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Diversity, distribution and threat status of Fabaceae plants in Costa Rica: a 135-year herbarium record

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ABSTRACT. Introduction: The Fabaceae family is one of the most abundant in Costa Rica, with at least 136 genera and 593 species, many of which are important for agriculture, forestry, and ornamental purposes. **Objective:** To understand species distribution and extent of collection efforts from the country's two main herbaria. **Methods:** We cleaned databases from 1887 to 2022 at the University of Costa Rica (USJ) and the National Herbarium (CR). **Results:** We documented the presence of 154 genera of Fabaceae, with Inga being the most abundant and diverse. The largest collection effort occurred in 1993, with records of 112 genera and 321 species. We identified 19 species that had not been collected for more than 40 years. Puntarenas emerged as the province with the highest number of genera and species records (117 and 406, respectively), while at the cantonal level, La Cruz, Bagaces, and Osa presented the largest numbers of genera (89, 84, and 79, respectively). Most records are from the Tropical Humid Forest life zone (biotemperature 18-24 °C; precipitation 2 000-4 000 mm). The largest number of species was associated with non-climbing evergreen trees (228 species), followed by non-climbing evergreen shrub/trees (74 species). Additionally, we identified 5 species classified as critically endangered, 29 as endangered, and 21 as near threatened. **Conclusion:** Our herbarium analysis of Fabaceae in Costa Rica revealed a rich diversity (154 genera, predominantly Inga), with a spatial bias towards Puntarenas and the Tropical Humid Forest. Key findings include 19 long-uncollected species and considerable numbers of threatened species, underlining the need for further conservation efforts and exploration to address taxonomic gaps.

Key Words: legumes, life zones, data science, biodiversity, conservation.

RESUMEN. Introducción: La familia Fabaceae es una de las más abundantes en Costa Rica, con al menos 136 géneros y 593 especies, muchas de las cuales son importantes para la agricultura, la silvicultura y usos ornamentales. **Objetivo:** Comprender la distribución de las especies y el alcance de los esfuerzos de recolección en los dos principales herbarios del país. **Métodos:** Depuramos bases de datos desde 1887 hasta 2022 del Herbario de la Universidad de Costa Rica (USJ) y del Herbario Nacional (CR). **Resultados:** Documentamos la presencia de 154 géneros de Fabaceae, con *Inga* como el más abundante y diverso. El mayor esfuerzo de recolección ocurrió en 1993, con registros de 112 géneros y 321 especies. Identificamos 19 especies que no se habían recolectado en más de 40 años. Puntarenas es la provincia con el mayor número de registros de géneros y especies (117 y 406, respectivamente), mientras que a nivel cantonal, La Cruz, Bagaces y Osa presentaron el mayor número de géneros (89, 84 y 79, respectivamente). La mayoría de los registros provienen de la zona de vida del Bosque Húmedo Tropical (biotemperatura 18-24 °C; precipitación 2 000-4 000 mm). El mayor número de especies estuvo asociado a árboles perennes no trepadores (228 especies), seguido por arbustos/árboles perennes no trepadores (74 especies). Además, identificamos cinco especies clasificadas como críticamente amenazadas, 29 en peligro y 21 casi amenazadas. **Conclusión:** Nuestro análisis de los herbarios sobre Fabaceae en Costa Rica reveló una rica diversidad (154 géneros, predominantemente *Inga*), con un sesgo espacial hacia Puntarenas y el Bosque Húmedo Tropical. Los hallazgos clave incluyen 19 especies no recolectadas en décadas y una cantidad considerable de especies amenazadas, subrayando la necesidad de mayores esfuerzos de conservación y exploración para abordar vacíos taxonómicos.

Palabras clave: leguminosas, zonas de vida, ciencia de datos, biodiversidad, conservación.

The Fabaceae family is one of the most abundant in Costa Rica, with approximately 136 genera and 593 species exhibiting varied habits, including herbs, vines, shrubs, and trees (Hammel et al., 2010). This wide variety significantly contributes to the structure and function of ecosystems, as many species are part of primary and secondary vegetation, act as nitrogen fixers, and provide food resources for local fauna such as insects and birds (Russo & Botero, 2014; Marcellus, 2023).

In the tropics and Costa Rica, the Fabaceae family is of great importance not only because of its edible legumes incorporated into the human diet but also because of forage species beneficial for livestock (Morales, 2016; Russo & Botero, 2014). Legumes hold significant economic and cultural value for local communities, as some Fabaceae species are used for food, livestock forage, construction materials, traditional medicines, and non-timber forest products (Morales, 2016; Russo & Botero, 2014; Nison & Shrikumar, 2023). By studying the diversity of Fabaceae in Costa Rica, we can identify and value available natural resources, promoting their conservation and sustainable use.

Given Costa Rica's priority on biodiversity conservation, understanding the diversity of Fabaceae is essential for designing appropriate conservation and management strategies. This includes identifying priority areas for conservation, protecting endemic or endangered species, and establishing ecological restoration programs.

Herbaria play essential roles in science and society by recording plant biodiversity, which helps us understand species distribution in a given area or period. Additionally, herbaria are crucial for scientific research, as they are necessary for identifying new species and studying their ecology and taxonomy. They also serve as valuable tools for education, scientific outreach, and conservation promotion. Importantly, herbaria contain plant samples with significant cultural or historical importance for the country (Tapia, 2015).

In Costa Rica, there are around nine herbaria, including the Juvenal Valerio Rodríguez Herbarium (JVR) of the National University, the National Institute of Biodiversity (INBio) which is part of the collection of the National Herbarium of Costa Rica (CR) of the National Museum of Costa Rica, the Herbarium of the Lankester Botanical Garden (JBL), the Herbarium of the Tropical Agricultural Research and Higher Education Center (CATIE), the Anastasio Alfaro González Herbarium of the National University (AAG), the Luis Diego Gomez Herbarium (HLDG) at the Los Cruces Biological Station (OET), the Herbarium of the La Selva Biological Station (LSCR), the National Herbarium of Costa Rica (CR) of the National Museum of Costa Rica (MNCR), and the Luis A. Fournier Herbarium of the University of Costa Rica (USJ). The oldest is the National Herbarium of Costa Rica, founded in 1887, known for its key role in collecting the country's flora. Its collection focuses on the biodiversity of Costa Rica and the Central American region (Tapia, 2015).

In this study, we analyze Fabaceae records from the National Herbarium of Costa Rica (CR), the country's largest and oldest plant collection with 136 years of history and around 500 000 specimens. We also examine data from the University of Costa Rica Herbarium Luis A. Fournier Origgi (USJ), established in 1936 and containing about 90 000 records. Our objective is to analyze the diversity of Fabaceae collected and recorded in the databases of the two main herbaria in the country to understand their distribution and abundance according to various variables. This information will be a valuable input for future ecology and conservation projects. Additionally, the generated data will help identify specific areas or conditions with high richness of endemic or threatened species that require increased monitoring or conservation actions.

By combining information from both databases, we aim to provide a more comprehensive view of Fabaceae biodiversity, geographic distribution patterns, and ecological trends. Both collections offer a robust representation of the Fabaceae diversity in the country. The newly unified and curated database, enriched with complementary information, will be an invaluable resource for understanding the diversity, conservation status, distribution patterns, and future research needs of this taxonomic group.

MATERIALS AND METHODS

To study the diversity of Fabaceae in Costa Rica, we utilized two databases: one from the Dr. Luis A. Fournier Origgi Herbarium (USJ) at the University of Costa Rica and another from the National Herbarium of Costa Rica (CR) at the National Museum of Costa Rica (MNCR), available online (https://biodiversidad.museocostarica.go.cr/). We processed and generated a new database using the statistical analysis software R (R Core Team, 2021). The Fabaceae database from the National Museum of Costa Rica contained 21,746 observations and 51 variables, while the USJ Herbarium database had 554 observations and 52 variables.

After retrieving the databases, we identified homologous variables to include in the new database. We removed empty or incomplete variables from both the MNCR and USJ Herbarium databases and modified some variables to ensure consistent format and structure. We refused the entry in the new database of observations with incomplete species names and missing geographic data. Using the available geographic variables, we extrapolated life zones from the Holdridge life zone classification system. We created the "Habit" variable by consulting the database from the Royal Botanic Gardens, Kew (https://powo.science.kew.org/) and using the classification from the International Legume Database and Information Service.

We evaluated the synonyms of the species, to avoid reporting the diversity of genera and species of Fabaceae with binomials, for this we created the variable "Accepted species name", consulting the database of the Royal Botanic Gardens at Kew and using the International Legume Database and Information Service. The results are reported using the variable "Accepted species name", we also kept the original taxonomic designations from the herbaria databases. Additionally, we categorized the Fabaceae species present in Costa Rica according to their threat status using the IUCN Red List of Threatened Species website.

RESULTS

Database: We generated a new database by merging the two existing databases and incorporating data from the IUCN Red List of Threatened Species and the International Legume Database and Information Service for Habit. The resulting database contained 13 721 observations and 27 variables (Table 1 in Appendix).

Diversity: We recorded 154 genera. The National Museum database included 63 exclusive genera, while the USJ Herbarium database included two exclusive genera. Additionally, 89 genera were shared between the two institutions. In total, we identified 618 species of Fabaceae, with 383 species exclusive to the National Museum and seven species exclusive to the USJ Herbarium. There were 228 species collected by both institutions.

The number of genera and species collected over the years reflects the history of Fabaceae specimen collection in Costa Rican herbaria (Fig. 1). The collection of Fabaceae in Costa Rica herbaria began in 1887, with data updated until 2022. The peak year for sample collection was 1993, with 112 genera and 321 species. Specimen collection peaked around 1990 and declined after 2010.

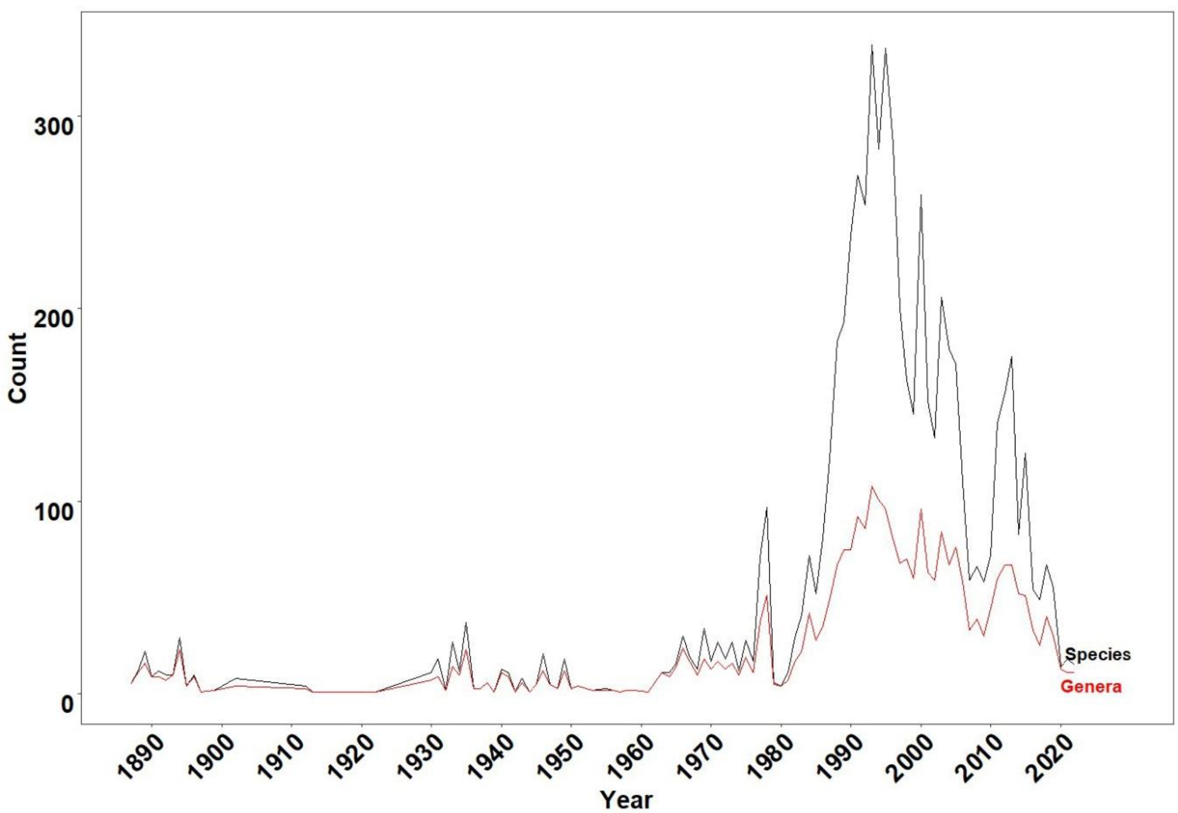


Fig. 1. Number of genera and species collected from 1887 to 2022.

When analyzing the Fabaceae genera with the most species in Costa Rica, *Inga* emerged as the most diverse genus, with 58 species recorded (Fig**.** 2). The second most diverse genus was *Senna* with 31 species, followed by *Lonchocarpus* with 29 species, *Mimosa* with 23 and *Desmodium* with 22 species.

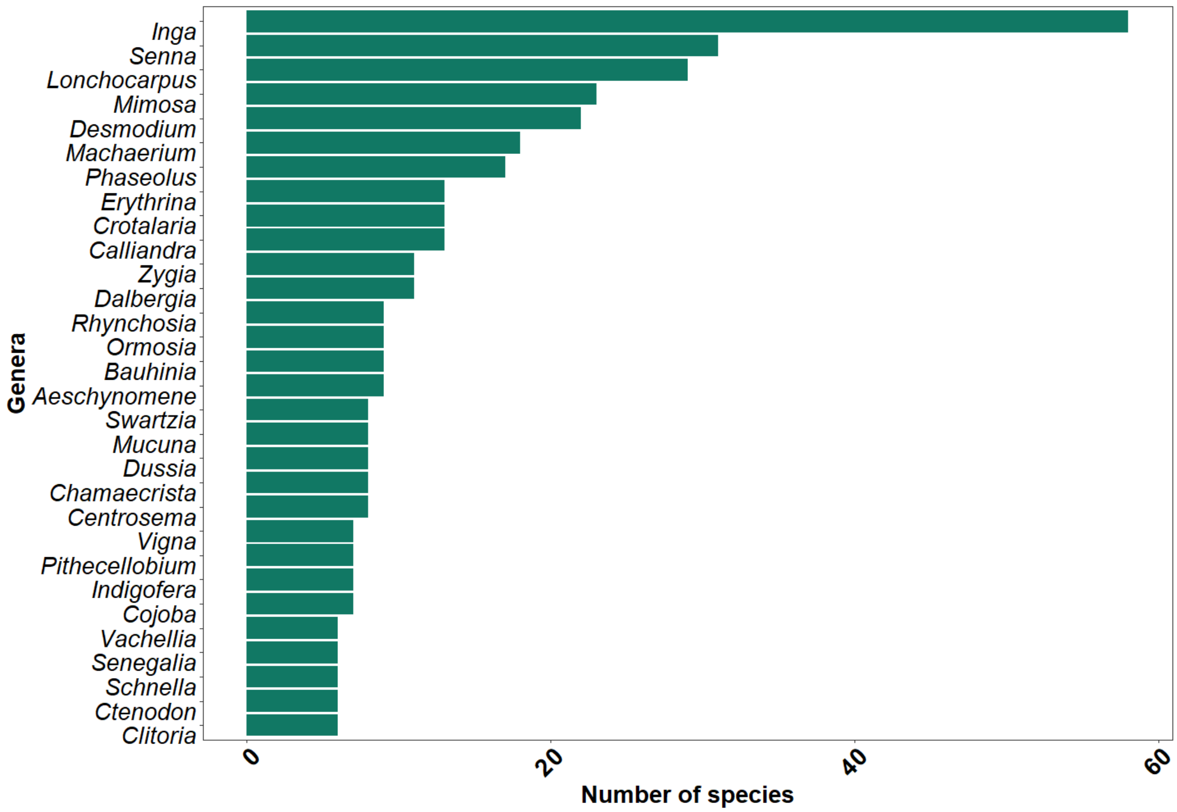


Fig. 2. The 30 Fabaceae genera with the highest number of species in the databases of the two herbaria.

The year with the highest number of observations was 1993, with 1 189 samples, followed by 1995 with 1 049 samples, and 1994 with 889 samples (Fig**.** 3). This trend aligns with the increase in collaborators at the National Museum during the 1990s, particularly from the National Institute of Biodiversity (INBio), which likely contributed to the high number of observations in those years.

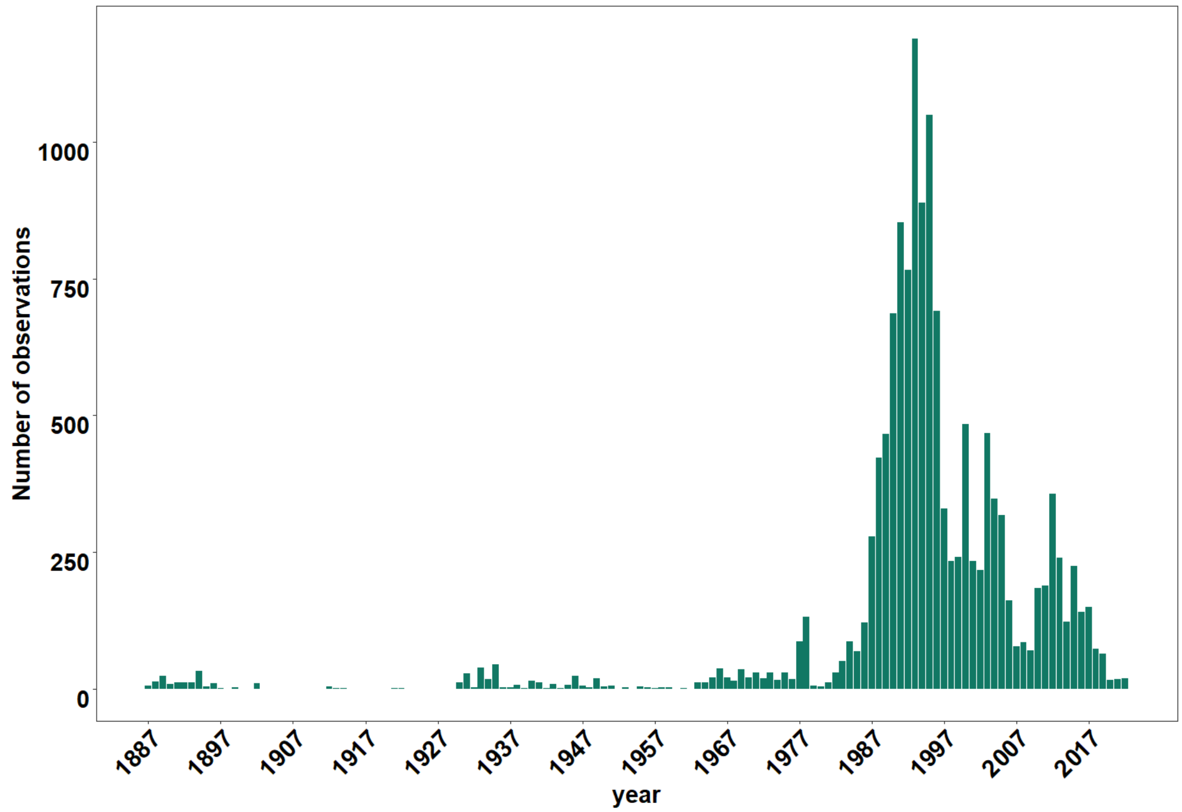


Fig. 3. Records per year.

We detected 19 species that have not been collected for more than 40 years. Notably, two of these species have not been collected for more than 100 years, while 599 species have been collected in the last 40 years. (Table 2 in Appendix & Fig**.** 4). The two species that have not been collected for over 100 years are *Desmodium orizabanum* (Hemsl.) and *Mimosa sensitiva* (L.). Many of these species may not have been collected again because they are no longer available. In addition, some species may have undergone name changes, such as *Inga leptoloba* (Schltdl.) to *I. punctata* (Wild.) and *Pithecellobium arboreum* (L.) to *Cojoba arborea* (L.), highlighting the need to update species names in herbaria records. It should be noted that our database took these name changes into account.

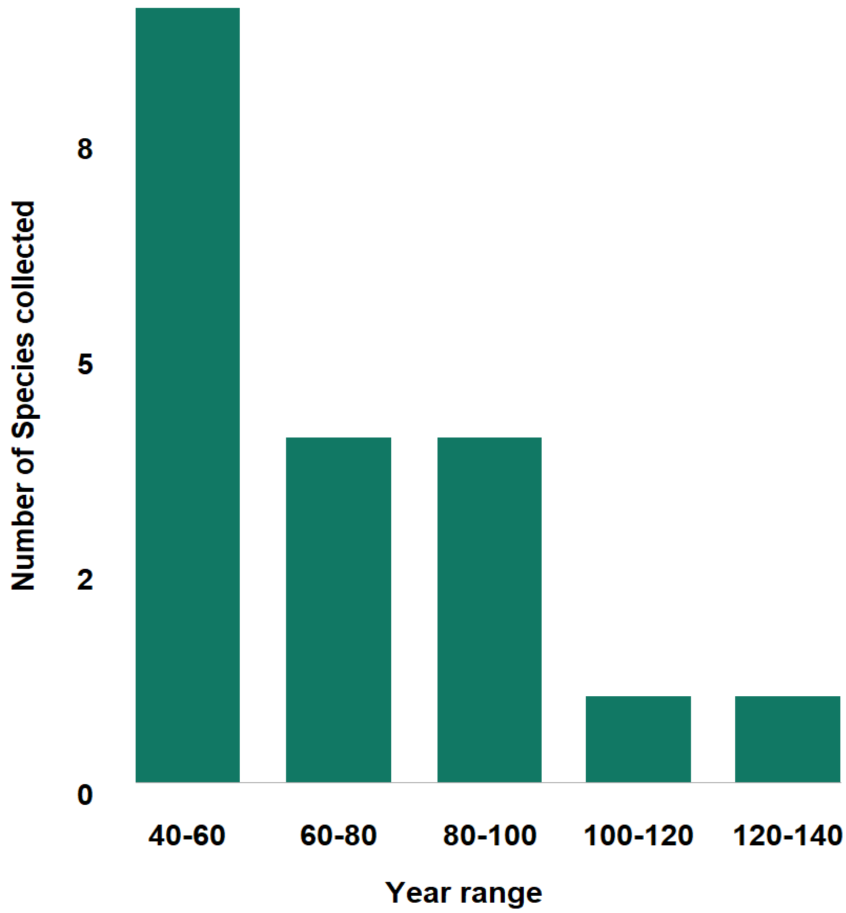
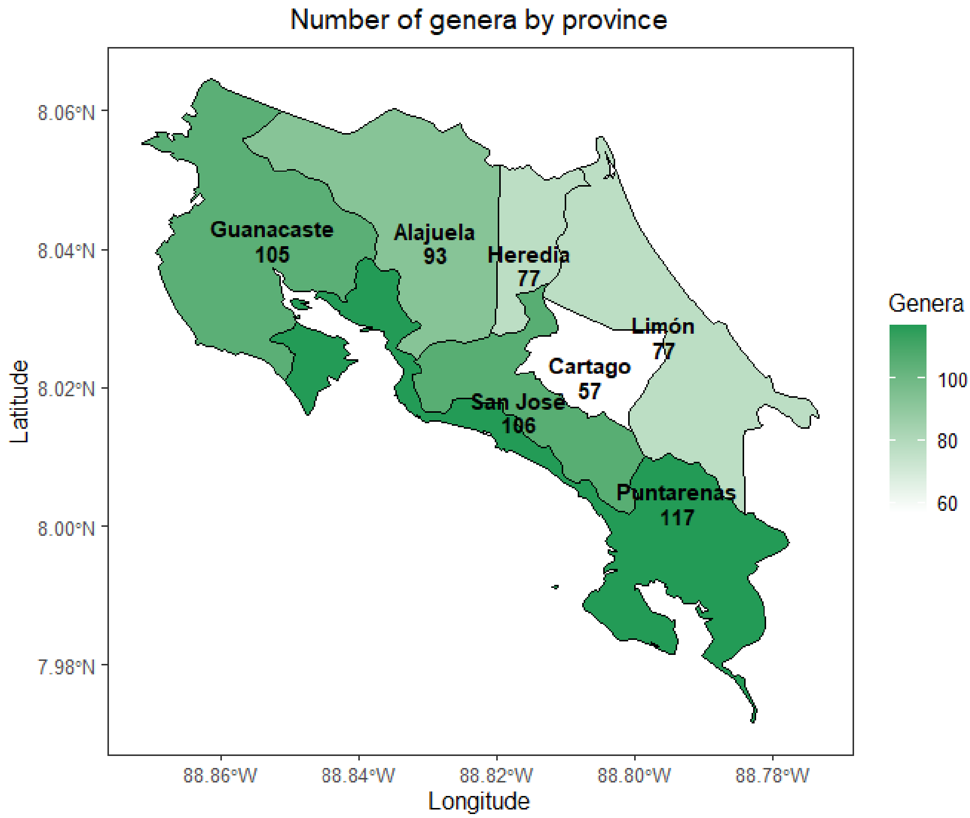


Fig. 4. Number of species that have not been documented again in more than 40 years (in 20-year intervals after the last collection)

We generated a map of the number of genera collected per province (Fig. 5). This map is divided into provinces and uses a color scale to indicate the number of genera collected. Puntarenas presented the highest number of genera and species collected (117 and 406, respectively). These results highlight the significant biodiversity of this province, likely due to its variety of life zones. Notably, the Osa Peninsula has a particularly strong influence on the high number of documented species.



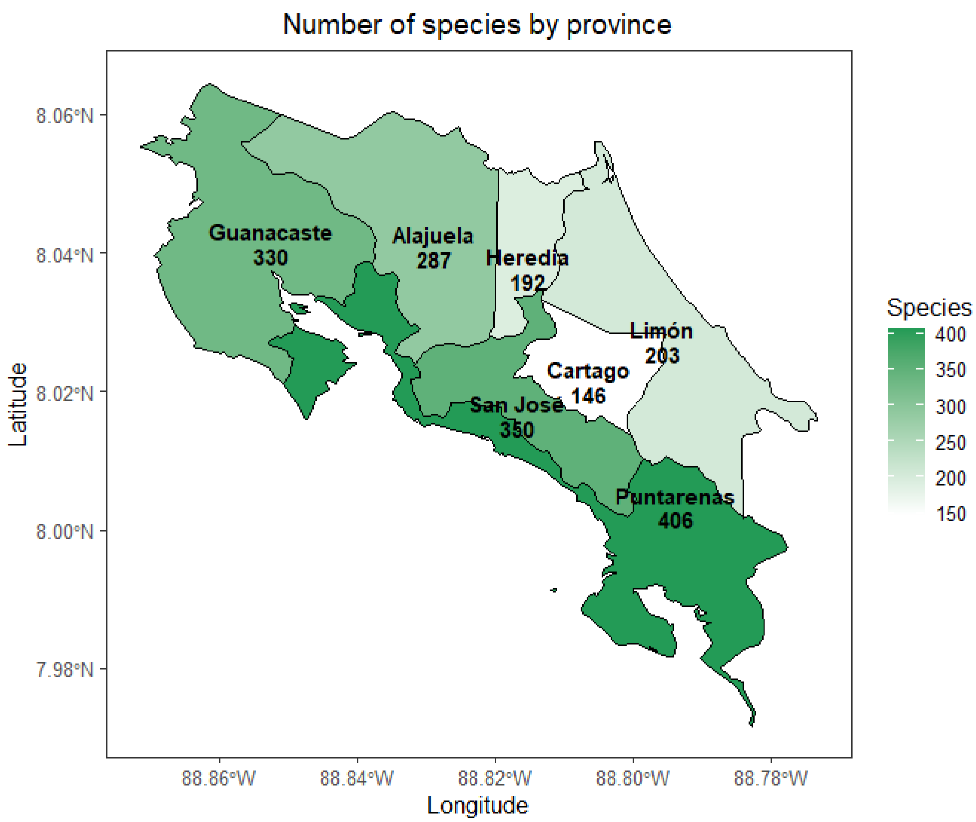


Fig. 5. Genera and species by province.

The collection density by canton in Costa Rica ranged from 0 to 2,95 specimens per km². The highest densities were observed in the cantons of Santa Ana, Belén, Alajuelita, and Santo Domingo (collections/km² > 2.0). Some cantons appear without collection records because there have been no collections registered or they did not passed the inclusion filters to this new database, such as having geographic coordinates and taxonomic identification at the species level. (Fig. 6). Collection efforts have been concentrated in the cantons of the Central Valley, while the lowest densities are found in the Huetar region (north) and the southern part of the Atlantic Huetar region (east) of Costa Rica (Fig. 6).

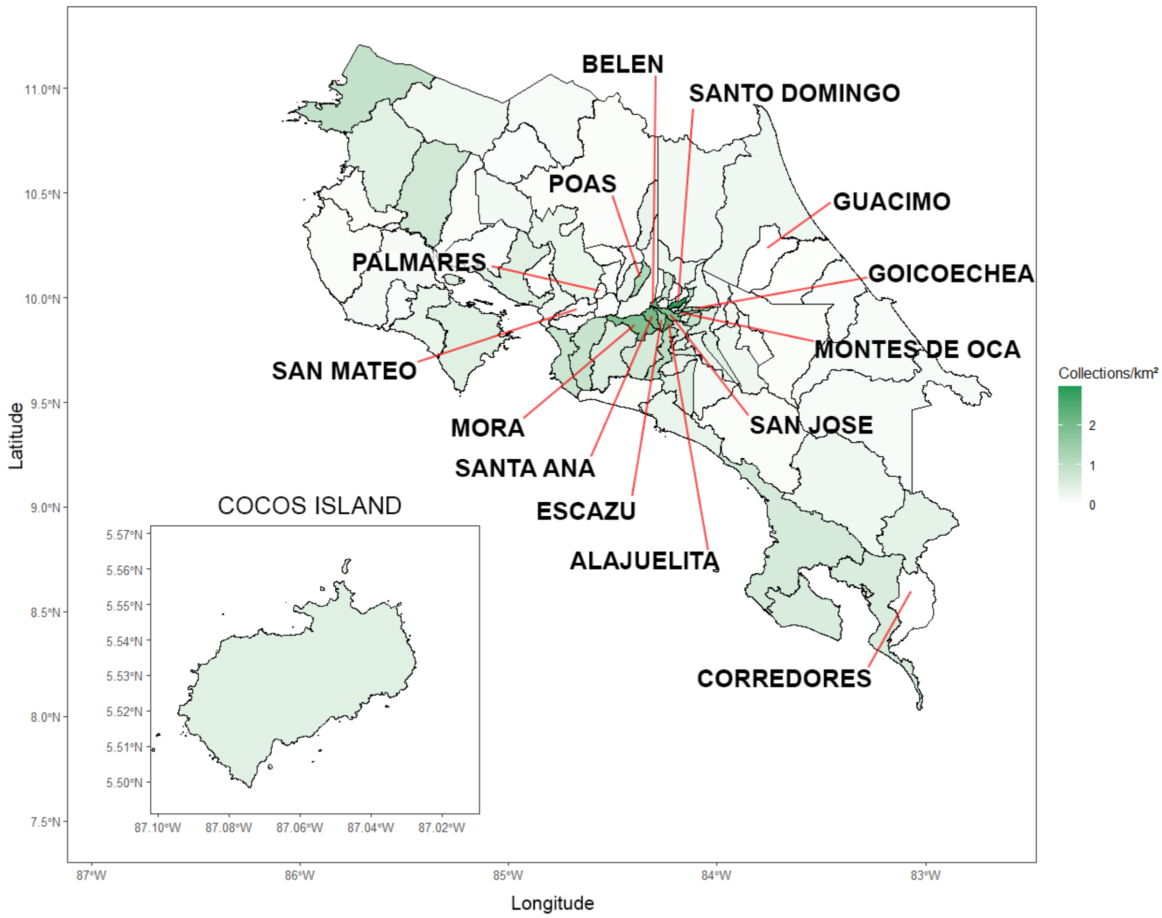


Fig. 6. Density of specimen collections per km^2 by canton.

At the cantonal level, we determined that La Cruz, Bagaces, and Osa presented the largest registry of genera, with 89, 84, and 79, respectively (Table 3 in Appendix). In contrast, the cantons with the lowest representation were San Pablo, San Rafael, Santa Barbara and Zarcero with 2 documented genera each. Regarding species per canton, La Cruz, Bagaces, and also Osa had the highest number of species, with 225, 207, and 201, respectively. San Pablo and Santa Barbara presented the least representation of species, with only two species documented each.

When analyzing species diversity according to the Holdridge life zone classification system, we found that the Tropical Humid Forest (Bh-T) presented the highest number of species collected, with 386 species (Table 4 in Appendix & Fig. 7). In second place, the Very Humid Premontane Forest (bmh-P) presented 352 species, and the Very Humid Premontane Forest Transition to Basal (bmh-P6) 341 species.

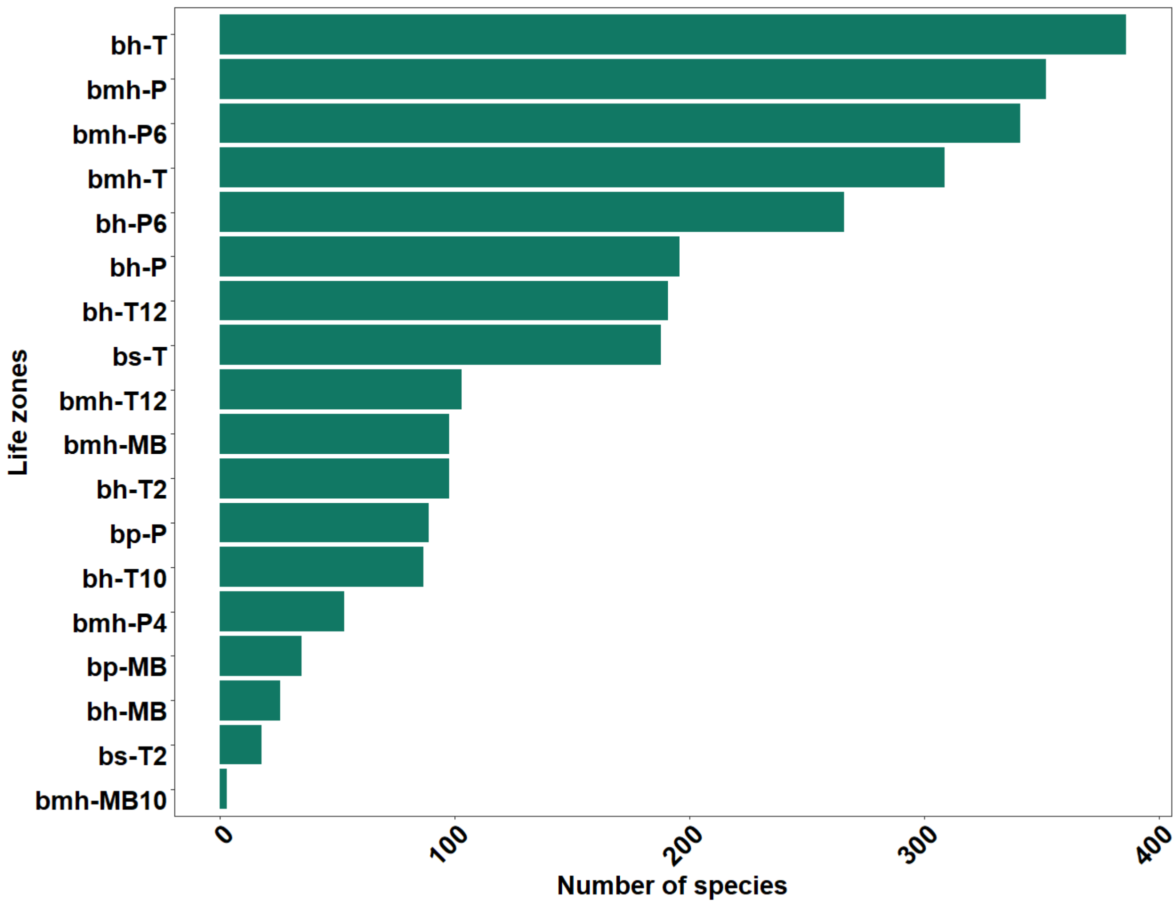


Fig. 7. Number of species according to life zones of the Holdridge Life Zone Classification System.

In relation to biotemperature ranges, we identified 121 species in the 12-18°C range, 562 species between 18-24°C, and 522 species between 24-30°C (Fig. 8). The highest number of species per precipitation interval (average annual precipitation in mm) was observed between 2 000-4 000 mm with 555 species, followed by the 1 000-2 000 mm interval with 386 species. The lowest number was observed in the 4 000-8 000 mm interval with 359 species (Fig. 8).

At the altitudinal level, the largest number of species was recorded in the Premontane level (600-1 600 masl in the Pacific or 400-1 500 masl in the Caribbean) with 562 species. This was followed by the Basal level (0-600 masl Pacific or 0-400 masl Caribbean) with 522 species, and finally, the Low Montane floor (1 600-2 600 masl Pacific or 1 500-2 600 masl Caribbean) with 121 species (Fig. 8).

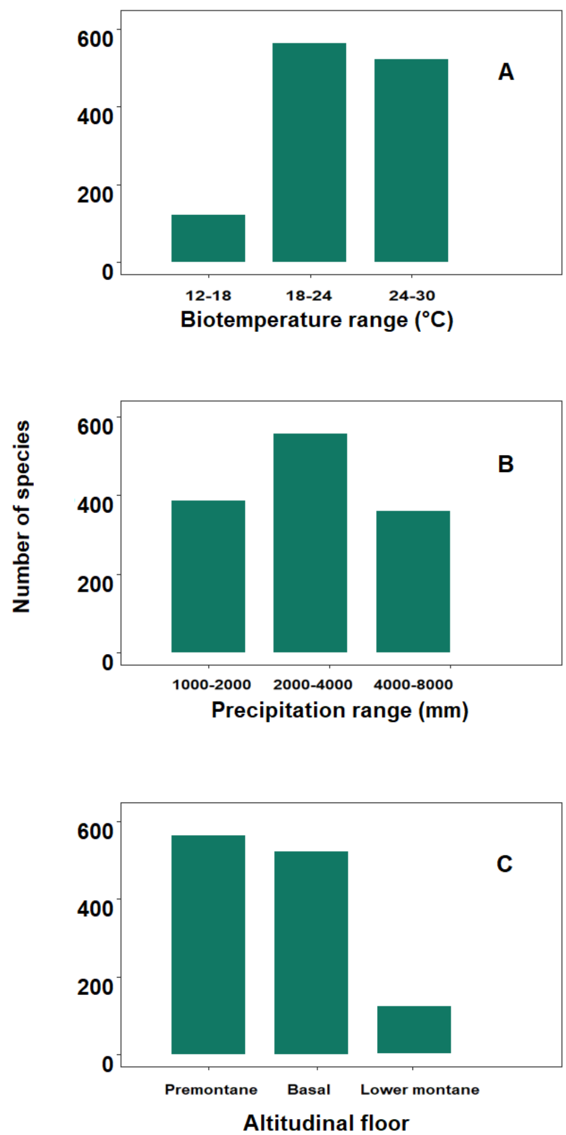


Fig. 8. Number of species according to: A) Biotemperature range (°C). B) precipitation interval (average annual precipitation in mm). C) Altitudinal floor, Premontane (altitude range of 600-1 600 masl Pacific or 400-1 500 masl Caribbean), Basal (altitude range of 0-600 masl Pacific or 0-400 masl Caribbean), and Low Montane floor (altitude range from 1 600-2 600 meters above sea level Pacific or 1 500-2 600 meters above sea level Caribbean).

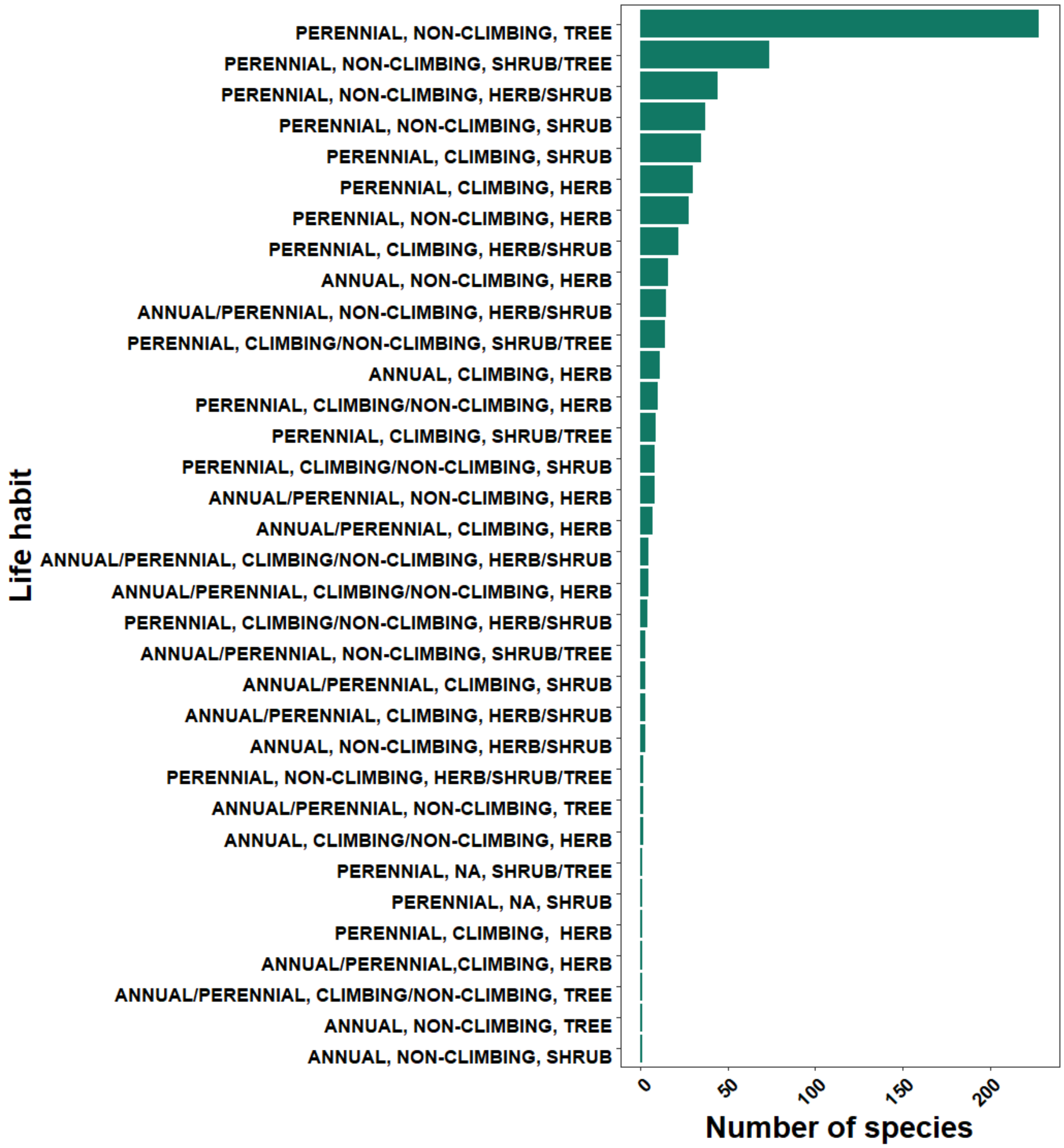


Fig. 9. Species according to habit (International Legume Database and Information Service classification).

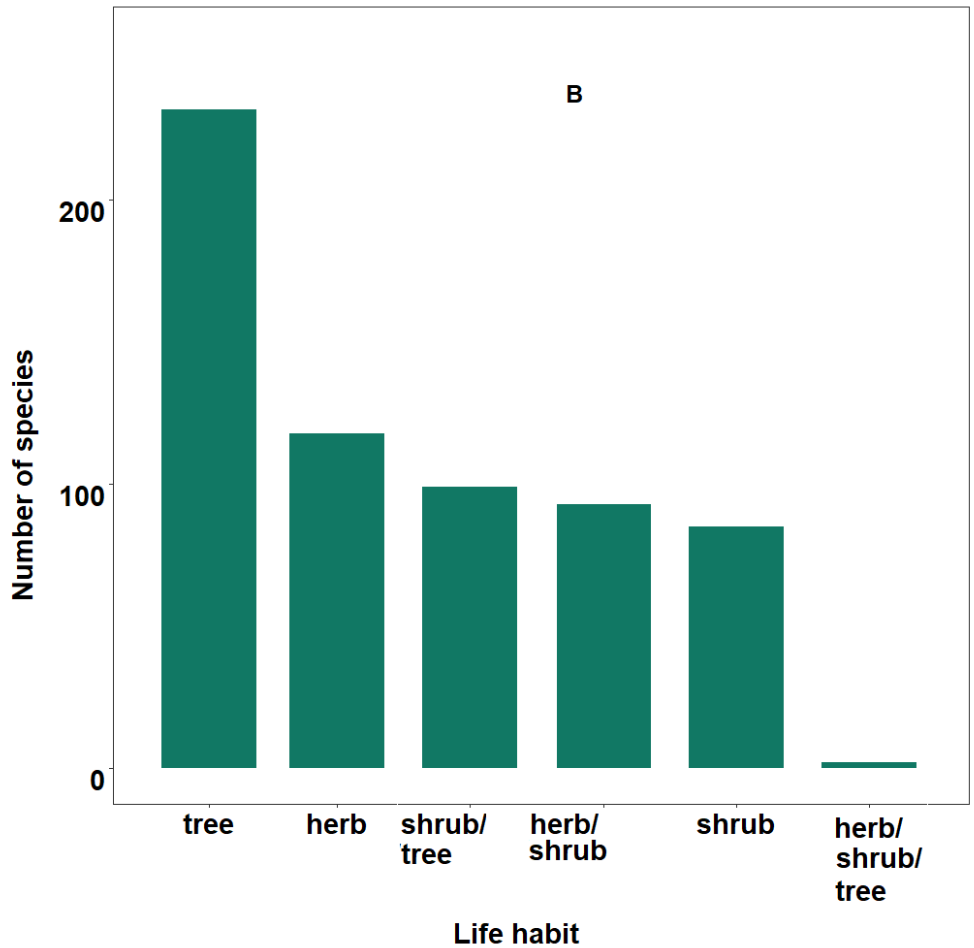


Fig. 10. Number of species according to the classification of life habits of species.

In relation to the plant's habit, we determined that the largest number of species recorded were perennial non-climbing trees, with 228 species, followed by perennial non-climbing shrubs/tree with 74 species (Fig**.** 9). Regarding estimated lifespan, most species are classified with a perennial lifespan, with 537 species, followed by those with an annual/perennial lifespan, with 52 species. Only 33 species were classified as having an annual lifespan. In terms of habit, 232 species were trees, 118 were herbs, and 85 were shrubs, while the rest were classified into combinations of these categories (Fig**.** 10).

When comparing the list of species obtained from the database against the Threat Status of Species list of IUCN, we determined that five species are classified as Critically Endangered, 29 as Endangered, 21 as Near Threatened, and 19 as Vulnerable (Table 5 in Appendix). Additionally, 262 species are considered of Least Concern, two species are Data Deficient, and 280 species are in the database but not listed by the IUCN.

DISCUSSION

In this work, we demonstrate the usefulness of herbarium databases for obtaining ecological information on plant groups, particularly focusing on the diverse and significant Fabaceae family. Additionally, we highlight the good representativeness of specimens from most species and genera described for the country in the two analyzed herbaria. We address the dispersion of collecting efforts and identify opportunities in areas with low sampling density. Furthermore, we emphasize the need to update many scientific name records and note the decline in sampling efforts and new records over the past decade

Within the records of Fabaceae, the genus *Inga* (Mill.) is one of the most representative and diverse in tropical areas, consistent with records for Costa Rica (Antunes et al., 2019; Doyle, 2001). The herbarium of the National Museum of Costa Rica houses the largest number of genera and species, providing 41% and 62% of the total observations of unique genera and species not shared, respectively. However, both the National Museum and the USJ Herbarium have made significant efforts to collect, preserve, and document a large portion of Costa Rica's Fabaceae diversity.

The oldest record of Fabaceae for Costa Rica in our database dates to April 1, 1887, by the collector Paul Biolley, of the species *Inga vera* (Willd.) in Desamparados, San José. The most recent record in our database is from October 27, 2022, by Silvia Lobo Cabezas, of the species *Calliandra calothyrsus* (Meisn.) in Cartago. New species have been reported in Costa Rica in the last five years, indicating ongoing sampling efforts. Debouck et al. (2020) described a new species of wild bean, *Phaseolus albicarminus* (Leguminosae, Phaseoleae), found in 2015 in the south of the Central Valley of Costa Rica, in León Cortés, San José, with its holotype located in the Luis A. Fournier Herbarium of the University of Costa Rica (USJ) (Debouck et al., 2020). Fonseca-Cortes (2021) described *Macropsychanthus magnus* (Leguminosae: Papilionoideae: Diocleae), a legume species related to *Macropsychanthus malacocarpus* (Ducke), found in Sarapiquí, Heredia, with its holotype in the Herbarium of the La Selva Biological Station (LSCR) (Fonseca-Cortes, 2021). Santamaria-Aguilar et al. (2022) described *Prioria peninsulae* (Leguminosae, Detarioideae), previously confused with *P. copaifera* (Griseb.), found in the mountains of the Osa Peninsula, in Golfito, Puntarenas, with its holotype in the National Herbarium of Costa Rica (CR) at the National Museum of Costa Rica (Santamaría-Aguilar, 2022).

A notable peak in genera and species records was observed between 1990 and 2015, likely due to the rise and fall of contributions from the National Biodiversity Institute (INBio) and its efforts to document Costa Rica's biodiversity (Sandlund, 1991). This led to an increase in the number of collaborating collectors, particularly during 1993, 1994, and 1995. Consequently, the highest number of genus and species records are found within this period (Fig. 1 & 3).

One of the most significant achievements of INBio was the National Biodiversity Inventory, through which thousands of species of flora and fauna were identified and documented. Despite its success and far-reaching impact, INBio faced financial challenges in its later years, primarily due to its reliance on international funding and donations. The 2008 global economic crisis led to restructuring and staff reductions, impacting its research efforts. These challenges correspond to the decrease in new records observed in the databases.

The province of Puntarenas presented the highest number of genera and species, consistent with findings by Vargas & Hidalgo-Mora (2013), who determined the larger basal area and aboveground biomass of Fabaceae in Puntarenas. This province experiences transitions from dry forest to humid forest and very humid forest. The presence of soils with high nutrient availability, moderately high pH, and lower leaching and chelation processes has made it one of the most degraded and fragmented ecosystems due to human activities such as land use changes for agriculture and livestock. This situation has benefited legumes, which are generally secondary forest species with colonizing ability (Herrerías et al., 2006; Vieira & Scariot, 2006). The Fabaceae family has incredible morphological diversity, allowing for an almost cosmopolitan distribution (The Legume Phylogeny Working Group et al., 2013).

We identified a significant sampling bias for Fabaceae across Costa Rica. When comparing the number of reported observations per canton and averaging them by square kilometer, it became evident that the most sampled cantons are located in the Central Valley—the most urbanized region of the country—as well as in cantons with prominent national parks, such as La Cruz, Garabito, and Osa (Table 3 in Appendix & Fig. 6). In contrast, the northern and Caribbean regions of the country were found to have the least sampled cantons. Despite this, these regions host considerable biodiversity, encompassing life zones like tropical wet forest (bh-T) and premontane very humid forest (bmh-P), which, according to our database, are precisely the zones with the highest diversity of legume species.

We determined that the life zone with the highest number of species recorded was the Tropical Humid Forest (Table 4 in Appendix & Fig. 7). The wide habitat diversity of Fabaceae enables colonization in various life zones. This family exhibits high diversity in the three types of tropical vegetation: humid forest, dry forest, and woody savanna. In comparison, other plant families cover only one type of vegetation (Yahara et al., 2013). Another characteristic benefiting habitat diversity is the symbiotic relationship with nodule-forming bacteria capable of nitrogen fixation, supporting survival in different ecosystems (Sprent, 2009; de Bedout-Mora et al., 2022).

Fabaceae species exhibit extremely diversified habits, including annual plants, shrubs, canopy trees, vines, and aquatic plants (Yahara et al., 2013). This diversity is reflected in the functional traits of leaves, stems, flowers, fruits, and seeds. For example, some climbing species modify their leaflets into adhering organs known as tendrils (Saikia et al., 2020). In Costa Rica, the dominant habit is non-climbing perennial trees (Fig. 9 & 10).

It is noteworthy that in Costa Rica there are more herbaria, and it is possible that new species may not be collected or preserved in the two herbaria analyzed, which underscores the need for increased sampling efforts, particularly to determine the status of populations and their protection needs. An analysis of nineteen plant species uncollected for over 100 years shows the presence of genera abundant within the Fabaceae family (Table 2 in the Appendix & Fig.4). While some species may have undergone taxonomic changes, none are currently considered endangered or have reduced populations (Quesada-Monge & Quiros-Brenes, 2003).

It is also important to note that the databases used in this analysis may include sampling errors. These sampling errors include spelling errors, errors in the names of the collection sites, errors in the reported geographic coordinates, and missing data. This is understandable given the long history of species recording by both herbaria and the changes in technology, such as GPS. In our analysis we have corrected most spelling errors and have not admitted those observations that did not have critical data for this analysis, such as geographic coordinates or full name of the species. However, we note the importance of accurate data collection is essential to maintain traceability of samples throughout the process.

In Costa Rica, we have identified five species as critically endangered and 22 as endangered. Yahara et al. (1998) and Raimondo et al. (2009), point out that Japan had 17 critically endangered species and eight endangered species, while South Africa had 36 critically endangered species and 85 endangered species. In this sense, it would seem that Costa Rica is not so seriously affected, but projections indicate that endemic species will be the most affected due to the loss of ecosystems due to climate change, deforestation and agriculture (Malcolm et al., 2006).

In Fabaceae, species loss is primarily due to high rates of selective deforestation, as many are highly valued for their wood (Yahara et al., 2013). The felling of timber species is one of the main threats to Fabaceae in Costa Rica, necessitating government intervention for their protection and conservation. For example, *Paramachaerium gruberi* (Brizicky), known as "sangrillo colorado," is a native species of Costa Rica listed as Critically Endangered by the IUCN. This tree, valued for its precious wood, has been endangered, leading to a total ban on the use of standing trees since 1997 (Jiménez, 1999; Estrada et al., 2005; Moya et al., 2013; Programa REDD/CCAD-GIZ-SINAC , 2015; Jiménez, 2022).

It is important to note that there are additional risks beyond excessive logging. Healey and Gara (2003) suggest that the introduction of species of forestry interest, such as *Tectona grandis* (L. f.) has negatively impacted the diversity and abundance of native species, causing size selection of those that can survive these environments. This indicates that not only deforestation, excessive logging, or climate change threaten the country's endemic plants, but also the introduction of exotic or forest species.

Although the International Union for Conservation of Nature (IUCN) Red List of Threatened Species was used to determine the conservation status of the species in the database, Costa Rica has categorized many other trees in the Fabaceae family as threatened or critically endangered without them appearing on the IUCN Red List as Critically Endangered. Many species considered vulnerable or critically endangered in Costa Rica are timber species of forestry interest, such as *Abarema barbouriana (Standl.), Chloroleucon eurycyclum* (Barneby & J.W.Grimes), *Newtonia suaveolens* (Miq.), and *Enterolobium schomburgkii* (Benth.). These species are listed on the Red List as being of least concern, but in Costa Rica, they are considered critically endangered, with some banned from logging (Estrada et al., 2005; Programa REDD/CCAD-GIZ-SINAC, 2015).

A recent study by Debouck et al. (2024) suggests that *Phaseolus albicarminus* (Debouck & N.Chaves)*, P. angucianae* (Debouck & Araya), and *P. hygrophilus* (Debouck) should be considered endangered because they are endemic species whose narrow distribution is threatened by deforestation for coffee plantations and cattle grazing, as well as by their presence outside protected areas (Debouck et al., 2024).

The Fabaceae family plays a crucial role in global biodiversity, particularly in Costa Rica, where it is one of the most diverse and representative plant families. The extensive collections in national herbaria, such as the National Museum of Costa Rica and the USJ Herbarium, underscore the importance of documenting and preserving this diversity. While significant strides have been made in collecting and identifying Fabaceae species, substantial gaps in sampling remain, especially in less-studied regions of the country. The discovery of new species in recent years highlights ongoing efforts to expand our understanding of this family. However, errors in sampling data and changes in species names pose challenges to accurately assessing the conservation status of many species.

Although Costa Rica is not as severely impacted by species loss as other countries, Fabaceae species remain vulnerable to deforestation, land-use change, and climate change, especially endemic species. These threats highlight the need for continued conservation efforts and updated biodiversity assessments. Targeted sampling in underrepresented regions and habitat preservation will be key to ensuring the survival of Costa Rica's rich Fabaceae diversity for future generations.

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ETHICS, CONFLICT OF INTEREST, AND FUNDING STATEMENT

The authors declare that they have fully complied with all pertinent ethical and legal requirements, both during the study and in the production of the manuscript; that there are no conflicts of interest of any kind; that all financial sources are fully and clearly stated in the acknowledgements section; and that they fully agree with the final edited version of the article. A signed document has been filed in the journal archives.

The statement of each author's contribution to the manuscript is as follows: D.C.P. and A.B.P.: Study design, data analysis and preparation of the manuscript. K.R.J.: proposed the project idea, providing the databases, review and final approval of the manuscript.

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APPENDIX

TABLE 1

Variables resulting from selection, modification or extrapolation in the new dataset

Variable	Description
Id_number	Numeric identifier granted by the MNCR or the Herbarium.
Db_origin	Database of origin of the observation.
Family	Family Fabaceae.
Genus	Taxonomic genus of the plant.
Species	Genus and species of the plant.
Range	If it was identified at the species level or just genus.
Collection	Indicates to which collection the specimen was located within the museum or herbarium.
Record_type	Indicates what type of specimen you have: specimen, organisms, parts of the organism, etc.
Collector	Indicates the name of the collector person.
Companion	Indicates the name of the people accompanying the collector.
Initial_collection_date	Initial collection date.
Final_collection_date	Final collection date.
Country	Country where the specimen was collected.
Province	Province where the specimen was collected.
Canton	Canton where the specimen was collected.
District	District where the specimen was collected.
Latitude	Latitude where the specimen was collected.
Longitude	Longitude where the specimen was collected.
Notes	Observations regarding the specimen.
Altitude	Altitude at which the specimen was found.
Redlistcategory	Category in which the species is found in the IUCN.

Life_style	Habit of the specimen (Annual/Perennial, Climbing/Non-Climbing, Tree/Shrub/Grass) according to the classification of the International Legume Database and Information Service.
Life_zone	A classification of bioclimatic areas defined by the Holdridge life zones system, based on combinations of biotemperature, precipitation, and potential evapotranspiration ratio.
Biotemperature	Temperature in Celsius, mean annual.
Floor	Altitudinal belts, a subdivision within the Holdridge life zones that accounts for changes in bioclimatic conditions with altitude.
Precipitation	The total amount of water, in the form of rain, snow, sleet, or hail, that falls to the ground within a given time period (annual).
Accepted_specie_name	Accepted species name, obtained by consulting the database of the Royal Botanic Gardens at Kew and using the International Legume Database and Information Service.

TABLE 2

List of species that have not been documented in more than 40 years (in 20-year intervals).

Specie	Last recollection date	Year difference	Interval of years
Mimosa sensitiva	1894-10-31	130	120-140
Desmodium orizabanum	1912-10-27	112	100-120
Mimosa polydactyla	1934-12-08	90	80-100
Desmodium sericeum	1935-11-19	89	80-100
Biancaea decapetala	1938-08-12	86	80-100
Melilotus indicus	1943-06-12	81	80-100
Acacia dentifera	1948-07-04	76	60-80
Lathyrus odoratus	1949-06-04	75	60-80
Medicago sativa	1949-06-04	75	60-80
Senna bacillaris	1963-12-15	61	60-80
Medicago arabica	1967-01-28	57	40-60
Desmodium molliculum	1971-08-30	53	40-60
Lysiloma divaricatum	1971-11-17	53	40-60
Piliostigma malabaricum	1972-02-02	52	40-60

Acacia verticillata	1973-03-01	51	40-60
Crotalaria juncea	1976-01-01	48	40-60
Melilotus albus	1983-04-11	41	40-60
Trifolium pratense	1984-02-12	40	40-60
Vicia sativa	1984-02-12	40	40-60

TABLE 3

Number of genera and species by canton.

Canton	Genera	Species
Abangares	23	38
Acosta	45	101
Alajuela	33	49
Alajuelita	26	38
Alvarado	8	11
Aserrí	26	65
Atenas	10	11
Bagaces	84	207
Barva	17	28
Belén	15	24
Buenos Aires	65	146
Cañas	23	34
Carrillo	14	17
Cartago	32	54
Corredores	8	9
Coto Brus	49	113
Curridabat	8	9
Desamparados	23	37

Dota	15	28
El Guarco	13	19
Escazú	24	37
Esparza	23	32
Flores	4	5
Garabito	53	99
Goicoechea	26	32
Golfito	72	174
Grecia	26	36
Guácimo	7	10
Guatuso	22	37
Heredia	33	52
Hojancha	15	19
Jiménez	8	10
La Cruz	89	225
La Unión	16	27
León Cortés Castro	6	14
Liberia	74	186
Limón	40	81
Los Chiles	34	69
Matina	21	35
Montes de Oca	12	14
Montes de Oro	9	10
Mora	52	111
Moravia	7	13
Nandayure	51	87

Naranjo	3	6
Nicoya	48	83
Oreamuno	7	10
Orotina	13	13
Osa	79	201
Paraíso	27	48
Parrita	18	19
Pérez Zeledón	43	81
Poás	22	44
Pococí	51	125
Puntarenas	73	177
Puriscal	62	127
Quepos	50	78
San Carlos	36	90
San Isidro	3	3
San José	33	52
San Mateo	3	3
San Pablo	2	2
San Rafael	2	3
San Ramón	40	91
Santa Ana	40	68
Santa Bárbara	2	2
Santa Cruz	44	65
Santo Domingo	33	48
Sarapiquí	47	104
Sarchí	4	7

Siquirres	13	24
Talamanca	59	123
Tarrazú	31	57
Tibás	4	4
Tilarán	21	45
Turrialba	34	62
Turrubares	59	126
Upala	48	111
Vázquez de Coronado	18	29
Zarcero	2	4

TABLE 4

Number of species according to the life zones of the Holdridge Life Zone Classification System.

Life zones	zone	Number of species
Very Humid Low Montane Forest Transition to Humid	bmh-MB10	3
Tropical Dry Forest Transition to Wet	bs-T2	18
Low Montane Humid Forest	bh-MB	26
Lower Montane Rainforest	bp-MB	35
Very Humid Premontane Forest Transition to Rainforest	bmh-P4	53
Tropical Wet Forest Transition to Dry	bh-T10	87
Premontane Rainforest	bp-P	89
Tropical Humid Forest Transition to Perhumid	bh-T2	98
Very Humid Low Montane Forest	bmh-MB	98
Very Humid Tropical Forest Transition to Premontane	bmh-T12	103
Tropical Dry Forest	bs-T	188
Tropical Humid Forest Transition to Premontane	bh-T12	191
Premontane Humid Forest	bh-P	196
Premontane Humid Forest Transition to Basal	bh-P6	266

Very Humid Tropical Forest	bmh-T	309
Very Humid Premontane Forest Transition to Basal	bmh-P6	341
Very Humid Premontane Forest	bmh-P	352
Tropical Moist Forest	bh-T	386

TABLE 5

Species classified as critically endangered (Critically Endangered), and in danger of extinction (Endangered) according to the IUCN Red List of Threatened Species.

Red list category	Species
Critically Endangered	*Paramachaerium gruberi*
Critically Endangered	*Dalbergia retusa*
Critically Endangered	*Dalbergia glomerata*
Critically Endangered	*Platymiscium parviflorum*
Critically Endangered	*Lathyrus odoratus*
Endangered	*Inga tenuiloba*
Endangered	*Tachigali versicolor*
Endangered	*Lonchocarpus haberi*
Endangered	*Swartzia maquenqueana*
Endangered	*Dalbergia tilarana*
Endangered	*Phaseolus dumosus*
Endangered	*Muellera unifoliolata*
Endangered	*Dalbergia melanocardium*
Endangered	*Copaifera camibar*
Endangered	*Styphnolobium monteviridis*
Endangered	*Dahlstedtia calcarata*
Endangered	*Macrolobium herrerae*
Endangered	*Inga golfodulcensis*
Endangered	*Inga herrerae*
Endangered	*Swartzia phaneroptera*

Endangered	*Ormosia intermedia*
Endangered	*Inga umbilicata*
Endangered	*Inga canonegrensis*
Endangered	*Calliandra grandifolia*
Endangered	*Zygia confusa*
Endangered	*Ateleia herbert-smithii*
Endangered	*Pithecellobium johansenii*
Endangered	*Zygia rubiginosa*
Endangered	*Inga stenophylla*
Endangered	*Inga bracteifera*
Endangered	*Styphnolobium parviflorum*
Endangered	*Styphnolobium sporadicum*
Endangered	*Dalbergia tucurensis*
Endangered	*Lonchocarpus alternifoliolatus*