Biovera-Epi: A new database on species diversity, community composition and leaf functional traits of vascular epiphytes along gradients of elevation and forest-use intensity in Mexico

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Abstract

Background

This data paper describes a new, comprehensive database (BIOVERA-Epi) on species distributions and leaf functional traits of vascular epiphytes, a poorly studied plant group, along gradients of elevation and forest-use intensity in the central part of Veracruz State, Mexico. The distribution data include frequencies of 271 vascular epiphyte species belonging to 92 genera and 23 families across 120 20 m × 20 m forest plots at eight study sites along an elevational gradient from sea level to 3500 m a.s.l. In addition, BIOVERA-Epi provides information on 1595 measurements of nine morphological and chemical leaf traits from 474 individuals and 102 species. For morphological leaf traits, we provide data on each sampled leaf. For chemical leaf traits, we provide data at the species level per site.
and land-use type. We also provide complementary information for each of the sampled plots and host trees. BIOVERA-Epi contributes to an emerging body of synthetic epiphytes studies combining functional traits and community composition.

New information

BIOVERA-Epi includes data on species frequency and leaf traits from 120 forest plots distributed along an elevational gradient, including six different forest types and three levels of forest-use intensity. It will expand the breadth of studies on epiphyte diversity, conservation and functional plant ecology in the Neotropics and will contribute to future synthetic studies on the ecology and diversity of tropical epiphyte assemblages.

Keywords
elevational gradient, vascular epiphytes, functional traits, forest-use intensity, carbon isotope ratio, nitrogen isotope ratio.

Introduction

Elevational gradients provide a wide range of opportunities for studying the effects of different ecological and evolutionary factors on biodiversity patterns. Steep elevational gradients in temperature, precipitation and other climatic variables usually play a fundamental role in shaping plant diversity (McCain and Grytnes 2010, Peters et al. 2019) and also contribute to linkages between plant traits and environmental conditions (Bruelheide et al. 2018, Keddy 1992). They are also used as proxies for understanding diversity patterns across latitudinal gradients (McCAin and Grytnes 2010), while controlling for species pools and biogeographic history (Ricklefs 2004). Nevertheless, anthropogenic forest disturbance may modify climatic conditions at local and regional scales which, in turn, may affect the response of species, causing upward shifts in the treeline (Cazzolla Gatti et al. 2019), shifting the distribution of plants and animals (McCain et al. 2016) and might be especially threatening for canopy-dwelling life forms, such as vascular epiphytes that are sensitive to changes in air humidity and temperature (Larrea and Werner 2010, Werner and Gradstein 2009, Zotz and Bader 2009). Furthermore, while a growing number of studies shows that climate change affects a wide range of species and ecosystems (Peters et al. 2019, Root et al. 2003, Trisos et al. 2020, Walther et al. 2002), few studies focus on vascular epiphytes and their composition, diversity and functional traits, especially comparing different levels of forest-use intensity.

Functional traits are measurable characteristics of individual plants impacting their growth, reproduction and survival (Violle et al. 2007) and reflect how species interact with their environment (Vesk 2013). Functional traits are widely used to elucidate mechanisms that underpin many ecological processes along vertical and horizontal environmental gradients (e.g. Petter et al. 2015, Bruelheide et al. 2018), but also evolutionary patterns associated
with variation in plant form and function, such as geographic distributions of woody and non-woody species (Díaz et al. 2015). Despite recent progress (e.g. Agudelo et al. 2019, Petter et al. 2015), studies in the field of functional traits of vascular epiphytes are rare, suggesting that our knowledge of the factors that determine the distribution of vascular epiphytes along environmental gradients is similarly limited.

Mexico is a country with high floristic diversity and endemism. Almost 50% of its 23,114 native species of vascular plants are endemic. However, Mexico has lost approximately half of its forest cover in the past 50 years (Barsimantov and Kendall 2012). Furthermore, it has been estimated that about 7.8% of the Mexican vascular flora are epiphytes, 750 of which (569 angiosperms and 181 pteridophytes) are native to Veracruz (Krömer et al. 2020). Vascular epiphytes usually reach their highest diversity in humid tropical forests at mid-elevations (Guzmán-Jacob et al. 2019, Küper et al. 2004, Körmer et al. 2005, Cardelús et al. 2006), (Fig. 3). Moreover, they contribute significantly to ecosystem functioning through biotic interactions and by providing microhabitats for other organisms (Nadkarni 1984, Veneklaas et al. 1990, Zotz 2016).

Even when epiphytes represent about 9% of all vascular plant species (Zotz 2016), they are strongly under-represented in global traits datasets. With this study, we aim at contributing to the percentage of epiphyte species represented in global datasets. We believe that the assemblage of local information in global databases covering species occurrences and functional traits can help to validate ecological theories at larger scales. In particular, the inclusion of an increasing number of studies on functional ecology can foster new frameworks and theories to better understand how biodiversity responds to an increasingly fragmented natural world. Here, we describe a new database on species
distributions and leaf functional traits of vascular epiphytes along gradients of elevation and levels of forest-use intensity.

**General description**

**Purpose:** BIOVERA-Epi includes plot data from an elevational gradient located in the central part of the State of Veracruz, Mexico. Specifically, it contains two distinct, but related datasets: the first dataset includes distribution and plot level frequency information (frequency subplot) for 271 vascular epiphyte species, sampled in 120 20 m × 20 m plots along the elevational gradient, ranging from 0 to 3500 m a.s.l. The second dataset includes measurements of nine morphological and chemical leaf traits for 102 species, 474 individuals and a total of 1595 leaves, which were sampled in 45 plots at three sites along the same elevational gradient. The leaf traits studied were: leaf area, leaf density, specific leaf area (SLA), leaf dry matter content (LDMC), leaf nitrogen content, leaf phosphorus content, leaf carbon content, nitrogen isotope ratio (d15N) and carbon isotope ratio (d13C). For each plot, we also provide geographical coordinates, forest-use intensity (old-growth, degraded, secondary) and elevation. For the surveyed host trees, we report diameter at breast height (DBH), total height (H) and species identity (see Data collection).
Conclusion: The species distribution dataset shows the value of old-growth forest for epiphyte diversity, but also show that degraded and secondary forest, depending on the elevation, may maintain a high species diversity and thus play an important role in conservation planning. Across our 120 study plots, Orchidaceae was the family with more species within the Angiosperms and Polypodiaceae within the Pteridophytes (Fig. 4). Furthermore, the leaf trait dataset shows the leaf trait variation among families, where some families show larger variation than others for both morphological and chemical traits (Figs 5, 6).

Figure 3. Total species number per elevation and forest-use intensity. Number of species of vascular epiphytes recorded at the different levels of forest-use intensity (FUI: OG; old-growth forest, DF; degraded forest and SF; secondary forest) at each of the study sites (0 m, 500 m, 1000 m, 1500 m, 2000 m, 2500 m, 3000 m and 3500 m). At each elevational site, five plots were sampled per FUI. Red points indicate the total number of species per study site.

Figure 4. Total number of species per family recorded in the 120 plots: a) Angiosperms, (b) Pteridophytes. Note the different scales of the y-axes.
Sampling methods

Sampling description:  Sampling design

The elevational gradient spanned from sea level to 3500 m on the eastern slopes of Cofre de Perote, a 4282 m extinct volcano located in the central part of Veracruz State, Mexico (Fig. 1). In this region, the Trans-Mexican volcanic belt and the Sierra Madre Oriental converge, creating complex geological conditions and combining floristic elements from the Nearctic and Neotropics. The climate in the study region ranges from dry and hot in the lowlands (mean annual temperature (MAT): 25°C; mean annual precipitation (MAP): 1222 mm yr$^{-1}$) to humid and temperate at mid-elevations (MAT: 13-19°C; MAP: 2952-1435 mm yr$^{-1}$) and dry and cold at high elevations (MAT: 9°C; MAP: 708 mm yr$^{-1}$; data according to the National Meteorological Service of Mexico 1951-2010). Along the elevational gradient, six main vegetation types are commonly found (Carvajal-Hernández and Krömer 2015): (1) semi-humid deciduous forest at 0-700 m, (2) tropical oak forest at 700-1300 m, (3) humid montane forest at 1300-2400 m, (4) pine-oak forest at 2400-2800 m, (5) pine forest at 2800-3500 m and (6) fir forest at 3500-3600 m.

Figure 5. Morphological leaf traits per family. Distribution of trait measurements across the 102 species and 10 families at 500, 1500 and 2500 m. Each point represents a leaf measurement (n = 1595).
We investigated three levels of forest-use intensity (FUI) that could be consistently found along the entire gradient (following Gómez-Díaz et al. 2017): (1) old-growth forests (OG) encompass mature forests with no or only few signs of logging and other human impacts and are classified as the lowest FUI; (2) degraded forests (DF) are forests with clear signs of past logging, sometimes with ongoing cattle grazing, removal of understorey and/or harvesting of non-timber forest products and are classified as intermediate FUI; and (3) secondary forests (SF) represent forests at an intermediate successional stage 15-25 years after abandonment (based on interviews with local landowners), often with signs of continued human impacts, such as the removal of understorey vegetation, non-timber forest products or partial tree cutting and occasional cattle grazing and are classified as high FUI.

Data collection: species distribution

We selected eight study sites, each separated by ca. 500 m in altitude along the elevational gradient, representing the following elevational ranges: 0-45 m, 610-675 m, 980-1050 m, 1470-1700 m, 2020-2200 m, 2470-2600 m, 3070-3160 m and 3480-3545 m. At each study site, we surveyed vascular epiphytes in five non-permanent 20 m × 20 m
plots for each of the three FUI levels, respectively, yielding a total of 120 plots (Suppl. material 1). We used a Garmin® GPSMAP 60Cx device (Garmin International, Inc. Kansas, USA) to record geographical coordinates and elevation for all plots. Vascular epiphytes were surveyed between July 2014 and May 2015 following the sampling protocol of Gradstein et al. 2003. First, ground-based surveys were conducted in four 10 m × 10 m subplots nested within each plot, to represent epiphyte assemblages in the forest understory up to a height of ~ 6 m (Krömer et al. 2006, Krömer and Gradstein 2016) using collecting poles and binoculars (Flores-Palacios and García-Franco 2001). We selected one mature host tree per plot, based on size, vigour and crown structure for safe canopy access. We climbed from the base to the outer portion of the tree crown using the single-rope climbing technique (Perry 1978) and recorded the presence of vascular epiphyte species in each of the five vertical tree zones according to Johansson (1974), (Fig. 2). Johansson zones are a frequently-used scheme to record and describe the spatial distribution of vascular epiphytes within tree trunks and canopies (Gradstein et al. 2003, Sanger and Kirkpatrick 2016). We recorded diameter at breast height (DBH) and total height for each climbed tree. We recorded the frequency of each species as the sum of incidences in the four nested subplots (frequency subplot, maximum frequency per plot = 4) (Suppl. material 2, Figs 3, 4). We also recorded the frequency of each species as the sum of incidences in the five Johansson zones of the central host tree (frequency.J.zones, maximum frequency = 5).

Data collection leaf trait dataset

In a separate sampling campaign from June to September 2016, leaf trait sampling took place at three of our studied elevational sites (0, 500 and 1500 m a.s.l.). In this field campaign, we aimed to resample as many vascular epiphyte species from the first survey as possible. At each elevation, epiphytes were sampled up to a height of 20 m on one or more trees using the single-rope climbing technique. Epiphytes below 6 m were sampled from the ground using a collecting pole. Functional traits were collected for all vascular epiphyte species classified as holoepiphytes (epiphytes in the strict sense, i.e. living their whole life cycle as epiphytes). In this dataset, we excluded nomadic vines because of their contact with the ground (Zotz 2013). Additionally, we excluded species of the family Cactaceae from trait measurements because stems are their main photosynthetic organs. This dataset differs in the sampling resolution between morphological and chemical traits; morphological traits include leaf measurements per individual at each study site and chemical traits include one measurement (from pooled samples) per species from each study site.

Leaf trait measurements

We collected between one and three leaves per adult individual from three individuals to obtain, if possible, a maximum of 10 leaves per species. We sampled fully expanded leaves without visible signs of herbivory or disease. Collected leaves were rehydrated in a sealed plastic bag and kept cool in a refrigerator at 7°C for a minimum of 8 hours before taking measurements. Leaf area was measured with a portable laser area meter (CI-202, CID Bio Science Inc. U.S.A.). Leaf thickness was measured with an electronic calliper.
Leaves were weighed to obtain fresh weight (balance: A and D GR-202; A and D Company, Tokyo, Japan; precision: 0.1 mg), then oven-dried at 70°C for 48 h or until obtaining a constant dry weight and reweighed to obtain dry weight. For each leaf, we determined the following morphological traits following Prez-Harguindeguy et al. 2013 and Kitajima and Poorter 2010: i) leaf area (LA = mm²), ii) specific leaf area (SLA = leaf area/dry weight; mm²/mg), iii) leaf density (LD = SLA/leaf thickness; g/cm) and iv) leaf dry matter content (LDMC = dry weight/fresh weight; g/g) (Suppl. material 3, Fig. 5). We measured the following leaf chemical traits: i) leaf nitrogen content (leaf nitrogen; %), ii) leaf carbon content (leaf carbon; %), iii) leaf phosphorus content (leaf phosphorus; %), iv) nitrogen isotope ratio (d¹⁵N; ‰), and v) carbon isotope ratio (d¹³C; ‰) (Suppl. material 4, Fig. 6). Dried leaf samples were ground and homogenised using a ball mill. To quantify leaf nitrogen content, leaf carbon content, d¹⁵N and d¹³C, we used an elemental analyser-isotope ratio mass spectrometer (Carlo Erba 1110 EA coupled via a Conflo III to a Delta PLUS, Thermo Electron, Bremen, Germany). We used an internal standard, which is a solution of proline and sucrose with a C:N ratio of 8.8, d¹⁵N of 0.16 (+/−0.15) and d¹³C of -10.20 (+/−0.13). We tested standards every ten samples, after which the IRMS was recalibrated using five certified isotope standards, i.e. IAEA-600, IAEA-N-1, IAEA-N2 and USGS-25. Atmospheric air (AIR) was used for d¹⁵N and the Vienna Pee Dee Belemnite (VPDB) for d¹³C as standards.

\[
d^{13}C (\%) = \left[ \left( \frac{C}{C_{\text{standard}}} \right) / \left( \frac{C}{C_{\text{sample}}} \right) - 1 \right] \times 1000
\]

\[
d^{15}N (\%) = \left[ \left( \frac{N}{N_{\text{standard}}} \right) / \left( \frac{N}{N_{\text{sample}}} \right) - 1 \right] \times 1000
\]

To determine leaf phosphorus, 5 mg of the sample were digested in 200 μl concentrated nitric acid (HNO₃) and 30 μl 30% hydrogen peroxide (H₂O₂) (Huang and Schulte 1985). Leaf phosphorus concentrations were determined colourimetrically (Murphy and Riley 1962). After digestion, 770 μl distilled water was added and the absorption by the molybdenum-phosphorus complex was measured at 710 nm using a UV-VIS spectrophotometer (Specord 50, Analytik Jena, Jena, Germany). Chemical analyses of samples were performed at the University of Oldenburg for phosphorus and at the University of Vienna, Department of Microbiology and Ecosystem Science for nitrogen, d¹⁵N and d¹³C.

**Species identification**

Vouchers from the first field campaign were collected, if possible, in triplicate for preservation as herbarium specimens. These specimens were identified using relevant literature (Croat and Acebey 2015, Espejo-Serna et al. 2005, Hietz and Hietz-Seifert 1994, Mickel and Smith 2004) and by comparison with specimens deposited at the National Herbarium (MEXU) and Universidad Nacional Autónoma de México in Mexico City and the herbarium of the Institute of Ecology (XAL) in Xalapa. Some taxa were sent to the following specialists for identification: Crassulaceae (Dr. Pablo Carrillo-Reyes, Universidad de Guadalajara), Cactaceae (Dr. Miguel Cházar-Bazáñez, Universidad Veracruzana), Bromeliaceae and Orchidaceae (Dr. Adolfo Espejo-Serna and MSc. Ana Rosa López-
Ferrari, Universidad Autónoma de México, Iztapalapa), Pteridophytes (Dr. Alan Smith, UC Berkeley, USA) and Peperomia (Guido Mathieu, Botanic Garden Meise, Belgium). Species not identified to species level were assigned to morphospecies, using the genus or family name followed by the registered elevation and a consecutive number (Suppl. material 5). The collection of species protected by Mexican Law was facilitated by a plant collection permit (NOM-059-SEMARNAT-2010) issued by the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT SGPA/DGVS/2405/14). All scientific names follow The Plant List version 1.1 (2013).

Geographic coverage

Description: Data were collected at eight different sites distributed across an elevational gradient along the eastern slopes of Cofre de Perote mountain, Veracruz State, Mexico.

Coordinates: 19.51 Latitude and -96.15 Longitude Latitude; -96.38 Longitude and 19.59 Latitude Longitude.

Taxonomic coverage

Description: 1) Epiphytes: The species distribution dataset covers 271 epiphyte species belonging to 92 genera and 23 families. The most species-rich families are Orchidaceae (82 species), Polypodiaceae (50), Bromeliaceae (41), Piperaceae (20), Cactaceae (14) and Araceae (12). A total of 72.2% of the sampled epiphyte individuals could be identified to species level, while another 26.1% were identified to genus level and 1.7% to family level. The trait dataset includes measurements for 1595 leaves from 474 individuals belonging to 102 species in 10 families. In total, most species were orchids (42.7%), followed by ferns (28.1%) and bromeliads (20.4%).

2) Phorophytes: The 120 climbed host trees belong to 32 tree species distributed in 25 genera and 21 families. Tree identification to the species level was possible in 53% of the cases, while another 44% were identified to genus level and 3% to family level.

Usage licence

Usage licence: Open Data Commons Attribution License

Data resources

Data package title: BIOVERA-Epi, a new database on species diversity, community composition and leaf functional traits of vascular epiphytes along an elevational gradient in Mexico

Number of data sets: 5
**Data set name:** Plot table

**Description:** Location of the 120 forest plots along the elevational gradient at the eastern slopes of Cofre de Perote mountain, Veracruz, Mexico (Suppl. material 1)

| Column label      | Column description                                           |
|-------------------|--------------------------------------------------------------|
| Plot_ID           | ID of each plot                                              |
| Vegetation        | Vegetation type                                              |
| FUI               | Forest-use intensity                                         |
| Site              | Name of the study site                                       |
| Elevation.precise | Metres above sea level                                       |
| Latitude          | Geographic coordinate                                        |
| Longitud          | Geographic coordinate                                        |
| Tree.name         | Scientific name of the central tree                          |
| DBH               | Diameter at breast height in centimetres                     |
| Tree.height       | Height of the tree in metres                                 |

**Data set name:** Distribution table

**Description:** Distribution data of 271 vascular epiphyte species at each plot along the elevational gradient and three levels of forest-use intensity (n = 5 plots per forest-use intensity within each elevation) (Suppl. material 2).

| Column label       | Column description                                                                 |
|--------------------|------------------------------------------------------------------------------------|
| Plot_ID            | ID of each plot                                                                    |
| Sp.code            | Code for each scientific species name                                              |
| Frequency          | The sum of incidences in the four nested subplots (maximum frequency per plot = 4) |
| JZone1             | Johansson zone 1                                                                   |
| JZone2a            | Johansson zone 2a                                                                  |
| JZone2b            | Johansson zone 2b                                                                  |
| JZone3             | Johansson zone 3                                                                   |
| JZone4             | Johansson zone 4                                                                   |
| JZone5             | Johansson zone 5                                                                   |
| Frequency.J.zones  | The sum of incidences in the Johansson zones (maximum frequency = 5)               |

**Data set name:** Morphological leaf traits
Description: Single leaf trait measurements (leaf area, leaf density, specific leaf area and leaf dry matter content) per 474 individuals of 102 species and a total of 1595 leaves (Suppl. material 3).

| Column label | Column description |
|--------------|--------------------|
| Site         | Name of the study site |
| FUI          | Forest-use intensity |
| Sp.code      | Code for each scientific species name |
| Ind.number   | Number of the individual |
| Leaf.number  | Number of the leaf |
| LA           | Leaf area |
| LD           | Leaf density |
| SLA          | Specific leaf area |
| LDMC         | Leaf dry matter content |

Data set name: Chemical leaf traits

Description: Chemical leaf trait measurements (leaf nitrogen content, leaf phosphorus content, leaf carbon content, nitrogen isotope ratio and carbon isotope ratio) per 102 species (Suppl. material 4).

| Column label    | Column description            |
|-----------------|-------------------------------|
| Site            | Name of the study site        |
| FUI             | Forest-use intensity          |
| Sp.code         | Code for each scientific species name |
| Leaf nitrogen   | Leaf nitrogen content         |
| Leaf carbon     | Leaf carbon content           |
| Leaf phosphorus | Leaf phosphorus content       |
| Delta15N        | Nitrogen isotope ratio        |
| Delta13C        | Carbon isotope ratio          |

Data set name: Species names

Description: Species scientific name and its corresponding family and species code (Suppl. material 5).

| Column label | Column description |
|--------------|--------------------|
Table 1.
Data documentation with information that describes the content and structure of each of the previous tables. The source of standardisation for each term used is provided in the Standardized according to column based on the Darwin Core glossary and the Thesaurus of Plant Characteristics (TOP). The name of the standardised term in the Standardized Term column. The term used in the present study in the Term in this study column. A definition is provided in the Definition column (following the Darwin Core, Thesaurus of Plant Characteristics or the given reference) and, if applicable, the unit of measurement in the Unit column.

| Standardised according to | Standardised Term | Term in this study | Definition | Unit |
|--------------------------|-------------------|--------------------|------------|------|
| Darwin Core              | Family            | Family             | The full scientific name of the family in which the taxon is classified. |      |
| Darwin Core              | Habitat           | Vegetation         | A category or description of the habitat in which the Event occurred. |      |
| Darwin Core              | locationID        | Plot_ID            | An identifier for the set of location information (data associated with dcterms: Location). May be a global unique identifier or an identifier specific to the dataset. |      |
| Darwin Core              | Locality          | Site               | The specific description of the place. Less specific geographic information can be provided in other geographic terms (higherGeography, continent, country, stateProvince, county, municipality, waterBody, island, islandGroup). This term may contain information modified from the original to correct perceived errors or standardise the description. |      |
| Darwin Core              | organismID        | Sp.code            | An identifier for the Organism instance (as opposed to a particular digital record of the Organism). May be a globally unique identifier or an identifier specific to the dataset. |      |
| Standardised according to | Standardised Term | Term in this study | Definition | Unit |
|--------------------------|-------------------|-------------------|------------|------|
| Darwin Core              | organismQuantityType | Frequency subplot Frequency J.zones | The type of quantification system used for the quantity of organisms. | |
| Darwin Core              | scientificName    | Species name / Tree name | The full scientific name, with authorship and date information, if known. When forming part of an Identification, this should be the name in lowest level taxonomic rank that can be determined. This term should not contain identification qualifications, which should instead be supplied in the IdentificationQualifier term. Note: we used a mixture of valid scientific names and informal names for plants not identified to the species level, therefore species names are not strictly Darwin Core-compliant. | |
| Darwin Core              | verbatimElevation | Elevation | The original description of the elevation (altitude, usually above sea level) of the Location. | metres above sea level (m a.s.l.) |
| Darwin Core              | DecimalLatitude   | Latitude | The geographic latitude (in decimal degrees, using the spatial reference system given in geodeticDatum) of the geographic centre of a Location. Positive values are north of the Equator; negative values are south of it. Legal values lie between -90 and 90, inclusive. | |
| Darwin Core              | DecimalLongitude  | Longitude | The geographic longitude (in decimal degrees, using the spatial reference system given in geodeticDatum) of the geographic centre of a Location. Positive values are east of the Greenwich Meridian; negative values are west of it. Legal values lie between -180 and 180, inclusive. | |
| Functional Diversity thesaurus | Plant height trait | Height | the height (PATO:height) of a whole plant (PO:whole plant) | m |
| Functional Diversity thesaurus | Leaf density | Lamina density (LD) | leaf dry mass per leaf volume | g/cm³ |
| Functional Diversity thesaurus | Leaf area | Leaf area (LA) | the area (PATO:area) of a leaf (PO:leaf) in the one sided projection | mm² |
| Functional Diversity thesaurus | Leaf dry matter content | Leaf dry matter content (LDMC) | the ratio of the dry mass of a leaf (TOP:leaf dry mass) to its water saturated fresh mass | g g⁻¹ |
| Standardised according to | Standardised Term | Term in this study | Definition | Unit |
|---------------------------|-------------------|-------------------|------------|------|
| Functional Diversity thesaurus | Specific leaf area | Specific Leaf Area (SLA) | the ratio of the area of a leaf (TOP:leaf area) to its dry mass (TOP:leaf dry mass) | mm² mg⁻¹ |
| Functional Diversity thesaurus | Leaf nitrogen content per leaf dry mass | Leaf nitrogen content | The ratio of the quantity of nitrogen of a leaf per unit dry mass. | % |
| Functional Diversity thesaurus | Leaf carbon content per leaf dry mass | Leaf carbon content | The ratio of the quantity of carbon of a leaf per unit dry mass. | % |
| Functional Diversity thesaurus | Leaf phosphorus content per leaf dry mass | Leaf phosphorus content | The ratio of the quantity of phosphorus of a leaf per unit dry mass. | % |
| Craine et al. (2009) | Nitrogen isotope ratio (d¹⁵N;‰) | Nitrogen isotope ratio (d¹⁵N;‰) | The ratio of ¹⁵N to ¹⁴N of a leaf. | ‰ |
| Dawson et al. (2002) | Carbon isotope ratio (d¹³C;‰) | Carbon isotope ratio (d¹³C;‰) | The ratio of ¹³C to ¹²C of a leaf. | ‰ |
| This study | Forest-use intensity. (OG - old-growth forest, DF - degraded forest, SF - secondary forest) | | A level of forest fragmentation, subjected to ongoing disturbance and/or deforestation. | |
| This study | DBH | Diameter at breast height | cm |

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**Author contributions**

V.G.J and H.K conceived the main idea with input from D.C; V.G.J collected the data; and P.W revised the data. All authors made substantial contributions to the writing and editing of the manuscript.
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Supplementary materials

**Suppl. material 1: Plot table** [doi](https://doi.org/10.1007/978-3-319-39237-0)

**Authors:** Valeria Guzmán-Jacob, Patrick Weigelt, Dylan Craven, Gerhard Zotz, Thorsten Krömer & Holger Kreft  
**Data type:** Plot information  
**Brief description:** Location of the 120 forest plots along the elevational gradient at the eastern slopes of Cofre de Perote mountain, Veracruz, Mexico.  
[Download file](11.68 kb)

**Suppl. material 2: Distribution table** [doi](https://doi.org/10.1007/978-3-319-39237-0)  

**Authors:** Valeria Guzmán-Jacob, Patrick Weigelt, Dylan Craven, Gerhard Zotz, Thorsten Krömer & Holger Kreft  
**Data type:** Distribution data  
**Brief description:** Distribution data of 271 vascular epiphyte species at each plot along the elevational gradient and three levels of forest-use intensity (n = 5 plots per forest-use intensity within each elevation).  
[Download file](52.20 kb)

**Suppl. material 3: Morphological leaf traits** [doi](https://doi.org/10.1007/978-3-319-39237-0)

**Authors:** Valeria Guzmán-Jacob, Patrick Weigelt, Dylan Craven, Gerhard Zotz, Thorsten Krömer & Holger Kreft  
**Data type:** Leaf traits  
**Brief description:** Single leaf trait measurements (leaf area, leaf density, specific leaf area and leaf dry matter content) per 474 individuals of 102 species and a total of 1595 leaves.  
[Download file](98.16 kb)

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- Zotz G (2016) Plants on plants – The biology of vascular epiphytes. Fascinating Life Sciences [https://doi.org/10.1007/978-3-319-39237-0](https://doi.org/10.1007/978-3-319-39237-0)
Suppl. material 4: Chemical leaf traits

Authors: Valeria Guzmán-Jacob, Patrick Weigelt, Dylan Craven, Gerhard Zotz, Thorsten Krömer & Holger Kreft
Data type: Chemical leaf traits
Brief description: Chemical leaf trait measurements (leaf nitrogen content, leaf phosphorus content, leaf carbon content, nitrogen isotope ratio and carbon isotope ratio) per 102 species.
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Suppl. material 5: Species names

Authors: Valeria Guzmán-Jacob, Patrick Weigelt, Dylan Craven, Gerhard Zotz, Thorsten Krömer & Holger Kreft
Data type: species list
Brief description: Species scientific name and its corresponding family and species code.
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