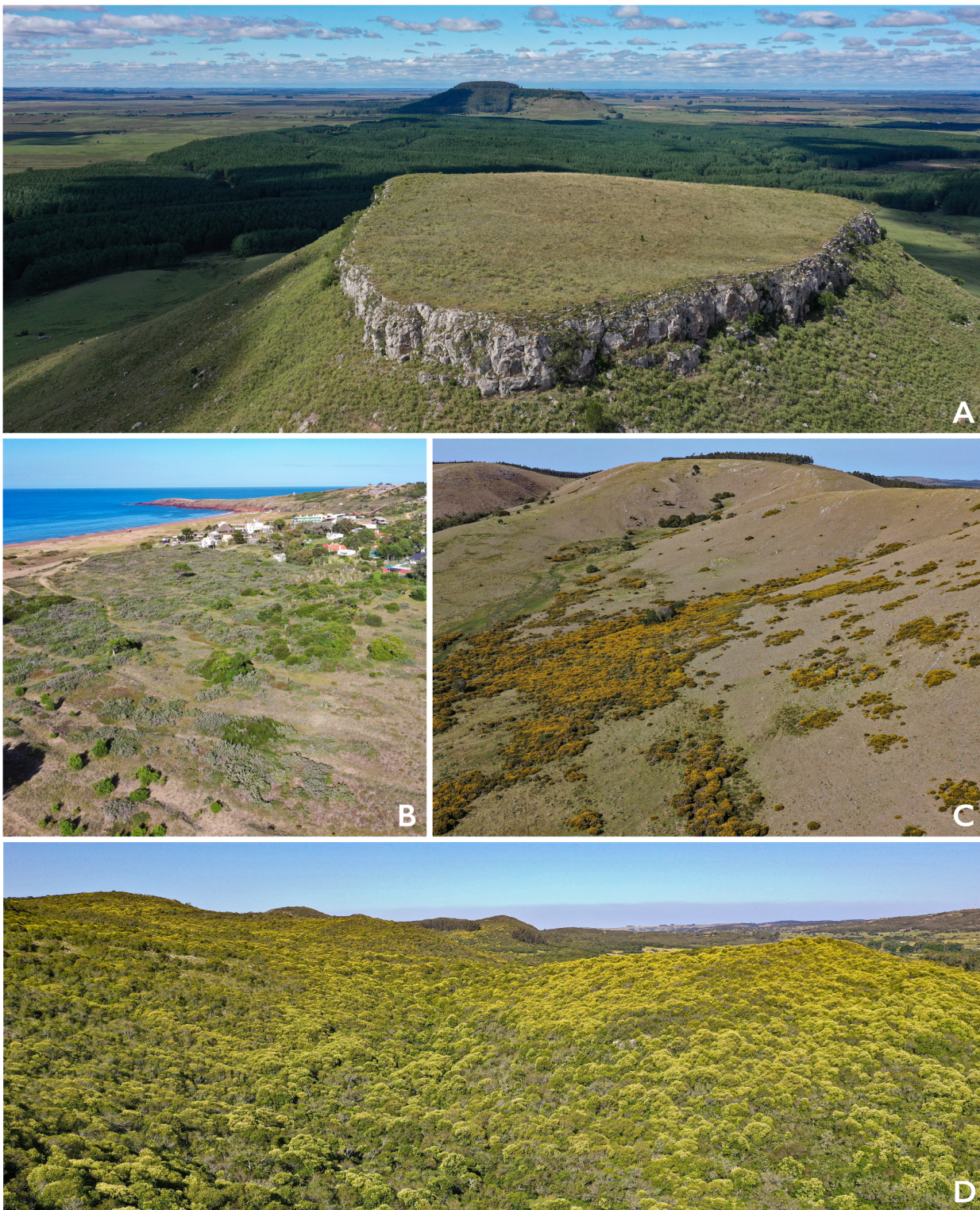


Fig. 11. Threats to the flora of Uruguay. **A**, Commercial forestry: large-scale tree plantations (dark *Pinus* stands in back) threaten native vegetation, especially in heterogeneous and diverse environments such as the flat hills (foreground) in northern Uruguay; **B**, Urbanization of coastal zones: real estate pressure (houses in top right) along the coast poses the main threat to coastal vegetation formations, many of which are unique and biologically rich; **C**, Biological invasions – *Ulex europaeus* L.: this thorny yellow-flowered shrub is one of the main threats to grasslands and shrublands, displacing native species and deeply altering these highly diverse systems; **D**, Biological invasions – *Ligustrum lucidum* W.T.Aiton: this exotic woody species invades and dominates southern and southwestern forests, severely altering their structure and composition (yellow-green trees dominating image) in this example from Lavalleja Department. — Photos: A–D, J. Mauricio Bonifacino.

(c) *Geographic distribution of plants.* – Detailed visualizations of species’ spatial distributions within Uruguay support the understanding of biodiversity patterns, and biogeographic relationships, and serve as tools for conservation planning and land management strategies. The information is presented through dynamic maps (e.g., Fig. 14) generated from herbarium records from national collections, observations from the iNaturalist platform, or both sources combined. These maps support multiple layers of analysis, including distribution points for each taxon with collection density; species richness per territorial unit, based on political divisions or a 20 × 20 km grid; and filters to display the distribution of native, exotic, endemic, or conservation-priority species. Like other components of the portal, geographic data are downloadable and adaptable for use in various analytical tools. For species with very restricted distributions, or those targeted by collectors who would deplete populations (e.g., cacti), specific locality information has been hidden from distribution maps and excluded from downloadable datasets to reduce risks to their conservation.

■ CONNECTING FLORISTIC KNOWLEDGE TO PARTICIPATION, PRACTICE AND POLICY

The floristic knowledge compiled in FUI not only advances scientific research but also draws strength from and contributes to its interaction with multiple sectors of society. Its impact is evident in citizen engagement, direct applications in livestock production and animal health, and various fields



Fig. 12. Emblem of Flora Uruguay Online. The capitulum of *Schlechtendalia luzulifolia* Less. (Compositae, Barnadesieae) was chosen for its scientific and symbolic value in reflecting both botanical identity and national heritage. — Photo: J. Mauricio Bonifacino.

related to land management, biodiversity conservation, and the development of environmental awareness.

Citizen science contributions to the study of Uruguay’s flora. – The incorporation of citizen science through the iNaturalist platform and the NaturalistaUY node (<https://www.naturalista.uy>) represents a major milestone in integrating society into the documentation and conservation of biodiversity (Callaghan & al., 2022). Since the first vascular plant observations were recorded in 2012, citizens and naturalists have contributed nearly 40,000 observations in Uruguay—most of them in the last five years. Many of these provide valuable data on groups underrepresented in traditional botanical collections, such as orchids, cacti, and other rare or hard-to-access species. These observations not only expand the known distribution of many species but have also led to the rediscovery of taxa unrecorded for decades and the addition of new records for the country (e.g., Mántaras, 2023; Castelli, 2024; Vescia, 2024).

Approximately 2000 vascular plant species have been recorded in Uruguay on iNaturalist with “research grade” status (i.e., confirmed by at least two identifiers), representing nearly two-thirds of the national flora. The most represented families are Compositae (~9250 observations, 342 spp.), Leguminosae (~3300, 170 spp.), and Solanaceae (~2200, 70 spp.). Families such as Gramineae and Cyperaceae, though taxonomically rich and ecologically dominant in the country, are notably underrepresented due to their inconspicuous nature and identification challenges from photographs. In contrast, more visually striking families like Cactaceae and Myrtaceae are overrepresented relative to their species richness. More than half of the observations are concentrated along the southern and southeastern coastal and hilly areas, especially in the departments of Canelones, Maldonado, and Rocha, likely reflecting the higher population density, and the popularity of seaside and hilly natural areas for recreation and tourism. These are followed by the western littoral region along the Uruguay River and the northeastern hill and ravine systems. The least represented areas are in the south-central departments of Flores, Florida, and Durazno, likely due to their lower population density, less diversified terrain and limited tourist attractions. Research-grade iNaturalist observations are integrated into FUI every two weeks through GBIF. These records are reviewed by taxonomic experts, and since FUI includes direct links to the original iNaturalist observations, identifications can be revalidated or corrected if needed. Furthermore, the integration of these data into FUI complements herbarium collections, enhances spatial distribution analyses, and provides a flexible tool for conservation planning.

Toxic plants and livestock production: FUI’s value for addressing a central challenge in Uruguay’s economy. – Beyond its scientific value, FUI offers practical applications for strategic sectors of the country. One of the most significant examples is its potential to support livestock production, one of Uruguay’s primary economic activities, through the identification and management of useful forage species as well as noxious invasive exotic grasses and toxic plants for cattle that account for approximately 10% of livestock mortality causes (UNIRADD, 2025). Moreover, the associated economic losses

Nomenclature & connectivity
Essential information about scientific names is provided, with links to other national and international databases. The navigation panel allows immediate access to all related taxonomic levels.

Bilingual access
The Flora Uruguaya Online displays all its information in Spanish or English.

Ecological profile
A summary of plant type, habitat, occupied environments, and phenology is provided.

Detailed morphology
Detailed information on all morphological characteristics of the taxon, newly prepared based on the diversity observed in Uruguay.

High-Resolution Images
High-quality images that can be viewed in full screen illustrate the most prominent and distinctive characteristics of each plant group, including microscopic details of various kinds.

Microcharacter images
High-quality images illustrate details of microcharacters derived from seeds and/or fruits, anatomy, pollen, and other features.

Supporting Evidence
Includes diagnostic characteristics, explanatory notes of various kinds, geographic distribution, literature citations, identification tools, and—most importantly—a list of collections that support the presence of each taxon in the country. All data is readily available for download to allow further analysis.

Citation & pdf
Each taxon treatment is accompanied by a citation recommendation and a link to download all the information as a PDF.

Fig. 13. Example of a species-level taxon treatment. For simplicity, distribution maps and additional data have been intentionally hidden.

extend beyond mortality, affecting productive parameters (e.g., weight loss, reduced milk yield, and carcass condemnation), reproductive performance (e.g., abortions, malformations, and infertility), and generating veterinary treatment and plant control costs (Pessoa & al., 2013). The genera involved in poisoning events vary regionally, with *Cestrum* L. (Solanaceae) and *Senecio* (Compositae) being the most frequently associated with cattle mortality (UNIRADD, 2025). In addition, land-use changes and the introduction of exotics have caused poisonings by previously unrecognized plants, complicating diagnoses due to unfamiliarity with the species involved. In this context, FUO will serve as a valuable tool for diagnosing and reducing plant poisoning. It will allow

professionals in the agricultural and livestock sectors to identify and locate populations of toxic plants, detect newly introduced species, and design management strategies based on systematic botanical information. Furthermore, its integration with the iNaturalist platform will facilitate the incorporation of field observations, promoting collaborative monitoring.

Native flora and Crop Wild Relatives: Strategic resources for agrobiodiversity and food security. – Knowing the native flora is essential for identifying and conserving plant genetic resources, especially the Crop Wild Relatives (CWR; Dempewolf & al., 2017). Several studies have highlighted the significance of native species as reservoirs of genetic diversity and the role of local landscapes, traditional knowledge, and

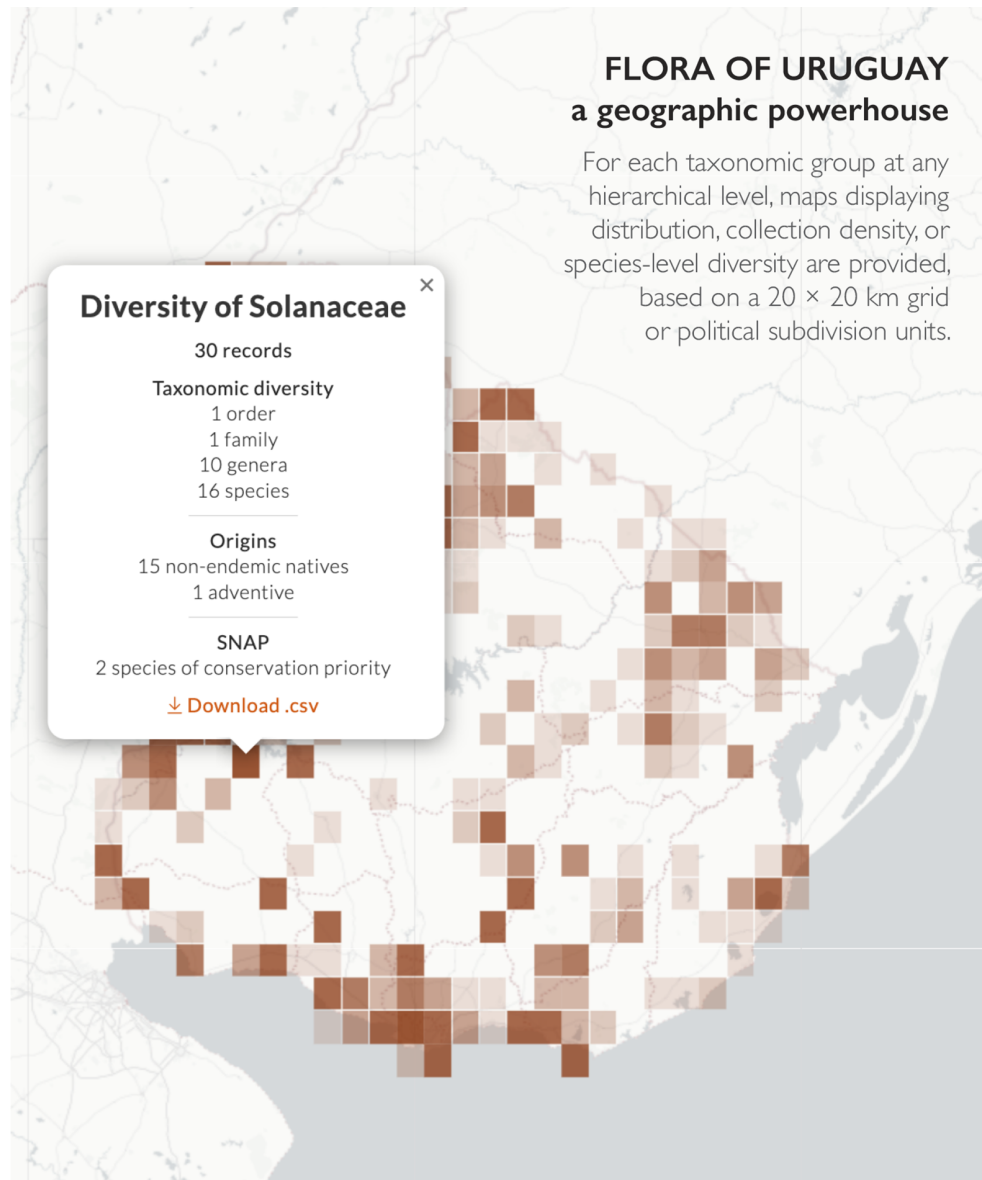


Fig. 14. Geographic distribution and taxonomic diversity as presented for each group in the Flora Uruguay Online, here exemplified by the family Solanaceae. All associated records can be downloaded by grid cell or for the entire map. Data sources include herbarium specimens and iNaturalist research-grade observations, used independently or combined. Each record indicates whether its location is precise or estimated; geographic coordinates are available when present for further analysis. The collections module allows for refined searches, including by geographic coordinates.

participatory breeding in their conservation and sustainable use (Calvete, 2013; Puppo & al., 2014, 2023; Rivas & Condon, 2015). In Uruguay, where agriculture is a cornerstone of the national economy, documenting and understanding CWR can lead to the discovery of new genes for drought tolerance, pest and disease resistance, or nutritional improvement—traits that are increasingly crucial in the face of global climate change and food insecurity. For example, Uruguay has wild relatives from food crops (<https://cwr.croptrust.org/crops/>; <https://www.fao.org/plant-treaty/>) including potato (*Solanum* sect. *Petota* Dumort.), peanut (*Arachis* L.), and barley (*Hordeum* L.) in addition to forage legume (*Arachis*, *Vicia* L., *Vigna* Savi) and grass species (*Eleusine* Gaertn., *Panicum* L., *Paspalum*, *Setaria* P.Beauv.). These genetic resources can enhance breeding programs not only for local crops like forage legumes and cereals but also for crops of global significance. Furthermore, the conservation of Uruguay's native flora through CWR research supports international commitments such as the CBD and the GSPC (<https://www.cbd.int/doc/publications/pc-brochure-en.pdf>). It also opens avenues for biotechnological innovation, sustainable agriculture, and international collaboration, positioning Uruguay as a key player in the global effort to safeguard agrobiodiversity and ensure food security. By providing a centralized, accessible source of floristic and ecological information, FVO can strengthen these efforts—supporting research on genetic resources, informing community-based initiatives, and enhancing the visibility and strategic value of Uruguay's native flora in agrobiodiversity planning.

Flora as a bridge between science, management, and society. – Uruguay's flora as studied, managed, and known through scientific collections plays a fundamental role across a wide range of social and biophysical domains. It acts as a source of knowledge, underpins numerous practical applications, and serves as a key element in the structure and function of the country's ecosystems. Its influence spans five major domains (Fig. 15): **A. Public policy and environmental management:** Institutions and regulatory frameworks depend on floristic information for planning, regulation, and decision-making at national and local levels, including environmental assessments, protected area management, and the work of government ministries and departments. **B. Sustainable production and use:** This includes economic and cultural practices based on plant knowledge, such as sustainable cattle grazing on natural grasslands, seed certification, native plant nurseries, ecotourism, beekeeping, sustainable forestry, medicinal and natural compound use, and the harvesting of fruits, timber, and fibers. It also encompasses intangible benefits such as cultural identity, artistic inspiration, and recreation, along with key ecosystem services like maintaining trophic networks, supporting pollinators, regulating climate, and ensuring water quality. In Uruguay, associations such as the *Alianza del Pastizal* (<https://alianzadelpastizal.birdlife.org>) and AUGAP (Uruguayan Association of Grassland Ranchers; <https://augap.com.uy>) play a key role in promoting and implementing sustainable grassland management, demonstrating how

coordinated efforts can link conservation goals with productive livelihoods. **C. Social engagement and collaboration:** This encompasses initiatives led by civil society and community organizations that promote direct engagement in understanding and conserving plant diversity. FVO will be a key resource for government agencies and natural area managers, supporting the implementation of natural resource management policies and enabling informed decision-making through precise species location data. **D. Education and scientific culture:** This emphasizes the integration of flora into formal education at all levels, technical training, and informal learning spaces such as museums, botanical gardens, and citizen science programs. **E. Science and knowledge generation:** This includes basic research in taxonomy, systematics, and ecology, as well as applied studies in conservation, genetics, and agroecology—many of which are supported by national initiatives such as Uruguay's Barcode of Life project.

■ FUTURE DEVELOPMENT AND CHALLENGES FOR FVO

Strengthening FVO will require progress on two fronts: (1) the development of new functionalities, and (2) the resolution of persistent structural limitations. Establishing the platform as a scientific reference tool will depend on both its technical expansion and institutional support to ensure long-term sustainability.

Future stages of FVO. – FVO aims to expand its taxonomic scope, enhance its digital infrastructure, and deepen its integration with national and international scientific networks, thereby establishing it as a dynamic and evolving reference tool with the following eight main milestones. **Taxonomic expansion:** Incorporation of bryophytes and fungi to complement the vascular flora and thus establish a national Flora and Funga database, recognizing the ecological and taxonomic diversity of these groups and their relevance to Uruguay's biogeographic and environmental heterogeneity. **Advanced digitization:** Generation of high-resolution images of herbarium specimens to complement initial digitization of label data, along with high-definition images of seeds and fruits. **Expansion of the palynological image library:** Currently available for ~4% of the taxa in FVO, the database will be expanded to include images for all recorded species. **Integration with Uruguay's barcoding node:** The FVO will contribute to the Uruguay Barcode of Life (UBOL) project by facilitating the verification of specimen identities in the national DNA barcode library and providing quick access to species data by region, enabling the development of local baselines for environmental DNA (eDNA) studies. **Connection to the Uruguayan GBIF node:** To feed validated taxonomic and distribution data from FVO into GBIF, contributing to a national checklist and ensuring alignment with GBIF data standards. **Virtual repatriation of collections:** Integration of data from Uruguayan plant specimens deposited in international herbaria. **Linkage with World Flora Online (WFO):** Ensuring interoperability with global

FLORA OF URUGUAY: more than just plants

Uruguay's flora as a foundation for science, culture, policy and sustainable living

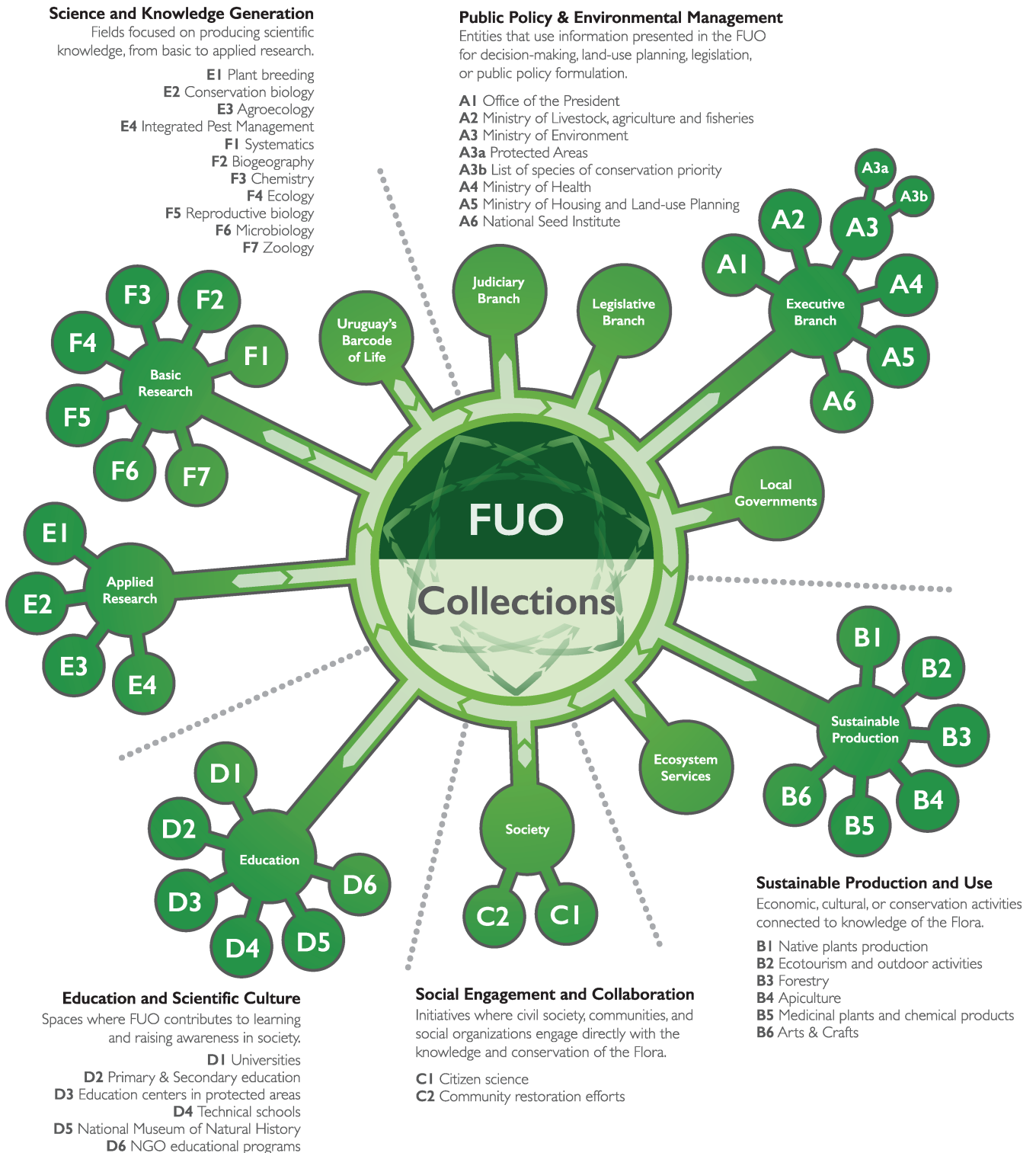


Fig. 15. Network of interactions with Flora Uruguay Online as a bridge to different sectors of national life. The FUO and the collections that support it intersect with social, productive, and scientific domains. The understanding of the Flora, summarized in FUO, and the conservation of collections are essential to public policy, sustainable resource use, research and innovation, formal and informal education, and civic engagement. Arrows indicate the main flows of information, all ultimately benefitting and feeding back from the knowledge synthesized in the FUO.

biodiversity networks by connecting FUO data to the WFO platform through the development of an API for data integration and access. **Continuous content updates:** Ongoing development of descriptions based on Uruguayan materials, incorporation of new herbarium specimens, images, and taxonomic and ecological observations, as well as the continual enrichment of all data associated with each taxon.

Challenges for the national flora: Infrastructure and conservation of botanical collections. – The advancement of botanical knowledge in Uruguay, embodied in the FUO initiative, rests on support for the country's botanical collections. Despite their importance, these collections are stored in cramped, historic buildings and face significant structural and logistical limitations that affect their full utilization. The most critical problems include insufficient space, inadequate conservation conditions, shortage of specialized staff for curation and maintenance, and limited budgets for digitization. In particular, space constraints are limiting collection growth and proper specimen storage, and are preventing the integration of new material needed to validate recent findings or to fully document distribution and phenology. One of the main priorities in Uruguayan botany is securing investment in infrastructure to unify all or part of the existing collections into a modern facility. Such a step would optimize resources, improve researcher access, and enhance archiving, studying, and managing the collections. Since the digital integration of specimen data is key to efficient and standardized management (Ondo & al., 2024), the development of FUO, which centralizes and organizes these data, further underscores the need to strengthen Uruguay's botanical collections.

■ CONCLUSIONS

The launch of the Flora Uruguaya Online represents a major step forward for the understanding and appreciation of the country's plant biodiversity by publicly making available a wealth of botanical information. Beyond its academic value, FUO promotes open knowledge, fosters environmental education, and strengthens the connection between society and its natural heritage. FUO facilitates research and conservation in the region by offering high-quality, detailed floristic data and making it an essential tool for scientists, policymakers, conservationists, and educators in Uruguay and neighboring countries. We hope that national authorities will recognize the value of this collective effort, acknowledge the importance of the collections that have made it possible, and adopt the necessary measures to ensure their protection and continued development. A deep understanding of the national flora is a strategic asset for sustainable land management, biodiversity conservation, and societal well-being.

■ AUTHOR CONTRIBUTIONS

JMB, AM, and AR designed the manuscript, compiled, organized, and analyzed the data, produced figures, wrote the first draft of the

manuscript, revised, and approved its final version. EM provided the foundational dataset for the whole FUO. EM, FH, AGR, CB, PMM, GS, VV, CT, PP, FL, MC, FG, MP, PB, RB, MZ, FC, GH, JI and KJW co-wrote the manuscript, revised, and approved its final version. All 83 national and international collaborators revised and approved the final version of the manuscript.

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