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The biogeographical kingdoms and regions of the world

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Abstract. This paper presents an updated overview of the world's biogeographical realms and regions in the terrestrial domain. It incorporates new data on floristic and vegetation aspects, along with recent regional information, which has emerged in the decades following the influential maps created by A. Takhtajan and R. Good. We elucidate the various biogeographic scales, ranging from kingdoms to districts, and outline the specific criteria that define them. We delve into the criteria used for characterizing the kingdoms and regions, with a particular focus on their floristic content, evolutionary background, and vegetation patterns, expressed through biomes and subbiomes. Additionally, we discuss the climatic conditions and their variability within and between these units. Our study identifies six kingdoms and 42 regions that are recognized for the entire planet and provides a concise summary for each of them.

Keywords: areal type, chorology, chorionomy, chronoelement, coenoelement, floristic element, geoelement, phytogeography, provincialism.

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Introduction

Brief history

Phytogeography, as a branch of botany, has developed over the past two centuries, from the early 19th century to the present day. Among its aims, the description of biogeographic territories has been the task of a series of botanists and their proposals have been very diverse according to the state of knowledge of the flora of the different parts of the world during that period. Such diversity of proposals has sometimes raised criticism about the convenience of such approaches as they have been considered nonobjective and not rigorous because they follow different criteria, as was pointed by Alphonse de Candolle, so early as in 1855. Nevertheless, we consider such region descriptions as a useful tool to understand and document the spatial patterns of the plant's distribution according to their ecological requirements and their evolutionary history.

The first attempt to classify flora based on geographic criteria was made by Treviranus (1803), who divided the world into eight different floras (Hauptfloren). Lamarck & A. P. de Candolle published, for the 3rd edition of the Flore Française (1805), the first phytogeographical map of the history comprising France (Ebach & Gouget 2006). Later, A. P. de Candolle (1820) classified the world's flora into 20 floristic regions without providing any map.

A global map of the entire world was not available until 1823 when Schouw published a map with 25 kingdoms (Florenreiche). In the last third of the 19th century, Engler (1879, 1882) divided the world into four realms and 32 regions and further divided the regions into provinces and districts, establishing a detailed hierarchical system for biogeographic territories. Drude in 1884 (Die Florereiche der Erde) defined 14 kingdoms and 55 regions incorporating a substantial amount of ecological information was compiled and made available later by Grisebach (1872).

Diels (1908) established the six floristic realms have been mostly accepted so far, as they have been retained by modern well-known authors such as Mattick (1964), Good (1974), and Takhtajan (1986). The latest contributions at a continental scale are due to Olson *et al.* (2001), Rivas-Martínez *et al.* (2001, 2011a) and to Cox *et al.* (2016) on a global scale.

Concepts

Environmental factors, particularly climatic ones, as well as the history of the Earth itself, with the vicissitudes it has suffered across the geological periods, have shaped the current distribution of the flora and the vegetation on the terrestrial domain. It defined the different floral territories into which the world's terrestrial surface can be currently divided (Costa, 2004; Loidi, 2021a). All species have limits, either ecological or geographic, outside of which they do not exist in nature. Consequently, each species possesses a unique ecological and geographic profile. The spatial patterns of biodiversity are determined by the way in which

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the geographic ranges (areal) of species overlap or exclude each other on the Earth's surface. The science that studies the distribution of organisms on Earth with attention to the patterns that are manifested and the causes that determine them, is Biogeography (or chorology). In short, we can say that it is the science that tries to document and understand the spatial patterns of biodiversity (Brown & Lomolino, 1998; Loidi, 2021a). In addition to knowing how organisms are distributed on the Earth's surface, Biogeography tries to find out their causes from an ecological and historical perspective. From a spatial perspective, Biogeography deals with the causes and mechanisms of dispersal that made it possible for species of diverse phylogenetic origin and different ecological requirements to cohabit in a certain region, although each one has a link to its specific habitat. Hence, we can also say that it is the discipline devoted to the study of the distribution of taxa and ecosystems across geographical space and through geological time (Loidi, 2021a).

Biogeography is a necessarily synthetic subject that develops at the intersection of other disciplines: ecology, systematics, evolutionary biology, paleontology, geography, and other earth sciences, such as geology, climatology, or oceanography, to the extent that all of them provide information to explain the distributions of organisms and their underlying causes. Biogeography is not an experimental science but a comparative observational one because it works on a scale of space and time in which manipulation is impossible.

Phytogeography, in the strict sense, deals only with plants, but there is, however, a tendency to make biogeography and phytogeography synonymous, since plants are the primary producers of ecosystems as well as the structural support of almost all terrestrial ones. This, together with their forced immobility, which makes them the beings most exposed to the mesological conditions of each point, makes plants an ideal subject for biogeographical synthesis.

Floristic element

As documented by Loidi (2021a) and also called "Geoflora" and "geographic or phytogeographic element", it is a concept was first used by Christ (1867) with a purely geographic meaning. Later it was used by Engler (1882), who introduced a historical component to the concept, forming the historic-geographic meaning he used to define the Arcto-Tertiary (*arkto-tertiäre*), Arctic-Alpine (*arktisch-alpine*), Tertiary-Boreal (*tertiär-boreal*), etc. floristic elements or geofloras. Braun-Blanquet (1922) redefines this concept in a basically geographic sense: "l'élément phytogéographique est l'éxpression floristique et phytosociologique d'un territoire étendu defini; il englobe les "sippes" et les collectivités phytogéographiques caractéristiques d'une région determinée". [The phytogeographical element is the floristic and phytosociological expression of a defined extended territory; it encompasses the "lineages" and the phytogeographic comunities characteristic of a given region]. Later, the concept of the floristic element has been broadened and differentiated by numerous authors to several meanings: "genetic" or "locative" floristic element (species with a common motherland); "migrational element" or "migrant" (species arrived by the same migratory routs); "chronoelement" or "historical element" (species migrated to the current locality at the same time); "coenoelement" (species closely associated with one particular vegetation community); "geographic element", "component" or "areal type" (species with a common modern distribution area; Reichert, 1921; Hayek, 1926; Walter, 1927; Wangerin, 1932; Kleopov, 1990).

Our definition sticks to the geographical meaning and is as follows: the set of taxa (basically families, genera, and species) not necessarily related ecologically (they use to live in a diversity of habitats) or phylogenetically, which have a common history along their evolutionary life by having lived together in a defined biogeographical territory. During the time in which they live together, they are affected in common by the climatic and geological episodes that have taken place and suffered together their effects on the biota: extinctions, radiations, migrations, etc.

Biogeographical regionalization (provincialism)

When examining the distribution areas of taxa, it becomes evident that they are not randomly or uniformly distributed. Instead, they exhibit patterns that make them appear somewhat grouped in particular territories. The partial or significant overlap of areas of different taxa, whether they are phylogenetically close or not, leads us to the definition of territories characterized by a unique set of taxa, that is, their flora or list of species. This concept can be referred to as "biogeographical regionalization". Each territorial unit possesses a specific flora and fauna, determined by the species residing within its boundaries, representing its genetic heritage or biodiversity in gamma terms. Many species have ranges that extend far beyond the boundaries of these territories, but that will serve to relate them to other territories as more taxa are shared between them. Thus, a nested or hierarchical system of relationships between territories defined by their floristic relationships can be built. Territories sharing more taxa are considered closer, and at the same time, larger entities can be conceived encompassing the smaller territories, in a hierarchical system that resembles the administrative-territorial system of any political state, which is divided into regions, these into provinces and these, in turn, into counties or into municipalities. The definition of each of these entities is based on their specific biota and the relationships between them based on the shared biota. This approach can be applied to all known taxonomic entities, so the level of knowledge of the flora and fauna plays an important role. Lower taxonomic levels, such as subspecies or varieties, to the extent that they represent initial stages in the speciation, characterize low-rank entities (districts, sectors), which can be quite similar

to each other if they are adjacent. Reversely, higher taxonomic levels, such as genera or families, define higher-ranking entities (regions, kingdoms), which differ significantly from each other due to their ancient evolutionary distinctions. Furthermore, vegetation, defined as the assemblage of plant communities, plays an important diagnostic role in lower-rank units, while its diagnostic value decreases in higher-ranking units, where all vegetation units are distinct (Figure 1). This approach results in the development of a geography based on the definition of hierarchically nested territories (Nelson 1978) that was called "provincialism" (Brown & Lomolino 1998). These territories also received the name "choria" by Turrill (1948), Takhtajan (1986), and Costa (2004), from the Greek *χορίου* (chorion). The knowledge about choria is known as "chorionomy", a term that could be considered a synonym with provincialism.

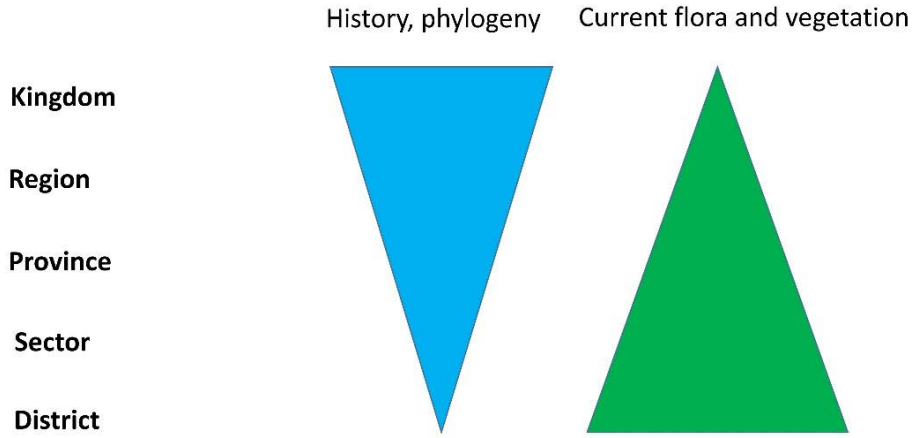

Figure 1. Relative importance of the historical-phylogenetic criteria in contrast with those of current flora and vegetation in the diagnose of the biogeographic territories of different rank.

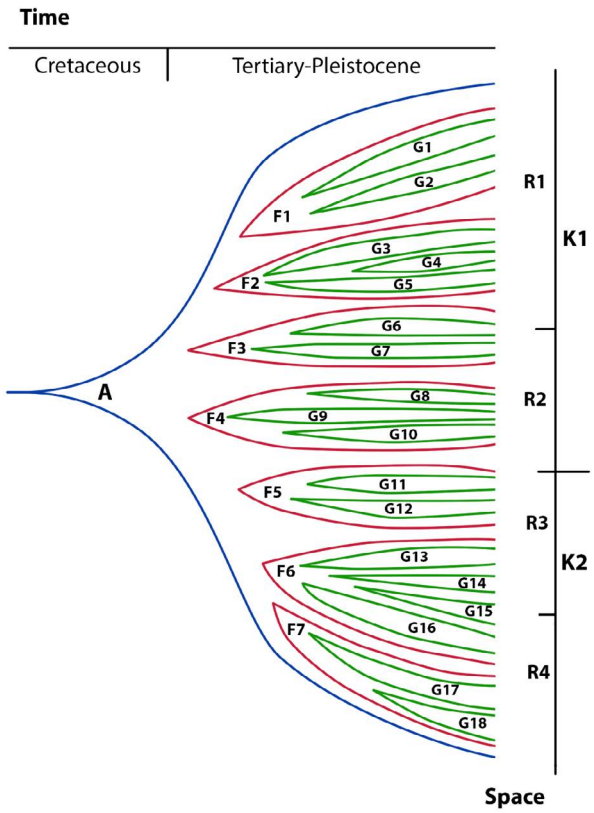

Figure 2. Diagram representing the temporary and spatial distribution of families and genera of Angiosperms in imaginary biogeographic kingdoms and regions. Angiosperms (A) originate in early-mid Cretaceous and expand all over the world. Within them originate orders, families, genera and species along the Tertiary. These taxa distribute in space following determined patterns. In the scheme are represented 7 families (F1 to F7) which are diversified into 18 genera (G1 to G18). They are distributed across two kingdoms (K1 and K2) and four regions (R1 to R4) (see table below for summarizing).

Kingdoms	Families and Genera	Regions	Families and Genera
K1	F1 (G1 + G2) + F2 (G3 + G4 + G5) + F3 (G6 + G7) + F4 (G8 + G9 + G10)	R1	F1 (G1 + G2) + F2 (G3 + G4 + G5) + F3 pp. (G6 pp.)
		R2	F4 (G8 + G9 + G10) + F3 pp. (G6 pp. + G7)
K2	F5 (G11+G12) + F6 (G13 + G14 + G15 + G16) + F7 (G17 + G18)	R3	F5 (G11+G12) + F6 pp. (G13 + G14 + G15 pp.)
		R4	F6 pp. (G 16 + G15 pp.) + F7 (G17 + G18)

The biogeographic definition and classification of a territory not only provide a strong identification of its current biota but also offer a framework for understanding its relationships with adjacent and more distant territories. The hierarchical model, in addition to reflecting a current reality concerning biodiversity and environmental conditions, also tries to reproduce its evolutionary history, in a similar way to how the modern plant systematic of phylogenetic principle does, in relation to the evolution of the different lineages over time (Figure 2). It is a matter of building a phylogenetic Biogeography, in the sense of Engler (1879; 1882), in which these criteria gain more significance at higher ranks and diminish at lower ranks, inversely to what happens with the ecological conditions. This has been also expressed by Cox (2001) about the floristic component of the territories: for the higher-ranking biogeographic units, such as Kingdoms, historical Biogeography has a strong weight, whereas ecological Biogeography is more relevant for lower-ranking units (provinces, sectors, districts). The hierarchical rank of the biogeographic system: kingdom > region > province > sector > district, is proportional to the antiquity of the taxa involved in its characterization: family > genus > species > subspecies.

This is related to the diversity content; the level provided by the floristic cast of each territory will be proportional to the number of species that constitute it, but also to the degree of phylogenetic diversity that this set contains. A list composed of species, many of them belonging to a few closely related genera, is less diverse than a similar number of species belonging to numerous genera with few species each, which are also grouped into very different families (Good, 1974). This serves to modulate the floristic independence of the territories since there are situations in which there are many neoendemisms that come from adaptive radiation, which cannot be matched in diagnostic quality with the information provided by very ancient lineages in relation to the historical reconstruction of the evolution of the biota of each territory. Something similar can be said about genera and even about families; the distributions of the taxa at these levels tell us of ancient relationships that must be weighed in the biogeographical classification.

Provincialism was one of the earliest approaches to the science of biogeography in the 18th and 19th centuries when the first maps with the regions of the world were published by authors such as Willdenow (1792), Schouw (1823), A. de Candolle (1855), Engler (1882; 1899), Drude (1884), Wallace (1876) and Grisebach (1884). In the 20th century, more documented and detailed contributions were made, among which Good (1974) and Takhtajan (1986) stand out. It is assumed that there is not a floristic continuum. The eco-bio-floristic space is discontinuous: sharper or fuzzier boundaries can be recognized and mapped at different scales. Discrete floristic entities (floristic elements) emerge in certain moments and locations and evolve, expand, migrate, or reduce driven by environmental and geographic changes (climate change, continental drift, orogenies, land connections and disconnections, etc.).

The main ranks in the systematic of the biogeographic territories are: Kingdom (Realm), Region, Province, Sector, and District, for which already Braun-Blanquet (1922; 1979) established the basic criteria for their definition. Intermediate ranges, such as sub-kingdom, sub-region, sub-province, and sub-sector, are often defined among them (Loidi, 2021a). Comments on vegetation concepts follow Loidi (2021b). Table 1 summarizes the criteria used to distinguish the different territorial units.

- **Kingdom** (Realm). Fr. *Empire*, Ger. *Florenreich*, Sp. *Reino*.

The Kingdom, or Realm, is the highest-ranking unit in the biogeographical system. Each of these territories has continental dimensions and its biotas show a certain degree of common and specific characteristics of each one, although they usually encompass a great diversity of climates. This is because each of them has had proper evolutionary trends relatively independent of each other. Kingdoms are separated by significant geographic barriers, such as oceans and vast warm deserts, or by pronounced differences in climate, such as tropical vs. temperate. Therefore, the kingdom is a large territory, usually covering one several continents, hosting high-ranking taxonomic entities like families, subfamilies, or tribes, along with the majority of genera and nearly all the species within its borders. The origin of Kingdoms can be traced back to evolutionary branching in the early stages of the Angiosperms, i.e. during the Cretaceous period.

Table 1. Summary of the defining criteria for the biogeographical categories, from Loidi 2021a modified. Biomes after Loidi et al. 2022.

	Flora	Plant Communities	Integrated Phytosociology	Biomes	Drivers
Kingdom (Realm)	Endemic families, subfamilies and tribes; very high generic and specific endemism. Paleogenic endemism of high rank	Practically all the classes are endemic, only synatropic or aquatic ones are cosmopolitan or subcosmopolitan		Several biomes-subbiomes represented (except Capensis)	Remote origin: late Cretaceous. High variability in climatic types.
Region	High generic and specific endemism. Few families endemic or with predominant position in the region. Paleogenic endemism of intermediate rank (genus)	Several exclusive classes and orders. Classes with their optimum within the region involved.		One or several biomes-subbiomes represented	Recent origin: Tertiary. Moderate variability in climatic types.
Province	Some endemic genera (usually monotypic or oligotypic). Still relevant specific endemism; paleogenic endemism of low rank (species). Statistically distinct assemblages of species.	Some alliances or suballiances endemic. Relevant association endemism.	Some exclusive climatophilous sigmeta. Particular altitudinal (mountain) vegetation zonation (cliserial geosigmetum).	One of the biomes-subbiomes represented	Determined by strong changes in climate and/or substrate
Sector	Low or absence of species endemism, occasionally endemic subespecies; long isolated islands increase endemic element	Some associations endemic	Several exclusive climatophilous geosigmeta.	One subbiome represented	Determined by changes in climate and/or substrate
District	Usually no endemism in the flora. Slight floristical differences with neighbour districts are due to geomorphology: relief or substrata, or to slight differences in climate.	No syntaxonomical endemism; in some cases lower rank syntaxa like subassociation, variant and facies are exclusive. Some associations are lacking in neighbouring districts	Geomorphologically homogeneous territory. At least one climatophilous geosigmetum and some geopermasigmeta exclusive to the territory.	One subbiome represented	Determined by slight changes in climate and/or substrate

Within a kingdom, several biome types and high-rank climatic types are found. Six kingdoms are traditionally recognized on Earth (Figure 3): Holartic, Paleotropical, Neotropical, Capensis, Australian, and Holoantarctic (Rikli, 1913; Schroeder, 1998; Frey & Lösch, 2010, Cox *et al*., 2016).

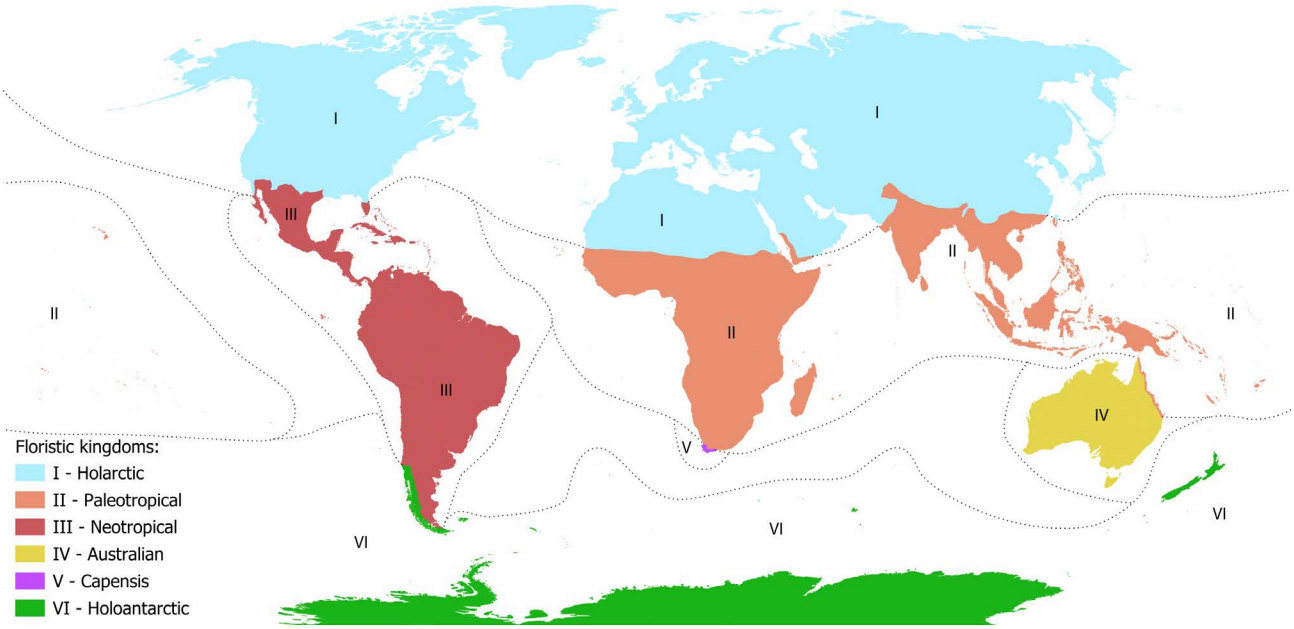

Figure 3. Biogeographic kingdoms of the world. I, Holarctic; II, Peleotropical; III, Neotropical; IV, Australian; V, Capensis; VI, Holantarctic.

• **Region**. Fr. *région*, Ger. *Gebiet* or *Region*, Sp. *región*.

The kingdoms are further divided into regions, which are extensive territories characterized by a high level of floristic specificity, which can include some small endemic families, and the level of endemism increases as we descend to lower taxonomic ranks such as genera and species, where it encompasses a majority of the taxa. Although not strictly endemic, there are important families whose geographical distribution focuses on a certain region, where its dispersion center resides. An example of this is the *Cistaceae* family which is closely associated with the Mediterranean region. Its differentiation could be established along the Tertiary, a time when most of the modern Angiosperm lineages diverged. The regions can be characterized by having a phytosociological class that is exclusive or, more frequently, there are several who find their optimum in it. The *Quercetea ilicis* has its optimum in the Mediterranean region, while the *Molinio-Arrhenatheretea* has it in the Eurosiberian. At lower syntaxonomic levels, such as orders and alliances, endemicity increases exponentially. From the physiognomic perspective regarding biomes (Loidi *et al*., 2022), certain types of formations predominate due to the general climatic conditions. For example, within the Holarctic kingdom, the "Oceanic sclerophyllous-microphyllous evergreen forests and shrublands" characterizes the Mediterranean and Californian regions, the "Temperate deciduous forests" characterizes in an outstanding way the Eurosiberian, Chinese-Japanese and North American Atlantic regions, while the "Boreal forest" prevails in the Circumboreal and in that of the Rocky Mountains and the "deserts and semi-deserts" in the Saharo-Sidian. Nevertheless, there is a certain variability in climatic and physiognomic types within each region. The exact number of recognized biogeographical regions worldwide varies depending on the authors. In our classification, we accept a total of 42 regions.

Vegetation is also a relevant trait to characterize the biogeographical regions. At this level, we consider that defining by means of biotic units at the level of biomes and subbiomes (Loidi *et al*., 2022) is adequate, as is explained in the region's descriptions and summarized in Table 2.

• **Province**. Fr. *domaine*, Ger. *Provinz*, Sp. *Provincia*.

It is a territory of regular dimensions in which the degree of endemicity scarcely reaches the genus level, usually with some mono- or oligospecific genera, and their distinctiveness becomes particularly evident at the species level. In a syntaxonomic context, there are endemic alliances of provinces. Although at the level of associations, we observe greater specificity, having associations of potential natural vegetation peculiar to the provinces. Regarding the organization of the landscape, the provinces have a particular altitudinal zonation of vegetation (oreogeosigmetum, Loidi 2021b). Provinces are also characterized by clearly distinguishing climatic and edaphic conditions.

• **Sector** (Ger. *Bezirk*).

It is a territory of modest dimensions. Endemicity affects a reduced proportion of taxa, typically at the subspecific level, occasionally affecting only a small number of species. What truly distinguishes a sector is the set or combination of taxa inhabiting it (the floristic catalog). It can have some exclusive associations although not of potential natural vegetation. The defining feature of a sector is its particular zonation of vegetation, determined by its topographic geosigmetum, often described using the Ridge-Slope-Valley geocomplex model (Alcaraz, 1996; Loidi, 2021b; Navarro-Sánchez, Luebert & Molina-Abril, 2023). The climate and/or substrate change between adjacent sectors in a relevant way.

• **District**

It is the lowest unit of the chorionomic system. According to Braun-Blanquet (1979), it is defined by "particular communities of lower rank (variants, facies), there are no endemic species in own associations". Typically, a district encompasses a relatively small territory, where endemicity is either non-existent or occurs sporadically. However, what sets a district apart is its exceptional biogeographic homogeneity in terms of mesoclimate conditions, relief features, lithology, and the origins of the flora that populates it. Therefore, in a district, there is a unique pattern in the arrangement of plant communities across the landscape. This pattern is expressed through dynamic-catenal relationships among the plant communities. The lower alteration in this pattern, which can be caused by a slight change in the conditions of relief, climate, or lithology, determines a district change. In essence, a district is a territory of variable dimensions, characterized by geomorphological, lithological, and climatic homogeneity, that has a main geosigmetum, and one or few more special geosigmeta (edaphophilous). A modification in the catenal arrangement of any sigmetum, or a change in a geosigmetum, distinguishes one district from any other limiting one (Alcaraz, 1996).

Materials and methods

The map of the biogeographical kingdoms and regions of the Earth has been drawn using QGIS software (QGIS Development Team 2009). It contains GIS vector layers (in a zip archive) with polygons classified to the level of kingdoms and regions (Appendix S1). The polygons are also assigned to the corresponding subbiomes, biomes, ecozones and domains following Loidi *et al*. (2023). Formats are as follows: GeoJSON, ESRI shapefile, and QGIS Layer settings files. Coordinate reference system (CRS): EPSG:4326 - WGS 84; Charset Encoding: UTF-8.

Approximate area of different biogeographical regions in the Table 2 is calculated in a World Cylindrical Equal Area projection, ESRI: 54034. Distribution of the

biogeographic regions and kingdoms across the world in the Robinson projection (ESRI: 54030) is presented in the Figures 3 and 4.

In order to distinguish the 42 regions, the distribution of biomes and subbiomes has typically been used. For example, the Guineo-Congolian region (14) limits are those of the "Tropical Rain Forest", the Mediterranean (5) and Southwestern Australian (37) regions occupy the area of the "Oceanic sclerophyllous-microphyllous evergreen forests and shrublands", the Circumarctic region (1) occupies the area of the "Polar Tundra" in the northern hemisphere, the limit between the Circumarctic (2) and Eurosiberian (3) regions are those between the "Lowland boreal taiga" and the "Temperate deciduous forest", etc.

Comments about climate and biomes follow Rivas-Martínez *et al.* (2011b) and Loidi *et al.* (2022). The taxa names have been updated after the POWO database except those marked with an asterisk which use the names of the traditional botanical literature of the last decades.

The Kingdoms (realms) and Regions of the Earth

This work aims to provide an update of the maps created by Good (1974) and especially Takhtajan (1986) by taking into account new available information on the flora, vegetation, and climate of the recognized territorial units. Other relevant authors are Heywood (1978); Costa (2004); Frey & Lösch (2010); Pfadenhauer & Klötzli (2014); Morrone (2015) and Rivas-Martínez *et al.* (2001; 2011a). Thus, the biogeographical regions proposed in this work have been built largely accepting the traditional criteria and classifications of mentioned authors. In the cases of divergence, explanations are given. Figure 4 shows the 42 biogeographic regions of the world grouped into the six kingdoms.

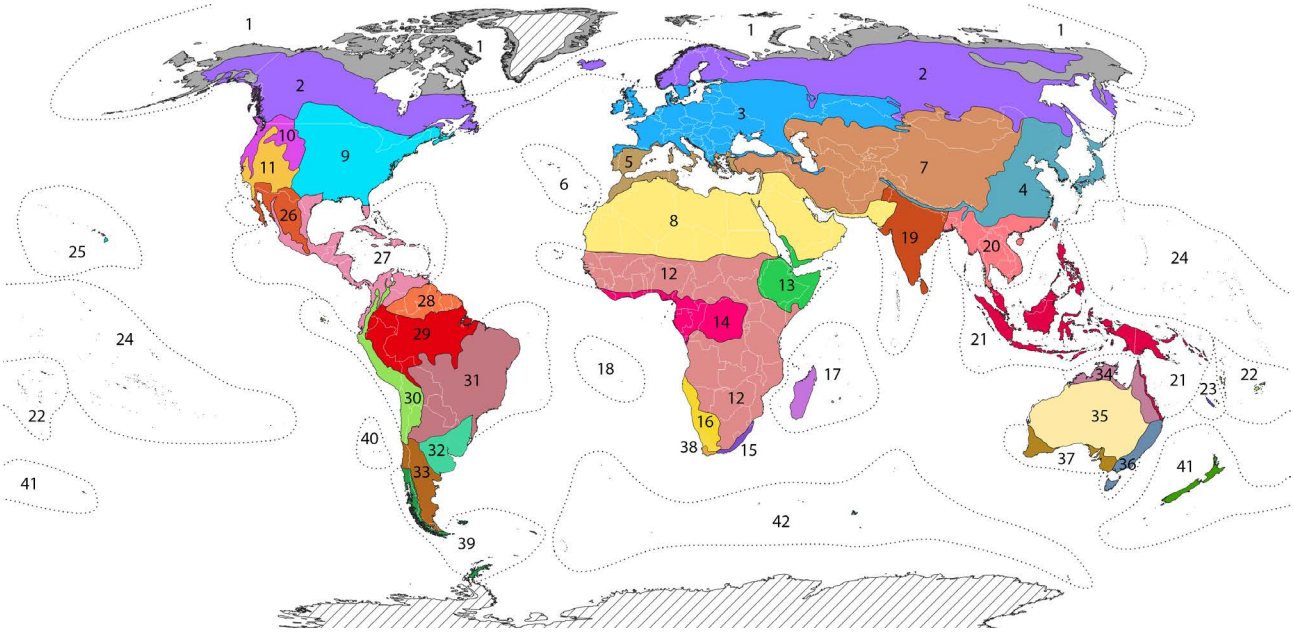

Figure 4. The 42 biogeographic regions of the world. 1, Circumarctic; 2, Circumboreal; 3, Eurosiberian; 4, Chinese-Japanese; 5, Mediterranean; 6, Macaronesian; 7, Irano-Turanian; 8, Saharo-Sindian; 9, North American Atlantic, 10, Rocky Mountains; 11, Western North American (California and Great Basin). 12, Sudano-Zambezian, 13, Ethiopian-Southarabian; 14, Guinean-Congolese; 15, Southeastern African; 16, Karoo-Namibian; 17, Malagasy; 18, St. Helena and Ascension; 19, Indian; 20, Indo-Chinese; 21, Malesian; 22, Fijian; 23, Neocaledonian; 24, Polinesian; 25, Hawaian; 26, Madrean; 27, Antillean-Mesoamerican; 28, Orinoco-Guyana; 29, Amazonian; 30, Andean-Pacific; 31, Brazilian-Parana; 32, Pampean; 33, Central Chilean-Western Patagonian; 34, North Australian, 35, Central Australian (Eremean); 36, Tasmanian-Southeastern Australian; 37, Southwestern Australian; 38, Capensis; 39, Valdivian-Magellanic; 40, Juan Fernández; 41, New Zealand; 42, Circumantarctic archipelagos.

I. Holarctic kingdom

It is the largest among the 6 kingdoms, encompassing all the emerged lands in the northern hemisphere above the Tropic of Cancer. Its scope is bicontinental and this is due to the connection between Eurasia and North America (North Atlantic Land Bridge), which persisted until relatively recently in its northern zone, allowing for genetic exchange and biota migration (Tiffney, 1985; Denk *et al*., 2011). This kingdom hosts up to 60 characteristic families of regular size, as well as some small-sized ones, such as the Adoxaceae, Cephalotaxaceae, Ginkgoaceae, Hippuridaceae, Paeoniaceae or Scheuchzeriaceae. Other families reach their optimum in this kingdom, although they extend beyond its borders, such as Apiaceae, Betulaceae, Brassicaceae, Butomaceae, Campanulaceae, Caprifoliaceae, Caryophyllaceae, Diapensiaceae, Fagaceae, Fumariaceae, Pinaceae, Platanaceae, Pyrolaceae, Primulaceae, Ranunculaceae, Rosaceae, Salicaceae, Sapindaceae (subfamily Hippocastanoideae) and Saxifragaceae (Costa, 2004). Some tree genera, both gymnosperms such as *Abies*, *Pinus*, *Larix*, or *Picea*, or angiosperms such as *Fagus* or *Betula*, form extensive forests and are endemic to

this unit. Other representative predominantly Holarctic genera are *Aquilegia*, *Epipactis*, *Fritillaria*, *Iris*, *Spiraea*, *Trollius*, or *Veratrum*. The Holarctic flora has a notable representation in the high-elevation areas of the tropical mountains, which have served as a migratory bridge between the temperate regions of both hemispheres, especially during the cold periods of glaciation. This is indicated by the distribution of genera such as *Artemisia*, *Berberis*, *Rhamnus*, *Rosa*, *Sambucus*, and *Thalictrum*. For southward migration across African mountains, we observe genera like *Allium*, *Cirsium*, *Crepis*, *Erica*, or *Subularia*. Meanwhile, *Alnus*, *Draba*, *Cotoneaster*, *Juglans*, *Pinguicula*, and *Ribes* have migrated through the Andes. *Acer*, *Androsace*, *Euonymus*, *Pyrola*, and *Rhododendron* have expanded southward through the Asian mountains.

Table 2. Biomes and subbiomes after Loidi et al. (2022) represented in the 42 biogeographic regions of the world with % of land occupation. The 20 subbiomes considered are: 1a Polar tundra, 1b Tundras of the temparate mountains in cryoro belt, 1c Tundras of the tropical mountains in cryoro belt, 2a Lowland boreal Taiga, 2b Forests and shrublands of the temperate oro belt, 3a Temperate deciduous forests, 4a Lauroid evergreen forest of the lowlands, 4b Conifer coastal forests, 4c Tropical-subtropical montane cloud lauroid and conifer evergreen forest, 5a Oceanic scleropyllous-microphyllous evergreen forests and shrublands (Mediterranean), 5b Continental scrub and woodlands, 5c Patagonian shrubland, 6a Forest-steppe, 6b Grass-steppe, 7a Cold deserts and semi-deserts, 7b Temperate deserts and semi-deserts, 7c Warm deserts and semi-deserts, 8a Tropical xeric shrublands and woodlands, 8b Tropical pluvisesonal forests and woodlands, 9a Tropical rain forests. Abbreviations are: K, Kingdom; N., Region number.

			Biomes and subbiomes																				
			1			2		3	4			5			6		7			8		9	
K	N.	Regions	1a	1b	1c	2a	2b	3a	4a	4b	4c	5a	5b	5c	6a	6b	7a	7b	7c	8a	8b	9a	Area (km^2)
I	1	Circumarctic	100																				7758310
	2	Circumboreal	<1	2		97	<1								1								17521648
	3	Eurosiberian		1		<1	1	55				<1	<1		18	25	<1						8255922
	4	Chinese-Japanese		<1			<1	59	28		13												4583809
	5	Mediterranean		<1			<1	7				89	4					<1					1453070
	6	Macaronesian		<1			<1				36	19						43					10854
	7	Irano-Turanian		15		<1	11	<1			<1		13		4	9	40	8					13804491
	8	Saharo-Sindian										<1						40	60				13393677
	9	North American Atlantic				<1		50	10						10	30							6240632
	10	Rocky Mountains		2			82			17													1255277
	11	Western North American (California and Great Basin)										12	67				7	13	<1	<1			1400236
II	12	Sudano-Zambezian			<1						<1								<1	24	74		13653807
	13	Ethiopian-Southarabian			<1						20								12	46	21		2066335
	14	Guinean-Congolese			<1						<1											100	2583513
	15	Southeastern African							96		4												159963
	16	Karoo-Namibian																71	29				942023
	17	Malagasy									<1										79	21	600110
	18	St. Helena and Ascension									20										80		214
	19	Indian									<1									35	59	6	2682409
	20	Indo-Chinese																			29	71	2745187
	21	Malesian			<1						3										4	93	3159213
	22	Fijian																				100	36157
	23	Neocaledonian									<1										100		18841
	24	Polinesian																			2	96	7402
	25	Hawaian									22											78	16856
III	26	Madrean									32		<1					25	22	21	<1		1330859
	27	Antillean-Mesoamerican			<1						1									2	51	46	2904484
	28	Orinoco-Guyana									<1											100	1372723
	29	Amazonian									<1											100	4232827
	30	Andean-Pacific			42						28								19	9	2	<1	1787716
	31	Brazilian-Parana									<1									11	84	4	6418560
	32	Pampean							100														1245639
	33	Central Chilean-Western Patagonian			3							9		88									1212576

IV	34	North Australian												<1	100	<1	1031056
	35	Central Australian (Eremean)											46	23	31	<1	5304372
	36	Tasmanian-Southeastern Australian		1			99										669404
	37	Southwestern Australian							100								574942
V	38	Capensis							100								45023
VI	39	Valdivian-Magellanic	13			11	16	60									432875
	40	Juan Fernández							98					1			145
	41	New Zealand		6				94									268731
	42	Subantarctic archipelagos	98					2									9021

1. Circumarctic region

It encompasses the areas subject to a cold tundral climate surrounding the Arctic glacial ocean in Eurasia and North America, including southern Greenland. The climatic conditions here are very harsh and correspond to those of polar ones, with maximum average temperatures in the warmest month not exceeding 10ºC, a plant activity period of up to 3 months, and a cold season of 8 months, with temperatures very often below 0 ºC. The soils have a permanently frozen horizon (permafrost) and this prevents the development of trees. The ice melt that occurs during the short warm season leads to the formation of swampy areas with peat bogs. Despite its low productivity, the tundra supports seasonal predation by large herbivores such as reindeer.

The vegetation within the Circumarctic region is very homogeneous throughout the territory, primarily consisting of low-sized bushes, herbs, mosses, and lichens, in a formation known as tundra (subbiome type 1a Polar tundra). Willows and creeping birches, as well as Ericaceae of the genera *Arctostaphylos*, *Calluna*, *Cassiope*, *Empetrum*, *Phyllodoce*, *Vaccinium*, etc., form the main biomass. There are also other genera such as *Dryas*, *Oxyria*, *Pedicularis*, *Potentilla*, *Saxifraga*, etc. The flora is made up of up to 2000 species of vascular plants, among which there are many that are spread over both continents, such as *Carex bigelowii*, *Cassiope tetragona*, *Dryas octopetala*, *Oreomecon radicata*, *Phippsia algida*, *Salix herbacea*, *S. polaris*, *Saxifraga oppositifolia*, etc. (Polunin, 1954). Some of these species are also found in the alpine belts of the mountains of the temperate zone, forming what has been called the arctic-alpine disjunction, which was formed with the migrations induced by the Quaternary glaciations (Abbot & Bronchmann, 2003; Murray, 1995).

This region has been recognized in its Eurasian-North American bicontinental scope by a majority of the authors since the earliest times (Krasnov, 1899, Engler, 1903; Good, 1974; Schroeder, 1998; Costa, 2004; Pfadenhauer & Klötzli, 1014).

2. Circumboreal region

It is the largest of the floristic regions of the world, since it covers the entire boreal climate zone of both Eurasian and North American continents, similar to the previous region. This conception is not coincident with traditional authors who mostly split it into two or more units across North America, East Asia, and western Siberia, but we decided to accept a unifying criterion, as suggested by Talbot & Meades (2011) as there is a strong homogeneity of the flora at the level of the genus in both continents. The boundary with the Circumarctic region is marked by the transition from coniferous forest to tundra, while its southern limit corresponds to the transition to deciduous temperate forest. The climate here is of the boreal type, characterized by long winters of no less than six months and short summers in which the number of days with more than 10ºC does not exceed 120. The zonal soils are of the podzol type, in harmony with the climate conditions and vegetation type.

The vegetation is dominated by coniferous forests consisting of genera like *Pinus*, *Larix*, *Picea*, and *Abies*, forming the taiga ecosystem. In addition, there is a notable participation of birches (*Betula*) and aspens (*Populus tremula*, *P. tremuloides*), which come to form forests in some successional situations. Peat bogs are also frequent, occurring extensively due to the flat topography of much of the territory. They are formed as a result of low evapotranspiration rates not compensating for water inputs and, if there is no drainage to evacuate the excess, the water tends to accumulate in the soil, forming a water table that is always close to the surface or even above it (pondings, lagoons). Under such conditions, the organic matter does not decompose completely due to the short vegetative period and the anaerobic conditions of the water environment, forming peat. Various bryophytic species develop in these peat bogs, including those of the *Sphagnum* genus, as well as a series of vascular plants such as *Andromeda polifolia*, *Drosera rotundifolia*, *Eriophorum vaginatum*, *Ledum palustre*, *Trichophorum cespitosum*, *Vaccinium oxycoccos*, and others.

The biomes and subbiomes represented in this region are mostly the 2a (Lowland boreal taiga), and 1b (Tundras of the temperate mountains in cryoro belt) in the mountain areas at higher elevations.

The flora is relatively poor and with low endemicity given the recent climatic oscillations of the Pleistocene that formed the enormous ice sheets during the cold periods in areas that today are covered by these forests. There is a distribution of tree species in three main areas: the Western Eurosiberian (*Betula pubescens*, *Larix sibirica*, *Picea abies*, *Pinus sylverstris*, *Populus tremula*), Central-Eastern Siberia (*Abies sibirica*, *Larix gmelinii*,

Picea obovata, *Pinus sibirica*) and North America (*Abies balsamea*, *Betula papyrifera*, *Larix laricina*, *Pinus banksiana*, *Picea glauca*, *P. mariana*, *Populus tremuloides*). The undergrowth of the taiga is made up of a dense plant layer in which mosses and lichens have a strong role and in which vascular species such as *Arctous alpina*, *Linnaea borealis*, *Rubus chamaemorus*, *Vaccinium myrtillus*, *V. vitis-idaea*, *V. uliginosum*, etc. participate (Hytteborn *et al.*, 2005; Weber & Van Cleve, 2005). In a similar way to what happens with the Arctic flora, part of the boreal flora and vegetation is also found in the temperate mountains of the northern hemisphere continents, where it is dominant in altitudinal ranges that comprise the oro (subalpine) belts of these mountains.

3. Eurosiberian region

The Eurosiberian region encompasses territories with a pluviestival temperate climate, spanning most of Europe, except for the northernmost regions which belong to the Circumboreal and Circumarctic regions. It extends from the southern regions of Scandinavia and the Baltic, southwards to northern Iberia, Italy, the southern Balkans, northern Anatolia, and the Caucasus. The European boundaries of this region are coincident with those defined by Rivas-Martínez *et al*., (2001). To the east, the Eurosiberian region extends into eastern Europe and crosses the Urals, forming a narrowing wedge that reaches into central Asia. Another extension is the Hyrcanian area in northern Iran, which forms an east-west fringe along the northern slopes of the Alborz range and is bordered by the Caspian Sea. These areas receive abundant rainfall from north winds carrying moisture from the Caspian Sea. The Hyrcanian province is connected to the rest of the Eurosiberian region through the South Caucasian Mountain ranges in Armenia.

The zonal vegetation of this region are temperate deciduous forests (Loidi *et al*., 2021; Loidi & Marcenò, 2022), corresponding to the subbiome 3a (Temperate deciduous forest). In the areas north of the Black Sea and central Asia, steppes of the biome 6 (subbiomes 6a Forest-steppe and 6b Grass-steppe) cover large areas. In the high mountain ranges are also found the subbiomes 1b (Tundras of the temperate mountains in cryoro belt), and 2b (Forests and shrublands of the temperate oro belt). Its latitudinal amplitude is most pronounced along the Atlantic coasts thanks to the moderating influence of the Gulf Stream, which softens extreme temperatures, especially in winter, promoting the existence of deciduous forests and even allowing a certain penetration of Mediterranean plants from the south. As we move towards the east, the climate becomes more continental, leading to a reduction of areas occupied by deciduous forests, with a much narrower strip of such forests in Russia and Kazakstan. East of the Urals, deciduous forests disappear in western Siberia.

As for its flora, there are some small genera that can serve to characterize this region, such as *Erinus*, *Nigritella*, *Ramonda*, or *Soldanella*. The trees belong to Holarctic genera that are also present in the other homologous regions of the Asian and North American continents, such as *Acer*, *Carpinus*, *Fagus*, *Fraxinus*, *Populus*, *Quercus*, *Ulmus* and others. In general, the number of tree species is comparatively low due to extinctions during the Pleistocene cold periods, which were more frequent in Europe compared to North America and East Asia. Some species of the broad range have their geographic distribution basically in this region, such as *Campanula glomerata*, *Conium maculatum*, *Dactylis glomerata*, *Geranium pratense*, *Heracleum sphondylium*, *Holcus lanatus*, *Lamium album*, *Paris quadrifolia*, *Ranunculus acris* or *Solanum dulcamara*.

In the central and western territories of the Eurosiberian region, oak forests dominate, with *Quercus petraea* and *Q. robur* as common species, often accompanied by *Carpinus betulus* and *Fraxinus excelsior* on the fertile soils or *Betula pendula* and *Pinus sylvestris* on less fertile ones. At medium altitudes, beech forests become prevalent, with *Fagus sylvatica* being the most widespread species, which is replaced by *Fagus orientalis* in the euxinic and hyrcanic areas, together with *Parrotia persica* in the latter.

The entire southern fringe of this Eurosiberian region, encompassing the northern Iberian Peninsula, southern France, central-northern Italy, and a large part of the Danube basin and the Balkans, is under the sub-Mediterranean climatic variant, in which there is a month in the summer in which rainfall is less than twice its average temperature. There is a whole flora that characterizes this strip, with marcescent species such as *Quercus cerris*, *Q*, *frainetto*, *Q. pubescens*, or *Q. pyrenaica*, in which genuinely Mediterranean plants often penetrate, such as *Q. ilex*, *Q. suber*, *Rubia peregrina*, and *Ruscus aculeatus* (García-Mijangos *et al*., 2015).

The degradation of the forests leads to bushy vegetation that develops especially in the westernmost areas (Loidi *et al*., 2020a), in which ericoids of the *Calluna*, *Daboecia*, and *Erica* genera dominate, as well as some woody legumes from the *Genista* and *Ulex* genera (heathers and gorses). In much of Europe, land use has transformed the landscape into a countryside mosaic, generally referred to by the French term “bocage”, characterized by a mix of meadows and natural hedgerows (Loidi *et al*., 2020b), a result of an agro-livestock land use model.

Currently, the eastern part of Europe lies within the biome of the steppe. However, during the Quaternary, territories occupied by steppe vegetation covered also other large parts of the European continent. Thus, many steppic species are common along the Eurosiberian region as a component of dry grasslands: *Astragalus austriacus*, *A. onobrychis*, *Bromus erectus*, *Coronilla varia*, *Filipendula vulgaris*, *Linum austriacum*, *Phlomis herba-venti*, *Pimpinella saxifraga*, *Potentilla recta*, *Salvia nemorosa*, *Stipa pulcherrima*, *Thymus pannonicus*, etc.

The Eurosiberian region features a series of expansive mountain ranges that run through this region mostly from west to east (Ozenda, 1985), such as the Pyrenees, Alps, Apennines, Carpathians, and Caucasus. These mountain

ranges diversify the vegetation and significantly enrich the region's flora through the presence of numerous endemic species. In the mountains, the supra (montane) belt is usually occupied by beech forests, which are often accompanied by white fir, *Abies alba*. In the oro (subalpine) levels, coniferous forests similar to those of the Circumboreal region are installed, in which species such as *Larix decidua*, *Picea abies*, *Pinus cembra*, *P. mugo* or *P. uncinata* are found; they are accompanied by thickets of some broadly distributed taxa such as *Arctostaphylos uva-ursi*, *Chamaemespilus alpina*, *Kalmia procumbens*, *Rhododendron ferrugineum*, *Vaccinium uliginosum* subsp. *microphyllum*, etc. The cryoro (alpine) belt is populated by high mountain grasses and sedges dominated by species of *Carex*, *Elyna*, and *Festuca*. The alpine (cryoro-) and subalpine (oro-) levels of European mountains have an intimate relationship with the arctic tundra and boreal forests respectively, due to the Pleistocene climatic oscillations.

As these mountain massifs are separated, their high-altitude areas become isolated during warm periods, such as the present, leading to typical allopatric speciation and the development of distinct endemisms within each range. However, during the cold periods of the Pleistocene, these upper mountain levels came into contact, fostering intense floristic exchanges among the mountains. As a result, there is a number of species common to many of these massifs, indicating a migratory relationship. Examples include *Carlina acaulis*, *Crocus albiflorus*, *Gentiana acaulis*, *G. lutea*, *Geum montanum*, *Globularia cordifolia*, *Leontopodium alpinum*, *Linaria alpina*, *Primula auricula*, *Sepervivum arachnoideum*, and *Trifolium alpinum*, among others. During these cold phases, orophilic floras of the mountains also came into contact with the arctic and boreal zones, giving rise to a distinct community of flora and vegetation known as the arctic-alpine element, complemented by the boreal-subalpine element. Some species of this arctic-alpine element are *Dryas octopetala*, *Salix herbacea*, and *Saxifraga oppositifolia*, while the boreal-subalpine element can be represented by some trees like *Picea abies* and *Pinus cembra*.

About native plant species useful to humans, there are a few examples, including *Brassica oleracea* (cabbage), *Pyrus communis* (pear), and *Rheum rhaponticum* (rapontic).

4. Chinese-Japanese region

It includes the temperate non-tropical and non-boreal territories of East Asia, extending from the Far East of Russia, the Amur River area and Transbaikalia, a large part of mainland China (Ching, 1991; Hou, 1983), the Korean peninsula and the archipelagos of Japan and the South Kuriles, northern Taiwan (Formosa) and the southern part of Sakhalin Island. To the south, it shares borders with the Paleotropical kingdom, Indo-Pacific subkingdom, along a line running from near Quanzhou, north of Guangzhou, to the foothills of the mountains in northern Myanmar. This border extends throughout the Himalayas, bordering the Indian subcontinent. This excludes the southern tip of mainland China, which belongs to the Indochinese region, and the southern foothills of the Himalayas, which belong to the Indian region. To the west, the region borders the dry and arid regions of Western Tibet, Qinghai, Gobi, and Mongolia. Four subregions can be differentiated: eastern Russia and northeastern China, the insular zone of Japan and adjacent islands (Takeda, 1913), temperate continental China, and the Himalayan zone.

This region is homologous to the North American Atlantic and Eurosiberian regions. Its climate is basically temperate pluviestival and its flora is exceptionally diverse, hosting numerous ancient elements that have become extinct in the other two regions. It is accepted by most of the authors (Good, 1974; Takhtajan, 1986; Costa, 2004) quite in the same concept as we present here. It has about 20 small endemic families, such as Ginkgoaceae, Trochodendraceae, Cephalotaxaceae, and Hostaceae. In addition, it has about 300 endemic genera, some of which are paleoendemic, such as *Cryptomeria*, *Metasequoia*, *Pseudotaxus*, and *Paulownia*. This confirms that archaic forms, coexisting with more modern ones, have found refuge in this region. Other notable genera include *Caryopteris*, *Chionographis*, *Davidia*, *Leycesteria*, *Litchi*, *Metaplexis*, *Rodgersia*, and many more. Among the plant species, we can mention *Actinidia chinesis* (kiwi), *Alniaria alnifolia*, *Callistephus chinensis*, *Clematis montana*, *Glycine max* (soy), *Hydrangea macrophylla* (hydrangea), *Morus alba* (mulberry), *Oryza sativa* (rice), *Panax ginseng* (ginseng), *Rheum palmatum* (Chinese rhubarb), *Rosa rugosa* (dune rose), *Stachys affinis*, *Trachycarpus fortunei* (Chinese windmill palm), *Wisteria sinensis* (wisteria), etc.

The flora of this region is exceptionally rich, undoubtedly the most diverse in the Holarctic kingdom, and it is especially so in trees, widely surpassing its other two homologous regions mentioned above (Latham & Ricklefs, 1993). Its arboreal flora consists of broadleaved species from genera like *Acer*, *Fagus*, *Quercus*, *Prunus*, etc., as well as conifers, presenting great diversification in both groups. This is explained by the Quaternary climatic history in this region (Li, 1952). As it is known, the ice sheet that covered western Eurasia did not extend to central and eastern Siberia, which remained ice-free during the glacial periods of the Pleistocene. This marked a significant difference compared to North America and Europe, which suffered extensive coverage of the ice sheet. Therefore, it is believed that the late Tertiary temperate flora inhabiting the mid-latitudes of the northern hemisphere continents should have suffered fewer extinctions in East Asia than it did in the other two regions, particularly Europe. For this reason, it is considered that the Chinese-Japanese flora is a descendant, with few alterations, of the one that existed in the final Tertiary and gives a fairly representative image of the flora and vegetation that must have dominated in the temperate mid-latitudes in the Neogene (Loidi & Marcenò, 2022).

In the northernmost areas, such as Manchuria, the Khingan Mountains, Sikhote-Alin, and the Amur

Valley, the forests comprise a mixture of deciduous and coniferous trees, including *Betula ermanii*, *Corylus sieboldiana*, *Fraxinus mandshurica*, *Pinus koraiensis*, *Quercus mongolica*, *Tilia amurensis*, and others. The oro (subalpine) belt of the mountains, as in the Changbai Shan, is populated by species from the East Siberian taiga, such as *Abies nephrolepis*, *Betula platyphylla*, *Larix gmelinii*, *Picea jezoensis*, *P. koraiensis*, *Pinus koraiensis*, *P. pumila*, etc., which are accompanied by local species such as *Rhododendron aureum*. The supraforestal cryoro (alpine) levels are occupied by alpine grasslands of *Kobresia myosuroides* with *Dryas octopetala* var. *asiatica.* In the river floodplains, the gallery forests consist of species like *Alnus hirsuta* or *Salix rorida*. As a food plant native to this area, we can mention *Fagopyrum esculentum* (buckwheat).

The complex system of archipelagos and peninsulas in East Asia has been a stage for intense migrations since the end of the Tertiary. These movements were driven by the glacial cycles of the Pleistocene and were made possible by land connections established during periods of reduced sea levels (Momohara, 1994). Thus, the Japanese archipelago was connected to the mainland at both its northern and southern ends, through the island of Sakhalin and the Korean peninsula. Additionally, the Kuriles once formed a land bridge connecting Japan to the Kamchatka Peninsula. Consequently, the flora and vegetation of Japan (Kadono *et al*., 1993) bear the influence of these migrations, featuring both arctic plants moving southward and subtropical plants extending their range northward. In the northern and middle sectors of Japan, particularly in the lowlands and midlands, deciduous forests thrive with species like *Betula maximowicziana*, *Fagus crenata*, *Hamamelis japonica*, *Quercus dentata*, *Q. mongolica*, *Q. serrata*, *Ulmus davidiana*, *U. parvifolia*, etc. The landscape also includes bamboos from the *Sasa* and *Pseudosasa* genera, such as *Pseudosasa japonica*, *Sasa kurilensis*, *S. senanensis*. At subalpine (oro) levels, conifers dominate, including *Abies mariesii*, *A. sachalinensis*, *Larix gmelinii*, *Picea jezoensis*, *P. glehnii*, *Pinus thunbergii*, *Tsuga sieboldii*, and more. In the central and southern territories of Japan, various conifer species inhabit low and medium areas, particularly in edaphoxerophilous locations. These include *Abies firma*, *Chamaecyparis obtusa*, *Cryptomeria japonica*, *Larix kaempferi*, *Pinus densiflora*, *P. parviflora*, *Pseudotsuga japonica*, and *Sciadopitys verticillata*. In the southern part of the archipelago, a zone of laurel forests prevails, predominantly composed of evergreen species such as *Castanopsis cuspidata*, *C. sieboldii*, *Diospyros kaki*, *Eurya japonica*, *Ligustrum japonicum*, *Neolitsea aciculata*, *N. sericea*, and more (Miyawaki *et al*., 1994).

Moving beyond Japan, another substantial territory lies to the north of the Yangtze River (Blue River) in China, intersected by the Huang He or Yellow River. This vast plain, covered in loess deposits, has a notable steppe influence from the interior of the Asian continent. Its pluviometric seasonality is primarily driven by the monsoon regime, which determines rains in summer and cold winters. Although natural vegetation has been largely replaced by millennia of intensive agriculture, remnants of wooded steppe persist, with certain elements of continental affinity, such as *Quercus mongolica* and *Sorbus discolor*.

South of the Yangtze River, temperatures are milder, and the vegetation is notably enriched with archaic elements, such as *Ginkgo biloba* and *Eucommia ulmoides* (gutta-percha), both of them being the only representatives of their respective families. Other examples of relicts are the monotypic genera *Eomecon* (*E. chionantha*), *Metasequoia* (*M. glyptostroboides*), *Pseudolarix* (*P. amabilis*), *Pseudotaxus* (*P. chienii*), *Sinofranchetia* (*S. chinensis*), etc. The climate is temperate pluviestival, with high rainfall, mild temperatures, and minimal frosts, which gives rise to an evergreen laurel forest (Yong-Chang & Lian-Jun, 2016). It extends over large areas of southeastern China, reaching, thanks to the effect of warm currents, the extreme south of Korea, and the southern part of Japan. As a whole, this laurel forest is made up of numerous species, such as *Aucuba japonica*, *Camellia japonica*, *Castanopsis sclerophylla*, *Cinnamomum camphora*, *Ilex latifolia*, *Lithocarpus glaber*, *Pittosporum tobira*, *Quercus acuta*, *Q. gilva*, *Q. glauca*, *Symplocos stellaris*, and others. These forests coexist alongside deciduous forests of broader range, thriving in the midlands of the mountains, and include species like *Acer palmatum*, *Carpinus cordata*, *Castanea henryi*, *Fagus crenata*, *F. engleriana*, *F. hayatae*, *F. sinensis*, *F. lucida*, *Platycarya strobilacea*, *Quercus serrata*, *Magnolia denudata*, *Toxicodendron trichocarpum*, *Triadica sebifera*, etc. In situations of spurs and very steep slopes, *Pinus taiwanensis*, *Rhododendron mariesii*, and *Sorbus commixta* appear. Certain species, such as *Lithocarpus dodonaeifolius* and *L. formosanus*, are endemic to Taiwan. These forests also harbor several species of bamboo from the *Phyllostachys* genus, which are widely used in Oriental agrarian and urban cultures.

The Tibetan-Himalayan subregion encompasses the mid- and high-altitude territories spanning the entire Himalayan range and eastern-central Tibet (Schmid, 1937; Singh & Singh, 1987). It extends from Kashmir to Assam, the mountains of northern Burma, and the province of Yunnan in China. This subregion is characterized by the presence of the great rivers (Nujiang, Mekong, and Yangtze), running parallel to one another and separated by high mountain ranges in a north-south orientation. This territory is the center of dispersal for various genera that have undergone significant diversification and subsequently spread to other areas. Among these genera, *Cremanthodium* is noteworthy, with around 70 species concentrated in this area, along with *Codonopsis*, *Meconopsis*, and, particularly, the *Rhododendron* genus. Of the 1,000 species of *Rododendron*, approximately 700 inhabit the Himalayas, contributing significantly to the subregion's forested areas. These species of rhododendrons are particularly concentrated in the region of the gorges of the great rivers, in the territory of Yunnan. One of them, *Rhododendron arboreum*, is the national flower of Nepal. The Himalayan cedar forests, consisting of

Cedrus deodara, coexist with the *Abies spectabilis*, *Picea smithiana*, *Pinus gerardiana*, and *P. roxburghii* forests. There are also Himalayan representatives of the *Quercus* genus, such as the evergreens *Q. leucotrichophora*, *Q. baloot*, *Q. floribunda*, and *Q. semecarpifolia*.

The subbiomes covering the Chinese-Japanese region are 3a (Temperate deciduous forests) in the central and northern territories, 4a (Lauroid evergreen forest of the lowlands) in areas south to the Yangtze river, 4c (Tropical (and subtropical) montane cloud lauroid and conifer evergreen forests) in mid-elevations of the mountains (Yunnan and southern Himalaya), 1b (Tundras of the temperate mountains in cryoro belt), and 2b (Forests and shrublands of the temperate oro belt), locally represented in the high mountains.

5. Mediterranean region

It includes the countries and territories that surround the sea from which it takes its name. On its western side, it opens to the Atlantic from the Ria de Aveiro, in Portugal, to the south of Morocco, on the edge of the Sahara, covering approximately three-quarters of the Iberian Peninsula. It also includes southeastern France (Languedoc and Provence), the Tyrrhenian coastline of the Italian Penisula, initially as a narrow strip in Tuscany and Lazio, gradually expanding, to encompass most of Campania and the southern part of the Italian peninsula (Magna Graecia), as well as its Adriatic coasts, stretching as far as Pescara. In the Balkans, it encompasses the Dalmatian, Montenegrin, and Albanian coasts, and the Hellenic Peninsula, excluding its Pindus inland. It continues along the coasts of the Aegean, both on its European and Asia Minor sides the western regions of Syria, Lebanon, Palestine, and Israel up to Gaza, where the Saharo-Sindian region reaches the Mediterranean Sea. In North Africa, the region contains an enclave in Cyrenaica and occupies the entire northern fringe of the Maghreb countries: Tunisia, Algeria, and Morocco (White, 1983). All the islands within the Mediterranean Sea are part of this region, including the Balearic Islands, Malta, Corsica, Sardinia, Sicily, Crete, Cyprus, and the Aegean archipelagos. The coastal areas of the north of the Adriatic, encompassing Marche, Emilia-Romagna, and Veneto, are excluded, as they belong to the Eurosiberian region. The coasts of Sinai, Egypt, and Libya, except for Cyrenaica and Tripolitania, are also excluded as they are part of the Saharo-Sindian region.

The area of the Mediterranean region is coincident with the proposed by Good (1974), Takhtajan (1986), Costa (2004), and Rivas-Martínez *et al.* (2001). It is one of the richest territories in flora (Quézel, 1995; Quézel & Barbero, 1982), reaching 25,000 species, of which about 60% are endemics. It has some small endemic families, such as Cneoraceae, as well as other larger ones that have their optimum in this region, such as Cistaceae and Globulariaceae. As for endemic genera, there are around 150, including *Chamaerops*, *Coris*, *Phillyrea*, *Rosmarinus*, *Ruscus*, *Santolina*, *Sarcopoterium*, etc. Others show their optimum in this region, such as *Adenocarpus*, *Cistus*, *Helianthemum*, *Lavandula*, *Sideritis*, *Thymus*, etc.

The remarkable diversity in the Mediterranean region is attributed to a history in which the Messinian Salinity Crisis played a role in the Mediterranean Sea's partial drying (Pignatti, 1978; Roveri *et al*., 2014) as well as the Pleistocene extinctions. The lowered sea level enabled colonization of currently submerged lands and facilitated island connections, providing substantial additional territory for refuge and speciation opportunities (Mai, 1989). Another important reason is the great heterogeneity of existing habitats, ranging from hyperhumid to subarid and arid areas and from infra to cryoro thermotypes. A great lithological variety and a rugged orography are superimposed on this climate diversity. In this sense, remarkable are the massifs of the Iberian Peninsula (Central Cordillera, Iberian, and Betic Systems), Italian Peninsula (Southern Apennines, Sila, Pollino), those of the Maghreb (Rif, Atlas), Peloponnese, Anatolia (part of Taurus), Lebanon, plus those of great islands.

The climate is almost exclusively of the Mediterranean type (temperate aridiestival), with a high thermal and ombric variability, as previously mentioned. The vegetation reflects adaptations to this climate, with a prevalence of sclerophyllous and microphyllous woody plants. Mature stages of natural vegetation are dominated by various species of *Quercus*, such as the evergreen *Quercus coccifera*, *Q. coccifera* var. *calliprinos*, *Q. ilex*, *Q. rotundifolia*, *Q. suber*, etc. In somewhat more humid biotopes, marcescent leaf species like *Quercus canariensis*, *Q. faginea*, *Q. ithaburensis*, *Q. lusitanica*, or *Q. trojana* thrive. Certain areas feature other tree species that play a significant role in the Mediterranean forest, including *Ceratonia siliqua*, *Olea europaea* subsp. *europaea*, and *Sideroxylon spinosum*. In regions with more oceanic and humid conditions, lower trees with a lauroid morphology and broader distribution emerge, such as *Arbutus unedo*, *Laurus nobilis*, and *Viburnum tinus*, in addition to lianas like *Smilax aspera*.

In addition, the Mediterranean flora boasts a diverse range of conifers that play crucial roles in areas where conditions hinder the predominance of broadleaved trees. Thus, there are several species of pines involved in natural ecosystems when aridity conditions, sandy substrate, or continentality are more pronounced. These species include *Pinus brutia*, *P. halepensis*, *P. pinaster*, and *P. pinea*. The same applies to junipers, among which we find *Juniperus oxycedrus*, *J. phoenicea*, *J. thurifera*, and *J. turbinate*. Coastal dunes are home to *Juniperus macrocarpa* and Portuguese endemic *J. navicularis*. In North Africa, *Tetraclinis articulata* is common in subarid and thermal areas. In mountainous regions, gymnosperms play a prominent role. This includes species like *Cupressus sempervirens*, *Pinus nigra* subp. *salzmannii*, *P. sylvestris* var. *iberica* and *var. nevadensis*, and *Juniperus sabina*. In Areas with higher precipitation, species like the cedars, *Cedrus atlantica* and *C. libani*, thrive. Firs also thrive in environments similar to those of the cedars. This taxonomic diversification has resulted from the fragmentation of these areas, leading to allopatric

speciation from a common circummediterranean ancestor of the Tertiary (Linares, 2011). Thus, we find a variety of fir taxa surrounding different mountainous massifs of the Mediterranean and Black Seas: *Abies pinsapo* subsp. *pinsapo* (Betic), *A. pinsapo* subsp. *marocana* (Rif), *A. numidica* (Algeria), *A. nebrodensis* (Madonie, Sicily), *A. cephalonica* (Peloponnesus), *A.* × *borisii-regis* (Greece, Macedonia, Albania, Bulgaria), *A. nordmanniana* subsp. *equi-trojani* (Euxinian province), *A. nordmanniana* subsp. *nordmanniana* (Western Pontic mountains) and *A. cilicica* (Taurus-Lebanon). These can be related to the other major European fir species of the Eurosiberian region, *Abies alba*, which would complete the circle from the north.

As for bushy vegetation, called *maquis* in some areas, it serves as a substitute stage for the Mediterranean forest or as a mature stage in regions with less rainfall (subarid or arid). It includes many species such as *Chamaerops humilis*, *Cneorum tricoccon*, *Rhamnus alaternus*, *Phillyrea angustifolia*, *P. latifolia*, *Pistacia atlantica*, *P. lentiscus*, *Quercus coccifera*, and others. Another characteristic and widespread vegetation in the Mediterranean Region is scrub, shrubby vegetation known by various names like garrigue, phrygana, matorral, tomillar, romeral, jaral, depending on geographical zones and dominant species. This type of vegetation often occupies soils degraded by erosion, often caused by fires or overgrazing. It features numerous genera of *Lamiaceae*, such as *Rosmarinus*, *Salvia*, *Teucrium*, *Thymbra*, *Thymus*, *Sideritis*, as well as *Cistaceae* genera like *Cistus*, *Fumana*, *Halimium*, or *Helianthemum*. Other genera from Leguminosae, such as *Anthyllis*, *Astragalus*, *Coronilla*, *Genista*, and others, and from *Apiaceae*, such as *Bupleurum*, and *Rosaceae* like *Sarcopoterium*, also participate extensively, along with numerous chamaephytic species, many of which are endemic to specific small areas. Lastly, the Mediterranean region is characterized by the abundance of annual plant communities of ephemeral and early phenology, well-adapted to cope with the severe summer aridity typical to its climatic conditions.

The main and most representative zonal biotic unit present in this region is subbiome 5a (Oceanic sclerophyllous-microphyllous evergreen forests and shublands - Mediterranean), which is prevalent in lowlands and midlands. In some continental areas of the Iberian Peninsula and North Africa, subbiome 5b (Continental scrub and woodlands) can be identified. In highly humid areas, typically in mountainous regions, subbiome 3a (Temperate deciduous forests) is represented, and in the higher elevations of the mountains, subbiomes 2b (Forests and shrublands of the temperate oro belt) and 1b (Tundras of the temperate mountains in cryoro belt), can be found.

6. Macaronesian region

It is composed of a small number of archipelagos of volcanic origin that extend through the mid-latitudes of the North Atlantic: the Canary, as well as the Selvagens, Madeira, and the Azores archipelagos. The Cape Verde Islands have traditionally been included in this region (Good, 1974; Takhtajan, 1986), but their position south of the Tropic of Cancer and their flora, practically all of African paleotropical lineages, make it advisable to exclude them from it and include them in the Sudano-Zambezian region. Other authors (Rivas-Martínez *et al*., 1993, 2014; Del Arco Aguilar & Rodríguez Delgado, 2018; Capelo *et al*., 2021) link these Macaronesian islands to the Mediterranean region because of the high number of taxa of Mediterranean origin in their flora and the significant presence of Mediterranean vegetation types in their subarid areas. Nevertheless, considering the historical factor provided by the presence of lauroid forests, we believe that these archipelagos can constitute a biogeographic region separate from the Mediterranean (Schroeder, 1998; Frey & Lösch, 2010; Pfadenhauer & Klötzli, 2014). Yet other authors (Cox, 2001; Cox *et al*., 2016) include these archipelagos in the Paleotropical kingdom due to the high proportion of Tertiary tropical or subtropical flora, especially in the Canaries and Madeira. However, the extratropical element, be it Mediterranean or Atlantic, exceeds the Tropical one, and their location north of the Tropic of Cancer leads us to include the aforementioned three archipelagos in this region within the Holarctic realm.

The Macaronesian islands are oceanic in nature, that is, they emerge from the seabed due to volcanic activity, they are not fragments of continents that have broken off. Therefore, all their biota has an imported origin through dispersal vectors capable of crossing the sea that separates them from the mainland or other islands. However, the proximity to the continents is very different in each archipelago: the Canary Islands are very close to the African continent, while the other archipelagos are much further away, both from Africa and from Europe. That is why the Canary Islands reflect more intensely the relations with the nearby continent, being considered as quasi-continental islands. Its flora is very original and reflects the different waves of immigration (migroelements) that have been received at different times, from the humid subtropical tertiary flora to the Mediterranean flora and the arid afrotropical flora (geoelements), which have arrived on the islands in different periods and within the framework of different climatic contexts (chronoelements). Currently, thanks to the highly mountainous relief of most of them, the diversity of habitats and abundance of vegetation layers that this entails, allow these different historical waves of migration to be accommodated at their corresponding altitude levels, like the pages of a book that tell the sequence of the advents of the different types of flora (Fernández-Palacios *et al*., 2011).

Due to its insular condition and antiquity (they started to emerge about 20 my ago in the middle and final phases of the Tertiary), the endemicity of the Macaronesian flora is very remarkable, particularly at the species level. As for the endemic genera, we can mention *Aichryson*, *Cedronella*, *Isoplexis*, *Picconia*, as well as *Phyllis*, *Semele* (Canary Islands), *Melanoselinum*

and *Musschia* (Madeira), while in the Azores there are no endemic genera for this archipelago.

These archipelagos are affected by the Azores anticyclone, which causes dry weather during summer. The severity of the drought varies among the islands - it is more severe in the Canary Islands (especially in the eastern islands that are closer to the African continent), less severe in Madeira, and even less severe in the Azores. The intensity of the drought decreases gradually from southeast to northwest across the archipelagos. Another important circumstance in the islands' climate is the condensation of fog that happens at medium elevations (middle ranges), causing hidden precipitation that very effectively moistens the surfaces of plants, soil, and rocks, providing a large amount of water in a liquid state. These mists form the so-called "sea of clouds" that clings to the northern slopes of the islands, which is reinforced during the summer under the influence of the Azores anticyclone that enhances the flow of the trade winds. Consequently, on these islands, if they reach the required elevations, a basically Mediterranean climate type subsists, but it is greatly attenuated by these hidden rainfalls, to the point that in Madeira and Azores, the mediterraneity is strongly attenuated and temperate pluviestival climate prevails. Furthermore, the insular condition determines that the thermal seasonality is very low and their climate is thus very oceanic. This situation recalls the conditions that existed in the middle of the Tertiary in North Africa and southern Europe, which was then covered with subtropical laurel forests (laurisilvas). The Macaronesian islands began to emerge at this time and received diasporas from the continental flora, largely lauroid species, which did so with the help of the numerous islands that then stood in their way and are now submerged below the waters by erosion (submarine mountains), which acted as stepping-stones in these migrations (Fernández-Palacios *et al*., 2017). These laurisilvas or Monteverde are formed by laurels of the genera *Apollonias*, *Laurus*, *Ocotea*, and *Persea*, as well as by *Heberdenia*, *Ilex*, *Picconia* or *Myrica*, constituting closed cloud forests, which use to host ferns such as *Culcita*, *Davallia*, *Hymenophyllum*, *Vandenboschia*, *Woodwardia*, and others, that currently have relict populations in the more oceanic habitats of the European Atlantic coast, in particular the Galician-Cantabrian area.

The lowest areas (infra) of the Canaries and Madeira are dominated by desertic and sub-desertic vegetation formed by succulent species, such as *Euphorbia balsamifera*, *E. canariensis*, *E. piscatoria*, *Ceropegia fusca* or *Kleinia neriifolia*, which together with *Plocama pendula* and others, make up the cardonales and tabaibales of the Macaronesian basal belts. In the levels above the succulent vegetation, a Mediterranean-type vegetation appears, with *Olea*, *Rhamnus*, and *Juniperus*, which is replaced by the Monteverde in the levels under the influence of the sea of clouds. Above it, on the islands that have sufficient elevation (meso), appears the belt of the Canary Island pine (*Pinus canariensis*), endemic to that archipelago, which receives much less rainfall than Monteverde. Above 2,000 m asl, in the supra belt (Tenerife and La Palma), there is a broom vegetation formed by *Spartocytisus supranubius* and in the summit area of Tenerife, in Pico del Teide, an oligospecific community of *Viola cheiranthifolia* (Del Arco Aguilar & Rodríguez Delgado, 2018).

Apart from the ancient Tertiary subtropical flora of the laurisilva, now extinguished on the continent, and the Mediterranean element, the influence of the African tropical arid flora (Rand-Flora) is very noticeable. Succulent plants such as *Kleinia neriifolia*, the genera *Ceropegia*, *Euphorbia*, and others participate in the latter, populating the lowest and most arid levels of the islands. This succulent desert occupies the entire eastern Canary islands and only the lower belts in the western ones and Madeira (Capelo *et al*., 2005) and are absent in the Azores (Elias *et al*., 2016). Other paleotropical genera are *Canarina*, *Dracaena*, *Periploca*, and *Sideroxylon*. The genus *Aeonium* is an example of African paleotropical migration that later radiated to the other islands, especially the Canaries, where there are up to 29 species (Del Arco Aguilar & Rodríguez Delgado, 2018).

Concerning the zonal subbiomes covering the islands of this region, due to its ruggedness and climatic diversity there are a high number of them: in the arid lowland areas of the Canaries and Madeira the dominant subbiome is 7b (Temperate deserts and semi-deserts), in a succulent-rich version; subarid and dry midlands are dominated by subbiome 5a (Oceanic sclerophyllous-microphyllous evergreen forests and shrublands - Mediterranean), in form of shrublands and in form of pine woods; the subhumid-humid cloud forests of the monteverde or laurisilva belong to the subbiome 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forest), and in the upper levels of the highest peaks, the subbiome 2b (Forests and shrublands of the temperate oro belt) can be recognized.

7. Irano-Turanian region

Vast territory that extends in Asia from the central area of the Anatolian plateau to Mongolia and western China, encompassing Kurdistan, Armenia, the Caspian and Aral countries, with Azerbaijan, central and northern Iran and Kazakhstan, Afghanistan, the Central Asian republics (Uzbekistan, Turkmenistan, Tajikistan, and Kyrgyzstan), central and northern Pakistan, Tibet, the arid Takla Makan and the regions of Xinjiang, Gobi, and Mongolia (Djamali *et al*., 2012; Manafzadeh *et al*., 2017). This extensive region shares common characteristics, including a temperate aridestival continental climate in many areas and a cold or temperate desertic climate. Its pronounced continentality results from its interior location, which is distant from the seas and experiences an attenuation of rainfall, contributing to desert climate conditions in some areas (Zohary, 1973). The Irano-Turanian region is crisscrossed by significant mountain systems, such as the Taurus Mountains in Anatolia, the Zagros and Alborz Mountain ranges in Iran, the Hindu Kush, Pamir, Tian Shan, and others. These mountain systems create

a multitude of regional climatic variations in terms of temperature and rainfall regimes due to differences in altitude and rain shadows. In most of its area, vegetation is characterized by scrubland, (often cushion-shaped), and also semi-desert or desert landscapes. Forests and woodlands thrive in elevated areas of mountains and high plateaus where precipitations are more abundant due to altitude. These woodlands can be broadleaved or coniferous depending on the territory.

The region has been accepted by most authors (Good, 1974; Takhtajan, 1986; Pfadenhauer & Klötzli, 2014).

One can barely count on a small endemic family, Biebersteiniaceae, and there are over 150 endemic genera, most of them monotypic (Sales & Hedge, 2013) as well as some other widespread genera having their optimum in this region, such as *Allium*, *Astragalus* and *Cousinia* (Léonard, 1981–1989). We can mention some typical species of this region, such as *Fallopia baldschuanica*, *Fritillaria imperialis*, *Iris halophila*, *Jasminum officinale*, *Psylliostachys suworowii*, *Lonicera nummulariifolia*, *Malus domestica* (apple), *Moluccella laevis*, *Prunus armeniaca* (apricot), *Spinacia oleracea* (spinach) or *Tulipa gesneriana* (tulip).

The Irano-Turanian region can be divided into two major halves, each with distinct characteristics, which are separated by the Central Asian Tian Shan and Pamir Mountain ranges (Schroeder, 1998). The eastern part is the Mongolian-Tibetan area and consists of deserts and steppes, being crossed by a series of mountain ranges that provide their own orophilic vegetation. In desert steppes, *Ephedra przewalskii*, *Nitraria sphaerocarpa*, *Reaumuria songarica*, *Salsola passerina*, *Stipa tianschanica*, *Sympegma regelii*, etc. are found. The western part of the region exhibits a notable Mediterranean and Eurosiberian influence, characterized by steppes, broadleaved and juniper woodlands in medium to high elevations. In the mountains, orographic rainfall allows the installation of deciduous forests, with species such as *Quercus brantii*, *Q. infectoria* subsp. *veneris*, *Q. macranthera*, *Q. petraea* subsp. *pinnatiloba*, *Q. robur* subsp. *pedunculiflora*, and others. Among the halophytic plants that inhabit the extensive salt marshes of this region, we can mention *Anabasis brevifolia*, *Artemisia cina*, *Haloxylon ammodendron*, and *Xylosalsola arbuscula*. As a native food crop, *Fagopyrum tataricum* (buckwheat) finds its origin in this area. The high elevations within the mountain ranges contribute to unique flora, often displaying Holarctic characteristics with numerous endemic species and some connections to the Eurosiberian world, especially in the more humid mountains (Noroozi *et al*., 2008). At high elevations in the Central Asian mountains, there is a particular flora, among which there are species like *Caragana versicolor*, *Carex tibetikobresia*, *Myricaria* prostrata, or *Poa glauca* subsp. *altaica*.

The subbiomes recognized in this region are the deserts 7a (Cold deserts and semi-deserts) and 7b (Temperate deserts and semi-deserts) in the most arid regions. The steppic areas of Mongolia and China under a monsoonal rainfall regime are covered by subbiomes 6a (*Forest-steppe)* and 6b (*Grass-steppe)*, while in the western areas, from Anatolia to central Asia, where the precipitation regime is aridiestival, the subbiome 5b (Continental scrub and woodlands) is broadly represented. The high elevations are extensive in this region and we can find the subbiome 1b (Tundras of the temperate mountains in cryoro belt) covering a huge area in the high Tibet and below it 2b (Forests and shrublands of the temperate oro belt) in the numerous ranges crossing the region.

The four spring cereals that are widely cultivated today come from the western subregion: *Triticum spp.* (wheat), *Hordeum vulgare* (barley), *Avena sativa* (oats), and *Secale cereale* (rye), which together with *Lathyrus oleraceus* (pea) and *Vicia faba* (bean) constituted the initial repertoire of plants that began to be cultivated since the Neolithic in the Fertile Crescent. As data of biogeographical interest, that indicates ancient migrations, there are a few species such as *Krascheninnikovia ceratoides* and *Bassia prostrata* that have a Mediterranean-Central Asian distribution.

8. Saharo-Sindian region

It corresponds to the largest desert territory in the world, spreading from the north African Atlantic coast to the northwest of India (Bharat), and including the deserts of Sahara (White, 1983; Quézel, 1965), Sinai, Arabia, Syria, Jordan and Iraq, southern Iran to the Sind, in southern Pakistan, and the Thar, in Rajasthan. This huge chain of deserts is located in the area of the subtropical highs, between the temperate zone to the north and the paleotropical world to the south. The region's northernmost strip receives limited rainfall in winter, while the southern areas experience rainfall primarily in the summer. This climatic duality contributes to distinct floristic influences depending on proximity to the temperate or tropical world. But despite this, and despite its vast size, there is a certain coherence in its flora and geographical continuity, allowing us to recognize it as a distinct floristic region. This duality and the fact that previously to the aridization of the climate happened along the Tertiary, in the late Cenozoic this area was covered by Tropical flora and fauna, brings to consider some authors (Cox, 2001) this region should be included in the Paleotropical kingdom better than in the Holarctic one. In such a case, the southern border of the Holarctic would be that of the Mediterranean region with the Sahara. However, in attention to the Mediterranean influence in the northern part of this desertic huge area and in their mountains, we prefer to keep it as a part of the Holarctic kingdom.

The defining characteristic of the Saharo-Sindian region is its general aridity, which becomes extreme in central areas. Nonetheless, there are significant rivers, including the Nile, Tigris-Euphrates, and Indus, with wide margins supporting hygrophilous riparian vegetation. Intermittent watercourses, known as oueds or wadis, and oases also provide better water conditions for plant survival and it is where a large part of the region's flora takes refuge. Another important biotope is that of the salt marshes, "shatt", of lagoons, depressions,

and low-salinized areas, in which some halophytic communities survive.

The flora is not numerous due to the harsh environmental conditions. Many plant species have adapted by seeking edaphic compensation on soils with slightly more moisture. Among the most frequent species, we can mention *Anastatica hierochuntica* (Rose of Jericho), *Aristida mutabilis*, *Balanites aegyptiaca*, *Calligonum comosum*, *C. crinitum*, *Calotropis procera*, *Capparis decidua*, *Chloris flagellifera*, *Citrullus colocynthis*, *Cornulaca monacantha*, *Chrozophora brocchiana*, *Cleome pallida*, *Grewia tenax*, *Leptadenia pyrotechnica*, *Neurada procumbens*, *Panicum turgidum*, *Savignya parviflora*, *Senegalia senegal* (Gum Arabic), *Zilla spinosa*, *Zygophyllum mandavillei*, etc. Among the trees that thrive along rivers, in oases, or oueds include *Populus euphratica*, *Tamarix aphylla*, and *Vachellia flava* while saline soils support species like *Nitraria retusa*, *Soda stocksii*, *Zygophyllum album*, and others. Despite the vast expanse of this territory, the endemicity is low compared to its floristic richness. Above the species level we can mention the genus *Mecomischus*, with 2 species, from the Sahara.

An essential biogeographical aspect is the influence of both the Mediterranean and paleotropical territories mentioned above. There are a series of important mountain massifs in the center of the Sahara, specifically the Hoggar (2,918 m asl), the Tassili n'Ajjer (2,158 m asl), and the Immidir and Tibesti (3,415 m asl). In the elevated areas of these mountains, above 1,500 m asl, conditions are somewhat more humid and refuge islands are formed for a flora called saharomontane. This flora is characterized by a mixture of Afrotropical, Irano-Turanian elements and, above all, plants with a Mediterranean affinity, such as *Cupressus dupreziana* and *Olea europaea* subsp. *laperrinei*, along with oleander, myrtle, mastic, lavender, and globularia, forming populations separated by more than 1000 km from the closest ones in the Mediterranean region. The only characteristic crop original to this region is the date palm (*Phoenix dactylifera*), which thrives in humid zones, oueds, and oases, and has been used since long ago.

In the easternmost portion of the region, in Hindustani territory, the Sind and Thar deserts exhibit a marked paleotropical Indian influence. Numerous species find their optimum distribution in this area, including *Drimia indica*, *Balanites roxburghii*, *Cenchrus biflorus*, *C. ciliaris*, *C. setigerus*, *Clerodendrum phlomidis*, *Commiphora wightii*, *Crotalaria burhia*, *Dactyloctenium scindicum*, *Gymnosporia emarginata*, *Mimosa hamata*, *Prosopis cineraria*, *Tecomella undulata*, *Vachellia jacquemontii*, *Withania somnifera*, *Ziziphus nummularia*, among others (Khan & Frost, 2001).

Subbiomes in this region are those of the desertic areas 7b (Temperate deserts and semi-deserts) and 7c (Warm deserts and semi-deserts). In the summital areas of the central Saharan mountains, the subbiome 5a (Oceanic sclerophyllous-microphyllous evergreen forests and shrublands – Mediterranean) can be recognized.

9. North American Atlantic region

It occupies the eastern half of North America, extending from the foothills of the Rocky Mountains to the Atlantic Ocean. It is bordered to the north by the Circumboreal region in southern Canada and to the south by the Gulf of Mexico and the Florida Peninsula, where it contacts the Neotropical realm. This large territory is traversed from north to south by the Appalachian Alignment, and several subunits can be distinguished within it, including the Interior Great Plains and the Atlantic Coastal Plain. The Mississippi fluvial network drains most of these plains. The region's climate is predominantly temperate pluviestival, with an oceanic influence along the coastal strip that becomes more continental towards the interior, where the steppe (prairie) appears in the internal zones of the Great Plains. There is a practically unanimous agreement in distinguishing this region (Good, 1974; Takhtajan, 1866; Rivas-Martínez *et al*., 1999; Schroeder, 1998; Costa, 2004; Pfadenhauer & Klötzli, 2014).

Its flora is very rich. It is home to two small plant families, Hydrastidaceae and Leitneriaceae, along with approximately 100 endemic genera. There are some ancient genera, some in disjunction with East Asia, such as *Illicium*, which is related to Southeast Asia, *Croomia* to Japan, *Schisandra* to East Asia, or *Dionaea*, which is endemic and monotypic, with its only species *D. muscipula* (Venus flytrap). In general terms, the region exhibits strong floristic connections with the Eurosiberian and Chinese-Japanese regions, as they share numerous genera that form temperate deciduous forests. In the ancient Tertiary, these three regions were geographically connected. Following their separation, each one had a different history, with differential extinctions depending on the intensity of the rigors of the glaciations and the orography of each region. As a result, the Chinese-Japanese region is the richest, while the Eurosiberian region is the poorest one among the three of them.

Some of its most widespread species are *Carya cordiformis*, *C. glabra*, *C. ovata*, *C. tomentosa*, *Castanea dentata*, *Fagus grandifolia*, *Hamamelis virginiana*, *Ilex opaca*, *Liriodendron tulipifera*, *Magnolia acuminata*, *Nyssa sylvatica*, *Quercus alba*, *Q. rubra*, and *Rhododendron maximum* in disturbed areas.

Given the approximately 2000 km that separate the region's boundaries, both in latitude and longitude, notable differences exist across its parts. For instance, to the north, the forests differ in having *Acer saccharum*, *Betula alleghaniensis*, *Pinus resinosa*, *P. strobus*, *Tsuga canadensis*, and others, while to the south appear *Carya pallida*, *C. texana*, *Castanea pumila*, *Liquidambar styraciflua*, *Magnolia macrophylla*, *M. fraseri*, *M. tripetala*, *Quercus marilandica*, etc., with *Tsuga caroliniana* at mid-elevations of the Appalachians, and *Abies fraseri* at higher altitudes (Greller, 1988).

The most thermal variant of these forests extends along the coast in a strip that starts in New Jersey and widens towards the south until it reaches northern Florida and the lower Mississippi Valley to Texas (Christensen, 1988). These forests are characterized by

a significant presence of evergreen laurel-type species such as *Magnolia grandiflora*, *M. virginiana*, *Quercus laurifolia*, and *Q. virginiana*, along with some palm trees like *Sabal palmetto* and the epiphytic bromeliad *Tillandsia usneoides* (Spanish moss), reflecting a subtropical influence. In this southern territory, there are vast swampy areas associated with the lower courses of large rivers or large shoals. In them, some original flooded forests of *Taxodium distichum*, *T. distichum* var. *imbricarium*, *Nyssa aquatica*, and *N. ogeche* are found. On riverbanks, gallery forests are populated by species such as *Carya aquatica*, *Carya illinoinensis* (pecan), and *Platanus occidentalis*.

Within the region's coastal ecosystems, certain areas carry significant biogeographical importance, such as the Atlantic coast dunes. In the northern section, where the waters are cold due to the influence of the Labrador Current, these dunes are characterized by *Calamagrostis breviligulata*, a main grass species that is vicarious of the European *C. arenaria*. Its southernmost known populations are in North Carolina. In the southern part of the Atlantic coast, influenced by the warm Gulf Stream, *Uniola paniculata* is the main dune species, which extends south to the Gulf of Mexico. In the south of the Florida peninsula, which is already included in the Neotropical kingdom, and characterized by a tropical climate, red mangroves (*Rhizophora mangle*) dominate, replacing reed beds in tidal marshes of estuarine systems.

Such a vast territory demonstrates remarkable biogeographical diversity. We can differentiate two main areas: one in the east and the other in the west. The eastern zone, with the Appalachians as its north-south axis, includes the regions on both slopes of this mountain range, the Atlantic coast, and the Mississippi River. This latitudinal stretch extends from the Great Lakes region in southern Ontario and Québec to Georgia and Alabama. It is a vast territory between the east coast and the plains west of the Mississippi, reaching the states of Arkansas, Iowa, and Minnesota. The western part covers the interior areas of this region, expanding over a wide strip to the west of the Mississippi basin, from the southern parts of Alberta, Saskatchewan, and southwestern Manitoba, down to Texas and New Mexico. It is the area of the Great Prairies or Great Plains (Sims, 1988), which is included within this biogeographic region. It is an area dominated by grassland vegetation in which tall grasses such as *Andropogon gerardi*, *Panicum virgatum*, *Schizachyrium scoparium*, and *Sorghastrum nutans* participate, as well as other smaller ones like *Bouteloua dactyloides*, *B. gracilis*, and *B. hirsuta*. Other grassland species found in these grasslands include *Gutierrezia sarothrae*, *Penstemon glaber*, and *Solidago rigida*, among others. These prairies are subject to frequent disturbances, including predation by large herbivores such as American bison and wildfires. If these disturbances were eliminated or reduced, perhaps the succession would lead to the establishment of a more extensive woody vegetation.

The subbiomes of this region are 3a (Temperate deciduous forests), 4a (Lauroid evergreen forest of the lowlands), 6a (Forest-steppe), 6b (Grass-steppe), and 2b (Forests and shrublands of the temperate oro belt) in the mountainous high-elevation areas.

10. Rocky Mountains region

It is formed by the complex orographic system of the Rocky Mountains. Its northern limit starts on latitude 59ºN in coastal Alaska and forms a narrow coastal strip that extends parallel to the Pacific coast across southern Alaska. It then traverses Canada, crossing coastal British Columbia before entering the conterminous United States. In the United States, this strip extends north-south through the western states, including Washington (Cascades), Oregon, and California. From there it diverges into two main branches: the western branch runs parallel to the coast through California (Coastal Ranges up to Monterey and Sierra Nevada), excluding the Central Valley; and the eastern branch, which expands across Montana, Idaho, Wyoming, and Colorado, including northeastern Utah and northern New Mexico. Between these two main branches lies a vast arid depression encompassing the deserts of southwestern North America, which are part of the Western North American (California and Great Basin) region.

The climate in this region is primarily characterized as temperate ombroestival, with some Mediterranean areas to the south. Due to its mountainous nature, the region features a significant representation of high mountain, oro, and cryoro zones. There is a strong gradient of continentality, transitioning from the highly oceanic coastal strip, intensely influenced by coastal fogs, to the strongly continental interior.

Its vegetation is dominated by gymnosperms, and its flora has a high proportion of them (Franklin, 1988; Peet, 1988), with about 30 species per 10,000 km^2, one of the areas of maximum gymnosperm diversity in the world. It is much richer in conifers than the neighboring Circumboreal region, the largest territory covered by coniferous vegetation in the world, where barely between 5 and 10 species are reached per 10,000 km^2. The different conifer species that make up most of its forests are distributed in perfectly defined vegetation belts. Some of the most common conifer species include *Abies concolor*, *A. grandis*, *A. lasiocarpa*, *A. magnifica*, *Juniperus scopulorum*, *J. occidentalis*, *Picea engelmannii*, *P. pungens*, *Pinus albicaulis*, *P. contorta*, *P. flexilis*, *P. lambertiana*, *P. ponderosa*, *Pseudotsuga menziesii*, etc. Alongside conifers, there are broadleaved species such as *Populus balsamifera*, *P. angustifolia*, *P. tristis*, and *Berberis aquifolium* in the undergrowth. Among the shrubby species, *Artemisia tridentata* stands out for its abundance. In the coastal zone, characterized by more oceanic conditions, there is a territory characterized by a whole range of species in which there is greater participation of broadleaved trees (Franklin, 1988): *Acer macrophyllum*, *Alnus rubra*, *Arbutus menziesii*, *Chamaecyparis lawsoniana*, *Fraxinus latifolia*, *Juniperus grandis*, *Rhododendron macrophyllum*, *Picea sitchensis*, *Pinus balfouriana*, *P. monticola*, *Quercus kelloggii*, *Sequoia sempervirens*,

Sequoiadendron giganteum, *Taxus brevifolia*, *Thuja plicata*, *Tsuga heterophylla*, *T. mertensiana*, and *Umbellularia californica*. These species differentiate a subunit closer to the Pacific coast from the more continental interior. Riparian forests in this region are characterized by the predominance of *Alnus rhombifolia* and *Populus tristis*.

The role of wildfire in this region's ecosystem functioning is significant. Fires lead to the rapid mineralization of organic matter, which tends to accumulate in the soil due to slow decomposition rates. They also release nutrients, making them available to plants and completing their nutrient cycle. Many conifer species in this region exhibit clear adaptations to fire, such as serotinous cones that open only upon exposure to heat or seeds that can only germinate once the accumulated organic matter in the soil has been consumed or subjected to thermal shocks.

While there are no endemic families in this region, it does boast around 40 endemic genera, with the paleoendemics *Sequoia* and *Sequoiadendron* of the Taxodiaceae being particularly notable. The redwood or *Sequoia sempervirens*, native to the coastal mountains of California, is the tallest tree in the world, with a height of 115.61 meters and a diameter of 7.9 meters. The giant sequoia or *Sequoiadendron giganteum*, found in the Sierra Nevada, reaches a height of 105.5 meters and a base diameter of 10 meters.

The subbiomes covering this region include 4b (Conifer coastal forests), 2b (Forests and shrublands of the temperate oro belt) in most of its area, and 1b (Tundras of the temperate mountains in cryoro belt) in the summital areas.

11. Western North American (California and Great Basin) region

Located to the south of the previous one, this region includes the western territories of the United States, primarily characterized by a temperate aridestival (Mediterranean s.l.) climate. The surrounding mountain ranges, mostly associated with the Rocky Mountains region, are oriented north to south and leave between them a series of depressions or large valleys that are subject to greater or lesser rain shadow effects. This is evident in places like the great Central Valley of California (which includes the basins of the Sacramento and San Joaquín rivers) and can be more pronounced in areas such as Death Valley, as well as the deserts of the Great Basin and Mojave, where the climate becomes desert-like. Numerous mountain ranges run through this region, including the transverse Sierras of Santa Ynez, San Bernardino, San Gabriel, and Santa Rosa in California, as well as the Sierra de San Pedro Mártir in Baja California. To the south, it shares its boundaries with the Madrean region, which is part of the Neotropical kingdom, because the climate changes basically in terms of seasonality. Rainfalls shift from winter to summer maxima, and temperatures attenuate their oscillation. Due to their proximity and historical climate changes which have led to floristic dispersal oscillations, there is a notable neotropical influence extending northwards along the coastal lowlands. This influence is particularly evident through the presence of cacti, which become more abundant in the warmer areas up to 34ºN, around Santa Monica in coastal California.

In the Californian province, which extends up to the latitude of 30ºN along the Pacific coastal area of Baja California, the Mediterranean climate (temperate aridestival) prevails. The vegetation responds with sclerophyllous formations of evergreen forest (Barbour, 1988) with *Notholithocarpus densiflorus*, *Quercus agrifolia*, *Q. chrysolepis*, *Q. douglasii*, and *Q. wislizeni*, among others. There is a substantial presence of gymnosperms that accompany this forest, such as *Juniperus californica*, *Pinus coulteri*, *P. quadrifolia*, *Torreya californica*, and others. On the Pacific coast, the climate becomes notably oceanic, and the mists originating from the cold California current, foster specific communities such as the coastal sage scrub. This scrub is formed by species like *Artemisia californica*, *Encelia californica*, *Salvia apiana*, *S. mellifera*, etc. This coastal strip is also the habitat of a series of trees, many of them conifers, such as *Hesperocyparis macrocarpa*, *Pinus muricata*, *P. radiata*, *P. torreyana*, and others. Of the prevalence of mafic and ultramafic substrates, such as serpentines, has driven intense speciation in this region's flora. Some tree species, like *Quercus dumosa*, *Pinus jeffreyi*, and *Pinus sabiniana*, are closely associated with these substrates. In areas with pronounced aridity, often on serpentines, shrubby vegetation known as *chaparral* (Keeley & Keeley, 1988) establishes, featuring sclerophyllous shrubs of various species, including *Adenostoma fasciculatum*, numerous *Arctostaphylos spp.* (manzanitas), *Ceanothus spp.*, *Photinia arbutifolia*, and *Quercus berberidifolia*. These chaparral ecosystems have a strong relationship with fire.

The flora of this region has, to varying degrees, adapted to arid conditions, mirroring the Euro-North African Mediterranean flora. This similarity is a result of their shared origins in the ancient Tetyan flora and subsequent transformations driven by climate aridification throughout the recent Tertiary. This is evidenced by the presence of common genera in both regions, such as *Arbutus*, *Cercis*, *Cupressus*, *Juniperus*, *Pistacia*, *Salvia*, and others.

In the interior territories, covering most of Arizona, Nevada, western New Mexico, and Utah up to southern Idaho, Oregon, and Washington, where aridity is more pronounced, deserts and semi-deserts develop (West, 1988). In higher elevation areas, and under highly continental conditions, open woodland formations appear featuring conifers, such as *Juniperus osteosperma*, *Pinus edulis*, and *P. monophylla*, known as pinyon-junper woodland, and *Pinus longaeva* in the interior mountains of California, Nevada, and Utah. The latter species holds the record for the oldest known ages of any tree species, reaching up to 5070 years in age.

The Great Basin desert, the coldest and most continental of North America, extends for about 409,000 km^2 mainly through the states of Nevada and

Utah. It is covered by a thicket of *Artemisia tridentata*, which is often associated with others such as some species of *Ephedra* and *Tetradymia glabrata*. In areas where the soil is saline, halophytic communities are installed with *Atriplex confertifolia*, *Grayia spinosa*, *Krascheninnikovia lanata*, and *Sarcobatus vermiculatus*.

To the south of the Great Basin, as temperatures rise and aridity increases, a warmer desert emerges: the Mojave desert. The vegetation here consists of thickets where *Larrea tridentata* is the dominant species, often accompanied by *Ambrosia dumosa* and *Atriplex polycarpa*. In this desert, *Yucca brevifolia* (Joshua tree) is also found as a characteristic species. This 124,000 km^2 desert extends through the states of California, Nevada, Utah, and Arizona, and features depressed areas with elevations below sea level, where the highest temperatures in the Western Hemisphere are recorded, in the Death Valley.

Regarding riparian forests, the main species are *Juglans californica*, *Platanus racemosa*, *Populus fremontii*, *Salix lasiolepis*, etc.

The subbiomes occupying this region are 5a (Oceanic sclerophyllous-microphyllous evergreen forests and shrublands - Mediterranean), mostly in the Californian province, 5b (Continental scrub and woodlands), mostly represented by the pinyon-juniper woodland, 7a (Cold deserts and semi-deserts), basically, the Great Basin desert, and 7b (Temperate deserts and semi-deserts), spread in the Mojave desert.

Most of the classic authors (Good, 1974; Takhtajan, 1986; Schroeder, 1998; Pfadenhauer & Klötzli, 2014) include the majority of these territories within a large Madrean region. However, following Rivas-Martínez *et al*. (1999) and Costa (2004), we consider the Western North American region (California and Great Basin), which is fundamentally Holarctic, to be separate from the Madrean region, located to the south and heavily influenced by Neotropical flora and vegetation. The Western North American region_is the result of merging the Californian and Great Basin regions established by Rivas-Martínez *et al*. (1999) and Costa (2004), with some minor modifications to its limits.

The tropical kingdoms

The tropics are the latitudinal lines that mark the region of the world where the sun's rays strike at a 90º angle twice a year and once within the tropics themselves, during the summer solstice corresponding to each hemisphere. In the rest of the planet, the sun's rays never strike perpendicularly. The Tropic of Cancer is located at a latitude of 23º 26' 14'' N, while the Tropic of Capricorn is situated at 23º 26' 17'' S. This area is mediated by the Equator, which lies at latitude 0º and receives perpendicular solar rays at the equinoxes. These conditions make the tropics the part of the planet that receives the highest amount of solar energy and experiences minimal or reduced thermal seasonality. Seasonality affects rainfall patterns in most of this area, leading to various types of tropical bioclimate. Rainfall tends to be concentrated in the months near the summer solstice in each hemisphere, that is, in summer, the more we move away from the Equator toward the Tropics. This effect intensifies with increasing latitude and is accompanied by a decrease in the amount of rainfall. Consequently, true deserts usually appear in areas near the Tropics. Near the equator, rainfall is abundant throughout the year, enabling the development of tropical rainforests with their remarkable biodiversity and high biomass. As we move towards the tropics, the climate becomes more pluviseasonal, with two or more months of drought, giving rise to monsoon forests and savannas. These become more xerophytic as precipitation decreases, becoming semi-deserts with rainfall below 500 mm and true deserts with rainfall below 200 mm.

In the estuaries at the mouths of the rivers, the characteristic tropical mangroves develop. They form forests that thrive in saline and semi-saline environments subject to tidal flooding and safe from waves. Tropical mountains exhibit distinct zonation patterns with formations that differ from extratropical mountain ecosystems. Depending on the area where the mountains are located, the lower elevations host vegetation typical of the region, either pluvial forests or savanna forests. At medium altitudes, above 1,500 m asl in elevation, lauroid formations are installed with adaptations to cold conditions, favoring increased rainfall and reduced temperatures, reaching the level of the mists. The upper limit of this forest can be around 3,500 or 4,000 m asl, and above this altitude, unique high-altitude formations specific to each region emerge, such as the *páramo* in the northern Andes, the *puna* in the central Andes, or the *Lobelia* communities in the African mountains.

There are numerous families and subfamilies that have a pantropical distribution, evoking an ancient union of the territories that today constitute two floral kingdoms. They are the Agavaceae, Arecaceae (Palmaceae), Begoniaceae, Bixaceae, Bombacoideae, Burmanniaceae, Burseraceae, Chrysobalanaceae, Combretaceae, Dilleniaceae, Dipterocarpaceae, Ehretiaceae, Erythroxylaceae, Flacourtiaceae, Gesneriaceae, Humiriaceae, Lecythidaceae, Limnocharitaceae, Malpighiaceae, Marantaceae, Melastomataceae, Meliaceae, Moraceae, Myristicaceae, Passifloraceae, Podostemaceae, Rhizophoraceae, Sapindaceae, Sapotaceae, Simaroubaceae, Sterculioideae, Trigoniaceae, Velloziaceae, Zingiberaceae, etc. It is important to indicate the significance of the group of grasses of the Andropogoneae tribe, with more than 90 genera and about 1200 species, all of them with C4 photosynthesis, which constitute the savanna grasslands and other tropical formations. It is also worth mentioning some notable genera with a pantropical distribution, such as *Bauhinia*, *Dioscorea*, *Eugenia*, *Ficus* (900 species), *Hibiscus*, *Justicia*, *Paullinia*, *Peperomia*, *Phyllanthus*, *Strychnos*, *Vernonia* or *Vitex*.

It is considered that it was in the tropics, during the warm phases of the Cretaceous, when angiospermes originated (Rodríguez-Barahona *et al*., 2020) and the

extant families originated in the tropical rainforests of the early Paleogene (Benton *et al*., 2021).

II. Paleotropical kingdom

It extends through the vast territories encompassing regions such as Africa south of the Sahara (excluding the Cape region), South and Southeast Asia, as well as the archipelagos of Insulindia and the Pacific. There are up to 40 endemic families in this kingdom, such as the Ancistrocladaceae, Aponogetonaceae, Musaceae, Nepenthaceae, Pandaceae, Pandanaceae, Pedaliaceae, or Salvadoraceae.

The regions of this kingdom, along with their boundaries, closely align with the maps provided by Good (1974) and Takhtajan (1986).

IIa. African subkingdom

Within the paleotropical world, tropical Africa represents the largest landmass (White, 1983), although its floristic richness is lower, with about 26,000 species (Lebrun & Stork, 2003–2006), compared to the Indo-Pacific region, which has about 50,000 species (Whitmore, 1998). The abundance of islands in the Pacific and the relatively fewer substantial mountains in Africa may contribute to these differences in species numbers. There are some Afrotropical families, such as Hydrostachyaceae, Melianthaceae or Selaginellaceae, as well as a certain number of genera: *Aframomum*, *Brachystegia*, *Monotes*, or *Rytigynia*. It is worth mentioning the succulent species of the *Euphorbia* genus, which have an eco-morphological form similar to that of South American cacti. The division of the African territories into regions is mostly consistent with that of Linder *et al.* (2012), particularly with what has been done for the vascular plants. For some authors (Pfadenhauer & Klötzli, 2014) this territory is considered a kingdom on its own.

The Afromontane Corridor

The mountains within tropical Africa can be categorized into three distinct groups: the Ethiopian peaks, the east-central African group (Kilimanjaro, Kenia, Ruwenzori, and their associated ranges), and the Cameroon and Bioko (Basilé peak) mountains located in west central Africa. All of them exhibit evident floristic relationships. The first two groups collectively form the eastern alignment that traverses the African continent from north to south, known as the Afromontane Corridor. This corridor begins in the Great Rift at the Red Sea and extends all the way to Zimbabwe. It forms a continuous highland ridge connecting the mountains of Ethiopia and Eritrea to those in South Africa (Drakensberg and Great Escarpment). The corridor passes through the highlands of Kenya, Tanzania, Uganda, Congo, Rwanda, Burundi, and Mozambique before reaching the South African Drakensberg (White, 1978; Galley & Linder, 2005). This ridge is marked by the highest mountains on the continent: Ruwenzori (5,109 m asl), Elgon (4,321 m asl), Kenya (5,199 m asl), and Kilimanjaro (5,892 m asl), each separated by great distances, but liked by highlands. This orographic system has been an important migratory corridor for the temperate flora, facilitating their dispersion across the continent. Evidence of this migration can be seen in the presence of genera such as *Agrostis*, *Alchemilla*, *Anagallis*, *Bartsia*, *Carex*, *Carduus*, *Echinops*, *Hypericum*, *Ranunculus*, *Satureja*, *Sonchus*, *Swertia*, and *Trifolium*. Another group includes temperate taxa of South African affinity, such as *Blaeria*, *Haplocarpha*, *Pelargonium*, *Protea*, etc.

Due to the isolation of these different massifs, which emerged separately from the tropical lowlands, the majority of their orophile flora shares a common ancestry with the African tropical flora, which has given rise to what is known as the Afromontane flora or element (Hedberg, 1964). Other taxa are Podocarpaceae, with *Podocarpus latifolius* and *Afrocarpus falcatus*, as well as *Afrocrania volkensii*, *Hagenia abyssinica*, *Juniperus procera*, *Ocotea bullata*, *Prunus africana*, and various species of *Olea*. As Afromontane endemics or sub-endemics, we can mention the genera *Ardisiandra*, *Balthasaria*, *Cincinnobotrys*, *Curtisia*, *Ficalhoa*, *Hagenia*, *Kiggelaria*, *Leucosidea*, *Platypterocarpus*, *Stapfiella*, *Trichocladus*, *Widdringtonia*, and *Xymalos*. Regarding its role as a migratory corridor, the case of the *Erica* genus stands out. It has two main distribution territories, one in Europe and the Mediterranean and the other in South Africa. Both must have been related through this corridor, as suggested by the current distribution of *Erica arborea*, present in the Mediterranean, Macaronesian, southern Arabian, Ethiopian, and Kenyan mountains. Probably, this genus reached the South African territory from the north and radiated there, reaching the high number of species existing today (McGuire & Kron, 2005).

At higher elevations of the mountains, above the level of the forests, there is a vegetation belt known as Afroalpine (Killick, 1978). This belt is characterized by the presence of tree senecios (*Dendrosenecio*) of a very particular morphotype with leaves aggregated at the upper end of the stems. It also includes other similar column-like plants such as tree lobelias: *Lobelia aberdarica*, *L. deckenii*, *L. giberroa*, *L. gregoriana*, and *L. telekii*, along with *Carduus keniensis* or *Haplosciadium abyssinicum*. These Afroalpine species coexist with representatives of Holarctic and South African temperate genera.

12. Sudano-Zambezian region

It occupies most of the territory in tropical Africa south of the Sahara, forming a wide arc that embraces the Guinean-Congolese region, extending from Sahelian West Africa and the Cape Verde Islands to Sudan, the plateaus of East Africa, and the southern Zambezian regions down to Angola (Werger & Coetze, 1978). This vast area can be subdivided into two subregions: the Sahelo-Sudanian in the northern part and the Zambezian in the southern part.

The vegetation of this region primarily consists of woodlands and savannahs subject to a basically tropical pluviseasonal climate. The savannah forests

are characterized by a discontinuous tree layer, predominantly composed of parasol and deciduous trees during the dry season. They are primarily comprised of legume species, such as *Afzelia*, *Albizia*, *Brachystegia* (miombo), *Faidherbia*, *Isoberlinia*, *Julbernardia*, *Pterocarpus*, and *Senegalia (S. senegal)*, as well as species from families like Bombacaceae (*Adansonia digitata*, baobab), Burseraceae (*Commiphora africana*), Combretaceae (*Combretum* and *Terminalia*), Ebenaceae (*Diospyros abyssinica*), Euphorbiaceae (*Croton macrostachyus*), Zygophyllaceae (*Balanites aegyptiaca*), etc. This tree stratum is complemented by a herbaceous stratum dominated by grasses from genera like *Andropogon*, *Aristida*, and *Hyparrenia*. These grasses wither during the dry season and turn green in the rainy season, offering high productivity capable of supporting a diverse range of large mammals. In this region, there is one small endemic family, Kirkiaceae, which is shared with Madagascar. Among the useful plants, we can mention *Dalbergia melanoxylon* (grenadilla), which is indigenous to this region and features dark, hard wood used in musical instruments like flutes, bagpipes, and oboes. In poorly drained soils, there are species such as *Colophospermum mopane*, valued for their exceptionally hard wood. Notably, this region is the home of *Oryza glaberrima* (African rice), an important food crop.

While many authors recognize this region with approximate boundaries and the concept as presented here (Takhtajan, 1986; Pfadenhauer & Klötzli, 2014), others such as Good (1974) and Schroeder (1998) split the area into two regions: a Sudanian region in the north and a Zambezian region in the south.

The subbiomes represented in this region are 8a (Tropical xeric shrublands and woodlands), 8b (Tropical pluvisesonal forests and woodlands), 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests), and 1c (Tundras of the tropical mountains in cryoro belt) in the highest elevations.

13. Ethiopian-Southarabian region

It covers the territories centered around the mountainous massifs of Ethiopia, together with the adjacent areas of Eritrea and Somalia. It also includes the extreme south of the Arabian Peninsula, mainly Yemen, and the Socotra archipelago. The prevailing climate in this region is characterized by a tropical pluviseasonal pattern with low rainfall, giving rise to open deciduous woody vegetation (Asefa *et al*., 2020). This region is known for its strong endemicity, fostered by the existence of numerous mountains that cause an increase in rainfall in their elevated areas. There are a couple of small endemic families, the Barbeyaceae and Dirachmaceae, and four genera, to which 614 species are added (Kelbessa & Demissew, 2014). A wide range of tree species thrives here, adapted to the prevailing tropical pluviseasonal climate. Some examples include *Albizia schimperiana*, *A. gummifera*, *Astropanax abyssinicus*, *Baphia abyssinica*, *Ceratonia oreothauma*, *Livistona carinensis* (Arecaceae), *Mimusops laurifolia*, *Senegalia pentagona*, *Sideroxylon mascatense*, *Vachellia abyssinica*, and many others (Friis, 1986). The diversity of vegetation in this region is caused by the mountains. As altitude increases, temperatures drop, and seasonal rainfall becomes more pronounced and bimodal. This provides an opportunity for the presence of taxa with non-tropical lineages but a Holarctic, Mediterranean nuance. Species such as *Juniperus procera*, *Olea europaea* subsp. *cuspidata*, *Buxus hildebrandtii*, *Celtis africana*, *Erica arborea*, *Olea welwitschii*, *Prunus africana*, *Rosa abyssinica* coexist with other Afromontane species like *Afrocarpus gracilior*, *Dracaena afromontana*, *Hagenia abyssinica*, *Ilex mitis*, and *Olea capensis* subsp. *macrocarpa*. There are a few species of important human use that are native to the forests of these mountains: myrrh (*Commiphora myrrha*, Burseraceae), coffee trees (*Coffea arabica*, – Arabic coffee, and *C. canephora* – Robusta coffee), khat (*Catha edulis*, Celastraceae), and the frankincense trees (*Boswellia frereana*, *B. sacra*, and *B. papyrifera*, Burseraceae).

The Socotra archipelago, subjected to prolonged isolation and a highly arid climate, boasts a high level of endemism, with approximately 30% of its around 800 species exclusive to the islands (Kilian & Hain, 2006). Notable species on the Socotra archipelago include *Adenium obesum* subsp. *socotranum* (Apocynaceae), *Boswellia elongata*, *Dendrosicyos socotranus* (Cucurbitaceae), *Dorstenia gigas* (Moraceae), *Dracaena cinnabari* (Asparagaceae), *Kalanchoe farinacea* (Crassulaceae), and *Punica protopunica* (Punicaceae).

The subbiomes represented in this region are 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests), distributed in the mountains, 7c (Warm deserts and semi-deserts), 8a (Tropical xeric shrublands and woodlands), and 8b (Tropical pluvisesonal forests and woodlands).

14. Guineo-Congolian region

It extends through the regions of the Gulf of Guinea, from the southern part of Senegal to the northern part of Angola, and the Congo River basin to Uganda and Lake Victoria, being almost totally under a tropical pluvial climate. It is a territory west-biased in the equatorial latitudes of central Africa which receives abundant precipitations from the Atlantic Ocean all year round, although a certain seasonality happens it does not produce a really dry season. The climate is mostly of the tropical pluvial type and the vegetation is mainly the tropical rainforest. The main drainage network is provided by the Congo fluvial system. It is a mostly flat territory where most of the areas have low elevations, although there are some mountains in it (Lebrun, 1960); we can mention the mount Cameroon (ca. 4,000 m asl), together with the highest elevation of the Bioko Island, Pico Basilé (3,011 m asl).

It is populated by a rich flora (Anon., 1948–1953) consisting of some 8,000 species of vascular plants with 80% endemicity, including families such as Dioncophyllaceae (with the large insectivorous liana

Triphyophyllum peltatum from Ivory Coast, Sierra Leone and Liberia), Hoplestigmataceae, Huaceae, Medusandraceae (Cameroon) or Scytopetalaceae. Among the endemic genera, we can mention *Afroguatteria*, *Gymnostemon*, *Letestudoxa*, *Toussaintia*, *Scyphocephalium*, *Stonesia*, etc.

The flora of the above-mentioned mountains shows clear relationships with the east African mountains' flora (Keay, 1955) and tropical montane evergreen forests occur in their mid and high elevations, with several species of the *Astropanax* genus as well as *Agarista salicifolia*, *Myrica arborea* or *Nuxia congesta;* the summital areas are covered by grasslands with *Deschampsia mildbraedii* and *Festuca abyssinica* (Hall, 1973; Proctor *et al*., 2007). The African tropical rainforests of the lowlands of this region reach a high diversity, reaching between 3,000 and 4,000 species per 10,000 km^2, among the highest values in the world (White, 1983; Sayer *et al*., 1992). This region presents some relationships with the Neotropical kingdom through punctual representatives of families whose optimum is found in tropical America, as is the case of the Bromeliaceae (*Pitcairnia feliciana*) or Rapataceae (*Maschalocephalus dinklagei*). We can mention some remakable species widespread in this region such as *Baikiaea insignis*, *Blighia sapida*, *Camoensia maxima*, *Clerodendrum splendens*, *Erythrina excelsa*, *Lophira alata*, *Maschalocephalus dinklagei*, *Marantochloa cuspidata*, *Monodora myristica*, *Pleiocarpa mutica*, *Spathodea campanulata*, *Stipularia africana*, *Uncaria africana*, as well as *Khaya senegalensis*, *Piptadeniastrum africanum* or *Staudtia kamerunensis* among the timber trees.

In the chapter on the plants of interest originating in this region we can mention the Calabar beans (*Physostigma venenosum*), the strophanthus (*Strophanthus hispidus*), the rauvolfia (*Rauvolfia vomitoria*), the colas (*Cola nitida*, *C. acuminata*), bitter cola (*Garcinia kola*), oil palm (*Elaeis guineensis*), melegueta pepper (*Aframomum melegueta*) and Liberian coffee (*Coffea liberica*). In the section on species of timber interest are *Khaya senegalensis*, *Piptadeniastrum africanum* or *Staudtia kamerunensis*. Other useful species are *Raphia vinifera*, *Erythrina excelsa*, *Funtumia elastica*, *Landolphia owariensis*, *Lophira alata*, *Pleiocarpa mutica*, etc.

There is a unanimous agreement among the authors in recognizing this region (Good, 1974; Takhtajan, 1866, Schroeder, 1998; Costa, 2004; Pfadenhauer & Klötzli, 2014).

The subbiomes represented in this region are 9a (Tropical rain forests), the most extended, 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests) in the mountains, and even 1c (Tundras of the tropical mountains in cryoro belt) in some high-altitude summits.

15. Southeastern African Region (Maputoland-Pondoland)

It occupies a narrow strip of land on the eastern slope of the Drakensberg range in southeastern South Africa, from southern Mozambique to Gqeberha (Port Elisabeth), and covers an area of approximately 16,000 km2. To the extent that it exceeds tropical latitudes, its climate is temperate pluviseasonal in its southern part, giving rise to the so-called "Afrotemperate Forest of Southern Africa." This contrasts with the northern part, where the climate is of the tropical pluviseasonal type, favoring a strong originality in its biota. (Mucina & Rutherford, 2006; Mucina *et al*., 2021). In the vegetation, meadows, thickets, and sclerophyllous shrubs predominate. The forests of this region have about 600 species of trees, which represent the greatest diversity in dendroflora of any temperate region in the world. This territory is recognized as a region by Takhtajan (1986) and Pfadeheuer & Klötzli (2014).

There are two endemic small families: Stangeriaceae and Rhynchocalycaceae and about 20 endemic genera. The level of specific endemicity is around 23%, with about 1900 species, such as *Albizia suluensis*, *Allophylus natalensis*, *Aloe thraskii*, *Brachylaena discolor*, *Encephalartos natalensis*, *Encephalartos woodii* (extinct in the wild), *Dracaena aletriformis*, *Erythrina caffra*, *Jubaeopsis caffra*, *Stangeria eriopus*, *Strelitzia nicolai*, and others. Some of the genera show a distribution linking this region with Madagascar (*Mascarenhasia*). There are numerous succulent species in its flora and that influences its plant communities. Regarding fauna, endemicity is outstanding regarding the high number of vertebrate species.

The subbiomes represented in this region are 4a (Lauroid evergreen forest of the lowlands) and 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests) at higher elevations.

16. Karoo-Namibian region

This region encompasses the desert and semi-desert territories of Southwest Africa, including the Namib Desert along the coast, the Kalahari Desert in the interior, and the Namaqualand area. It ranges from southern Angola to the west coast of South Africa, extending through Namibia and reaching into southwestern Botswana (Werger, 1978). There is a unanimous agreement in recognizing this region (Good, 1974; Takhtajan, 1866; Schroeder, 1998; Costa, 2004; Pfadenhauer & Klötzli, 2014).

The climatic features of this region are significantly influenced by the cold Benguela current, which leads to frequent coastal fogs. Some plant species here have adapted to take advantage of these conditions (Jurgens *et al*., 1997; Mucina *et al*., 2021). Among them is the very remarkable relic plant *Welwitschia mirabilis*, which is able to use the cryptoprecipitation that is produced by the condensation of mist on the surface of the leaves. In areas that receive some precipitation, there are open woodlands featuring species such as *Commiphora*, *Colophospermum* (*C. mopane*), *Senegalia* (*S. mellifera*), *Terminalia* (*T. sericea*), and *Vachellia* (*V. erioloba*, *V. haematoxylon*). These woodlands are complemented by an herbaceous stratum with grasses of the genera *Aristida*, *Eragrostis*, *Schmidtia*, and *Stipagrostis*.

Succulent plants, including *Hoodia gordonii*, are common in this region. Some useful plant species found here include kiwano (*Cucumis metuliferus*) and the citron melon (*Citrullus caffer*), both known for their watery edible fruits.

The Namaqualand area, part of this region, is covered by the succulent karoo (Milton *et al*., 1997), a semi-desert environment rich in succulent bushes and annual herbs. Winter rains here lead to an explosive and spectacular spring flowering by a multitude of species from families such as Compositae (*Arctotis*, *Didelta*, *Felicia*, *Gazania*, *Gorteria*), Crassulaceae (*Adromischus*, *Crassula*), and Aizoaceae - *Mesembryanthemoideae* - (*Antimima*, *Cheiridopsis*, *Lithops*, *Mesembryanthemum*). Succulence is a prominent feature among the vascular plants of this region (White, 1983).

Endemicity is high, with at least 80 endemic genera concentrated in some families such as Aizoaceae, Compositae, Liliaceae s.l., Gramineae, Scrophulariaceae, etc. Some of the endemic genera are *Adenolobus*, *Calicorema*, *Leucosphaera*, *Microloma*, *Nymania*, *Phymaspermum*, *Portulacaria*, *Sarcocaulon*, *Sisyndite*, etc. There are some genera that concentrate a high number of endemic species, such as *Aloe*, *Crassula*, *Euphorbia*, *Pelargonium*, *Zygophyllum*, and others. The Aizoaceae family, particularly the Mesembryanthemoideae subfamily, stands out with over 1500 endemic species.

The subbiomes covering this region are 7b (Temperate deserts and semi-deserts) and 7c (Warm deserts and semi-deserts) in the northern part.

17. Malagasy region

Its great floristic and faunal originality makes some authors consider it a subkingdom. It includes the large island of Madagascar and the surrounding archipelagos, including the Comoros, Aldraba, Seychelles, Almirante, and the Mascarene Islands (Mauritius and Réunion). All the authors agree in recognizing this region (Good, 1974; Takhtajan, 1986; Schroeder, 1998; Costa, 2004; Pfadenhauer & Klötzli, 2014).

The endemicity of the flora in this region is exceptionally high, extending even to the family level. Some of them are the small Barbeuiaceae, Didiereaceae, Didymelaceae, Diegodendraceae, Melanophyllaceae, Physenaceae, Sarcolaenaceae, and Sphaerosepalaceae. There are about 400 endemic and sub-endemic genera, with standouts like *Gravesia* and *Oncostemum*, with over 100 species, and *Noronhia*, with 40 species. Out of the approximately 10,000 plant species, a remarkable 85% are endemic to this region. Notable genera like *Kalanchoe* (Crassulaceae), *Euphorbia* (Euphorbiaceae), and *Adansonia* (Bombacaceae) also contribute to the high endemicity, with *Adansonia* having six out of eight species distributed only in Madagascar. Orchid richness is particularly high, with 900 species. Some well-known plants from this area are *Delonix regia* (Flamboyant from Madagascar), *Ensete perrieri* (Madagascar Banana), *Ravenala madagascariensis* (traveller's palm), etc. (Lourenço, 1996).

Phylogenetic relationships between the Malagasy flora and that of the Indian region are very notorious, with about three-quarters of the flora having connections to the Indian region, while only about a quarter has African origins. One example of this relationship is the distribution of the family Nepenthaceae throughout Madagascar and tropical Asia, indicating the ancient connection between Madagascar and India. Madagascar separated from the Indian subcontinent during the Late Cretaceous and drifted towards its current position adjacent to Africa.

The subbiomes that can be distinguished in this region are 8b (Tropical pluvisesonal forests and woodlands) in most of the island, 9a (Tropical rain forests in the humid east coastal strip), and 8a (Tropical xeric shrublands and woodlands) in some particular areas under drier conditions.

18. Saint Helena and Ascensión Islands region

In the middle of the South Atlantic Ocean are found two of the most isolated islands of the world located at a minimal distance of ca. 1,600 km from the nearest continental mass: St. Helena and Ascension.

St. Helena island (latitude: 16º S; area: 122 km^2) lies within the tropical zone at 1,800 km of distance from the closest African coast (Angola). The climate is tropical arid in the lowlands but rainfall increases dramatically in the mountains of the central part of the island (818 m asl) covering them with dense lauroid forests. There are 9 endemic genera such as *Commidendrum*, *Melanodendron*, *Mellissia*, *Nesiota* (extinct), *Trimeris*, *Trochetiopsis*, etc. 38 out of the 39 species of St. Helena are endemic, but several are already extinct. The flora exhibit affinities with southern Africa and Madagascar (Baker, 1973; Cronk, 1987).

Ascensión island (latitude: 8º S; area: 88 km^2) at 1,600 km of distance from the African coast, is smaller and more arid than the previous one, with less than 180 mm of annual precipitation and a tropical temperatures regime. The result is desertic vegetation in the midlands and lowlands a slightly moister conditions in the modest elevations of the center of the island. Only a few native species survive, including *Aristida adscensionis*, and the endemics *Euphorbia origanoides* and *Sporobolus durus*. Other characteristic species that are in common with St. Helena include *Oldenlandia adscensionis*, *Asplenium ascensionis*, and *Wahlenbergia linifolia*.

The high degree of endemicity on these islands, attributed to their isolation from both Africa and South America, justifies their recognition as a distinct biogeographical region, as most of the authors do (Good, 1974; Takhtajan, 1866, Schroeder, 1998; Pfadenhauer & Klötzli, 2014).

The subbiomes that can be distinguished in these islands are 7a (Warm deserts and semi-deserts), 8b (Tropical pluvisesonal forests and woodlands) in the lowlands, and 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests) in the elevations.

IIb. Indomalesian subkingdom

Its flora is overwhelmingly tropical but is enriched by the addition of elements of Laurasian origin from the Holarctic world, with which it contacts to the north, as well as by Gondwanan elements contributed by New Caledonia, New Guinea, and Australia. Some authors consider this unit as a kingdom (Pfadenhauer & Klötzli, 2014) although others support the rank of subkingdom (Takhtajan, 1986). Numerous endemic or sub-endemic plant families are found in this unit, including Anisophylleaceae, Carlemanniaceae, Dipteridaceae, Leeaceae, Matoniaceae, Nepenthaceae, Pentaphylacaceae, etc. The abundance of Dipterocarpaceae is also notorious. The contribution of Austral elements is remarkable by means of the presence of a significant number of species from families like Podocarpaceae and Araucariaceae. It is notorious that many archaic genera and families of angiosperms have survived in this territory, indicating the climatic stability that has been maintained since the Cretaceous when angiosperm radiation began, according to the fact that this space contains a high representation of archaic forms of flowering plants (Pfadenhauer & Klötzli, 2014).

Some notable species of this subkingdom include *Adina cordifolia*, *Ailanthus integrifolia*, *Albizia lebbekoides*, *Butea monosperma*, *Dillenia pentagyna*, *Ficus religiosa*, *Homalium tomentosum*, *Phyllanthus emblica*, *Piliostigma malabaricum*, *Rhodomyrtus tomentosa*, *Tetrameles nudiflora*, *Vachellia leucophloea*, etc.

Within this sub-kingdom, mangroves reach the greatest diversity on Earth (Saenger, 1998; Ricklefs *et al*., 2006), with up to 268 species linked to this habitat. Out of these, 52 are considered true mangroves, out of the 60 species of this type worldwide, making this territory the hub of mangrove species richness in the world (Basha, 2018). Some characteristic and frequent species of them are: *Acanthus ilicifolius*, *Acrostichum aureum*, *Aegiceras corniculatum*, *Avicennia alba*, *Bruguiera gymnorhiza*, *Carallia brachiata*, *Ceriops tagal*, *Heritiera fomes*, *H. littoralis*, *Rhizophora stylosa*, *Sonneratia ovata*, etc.

This subkingdom has also given rise to several plant species of human use, including *Mangifera indica* (mango), *Artocarpus heterophyllus* (jack tree), *A. incisa* (breadfruit), *Musa spp*. (banana), *Garcinia mangostana* (mangosteen), *Nephelium lappaceum* (rambutan), *Areca catechu* (betel), *Tectona grandis* (teak), and others, for various purposes such as food, medicinal use, timber, etc.

The division of this subkingdom into regions is unanimously recognized in the literature (Good, 1974; Takhtajan, 1866, Schroeder, 1998; Costa, 2004; Pfadenhauer & Klötzli, 2014) and coincident with the proposed classification.

19. Indian region

This region encompasses the Hindustan peninsula, including the southern foothills of the Himalayas, the Gangetic plain, the Deccan plateau, the western and eastern Ghats, as well as several insular territories such as the island of Ceylon (Sri Lanka) and the Maldives, Chagos, and Laccadives archipelagos. It is relatively poor in terms of genera from ancient families, which seems to be the result of the vicissitudes of this Gondwanan fragment. This subcontinent had to face dramatic climatic changes during its solitary migration northward and its late union with the Asian continent in the Tertiary (Molnar & Tapponier, 1977; White & Lister, 2012).

The ancient original Gondwanan flora that populated the subcontinent from when it separated from Gondwana until it joined Asia, about 45 million years ago in the Eocene, has almost completely disappeared and is revealed only in the fossil record (Lakhanpal, 1970). The tropical Asian flora massively replaced it, but it had limited time to evolve and produce numerous endemic elements. As a result, no families have been recognized in this region as exclusive to the territory. The subcontinent also lacks representatives of large taxa such as the *Ranunculales*, *Rosales*, and *Saxifragales*, which are widely distributed throughout other regions of the kingdom. The scarcity of palm trees and other primitive monocotyledons is also notable. Regarding the endemic genera, about 120 genera have been mentioned as such (Rao, 1972). A few of them include *Cullenia*, *Didyplosandra*, *Erinocarpus*, *Humboldtia*, *Leptacanthus*, *Mackenziea*, *Nilgirianthus*, *Nothopegia*, *Phlebophyllum*, *Poeciloneuron*, *Pseudostenosiphonium*, *Stemonoporus*, *Xenacanthus*, etc. Among the characteristic and frequently occurring tree species of this region, we can mention *Cassia fistula*, *Dalbergia latifolia*, *Lagerstroemia microcarpa*, *Pterocarpus marsupium*, *Santalum album*, *Shorea robusta or Terminalia anogeissiana*.

The climate in this region is fundamentally governed by the monsoon regime, which brings abundant summer rainfall alternating with periods of drought throughout the rest of the year. It is classified as the tropical pluviseasonal type, oscillating between sub-arid and hyper-humid ombrotypes. Under such conditions, the predominant natural vegetation types are the summergreen-winter deciduous woody formations: the tropical pluvisesonal forests and woodlands and the tropical xeric shrublands and woodlands. In some areas, such as the southern regions of Nepal, Nagaland, Assam, and Arunachal Pradesh in the foothills of the central and eastern Himalayas, rainfall increases substantially. The same occurs on the eastern side of the Western Ghats on the Malabar coast and western Sri Lanka along the shores of the Indian Ocean. This increase in precipitation results in the development of natural vegetation such as tropical evergreen forests, with lower elevations hosting tropical rain forests and mid-altitudes featuring Tropical-subtropical montane cloud lauroid evergreen forests.

The subbiomes present in this territory are 8a (Tropical xeric shrublands and woodlands) in the dry areas of the central and western parts, 8b (Tropical pluvisesonal forests and woodlands), 9a (Tropical rain forests) in the Malabar coast and central-eastern Himalayan foothills, and 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests) in the mountains of the Ghats and Sri Lanka.

20 Indochinese region

It comprises the Indochina peninsula in Southeast Asia, stretching from eastern Bangladesh and the Andaman

Islands. It includes Burma (Myanmar), Thailand, Laos, Cambodia, and Vietnam, extending to southern China (Canton) and Hainan Island (Zhu, 2017). The climate dynamics in this region are dominated by the monsoonal regime, which determines a dry season during winter and a rainy season in summer. However, due to a high rainfall regime throughout the year, the dry season is relatively mild, and the majority of the territory is covered with evergreen tropical rainforests. In areas with less rainfall, where the dry season is more pronounced, deciduous pluviseasonal tropical forests become dominant.

The flora is very rich, featuring numerous Dipterocarpaceae and many other tropical families. While there are no endemic families in this region, there are about 250 endemic and subendemic genera. The largest among them is *Parabarium*, with 29 species, as well as *Briggsia*, *Cystacanthus*, *Fordiophyton*, *Litchi*, *Lingnania*, *Plagiopteron*, and others (Vidal, 1964). We can mention some frequent and characteristic species, such as *Amherstia nobilis*, *Anamirta cocculus*, *Bauhinia purpurea*, *Dalbergia cochinchinensis*, *Dipterocarpus turbinatus*, *Garcinia cochinchinensis*, *Hydnocarpus kurzii* (chaulmugra, used in leprosy treatment), *H. castaneus*, *Camellia sinensis* (tea), *Corypha lecomtei* (a palm whose leaves are used as writing material), *Magnolia champaca*, *Musa coccinea*, *Styrax benzoides*, etc.

This region has received introgressions of temperate flora from the north due to glaciations, which have been conveyed by the mountain ranges that run through the territory (Zhu, 2008). Consequently, at elevations above 700 m, there is a flora of Holarctic origin related to that of central China, characterized by genera with a clear temperate nature, and which is represented by species such as *Pinus kesiya*, several *Quercus* of the subgenus *Cyclobalanopsis* (*Q. austrocochinchinensis*, *Q. blakei*, *Q. camusiae*, *Q. helferiana*, *Q. macrocalyx*, *Q. myrsinifolia*, *Q. poilanei*, *Q. thorelii*, and *Q. xanthotricha*), various *Castanopsis* and *Lithocarpus* (*L. curtisii*, *L. longipedicellatus*, *L. uvariifolius*).

The subbiomes represented in this region are 8b (Tropical pluvisesonal forests and woodlands), 9a (Tropical rain forests) in the rainy areas, and 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests) in the elevations.

21. Malesian region

It covers the area between Indochina and Australia, consisting of a series of islands and archipelagos known as Insulindia. Key territories within this region include Java, Sumatra, Borneo, the Philippines, Moluccas, Timor, New Guinea, and the surrounding islands. Additionally, the southern part of the Malesian Peninsula is part of this unit. The northeastern strip of the Cape York peninsula in Northeastern Australia (Queensland) can also be considered part of this region. Although traditionally included in the Australian kingdom by most of the authors, this area exhibits a strong influence from the Indomalesian flora and vegetation. This region is subject to a tropical climate that varies between pluvial and pluviseasonal, being covered by vegetation associated with tropical ombrophilous perennial and deciduous monsoonal forests.

Its floristic richness is very high, with an estimated 41,000 species of vascular plants. There are three small endemic families and subfamilies: Duabangoideae, Lophopyxidaceae, and Matoniaceae, and about 400 endemic genera such as *Aromadendrum*, *Diplycosia*, *Geunsia*, *Iguanura*, *Kibessia*, *Ptyssiglottis*, *Rafflesia*, *Riedelia*, *Schismatoglottis*, *Scyphostegia*, *Stenomeris*, *Tetramerista*, *Thottea*, and many more (Johns, 1995). Many of these islands have mountains (often volcanoes) of considerable altitude (Kerinci, 3,805 m asl in Sumatra; Semeru, 3,676 m asl in Java; Raya, 2,278 m asl in Borneo; Puncak Jaya, 4,884 m asl in Papua). These high-altitude areas feature examples of the flora of Holarctic origin, with genera such as *Agrostis*, *Anemone*, *Aster*, *Berberis*, *Cardamine*, *Cirsium*, *Deschampsia*, *Euphrasia*, *Galium*, *Gentiana*, *Cirsium*, *Geranium*, *Hypericum*, *Lonicera*, *Myosotis*, *Poa*, *Potentilla*, *Ranunculus*, *Rubus*, *Stellaria*, *Thalictrum*, *Valerianella*, *Veronica*, *Viola*, and trees such as *Pinus merkusii*, and various *Lithocarpus* (Edwards *et al*., 1990, Kitayama 1992). This likely has to do with a probable migratory route from the north through Indochina and the Malacca peninsula to these islands, which would be activated during the cold periods of the Pleistocene. Another notable contribution to the flora of the Malesian region is from the southern hemisphere. This is evident in the presence of genera such as *Caladenia*, *Gunnera*, *Haloragis*, *Nertera*, and *Thelymitra*. Additionally, there are several tree species, like *Eucalyptus* (comprising 15 species, 9 of which are not found in Australia, with some distributed across several islands, such as *E. deglupta*, which reaches the island of Mindanao in the Philippines). There are also 12 species of *Nothofagus* in the highlands of New Guinea (Papua), and some Podocarpaceae such as *Dacrycarpus imbricatus* are native to several islands at mid-elevations. Such elements of Austral flora are present in the Malesian region due to the Australian-Papuan connection established during the glacial periods, thanks to the drop in sea level. In a similar process to what occurred with the Holarctic flora, cold periods activated migratory routes that are now interrupted, whether between the mountains or the lowlands, which were once accessible during periods of land connections.

The lowlands of this region are covered by tropical rainforests in the most humid areas, while deciduous forests dominate in areas with lower rainfall. Generally, precipitation decreases towards the east. Some notable species of evergreen forests are: *Artocarpus elasticus*, *Epicharis parasitica Lansium domesticum*, and *Planchonia valida.* In deciduous forests, we can find: *Ailanthus integrifolia*, *Albizia lebbekoides*, *Dillenia pentagyna*, *Homalium tomentosum*, *Phyllanthus emblica*, *Piliostigma malabaricum*, *Tetrameles nudiflora*, *Vachellia leucophloea*, *V. tomentosa*, etc. In mid elevations, above 1,200 m asl, the laurel forest predominates, composed of trees from families such as Lauraceae, Magnoliaceae, or Myrtaceae, with abundant epiphytes (many of them orchids), lianas, palm trees,

and tree ferns. Above the forest line, there is a thicket of Ericaceae (*Gaultheria*, *Rhododendron*, *Vaccinium*), in which *Anaphalis javanica* (Compositae), known as the Java edelweiss, stands out.

The subbiomes in this region are 9a (Tropical rain forests), 8b (Tropical pluvisesonal forests and woodlands), 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests) in the mountain areas, and 1c (Tundras of the tropical mountains in cryoro belt) in the highest peaks.

22. Fijian region

It includes a number of southeastern Polynesian archipelagos of volcanic origin, including Fiji, New Hebrides, Samoa, and Tonga, along with other minor islands. Within this region, there is one endemic family Degeneriaceae and several endemic genera, such as *Balaka*, *Gillespiea*, *Hedstromia*, *Neoveitchia*, *Squamellaria*, etc. (Smith, 1951; Chew, 1975). Among the trees, there are common endemic species such as *Acacia mathuataensis*, *Aglaia amplexicaulis*, *Serianthes myriadenia*, the conifer *Acmopyle sahniana*, or the palm tree *Heterospathe longipes*. Among the useful plant species, we can mention a valuable timber conifer *Dacrydium nausoriense*, medicinal *Gardenia anapetes*, or aromatic Fiji Sandlewood *Santalum yasi*. The flora is close to Malesian region and to that of Papua and Solomon islands.

The subbiomes that can be recognized in this region are 9a (Tropical rain forests), 8b (Tropical pluvisesonal forests and woodlands), and 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests) in the mountain areas.

23. Neocaledonian region

It comprises the island of New Caledonia and the nearby Loyalty Islands archipelago, with a total area of 18,840 km^2. It is a particularly interesting territory for hosting in a small area a large number of species (3,200) with a high rate of endemicity (79%). These species are spread across 165 families and 788 genera (Morat, 1993). At the family level, endemicity is manifested in a few small taxa such as Amborellaceae, Oncothecaceae, and Phellinaceae, while there are about a hundred endemic genera, including *Cerberiopsis*, *Greslania*, *Montrouziera*, *Pancheria*, *Sparattosyce*, etc. Furthermore, among the 44 gymnosperm species, 43 are endemic (Morat, 1993). A notable number of these exclusive taxa are paleoendemics that are concentrated in primitive families, some belonging to gymnosperms like Araucariaceae and Podocarpaceae, and others within angiosperms, including the Winteraceae. It is estimated, that the Neocaledonian region hosts 18 paleoendemic taxa, among which *Amborella trichopoda* stands out, the only representative of the Amborellaceae family, considered the most primitive of the angiosperms. In the Araucariaceae, we can mention *Araucaria columnaris*, and the podocarp *Parasitaxus rustus*, the only known parasitic conifer in the world. There are also 17 species of palm trees, of which 16 are endemic.

This outstanding endemicity is related to the long isolation of this territory, which possibly began during the mid-Tertiary period. This isolation is supported by a high proportion of xerophytic woody species and a relatively low presence of herbaceous taxa. Another feature that confirms this long isolation of the Neocaledonian flora is the poor representation of families like Compositae (1 species), Gramineae (12 species), and Leguminosae, which typically have more significant representation in floras worldwide. Furthermore, there are no eucalypts, a plant group that likely evolved after the region's isolation.

Despite the predominance of the Indo-Malesian paleotropical floristic element, which is relatively recent in terms of arrival on the islands, this region exhibits a strong representation of flora with Australian origins. This is evidenced by the abundance of representative genera such as *Grevillea* and *Macadamia* within the Proteaceae family and Myrtaceae genera like *Melaleuca* and *Metrosideros*. In addition, according to Thorne (1965), there is a remarkable representation of the flora of the Antarctic-New Zealand origin, with genera such as *Agathis* (Araucariaceae), *Dacrydium*, *Podocarpus* (Podocarpaceae), *Libocedrus* (Cupressaceae), and *Nothofagus* with its five species (Read & Hope, 1996). The ferns in this region include species from the southern hemisphere, particularly genera like *Dicksonia*, *Cyathea*, and *Sphaeropteris* (e.g., *S. novae-caledoniae*). These presences indicate an ancient connection with the Gondwana continent, from which the region separated in the distant past. All these relationships reveal the continental nature of the island of New Caledonia, which has been isolated for an extended period, similar to the isolation experienced by New Zealand. However, in the case of New Caledonia, the more recent introduction of tropical components dominates and coexists with the archaic Gondwanan elements.

As for the natural vegetation, it is divided into two units, the tropical dry or pluviseasonal forest, which occupies a narrow strip at low altitudes (< 300 m asl) on the southwest side of the island, in the rain shadow of the prevailing monsoon winds and receiving under 1100 mm of annual precipitation. Species like *Ixora margaretae* and *Oryza neocaledonica* are found in this area. Apart from this, the tropical rainforest covers almost the entire remaining territory (Jaffre *et al*., 1994). In the most outstanding elevations, a punctual representation of tropical montane forests can be distinguished.

Therefore, the subbiomes in this region are 9a (Tropical rainforests), 8b (Tropical pluvisesonal forests and woodlands), and 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests) in the summital mountain areas.

24. Polynesian region

The Polynesian region comprises the central and eastern portions of the Pacific Ocean, consisting of thousands of tropical islands. Among them, we can mention the Marianas, Carolinas, Cook, Marquesas, Marshall, Society, Pitcairn, and Easter Island.

There are some endemic genera of this region that give it a floristic personality, such as *Bonnierella*, *Fitchia*, *Guamia*, *Pelagodoxa*, *Sclerotheca*, and *Tahitia*. The unique flora of these islands is shaped by various ecological processes, including adaptive radiation, isolation-induced endemism, and colonization by different vectors, often through wind or birds. This expansive archipelago provides an ideal setting for the study of island biogeography (Mueller-Dumbois & Fosberg, 1998).

The subbiomes in this region are 9a (Tropical rain forests) and 8b (Tropical pluvisesonal forests and woodlands).

25. Hawaiian region

Among the Pacific archipelagos, the Hawaiian Islands are the group with the greatest isolation in terms of distance from the neighboring islands. They are characterized by their steep terrain, often exceeding 1,000 m asl in elevation. For example, Mauna Loa in Hawaii reaches a towering height of 4,169 meters, and the peak of Haleakala (Red Hill) on the island of Maui stands at 3,055 meters. The Hawaiian Islands are oceanic, having emerged from the ocean due to volcanic activity, resulting in relatively young geological features. The ages of these islands range from 0.7 to 5 million years, leading to differences in colonization processes due to varying initiation times (Price & Wagner, 2018).

The Hawaiian flora reflects the migrations that have occurred throughout history. In addition to a dominant Indo-Pacific floristic element (23.2%), there are other origins of lower importance such as North American (11.6%), Neotropical (13.1%), and Australasian (10.8%) (Price, 2004). This diversity in geographic elements results from colonization processes of the islands from different origins and periods (Price & Wagner, 2018). The great wealth of ferns (168 species) stands out, plants that, as dispersed by the wind, indicate the success of this strategy among the colonizers of these islands. *Metrosideros polymorpha* is a representative of the tropical rain forests, whose ancestor must have reached the islands thanks to the wind, too. Other species arrived through bird-assisted transportation, either through feathers or ingestion. Some of the endemic genera are *Argyroxiphium*, *Clermontia*, *Cyanea*, *Diellia*, *Dubautia*, *Haplostachys*, *Hibiscadelphus*, *Isodendrion*, *Labordia*, *Lipochaeta*, *Neraudia*, *Nothocestrum*, *Platydesma*, *Sadleria*, *Schiedea*, *Stenogyne*, etc. As for the species, there is a 95% rate of endemicity. Such conditions of specificity have led most authors to accept this archipelago of 16,856 km^2 as an independent biogeographical region. Vegetation is adapted to topography and tropical climatic conditions (Sohmer & Gustafson, 1994). The lowlands, up to 900 m, correspond to a tropical (dry) pluviseasonal forest with some species such as *Colubrina oppositifolia*, *Erythrina sandwicensis*, *Ochrosia compta*, *Planchonella sandwicensis*, *Polyscias sandwicensis*, *Rauvolfia sandwicensis*, etc. In higher elevations, up to 1,250 m, precipitation rises, and the dry season lessens or vanishes, allowing for the establishment of a tropical rain forest. This forest is inhabited by species such as *Acacia koa*, *Antidesma platyphyllum*, *Bonamia menziesii*, *Eugenia reinwardtiana*, *Metrosideros polymorpha*, and others. In mid-altitudes, up to 1,700 m, rainfall increases further, and fog and mist become more common. These conditions are appropriate for the montane tropical forest, with many ferns (*Grammitis spp.*, *Hymenophyllum recurvum*, *Ophioglossum pendulum*, etc.) and epiphytes such as *Clermontia peleana* or *Peperomia tetraphylla*. These rainy forests comprise a high proportion of the endemic flora of the Hawaiian Islands. At higher elevations conditions become colder, and forests are replaced by shrublands. Some of the species in these levels are *Coprosma montana*, *Dubautia menziesii*, *Vaccinium reticulatum*, and others. There are also grasslands with *Deschampsia nubigena*, *Panicum tenuifolium*, or *Trisetum glomeratum*.

The subbiomes in this region are 9a (Tropical rain forests), 8b (Tropical pluvisesonal forests and woodlands), 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests) in the mountain areas, and 1c (Tundras of the tropical mountains in cryoro belt) in the highest peaks.

III. Neotropical kingdom

Tropical America extends from Mexico and Florida down to Patagonia. It is bounded to the north by the North American part of the Holarctic kingdom and to the south by the Holoantarctic kingdom in its Valdivian-Magellanic province. Together with the Paleotropical kingdom, it forms part of the Pantropical context, an entity characterized by significant floristic and vegetational diversity. In addition to the general biogeographical maps of the world mentioned earlier, there are some more that deal particularly with this territory and which have inspired many of our conceptions and limits (Josse *et al*., 2003; Rivas-Martínez *et al*., 2011a; Hazzi *et al*., 2018). All Neotropical ecosystems are strongly conditioned by a mountainous backbone of variable size and magnitude, which crosses this vast territory from north to south as an extension of the North American Rocky Mountains. To the north, these elevations begin in the Mexican plateau and the Sierras Madre Occidental and Oriental. The alignment continues with the Sierras Transversales and the neovolcanic axis before reaching the Sierra Madre del Sur in southern Mexico. In Central America, these mountain ranges, often volcanic in origin, form the isthmus's backbone and connect with the formidable Andean system, which spans the South American continent from north to south. This results in a division between a Pacific slope and a generally much more extensive Atlantic slope. All the climatic regimes that are distinguished in this continent are profoundly influenced by this orography, separating the spaces of Atlantic and Pacific influence in a net way. This mountain ridge has allowed the migration of temperate taxa after the establishment of the Panamanian connection about 3 million years ago (O'Dea *et al*., 2016). For instance, northern taxa, including genera like *Alnus* or *Quercus*, migrated south, while Antarctic taxa like *Podocarpus*

moved northwards. This facilitated the spread of species like *Drimys* or *Gaultheria*, which eventually reached North America.

In general, there is a clear context of pantropical flora, which is manifested in the existence of 91 families that are represented throughout the tropical world. There are also 19 families shared with tropical Africa and 16 with the Indomalayan area (Smith *et al*., 2994), making it evident that the Neotropical flora has a common origin with the Paleotropical one. The Bromaliaceae and Rapataceae families are noteworthy examples, with all their species located in the Neotropical kingdom except *Pitcairnia feliciana* and *Maschalocephalus dinklagei* respectively, which are both endemic to the Guinean territories of tropical Africa. Among Cactaceae, only one species, *Rhipsalis baccifera*, exists outside of the Western Hemisphere and is widespread throughout tropical Africa and America.

There are 48 endemic and subendemic families in this kingdom, among which the Bromeliaceae, Cactaceae, Cannaceae, Caricaceae, Cyclanthaceae, Heliconiaceae, Krameriaceae, Lacistemataceae, Quiinaceae, Rapataceae, Marcgraviaceae, Theophrastaceae, Tropaeolaceae, and Vochysiaceae stand out. Others, such as Solanaceae, although they are cosmopolitan, have their maximum representation in this kingdom, with *Solanum* boasting around 700 species in tropical America. The Neotropical genera are estimated to number around 3,500, with approximately 300 being endemic to this kingdom (Gentry, 1982). Examples of Neotropical genera include *Chrysophyllum*, *Cinchona*, *Mikania*, *Swietenia*, and many more. It is estimated that there are some 90,000 species in the Neotropical kingdom (Thomas, 1999; Smith *et al*., 2004).

The Neotropical vegetation reflects this floristic and environmental diversity and all the formations and biomes existing within the tropics can be found in this territory (Navarro-Sánchez & Molina-Abril, 2022; Loidi *et al.*, 2022). The division of this kingdom into regions is basically inspired by the proposals of Rivas-Martínez *et al.* (1999; 2011a) and Costa (2004) for the tropical territories of both North and South America.

26. Madrean region

This region includes the arid and high-elevation territories of the central-northern part of Mexico and a narrow strip of southwestern United States. The climate in this region is characterized by a tropical pattern, with highly variable rainfall regimes, transitioning from arid conditions in the deserts to more humid environments in the tropical pluviseasonal and high-elevated areas. Two prominent mountain ranges, the Sierra Madre Occidental and Sierra Madre Oriental, run north to south, creating a significant rain shadow effect between them. There are two deserts in the Madrean region created by the subtropical highs regime and rain shadows: the Sonora and Chihuahua deserts. To the south, the Madrean region shares boundaries with the Antillean-Mesoamerican region, encompassing the coastal areas of Mexico, Chiapas, and the Yucatán peninsula. Despite being located south of the Tropic of Cancer, the Madrean region experiences a strong influence of northern American (Holarctic) flora. The cooling effect of both the Sierra Madre Occidental and Sierra Madre Oriental Mountain ranges, as well as the high plateau known as the Mesa del Centro, allows a substantial presence of Holarctic flora to extend southwards, reaching as far as the central sector of the state of Oaxaca at 16ºN latitude.

The north-south mountain ranges, such as the Sierra Madre Occidental and the Oriental, are home to flora and vegetation in which elements with Holarctic lineages predominate. As seen in the Sierra Madre Occidental, the flora exhibits a high degree of diversification with genera like *Arbutus*, with 7 species, *Quercus*, with 54 out of 161 species in the country, or *Pinus*, with 24 out of 46 species, giving rise to forests dominated by evergreen oaks and pines (Velázquez *et al*., 2016; Medina García *et al*., 2020). This phenomenon occurs despite the region's location south of the Tropic of Cancer and its tropical seasonal thermal and rainfall regime. The cooler temperatures due to higher elevations have allowed Holarctic-Madrean flora to thrive in place of purely Neotropical flora (Miranda & Hernández, 1963; González Medrano, 2004).

In the arid areas of the region, particularly in the Sonora desert located south of the Mojave, the abundance of succulent plants is striking. This desert spans the states of Arizona and California in the United States and extends into the Mexican states of Baja California, Sonora, and Sinaloa, covering approximately 260,000 km^2. The climate is characterized as warm desertic, with rainfall regulated by the monsoon regime, primarily concentrated at the end of summer. This climate also introduces a tropical component to the environment. The Sonora desert is known for its rich diversity of cacti, with around 125 species, among which *Carnegiea gigantea* (saguaro) stands out, and with numerous representatives in genera such as *Cereus*, *Echinocereus*, *Ferocactus*, *Mammillaria*, *Opuntia*, etc. Another indicator species is *Ambrosia deltoidea*. In this environment, there is an endemic family of Fouquieriaceae, with species such as *Fouquieria splendens* (ocotillo) and *F. columnaris* (cirio). Some species of *Parkinsonia* (palo verde) are common in the region, such as *Parkinsonia microphylla* and *P. florida*.

The other desert in the Madrean region is the Chihuahua Desert, located further southeast and covering an area of approximately 450,000 km^2 through the states of New Mexico, southeastern Arizona, Texas west of the Pecos River, and, in Mexico, the states of Sonora, Chihuahua, Coahuila, and Zacatecas (Rzedowski, 2006). Due to its higher elevation, between 600 and 1,675 m asl, this desert features fewer thermophilic elements compared to the Sonora desert. However, daytime temperatures can still reach very high values. The rains have a monsoonal regime, like the Sonoran Desert. The vegetation is formed by a thicket dominated by *Agave lechuguilla*, *Atriplex canescens*, *Cylindropuntia imbricata*, *Larrea tridentata*, *Flourensia cernua*, *Munroa pulchella*, *Neltuma glandulosa*, *Parthenium incanum*, *Yucca elata*, *Y. treculiana*, etc., with a relevant

representation of cacti but smaller in comparison to that of Sonora.

In this region, there are three small families: Fouquieriaceae, Simmondsiaceae, and Setchellanthaceae, and about 250 genera endemic to the region. Its flora has adapted to arid conditions but retains characteristics derived from the Holarctic origin of many of its elements such as numerous species of *Quercus*, *Fagus*, or *Pinus* inhabiting the Mexican Sierra Madre ranges.

The initial proposal by Axelrod (1967) for the Madro-Tertiary geoflora, established its current distribution including most of the area of the Western North American (California and Great Basin) region. That induced several authors such as (Good, 1974; Takhtajan, 1986; Schroeder, 1998; Pfadenhauer & Klötzli, 2014) to sustain a Madrean region including the southwestwrn USA and Mexican territories. In contrast to these authors, we have chosen to retain only the southern part of this region under the name "Madrean region," which encompasses the two Mexican Sierras Madre due to the importance of the Neotropical flora in this area. In the proposal put forth by Rivas-Martínez *et al*. (1999) and Costa (2004), the Madrean region was limited to the highland areas. However, on our map, we have made adjustments to these boundaries, extending the region to include the dry areas of the midlands and lowlands, namely merging Mexican Xerophytic and Madrean regions established by the two aforementioned authors, albeit with some modifications to its limits.

Regarding the subbiomes present in this region, in the mountains of Sierra Madre Occidental and Oriental, 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests) dominates, while in the arid areas, there are 7b (Temperate deserts and semi-deserts) in Chihuahua desert, and 7c (Warm deserts and semi-deserts) in Sonora desert. In mid-elevation areas, 8a (Tropical xeric shrublands and woodlands) is predominant.

In terms of useful plants, corn (*Zea mays*) is a highly significant economic plant cultivated worldwide. Peyote (*Lophophora williamsii*), a plant with psychotropic effects, is also native to this region.

27. Antillean-Mesoamerican Region

It encompasses the Atlantic and Pacific coastal regions of Mexico, including the southern tip of Baja California (Los Cabos) and the Revillagigedo archipelago, the southern part of the Florida peninsula, the islands of the Antilles, Yucatan and all of Central America (Linares-Palomino *et al*., 2003). It also includes northern and western Venezuela, including Los Llanos, northwestern Colombia (Rangel *et al*., 1997), including its Pacific coast (Chocó), coastal Ecuador, and the Cocos Island. This region is recognized by all the authors (Good, 1974; Takhtajan, 1986; Schroeder, 1998; Rivas-Martínez *et al*., 2011a and Pfadenhauer & Klötzli, 2014).

Within this vast and heterogeneous territory, two parts can be clearly distinguished: the continental Mesoamerican (Hartshorn, 1988) and the insular Antilles (Samek *et al*., 1988). The first includes a thin isthmic portion formed by Costa Rica and Panama. It was not definitively formed until the Pliocene, making it relatively recent in geological terms. Despite this, it is very diverse in biotopes and reliefs, which favors high biodiversity. The insular part includes the Greater Antilles (Cuba, Hispaniola, Puerto Rico, and Jamaica) and Lesser Antilles (Leeward, Windward, Bahamas, etc.), connecting with the islands of Tobago and Trinidad, situated very close to the South American continent. The arrangement of these archipelagos, forming chains that connect the coasts of Venezuela with those of Florida and Yucatan, creates a series of migratory routes linking these continental extremes. These routes were likely more active during periods of lower sea levels in the colder phases of the Pleistocene. In the South American continental part, the Venezuelan region of Los Llanos stands out in the Orinoco basin. It consists of vast plains that experience seasonal flooding during the rainy season (Galán de Mera *et al*., 2006). This determines the existence of large prairies of graminoids, with genera such as *Andropogon*, *Aristida*, *Axonopus*, *Bulbostylis*, *Paspalum*, *Trachypogon*, etc., interspersed with groves of trees or shrubs.

Its climate oscillates between tropical rainy and tropical pluviseasonal, with some areas, like the Gulf of Maracaibo, where the rain shadow causes certain aridity (Guajira). The vegetation in response to these two broad climate types includes tropical rainforests and dry deciduous forests (Gillespie *et al*., 2000).

It is a region of great floristic diversity, with a high endemicity: one family, Plocospermataceae (Smith *et al*., 2004), more than 600 genera, and a rate close to 60% among the species. This is fostered by the abrupt relief and the large number of islands, some of them with numerous endemic species. Cuba, for example, exhibits increased endemism due to the prevalence of serpentines. Some typical genera of this region are *Aulonemia*, *Bouvardia*, *Coccoloba*, *Dahlia*, *Guaiacum*, *Hura*, and *Wallenia*. Among the species we can mention *Byrsonima crassifolia*, *Ceiba pentandra*, *Coccoloba diversifolia*, *Coccothrinax miraguama* (miraguano), *Cordia collococca*, *C. dentata*, *C. megalantha*, *Chrysophyllum cainito*, *Curatella americana*, *Hippomane mancinella* (manzanillo or the tree of death), *Lennoa madreporoides*, *Mimosa pudica*, *Roystonea regia* (royal palm), *Zamia pumila*, and many others. Some useful species native to this region are papaya (*Carica papaya*), peppers or chili peppers (*Capsicum* spp.), avocado (*Persea americana*), bean (*Phaseolus vulgaris*), broad bean or locust bean (*Phaseolus lunatus*), cassava (*Manihot esculenta*), guava (*Psidium guajava*), vanilla (*Vanilla planifolia*), and cocoa (*Theobroma cacao*).

The subbiomes presented in this region are 9a (Tropical rain forests), 8a (Tropical xeric shrublands and woodlands) in the Guajira of Maracaibo, 8b (Tropical pluvisesonal forests and woodlands), 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests) in the mountains, and 1c (Tundras of the tropical mountains in cryoro belt) in a few of the highest peaks.

28. Orinoco-Guyana region

It occupies the territories of the Guiana Shield, which extends through present-day Venezuela (on the right

bank of the Orinoco), the Guyanas, and the bordering areas of Brazil. With different sizes and limits, this region is generally recognized by all the authors (Good, 1974; Takhtajan, 1986; Schroeder, 1998; Rivas-Martínez *et al*., 2011a; Pfadenhauer & Klötzli, 2014). It is a relatively large territory known for its richness in endemic species, the majority of them found in the Tepuis massif in Venezuela. The highest peak among the Tepuis is Marahuaca, which reaches 2,832 m asl. This ancient Paleozoic massif, isolated from the Andes and much older, consists of Precambrian "Roraima" sandstone and quartzite, forming plateau-like mountains with steep vertical slopes known as tepuis. The soils in this region are highly acidic, and the climate ranges from tropical pluviseasonal in the west to tropical pluvial in the east. Consequently, the vegetation shifts from a tropical deciduous forest to an evergreen rainforest (Josse, 2014). In the tepuis, due to their elevation, the mists often condense on the slopes at intermediate altitudes, and this causes very humid mountain forests almost always shrouded in mist. The existence of numerous reliefs of this type, specific climatic conditions with increased humidity and cooler temperatures due to altitude, and the extremely acid substrates result in a distinct flora that sharply differs from the surrounding Amazonian and Antillean-Mesoamerican regions (Maguire, 1979; Berry *et al*., 1995–1997; Lozada *et al*., 2014). There is a high number of endemic species, close to 50% of the estimated 8,000 species believed to inhabit this region. Each tepuy has its own set of endemic species resulting from reproductive isolation, giving rise to a clear model of allopatric speciation among the numerous existing tepuis. Some of the endemic-subendemic genera are *Etericius*, *Heliamphora*, *Ledothamnus*, *Potarophytum*, *Stenopadus*, *Tryssophyton*, *Windsorina*, many of which are confined to the summits of tepuis (Steyermark, 1979).

This region is home to a variety of insectivorous plants, which have adapted to the nutrient-poor soils. Notable among them is the genus *Heliamphora*, with all 23 of its species originating from this region. It is also worth mentioning the existence of up to 6 species of *Voyria* (Gentianaceae), which lack chlorophyll and are fungal parasites (myco-heterotrophic). Some typical species of this region are *Angostura trifoliata* (angostura), *Caryocar villosum*, *Chlorocardium rodiei*, *Duguetia quitarensis*, and *Sauvagesia guianensis*.

The subbiomes of this region are 9a (Tropical rain forests), 8b (Tropical pluvisesonal forests) in some small areas under drier conditions, and 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests) in the mountains.

29. Amazonian region

It extends throughout the vast plain drained by the Amazon River and its extensive fluvial network, encompassing some adjacent territories within the Orinoco basin. This region spans the territories of Bolivia, Brazil, Colombia, Ecuador, and Peru (Josse *et al*., 2007; Navarro-Sánchez, 2011). It features a tropical pluvial climate characterized by consistently high temperatures year-round and abundant rainfall distributed throughout the year, with no distinct dry season. The vegetation corresponds to the so-called "hylea" or Amazonian equatorial forest, characterized by great biomass and diversity. The forest canopy comprises multiple strata, with the tallest trees reaching heights of 30 to 50 meters and a prevalence of Leguminosae in the upper levels. Different types of forests are distinguished based on the hydrological conditions influenced by the seasonal fluctuations in river flow. These include "tierra firme" (mainland) forests that are never flooded, "igapó" forests that experience temporary or permanent flooding with swampy black waters rich in organic matter, and "várzeas" that are flooded by mineral-laden white waters (Navarro-Sánchez, 2011). This region is recognized by various authors (Good, 1974; Takhtajan, 1986; Schroeder, 1998; Rivas-Martínez *et al*., 2011a and Pfadenhauer & Klötzli, 2014).

From a floristic and vegetational perspective, the Amazonian region is considered the equivalent of the Guinean-Congolese region but with a richer flora. There are three families (Dialypetalanthaceae, Duckeodendraceae, and Rhabdodendraceae), as well as nearly 100 genera endemic to this region. It reaches 8,000 species, with nearly half of them being endemic (Takhtajan, 1986). This territory boasts a remarkable plant diversity, with around 5,000 species per 10,000 km^2, earning it a reputation as one of the world's phytodiversity hotspots (Rizzini, 1997). Some noteworthy genera from this region are *Dilkea*, *Hevea*, and *Lissocarpa*. Among the large trees of the jungle, we can mention *Bertholletia excelsa*, *Brosimum utile*, *Cedrelinga cateniformis*, *Dinizia excelsa*, *Huberodendron ingens*, *Mauritia carana*, *Parkia gigantocarpa*, and others. The rubber tree *Hevea brasiliensis* also originates from the Amazon, as well as other ornamental species such as *Heliconia episcopalis* and *Victoria amazonica*.

The subbiome of this region is 9a (Tropical rain forests) almost exclusively.

30. Andean-Pacific region

It extends through the high- and midlands of the Andes Mountain range, extending from the northern part of Venezuela, where mountain alignments overlook the Sea of the Antilles in the Maracaibo area (Mérida Mountain range), to the 32ºS parallel, in the center of Chile (Martínez *et al*., 2009). This region also includes the desert coastal strip located between Tumbes in the north of Peru and the 32ºS parallel. It is a territory of great latitudinal amplitude since it ranges from 10ºN to 29ºS, which adds up to 40º of latitude in both hemispheres. This imposes a diversity of climatic regimes, basically tropical rainy in the north (Venezuela, Colombia, and Ecuador) and tropical pliviseasonal with distinct rainy and dry seasons in the south (Peru, Bolivia, Chile, and northwest Argentina). This rainfall regime is combined with the rain shadow projected by the Andes on the Pacific coastal strip in combination with the cold Humboldt current that bathes the northern Chilean

and Peruvian coasts, giving rise to the extreme South American Pacific desert. When the cold Humboldt current weakens near Tumbes, Peru, and the Pacific coast is influenced by warm waters from the Pacific equatorial current, the region experiences increased rainfall along the coasts of Ecuador (Esmeraldas-Guayaquil area) and the Chocó strip in Colombia (Rangel *et al*., 1997). Due to its floristic connections with the pluviseasonal Andes, we have decided to include the Pacific desert within this region.

The northern Andes stretch from Venezuela (Pico Bolívar 4,987 m asl) to Ecuador (Chimborazo 6,268 m asl), passing through Colombia, where they diversify into three mountain ranges: eastern, central, and western (Pico Cristóbal Colón 5,775 m asl). To the south, they extend into Peru (Huascarán 6,757 m asl) and Bolivia (Illimani 6,438 m asl), where they bifurcate into two parallel chains – the eastern and the western – giving rise to an intermediate plateau that covers a substantial area in its Bolivian section. From this zone, the Andes adopt a north-south orientation towards the southern tip of the continent, penetrating Chile and northeastern Argentina. The Andean-Pacific region gradually fades away, reaching the 32nd parallel South in the mountains and the 31st parallel South on the coast, therebeyond this point, the Central Chilean-Western Patagonian and Valdivian-Magellanic flora predominate.

This region is defined based on the general criterion of incorporating the coastal Pacific deserts into it and has been acknowledged by most authors (Good, 1974; Takhtajan, 1986; Schroeder, 1998; Rivas-Martínez *et al*., 2011a; Pfadenhauer & Klötzli, 2014). It includes the northern Andes (Ecuador, Colombia, and Venezuela), as well as the southern ones (Perú, Bolivia, Chile, and northern Argentina). Although the northern Andes were excluded in the approach by Rivas-Martínez *et al.* (2011a), we consider the Andean flora to exhibit remarkable unity.

The orophile flora of the Andes is relatively poor, estimated at less than 10,000 species. There are a few subendemic families such as Columelliaceae and likely hundreds of endemic genera and species. This pattern is attributed to the recent uplift of these mountains. While they originated in the upper Miocene, the current reliefs were shaped in the Plio-Quatrenary epoch, which means that the local flora has not had a significant amount of time to diversify. This flora comprises diverse contributions from various elements that have come into contact along the extensive latitudinal range. Nevertheless, this heterogeneity is balanced by the unity observed in the flora residing in the upper belts (supra, oro, and cryoro) of the numerous Andean massifs (Galán de Mera *et al*., 2003, 2006). This high-mountain flora is partially of temperate origin, featuring species from Holarctic genera like *Agrostis*, *Alnus*, *Arenaria*, *Astragalus*, *Berberis*, *Calamagrostis*, *Cerastium*, *Draba*, *Geum*, *Hydrangea*, *Ribes*, *Saxifraga*, *Viburnum*, and more. Even an oak species, *Quercus humboldtii*, can be found in the northern Andes. On the other hand, a few Antarctic genera extend into tropical latitudes, such as *Azorella*, *Colobanthus*, and *Ourisia*. However, there are numerous typical (though not exclusive) Andean genera, including *Ascidiogyne*, *Alstroemeria*, *Aynia*, *Bishopanthus*, *Chucoa, Culcitium*, *Desfontainia*, *Doselia*, *Ellenbergia*, *Hypseocharis*, *Lophopappus*, *Oxychloe*, *Parastrephia*, *Schizotrichia*, *Weberbauera*, *Werneria*, etc. In addition to these, there are more widespread genera with this Andean region as their center of speciation, such as *Alonsoa*, *Barnadesia*, *Calceolaria*, *Cinchona*, *Fabiana*, *Hesperomeles*, *Loasa*, *Mutisia*, *Puya*, etc.

The northern Andes, situated within a tropical rainy climate, are characterized by the presence of dense forests on both slopes – the Pacific and the Atlantic – that receive consistent rainfall. Above 3,000 m asl, they present a characteristic ecosystem known as the "páramo" (from Spanish, meaning barren, flat, wind-exposed, and often elevated land). This ecosystem is often enveloped in mist (Galán de Mera *et al*., 2015) and is dominated by caulirosulate nanophanerophytes from the genus *Espeletia*, commonly known as "frailejones", which belong to the Compositae family. The páramo is a very unique formation with a stratum of grasses and a group of frailejones, resembling the arborescent senecios and lobelias found in the high mountains of Africa. Above 4,500 m asl, the frailejones give way to formations of several *Senecio* species belonging to the *Culcitium* section.

In the central Andes, from the Peruvian-Ecuadorian border to the south, the páramo is replaced by a grassland vegetation called the "puna" (from Quechua, meaning highland). The puna thrives at latitudes above 3,200–3,800 m asl, depending on latitude (Galán de Mera *et al*., 2003, 2004, 2009). It is a natural vegetation that has originated in coevolution with the auchenids (the South American section of camelids): alpaca, guanaco, llama, and vicuña, which are characteristic to this area. Grasses are dominant (pajonales) and some key species include *Aciachne ssp*., *Cinnagrostis vicunarum*, *Festuca dolichophylla*, *F. chrysophylla*, *Jarava ichu* (ichu), etc. These species coexist with those of specific high Andean genera like *Acaulimalva*, *Azorella*, *Niphogeton*, or *Perezia*, forming extensive grasslands in the puna. A notable puna species is the bromeliad *Puya raimondii*. The pajonales are closely linked to grazing by native auchenids, along with introduced livestock, primarily sheep. As a result, they are expanded across these high-altitude areas. In the humid depressions, peat bogs form and are covered with hard crusts composed of species like *Distichia muscoides*, *Isoetes andicola*, *Plantago tubulosa*, *Rockhausenia apiculata*, and others (Navarro-Sánchez & Molina-Abril, 2022). As less disturbed vegetation there are copses of *Polylepis* (Navarro-Sánchez *et al*., 2005) and in certain regions thickets of species such as *Fabiana densa*, *Lampayo castellani*, *Lobivia pentlandii*, or *Parastrephia quadrangularis* dominate (Navarro-Sánchez & Molina-Abril, 2019). At altitudes above 4,300 m asl, the vegetation endures extreme conditions, with the possibility of frost all year round, average annual temperatures below 0ºC, and strong winds. Many of the plants, often endemic, acquire a pulvinular or rosette shape, along with a strong root apparatus, forming open communities.

In the pluviseasonal Andes, the Atlantic slope receives moisture from the trade winds originating in the Atlantic Ocean. This creates frequent mists that give rise to the rainy and misty mountain forests known as "yungas". On the contrary, the Pacific side is situated in a rain shadow, and the slope toward the coast experiences increasing aridity, culminating in the coastal desert (Galán de Mera *et al*., 2009). On this side, cacti are abundant, such as *Neoraimondia arequipensis* and some species of *Armatocereus*. As the altitude decreases, cacti become less common until reaching a desert area devoid of vascular vegetation. In the vicinity of the Pacific coast, the cold ocean water temperature generates "garúas", which are coastal mists that provide moisture to the hills in the area. This humidity is used by some species of the genus *Tillandsia* (Bromeliaceae) lacking roots but equipped with trichomes capable of condensing water from the fog and absorbing it (Pinto *et al*., 2006). Human, agricultural, and industrial activities are concentrated along the banks of the Andean rivers that cross this strip of desert on their way towards the Pacific, with cities such as Arica, Lima, Trujillo, or Piura. In this arid and desert strip of the Chilean-Peruvian Pacific coast, two endemic (sub)families exist: Malesherbioideae and Nolanaceae.

The Galapagos Islands are in the "dry zone" of the equatorial Pacific. Their lowlands are arid and the highlands are moister due to cloud accumulation between 200 and 500 m asl. For that reason, they present strong relations with the desertic areas of coastal South America and are considered part of the Andean-Pacific region. The Galapagos Islands exhibit a relatively low number of endemic plant species. However, they are home to various species of the genus *Scalesia* in the humid midlands, as well as *Gaultheria howellii* at higher elevations. In the arid lowlands, some endemic cacti such as the chandelier-shaped cactus, *Jasminocereus thouarsii*, the lava cactus *Brachycereus nesioticus*, and the Galápagos prickly pear (tuna gigante) *Opuntia galapageia* can be found (Wiggins & Porter, 1971).

This Andean-Pacific region is home to a large number of plant species of economic use, either food, medicinal, or textile, such as *Annona cherimola* (cherimoya), *Carludovica palmata* (jipijapa), *Ceroxylon alpinum* (Holy Week palm), *Chenopodium quinoa* (quinoa), *Cinchona calisaya*, *C. officinalis*, *C. pubescens* (quinas), *Erythroxylum coca* (coca), *Krameria lappacea* (ratania), *Nicotiana tabacum* (tobacco), *Schinus molle* (false pepper tree), *Solanum betaceum* (tree tomato), *S. lycopersicum* (tomato), *S. tuberosum* (papa or potato) and *Ullucus tuberosus* (olluco).

There is a high variety of subbiomes represented in this region: 8b (Tropical pluvisesonal forests and woodlands) and 8a (Tropical xeric shrublands and woodlands) in the interandine valleys, 7c (Warm deserts and semi-deserts) in the coastal Pacific desert, 7b (Temperate deserts and semi-deserts) in the upper levels of the coastal desertic area, 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests) in the rainy mid elevations, and 1c (Tundras of the tropical mountains in cryoro belt) in the large páramo and puna areas.

31. Brazilian-Paraná region

It is located on the great hydrographic basin of the Paraná-Paraguay River network, to the east of the Andean chain, occupying vast regions of Brazil, Paraguay, Bolivia, and northeastern Argentina. It is bordered by the Amazon region to the north and the Pampean and Central Chilean-Western Patagonian regions to the south, approximately around the 31º S parallel. It experiences a pluviseasonal tropical climate, with varying levels of rainfall, from the high values along the Brazilian Atlantic coastal strip (São Paulo, Rio de Janeiro, Espirito Santo) to the driest areas in northeastern Brazil and the most inland regions of Chaco. It spans the Brazilian states of Mato Grosso, Goias, and Minas Gerais (Rizzini 1997). This region aligns with the concept followed by most authors (Good, 1974; Takhtajan, 1986; Schroeder, 1998; Pfadenhauer & Klötzli, 2014) and combines the two regions proposed by Rivas-Martínez (2011a), namely Chacoan and Brazilian-Paranense regions.

Among the widely distributed taxa in this region, we can point out the genera *Allagoptera* (stemless dwarf palms), *Arachis*, *Barjonia*, *Castelnavia*, *Microlicia*, *Pygmaeorchis*, *Spathicarpa*, and *Wunderlichia*, as well as numerous species such as *Ananas sagenaria*, *Ceiba ventricosa*, *Hancornia speciosa*, *Handroanthus heptaphyllus*, *Libidibia ferrea* (ironwood), *Melanoxylon brauna*, *Myracrodruon urundeuva*, *Nautonia nummularia*, and *Soaresia velutina*.

In the Brazilian Atlantic coastal zone, stretching from Bahia to Rio, the Atlantic rainforest, or Mata Atlântica, thrives due to the high rainfall that mitigates the dry season (Rizzini, 1997). It is formed by evergreen tropical rainforests, of great density and diversity. Notably, this area contains representatives of the temperate Gondwanic element, such as *Araucaria angustifolia* and *Podocarpus lambertii*. In addition, there are some small genera typical of this area such as *Fernseea* (Bromeliaceae) and *Schlumbergera* (Cactaceae), and species such as *Aechmea araneosa*, *Albertinia brasiliensis*, *Alseis involuta*, *Amburana cearensis*, *Astrocaryum aculeatissimum*, *Attalea humilis*, *Caryocar edule*, *Cariniana legalis*, *Cavanillesia arborea*, *Cordia taguahyensis*, *Couratari macrosperma*, *Dalbergia nigra*, *Duguetia sessilis*, *Ficus christianii*, *Inga subnuda*, *Heteropterys coleoptera*, *Lecythis pisonis*, *Paubrasilia echinata* (Brazilian wood), *Tabebuia obtusifolia*, *Terminalia parvifolia* subsp. *rabelloana*, etc.

The interior territories of south-central Brazil feature a unique ecosystem known as "cerrado" (Rizzini, 1997; Josse, 2014), which extends west into the "Chiquitano" forest of Bolivia (Navarro-Sánchez, 2011). The cerrado develops under a tropical rainy seasonal climate with a pronounced dry season and features a nutrient-poor substrate, primarily granite, at considerable elevations. These conditions, among which nutrient scarcity plays a relevant role, result in a savannah vegetation characterized by an open layer of trees and shrubs, dominated by hard-leaved evergreens (sclerophylls) with broad leaves (macrophyllous). Below this layer, there is a more or less continuous tapestry of herbaceous plants of various sizes that synchronize their

phenology with the seasonal rains. In some areas, woody elements disappear, and a pure grassland establish (Campo limpo). Among the trees and shrubs, we can mention *Aspidosperma tomentosum*, *Byrsonima verbascifolia*, *Cavanillesia umbellata*, *Curatella americana*, *Davilla elliptica*, *Diospyros lasiocalyx*, *Eriotheca pubescens*, *Palicourea rigida*, *Qualea grandiflora*, *Q. parviflora*, *Simarouba versicolor*, *Handroanthus ochraceus*, *Vochysia elliptica*, and *V. thyrsoidea*. The herbaceous stratum includes sedges of the genus *Bulbostylis*, grasses, such as *Axonopus aureus* and *Trachypogon spicatus*, as well as other plants such as of the showy Eriocaulaceae like *Comanthera cipoensis* or the genus *Paepalanthus*.

Northeastern Brazil (Rio Grande do Norte, Paraiba, Alagoas, Pernambuco, and others) is subject to a more arid climate, with annual rainfall ranging from 250 to 700 mm and a strong seasonality marked by a prolonged dry season. This determines that the vegetation is a thorny deciduous shrub rich in succulent cacti known as "caatinga" (Rizzini, 1997; Josse, 2014), which translates to "white forest" in the Tupi language. The woody plants in this ecosystem have evolved clear adaptations to xeric conditions, such as thick rhytidomes (bark), spinescence, and leaf shedding. Additionally, there is an ephemeral herbaceous component that takes advantage of the short rainy period to complete its life cycle. The caatinga can be subdivided into two parts, the interior, known as "sertão" (backlands or backwoods in Portuguese), and the coastal or rugged part. Notable species in the caatinga include *Calliandra depauperata*, the palm *Copernicia prunifera* (carnauba), *Fraunhofera multiflora*, *Mimosa tenuiflora*, *Pereskia aureiflora*, *Sarcomphalus joazeiro*, *Spondias tuberosa*, and cacti like *Cereus jamacaru* or *Xiquexique gounellei*.

In the interior territories of this region, to the east of the Bolivian and North Argentinian Andes, there is an area with a strong floristic and vegetational personality known as "El Chaco". It extends through northern Argentina, Paraguay (Navarro-Sánchez & Molina-Abril, 2006), and southeastern Bolivia (Navarro-Sánchez, 2011; Navarro-Sánchez *et al*., 2011). The climate in Chaco is characterized as tropical pluviseasonal, with varying annual rainfall typically between 500 and more than 1000 mm. The Chaco forest is dry, semi-deciduous, and microphyllous (with small leaves). The dominant species are *Aspidosperma quebracho-blanco* (white quebracho) and *Schinopsis balansae* (quebracho-colorado), *S. lorentzii*, *Ceiba chodatii*, *C. speciosa*, to which are added *Copernicia alba*, *Geoffroea decorticans*, *Jodina rhombifolia*, *Libidibia paraguariensis*, *Myracrodruon balansae*, *Neltuma alba*, *N. kunzei*, *N. nigra*, *N. ruscifolia*, *Sarcomphalus mistol*, *Sideroxylon obtusifolium*, *Strombocarpa torquata Trithrinax campestris*, etc.

It is important to note the presence of extensive floodplain areas subject to various flooding regimes, particularly the "Gran Pantanal" located at the confluence of the Brazilian Mato Grosso, northern Paraguay, and western Bolivia, spanning the departments of Santa Cruz and Beni (Navarro-Sánchez & Ferreira, 2009; Navarro-Sánchez *et al*., 2010; Navarro-Sánchez, 2011) and covering a total extent of 340,000 km^2.

As plants of economic interest originating from this region, we can list *Ananas comosus* (pineapple), *Arachis hypogaea* (peanut), *Carapichea ipecacuanha* (Brazilian ipecacuanha), *Copernicia prunifera* (carnauba), *Ilex paraguariensis* (mate) and *Passiflora edulis* (passion flower).

The subbiomes covering this region are 8a (Tropical xeric shrublands and woodlands) for the Caatinga and southern Chaco, 8b (Tropical pluvisesonal forests and woodlands) for most of the area, and 9a (Tropical rain forests) in the coastal Brazilian strip covered by the Mata Atlântica.

32. Pampean region

It covers northeastern Argentina, including provinces like Buenos Aires, Santa Fe, Entre Ríos, Río Negro, Córdoba, and La Pampa. It also extends into Uruguay and the southern part of the state of Río Grande do Sul in Brazil. This region is also recognized by many authors (Good, 1974; Schroeder, 1998; Rivas-Martínez *et al*., 2011a; Pfadenhauer & Klötzli, 2014). It is a flat territory, barely interrupted by modest reliefs, which is under a temperate oceanic summer-rainy climate with mild winters. The rainfall predominately comes from the Atlantic and is concentrated during the summer months. The soils in this region are deep and rich in fine particles and organic matter, making it one of the world's most fertile areas. This fertility has led to extensive afforestation, pasture expansion, and widespread cultivation (Cabrera, 1971; Paruelo *et al*., 2001; Oyarzabal *et al*., 2018).

The arboreal element is scarcely represented at present. Common species include *Vachellia caven* (espinillo), *Condalia microphylla* (piquillín), *Phytolacca dioica* (ombú or bellasombra), *Neltuma caldenia* (caldén), *N. flexuosa* (algarrobo), etc. The predominant landscape element in the Pampean region is grasslands, consisting of a mix of exotic species, mainly of European or Eurasian origin, and South American species. Notable native tropical grasses in the Pampas include *Bothriochloa laguroides*, *Bromus catharticus*, *Chascolytrum subaristatum*, *Dichanthelium sabulorum*, *Hordeum stenostachys*, *Leersia hexandra*, *Melica brasiliana*, *Nassella neesiana*, *N. melanosperma*, *Panicum gouinii*, several species of *Paspalum* (*P. quadrifarium*, *P. vaginatum*, *P. dilatatum*, *P. notatum*), *Poa bonariensis*, *Setaria parviflora*, *Sporobolus indicus*, or *Stenotaphrum secundatum*. These grasses coexist with other species of the Leguminosae family, namely *Adesmia bicolora* or *Vicia graminea*, and are often found alongside a wide variety of European clovers. *Cortaderia selloana*, a grass species native to the Pampean region, has become invasive and is causing problems in numerous countries around the world.

The subbiome covering this region is 4a (Lauroid evergreen forest of the lowlands).

33. Central Chilean-Western Patagonian region

It is an interesting South American territory situated at an extratropical latitude, yet it is primarily inhabited by

neotropical flora. We describe this region in accordance with the concept established by Rivas-Martínez *et al.* (2011a), encompassing areas on both the Pacific and Atlantic sides of the southern Andes. It covers the central coastal stretch of Chile between latitudes 31º and 37ºS, extends across the central Andes from 32º to 35º S, and continues along the Argentinian side, encompassing the entire Patagonia region from Mendoza and Río Colorado to Santa Cruz province. This diverse territory is unified by its temperate aridiestival type (Mediterranean) climate, characterized by various degrees of aridity and thermicity. It is also home to the Andean Mountain Range's highest peak, Aconcagua, towering at 6,960 m asl.

The Mediterranean climate in the central region of Chile is the result of a winter influx of austral low-pressure systems and associated fronts, which alternate with the dominance of high-pressure systems in the summer. South of the 37ºS parallel, prevailing westerly winds bring frequent disturbances and abundant rainfall throughout the year, defining the Valdivian-Magellanic region.

The Andes, despite reaching lower altitudes, cast a potent rain shadow over the Argentine side, leading to a more arid climate under the Atlantic's influence, resulting in severe summer droughts. In the Chilean coastal strip, the vegetation is of the sclerophyllous type (Josse, 2014), with species such as *Jubaea chilensis*, *Peumus boldus* (boldo), *Orites myrtoideus*, or *Quillaja saponaria* (quilay). In the Andean section (Andes Mendocinos), a cushion-shaped scrub develops, in which the genus *Adesmia* (Leguminosae) is represented, with species such as *A. obovata*, *A. pinifolia*, and *A. subterranea.*

While the conditions of the Chilean coast are oceanic (Luebert & Pliscoff, 2006, 2022), those of the Argentinian slope are more extreme. The eastern Patagonian zone is covered by scrub vegetation in which remarkable forms of adaptation to wind and drought abound (León *et al*., 1998; Paruelo *et al*., 2001). It is formed by leafless bushes, with reduced or thorny leaves, or by cushion-shaped species. A herbaceous stratum consisting of grasses and other herbaceous plants provides sustenance for livestock. The soils are predominantly skeletal, sandy-stony, except in humid depressions. Trees are rarely found. The Halophytaceae family can be considered endemic to this Patagonian territory. Typical species in the scrub ecosystem include *Adesmia volckmannii*, *Azorella prolifera*, *Nassauvia axillaris*, *N. glomerulosa*, *Senecio filaginoides*, etc.

Climatic conditions become harder towards the south of Patagonia, where they become inhospitable. Temperatures decrease while rainfall can drop to as low as 270 or 100 mm. Furthermore, the southernmost areas are subjected to winter frosts and snowfalls that can extend for a significant portion of the year. Some species widespread in this region are *Berberis microphylla*, *Grindelia chiloensis*, *Larrea divaricata*, *Lycium chilense*, *Maihuenia patagonica*, *Mulguraea ligustrina*, *Sisyrinchium striatum*, and others.

The subbiomes present in this region correspond to the extratropical types: 5a (Oceanic sclerophyllous-microphyllous evergreen forests and shrublands - Mediterranean) in the Pacific coastal Chilean area, and 5c (Patagonian shrubland) in the Argentinian Patagonia, while in the southern Andes there are subbiomes 2b (Forests and shrublands of the temperate oro belt) and 1b (Tundras of the temperate mountains in cryoro belt) in the highest elevations.

Thanks to the Mediterranean climate of this region, both in the Chilean and Argentinian zones, some of the most important wine-producing areas in South America are found here.

IV. Australian kingdom

It consists of the Australian continent, excluding the eastern coastal strip of the Cape York peninsula, as well as the island of Tasmania, which has been periodically connected to the mainland due to fluctuations in sea levels. It is a part of the tectonic plates that separated from Gondwana, sharing a Gondwanan floristic background that has gradually evolved over time (Specht, 2014). Still in the Paleocene, there was a possibility of floral exchange between Australia and South America via a southern route. Approximately 45 million years ago, Australia definitively separated from the larger southern continent and embarked on a northward journey, initially accompanied by New Guinea. This shift towards the equator resulted in a gradual exit from the temperate climatic zone and entry into the tropical zone. As a result, the southern part of the continent still experiences temperate conditions, while the central part is influenced by subtropical highs, and the north is situated in the warm zone affected by intertropical convergences. These climate shifts have had a profound impact on the continent's biota, leading to numerous extinctions and driving intense speciation. The old connection between New Guinea and Australia has been largely commented on (Hall & Holloway, 1998; Cox, 2001). New Guinea, after separating from the mainland, came into contact with the Malesian territories, which were located fully within the tropical zone. As a result, the Paleotropical flora and vegetation invaded most of its territory, pushing the Australian elements to the highlands of the island. The original Australian biotas were Antarctic and adapted to a temperate summer-rainy climate. However, during its journey towards the equator, Australia transitioned through different climatic zones, disrupting the initial distribution patterns of its biota. This transition led to the aridization of the climate, which currently affects the central regions with particular intensity. Additionally, there was a reversal of the seasonal rhythm of aridity, with aridity shifting from summer to winter in the northern areas influenced by tropical climates. A cartographic representation of the current climatic conditions of this continent is provided by the maps of Rivas-Martínez (Rivas-Martínez *et al*., 2015a,b). Another important factor is isolation. Since its separation from Antarctica, Australia had practically no contact with other landmasses. As a result, its biota experienced limited migration, contributing to the extraordinary originality of the continent's biota.

The prolonged evolutionary pressure exerted on its flora and fauna, primarily of Gondwanan origin, has given rise to autonomous evolution with minimal external influences. This is the reason why this territory now boasts an exceptionally unique flora, justifying its classification as a distinct kingdom. It should also be noted that the Australian craton, which is ancient and solid, consists of siliceous rocks with very low levels of bases and phosphorus. Consequently, this results in extremely poor soils, further distinguishing its flora and vegetation.

There are 19 endemic families, including Brunoniaceae, Cephalotaceae, Dasypogonaceae, Gyrostemonaceae, Tetracarpaeaceae, Tremandraceae, and Xanthorrhoeaceae. There is a large representation of Gondwanan lineages expanded throughout several southern hemisphehre territories, such as Casuarinaceae, Epacridaceae, and Restionaceae. Of particular interest are the Proteaceae, with 840 species, most of them endemic, and include endemic genera like *Banksia*, *Hakea*, and *Grevillea*. In the same sense, the presence in the southeastern regions and Tasmania of representatives of southern beeches of the *Nothofagus* genus is significant. Other genera such as *Hebe* or *Donatia* point to the same relationship. As a whole, there are about 500 endemic genera in the Australian flora. Furthermore, Australia is one of the territories in which a substantial number of archaic gymnosperms of the *Cycadales* order have been preserved, with genera such as *Bowenia*, *Cycas*, *Lepidozamia*, and *Macrozamia*. The absence of members of families that are widely represented in most parts of the world, such as Papaveraceae or Saxifragaceae, is also striking.

Another trait of the Australian flora is the significant contribution of the Myrtaceae family (mostly of the *Leptospermoideae* subfamily), with a high number of genera and species. Within this family, the eucalypts (genera *Eucalyptus* and *Corymbia*) originated, possibly at the end of the Paleocene (Rozefelds, 1996). They were once distributed across various regions of Gondwana, with fossil remains found in South America and New Zealand. However, today, they are primarily concentrated in the Australian Kingdom and New Guinea, with more than 700 known species, constituting 75% of modern Australian forest vegetation. The expansion of the *Eucalyptus* genus appears to coincide with the climatic aridization that affected the continent during the latter part of the Tertiary period. Their remarkable adaptation to fire has likely contributed to their dominance, especially after human populations settled on the continent. It is important to highlight the role of fire in Australian terrestrial ecosystems; many significant species from various genera and families exhibit clear adaptations to this disturbance (pyrophytic). Another example is the *Acacia* genus (*Mimosoideae*), which includes 500 non-spiny species with phyllodes in Australia. Their radiation and expansion appear to have been influenced by similar factors to those affecting eucalypts. Other notable contributors to the Australian flora are *Casuarina*, *Melaleuca*, and *Leptospermum*.

In addition to the usually mentioned habitats in Australia such as eucalypt woodlands and many others (Specht, 1999), there are numerous rocky outcrops, often composed of granite, scattered across various regions. These rocky outcrops constitute a distinctive feature of Australian ecosystems. They provide a home to specialized organisms that make significant contributions to the kingdom's overall biodiversity (Michael & Lindenmayer, 2018).

The Australian kingdom is recognized by all the modern authors (Good, 1974; Takhtajan, 1986; Schroeder, 1998; Rivas-Martínez *et al*., 2011a; Pfadenhauer & Klötzli, 2014), and has been the subject of various regionalization trials (Ebach, 2012), although we have accepted the one that divides it into the four regions (CAPAD, 2012) that we discuss below.

34. North Australian region.

The northern third of the Australian continent primarily experiences a tropical pluviseasonal climate. It includes the territories between Roebuck Bay, in the Indian Ocean, and the vicinity of Gladstone, on the Pacific coast, marked by the presence of the Great Barrier Reef. The coastal section within this region largely coincides with mangrove habitats. Rainfall is concentrated in the summer months, and a dry season prevails during the winter. The landscape is characterized by open vegetation dominated by eucalypts, well-adapted to cope with the pronounced seasonality of rainfall (Beadle, 1981). The most important species include *Eucalyptus tectifica*, *E. tetrodonta*, *E. miniata*, *Corymbia foelscheana*, *C. latifolia*, *C. flavescens*, *C. polycarpa*, *C. nesophila*, *C. clarksoniana*, *C. grandifolia*, *C. bleeseri*, *C. ferruginea*, etc. (Beadle, 1981; Beard *et al*., 2000). There are also forest formations dominated by several species of *Melaleuca* (*M. viridiflora*, *M. leucadendra*, *M. argentea*, *M. dealbata*, *M. nervosa*). Among the endemic taxa, some are notable for their ancient origins, such as the monospecific family Austrobaileyaceae (*Austrobaileya scandens*). The presence of a species from the genus *Adansonia* (*A. gregorii*) in this territory is notorious, indicating an African-Malagasy paleotropical relationship. In the eastern coastal strip of the Cape York Peninsula, located in northern Queensland, increased rainfall results in a tropical pluvial climate, leading to the establishment of rainforests with a strong Papuan influence. Consequently, this territory has been included in the Malesian region of the Paleotropical kingdom.

The subbiome covering the entire area of this region is 8b (Tropical pluvisesonal forests and woodlands).

35. Central Australian region (Eremean).

It is a vast territory under an arid climate that occupies the central part of the continent, overlooking the Indian Ocean between the vicinity of Roebuck Bay and Shark Bay. It comprises deserts and shrubby or subarboreal semi-desert woody formations. Among them is the so-called "mulga", vegetation that covers a large area and consists primarily of *Acacia aneura*, a species with irregular foliation adapted to the unpredictable availability of water. In the clearings of mulga,

communities of ephemeral therophytes thrive following rainfall, painting the landscape with their colorful and vibrant flowers (Pignatti, 1994). In addition to mulga, this region is characterized by formations of distinctive spiny xerophytic grasses, commonly referred to as "spinifex", with *Triodia* species dominating. Another notable genus of grasses in this area is *Astrebla*, also well-adapted to extreme arid conditions. The Central Australian region also features frequent inland salt marshes, populated by Chenopodiaceae of genera such as *Atriplex*, *Maireana*, *Sclerolaena*, *Tecticornia*, and others. In areas with more humid soils, relicts of ancient flora adapted to hygrophilous conditions can be found, including the cycad *Macrozamia macdonnellii* and the palm *Livistona mariae* (Beard *et al*., 2000).

Plants that have environmental or social uses from this region are, for example, *Swainsona formosa* (Sturt's Desert Pea), which is the state flower of Southern Australia, or numerous bush tomatoes, like *Solanum centrale*, *S. chippendalei*, *S. diversiflorum*, *S. orbiculatum*, etc., which have been used as a food source by aboriginal groups.

The subbiomes covering this region are 7b (Temperate deserts and semi-deserts), 7c (Warm deserts and semi-deserts), and 8a (Tropical xeric shrublands and woodlands).

36. Tasmanian-Southeastern Australian region.

This region encompasses a strip of land approximately 300 km wide along the southeastern Australian coast and the island of Tasmania, stretching from the border with the North Australian region to the boundary between the states of Victoria and South Australia, near Mount Gambier. South of the Tropic of Capricorn, seasonality conditions are inverse to those to the north, with distinguishable winter and summer temperatures. Precipitation patterns in this region are typical of extratropical regions, with the majority of rainfall occurring during the winter. However, the eastern-southeastern part of the continent experiences significant summer precipitation due to the influence of the Eastern Australian current, which brings warm water to its coasts and promotes rainfall during the warm season. This results in a temperate rainy-summer (pluviestival) climate type. In this region, due to the most favorable conditions, most of the human population of the continent is concentrated. A mountainous alignment, the Great Dividing Range, parallels the coast and extends across the entire territory. In the southern section of this range, known as the Australian Alps, elevations surpass 2,000 m asl, and it is where the continent's highest point, Mount Kosciuszko, with an elevation of 2,228 m asl, is situated. This alignment causes a rain shadow to the west so that towards the center of the continent the climate becomes progressively more arid until entering the Eremean province. The island of Tasmania has notable mountain groups with numerous peaks above 1,200 m asl, with the highest elevation being Mount Ossa at 1,617 m asl.

This Great Dividing Range is strongly influenced by the Pacific Ocean and receives substantial rainfall on its eastern slopes, usually exceeding 1000 mm, creating favorable conditions for agriculture and livestock farming. The natural vegetation of the Pacific slope is dominated by the generically called rainforests, which are predominately composed of eucalypts, that include tall species forming large forests in the rainy climate (Keith & Sanders, 1990), such as *Eucalyptus globulus*, which is fast-growing and widely used in timber plantations around the world, along with *E. nitens*, *E. obliqua*, and E. regnans, which can reach heights of up to 100 m. In mountainous areas, where orographic rainfall is more pronounced, various species of southern beech (*Nothofagus cunninghamii*, *N. gunnii*, and *N. moorei*) and tree ferns of the genus *Dicksonia* (*D. antarctica* and *D. youngiae*), *Alsophila* (*A. australis*), or *Sphaeropteri*s (*S. cooperi*) are found. While lowland and middland areas are dominated by diverse eucalypt species (*Eucalyptus coccifera*, *E. urnigera*), higher altitudes in inland areas, isolated from coastal influences, host conifer-eucalypt forests rich in Cupressaceae. These conifer-eucalypt forests, featuring *Callitris columellaris* and *C. endlicherii*, thrive in an interior, higher-elevation strip of territory known as Tablelands. This area has a dry continental climate and separates the humid oceanic coastal strip from the Eremean desert. In the highest mountain areas, the forest vegetation disappears and scrub communities with *Kunzea*, *Grevillea*, *Bossiaea*, and others, thrive. These high-altitude areas also feature grass communities of *Poa* and *Danthonia*, with the latter being invasive, as well as the development of peat bogs, where humid *Epacris* heaths are established along their edges.

The island of Tasmania has a strong floristic personality, which is why some authors separate it as a different biogeographic territory. It has a series of highly localized genera, some of which are endemic to the island, such as *Agastachys* (Proteaceae), *Athrotaxis* (Cupressaceae), *Bellendena* (Proteaceae), *Diselma* (Cupressaceae), or *Tetracarpaea* (Tetracarpaeaceae). Others, such as *Acradenia* (Rutaceae), *Pherosphaera* (Podocarpaceae), and *Telopea* (Proteaceae), link it to the continental territories of southeastern Australia. Mountainous areas on the island feature rainforests with species like *Nothofagus cunninghamii*, *Atherosperma moschatum*, *Athrotaxis selaginoides*, *Eucryphia lucida*, *Lagarostrobos franklinii*, and the region's only deciduous woody species *Nothofagus gunnii* (Jarman *et al*., 1994).

The subbiomes covering this region are 4a (Lauroid evergreen forest of the lowlands, 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forests) in the rainforests of the oceanic mid-elevations, 5b (Continental scrub and woodlands) in the interior Tablelands of the Great Dividing Range, and 1b (Tundras of the temperate mountains in cryoro belt) in the highest mountains.

37. Southwestern Australian region.

It comprises the southwestern corner of the continent and a narrow strip along its southern coast up to the

Adelaide region. The climate is of the Mediterranean type (temperate arid-summer or aridiestival), with precipitations mostly in winter. The Sterling mountains, which reach 1000 m asl, receive the highest amount of rainfall (Pignatti *et al*., 1993).

The vegetation is dominated by eucalypts of numerous species, among which we can mention some species such as *Eucalyptus marginata* (jarrah), *E. redunca*, *E. wandoo*, or *Corymbia calophylla*. The species *E. diversicolor* (karri), which grows up to 90 m, is the most ombrophilous of the eucalypts and is limited to the Sterling Range (Beard, 1975, 1990; Pignatti *et al*., 1993). Although the precipitations are high, the dryness of the summer does not allow the survival of *Nothofagus*. Depending on various environmental conditions and disturbance regimes, often linked to fire, in this region there are frequent formations of sclerophyllous scrub (kwongan) rich in Proteaceae (Mucina *et al*., 2014), and coppice vegetation (mallee) consisting of eucalypt multi-rooted shrubs. Two morphologically similar species stand out, such as *Xanthorrhoea preissii* and *Kingia australis*, which are extremely adapted to fire.

There is a high representation of Proteaceae (*Adenanthos*, *Banksia*, *Conospermum*, *Grevillea*, *Hakea*, *Isopogon*, *Petrophile*, etc.), as well as Compositae, Casuarinaceae, Epacridaceae, Myrtaceae (*Leptospermum*, *Melaleuca*), Rhamnaceae, Verbenaceae, and others. There are about 125 endemic genera, such as *Eremosyne* or *Emblingia*. Another endemic genus is *Anigozanthos* (Haemodoraceae), with 11 species of showy and peculiar flowers that receive the name of kangaroo paw. The region is estimated to have more than 2,800 vascular plant species, with over 2,400 of them being endemic (Beard, 1969). In relation to the poverty of the soils, there is a large representation of insectivorous plants of the genera *Cephalothus* (endemic), *Drosera* (some of which develop a lianoid habit), and *Utricularia* (Beard *et al*., 2000).

In this territory, as in central Australia, endorheic depressions are frequent where salt accumulates by drainage and evaporation. This salinity is supposedly of marine origin. In them, a particular vegetation thrives with wooded communities of *Casuarina obesa*, and thickets of *Atriplex*, *Maireana*, *Tecticornia*, etc. (Specht 1999).

The coastal dunes present communities of succulent species, such as *Tetragonia* and *Cakile maritima* (cosmopolitan) in the embryonic dune. The shifting dunes contain grasses of the genus *Spinifex* (*S. sericeus*) coexisting with *Olearia axillaris*. The stabilized Tertiary dunes are populated by a larger vegetation, with species of *Acacia*, *Hakea*, *Rhagodia*, *Scaevola*, etc. (Groves, 1994).

The subbiome represented in this region is 5a (Oceanic sclerophyllous-microphyllous evergreen forests and shrublands - Mediterranean).

V. Capensis kingdom

Due to the strong influence of the African paleotropical flora, some phytogeographers include this restricted territory within this kingdom, although they always emphasize its remarkable singularity (White, 1983; Costa, 2004). In terms of fauna, it does not exhibit any distinctiveness compared to the African tropical fauna, and zoogeography does not distinguish this territory (Cox, 2001; Galley & Linder, 2005; Linder *et al*., 2012). Nonetheless, most botanical authors, such as Takhtajan (1986), Schroeder (1998), and Pfadenhauer & Klötzli (2014), consider the Capensis region as a Kingdom due to its high endemic content in a small area (edemic density), its climatic distinctiveness (Mediterranean type climate) and in reasons based in historical Biogeography (Cox, 2001). The discussion is still open and we decided to stick to Takhtajan's classification until more evidences are accumulated.

38. Capensis region

It is one of the smallest regions, covering just the southwestern tip of the African continent in what is known as the Cape region (Born *et al*., 2007), with an area of approximately 45,000 km^2. Its climate is of the Mediterranean type (temperate aridiestival), characterized by a dry season in the summer.

Its flora consists of around 9,000 species of vascular plants, of which 73% are endemic (Bredenkamp, 2019). Many of these plants comprise the typical evergreen and microphyllous oligotrophic scrub known as "fynbos" (Taylor, 1978), which is closely associated with fires (pyrophytic). According to White (1983), the region is home to approximately 520 species of *Erica*, 145 of *Crassula*, 140 of *Phylica*, as well as small-leaved Rutaceae, Proteaceae of the genera *Protea*, *Leucadendron*, and *Leucospemum*, and numerous Restionaceae (3/4 of their species being South African). In addition, geophytes of genera such as *Amaryllis*, *Clivia*, and *Freesia* are particularly frequent, and there is a relevant representation of other genera such as *Pelargonium* (200 species) or *Stapelia*. Tree species are scarce within the native flora; among the tallest species, the proteaceous *Leucadendron argenteum* and the cupressaceous *Widdringtonia nodiflora* stand out. Other communities include the "sandeveld*"* formation, which thrives on dry sandy soils with efficient drainage and is characterized by a herbaceous layer and various trees and shrubs like *Vachellia haematoxylon*, *Boscia albitrunca*, *Terminalia sericea*, and others. The "restonveld*"* formation establishes on richer soils with a finer texture and features a more substantial herbaceous component along with bushes like *Dicerothamnus rhinocerotis*.

According to Takhtajan (1986) and Taylor (1978), the main endemic and sub-endemic families of this kingdom are Bruniaceae, Greyaceae, Geissolomataceae, Grubbiaceae, Peneaceae, Roridulaceae, and Stilbaceae. There are about 200 endemic genera, some of which contain numerous species, including *Agathosma*, *Aspalathus*, *Heliophila*, and *Retzia*.

The subbiome represented in this region is 5a (Oceanic sclerophyllous-microphyllous evergreen forests and shrublands – Mediterranean).

VI. Holoantarctic kingdom

According to Engler (1882), Drude (1884), Reiche (1907), Diels (1908), Skottsberg (1916), and several modern authors such as Takhtajan (1986), Schroeder (1998), and Pfadenhauer & Klötzli (2014), this floristic kingdom encompasses the continent of the same name, the small archipelagos surrounding it, the New Zealand archipelago, and the extreme south of South America (Valdivian-Magellanic region), including the Juan Fernández islands. Except for the northernmost territories, which were connected to Antarctica before the complete separation of Gondwana, the continent of Antarctica nucleated this floristic kingdom. Today, this vast landmass is almost entirely covered by a thick mantle of ice, with only a few ice-free areas in the latitudes farthest from the South Pole, encompassing the Antarctic Peninsula, the Circumantarctic Ocean islands, and some areas in the Queen Elizabeth Range in Antarctica.

However, this kingdom was not always so poor in flora and fauna (Truswell, 1990). Before the ice cap extended across the entire continent of Antarctica, diverse biota had adapted to the extremely seasonal light and thermal conditions imposed by its high latitude (Creber, 1990). The prevailing climate in this territory appears to have been temperate pluviestival (also known as cool-temperate). Fossils of tree ferns from the orders Cyatheales and Glossopteridales have been discovered, along with gymnosperms from the Benettitales, Araucariaceae, and Podocarpaceae families. In terms of angiosperms, remnants attributable to *Nothofagus* and representatives of Myrtaceae, Cunoniaceae, Monimiaceae, and others have been recorded (Cantrill & Poole, 2012). As for the megafauna, the large Triassic dinosaurs stand out, such as *Lystrosaurius* (Kitching *et al*., 1972). The evolutionary history should be considered relevant in sustaining the highest ranks of biogeographical units, such as kingdoms or even regions, so it is relevant to illustrate this issue in this case.

The formation of ice in Antarctica began with the isolation of the continent following the opening of the Antarctic Strait, as it disconnected from the last remaining landmass with which it shared an isthmus, South America, around 30 million years ago. The ice cap gradually expanded to form the existing ice sheet, leading to the extinction of nearly all its flora and fauna. Only the Austro-American and New Zealand regions remained untouched by this extensive glaciation, preserving part of the original Gondwanan biota. Since their separation, these regions underwent divergent evolution in their floras, which was further influenced by subsequent external influences and migrations. This has deeply marked their biotas, particularly that of the Valdivian-Magellanic region, which has a strong representation of flora of Neotropical origin.

It is known that Gondwanan flora is present to varying degrees in most southern hemisphere areas, including tropical South America, Australia, New Caledonia, and the Cape region. However, the link of these territories to the Holantarctic kingdom is blurred by the overwhelming invasion of tropical floras (South America) or the generation of endemic taxa (Cape, Australia). Consequently, there are not enough arguments to support the inclusion of these territories in the Holoantarctic kingdom. However, both New Zealand and the Valdivian-Magellanic region can be associated with the Holoantarctic kingdom due to the preservation and notable presence of temperate Gondwanan flora, despite moderate to low introgressions of northern floras from neighboring continents.

In summary, the existence and extent of this kingdom can be substantiated by two main arguments: the shared paleobiogeographic origin of its main two parts, characterized by the conservation of a substantial proportion of temperate Gondgwanan flora, and the recognition of a kingdom homologous to the Holarctic in the southern hemisphere, which was more expansive in the early Tertiary period but has since contracted due to glaciation and fragmentation.

There are 15 families and 60 genera that support a southern realm (Moreira-Muñoz, 2007). Notable examples include small, oligotypic families, distributed either in the Valdivian-Magellanic region (Misodendraceae) or in the Neozealadian (Hectorellaceae), which are endemic to this kingdom. Additionally, there are other taxa that indicate their former connection, such as the genera *Colobanthus*, *Donatia*, *Laurelia*, *Lepidothamnus*, *Marsippospermum*, *Nothofagus*, *Podocarpus*, *Pseudopanax*, *Ourisia*, *Rostkovia*, and more. Among ferns, which reveal more remote relationships, some genera have spread across the southern hemisphere, such as *Cyathea* and *Dicksonia*. Furthermore, certain species are shared, like *Blechnum penna-marina*, which is also found in Australia, *Hymenophyllum ferrugineum* and *Notogrammitis billardierei*, present in New Zealand, southeastern Australia, and Tasmania, and represented in South America by the *magellanica* variety. All this set of evidences allows us to evoke the ancient connection of these territories and advocate for the existence of this disjointed and elusive Antarctic kingdom, even though no modern family encompasses the different territories of this kingdom.

The division into regions of this kingdom is basically the same as that accepted by most modern authors (Good, 1974; Takhtajan, 1986; Schroeder, 1998; Pfadenhauer & Klötzli, 2014).

39. Valdivian-Magellanic region

It encompasses the territories of the southern tip of the South American cone, starting from the Biobio River in Chile and the Gallegos River in Argentina, and extending to Tierra del Fuego, the Falkland (Malvinas) Islands, as well as the northern tip of the Antarctic Peninsula and the islands between both continental extremes: South Orkney South Sandwich, and South Georgia islands (Moreira-Muñoz, 2011). The region's flora displays a strong Neotropical and Holarctic influence, due to its location along the Andean migratory route. However, remnants of a Gondwanan heritage persist, signaling the

historical connection of this area with Antarctica through the former isthmus that linked the northern tip of the Antarctic Peninsula, now separated by just 800 km of ocean. At the Antarctic end, only two species of vascular plants are recorded in the northern and western parts of the Antarctic Peninsula: *Colobanthus quitensis*, which is also widespread throughout the Andean cordillera, and *Deschampsia antarctica*, which reaches some of the islands that emerge in the stretch of ocean in between (South Georgia, South Sandwich, etc.).

The climate of this region is mostly temperate pluviestival (summer-rainy), receiving most of the abundant rains from the South Pacific westerlies. The southernmost areas in Tierra del Fuego, Falklands, and Antarctica are submitted to boreal conditions. The mountains also create conditions for cold-adapted vegetation in the summital areas.

The forests of this region are dominated by species of austral character (Josse, 2014). Notable among these are deciduous southern beech species, such as *Nothofagus pumilio*, locally known as lenga (Amigo & Rodríguez-Guitián, 2015), and ñire or *N. antarctica*. These species form the Magellanic forest and delineate the altitudinal forest limit, which reaches up to 500–600 m asl on Isla Grande in Tierra del Fuego. In addition to these deciduous trees, the Valdivian forest includes other evergreen tree species, such as *Nothofagus betuloides* (guindo), *Araucaria araucana* (pehuén), *Aristotelia chilensis* (maqui), *Austrocedrus chilensis Lepidothamnus fonkii*, *Drimys winteri* (canelo), *Maytenus magellanica*, *Embothrium coccineum* (notro), *Pilgerodendron uviferum* (Guaitecas cypress), and *Podocarpus nubigenus* (Josse, 2014). The shrub layer in this region is home to various species, including *Berberis microphylla* (calafate), *B. ilicifolia* (michay), and *Fuchsia magellanica* (chilco). Above the forest line, there are communities of diverse nature, with characteristic species of the region such as *Abrotanella emarginata*, *Azorella lycopodioides*, *Bolax gummifera* (which forms cushions in clarified and drained areas), *Drapetes muscosa*, *Empetrum rubrum* (brecillo), *Gaultheria pumila*, and others (Luebert & Pliscoff, 2006, 2022).

Among the endemic element, some small families stand out, including Aextoxicaceae, Misodendraceae (*Nothofagus* parasites) and Philesiaceae, as well as some genera, usually monospecific, such as *Austrocedrus*, *Caldcluvia*, *Chiliotrichum*, *Fascicularia*, *Fitzroya*, *Hamadryas*, *Lapageria* (*L. rosea* is the national flower de Chile), *Lardizabala*, *Nanodea*, *Pilgerodendron*, *Saxegothaea*, *Saxifragella*, *Tepualia*, *Tetroncium*, *Valdivia*, etc.

The subbiomes present in this region are 4a (Lauroid evergreen forest of the lowlands), 3a (Temperate deciduous forests) in mid-elevations, 2b (Forests and shrublands of the temperate oro belt), and 1b (Tundras of the temperate mountains in cryoro belt) in the upper levels of the Andes. Subbiome 1a is represented in the subanctartic archipelagos and in the nortehern tip of the Antarctic Peninsula.

40. Juan Fernández archipelago region

This region consists of the Pacific islands of Juan Fernández (Masatierra, today Robinson Crusoe Island, and Masafuera, today Alejandro Selkirk Island), along with the Desventuradas (San Ambrosio and San Félix). These volcanic islands are located around 600 km off the Chilean coast, spanning latitudes between 26 to 33º S, outside the intertropical zone. The region experiences a Mediterranean climate (aridiestival temperate) that is tempered by its strong oceanic influence. The existing forests are evergreen and exhibit remarkable floristic singularity, with a high degree of endemicity (Skottsberg, 1945; Stuessy *et al*., 1992; Greimler *et al*., 2002). There are two endemic families (Lactoridaceae and Thyrsopteridaceae) and over 20 genera, most of them monotypic or oligospecific, such as *Cuminia* (*C. eriantha*), *Dendroseris* (8 species), *Festuca masatierrae*, *Juania* (*J. australis*), *Lactoris* (*L. fernandeziana*), *Podophorus* (*P. bromoides*), *Robinsonia* (8 species), *Thyrsopteris* (*T. elegans*), and *Yunquea* (*Y. tenzii*). In addition, there are up to 126 endemic species out of 195 in the archipelago, such as the giant *Plantago fernandezia* or *Greigia berteroi* (Stuessy *et al*., 1992).

Floristic relationships in the Juan Fernández region exhibit connections to the Antarctic world, particularly through species like *Blechnum penna-marina*, *Hymenophyllum falklandicum*, *Sticherus quadripartitus*, and *S. squamulosus*, which are also found in the Valdivian-Magellanic region. Other remarkable species include *Lophosoria quadripinnata*, which belongs to Gondwanan genus, and *Coprosma petriei* (Rubiaceae), which also inhabits New Zealand, Australia, and Polynesia. Due to these relationships, the region is affiliated with the Holantarctic kingdom, following the criteria of Takhatajan (1986). Furthermore, an important part of the Juan Fernánez flora has relations with Polynesia, especially with the Hawaiian Islands, and with South America, having inspired some authors the inclusion of this region in the Neotropical kingdom (Pfadenhauer & Klötzli, 2014). The strong relationships of its flora with the Valdivian-Magellanic and other Gondwanan territories is the reason this region is included in the Holoantarctic kingdom and not in the Neotropical. Glaciations influenced these islands less than the Valdivian-Magellanic region, so they can be considered as a refuge for thermophilic flora.

The subbiomes represented in the Juan Fernández archipelago region include 5a (Oceanic sclerophyllous-microphyllous evergreen forests and shrublands – Mediterranean) and 4c (Tropical-subtropical montane cloud lauroid and conifer evergreen forest) in the elevations.

41. Neozealandian region

It comprises the two largest islands of the New Zealand archipelago, the North Island and the South Island, as well as several smaller islands including Lord Howe Island, Stewart Island, and the Auckland Islands to the south. The North Island is primarily volcanic, featuring elevations like Ruapehu (2,797 m asl) and Egmont (2,518 m asl), while the South Island is characterized by the formidable Southern Alps mountain range running from north to south, including peaks such as Mount

Tasman (3,498 m asl) and Mount Cook or Aoraki (3,764 m asl), which support significant glacial features with four tongues extending to low altitudes. The traces of Pleistocene glaciations in this mountain range are evident, to the extent that in its southern section, the glaciers reached sea level and carved out a series of fjords (Fiordland). This mountain range causes a strong rain shadow effect on its southeastern foothills, where the areas with the least precipitation of the archipelago are located. In any case, New Zealand is generally a rainy and strongly oceanic country (Rivas-Martínez *et al*., 2015a), where humid to hyper-humid ombrotypes predominate, and falls within the temperate pluviestival bioclimate.

The continent of Zealandia (Mortimer *et al*., 2017), which includes present-day New Zealand and New Caledonia, separated from Australia prior to its complete detachment from Gondwana approximately 85 million years ago. Zealandia is mostly submerged today, with only the mentioned archipelagos remaining above sea level. Although it had remote connections to the Australian continent, as has been highlighted by Pole (1994), it has very few floristic and faunal similarities with Australia due to the lengthy period of isolation (e.g., no acacias, casuarinas or eucalypts, very few Proteaceae, no marsupials, etc.). This increases its originality and independence from Australia (Burbidge, 1960), highlighting its Antarctic character and relations with the Valdivian-Magellanic world, even though these connections are ancient and remote. While some biogeographic proposals have linked the Neozealandian region with Australia (Cox, 2001; Costa, 2004) due to their shared origins and distant floristic relationships, other authors (Good, 1974; Takhtajan, 1986; Schroeder, 1998; Pfadenhauer & Klötzli, 2014) emphasize the Antarctic origin of a significant portion of its flora.

This territory stands out as a place where the original biota of the Antarctic world has been best preserved after its ancient separation, which began 100 million years ago. Throughout that time, the climate has remained temperate with rainy summers, undergoing little substantial change. Moreover, it had no contact with other islands or continents and doesn't appear to have been completely submerged under the sea (although it came close). As a result, its original biotas have been safeguarded from extensive introgression and total extinction. Like Noah's Ark, the New Zealand archipelago serves as a sanctuary for many lineages from ancient Antarctica that have endured to the present day, thanks to its remarkable climatic stability. This doesn't negate the fact that, over such a long period, there have been limited migrations of diverse origins, with Polynesians and Australians being the most notable, with the former being more prevalent in the northern sector of the North Island. These migrations are often associated with adaptive radiation phenomena, which are clearly visible in the flora of the islands, as is the case of *Aciphylla*, *Anisotome*, *Chionochloa*, *Coprosma*, *Raoulia*, *Veronica* (incl. *Hebe*), etc.

Endemicity in the vascular flora is notably high (Wilton & Breitwiser 2000, Wilton *et al*., 2016). Apart from a small family, Hectorellaceae, there are 49 exclusive endemic genera. Species-level endemism reaches 80% in angiosperms and nearly 100% in gymnosperms (Wilton & Breitwiser, 2000). In the case of ferns, there is substantial species richness, with 45% shared with southern Australia and Tasmania. The remarkable endemism of the arboreal fern genera *Cyathea* and *Dicksonia* is particularly noteworthy. The absence of representatives of *Eucalyptus* or *Acacia*, which are common in Australia, is likely due to Zealandia's separation before the radiation of these genera occurred.

Most woody plants are evergreen (Wardle, 1964) and are dispersed by birds, with few defenses against mammalian predation, such as spinescence or the accumulation of toxic substances in their organs. It is important to note that mammals are virtually absent in the native fauna of the archipelago. Additionally, divaricate leaf architectures and small flowers are prevalent, interpreted as adaptations to herbivory by large flightless birds (moas). Nitrogen-fixing species, those with adaptations to fire, and those with an annual life-form are rare. White and small flowers are common, and dioecy is a prevalent trait (McGlone & Richardson, 2022).

Regarding the altitudinal zonation of vegetation, there is a basal belt characterized by multi-specific forests dominated by Podocarpaceae, in which numerous species of the aforementioned genera and ferns participate. This belt reaches up to 600–1,000 m asl, depending on the latitude. Above it, there is a montane belt dominated by southern beeches, whose upper limit is marked by *Nothofagus menziesii* and *N. solandri*, and reaches 1,000 to 1,500 m asl of altitude. Above the beech forest level, there is a broad belt dominated by grasses, mainly *Chionochloa* (snowgrasses), inhabited by a large number of Compositae species of the genera *Celmisia* and the endemic *Raoulia* and *Haastia*, whose dense hairiness and cushion form make them creditors of the denomination of "vegetable sheep". The humid and swampy forests are dominated by *Dacrycarpus dacrydioides* (Kahikatea), a tree of great size and economic importance (Wardle, 1991).

Phormium tenax (New Zealand flax) is the contribution of the New Zealand flora to the collection of useful plants for textile application.

The subbiomes represented in this region are 4a (Lauroid evergreen forest of the lowlands) and 1b (Tundras of the temperate mountains in cryoro belt) in the high mountains.

42. Subantarctic archipelagos region

It includes the archipelagos of Tristan da Cunha, Prince Edward, Croizet, Kérguelen, and others, which encircle a significant portion of the Antarctic continent. They are characterized by poor flora, lacking trees, and featuring an abundance of bryophytes and lichens. Among the limited vascular plants inhabiting some of these islands, it is worth mentioning the endemic Kerguélen cabbage *Pringlea antiscorbutica*, edible and also highly valued

for its effectiveness in treating scurvy (Scott, 1990). Another endemic genus found in this region is *Lyallia*, also native to the Kerguelen Islands.

The only subbiome represented is 1a (Polar tundra).

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None.

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Supplementary Material

Appendix S1. GIS vector layers with polygons classified to the level of kingdoms and regions (zip file).