Edgar Heim

Catalog of Ferns, Gymnosperms and Flowering Plants of the Department of Arequipa, Peru

A detailed inventory of all plants of Arequipa

About the author

Edgar Heim was born in Lima, Peru. He studied food technology in Switzerland and has practiced that profession for more than 30 years, first as a manager in industrial companies, then as a lecturer.

Since his youth, he has been fascinated by nature, biodiversity, and ecology. Botany and traveling are his passions. Over the years he has collected information about vegetation and plants from all over the world and systematically compiled it in a database. This catalog was generated from this data.

Preface

The department of Arequipa still has some white spots botanically. Each year botanists describe several new species for the area. This catalog was produced to provide an overview of the current status of known species for the department. For this purpose, the current botanical literature was studied in-depth and several trips were made to all the provinces of Arequipa.

The catalog describes 1,362 species of ferns and flowering plants for the department of Arequipa. This is 200 additional species to the last systematic inventory by Quipuscoa, Dillon, & Ortíz in 2006. 95 species are mentioned for the first time for Arequipa and 26 species mentioned in previous sources for Arequipa were excluded.

The catalog includes a brief description of the species, information about their ecology, distribution, and human use. In addition to information on systematics and phylogeny, the appendix lists the most commonly used synonyms.

With this catalog, the author hopes to contribute to the knowledge and conservation of biodiversity in southern Peru.

Acknowledgments

Like all botanists, I have benefited from the whole corpus of earlier work by generations of botanists, from Ruiz & Pavón, Humboldt & Bonplain, McBride and Bracko & Zarucchi onwards.

I have received generous help in many ways from botanists around the world. I am most grateful to Daniel Montesinos-Tubée, who encouraged me to publish this catalog, to Irene and Remigio, two experienced guides who showed me beautiful spots in Arequipa, and to my wife Ruth, who patiently accompanied me on most of my trips.

Please let me know if you notice any errors or have any questions.

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Arequipa and its vegetation

Geography of Arequipa

Arequipa, one of the 24 departments of Peru, is located between 14°40’ S and 17°20’ S latitude and 70° 50’ W and 75°10’ W longitude. It borders the Pacific Ocean to the west, the departments of Ica, Apurimac, and Ayacucho to the north, Cuzco and Puno to the east, and Moquegua to the south (Figure 1).

Figure 1: Location of the department of Arequipa in Peru and the 8 provinces of Arequipa (https://www.tes.com/)

Arequipa has an area of 63,345 km^2 and the census of 2017 set the population to 1,383,000 out of which about 1 million

live in the capital, the City of Arequipa.

The economy is mainly based on trade (about 15 % of GDP), agriculture (13 % of GDP), construction (about 11% of GDP), and mining (9 % of GDP). Tourism has been successfully developed in Peru such that the number of foreign overnight visitors (tourists) rose from 3,215,000 in 2014 to 4,419,000 in 2018 (OECD, 2020). Arequipa offers many tourist attractions and may benefit more than average from this growth.

Geology of Arequipa

Active volcanoes shape the landscape of the department. In the North, the volcanoes Nevado Solimana (6093 m), Coropuna (6425 m), and Ampato (6288 m) emerge from the desert. Between the high mountains, the Cotahuasi River and the Colca River have carved the deepest canyons in the world. The City of Arequipa itself is surrounded by three volcanoes, Chachani (6057 m), Misti (5822 m), and Picchu-Picchu (5664 m). Evidence of volcanic activity can be found everywhere. The road cuts in rural areas make visible the layers of ash and lava flows from several eruptions. A white volcanic rock called sillar is a popular building material in the region.

Nevertheless, most of the soils in Arequipa are of sedimentary or alluvial origin. As the South American plate drifted westwards, it collided with the Nazca Plate 150 million years ago. The latter was pushed down and formed a rift valley which was gradually filled up with eroded material from the adjacent South American plate. 60 million years ago, uplift formed the Andes and shifted these sediments to the high plateaus of the Andes.

The uplift of the Andes has dramatically altered the watersheds on the South American Plate. Rivers that used

to drain into the Pacific Ocean were retained by the high mountains and had to find a way to dewater elsewhere.

Huge inland seas formed in the inter-Andean depressions and on the eastern slopes of the Andes. Testimony to this process is the Lake Titicaca and the saline lakes in southern Peru and western Bolivia. Over time, the water found new ways to the ocean, the contemporary continental divide was formed. Some rivers carved huge canyons to the Pacific (e.g Colca, Cotahuasi), others formed a new dewatering system eastward, the Amazonas Basin. Arequipa is mainly drained to the Pacific, but the waters of the far northeastern part take a long way to the Atlantic Ocean. Some hydrologic systems found no way out to the ocean and formed a network of salt lakes, e.g., Lake Titicaca drains through the Desaguadero River to Lake Poopó, a salt lake in Bolivia with no outlet.

The huge inland lakes were filled with alluvial sediments and formed vast inter-Andean plains - the mesetas altoandinas of today (e.g., Pampa de Cañahuas on the way to Colca).

Generally, marine sediment is calcareous. Also, the lava and the ash from volcanic eruptions normally react alkaline. In addition, the climate of Arequipa is arid so that the soil was not excessively washed out. Therefore, most soils are neutral or alkaline. Nevertheless, there are also siliceous soils (e.g., a range south of the city of Arequipa on the road to Chapi), either formed by intrusive rocks or due to high sand content. A detailed geological map of Arequipa is available from the Instituto Geológico Minero y Metalúrgico (INGEMMET, 2014).

Phytogeography of Southern Peru

Peru is part of the Neotropical floristic kingdom, specifically the Andean floristic region. Galan de Mera, Vicente Orellana

& Garcia (1997) divide the Peruvian South into five biogeographical provinces (Figure 2).

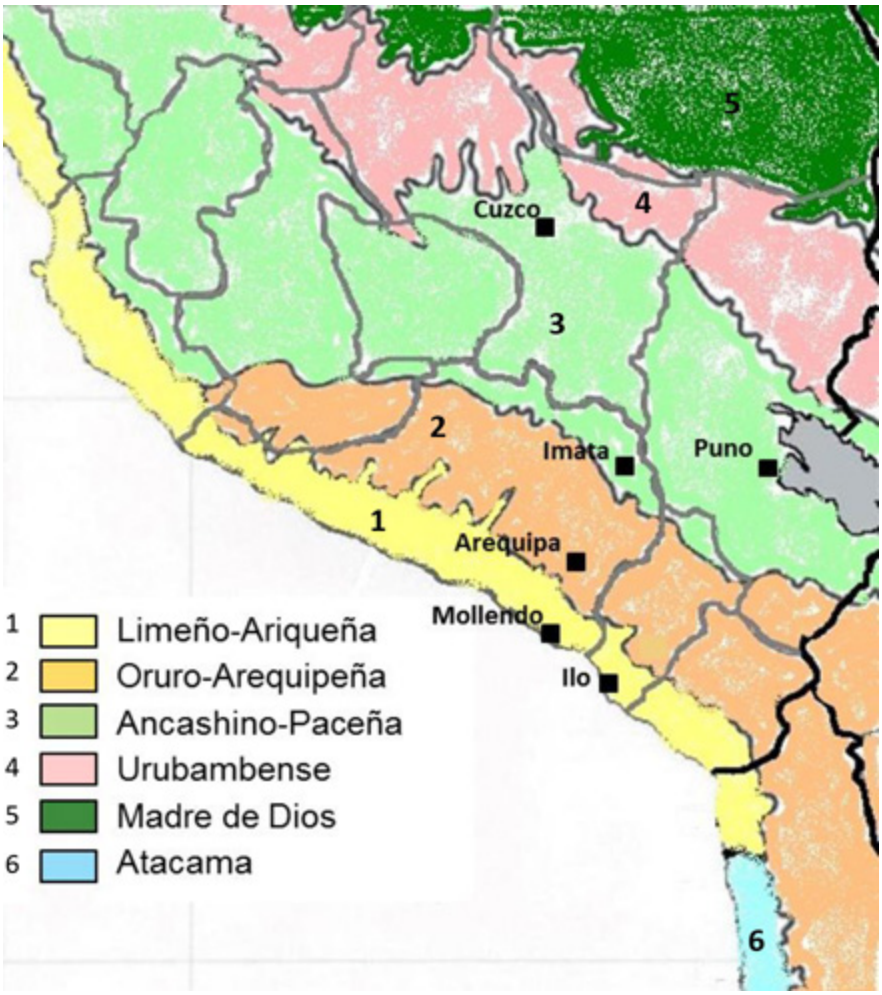

Figure 2: Phytogeographic provinces of southern Peru (Galán de Mera et al., 2009, with additions)

Based on the biome classification of Walter & Breckle (1999), the desert provinces Limeño-Arequipeña and Atacama belong to the zonobiome III, the subtropical desert vegetation. The Oruro-Arequipeña, Ancashino-Paceña and Urubambense provinces belong to the orobiome II, a seasonal vegetation of tropical mountains. The province Madre de Dios is a transition stage between zonobiome I and II, a gradual change from evergreen tropical forests to tropical seasonal forests.

Climate and vegetation

The climate of Arequipa is strongly influenced by the Humboldt Current, a cold ocean current that flows northwards along the Pacific Coast from southern Chile to central Peru. The Humboldt Current cools the marine air and prevents it from taking up moisture offshore, which makes onshore precipitation rare. Along the coast, it rains only at El Niño events which occur every 7-10 years. In the time between such rainfalls, the Atacama Desert is the driest place on earth (average rainfall of as little as 1 mm per year).

The climate diagrams in Figure 3 underline the gradient in temperature, precipitation, and aridity on the transect of the Pacific Coast to the inter-Andean valleys. The temperature is relatively constant throughout the year at all three sites. The decreasing temperature from Ilo to Cuzco is an effect of altitude, partially compensated by the intense solar radiation at high elevation. In contrast, precipitation increases dramatically with altitude. While the climate on the coast is strongly arid, in Arequipa the months of January and February are humid, and in Cuzco, the rainy season lasts seven months. Unfortunately, there is no long-term climate data available for the northeastern part of Arequipa, but it would probably not differ significantly from the data of Cuzco.

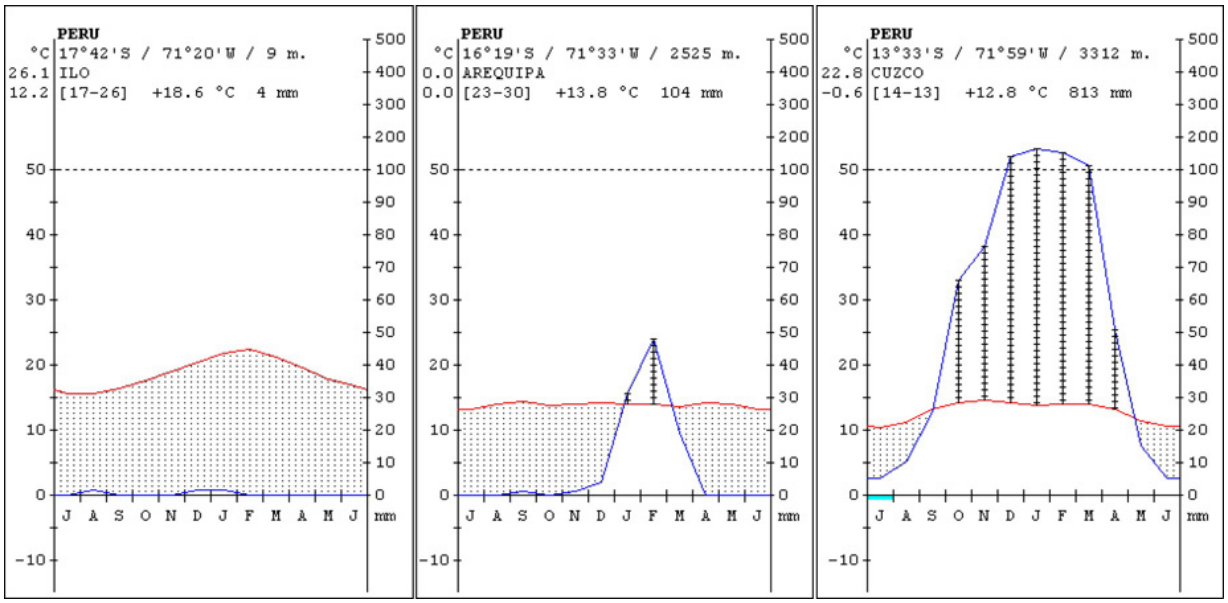

Figure 3: Climate diagrams of Ilo on the Pacific coast, Arequipa at 2500 m on the western slopes of the Andes and Cuzco, an interandean valley (Rivas-Martinez & Rivas-Saenz, 1996-2009)

The Humboldt Current prevents rainfall but fosters the formation of fog and clouds. In winter, most of the coastal plains are capped with high fog for months. This fog causes precipitation at altitudes between 250 and 1000 m enabling the growth of seasonal vegetation called fog desert, fog oasis, or lomas (Figure 4).

Above 800-1000 m the influence of the fog decreases. The high mountains, which produce clouds and seasonal rains through orographic lifting are too far away to generate precipitation. This abiotic zone is located between 1000-2000 m, a very dry, virtually lifeless landscape (Figure 5 and Figure 6).

The higher you get into the Andes, the more pronounced is the influence of the rainy season on the vegetation. Above 2500 m the landscape is predominantly covered by xeric scrublands with abundant cacti (Figure 7). At 3000 m the scrub grows denser, and the plant diversity increases. On southern slopes, these scrublands give way to Polylepis-forests (Figure 8), an ecosystem with particularly high

biodiversity that ascends towards 4500 m. On the sun-exposed northern slopes and in the plains, the Tolares - a kind of heath-vegetation - take over. On drier spots, Festuca orthophylla-grassland outcompetes the shrubs.

Above 4500 m the environment gets harsher. Frost at night is common, also in summer, while the surface is heated up to 40°C or even more by the strong radiation during the day. At this altitude, the plants grow generally smaller and insulate themselves by forming cushions (Figure 9). The evaporation exceeds the precipitation so that most of the high-altitude plants show pronounced succulence. Icy winds and high herbivore pressure favor cushion plants and species with thorns and spikes or coarse leaves. Above 5000 m the landscape changes over to a rocky environment with only a few highly specialized plants. Up from 5500 m, there is snow and ice.

In more humid places grow various azonal vegetation types. Characteristic moors evolve in wet places at high altitudes, the bofedales (Figure 12). Depressions without drainage form seasonally dry salt lakes (Figure 10) with distinct halophile vegetation, mainly consisting of algae. The pristine riverine vegetation consists of shrubs and small trees (Figure 11) but was largely displaced by agriculture. Along the coast, the rivers form large wetlands (e.g., in Camaná and Mejía). These green vegetation belts contrast distinctively with the sandy desert (Figure 5).

Figure 4: Lomas of Atiquipa at 800 m

Figure 7: Xeric shrubland at 3000 m in Chivay

Figure 10: Salt lake with Festuca orthophylla at 4500 m in Salinas

Figure 5: Abiotic zone and Rio Majes 1000 m

Figure 8: Polylepis forest at 4000 m in Aguada Blanca

Figure 11: Riparian vegetation Rio Chili in Arequipa at 2300 m

Figure 6: Upper end of the abiotic zone at 2500 m

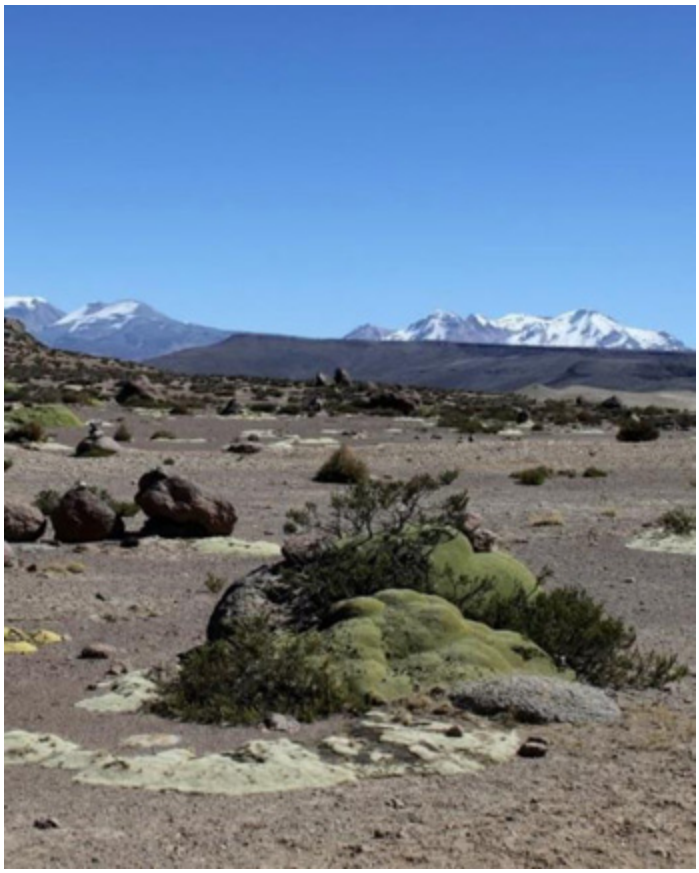

Figure 9: Cushion plants (Azorelletum) at 4900 m, Pampa de Cañahuas on the way to Colca

Figure 12: Bofedal, a moor at 4500 m

Figure 13 shows the vegetation map of southern Peru. Galán de Mera et al. (2009) described the bioclimatic zonation of southern Peru as shown in Table 1. Montesinos-Tubée (2016) has studied the mountain vegetation of SPeru in detail and described all the plant communities of the department of Moquegua.

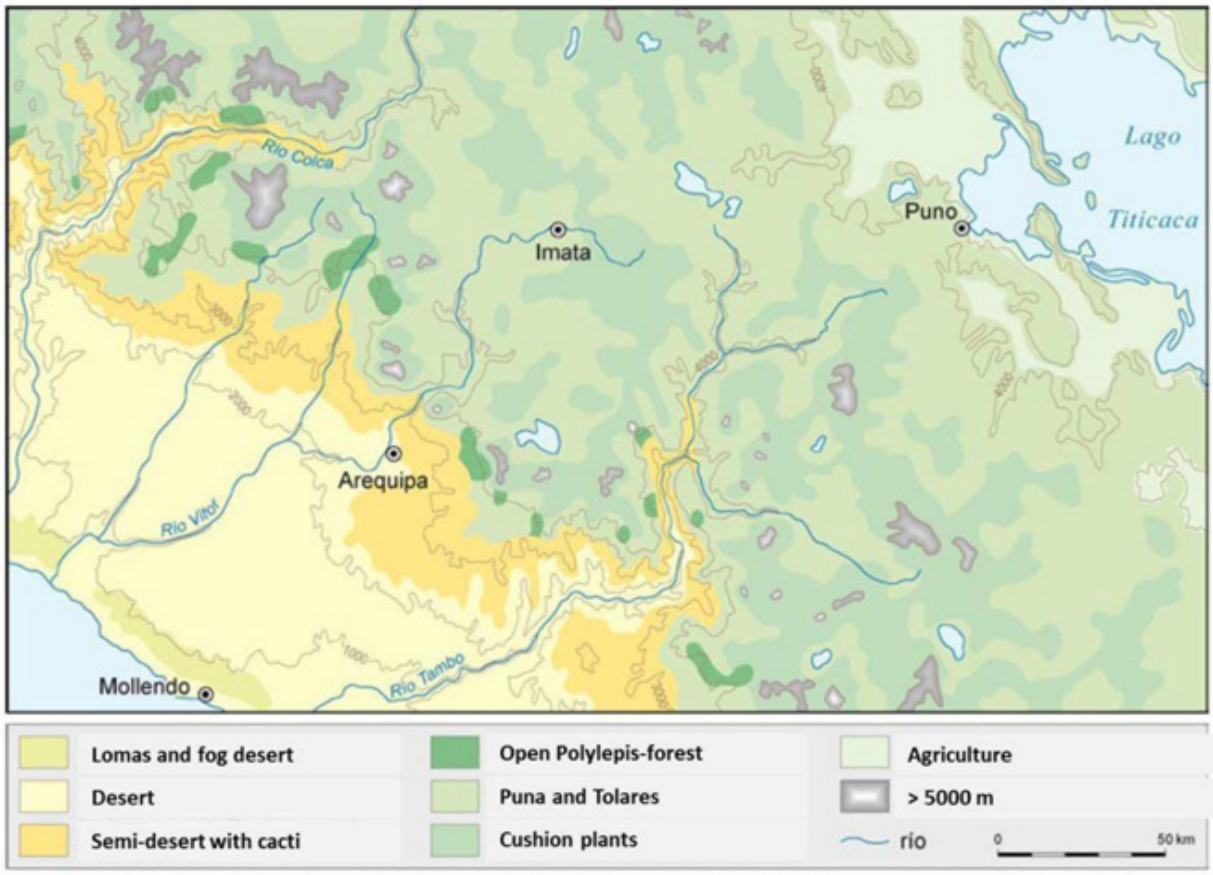

Figure 13: Vegetation map of Arequipa from Richter, Emck, & Muñoz-Moreira (2007)

Table 1: Bioclimatic description of the transect from the Pacific Ocean to the high mountains in the department of Arequipa

Bioclimate	Altitudinal interval (m)	Indicative plants	Vernacular name	Characteristic plant formation (class)
Termotropical hyperarid	0 - 1000	Tillandsia purpurea	Chala	Batido-Sarcocornietea ambiguae (halophilic vegetation)
				Xyrido carolinianae-Typhetea domingensis (wet locations)
				Tessario integrifoliae-Baccharidetea salicifoliae (shrubland at humid locations)
				Carico candicantis-Caesalpinietea spinosae (riparian forests)
				Palauo dissetae-Nolanetea gayanae (lomas)
Termotropical ultrahyperarid	1000 - 2000	Abiotic desert without any plant growth	Yunga	Acacio macranthae-Prosopidetea pallidae (riparian shrubland)
Termotropical arid	2000 - 2100	Neoraimondia arequipensis	Yunga	Opuntietea sphaericae (poor and discontinuous stands)
Mesotropical arid-semiarid	2100 - 3100	Armatocereus matucanensis Corryocactus aureus Euphorbia apurimacensis	Yunga	Opuntietea sphaericae (dense stands with high diversity)
Supratropical semiarid-dry	3100 - 3800	Cantua buxifolia Diplostephium tacorense Puya densiflora	Quechua	Opuntietea sphaericae (northern slopes) Deuterocohnio longipetalae-Puyetea ferrugineae (southern slopes)
Orotropical dry-subhumid	3800 - 4800	Festuca orthophylla Parastrephia quadrangularis Puya densiflora	Puna	Calamagrostietea vicunarum
Cryotropical dry-subhumid	4800 - 6380	Nototriche obcuneata Xenophyllum poposum	Janca	Calamagrostietea vicunarum

(Galán de Mera et al., 2009, with the addition of the characteristic plant formation)

The Flora of Arequipa

Brako & Zarucchi (1993) listed 17.143 species in “The Catalogue of the Flowering Plants and Gymnosperms of Peru”. Ten years later, Ulloa, Zarucchi, & León (2004) added 1.845 species, many of them new to science. The ferns of Peru were cataloged by Tryon & Stolze (1989-1994) and Smith et al. (2005) with a total number of 1.200 species. Therefore, around 20.000 vascular plants (pteridophytes, gymnosperms, and angiosperms) can be found in Peru. Most of them grow in the so-called biodiversity hotspot of Peru on the eastern slopes of the Andes, in the montane rain forests and cloud forests.

Brako & Zarucchi (1993) listed 788 flowering plants for the department of Arequipa (number without ferns, subspecies, and varieties, and without counting the species recognized as synonyms in the meantime). Quipuscoa, Dillon, & Ortíz (2006) mentioned 1.160 vascular plants for the department on the XI Congreso Nacional de Botánica in Puno in 2006.

To produce this catalog, the current botanical literature was studied in detail and several trips were made to all the provinces of Arequipa. 1362 vascular plants are recognized in this catalog for the department of Arequipa. A total of 95 species not yet documented for the department were added (records of the author) and 26 species mentioned at least once for Arequipa in previous sources have been excluded (see appendix 6). The species mentioned for the first time for Arequipa were documented photographically and the pictures were uploaded to the platform iNaturalist.org (only the native and naturalized species).