



TRY plant trait database – enhanced coverage and open access

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Abstract

Plant traits—the morphological, anatomical, physiological, biochemical and phenological characteristics of plants—determine how plants respond to environmental factors, affect other trophic levels, and influence ecosystem properties and their benefits and detriments to people. Plant trait data thus represent the basis for a vast area of research spanning from evolutionary biology, community and functional ecology, to biodiversity conservation, ecosystem and landscape management, restoration, biogeography and earth system modelling. Since its foundation in 2007, the TRY database of plant traits has grown continuously. It now provides unprecedented data coverage under an open access data policy and is the main plant trait database used by the research community worldwide. Increasingly, the TRY database also supports new frontiers of trait-based plant research, including the identification of data gaps and the subsequent mobilization or measurement of new data. To support this development, in this article we evaluate the extent of the trait data compiled in TRY and analyse emerging patterns of data coverage and representativeness. Best species coverage is achieved for categorical traits—almost complete coverage for 'plant growth form'. However, most traits relevant for ecology and vegetation modelling are characterized by continuous intraspecific variation and trait–environment relationships. These traits have to be measured on individual plants in their respective environment. Despite unprecedented data coverage, we observe a humbling lack of completeness and representativeness of these continuous traits in many aspects. We, therefore, conclude that reducing data gaps and biases in the TRY database remains a key challenge and requires a coordinated approach to data mobilization and trait measurements. This can only be achieved in collaboration with other initiatives.

KEYWORDS

data coverage, data integration, data representativeness, functional diversity, plant traits, TRY plant trait database

A list of authors and their affiliations appears in the Appendix.

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1 | INTRODUCTION

Plant traits—the morphological, anatomical, physiological, biochemical and phenological characteristics of plants measurable at the individual plant level (Violle et al., 2007)—reflect the outcome of evolutionary and community assembly processes responding to abiotic and biotic environmental constraints (Valladares, Gianoli, & Gomez, 2007). Traits and trait syndromes (recurrent coordinated expressions of multiple traits) determine how plants perform and respond to environmental factors (Grime, 1974; Wright et al., 2017), affect other trophic levels (Lavorel et al., 2013; Loranger et al., 2012, 2013), and provide a link from species richness to functional diversity, which influences ecosystem properties and derived benefits and detriments to people (Aerts & Chapin, 2000; Díaz et al., 2004, 2007; Garnier & Navas, 2012; Grime, 2001, 2006; Lavorel et al., 2015; Lavorel & Garnier, 2002). In the context of the Global Earth Observation Biodiversity Observation Network (GEO BON) species traits are considered an Essential Biodiversity Variable to inform policy about biodiversity change (Kissling et al., 2018; Pereira et al., 2013). A focus on traits and trait syndromes, therefore, provides a crucial basis for quantitative and predictive ecology, ecologically informed landscape conservation and the global change science–policy interface (Díaz et al., 2016; McGill, Enquist, Weiher, & Westoby, 2006; Westoby & Wright, 2006). To fully realize this potential, plant trait data not only need to be available and accessible in appropriate quantity and quality but also representative for the scales of inference and research questions (König et al., 2019). Here we analyse where the TRY plant trait database stands with respect to coverage and representativeness after 12 years of operation. We further review the mechanisms and emergent dynamics helping to increase both.

1.1 | A global database of plant traits—A brief history

Before the foundation of TRY in 2007, several research groups had already developed major plant trait databases with remarkable success, e.g. the Ecological Flora of the British Islands

(Fitter & Peat, 1994), the Seed Information Database (Royal Botanical Gardens KEW, 2008), BIOPOP (Poschlod, Kleyer, Jackel, Dannemann, & Tackenberg, 2003), GLOPNET (Wright et al., 2004), BioFlor (Klotz, Kühn, & Durka, 2002, 2017), LEDA (Kleyer et al., 2008), BROT (Paula et al., 2009), USDA PLANTSdata (Green, 2009) and BRIDGE (Baraloto, Timothy Paine, Patino, et al., 2010). However, these databases were either focused on particular regions (BioFlor, LEDA, BIOPOP, BROT, USDA Plants, Ecological Flora of the British Islands, BRIDGE) or specific traits (GLOPNET, SID). A ‘database of databases’ was in discussion for some time, but it had been impossible to secure long-term funding for such a project. Finally, at a joint workshop of the International Geosphere-Biosphere Program (IGBP) and DIVERSITAS, the TRY database (TRY—not an acronym, rather a statement of sentiment; <https://www.try-db.org>; Kattge et al., 2011) was proposed with the explicit assignment to improve the availability and accessibility of plant trait data for ecology and earth system sciences. The Max Planck Institute for Biogeochemistry (MPI-BGC) offered to host the database and the different groups joined forces for this community-driven program. Two factors were key to the success of TRY: the support and trust of leaders in the field of functional plant ecology submitting large databases and the long-term funding by the Max Planck Society, the MPI-BGC and the German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, which has enabled the continuous development of the TRY database.

At the time of the foundation of TRY, data sharing was not yet a common practice in ecology (Kattge et al., 2011; Reichman, Jones, & Schildhauer, 2011). This was an important obstacle for scientific progress. The first important step of the initiative was, therefore, to jointly develop a data sharing policy. This was based on permission of data set owners and a ‘give-and-take’ system: to keep the TRY database growing, the right to request data was coupled to data contribution. Exceptions were data requests for vegetation modelling projects, as modellers typically do not own plant trait data. At an open workshop in 2013, the members decided to offer the opportunity to make data publicly available and trait data contribution was no longer a requirement for data access. In 2014, this decision was implemented in the TRY Data Portal and was immediately followed by an ‘explosion’ of the number of data requests (Figure 1a): TRY

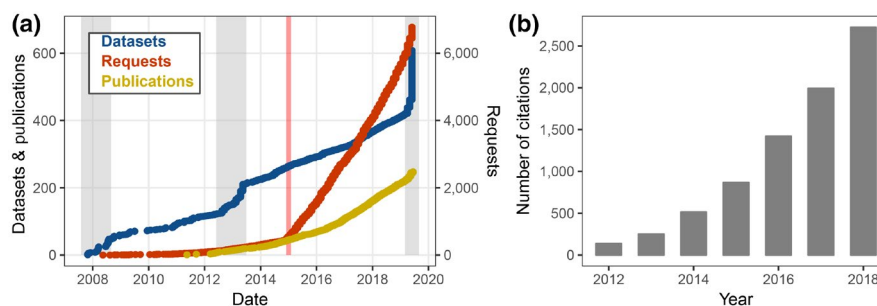


FIGURE 1 TRY performance statistics, status 1 July 2019. (a) Cumulative numbers of data sets and publications (left axis) and data requests (right axis); light grey vertical bars indicate calls for data contribution; the red vertical bar indicates the date of opening TRY to the public. (b) Number of citations for publications using trait data via TRY (Google Scholar)

started to serve more than 1,000 requests per year, so that as of July 2019, about 700 million trait records accompanied by 3 billion ancillary data have been released for 7,000 requests, submitted by more than 5,000 registered users. Since 2019, the TRY database is open access under a Creative Commons Attribution license (CC BY 4.0, <https://creativecommons.org/licenses/by/4.0>): anyone can use and redistribute data received via TRY under the only condition of appropriate citation of the TRY database and the references of contributing data sets. Restriction of data access now is the exception and limited to 2(+2) years, after which the data sets become public.

Since 2014, the TRY Data Portal (<https://www.try-db.org/TryWeb/dp.php>) has become the central access point of the TRY database: the portal organizes data uploads, searches and requests, and enables interaction between data contributors, management and users. The portal provides an account for each data set custodian (the individual who directly contributed the data set), which provides precise bookkeeping about the use of his or her trait data via TRY. The TRY Data Portal also provides a link to the TRY File Archive (<https://www.try-db.org/TryWeb/Data.php>), which offers climate and soil data for TRY measurement sites, standardized

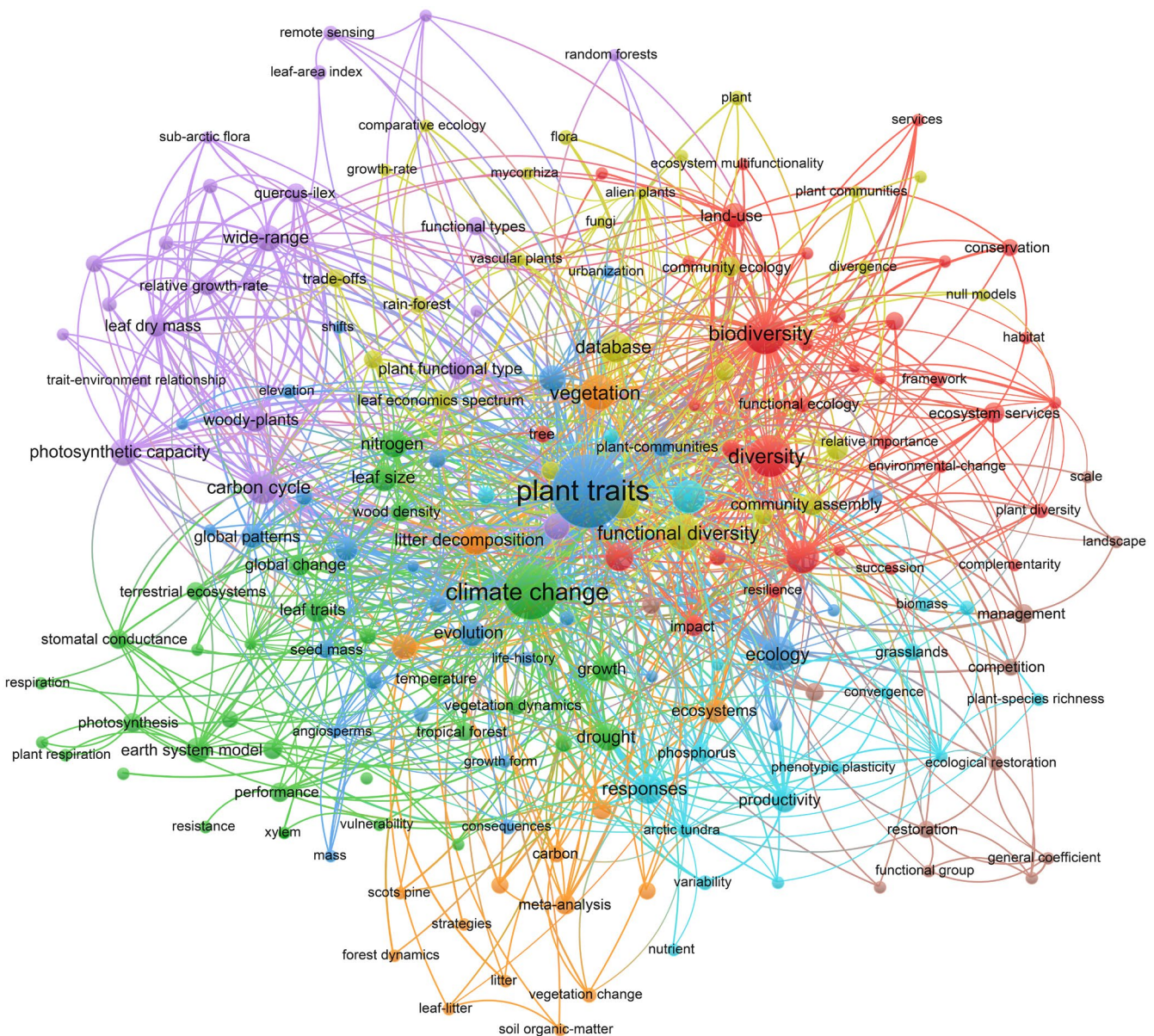


FIGURE 2 Cluster analysis of keywords from peer-reviewed publications using plant trait data via TRY. The size of the circles and letters indicates the frequency of the keywords, colours indicate the eight clusters around the central keywords (from largest to smallest cluster): biodiversity (red), climate change (dark green), plant traits (dark blue), functional diversity (light green), carbon cycle (violet), community (light blue), vegetation (orange) and environmental filtering (brown). The analysis is based on 190 publications with DOIs compiled by ISI Web of Science (<https://clarivate.com/products/web-of-science>). The analysis was performed with VOSviewer version 1.6.11 (<https://www.vosviewer.com>) using the default settings and only minor editing of selected terms. The clustering technique used by VOSviewer is discussed by Waltman, van Eck, and Noyons (2010). Due to limited space not all central keywords of small clusters are displayed. Material to display the results in detail using the VOSviewer software is provided in the Supporting Information

categorical traits relevant to attribute species to plant functional types (PFTs), and provides the opportunity to publish plant trait data sets and receive a DOI.

Trait data via TRY contributed to at least 250 scientific applications and publications (Figure 1a), among these 202 peer-reviewed publications in 83 different scientific journals, covering a broad range of topics, from 'Landscape and Urban planning' to 'Geoscientific Model Development'. Twenty publications were directly related to vegetation model development, while 230 were empirical studies. A cluster analysis of keywords from the peer-reviewed publications shows eight clusters around the central keywords biodiversity, climate change, plant traits, functional diversity, carbon cycle, community, vegetation and environmental filtering (Figure 2). Citations of publications using trait data via TRY have increased exponentially, leading to about 10,000 citations and an h-factor of 46 for the TRY database (Figure 1b).

During 12 years of development, versions 1–5 of the TRY database have been released with an increasing number of contributed data sets and trait records (Tables 1 and 2; Figure 1a). Currently, TRY is working on version 6. As of July 2019, the TRY database comprised 588 data sets from 765 data contributors (Table A1). The dynamics of the number of data sets in TRY indicates an increasing success of calls to the scientific community for data

contribution in 2007, 2013 and 2019. When the manuscript was submitted, data contributions responding to the call in 2019 were not yet fully integrated into the TRY database. Therefore all analyses presented in this paper are based on versions 1–5 of the TRY database (Table 1). TRY version 5, released on 26 March 2019, contains 387 data sets providing 11.8 million trait records, accompanied by 35 million ancillary data, for 2,091 traits and 280,000 plant taxa, mostly at the species level (Table 2). Data coverage is still driven by a few large (often integrated) databases, but increasingly small data sets (mostly primary data) contribute to the overall coverage (Figure 3a). Plant trait data in TRY can be traced to >10,000 original references. This highlights the breadth of data integrated in the TRY database and its nature as database of databases, a 'second generation of data pooling' (M. Westoby, personal communication, August 24, 2009).

We now observe a tendency that new trait-based research is increasingly planned against the background of the TRY database. Coverage and availability of trait data in TRY stimulate trait-based research, which then often leads to the identification of unexpected data gaps. This motivates data mobilization and/or new measurements, which improve the availability of plant trait data for the research community, and—if contributed to TRY—help the database grow. Examples for such a 'feed-forward data integration loop' are provided in Box 1.

To support this process, in this article, we take stock of the data compiled in the TRY database and present emerging patterns of data coverage and representativeness with a focus on the identification of principal and systematic gaps. Finally, we discuss ways forward and the potential future role of the TRY initiative for the research community.

TABLE 1 TRY database versions

| Version | Data acquisition and import | Data release | Status |
|---------|-----------------------------|--------------------------|---------------------------|
| 1 | October 2007–July 2009 | October 2008–April 2011 | Restricted, give-and-take |
| 2 | July 2009–April 2011 | April 2011–December 2014 | Restricted, give-and-take |
| 3 | April 2011–April 2014 | December 2014–July 2017 | Optionally open access |
| 4 | April 2014–February 2017 | July 2017–March 2019 | Optionally open access |
| 5 | February 2017–March 2019 | March 2019– | Open access |
| 6 | March 2019– | | Open access |

TABLE 2 Data coverage from TRY version 1 to 5

| Version | Trait records | Entities | Trait records per entity | Traits | Average number of records per trait | Species | Geo-referenced trait records | Sites | Ancillary data |
|---------|---------------|-----------|--------------------------|--------|-------------------------------------|---------|------------------------------|--------|----------------|
| 1 | 2,077,640 | 1,110,303 | 1.87 | 661 | 3,143 | 57,591 | 682,108 | 8,276 | 4,439,783 |
| 2 | 2,376,231 | 1,207,669 | 1.97 | 743 | 3,198 | 65,746 | 871,582 | 8,513 | 4,758,033 |
| 3 | 5,783,482 | 2,246,967 | 2.57 | 1,149 | 5,033 | 92,146 | 2,201,242 | 11,844 | 11,834,960 |
| 4 | 7,162,252 | 3,435,238 | 2.08 | 1,981 | 3,615 | 141,461 | 2,978,776 | 16,480 | 14,644,354 |
| 5 | 11,850,781 | 5,102,993 | 2.37 | 2,091 | 5,668 | 279,875 | 4,952,839 | 20,953 | 35,516,190 |

2 | MATERIALS AND METHODS

2.1 | Plant trait data in the TRY database

Plant traits can be classified as categorical (qualitative and ordinal) or quantitative (continuous) traits (Kattge et al., 2011). Some traits are rather stable within species (mostly categorical traits), and some of these can be systematically compiled from species checklists and floras (e.g. Weigelt, König, & Kreft, 2019).

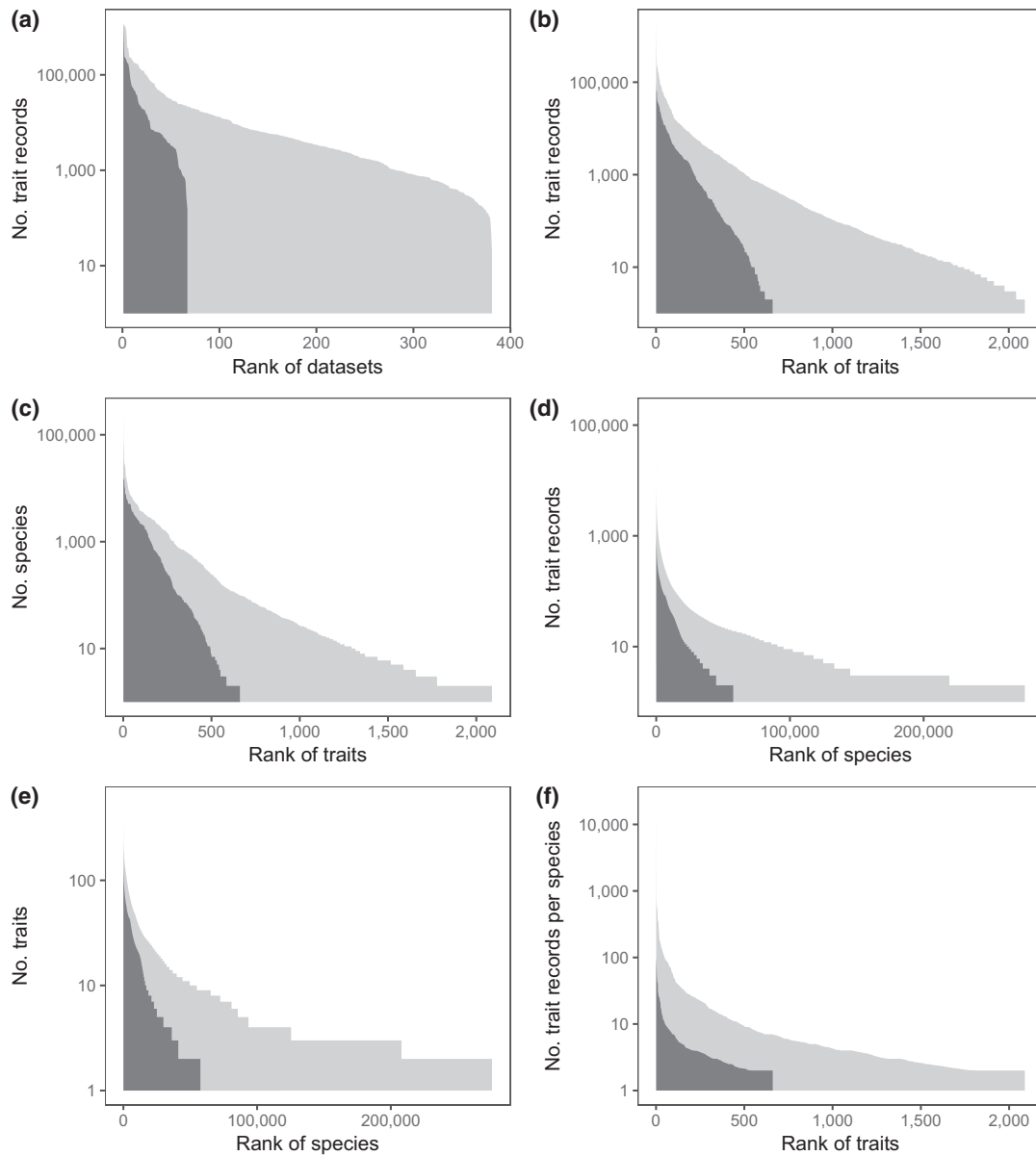


FIGURE 3 Trait data coverage of TRY version 1 (dark grey) and 5 (light grey). Data coverage in TRY is characterized by long-tailed rank-size distributions: (a) rank of dataset by trait records, (b) rank of traits by number of records, (c) rank of traits by number of species, (d) rank of species by trait records, (e) rank of species by number of traits, (f) rank of traits by number of records per species (averaged by trait). Note that y-axes are log-scaled

However, most traits relevant to ecology and earth system sciences are characterized by intraspecific variability and trait–environment relationships (mostly quantitative traits). Both kinds of traits are compiled in the TRY database, but with a focus on continuous traits. These traits have to be measured on individual plants in their particular environmental context. Each such trait measurement has high information content as it captures the specific response of a given genome to the prevailing environmental conditions. The collection of these quantitative traits and their essential environmental covariates is important but often tedious and expensive: researchers need to travel to the objects of interest—often to remote

places—or they need to develop experiments creating specific environmental conditions. While trait measurements themselves may be relatively simple, the selection of the adequate entity (e.g., a representative plant in a community, or a representative leaf on a tree) and obtaining the relevant ancillary data (taxonomic identification, soil and climate properties, disturbance history, etc.) may require sophisticated instruments and a high degree of expertise and experience. Besides, these data are most often individual measurements with a low level of automation. This not only limits the number of measurements but also causes a high risk of errors, which need to be corrected a posteriori, requiring substantial human work. The

BOX 1 Examples for the 'feed-forward data integration loop' observed in the context of the TRY database

- Iversen et al. (2017) indicated that in the TRY database only 1% of trait records were related to roots. This motivated the development of the Fine-Root Ecology Database (FRED) specializing in the mobilization of fine-root trait records from the literature (Iversen et al., 2017). In the meantime, the first versions of the FRED database have been contributed to the TRY database. The improved number and availability of trait data on roots allowed for a project on root trait functionality in a whole-plant context (https://www.idiv.de/en/sdiv/working_groups/wg_pool/sroot.html), which motivated additional mobilization of root trait data.
- The promising coverage of plant trait data from tundra regions in the TRY database encouraged the inclusion of plant traits in an analysis of tundra ecosystem change, scaling shrub expansion from site to biome (Bjorkman, Myers-Smith, Elmendorf, Normand, R uger, et al., 2018). In the context of the project, a large number of additional trait data were mobilized by the Tundra Traits Team (Bjorkman, Myers-Smith, Elmendorf, Normand, Thomas, et al., 2018), which have recently been contributed to the TRY database.
- Moreno-Mart nez et al. (2018) estimated the worldwide variation of several leaf traits to improve the parameterization of global vegetation models and remote sensing approaches predicting, for example, gross primary productivity. Due to the low representation of traits for crop species in the TRY database, they could not provide estimates for major agricultural regions (see white spots in figure 5 of Moreno-Mart nez et al., 2018). The identification of these gaps motivated mobilization of trait data for crop plants and agro-ecosystems (Engemann et al., 2016; Martin, Hale, et al., 2018; Martin & Isaac, 2015), which were then contributed to the TRY database.
- Trait data on plant growth form (tree, shrub, herb, etc.) were compiled by TRY, extended and consolidated in the context of the BIEN initiative (Engemann et al., 2016; Enquist, Condit, Peet, Schildhauer, & Thiers, 2016) and then contributed to the development of the GIFT database (Weigelt, K nig, & Kreft, 2019). The upgraded plant growth form data were contributed again to TRY.
- Plant species richness is unequally distributed across the globe, with the highest species richness observed in the tropics (von Humboldt, 1817). The highest numbers of species with measurements in TRY are also found in the tropics, but as well the largest gap relative to reported species richness: less than 1% of estimated species richness is represented in TRY (Jetz et al., 2016). This principal and systematic mismatch of data coverage and representativeness has contributed to motivate the development of a 'global biodiversity observatory' of in situ measurements and space-borne remote sensing that tracks temporal changes in plant functional traits around the globe to fill critical knowledge gaps, aid in the assessment of global environmental change and improve predictions of future change (Jetz et al., 2016).
- TRY is involved in the sPlot initiative to establish a global vegetation-plot database (www.idiv.de/en/splot.html). sPlot supports the analysis of plant communities across the world's biomes by combining vegetation-plot data with traits from the TRY database (Bruehlheide et al., 2019). This has resulted, for the first time, in global analyses of plant functional community data (Bruehlheide et al., 2018). In contrast to single species measurements or trait values aggregated in grid cells, using vegetation-plot data allows understanding the role of traits for biotic interactions and community assembly processes. In turn, trait data measured in the context of sPlot are contributed to TRY.

integration of these data from different sources into a consistent data set requires a carefully designed workflow with sufficient data quality assurance (see Box 2: TRY data integration workflow).

These measurements of quantitative traits are single sampling events for particular individuals at certain locations and times, which preserve relevant information on intraspecific variation and provide the necessary detail to address questions at the level of populations or communities. Within individual field campaigns or experiments, researchers often aim to measure complete sets of these data: all traits of interest for all individuals or species in the analyses. However, across studies and data sets and at large scales, the coverage of these data shows major gaps, which provide major challenges concerning data completeness and representativeness (K nig et al., 2019).

3 | RESULTS

3.1 | Data coverage

Compared to TRY database version 1 and the state reported in Kattge et al. (2011), TRY version 5 has substantially grown with respect to the number of trait records, traits, species, entities, geo-referenced measurement sites and ancillary data (Table 2).

3.2 | Trait records and entities

The numbers of trait records (individual trait measurements) and entities (individual plants or plant organs on which the measurements have been taken) increased by a factor of about 6 for trait

BOX 2 The data integration workflow for the TRY database version 5

Data acquisition

In the context of the TRY initiative, data acquisition so far relies on active contributions by the community—data sets need to be sent by email or uploaded at the TRY website (<https://www.try-db.org/TryWeb/Submission.php>). From time to time (2007, 2013 and 2019), TRY sends out calls for data contributions to the community. However, so far there has been no systematic screening of public data repositories like DRYAD or PANGAEA for plant trait data.

Data integration

The basic principle of data integration in the TRY database is to preserve the original trait and ancillary data and annotate these with complementing and consolidated information. Data integration consists of three major components: data consolidation, complementation and quality assurance. We here provide a brief overview; a detailed description can be found in Supporting Information and on the TRY website (<https://www.try-db.org/TryWeb/Database.php>).

Data consolidation

The data structure is transformed into the entity-attribute-value (EAV) model and the OBOE schema (Madin et al., 2007) as used in the TRY database: a long table of trait records and ancillary data where all trait records and ancillary data measured on the same entity (individual plant or plant organ on which the measurements have been taken) are linked by a unique identifier. Plant taxonomy is consolidated using the Taxonomic Names Resolution Service (TNRS; <http://tnrs.iplantcollaborative.org>; Boyle et al., 2013) with a taxonomic backbone based on the Plant List (<http://www.theplantlist.org>), Missouri Botanical Garden's Tropicos database (<http://www.tropicos.org>), the Global Compositae Checklist (<https://www.compositae.org/checklist>), the International Legume Database and Information Service (<http://www.ildis.org>), and USDA's Plants Database (<http://plants.usda.gov>). Trait names and definitions are consolidated across all data sets, based on the TOP thesaurus of plant characteristics (Garnier et al., 2017) or the plant trait handbook (Pérez-Harguindeguy et al., 2013), if possible. For continuous traits with more than 1,000 records, units are standardized and trait values recalculated. Most relevant ancillary data—geo-references, measurement date, exposition, maturity, and health—are consolidated across data sets and, if possible, to external standards, like the decimal representation of latitude and longitude, or ISO 8601 (YYYY-MM-DD) for the date.

Data complementation

After consolidation, additional trait values are derived from contributed trait data where possible; for example, leaf nitrogen content per area from leaf nitrogen content per dry mass and specific leaf area (SLA) if both were measured on the same entity.

Data quality assurance

Continuous traits with >1,000 records in the database are subject to a three-step process: (a) Systematic errors, like a wrong unit for a given trait for all records of a specific data set, are identified across data sets with semi-automated procedures and corrected. (b) Z-scores are calculated for each standardized trait value to indicate outliers and potential errors of individual trait records. (c) Duplicate trait records are identified based on consolidated trait names, taxonomy, units and values. Geo-references are checked against the ESA CCI Land Cover Map of Global Water Bodies (<https://www.esa-landcover-cci.org/?q=node/162>) to assure at least that the provided locations are on land.

After a data set has been integrated into the TRY database, the data set custodian is asked for feedback; that is, whether consolidated trait names are appropriate and consolidated values correct. Data are reformatted for data release and format errors (i.e. tabs and line breaks in database cells) are corrected. Finally, the original and consolidated data (including flags for outliers and duplicates) are released on request as tab-delimited text files.

records and 5 for entities from TRY version 1 (2.1 million trait records measured on 1.1 million entities) to TRY version 5 (11.8 million trait records measured on 5.0 million entities). The average number of trait records per entity increased from 1.9 to 2.4 (Table 2).

3.3 | Traits

The number of traits has grown steadily from TRY version 1 to 5, apart from a steep step from TRY version 3 to 4 (Table 2). This step was caused by the contribution of the FRED database, which added

about 700 new traits for roots. Data coverage across traits is characterized by long-tail distributions: a small number of traits is well covered by records and species, while the majority of traits has only very low coverage of records and species (Figure 3). However, the number of continuous traits with more than 1,000 records (which are subject to intense data quality assurance during integration) has increased from about 200 in TRY version 1 to 600 in TRY version 5 (Figure 3b). The number of traits with data for more than 100 species has increased from 300 to 700 (Figure 3c). In parallel, the number of records per trait and species ('intraspecific retakes') has increased from almost zero traits with on average more than 10 records per

trait–species combination in TRY version 1 to more than 500 in TRY version 5 (Figure 3f).

The traits with the best species coverage in TRY version 5 are mostly categorical (Table 3). The categorical traits used for the

TABLE 3 Traits with best species coverage. The 30 traits covering the highest number of species in the TRY database version 5 and the number of species represented for these traits in TRY version 1. Data type: cat = categorical; con = continuous. Sorted by the number of species in TRY 5

| Trait name | Data type | Number of species | |
|---|-----------|-------------------|---------|
| | | TRY 1 | TRY 5 |
| Plant growth form | cat | 31,327 | 263,357 |
| Plant woodiness | cat | 14,628 | 79,298 |
| Leaf type | cat | 7,934 | 62,904 |
| Leaf compoundness | cat | 7,998 | 57,922 |
| Leaf photosynthesis pathway | cat | 15,609 | 37,315 |
| Leaflet number per leaf | con | 0 | 30,296 |
| Plant height vegetative | con | 13,899 | 28,944 |
| Leaf phenology type | cat | 14,622 | 28,514 |
| Species tolerance to frost | cat | 2,180 | 28,122 |
| Seed dry mass | con | 14,602 | 27,022 |
| Species occurrence range: native versus invasive | cat | 11,313 | 25,067 |
| Plant lifespan | cat, con | 7,617 | 24,712 |
| Dispersal syndrome | cat | 7,528 | 21,717 |
| Plant nitrogen fixation capacity | cat | 10,504 | 18,247 |
| Leaf area ^a | con | 8,873 | 16,663 |
| Leaf area per leaf dry mass (specific leaf area) ^b | con | 7,879 | 16,460 |
| Plant resprouting capacity | cat | 3,320 | 15,997 |
| Seed germination rate (germination efficiency) | con | 6,698 | 15,822 |
| Plant life form sensu Raunkiaer | cat | 7,710 | 15,766 |
| Pollination syndrome | cat | 4,064 | 15,631 |
| Leaf shape | cat | 3,191 | 15,594 |
| Flower sex | cat | 3,572 | 13,735 |
| Leaf distribution arrangement type | cat | 3,998 | 13,130 |
| Leaf nitrogen content per leaf dry mass | con | 6,291 | 12,238 |
| Stem specific density | con | 9,813 | 11,001 |
| Flower colour | cat | 4,747 | 10,507 |
| Seed storage behaviour | cat | 10,161 | 10,161 |
| Fruit type | cat | 3,644 | 9,573 |
| Leaf margin type | cat | 0 | 9,179 |
| Wood growth ring distinction | cat | 5,121 | 9,103 |

^aIn case of compound leaves: leaflet, undefined if petiole is included or excluded.

^bUndefined if petiole is included or excluded.

classification of PFTs—plant woodiness, plant growth form, leaf type (broadleaved vs. needle-leaved), leaf phenology type (deciduous vs. evergreen), leaf photosynthesis pathway (C3, C4, CAM)—are still among the best covered. However, the number of species characterized for each of these traits has substantially increased from TRY version 1 to 5, most significantly for plant growth form from 31,327 to 263,357 species, supported by the contribution from the GIFT database (Weigelt, König, & Kref, 2019).

The quantitative traits with the highest species coverage are still the six traits which were already prominent in TRY version 1 and involved in the analysis of the global spectrum of plant form and function (Díaz et al., 2016): plant height, seed mass, leaf area, leaf area per dry mass, leaf nitrogen content per dry mass and stem specific density (SSD). However, in general, the coverage of continuous traits already present in TRY 1 has substantially improved. This facilitates a more robust characterization of frequency distributions (Figure 4). In most cases, the range of observed trait values did not change much from TRY version 1 to 5, but the shapes of frequency distributions became more regular and pronounced, especially for multimodal frequency distributions like plant height and leaf $\Delta^{13}C$. Noteworthy, the examples in Figure 4 lack several kinds of traits because they are missing relevant numbers of trait records, like roots (only one trait), flowers and dead plant material (litter), secondary metabolites or data related to trophic interactions.

The 30 traits that were most often requested (Table 4) are dominated by continuous traits related to the global spectrum of plant form and function (Díaz et al., 2016), the leaf economics spectrum (Wright et al., 2004) and rooting depth. Only seven categorical traits are among these 30 traits. This indicates a switch between well covered—categorical—traits (Table 3) and most frequently requested—continuous—traits (Table 4). The first five most documented traits are categorical whereas among the 10 most requested traits, only one is categorical. However, within continuous traits, there is, in general, a good match between traits characterized for most species and traits most often requested. To some extent this may be influenced by the amount of available data for the individual traits. However, a noteworthy exception is rooting depth, as 10% of requests ask for this trait, while it is 'only' covered for 3,886 species, mostly contributed via the Global Dataset of Maximum Rooting Depth (Fan, Míguez-Macho, Jobbágy, Jackson, & Otero-Casal, 2017). This mismatch indicates a demand for more data on the most relevant below-ground traits.

3.4 | Species

From TRY version 1 to 4, the number of species increased slowly, but almost doubled to version 5 due to the contribution of plant growth form data from the GIFT database, which added about 100,000 new species. As in the case of traits, the data coverage for species is characterized by long-tail distributions: few species are covered well by measurements and traits, while the majority

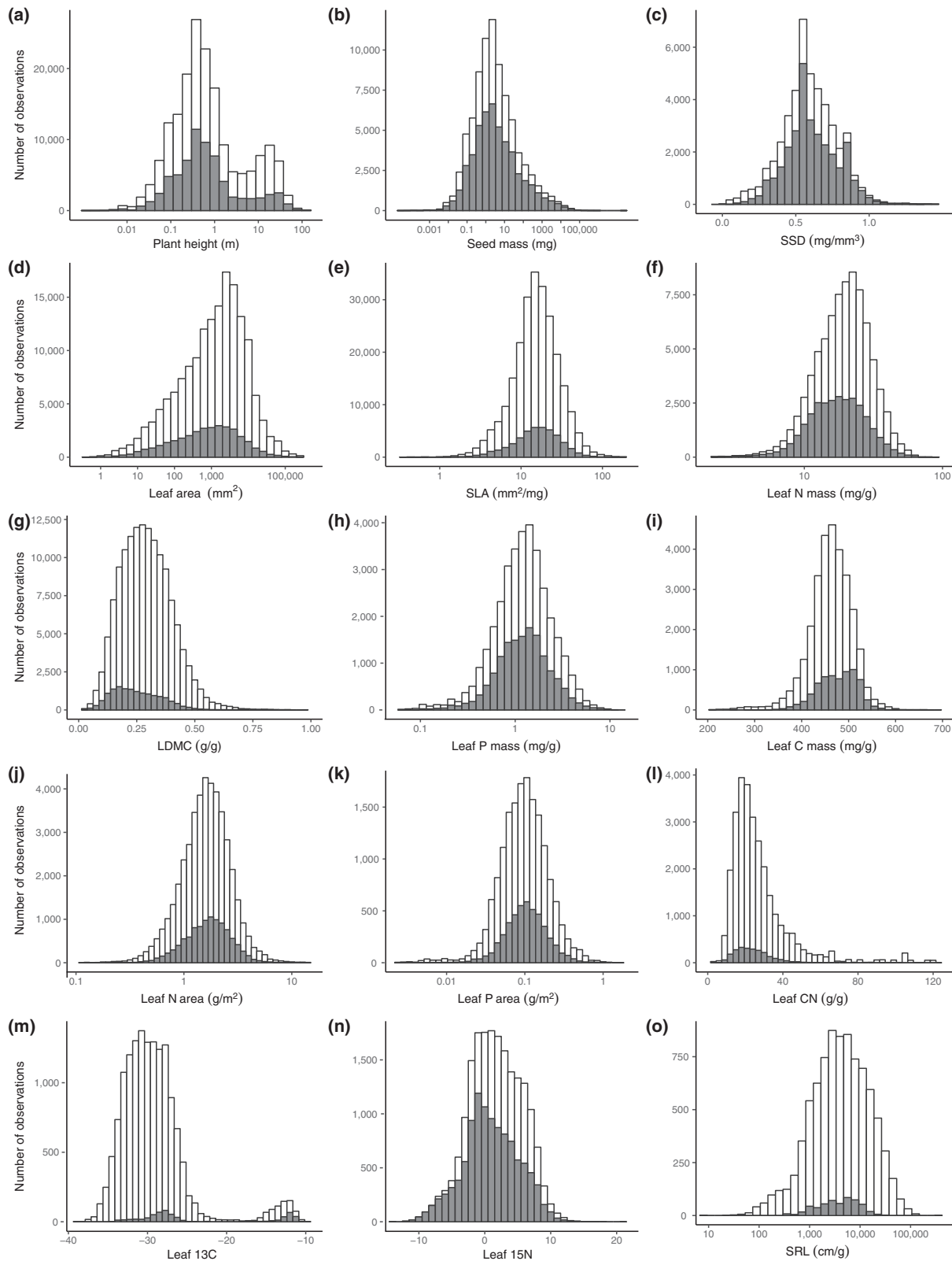


FIGURE 4 Frequency distributions of observations for 15 ecologically relevant and well sampled continuous traits from different plant organs. Grey: TRY version 1; white: TRY version 5. (a) Plant height, (b) Seed mass, (c) SSD: stem dry mass per stem fresh volume (stem specific density), (d) Leaf area, (e) SLA: leaf area per leaf dry mass (specific leaf area), (f) Leaf N mass: leaf nitrogen content per leaf dry mass (leaf nitrogen concentration), (g) LDMC: leaf dry mass per leaf fresh mass (leaf dry matter content), (h) Leaf P mass: leaf phosphorus content per leaf dry mass, (i) Leaf C mass: leaf carbon content per leaf dry mass, (j) Leaf N area: leaf nitrogen content per leaf area, (k) Leaf P area: leaf phosphorus content per leaf area, (l) Leaf CN: leaf carbon content per leaf nitrogen content, (m) Leaf 13C: leaf 13C carbon isotope signature, leaf $\Delta^{13}\text{C}$, (n) Leaf 15N: leaf 15N nitrogen isotope signature, (o) SRL: root length per root dry mass (specific root length)

TABLE 4 Most often requested traits. The 30 traits with the highest number of requests (status 1 October 2019). Number of requests and in parentheses the percentage relative to all 7,330 requests

| Trait | Data type | Number of requests |
|--|-----------|--------------------|
| Leaf area per leaf dry mass (specific leaf area or 1/LMA) ^a | con | 2,977 (41%) |
| Plant height vegetative | con | 2,159 (29%) |
| Leaf nitrogen (N) content per leaf dry mass | con | 1,938 (26%) |
| Leaf area ^b | con | 1,676 (23%) |
| Plant growth form | cat | 1,625 (22%) |
| Seed dry mass | con | 1,580 (22%) |
| Leaf nitrogen (N) content per leaf area | con | 1,221 (17%) |
| Leaf phosphorus (P) content per leaf dry mass | con | 1,170 (16%) |
| Plant lifespan (longevity) | con | 1,168 (16%) |
| Leaf dry mass per leaf fresh mass (leaf dry matter content) | con | 1,147 (16%) |
| Leaf phenology type | cat | 1,047 (14%) |
| Leaf carbon (C) content per leaf dry mass | con | 973 (13%) |
| Dispersal syndrome | cat | 958 (13%) |
| Stem specific density | con | 951 (13%) |
| Leaf photosynthesis rate per leaf area | con | 896 (12%) |
| Leaf dry mass (single leaf) | con | 896 (12%) |
| Leaf photosynthesis pathway | cat | 874 (12%) |
| Leaf thickness | con | 852 (12%) |
| Plant nitrogen (N) fixation capacity | con | 833 (11%) |
| Leaf carbon/nitrogen (C/N) ratio | con | 817 (11%) |
| Plant life form sensu Raunkiaer | cat | 801 (11%) |
| Leaf lifespan (longevity) | con | 790 (11%) |
| Root rooting depth | con | 733 (10%) |
| Plant growth rate | con | 727 (10%) |
| Leaf type | cat | 727 (10%) |
| Leaf phosphorus (P) content per leaf area | con | 719 (10%) |
| Plant functional type | cat | 710 (10%) |
| Plant woodiness | cat | 708 (10%) |
| Leaf photosynthesis rate per leaf dry mass | con | 701 (10%) |
| Plant reproductive phenology timing | con | 672 (9%) |

^aUndefined if petiole is included or excluded.

^bIn case of compound leaves: leaflet, undefined if petiole is included or excluded.

of species has only very low data coverage (Figure 3d–f). The species characterized by the most traits tend to be northern temperate trees or globally distributed pasture species (Table 5). Out of the top 30 species with the best trait coverage, 27 (90%) originate in Central or Northern Europe.

TABLE 5 Species with best trait coverage. The 30 species with the highest number of traits in the TRY database version 5 and number of traits represented for these species in TRY version 1 and 5. Sorted by the number of traits in TRY 5

| Species | Plant growth form | Number of traits | |
|------------------------------|-------------------|------------------|-------|
| | | TRY 1 | TRY 5 |
| <i>Pinus sylvestris</i> | Tree | 264 | 569 |
| <i>Fagus sylvatica</i> | Tree | 237 | 517 |
| <i>Picea abies</i> | Tree | 252 | 475 |
| <i>Quercus robur</i> | Tree | 194 | 435 |
| <i>Acer saccharum</i> | Tree | 139 | 430 |
| <i>Betula pendula</i> | Tree | 265 | 429 |
| <i>Achillea millefolium</i> | Herb | 209 | 403 |
| <i>Acer pseudoplatanus</i> | Tree | 186 | 397 |
| <i>Trifolium pratense</i> | Herb | 181 | 395 |
| <i>Quercus rubra</i> | Tree | 190 | 388 |
| <i>Dactylis glomerata</i> | Herb | 193 | 387 |
| <i>Plantago lanceolata</i> | Herb | 156 | 386 |
| <i>Vaccinium vitis-idaea</i> | Shrub | 189 | 382 |
| <i>Trifolium repens</i> | Herb | 173 | 380 |
| <i>Fraxinus excelsior</i> | Tree | 196 | 378 |
| <i>Acer platanoides</i> | Tree | 186 | 378 |
| <i>Quercus petraea</i> | Tree | 194 | 368 |
| <i>Poa pratensis</i> | Herb | 195 | 366 |
| <i>Holcus lanatus</i> | Herb | 178 | 364 |
| <i>Tilia cordata</i> | Tree | 153 | 362 |
| <i>Calluna vulgaris</i> | Shrub | 190 | 360 |
| <i>Lotus corniculatus</i> | Herb | 153 | 360 |
| <i>Pseudotsuga menziesii</i> | Tree | 141 | 356 |
| <i>Medicago lupulina</i> | Herb | 145 | 351 |
| <i>Festuca rubra</i> | Herb | 175 | 347 |
| <i>Sorbus aucuparia</i> | Tree | 197 | 335 |
| <i>Phleum pratense</i> | Herb | 179 | 335 |
| <i>Quercus ilex</i> | Tree | 195 | 333 |
| <i>Betula papyrifera</i> | Tree | 126 | 332 |
| <i>Vaccinium uliginosum</i> | Shrub | 169 | 330 |

3.5 | Entity × trait and species × trait matrices

The trait data in the TRY database can be represented by two two-dimensional matrices: the entity × trait matrix, with entities in rows and traits in columns; and the species × trait matrix, with species in rows and traits in columns. Both matrices are characterized as large but sparse: high numbers of entities, species and traits in TRY make the two matrices large, but many cells in the matrices are empty. From TRY version 1 to 5 the size of the matrices has grown by a factor of 15, but at the same time the number of trait records to fill

the cells increased only by a factor of about 5 and thus the matrices became even sparser: the fractional coverage decreased from 0.4% to 0.1% (entity \times trait) and 1.4% to 0.4% (species \times trait; Figure 5a). This sparsity together with the observed long-tail distributions has consequences, especially for multivariate analyses. Given that on average only two to three traits of the 2,091 traits in TRY version 5 are measured on an individual plant (entity), a multivariate analysis based on individuals is indeed practically impossible, as mentioned by Shan et al. (2012). Even after aggregation at the species level, the decline of the number of species with complete trait coverage when adding a new trait, for example for multivariate analysis, is surprisingly high (Figure 5b). Additionally, the final number of species represented in the analysis is determined by the trait with the lowest species coverage. Therefore multivariate analyses with more than about six traits are still very much limited by the number of species. The same applies when species have to be classified by several categorical traits, like for example in the context of PFTs.

3.6 | Ancillary data

The numbers of ancillary data, geo-referenced trait records and trait records with measurement date increased by a factor of almost 10 from TRY version 1 to TRY version 5 (Table 2). The ratio of ancillary data to trait records, therefore, increased from TRY version 1 to 5 from 2:1 to 3:1 and the fraction of geo-referenced trait records from about 33% to 42% (Table 2). The number of geo-referenced trait records with information on measurement date that could be standardized to year, month and day increased from 290,000 in TRY version 1 (15% of all trait records) to 2.5 million records in TRY version 5 (20%). The increasing ratio of ancillary data to trait records indicates growing awareness for the relevance of environmental conditions during plant growth and trait measurements. In this context, geo-references (and date) are crucial, as they allow trait records to be related to information on climate, soil or biome type from external sources.

The geographic coverage of trait measurements has substantially improved from TRY version 1 (8,276 measurement sites representing 1,260 $1^\circ \times 1^\circ$ grid-cells) to TRY version 5 (20,953 sites representing

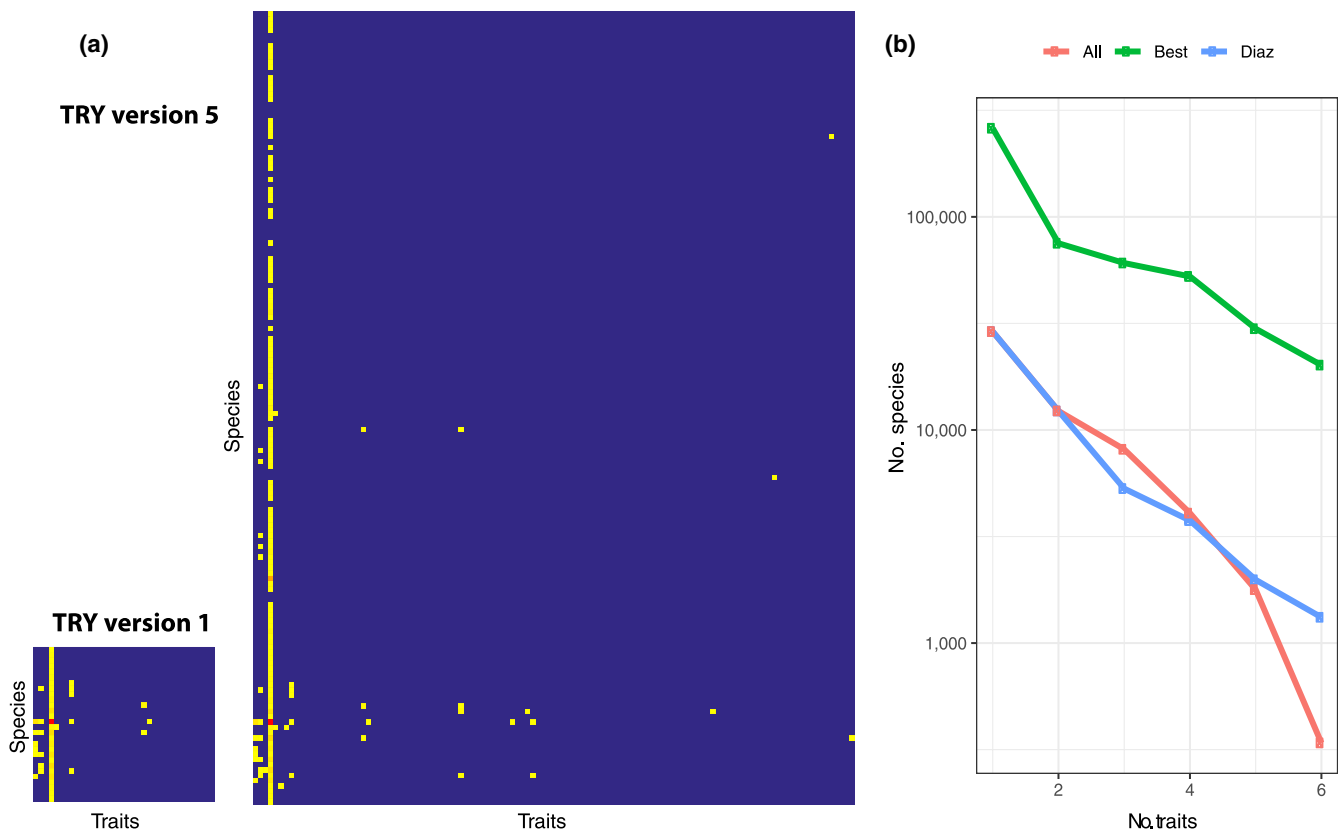


FIGURE 5 (a) Comparison of the species \times trait matrix from TRY version 1 and version 5. The sizes of the boxes represent the numbers of species and traits. Blue: missing data; bright colour: the presence of data (yellow to red indicating an increasing number of measurements). For visibility, only 5% of traits and 0.05% of species are shown (randomly selected, with TRY version 1 as a subsample of TRY version 5; ordering of species and traits by submission date). 'Plant growth form' with entries for almost all species has been selected coincidentally. (b) Multivariate analyses: the decline of the number of common species with an increasing number of traits. Green: the six best covered traits in TRY version 5 (categorical traits: plant growth form, plant woodiness, leaf type, leaf compoundness, leaf photosynthetic pathway, leaflet number per leaf); blue: six traits representing plant form and function in Díaz et al. (2016); red: the best covered quantitative traits representing each of the six plant parts (see Figure 6): shoot (plant height vegetative), reproductive organs (seed dry mass), whole plant (plant lifespan), leaves (SLA), roots (rooting depth) and dead material (litter decomposition rate)

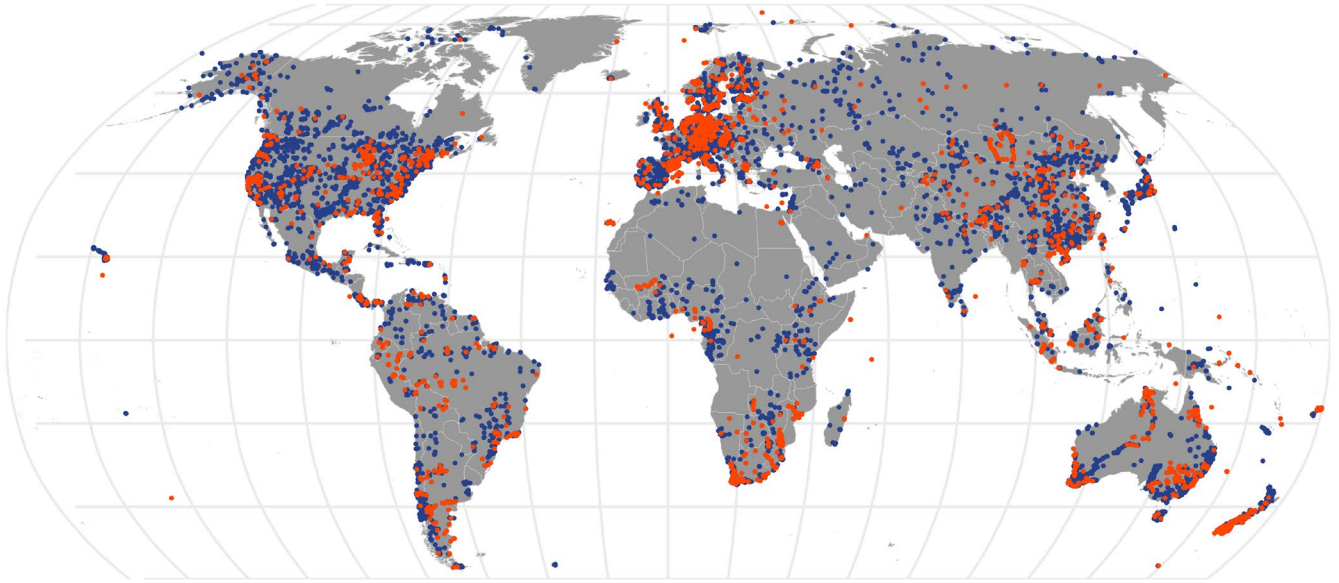


FIGURE 6 Geographic coverage of measurement sites in TRY version 1 (red) and additional measurement sites in TRY version 5 (blue)

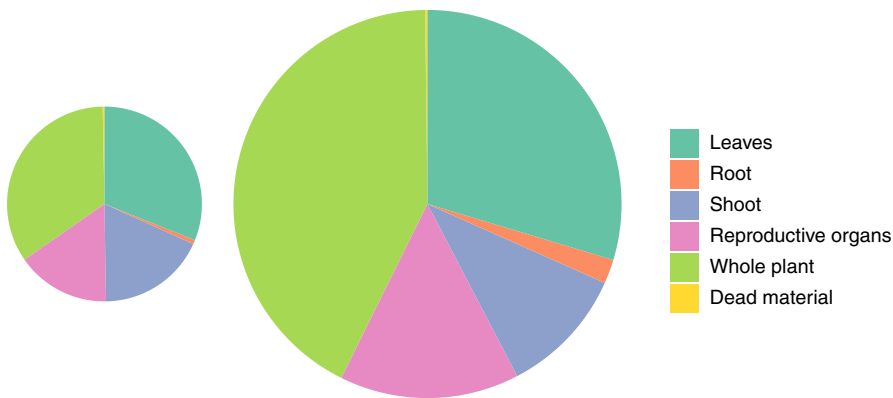


FIGURE 7 Distribution of trait records among plant parts. Different sizes of circles indicate different data coverage in TRY version 1 (left, 2.1 million trait records) and TRY version 5 (right, 11.8 million trait records)

3,320 $1^\circ \times 1^\circ$ grid-cells; Table 2; Figure 6). Europe still has the highest density of measurement sites, but TRY version 5 also provides good coverage for the United States and China. The number of measurement sites has substantially improved for several other regions as well, for example Central America, Russia, Asia and parts of central Africa. However, there are still obvious gaps in boreal regions (Canada, East Russia) and some parts of the tropics and subtropics, particularly in Africa (Figure 6).

3.7 | Data completeness and representativeness

To progress from a description of data coverage towards an analysis of representativeness, we need a baseline for comparison. At the global scale, this information has been lacking. Reference data sets have become available only recently for plant growth form (Weigelt, König, & Kref, 2019) and phylogeny (Smith & Brown, 2018) representing about 260,000 and 356,000 of the 400,000 extant species. Together with estimations for the global distribution of plant species richness (Kier et al., 2005), it seems now possible and timely to explicitly address

representativeness of plant trait data in the TRY database along five key dimensions: (a) Are trait data in TRY well distributed among plant parts? (b) Are the species in TRY and for individual traits representative for global plant growth forms and functional types? (c) Are the species in TRY and for individual traits representative according to phylogeny? (d) Does the geographic distribution of species richness in TRY represent the estimated pattern of global species richness? (e) Is data coverage sufficient to represent intraspecific variation?

3.8 | Distribution of trait records among plant parts

Trait records in the TRY database are very unequally distributed among different plant parts (Figure 7): leaves and the whole plant are well represented; shoot and reproductive organs are moderately represented; roots and dead material (morphological and chemical feature of litter and coarse woody debris, but also decomposition rates) are not well represented. Within reproductive organs, seeds are better represented than floral traits, mostly due to contributions from the Seed Information Database. The skewed distribution of

trait records to the different parts of the plants has only changed little from TRY version 1 to 5. However, the fraction of records for root traits has substantially increased (from 0.7% to 2.0%), due to the contribution of the FRED database.

3.9 | Plant growth form and PFTs

The most basic approach to characterize functional groups of plant species and their impact on vegetation and ecosystem function is the plant growth form, with its simplest classification to herbs, shrubs and trees. We compare here the fraction of the different plant growth forms for trait measurements in TRY version 5 to a comprehensive baseline of plant growth form for >280,000 of the extant 400,000 species, which is currently developed in the context of the GIFT database project.

In GIFT, about 50% of species are currently assigned to herbs, 30% to trees and 20% to shrubs (Figure 8). This distribution is well reflected by the species in TRY (excluding data from the GIFT database). However, the six best covered continuous traits in TRY indicate that this distribution is very much trait dependent, with a bias towards trees versus herbs, while the fraction of shrubs is surprisingly constant and close to the fraction in the GIFT database (Figure 8). The overrepresentation of trees is most obvious for SSD, which is not surprising because SSD is a more general concept derived from wood density, a trait relevant for forestry, timber industry and estimates of forest vegetation biomass. However, the tendency of relatively more data for trees compared to other growth forms is also obvious for SLA, leaf nitrogen content per dry mass and leaf area, but opposite for root length per root dry mass (specific root length), which is frequently reported for herbs.

Apart from plant growth form, three additional categorical traits are relevant to determine PFTs commonly used in global vegetation models: leaf type (broadleaved vs. needle-leaved) and leaf phenology type (deciduous vs. evergreen) for tree species, and photosynthetic pathway (C3, C4, CAM) for herbaceous species. TRY provides leaf type and leaf phenology type, for about 10% of the estimated

130,000 tree species worldwide and photosynthetic pathway for about 6% of estimated 200,000 herb species.

3.10 | Phylogeny

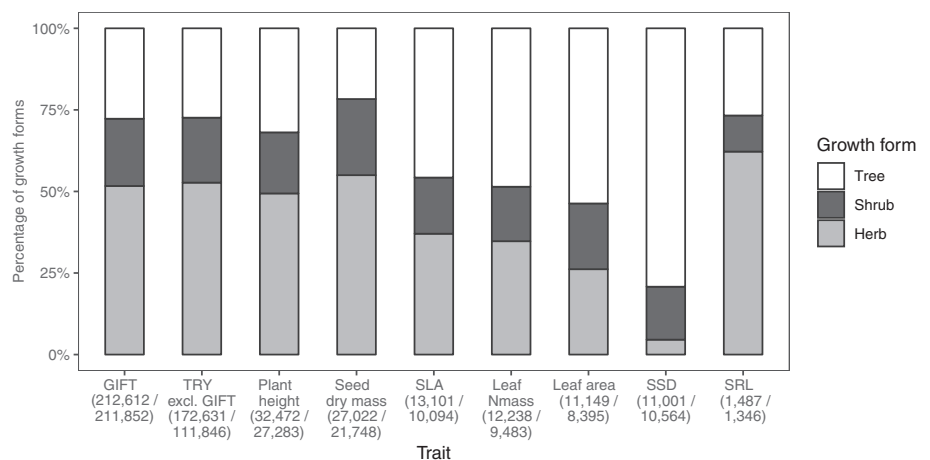
Smith and Brown (2018) published a series of broadly inclusive seed plant phylogenies. Here we chose the most comprehensive phylogeny (ALLMB), containing 356,305 taxa, as a baseline to visualize the coverage of TRY in a phylogenetic context. Taxa in ALLMB were cut to binomials and consolidated using the TNRS with TPL, GCC, ILDIS, TROPICOS and USDA as the taxonomic backbone (the same approach as for TRY). After consolidation, we could match the taxa in the phylogeny to 208,406 of the 279,875 taxa in TRY. Higher level taxonomy is based on Zanne et al. (2014).

Visually, the 208,000 species with data in TRY are well distributed across the 350,000 species represented in the phylogeny of seed plants (Figure 9). An ancestral state reconstruction (ASR) of species trait number confirms that the long-tail distribution previously seen at the species level also holds in a phylogenetic context: some clades are covered very well (bright colours), while most clades have lower data coverage (dark colours). The ASR additionally shows how deep in phylogeny data gaps are rooted. This indicates the potential for, and limits to, phylogenetically or taxonomically informed gap-filling (Schrodte et al., 2015). Examples of high-coverage clades are (parts of) the Pinales, Poales and Asterales. When looking at the six best-covered continuous traits individually, we find these too are well distributed across the phylogeny (Figure 9).

3.11 | Geographic distribution of species richness

Jetz et al. (2016) reported a latitudinal gradient in disparities between plant species with regional measurements in TRY and estimated species richness, with the largest gap observed in the tropics, because these are especially rich in species. To address this in more detail, we

FIGURE 8 Fraction of species with plant growth forms herb, shrub and tree in the GIFT database, in TRY version 5 (excl. GIFT) and for the six best covered continuous traits in TRY version 5: plant height, seed dry mass, leaf area per leaf dry mass (SLA), leaf N per dry mass, leaf area and stem specific density (SSD), and one well covered root trait: specific root length (SRL). In parentheses: the number of species with data for the trait and the number of species for which the growth form could be determined as tree, shrub or herb



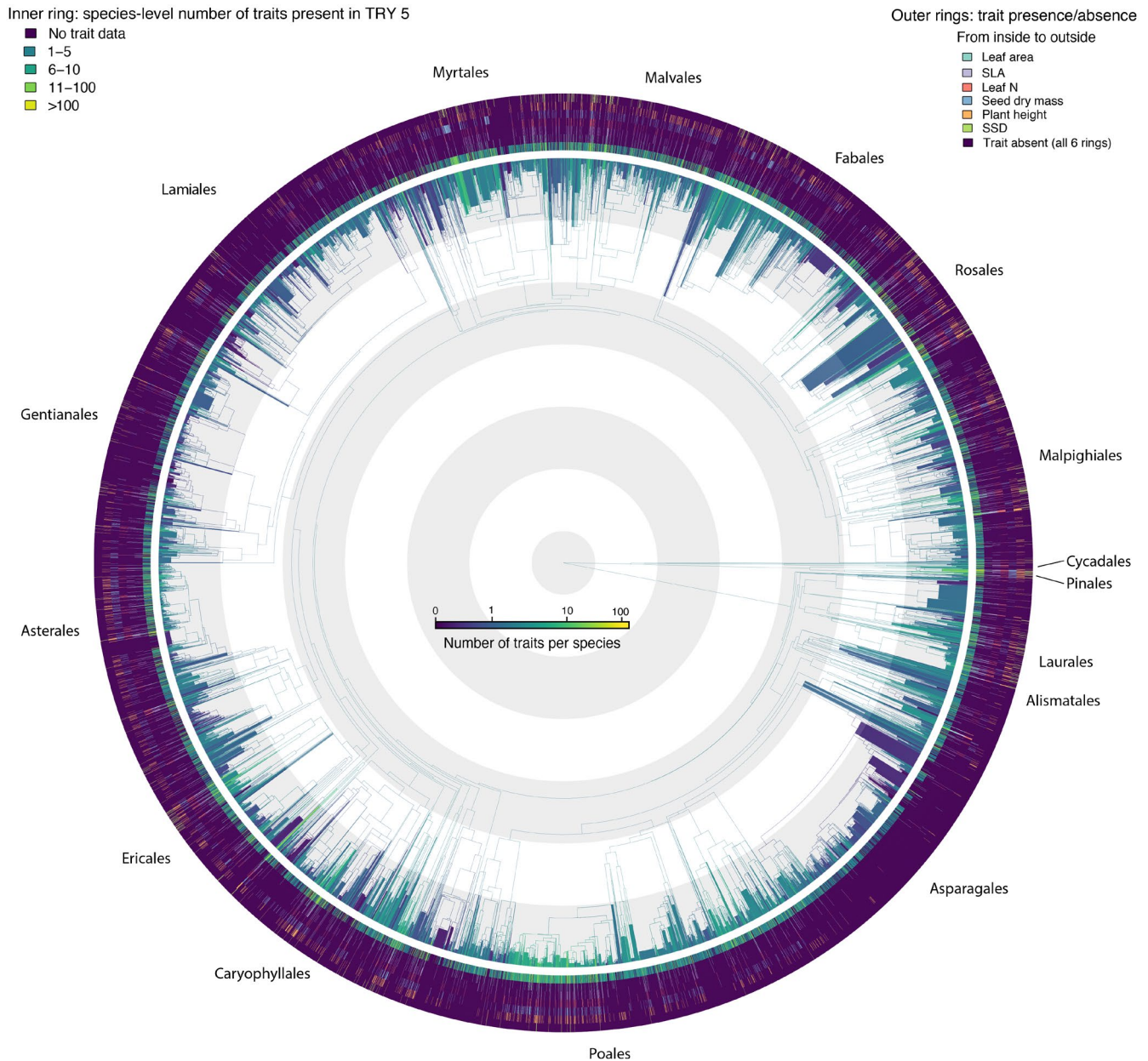


FIGURE 9 Trait coverage per species projected on a global phylogeny. The presence of trait data for plant species in the TRY database version 5 matched to the global ALLMB phylogeny published by Smith and Brown (2018). Rings surrounding the phylogeny indicate from inside outwards: (i) number of traits per species (innermost ring); (ii) presence of data for six of the best covered continuous traits, specifically: leaf area, leaf area per leaf dry mass (SLA), leaf nitrogen content per dry mass (LeafN), seed dry mass, plant height and stem specific density (SSD). Colours of phylogeny branches represent an ancestral state reconstruction of the number of traits per species. White and grey circles indicate periods of 50 million years. For visibility, only 5% of species (randomly selected) are presented

here ask if the TRY database provides trait information for a relevant number of plant species in the different regions worldwide. To characterize regions in an ecologically meaningful way we adopt the ecoregions introduced by Olson et al. (2001), which are defined as relatively large units of land containing a distinct assemblage of natural communities and species, with boundaries that approximate the original extent of natural communities before major land-use change. The ecoregions are nested within biomes with biotic communities formed in response to a shared physical climate, most importantly temperature and rainfall. We compare the number of species, which have trait

measurements in an ecoregion in TRY version 5 to species numbers per ecoregion estimated by Kier et al. (2005). This approach accounts to some extent for intraspecific trait variation, as it counts only species with at least one trait measurement in the given ecoregion.

The 839 ecoregions defined by Olson et al. (2001) are very different in size, from 6 km² (San Felix-San Ambrosio Islands temperate forests) to 4,639,920 km² (Sahara desert) with species numbers ranging from 0 (St. Peter and St. Paul rocks and the Maudlandia Antarctic desert) to 10,000 (Borneo lowland rain forests). The TRY database contains no trait measurements for 271 mostly small ecoregions and

up to 1,400 species for some ecoregions in Europe (Alps conifer and mixed forests) and tropical South America (Napo moist forests, Tapajos-Xingu moist forests). In general, high absolute numbers of species with trait measurements for ecoregions are found in Europe,

East Asia, Oceania, Australia, tropical South America and the United States (Figure 10a). East Asia, Oceania and tropical South America are also the regions with the highest numbers of species per ecoregion estimated by Kier et al. (2005; Figure 10b).

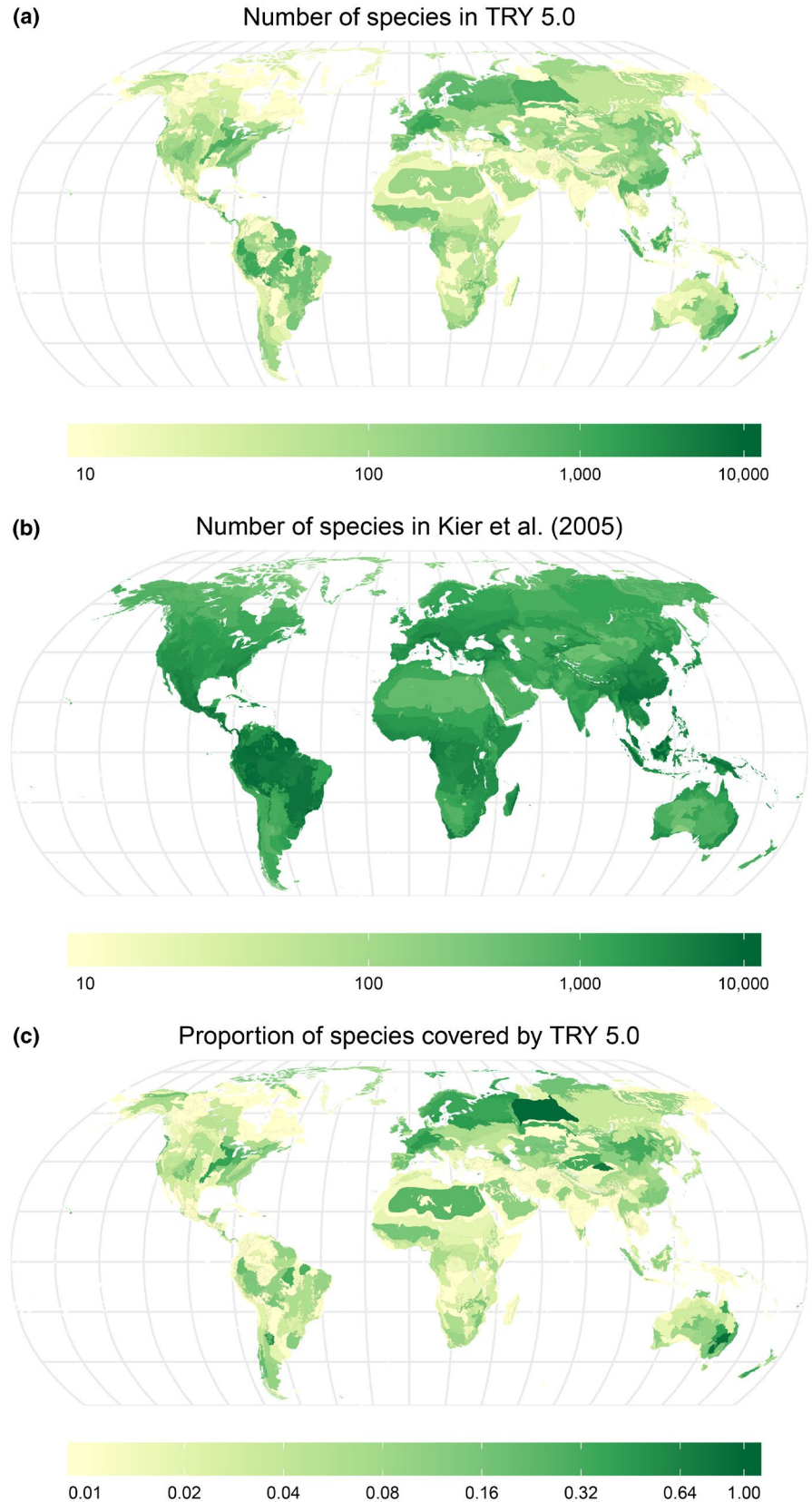


FIGURE 10 Geographic representativeness: (a) the number of species with at least one trait measurement in an ecoregion in TRY version 5; (b) number of species per ecoregion estimated by Kier et al. (2005); (c) fraction of species represented in TRY version 5 versus number of species per ecoregion estimated by Kier et al. (2005)

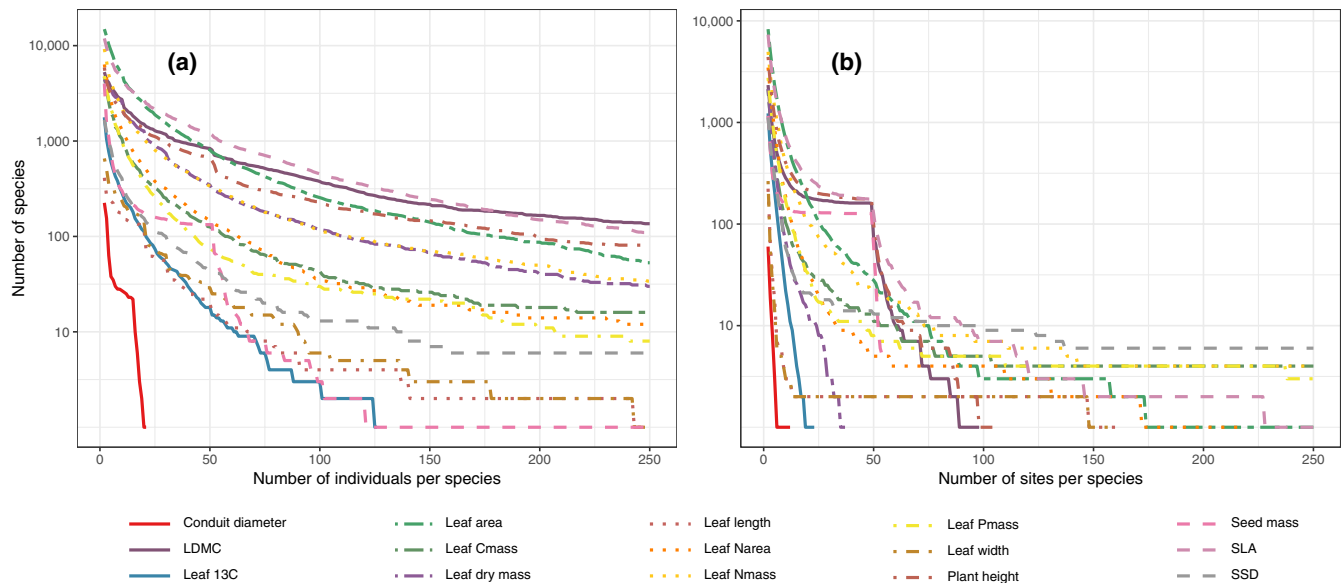


FIGURE 11 Data coverage enabling examination of intraspecific variation: impact of the minimum number of individuals per species (a) and measurement sites per species (b) on the number of species available for analyses of intraspecific variation. Measurement sites were classified as different if they differed at least by 0.01 degrees in latitude or longitude. LDMC: leaf dry matter content; Leaf 13C: Leaf carbon (C) isotope signature (leaf $\Delta^{13}\text{C}$); Leaf C mass: leaf carbon content per leaf dry mass; Leaf N area: leaf nitrogen content per leaf area; Leaf N mass: leaf nitrogen content per leaf dry mass; Leaf P mass: leaf phosphorus content per leaf dry mass; SLA: leaf area per leaf dry mass (specific leaf area); SSD: stem specific density

The best relative coverage in TRY (Figure 10c) is provided for the Marielandia Antarctic tundra (two species estimated and in TRY) and for a large ecoregion in Central Russia (West Siberian taiga, 900 species estimated, 885 in TRY). The species in the Russian ecoregion are measured at several sites relatively well distributed across the ecoregion, but dominated by just one trait, 'mycorrhiza infection intensity' contributed by the mycorrhizal intensity database (Akhmetzhanova et al., 2012). Some other ecoregions are also well covered with data for more than 50% of estimated species (Southeast Australia temperate savanna, Qaidam Basin semi-desert, Córdoba forests and mountain grasslands). Apart from these individual ecoregions spread across the world, large parts of Europe are well covered, with trait data for about 30% of the species number estimated by Kier et al. (2005). Some ecoregions in East Asia, Australia, tropical South America, the Sahara, and the United States are also well covered, providing data for about 20% of estimated species richness. Very low relative coverage (<2%) is observed for major parts of Canada, Africa, western Asia (Iran, Iraq, Pakistan, Afghanistan) and major parts of India.

3.12 | Intraspecific variation

Understanding and predicting intraspecific variation for a relevant number of traits and species is still in its infancy. Given that TRY is collecting trait measurements on individual plants, the TRY data set might be suited to address these questions. A precondition for such analyses is a minimum number of measurements on different individual plants at different sites per trait and species. To assess this issue, we plotted

the number of species for which TRY version 5 contains a minimum number of individual measurements (Figure 11a) and the number of species for which TRY version 5 contains measurements from a minimum number of individual sites (Figure 11b) for the 15 best-covered continuous traits. By increasing the minimum number of individuals or sites, the number of species available for analysis decreases sharply (more than exponentially), whereas the exact slope is trait specific. The characterization of intraspecific variation in Kattge et al. (2011) relied on at least 20 individuals per species. Based on this criterion, TRY 5 provides information for hundreds to thousands of species for 14 out of the 15 traits (Figure 11a). Assuming a more realistic limit of 100 individuals per species, SLA and LDMC are sufficiently covered for about 300 species, and four other traits for more than 100 species. Assuming a minimum number of 200 individuals per species, four traits still allow for an analysis of 100 species, and nine traits allow for the analysis of intraspecific variation of more than 10 species. However, the numbers are more humbling if the environmental context is taken into account (Figure 11b). If we assume that trait records from a minimum number of 50 sites per species are necessary to represent intraspecific variation, four traits are sufficiently covered for about 100 species. If 100 sites are necessary, no trait is covered by data for more than 10 species.

4 | DISCUSSION

Plant trait data provide a wealth of information directly relevant in several scientific contexts, from conservation, ecology and evolution to earth system sciences. To fully realize this potential, the TRY

initiative was initiated in 2007 as a 'database of databases' and leading groups in the field of functional plant ecology joined forces for this community-driven program. The TRY database now provides an unprecedented number of consolidated plant trait data, which have become easily accessible at the TRY Data Portal under an open access data policy.

The TRY database is well accepted by the scientific community and has facilitated progress in different aspects of research, for example in global vegetation modelling from static PFTs to a more continuous representation of biodiversity (e.g. Peaucelle, Bellassen, Ciais, Peñuelas, & Vióvy, 2016; Sakschewski et al., 2015, 2016; Verheijen et al., 2013, 2015), extending macroecology and biodiversity by functional aspects (e.g. Bjorkman, Myers-Smith, Elmendorf, Normand, Rüger, et al., 2018; Bruelheide et al., 2018; Craven et al., 2018; Newbold et al., 2015), linking soil characteristics to vegetation attributes (e.g. Boeddinghaus et al., 2019; de Vries et al., 2012; Delgado-Baquerizo et al., 2018) and providing data for global maps of plant traits (e.g. Butler et al., 2017; Moreno-Martínez et al., 2018). The central keywords of the cluster analysis in Figure 2 (biodiversity, climate change, plant traits, functional diversity, carbon cycle, community, vegetation and environmental filtering) seem to reflect the expectation that improved knowledge of plant functional diversity, mediated by plant traits, contributes to a better understanding of vegetation feedbacks to climate change and drivers and consequences of plant biodiversity loss.

Data coverage of the TRY database is characterized by four attributes: (a) long-tail distributions, (b) sparse matrices, (c) increasing number of ancillary data per trait record and (d) increasing geographic coverage. So far the size of the two sparse matrices (entity \times trait and species \times trait) has increased faster than the number of trait records to fill the matrices. Therefore the sparseness of the matrices has increased from TRY version 1 to 5 (the fractional coverage declined). Rather than converging in a small number of traits, the scientific community continues to measure a large, diverse number of traits, following equally diverse motivations.

However, given the number of species has a natural limit and assuming the number of traits will continue to grow, but more slowly, once the most obvious ones have been covered, we expect that the sparseness of the entity \times trait matrix will become stable: new data adding new rows for entities, but not many new columns for traits. In comparison, the sparseness of the species \times trait matrix should decline in the future; new data will mostly contribute to filling the matrix and increasing the number of species with data per trait. This reduced sparseness of the species \times traits matrix will systematically improve the applicability of trait data for macroecology and earth system modelling and will facilitate multivariate analyses for an increasing number of traits. In parallel, the number of records per species–trait combination is increasing: between TRY 1 and 5 it already doubled and will further increase in the future. This increasing number of records per species–trait combination will improve data coverage for analyses of intraspecific trait variation and trait–environment relationships accounting for intraspecific variation. It is noteworthy that the matrix will not only become more complete,

but the traits will increasingly be able to inform each other. The 'usual suspects' (i.e. the best covered continuous traits) might not be masters of all traits, but they surely will be very useful as baseline traits and provide a background against which other—maybe more influential—traits can be analysed for coverage, representativeness, orthogonality, etc.

4.1 | Data completeness and representativeness

Despite unprecedented and continuously growing data coverage, we observe a humbling lack of completeness and representativeness in many aspects. The best species coverage is achieved for categorical traits relevant to determine PFTs commonly used in global vegetation models. For the traits 'woodiness' and 'plant growth form', even full species coverage is within reach, due to the contribution of data from the GIFT database. For the first time, this provides a global baseline for these traits, which are relevant to understand basic patterns of variation for several other traits (Díaz et al., 2016). With this baseline, future analyses will be able to address representativeness in addition to coverage, which will substantially contribute to better understand the global pattern of plant traits relevant for biodiversity and ecosystem function (König et al., 2019).

Most traits directly relevant for ecology and vegetation modelling are characterized by intraspecific variation and trait–environmental relationships; for these traits, completeness at the global scale is impossible and representativeness is challenging. We find that in the current version of the TRY database, these traits are biased against roots, floral traits and dead organic material, like litter or coarse woody debris. Plant growth forms and phylogeny are generally well represented, but there are significant biases for individual traits. The global distribution of species richness is only marginally reflected by trait measurements. We observe a general bias towards temperate biomes. In contrast to Jetz et al. (2016), the tropics do not stand out as especially underrepresented in our analysis; apart from Europe, all continents contain major regions that are very sparsely represented in TRY.

So far we addressed representativeness in a geographic context only based on species richness, the number of species observed in an ecoregion. To address representativeness in an ecologically more meaningful context, species identity and species abundance should be taken into account. Both aspects are relevant to community attributes and ecosystem function. There is ample evidence in the literature of the high influence, at the level of community structure and ecosystem dynamics, of species that represent a large proportion of the total local biomass (consisting of large individuals and/or large total cover). Such species have a particularly large impact on the community weighted mean trait value (Garnier et al., 2004), and particularly large individual trees may overrule remaining trees' attributes (Ali et al., 2019). Initial evidence indicates that abundant species are better covered in TRY than rare species. Bruelheide et al. (2019) show that the 25% most dominant or most frequent species

compiled in the sPlot vegetation-plot database are better represented by trait data in the TRY database than species observed on the plots overall. We also checked this for the 227 hyperdominant species of the Amazonia tree flora identified by ter Steege et al. (2013). After the consolidation of species names via TNRS, all 227 hyperdominant species are present in the TRY database, with on average 69 traits per species, which is far above average (see Figure 3e). We therefore conclude that the coverage of trait data in TRY is biased towards the more abundant species in the respective ecoregions—which is reasonable and welcome for many kinds of analyses.

We have reported that intraspecific variation in space is increasingly well covered, but variation in time is hard to estimate. Nevertheless, intraspecific variation in time is relevant for several traits to characterize the seasonal variation of plant and ecosystem function (Xu & Baldocchi, 2003; Xu & Griffin, 2006) and long-term trends to inform policy about biodiversity change (Kissling et al., 2018). About half of the geo-referenced trait records have information on the sampling date that could be standardized to year, month and day, but systematic replicates over time ('time series') are rare (but see e.g. the 'Photosynthesis Traits Database'; Xu & Baldocchi, 2003). In principle, 'non-time series' data allow detection of trait changes over time (Craine et al., 2018), but these analyses are very challenging, as most traits demonstrate stronger variation in geographic space along climate and soil gradients than over time. In addition, the variations of traits on different time scales (diurnal, seasonal, inter-annual variation and long-term trends) are superimposed and hard to disentangle. Apart from this, there is a need to collect and report repeated trait measurements from the same location or population to monitor biodiversity change and inform policy, for example in the context of GEO BON (Kissling et al., 2018).

4.2 | Ways forward

Figure 1 shows the most obvious way to mobilize additional trait data: the TRY initiative should regularly send calls for data contribution to the wider scientific community, that is the network of more than 6,000 researchers contributing and using trait data via TRY. These calls should be combined with regular publications of respective reference papers. This can be combined with (a) a systematic collection of data sets from public data repositories, which is becoming more effective with the general move by many journals to require that authors make their data open access; and (b) systematic extraction of trait data from the ecological literature, floras and herbarium specimens, which is a promising task, especially for its potential to open a window into the past. In parallel, TRY should further support the 'feed-forward data integration loop' outlined above: using trait data via TRY, identifying gaps, mobilizing and/or measuring new data, contributing additional data to TRY. This has proven very effective for focused data mobilization. If relevant gaps are detected, TRY can also send specific calls to the community.

As TRY has been designed as a community cyber-infrastructure based on the idea of incentive-driven data sharing (Kattge, Díaz, &

Wirth, 2014), the collaboration and data exchange with other plant trait databases will continue to be the key to achieve a comprehensive representation of plant traits. TRY is, therefore, collaborating with many more recent trait database initiatives, such as, for example, FRED, GIFT, BIEN and the Tundra Trait Team, and since the early days of TRY—GLOPNET, LEDA, SID, BioFlor, BIOPOP, BROT, the Ecological Flora of the British Isles, eHALOPH, USDA PLANTSdata, BRIDGE and many others. Importantly, these collaborations need to provide mutual benefit. Based on these collaborations, the TRY database may serve as a central node for plant traits in an overarching network of trait databases, currently emerging in the context of the Open Traits Network (Gallagher et al., in press). Finally, new techniques and approaches are gradually becoming available, which may substantially change how plant trait data are collected: remote sensing, citizen sciences, microbiological and molecular screening, etc.

4.3 | Towards a third generation of plant trait data integration and sharing

We expect that the combination of (a) systematic involvement of the TRY network towards extraction and mobilization of legacy and recent trait data from public repositories, ecological literature, floras and herbaria, (b) facilitation of the 'feed-forward data integration loop' and (c) intensified collaboration of all plant trait-related initiatives, including new approaches and techniques, will be effective towards an increasingly comprehensive representation of plant traits. After the development of integrated databases focused on specific regions or topics, and the development of a 'database of databases', such a joined effort might be leading towards a third generation of plant trait data integration and sharing.

5 | CONCLUSION

TRY has received institutional support since 2007 and is still growing considerably in quantity and quality. While TRY may be considered a success and potentially a role model for database initiatives, it is important to realize that this development needed time and patience. It took until 2011 for the first TRY publications to appear because the early years of TRY were mostly devoted to the development of the database, organizing the community process towards a joint data sharing policy and building trust. This process involved initially dozens and later hundreds of scientist when it came to agree on moving towards open access. These dynamics do not fit into 3 year funding cycles as typically offered by national funding agencies. A key lesson of TRY is that the development of a database that is trusted by the community and accepted for its service and quality also needs the trust of the funders, that is long-term support, at the scale of decades rather than years. It also needs journals that are willing to accept long author lists and extended references lists to adequately acknowledge the original contributions that are the building blocks of communal databases.

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CONFLICT OF INTEREST

All authors declare no conflict of interest.

AUTHOR CONTRIBUTION

Jens Kattge, Gerhard Bönisch, Sandra Díaz, Sandra Lavorel, Iain Colin Prentice, Paul Leadley and Christian Wirth developed the concept and draft manuscript. Susanne Tautenhahn and Gijbert Werner contributed analyses and plots for Figures 9, 10 and 11. The other authors contributed plant trait data and/or supported data curation and analysis. All 729 authors contributed to writing.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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APPENDIX

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Sangolquí, Ecuador, ⁶¹⁰Department of Botany, Goa University, Goa, India, ⁶¹¹Department of Ecology and Environmental Sciences, Pondicherry University, Puducherry, India, ⁶¹²Carl von Ossietzky University of Oldenburg, Oldenburg, Germany, ⁶¹³Zoology Department, Edward Grey Institute, Oxford University, Oxford, UK, ⁶¹⁴Department of Zoology, Cambridge University, Cambridge Conservation Initiative, Cambridge, UK, ⁶¹⁵Ministry of Education Key Laboratory for Earth System Modeling, Department of Earth System Science, Tsinghua University, Beijing, China, ⁶¹⁶Institute of Desertification Studies, Chinese Academy of Forestry, Beijing, China, ⁶¹⁷Institute of Geography, Fujian Normal University, Fuzhou, China, ⁶¹⁸Department of Landscape Architecture, University of Sheffield, Sheffield, UK, ⁶¹⁹Department of Biology, Colgate University, Hamilton, NY, USA, ⁶²⁰Ecological Sciences, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands, ⁶²¹Maritime and Science Technology Academy, Miami, FL, USA, ⁶²²Free University of Bozen-Bolzano, Bolzano, Italy, ⁶²³University of Winnipeg, Winnipeg, Manitoba, Canada, ⁶²⁴The James Hutton Institute, Dundee, UK, ⁶²⁵King Saud University, Riyadh, Saudi Arabia, ⁶²⁶University of California - Irvine, Irvine, CA, USA, ⁶²⁷Southwest Biological Science Center, U. S. Geological Survey, Moab, UT, USA, ⁶²⁸Department of Biology, Duke University, Durham, NC, USA, ⁶²⁹NSW Department of Primary Industries, Parramatta, NSW, Australia, ⁶³⁰Hiroshima University, Higashi-Hiroshima, Japan, ⁶³¹Graduate School of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Japan, ⁶³²SUNY-College of Environmental Science and Forestry, Syracuse, NY, USA, ⁶³³Centre d'Ecologie et des Sciences de la Conservation (CESCO), Muséum National d'Histoire Naturelle, Centre National de la Recherche Scientifique, Sorbonne-Université, Paris, France, ⁶³⁴Laboratório de Ecologia Vegetal (LEVEG), Porto Alegre, RS, Brazil, ⁶³⁵Biological Sciences, George Washington University, Washington, DC, USA, ⁶³⁶National Taiwan University, Taipei, Taiwan, ⁶³⁷College of Life Sciences, Zhejiang University, Hangzhou, China, ⁶³⁸Forestry College, Beijing Forestry University, Beijing, China, ⁶³⁹Institut National Polytechnique Félix Houphouët-Boigny (INP-HB), Yamoussoukro, Côte d'Ivoire, ⁶⁴⁰Institute for Biology and Environmental Sciences, University Oldenburg, Oldenburg, Germany

TABLE A1 Datasets contributed to the TRY plant trait database. Sorted by custodian surname. ID: Dataset ID in the TRY database, Name, Custodian, TRY version to which the dataset was submitted (in parentheses first submission), availability of the dataset (status 1.10.2019), reference

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|---|--------------------|---------|--------------|---|
| 403 | Iranian Plant Trait Dataset | Mehdi Abedi | 5 | Public | Unpublished |
| 429 | TraitDunes | Alicia T.R. Acosta | 5 | Restricted | Unpublished |
| 553 | Herbaceous leaf traits database from Mediterranean serpentine and non-serpentine soils | George Adamidis | 6 | Restricted | Adamidis, Kazakou, Fyllas, and Dimitrakopoulos (2014) |
| 152 | Functional Traits of Graminoids in Semi-Arid Steppes Database | Peter Adler | 3 | Public | Adler, Milchunas, Lauenroth, Sala, and Burke (2004) |
| 285 | Functional traits explaining variation in plant life history strategies | Peter Adler | 4 | Public | Adler et al. (2013) |
| 582 | Guisane2080 | Cécile Albert | 6 | Restricted | Albert et al. (2010) |
| 583 | Ecophy | Cécile Albert | 6 | Restricted | Albert et al. (2011) |
| 268 | Seed Longevity of European Early Successional Species | Harald Albrecht | 3 | Public | Unpublished |
| 535 | Annual mortality rate of mature trees in central Amazon rainforest over 5 decades of monitoring | Izabela Aleixo | 6 | Restricted | Aleixo et al. (2019) |
| 559 | Haeon_South_Korea_Traits | Hamada Ali | 6 | Public | Ali, Reineking, and Münkemüller (2017) |
| 150 | French Weeds Trait Database | Bernard Amiaud | 3 | Public | Unpublished |
| 376 | Biomass allocation in beech and spruce seedlings | Christian Ammer | 4 | Public | Schall, Lödige, Beck, and Ammer (2012) |
| 100 | Plant Traits in Pollution Gradients Database | Madhur Anand | 2 | Restricted | Unpublished |
| 624 | CPCRW Carbon Dynamics Along Permafrost Gradient: Specific Leaf Area of Alder and Spruce | Carolyn Anderson | 6 | Public | Unpublished |
| 622 | Daintree Rainforest Functional Traits Data | Deborah Apgaua | 6 | Public | Apgaua et al. (2015) |
| 97 | Plant Physiology Database | Owen Atkin | 1 | Public | Campbell et al. (2007) |
| 286 | Global Respiration Database | Owen Atkin | 4 | Public | Atkin et al. (2015) |
| 405 | JACARE A-Ci leaf trait database 2017 | Owen Atkin | 5 | Restricted | Bahar et al. (2016) |
| 629 | Traits of Plants in Canada (TOPIC) | Isabelle Aubin | 4 (6) | Restricted | Aubin et al. (2012) |
| 666 | Iranian Marl database | Khadijeh Bahalkeh | 6 | Public | Unpublished |
| 76 | European Mountain Meadows Plant Traits Database | Michael Bahn | 1 | Restricted | Bahn et al. (1999) |
| 101 | Photosynthesis Traits Database | Dennis Baldocchi | 2 | Public | Xu and Baldocchi (2003) |
| 154 | Leaf Photosynthesis and Nitrogen at Oak Ridge Dataset | Dennis Baldocchi | 2 | Public | Wilson, Baldocchi, and Hanson (2000) |
| 269 | The Bridge Database | Chris Baraloto | 3 | Public | Baraloto, Timothy Paine, Poorter, et al. (2010) |
| 422 | Hawaii native and non-indigenous species. Traits and environment | Zdravko Baruch | 5 | Public | Baruch and Goldstein (1999) |
| 576 | Bauerle Vcmax and Jmax data | William Bauerle | 6 | Restricted | Bauerle et al. (2012) |
| 502 | Yangambi arboretum | Marijn Bauters | 6 | Restricted | Bauters et al. (2015) |
| 504 | Djolu | Marijn Bauters | 6 | Restricted | Bauters et al. (2019) |
| 505 | Nyungwe_Rwanda | Marijn Bauters | 6 | Restricted | Bauters et al. (2017) |
| 654 | Plant height of Mediterranean herb layer communities, Sardinia, Italy | Erika Bazzato | 6 | Restricted | Unpublished |
| 277 | UV-B Radiation Sensitivity of Hieracium Pilosella | Michael Beckmann | 3 | Public | Beckmann, Hock, Bruelheide, and Erfmeier (2012) |

(Continues)

TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|--|---------------------------------|---------|--------------|---|
| 631 | <i>Pinus</i> traits from Beloiu | Carl Beierkuhnlein | 6 | Restricted | Unpublished |
| 379 | Stomatal conductance photosynthesis, soil water content & survival along a water stress experiment | Michaël Belluau | 4 | Public | Belluau and Shipley (2017) |
| 425 | Linking hard and soft traits | Michaël Belluau | 5 | Public | Belluau and Shipley (2018) |
| 373 | Leaf vein density of <i>Fagus sylvatica</i> L. and <i>Quercus faginea</i> Lam. | Raquel Benavides | 4 | Public | Unpublished |
| 515 | A-Ci curves | Lahcen Benomar | 6 | Public | Benomar et al. (2018) |
| 658 | Functional Traits of Tropical Dry Forest (Colombia) Fundación Natura and Enel-Emgesa | Mary Berdugo | 6 | Restricted | Unpublished |
| 225 | Diameter at Breast Height and Life Form of Amazonian Flora | Erika Berenguer | 3 | Restricted | Unpublished |
| 397 | Fine root traits of 141 Central European grassland species | Joana Bergmann | 5 | Public | Bergmann, Ryo, Prati, Hempel, and Rillig (2017) |
| 294 | Siberian shrub allometry | Logan Berner | 4 | Public | Berner et al. (2015) |
| 381 | Leaf traits from Baltic Island species | Markus Bernhardt-Römermann | 4 | Restricted | Unpublished |
| 411 | Fall Velocity from Baltic Island species | Markus Bernhardt-Römermann | 5 | Restricted | Unpublished |
| 450 | BryForTrait—A life-history trait database of forest bryophytes | Markus Bernhardt-Römermann | 5 | Public | Bernhardt-Römermann, Poschlod, and Hentschel (2018) |
| 178 | PLANTATT—Attributes of British and Irish Plants | Biological Records Centre (BRC) | 3 | Public | Hill, Preston, and Roy (2004) |
| 468 | Tundra Trait Team Database | Anne Bjorkman | 6 | Public | Bjorkman et al. (2018) |
| 102 | Photosynthesis and Leaf Characteristics Database | Benjamin Blonder | 2 | Public | Unpublished |
| 226 | Leaf Structure, Venation and Economic Spectrum | Benjamin Blonder | 3 | Public | Blonder, Violle, Bentley, and Enquist (2010) |
| 295 | Leaf functional traits in the Hawaiian silversword alliance | Benjamin Blonder | 4 | Public | Blonder, Baldwin, Enquist, and Robichaux (2015) |
| 359 | Plant traits of <i>Arabidopsis thaliana</i> | Benjamin Blonder | 4 | Public | Blonder, Vasseur, et al. (2015) |
| 360 | Fossil Leaf Traits | Benjamin Blonder | 4 | Public | Blonder, Royer, Johnson, Miller, and Enquist (2014) |
| 361 | Angiosperm leaf venation networks | Benjamin Blonder | 4 | Public | Blonder and Enquist (2014) |
| 362 | Leaf economics spectrum and venation networks in <i>Populus tremuloides</i> | Benjamin Blonder | 4 | Public | Blonder, Violle, and Enquist (2013) |
| 517 | Mt Baldy whole plant traits | Benjamin Blonder | 6 | Public | Blonder et al. (2018) |
| 296 | Northern mixed-grass prairie species traits—Wyoming, USA | Dana Blumenthal | 4 | Public | Unpublished |
| 242 | Ellenberg Indicator Values | Gerhard Boenisch | 3 | Restricted | Ellenberg and Leuschner (2010) |
| 47 | South African Woody Plants Database (ZLTP) | William Bond | 1 | Public | Unpublished |
| 156 | Plant Traits of Canadian Forests | Benjamin Bond-Lamberty | 3 | Public | Bond-Lamberty, Wang, Gower, and Norman (2002) |
| 157 | Litter N Content of Canadian Forests | Benjamin Bond-Lamberty | 3 | Public | Bond-Lamberty, Gower, Wang, Cyr, and Veldhuis (2006) |
| 420 | Chinese savanna trees—aboveground trait data | Coline Boonman | 5 | Restricted | Unpublished |
| 297 | Traits of <i>Polygonum viviparum</i> L. | Florian Boucher | 4 | Public | Boucher, Thuiller, Arnoldi, Albert, and Lavergne (2013) |

(Continues)

TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|---|--------------------------|---------|--------------|---|
| 636 | La Selva FT Data | Vanessa Boukili | 6 | Public | Boukili and Chazdon (2017) |
| 421 | LECA—Traits of the European Alpine Flora | Louise Boulangeat | 5 | Public | Unpublished |
| 3 | Australian Fire Ecology Database | Ross Bradstock | 1 | Public | Unpublished |
| 165 | Leaf Traits From Madagascar | Kerry Brown | 3 | Restricted | Brown et al. (2013) |
| 428 | Trait and biomass data 2014 and 2015 of the BE_LOW project | Helge Bruelheide | 5 | Public | Herz et al. (2017) |
| 641 | Parana Tree Traits (2015) | Federico Brumnich | 6 | Public | Brumnich, Marchetti, and Pereira (2019) |
| 298 | Plant traits from Greby, Oeland, Sweden | Hans Henrik Bruun | 4 | Restricted | Baastrup-Spohr, Sand-Jensen, Nicolajsen, and Bruun (2015) |
| 545 | Dataset on reproductive traits of Scandinavian alpine plants | Hans Henrik Bruun | 6 | Public | Bruun (2019) |
| 632 | Atractocarpus from new Caledonia | David Bruy | 6 | Public | Bruy et al. (2018) |
| 427 | Coffea arabica var. Caturra—leaf traits | Serra Willow Buchanan | 5 | Public | Buchanan, Isaac, Van den Meersche, and Martin (2018) |
| 416 | Garmisch-Partenkirchen elevational gradients | Solveig Franziska Bucher | 5 | Restricted | Bucher et al. (2016) |
| 7 | Cedar Creek Plant Physiology Database | Daniel Bunker | 1 | Restricted | Unpublished |
| 585 | Arable weed trait data set | Jana Bürger | 6 | Restricted | Unpublished |
| 158 | Plant Traits from Circeo National Park, Italy | Sabina Burrascano | 3 | Public | Burrascano et al. (2015) |
| 159 | Traits of US Desert Woody Plant Species | Bradley Butterfield | 3 | Public | Butterfield and Briggs (2010) |
| 160 | SLA and LDMC for Canadian Wetland Species | Chaeho Byun | 3 | Restricted | Byun, de Blois, and Brisson (2012) |
| 447 | Herbaceous plants of Rouge National Urban Park | Marc Cadotte | 5 | Public | Sodhi, Livingstone, Carboni, and Cadotte (2019) |
| 448 | Cadotte 2017 Ecology Letters: herbaceous traits measured in the field | Marc Cadotte | 5 | Public | Cadotte (2017) |
| 446 | Ring-width dataset of dead and living trees | Maxime Cailleret | 5 | Restricted | Cailleret et al. (2017) |
| 522 | Ecophysiology of Selaginella and fern species in a Costa Rica wet tropical forest floor | Courtney Company | 6 | Public | Company, Martin, and Watkins (2018) |
| 161 | Leaf Traits in Central Apennines Beech Forests | Giandiego Campetella | 3 | Public | Campetella et al. (2011) |
| 220 | Leaf Traits in Italian Central Apennines Beech Forests | Giandiego Campetella | 3 | Public | Campetella et al. (2011) |
| 406 | Whole plant traits and leaf traits of four grassland species in Central Apennines (Italy) | Giandiego Campetella | 5 | Restricted | Wellstein et al. (2013) |
| 600 | Bay of Biscay dunes | Juan Antonio Campos | 6 | Restricted | Torca, Campos, and Herrera (2019) |
| 503 | Leaf and whole plant traits of Val Cervara old growth beech forest (Central Apennine, Italy) | Roberto Canullo | 6 | Restricted | Unpublished |
| 649 | Alpine tundra plants—Effects of climate warming on traits of species in mid-latitude snowbeds | Michele Carbognani | 6 | Public | Unpublished |
| 595 | UFPR Atlantic Forest Tree Traits | Marcos Carlucci | 6 | Restricted | Unpublished |
| 670 | Fabio Carvalho lowland fen peatland | Fabio Carvalho | 6 | Restricted | Carvalho, Brown, Waller, and Boom (2019); Carvalho, Brown, Waller, Bunting, et al. (2019) |
| 299 | Traits related to riparian plant invasion in South East Australia | Jane Catford | 4 | Restricted | Catford, Morris, Vesk, Gippel, and Downes (2014) |

(Continues)

TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|--|-------------------------|---------|--------------|---|
| 354 | Cedar Creek prairie plants (leaf, seed, dispersule, height, plant, root) | Jane Catford | 4 (5) | Restricted | Catford et al. (2019) |
| 54 | Floridian Leaf Traits Database | Jeannine Cavender-Bares | 1 | Public | Cavender-Bares, Keen, and Miles (2006) |
| 227 | Leaf Structure and Economics Spectrum | Bruno E. L. Cerabolini | 3 (4) | Restricted | Pierce, Ceriani, De Andreis, Luzzaro, and Cerabolini (2007) |
| 228 | Flora d'Italia Functional Traits Hoard (FIFTH) | Bruno E. L. Cerabolini | 3 | Restricted | Cerabolini et al. (2010) |
| 229 | Hydrophytes Traits Database | Bruno E. L. Cerabolini | 3 (4) | Restricted | Pierce, Brusa, Sartori, and Cerabolini (2012) |
| 371 | Olive Lawn Orchid Trait Database (OLO) | Bruno E. L. Cerabolini | 4 | Restricted | Pierce, Vagge, Brusa, and Cerabolini (2014) |
| 372 | Malga San Simone Trait Database (MSS) | Bruno E. L. Cerabolini | 4 | Restricted | Cerabolini, Pierce, Luzzaro, and Ossola (2009) |
| 377 | Functional Traits of Trees in Golfo Dulce, Costa Rica | Eduardo Chacon | 4 | Public | Chacón-Madrigal, Wanek, Hietz, and Dullinger (2018) |
| 300 | Leaf traits from the Loess Plateau region of northern Shaanxi in China | Yongfu Chai | 4 | Restricted | Unpublished |
| 120 | Tropical Respiration Database | Jeffrey Chambers | 2 | Public | Chambers et al. (2004) |
| 73 | Tundra Plant Traits Database | F Stuart Chapin III | 1 | Public | Unpublished |
| 501 | Leaf traits of beech forest understory species | Stefano Chelli | 6 | Restricted | Unpublished |
| 611 | Temperate tree species in New Jersey USA | Anping Chen | 6 | Public | Chen, Lichstein, Osnas, and Pacala (2014) |
| 498 | Fruit type, fruit dimension and flowering time | Si-Chong Chen | 6 | Public | Chen, Cornwell, Zhang, and Moles (2017) |
| 499 | Growth form data for 3581 Australian species | Si-Chong Chen | 6 | Public | Chen et al. (2017) |
| 491 | Leaf inclination angle | Francesco Chianucci | 6 | Public | Chianucci et al. (2018) |
| 370 | Trait Data from Niwot Ridge LTER (2016) | Adam Chmurzynski | 4 | Public | Unpublished |
| 489 | Pladias: Ellenberg-type indicator values for the Czech flora | Milan Chytrý | 6 | Public | Chytrý, Tichý, Dřevojan, Sádlo, and Zelený (2018) |
| 349 | Mediterranean psammophytes | Daniela Ciccarelli | 4 | Public | Ciccarelli (2015) |
| 394 | Great Basin sagebrush seedlings-greenhouse experiment | Courtney Collins | 5 | Public | Unpublished |
| 1 | Abisko and Sheffield Database | Johannes Cornelissen | 1 | Public | Cornelissen et al. (2004) |
| 37 | Sheffield Database | Johannes Cornelissen | 1 | Public | Cornelissen, Diez, and Hunt (1996) |
| 72 | Sheffield and Spain Woody Database | Johannes Cornelissen | 1 | Public | Castro-Díez, Puyravaud, Cornelissen, and Villar-Salvador (1998) |
| 121 | Fern Spore Mass Database | Johannes Cornelissen | 2 | Public | Unpublished |
| 55 | Jasper Ridge Californian Woody Plants Database | Will Cornwell | 1 | Public | Preston, Cornwell, and DeNoyer (2006) |
| 89 | ArtDeco Database | Will Cornwell | 1(2) | Restricted | Cornwell et al. (2008) |
| 430 | A Global Dataset of Leaf $\Delta^{13}C$ Data | Will Cornwell | 5 | Public | Cornwell et al. (2018) |
| 280 | Global Woodiness Database | William Cornwell | 3 | Public | Zanne et al. (2014) |

(Continues)

TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|--|----------------------|---------|--------------|--|
| 10 | Roots Of the World (ROW) Database | Joseph Craine | 1 | Public | Craine, Lee, Bond, Williams, and Johnson (2005) |
| 130 | Global 15N Database | Joseph Craine | 1 | Public | Craine et al. (2009) |
| 163 | Plant Traits for Grassland Species (Konza Prairie, Kansas, USA) | Joseph Craine | 3 | Public | Craine et al. (2011) |
| 230 | Panama Tree Traits | Dylan Craven | 3 | Public | Craven et al. (2007) |
| 378 | Traits of the Hungarian flora | Anikó Csecserits | 4 | Public | Lhotsky, Csecserits, Kovács, and Botta-Dukát (2016) |
| 293 | Jasper Ridge leaf chemistry data | Kyla Dahlin | 4 | Public | Dahlin, Asner, and Field (2013) |
| 164 | Italian Alps Plant Traits Database | Matteo Dainese | 3 | Public | Dainese and Bragazza (2012) |
| 346 | Leaf traits of <i>Dipterocarpus alatus</i> Roxb. ex. G. Don | Anh Tuan Dang-Le | 4 | Public | Dang-Le, Edelin, and Le-Cong (2013) |
| 500 | Pladias: Life forms and heights of the Czech flora | Jiri Danihelka | 6 | Public | Kaplan et al. (2019) |
| 388 | Leaf traits (and a few seed weights) collected from plants in the Macquarie Marshes, Australia | Samantha Dawson | 5 | Restricted | Dawson et al. (2017) |
| 224 | LBA-ECO CD-02 C and N Isotopes in Leaves and Atmospheric CO ₂ , Amazonas, Brazil | Alessandro de Araujo | 3 | Public | de Araujo et al. (2012) |
| 643 | Lapalala grass trait data 2019 | Arend de Beer | 6 | Restricted | Unpublished |
| 289 | Cabo de Gata-Níjar Natural Park | Angel de Frutos | 4 | Restricted | de Frutos, Navarro, Pueyo, and Alados (2015) |
| 167 | Leaf N-Retention Database | Franciska de Vries | 3 | Public | de Vries and Bardgett (2016) |
| 525 | Arboretum Grosspoessna 2014 leaf chemical and photosynthesis traits | Benjamin Dechant | 6 | Restricted | Dechant, Cuntz, Vohland, Schulz, and Doktor (2017) |
| 644 | <i>Quercus petraea</i> Photosynthesis Seasonal Climate Chambers Dataset | Nicolas Delpierre | 6 | Restricted | Verdier et al. (2014) |
| 645 | Barbeau Leaf Minerals, <i>Quercus petraea</i> , <i>Carpinus betulus</i> | Nicolas Delpierre | 6 | Restricted | Delpierre, Berveiller, Granda, and Dufrene (2015) |
| 166 | Traits of Hemiparasitic Plants | Andreas Demey | 3 | Public | Demey et al. (2013) |
| 368 | Wood traits of trees and lianas from the Brazilian Atlantic Forest | Arildo Dias | 4 | Restricted | Unpublished |
| 542 | <i>Smilax auriculata</i> nonstructural carbohydrates under-ground | Milton Diaz | 6 | Restricted | Unpublished |
| 86 | Sheffield-Iran-Spain Database | Sandra Díaz | 1 | Public | Díaz et al. (2004) |
| 189 | Mycorrhiza Database | Ian Dickie | 3 | Public | Koele, Dickie, Oleksyn, Richardson, and Reich (2012) |
| 231 | TROBIT West Africa | Tomas Domingues | 3 | Restricted | Domingues et al. (2010) |
| 232 | LBA ECO CD02: Tapajos Leaf Water Potential | Tomas Domingues | 3 | Restricted | Almeida et al. (2001) |
| 255 | LBA ECO Tapajos: Leaf Characteristics and Photosynthesis | Tomas Domingues | 3 | Restricted | Domingues, Martinelli, and Ehleringer (2007) |
| 614 | Ausplot traits | Ning Dong | 6 | Public | Dong et al. (2017) |
| 169 | Traits for Submerged Species (Aquatic Macrophytes) | Matthew Dunkle | 3 | Public | Unpublished |
| 301 | Specific leaf area responses to environmental gradients through space and time | John Dwyer | 4 | Public | Dwyer, Hobbs, and Mayfield (2014) |
| 467 | Data on chlorophylls and carotenoids in plants and lichens at the European Northeast of Russia | Olga Dymova | 6 | Restricted | Golovko, Dymova, Yatsco, and Tabalenkova (2011) |

(Continues)

TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|---|---------------------------|---------|--------------|---|
| 462 | RBG Kew Palm leaf traits | Thaise Emilio | 6 | Restricted | Unpublished |
| 380 | Plant growth form dataset for the New World | Kristine Engemann | 4 | Public | Engemann et al. (2016) |
| 129 | The Americas N&P database | Brian Enquist | 2 | Public | Kerkhoff, Fagan, Elser, and Enquist (2006) |
| 488 | IR_DowlatAbad | Mohammad Bagher Erfanian | 6 | Restricted | Unpublished |
| 171 | Seed Characteristics of Ericaceae | Jaime Fagundez | 3 | Public | Fagúndez and Izco (2008); Fagúndez, Juan, Fernández, Pastor, and Izco (2010) |
| 431 | BAAD: a biomass and allometry database for woody plants | Daniel Falster | 4 | Public | Falster et al. (2015) |
| 432 | Global Dataset of Maximum Rooting Depth | Ying Fan Reinfelder | 5 | Public | Fan et al. (2017) |
| 53 | Chinese Leaf Traits Database | Jingyun Fang | 1 | Restricted | Han, Fang, Guo, and Zhang (2005) |
| 594 | Traits <i>Arum pictum</i> Farris UNISS | Emmanuele Farris | 6 | Public | Unpublished |
| 477 | Fazlioglu et al. 2018_raw data | Fatih Fazlioglu | 6 | Public | Fazlioglu, Wan, and Bonser (2018) |
| 478 | Fazlioglu 2011, MSc Thesis | Fatih Fazlioglu | 6 | Public | Fazlioglu (2011) |
| 480 | Fazlioglu 2008 | Fatih Fazlioglu | 6 | Public | Fazlioglu (2008) |
| 481 | Fazlioglu et al. 2016 | Fatih Fazlioglu | 6 | Public | Fazlioglu, Al-Namazi, and Bonser (2016) |
| 482 | Fazlioglu et al. 2017 | Fatih Fazlioglu | 6 | Public | Fazlioglu, Wan, and Bonser (2016) |
| 490 | Fazlioglu et al. 2016-Data-synthesis | Fatih Fazlioglu | 6 | Public | Fazlioglu and Bonser (2016) |
| 271 | Plant Trait Database from Bajo Calima Region (Buenaventura, Colombia) | Fernando Fernández-Méndez | 3 | Public | Bocanegra-González, Fernández-Méndez, and Galvis-Jiménez (2015) |
| 513 | Traits of urban trees of Ibagué, Colombia | Fernando Fernández-Méndez | 6 | Public | Unpublished |
| 668 | Traits of urban species from Ibagué Colombia | Fernando Fernández-Méndez | 6 | Public | Núñez-Florez, Pérez-Gómez, and Fernández-Méndez (2019) |
| 74 | Costa Rica Rainforest Trees Database | Bryan Finegan | 1 | Public | Finegan et al. (2015), Chain-Guadarrama, Imbach, Vilchez-Mendoza, Vierling and Finegan (2017) |
| 561 | Nutrient Network leaf trait dataset | Jennifer Firn | 6 | Public | Firn et al. (2019) |
| 172 | Leaf Characteristics of <i>Pinus sylvestris</i> and <i>Picea abies</i> | Katrin Fleischer | 3 | Restricted | Unpublished |
| 104 | Categorical Plant Traits Database | Olivier Flores | 2 | Public | Unpublished |
| 414 | eHALOPH—Halophytes Database (2018) | Tim Flowers | 3 (4,5) | Public | Flowers, Santos, Jahns, Warburton, and Reed (2017) |
| 302 | Traits from Semi-Arid Mediterranean Ecosystems | Daniel Flynn | 4 | Public | de Frutos et al. (2015) |
| 366 | Plant Traits from LTER Matsch (Mazia), Italy | Veronika Fontana | 4 | Restricted | Unpublished |
| 174 | Ecological Flora of the British Isles | Henry Ford | 3 | Public | Fitter and Peat (1994) |
| 272 | Plant Coastal Dune Traits (France, Aquitaine) | Estelle Forey | 3 | Public | Unpublished |
| 170 | Plant Functional Traits of Arid Steppes in Eastern Morocco (ECWP-Morocco) | Cedric Frenette-Dussault | 3 | Public | Frenette-Dussault, Shipley, Léger, Meziane, and Hingrat (2011) |

(Continues)

TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|--|------------------------|---------|--------------|--|
| 105 | Traits from Subarctic Plant Species Database | Gregoire Freschet | 2 | Public | Freschet, Cornelissen, van Logtestijn, and Aerts (2010) |
| 234 | Leaf Traits Mount Hutt, New Zealand | Gregoire Freschet | 3 | Public | Kichenin, Wardle, Peltzer, Morse, and Freschet (2013) |
| 507 | Freschet et al. 2018 | Gregoire Freschet | 6 | Public | Freschet et al. (2018) |
| 510 | Freschet et al. 2015—VU greenhouse | Gregoire Freschet | 6 | Public | Freschet, Swart, and Cornelissen (2015) |
| 511 | Freschet et al. 2015—Mount Hutt | Gregoire Freschet | 6 | Public | Freschet, Kichenin, and Wardle (2015) |
| 661 | Mediterranean Forests in Transition (MEDIT) dataset | Nikolaos Fyllas | 6 | Restricted | Fyllas et al. (2017) |
| 175 | BASECO: a floristic and ecological database of Mediterranean French flora | Sophie Gachet | 3 | Public | Gachet, Vela, and Tatoni (2005) |
| 106 | Climbing Plants Trait Database | Rachael Gallagher | 2 | Public | Gallagher, Leishman, and Moles (2011) |
| 176 | Climbing plants trait dataset | Rachael Gallagher | 3 | Public | Gallagher and Leishman (2012) |
| 177 | Litter Traits Dataset | Pablo García-Palacios | 3 | Public | García-Palacios, Maestre, Kattge, and Wall (2013) |
| 45 | The VISTA Plant Trait Database | Eric Garnier | 1 | Restricted | Garnier et al. (2007) |
| 383 | Species and trait shifts in Apennine grasslands | Eleonora Giarrizzo | 4 | Public | Giarrizzo et al. (2016) |
| 664 | Khalil Prairie Plant Traits | David Gibson | 6 | Public | Khalil, Gibson, Baer, and Willand (2018) |
| 382 | Species able to reproduce after fire in a Brazilian Savanna | Aelton B. Giroldo | 4 | Restricted | Giroldo (2016) |
| 514 | Macquarie xylem leaf site hydraulics | Sean Gleason | 6 | Public | Unpublished |
| 304 | Leaf traits from North West Italy | Giovanni Gligora | 4 | Restricted | Unpublished |
| 348 | Leaf traits data (SLA) for 56 woody species at the Smithsonian Conservation Biology Institute-Forest | Erika B. Gonzalez-Akre | 4 | Public | Gonzalez-Akre, McShea, Bourg, and Anderson-Teixeira (2015) |
| 267 | Functional Traits for Restoration Ecology in the Colombian Amazon | Andres Gonzalez-Melo | 3 | Restricted | Unpublished |
| 529 | Diurnal and nocturnal gas exchange <i>Quercus</i> spp. | Elena Granda | 6 | Restricted | Unpublished |
| 530 | Seasonal gas exchange photoperiod <i>Quercus</i> spp. | Elena Granda | 6 | Restricted | Granda et al. (2020) |
| 92 | PLANTSdata USDA | Walton Green | 1 | Public | Green (2009) |
| 512 | Chromosome numbers of the Flora of Germany | Thomas Gregor | 6 | Public | Paule et al. (2017) |
| 275 | Plant Traits From Spanish Mediterranean shrublands | Nicholas Gross | 3 | Public | Unpublished |
| 460 | TRY Categorical Traits Dataset (update 2018) | Angela Guenther | 5 | Public | Unpublished |
| 179 | Leaf Gross Morphometrics Within one Species in Relation to Latitude, Altitude and Time | Greg Guerin | 3 | Public | Guerin, Wen, and Lowe (2012) |
| 123 | Virtual Forests Trait Database | Alvaro G. Gutierrez | 2 | Public | Gutiérrez and Huth (2012) |
| 609 | SERC-PREMIS Leaf Trait Dataset | Lillie Haddock | 6 | Public | Unpublished |
| 586 | <i>Cedrus atlantica</i> traits | Alain Hambuckers | 6 | Restricted | Unpublished |
| 180 | Leaf Ash Content in China's Terrestrial Plants | Wenxuan Han | 3 | Public | Han et al. (2012) |
| 181 | Leaf Nitrogen and Phosphorus for China's Terrestrial Plants | Wenxuan Han | 3 | Public | Chen, Han, Tang, Tang, and Fang (2013) |
| 236 | Chinese Traits | Sandy Harrison | 3 | Public | Prentice et al. (2010) |

(Continues)

TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|--|------------------|---------|--------------|---|
| 237 | Harze Trait Intravar: SLA, LDMC and Plant Height for Calcareous Grassland Species in South Belgium | Mélanie Harzé | 3 | Public | Unpublished |
| 183 | Komati Leaf Trait Data | Wesley Hattingh | 3 | Restricted | Unpublished |
| 541 | Rede Amazônia Sustentável | Joseph Hawes | 6 | Public | Unpublished |
| 184 | Cold Tolerance, Seed Size and Height of North American Forest Tree Species | Bradford Hawkins | 3 | Public | Unpublished |
| 367 | Tree species functional traits from Dinghushan Biosphere Reserve, southern China | Pengcheng He | 4 | Public | Li et al. (2015) |
| 669 | Leaf Economics Traits of Woody Species in Dinghushan Biosphere Reserve, Southern China | Pengcheng He | 6 | Public | He et al. (2019) |
| 238 | Fire-Related Traits in Proteaceae and Pinaceae | Tianhua He | 3 | Public | He, Lamont, and Downs (2011); He, Pausas, Belcher, Schwilk, and Lamont (2012) |
| 434 | Seed mass and nutrient concentration in <i>Grevillea</i> and <i>Hakea</i> species | Tianhua He | 5 | Public | He, Fowler, and Causley (2015) |
| 472 | Traits data for plant species from Western Australia | Tianhua He | 6 | Public | Unpublished |
| 628 | Peel Forest New Zealand Sycamore dataset | Mason Heberling | 6 | Public | Heberling and Mason (2018) |
| 634 | Trillium Trail Forest Wildflower Carbon Gain Phenology | Mason Heberling | 6 | Public | Heberling, Cassidy, Fridley, and Kalisz (2019) |
| 546 | Bark, Leaf and Root traits of tropical trees from the semi-deciduous forests of TENE, West Africa | Bruno Hérault | 6 | Restricted | Unpublished |
| 115 | Herbaceous Traits from the Öland Island Database | Thomas Hickler | 2 | Restricted | Hickler (1999) |
| 384 | Panama wood anatomy | Peter Hietz | 4 | Restricted | Hietz, Rosner, Hietz-Seifert, and Wright (2016) |
| 48 | Dispersal Traits Database | Steve Higgins | 1 | Restricted | Unpublished |
| 305 | Araucaria Forest Database | Pedro Higuchi | 3 | Public | Unpublished |
| 567 | LABDENDRO Brazilian Subtropical Forest Traits Database [Dataset IV] | Pedro Higuchi | 6 | Restricted | Unpublished |
| 185 | cDNA Content of Carex | Andrew Hipp | 3 | Public | Chung, Hipp, and Roalson (2012) |
| 671 | Morton Arboretum Experimental Prairie traitset 1, 2019 | Andrew Hipp | 6 | Public | Hipp et al. (2018) |
| 659 | Sjöman-Hirons Leaf Turgor Loss with Osmotic Potential at Full Turgor | Andrew Hirons | 6 | Restricted | Sjöman, Hirons, and Bassuk (2015) |
| 509 | Leaf functional traits for tropical saplings from Jianfengling, Hainan Island, China | J. Aaron Hogan | 6 | Public | Hogan, Valverde-Barrantes, Ding, Xu, and Baraloto (2019) |
| 306 | Plant traits from Costa Rica | Karen Holl | 4 | Public | Unpublished |
| 291 | MARGINS—leaf traits database | Daniel Hornstein | 4 | Public | Unpublished |
| 476 | Leaf traits and litter properties in Dinghu mountain, Guangdong province, China | Enqing Hou | 6 | Public | Hou, Chen, McGroddy, and Wen (2012) |
| 287 | Biomass allocation of Carex obnupta and Carex stipata | Nate Hough-Snee | 4 | Public | Hough-Snee, Nackley, Kim, and Ewing (2015) |
| 355 | Knautia arvensis; Mid-Norway | Knut Hovstad | 4 | Restricted | Unpublished |
| 580 | Alpyr | Estela Illa | 6 | Restricted | Unpublished |
| 551 | Coffee traits | Marney Isaac | 6 | Public | Isaac et al. (2017) |
| 463 | Leaf Chlorophyll and Carotenoids Database | Leonid Ivanov | 6 | Restricted | Unpublished |

(Continues)

TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|---|------------------------|---------|--------------|---|
| 339 | FRED—Fine-Root Ecology Database | Colleen Iversen | 4 (5) | Public | Iversen et al. (2017) |
| 606 | Colt Park Mesocosms | Benjamin Jackson | 6 | Public | De Long et al. (2019) |
| 240 | Nutrient Resorption Efficiency Database | Robert Jackson | 3 | Public | Vergutz, Manzoni, Porporato, Novais, and Jackson (2012) |
| 186 | Growth and Herbivory of Juvenile Trees | Hervé Jactel | 3 | Public | Unpublished |
| 579 | Effect of drought on pine needle traits | Hervé Jactel | 6 | Public | Unpublished |
| 81 | Global Leaf Element Composition Database | Steven Jansen | 1 | Public | Watanabe et al. (2007) |
| 82 | Global Wood Anatomy Database 2 | Steven Jansen | 1 | Public | Unpublished |
| 187 | Xylem Functional Traits (XFT) Database: Nature Subset | Steven Jansen | 3 | Public | Choat et al. (2012) |
| 241 | Xylem Functional Traits (XFT) Database | Steven Jansen | 3 | Public | Choat et al. (2012) |
| 389 | Leaf element composition of ferns and lycophytes | Steven Jansen | 5 | Public | Schmitt et al. (2017) |
| 673 | Wagenführ Woodatlas | Steven Jansen | 6 | Public | Wagenführ (2007) |
| 650 | SLA data La Palma 2019 (MIREN project) | Anke Jentsch | 6 | Public | Unpublished |
| 651 | SLA data La Palma 2019 (SLA project) | Anke Jentsch | 6 | Public | Unpublished |
| 523 | SLA and height data of exotic plant species in highland forest of Java and Bali | Decky Indrawan Junaedi | 6 | Restricted | Unpublished |
| 524 | AlpinePlants Austria | Robert R. Junker | 6 | Restricted | Unpublished |
| 516 | Pladias: Flowering time of the Czech flora | Zdenek Kaplan | 6 | Public | Kaplan et al. (2019) |
| 449 | KIT herbaceous functional gradient (median) | Teja Kattenborn | 5 | Restricted | Kattenborn, Fassnacht, and Schmidlein (2018) |
| 526 | KIT herbaceous functional gradient (weekly measurements) | Teja Kattenborn | 6 | Restricted | Kattenborn and Schmidlein (2019) |
| 67 | Leaf Physiology Database | Jens Kattge | 1 | Public | Kattge, Knorr, Raddatz, and Wirth (2009) |
| 398 | Yangambi (DR Congo) tropical forest tree traits | Elizabeth Kearsley | 5 | Restricted | Kearsley et al. (2016) |
| 404 | Leaf nutrients and SLA for old field shrubs and small trees from northeastern Connecticut, USA | Nicole Kinlock | 5 | Public | Unpublished |
| 60 | KEW African Plant Traits Database | Don Kirkup | 1 | Restricted | Kirkup, Malcolm, Christian, and Paton (2005) |
| 188 | Orchid Trait Dataset | Yael Kisel | 3 | Public | Kisel et al. (2012) |
| 540 | PalmTraits 1.0 | W. Daniel Kissling | 6 | Public | Kissling et al. (2019) |
| 336 | Ecophysiological traits of <i>Pinus halepensis</i> Miller | Tamir Klein | 4 | Public | Klein, Di Matteo, Rotenberg, Cohen, and Yakir (2012) |
| 25 | The LEDA Traitbase | Michael Kleyer | 1 (3) | Public | Kleyer et al. (2008) |
| 243 | CLO-PLA: a Database of Clonal Growth in Plants | Jitka Klimešová | 3 | Public | Klimešová and de Bello (2009) |
| 273 | Plant Trait Database in East and South-East Asia | Fumito Koike | 3 | Restricted | Koike (2001) |
| 308 | Plant traits from Andorra | Benjamin Komac | 4 | Restricted | Komac, Pladevall, Domènech, and Fanlo (2014) |
| 552 | Plants of the Experimental forest of the Botanical Garden Institute FEB RAS (Vladivostok, Russia) | Kirill Korznikov | 6 | Public | Unpublished |
| 190 | Yasuni Ecuador Leaves | Nathan Kraft | 3 | Public | Kraft, Valencia, and Ackerly (2008) |
| 191 | Baccara—Plant Traits of European Forests | Koen Kramer | 2 | Public | Unpublished |
| 4 | BiolFlor Database | Ingolf Kühn | 1 | Public | Klotz, Kühn, and Durka (2002, 2017) |

(Continues)

TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|--|-------------------------|---------|--------------|---|
| 469 | ACi-TGlob V1.0: A Global dataset of photosynthetic CO ₂ response curves of terrestrial plants | Dushan Kumarathunge | 6 | Public | Kumarathunge et al. (2019) |
| 528 | Hawaii Floral traits | Jonas Kuppler | 6 | Restricted | Kuppler et al. (2017) |
| 52 | Traits of Bornean Trees Database | Hiroko Kurokawa | 1 | Restricted | Kurokawa and Nakashizuka (2008), unpublished |
| 309 | Plant traits of grassland species | Kim La Pierre | 4 | Public | La Pierre and Smith (2014) |
| 265 | Saskatchewan Plant Trait Database | Eric Lamb | 3 | Public | Guy, Mischkolz, and Lamb (2013); Letts, Lamb, Mischkolz, and Romo (2015) |
| 192 | Meadow Plant Traits: Biomass Allocation, Rooting depth | Vojtech Lanta | 3 | Public | Unpublished |
| 193 | Plant Traits for <i>Pinus</i> and <i>Juniperus</i> Forests in Arizona | Daniel Laughlin | 1 (3) | Public | Laughlin, Fulé, Huffman, Crouse, and Laliberté (2011) |
| 536 | NZ kettehole plant traits | Daniel Laughlin | 6 | Public | Purcell, Lee, Tanentzap, and Laughlin (2018) |
| 538 | NZ tree traits | Daniel Laughlin | 6 | Public | Jager, Richardson, Bellingham, Clearwater, and Laughlin (2015) |
| 310 | French Alps Trait Data | Sandra Lavorel | 4 | Public | Lavorel et al. (2010) |
| 98 | New South Wales Plant Traits Database | Michelle Leishman | 1 | Public | Unpublished |
| 244 | Global Wood Anatomy Database 1 | Frederic Lens | 1 (3,4) | Public | Lens, Endress, Baas, Jansen, and Smets (2008); Lens, Gasson, Smets, and Jansen (2003); Lens et al. (2011) |
| 274 | Crown Architecture Database | Felipe Lenti | 3 | Public | Unpublished |
| 663 | Plant three traits (SLA, LA, Height) of 14 plots in Eastern Tibetan subalpine meadow | Xine Li | 6 | Public | Li, Nie, Song, Zhang, and Wang (2011) |
| 419 | Sherbrooke Dataset | Yuanzhi Li | 5 | Public | Li and Shipley (2018) |
| 642 | USA-China Biodiversity (USA samples) | Jeremy Lichstein | 6 | Restricted | Unpublished |
| 435 | Functional Resilience of Temperate Forests Dataset | Mario Liebergesell | 5 | Public | Liebergesell et al. (2016) |
| 436 | Global Leaf Gas Exchange Database (I) | Yan-Shih Lin | 5 | Public | Lin et al. (2015) |
| 646 | AM fungi and plant growth | Daijun Liu | 6 | Public | Unpublished |
| 647 | Observation of Ginkgo tree morphological difference | Daijun Liu | 6 | Public | Unpublished |
| 565 | Seed Information Database, Royal Botanic Gardens, Kew | Udayangani Liu | 1 (3,6) | Public | Royal Botanic Gardens Kew (2019) |
| 34 | The RAINFOR Plant Trait Database | Jon Lloyd | 1 | Restricted | Fyllas et al. (2009) |
| 602 | Chajul secondary forest species | Madelon Lohbeck | 6 | Restricted | Lohbeck et al. (2012) |
| 657 | Plant traits along primary succession | Alvaro Lopez-Garcia | 6 | Restricted | Unpublished |
| 413 | Extension of Zanne et al. Global wood density database | Gabriela Lopez-Gonzalez | 5 | Public | Unpublished |
| 195 | Leaf Herbivores, Fibres and Secondary Compounds For European Grassland Species | Jessy Loranger | 3 | Public | Loranger et al. (2012) |
| 508 | Pladias: leaf traits in the Czech flora | Zdeňka Lososová | 6 | Public | Findurová (2018) |
| 80 | French Massif Central Grassland Trait Database | Frédérique Louault | 1 | Public | Louault, Pillar, Aufrère, Garnier, and Soussana (2005) |
| 311 | Structural and biochemical leaf traits of boreal tree species in Finland | Petr Lukes | 4 | Public | Lukeš, Stenberg, Rautiainen, Möttö, and Vanhatalo (2013) |

(Continues)

TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|--|-------------------------|---------|--------------|--|
| 312 | Traits of temperate rainforest tree seedlings from New Zealand | Chris Lusk | 4 | Restricted | Lusk, Kaneko, Grierson, and Clearwater (2013) |
| 667 | Intraspecific variation leaf traits temperate rainforest | Chris Lusk | 6 | Public | Lusk (2019) |
| 605 | Terrestrial Mediterranean Orchids Functional Traits | Michele Lussu | 6 | Restricted | Unpublished |
| 342 | Photosynthesis Traits Worldwide | Vincent Maire | 4 | Public | Maire et al. (2015) |
| 196 | RAINFOR Leaf Shape, Driptip, Compoundness and Size Database | Ana Malhado | 3 | Public | Malhado et al. (2012); Malhado, Malhi, et al. (2009); Malhado, Whittaker, et al. (2009); Malhado et al. (2010) |
| 108 | The DIRECT Plant Trait Database | Peter Manning | 2 | Public | Fry, Power, and Manning (2013) |
| 245 | Ecotron Species Composition and Global Change Experiment | Peter Manning | 3 | Public | Manning et al. (2006) |
| 197 | Plant Hydraulic Traits | Stefano Manzoni | 3 | Public | Manzoni, Vico, Porporato, and Katul (2013) |
| 607 | Sardinia elevation gradient | Michela Marignani | 6 | Public | Campetella et al. (2019) |
| 313 | Wood carbon content database | Adam Martin | 4 | Public | Thomas and Martin (2012) |
| 423 | Leaf economic traits in wheat and maize | Adam Martin | 5 | Public | Martin, Hale, et al. (2018) |
| 433 | Wood carbon database | Adam Martin | 5 | Public | Martin, Doraisami, and Thomas (2018) |
| 438 | Crop Trait Database | Adam Martin | 5 | Public | Martin, Hale, et al. (2018) |
| 548 | Leaf economic traits in soy | Adam Martin | 6 | Public | Hayes et al. (2018) |
| 549 | Soy root traits | Adam Martin | 6 | Public | Martin et al. (2019) |
| 550 | Leaf economic traits in coffee | Adam Martin | 6 | Public | Martin et al. (2017) |
| 344 | Los Tuxtlas functional traits | Cristina Martínez-Garza | 4 | Public | Martínez-Garza, Bongers, and Poorter (2013) |
| 527 | CNP seed stoichiometry | Tereza Mašková | 6 | Restricted | Unpublished |
| 109 | Leaf Chemical Defense Database | Tara Joy Massad | 2 | Public | Unpublished |
| 357 | Functional traits of woody species in the Brazilian semi-arid region | Guilherme Mazzochini | 4 | Public | Unpublished |
| 475 | Woody plant traits from southeast Queensland, Australia | James McCarthy | 6 | Public | McCarthy, Dwyer, and Mokany (2019) |
| 459 | Yasuni Ecuador Leaf Drought Tolerance and Mechanical Toughness | Ian McFadden | 5 | Restricted | McFadden et al. (2019) |
| 465 | Yasuni Ecuador Leaf ITV | Ian McFadden | 6 | Public | Fortunel, McFadden, Valencia, and Kraft (2019) |
| 281 | Minimum Freezing Exposure Database | Daniel McGlenn | 3 | Public | Zanne et al. (2014) |
| 408 | Alaska Peatland Experiment PFT values | Mara McPartland | 5 | Public | Unpublished |
| 390 | <i>Rhododendron</i> leaf and root economics traits | Juliana Medeiros | 5 | Public | Medeiros, Burns, Nicholson, Rogers, and Valverde-Barrantes (2017) |
| 12 | ECOCRAFT | Belinda Medlyn | 1 | Public | Medlyn et al. (1999) |
| 437 | Global Leaf Gas Exchange Database (II) | Belinda Medlyn | 5 | Public | Knauer et al. (2017) |
| 314 | Shoot dry mass of annual grassland species | Zia Mehrabi | 3 | Restricted | Unpublished |
| 278 | Photosynthetic Capacity Dataset | Patrick Meir | 1 | Public | Meir et al. (2002) |
| 198 | Global Leaf-Sapwood Area Ratios | Maurizio Mencuccini | 3 | Public | Unpublished |
| 199 | Whole Plant Hydraulic Conductance | Maurizio Mencuccini | 3 | Public | Mencuccini (2003) |

(Continues)

TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|--|----------------------|---------|--------------|---|
| 113 | Panama Leaf Traits Database | Julie Messier | 2 | Public | Messier, McGill, and Lechowicz (2010) |
| 592 | Mont Mégantic Individual Traits 2016–2017 | Julie Messier | 6 | Public | Messier, Violle, Enquist, Lechowicz and McGill (2018) |
| 315 | Leaf traits for <i>Picea glauca</i> and <i>Pinus sylvestris</i> on University of Calgary (Canada) campus | Sean Michaletz | 4 | Public | Michaletz and Johnson (2006) |
| 539 | Thermo-Mediterranean species along Greece | Chrysanthi Michelaki | 6 | Restricted | Michelaki et al. (2019) |
| 200 | Altitudinal Vicariants Spain | Ruben Milla | 3 | Public | Milla and Reich (2011) |
| 415 | Ozark glade grassland plants | Jesse Miller | 5 | Public | Miller, Ives, Harrison, and Damschen (2017) |
| 247 | Traits of Halophytic Species in North-West-Germany | Vanessa Minden | 3 | Restricted | Minden and Kleyer (2011) |
| 290 | Traits of halophytic species | Vanessa Minden | 4 | Restricted | Minden and Kleyer (2015) |
| 316 | Element contents of plant organs of halophytic species, NW-Germany | Vanessa Minden | 4 | Restricted | Minden and Kleyer (2014) |
| 456 | Trait-responses of <i>Impatiens</i> species to light and nutrients | Vanessa Minden | 5 | Restricted | Minden and Gorschlüter (2016) |
| 457 | Antibiotics-effects on plant traits | Vanessa Minden | 5 | Restricted | Minden, Deloy, Volkert, Leonhardt, and Pufal (2017) |
| 458 | Antibiotics-effects on plant elements | Vanessa Minden | 5 | Restricted | Minden, Schnetger, Pufal, and Leonhardt (2018) |
| 518 | Plant traits along NPK gradients | Vanessa Minden | 6 | Restricted | Minden and Olde Venterink (2019) |
| 317 | Traits of <i>Hypochaeris radicata</i> under shade and drought conditions | Rachel Mitchell | 4 | Public | Unpublished |
| 28 | Global Seed Mass, Plant Height Database | Angela Moles | 1 | Public | Moles et al. (2005); Moles et al. (2009) |
| 201 | <i>Phalaris arundinacea</i> Genotypes | Jane Molofsky | 3 | Restricted | Lavergne and Molofsky (2007) |
| 266 | Hawaiian Lobeliad | Rebecca Montgomery | 3 | Public | Givnish, Montgomery, and Goldstein (2004) |
| 202 | Traits from the Wildfire Project | Marco Moretti | 3 | Public | Moretti and Legg (2009) |
| 307 | Hokkaido leaf traits | Akira Mori | 4 | Restricted | Mori et al. (2015) |
| 537 | Hokkaido plant traits 2 | Akira Mori | 6 | Restricted | Unpublished |
| 555 | Teshio grassland plant traits | Akira Mori | 6 | Restricted | Unpublished |
| 556 | Utana forest tree traits | Akira Mori | 6 | Restricted | Unpublished |
| 557 | Kuujuarapik-Whapmagoostui | Akira Mori | 6 | Restricted | Unpublished |
| 655 | Functional Flowering Plant Traits | Jane Morrison | 6 | Public | Unpublished |
| 318 | Leaf traits related to mesophyll conductance in wild relatives of tomato (<i>Solanum lycopersicon</i>) | Christopher Muir | 3 | Public | Muir, Hangarter, Moyle, and Davis (2013) |
| 648 | LEVEG-UFRGS | Sandra Müller | 6 | Restricted | Unpublished |
| 353 | Old fields of Eastern US (Siefert Data) | Luka Negoita | 4 | Public | Siefert, Fridley, and Ritchie (2014) |
| 484 | <i>Larix occidentalis</i> branch section, specific leaf area and dry mass | Andrew Nelson | 6 | Restricted | Williams and Nelson (2018) |
| 409 | Seed trait data from Neuschulz et al. 2016 | Eike Lena Neuschulz | 5 | Restricted | Neuschulz et al. (2016) |
| 560 | Fruit Traits Ecuador | Eike Lena Neuschulz | 6 | Public | Quitíán et al. (2018) |
| 49 | Tree Tolerance Database | Ülo Niinemets | 1 | Restricted | Niinemets and Valladares (2006) |

(Continues)

TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|--|-----------------------------|---------|--------------|---|
| 87 | Global Leaf Robustness and Physiology Database | Ülo Niinemets | 1 | Restricted | Niinemets (2001) |
| 426 | Ti Tree Database | Rachael Nolan | 5 | Public | Nolan et al. (2017) |
| 453 | European North Russia | Alexander Novakovskiy | 5 | Public | Dalke, Novakovskiy, Maslova, and Dubrovskiy (2018) |
| 656 | Decomposition experiment with standard substrate. Functional traits (SLA, LDMC and SSD) | Ricardo Oliveira | 6 | Restricted | Oliveira, Marques, and Marques (2019) |
| 203 | Plant Traits from Romania | Kinga Öllerer | 3 | Public | Ciocârlan (2009), Sanda, Bitanicolae and Barabas (2003) |
| 635 | Olson PNAS 2018 | Mark E. Olson | 6 | Restricted | Olson, Soriano, et al. (2018) |
| 637 | Rosell Olson Self Non self VD scaling | Mark E. Olson | 6 | Restricted | Rosell and Olson (2014) |
| 638 | Olson et al. AnnBot 2018 Corners Rules | Mark E. Olson | 6 | Restricted | Olson, Rosell, Zamora Muñoz, and Castorena (2018) |
| 640 | Olson et al. EcoLett Vessel diameter scaling | Mark E. Olson | 6 | Restricted | Olson et al. (2014) |
| 124 | Leaf Biomechanics Database | Yusuke Onoda | 2 | Restricted | Onoda et al. (2011) |
| 410 | Onoda 2017 leaf traits dataset | Yusuke Onoda | 5 | Public | Onoda et al. (2017) |
| 319 | Plant Traits from Fynbos Forests in the Cape Region | Renske Onstein | 4 | Public | Onstein, Carter, Xing, and Linder (2014) |
| 88 | The Netherlands Plant Traits Database | Jenny Ordoñez | 1 | Public | Ordoñez et al. (2010) |
| 520 | Pinnacle Reserve, ACT | Andrew O'Reilly-Nugent | 6 | Public | O'Reilly-Nugent et al. (2019) |
| 604 | Absorptive root morphological traits of boreal and hemi-boreal alder, birch and spruce forests | Ivika Ostonen | 6 | Public | Ostonen et al. (2013); Ostonen, Tedersoo, Suvi, and Lõhmus (2009) |
| 603 | Plant traits of granite outcrops' vegetation of Southwestern Australia | Gianluigi Ottaviani | 6 | Restricted | Ottaviani, Marcantonio, and Mucina (2016) |
| 365 | Tree of sex: a database of sexual systems | Sarah Otto | 4 | Public | The Tree of Sex Consortium () |
| 116 | The Netherlands Plant Height Database | Wim Ozinga | 2 | Restricted | Unpublished |
| 204 | Impatiens glandulifera Dataset | Anna Pahl | 3 | Public | Pahl, Kollmann, Mayer, and Haider (2013) |
| 439 | Functional Traits of Trees | C. E. Timothy Paine | 5 | Public | Paine et al. (2015) |
| 464 | Leaf traits of selected trees and Liana traits | Vivek Pandi | 6 | Public | Unpublished |
| 623 | Fagus sylvatica Paggeo Greece | Aristotelis C. Papageorgiou | 6 | Public | Unpublished |
| 320 | Grassland Plant Trait Database | Meelis Pärtel | 3 (4) | Public | Takkis (2014) |
| 27 | BROT Plant Trait Database | Juli Pausas | 1 | Public | Paula et al. (2009) |
| 440 | P50R—A global P50 and Resprouting Database | Juli Pausas | 5 | Public | Pausas et al. (2015) |
| 441 | BBB—A global Belowground Bud Bank database | Juli Pausas | 5 | Public | Pausas, Lamont, Paula, Appezzato-da-Glória, and Fidelis (2018) |
| 474 | BROT 2.0 | Juli Pausas | 6 | Public | Tavşanoğlu and Pausas (2018) |
| 270 | Plant Traits of Acidic Grasslands in Central Spain | Begoña Peco | 3 | Public | Peco, de Pablos, Traba, and Levassor (2005) |
| 91 | Catalonian Mediterranean Forest Trait Database | Josep Peñuelas | 1 | Restricted | Ogaya and Peñuelas (2003) |
| 114 | Hawaiian Leaf Traits Database | Josep Peñuelas | 2 | Restricted | Peñuelas et al. (2009) |
| 131 | Catalonian Mediterranean Shrubland Trait Database | Josep Peñuelas | 1 | Restricted | Unpublished |
| 493 | Weiqli-Sardans-Peñuelas China plants | Josep Peñuelas | 6 | Restricted | Unpublished |
| 496 | Garraf-Peñuelas | Josep Peñuelas | 6 | Restricted | Peñuelas et al. (2017) |
| 497 | Prades-Peñuelas | Josep Peñuelas | 6 | Restricted | Peñuelas et al. (2018) |

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TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|--|----------------------|---------|--------------|---|
| 591 | Mediterranean mixed forest | Antonio Jesus Perea | 6 | Restricted | Unpublished |
| 75 | ECOQUA South American Plant Traits Database | Valerio Pillar | 1 | Restricted | Müller, Overbeck, Pfadenhauer, and Pillar (2006) |
| 387 | LEVA-UFPE plant trait database | Bruno Pinho | 5 | Restricted | Unpublished |
| 470 | Neotropical woody plants functional trait database | Bruno Pinho | 6 | Restricted | Unpublished |
| 533 | Atlantic forest and Mexican forests | Bruno Pinho | 6 | Restricted | Pinho et al. (2017) |
| 321 | Leaf angles | Jan Pisek | 3 | Public | Pisek, Sonntag, Richardson, and Möttus (2013) |
| 417 | Leaf angles Raabe et al. 2015 | Jan Pisek | 5 | Public | Raabe et al. (2015) |
| 168 | Traits for Herbaceous Species from Andorra | Clara Pladevall | 3 | Restricted | Unpublished |
| 95 | The Tansley Review LMA Database | Hendrik Poorter | 1 | Restricted | Poorter, Niinemets, Poorter, Wright, and Villar (2009) |
| 110 | Categorical Plant Traits Database | Hendrik Poorter | 2 | Public | Unpublished |
| 248 | Photosynthesis Type Database | Hendrik Poorter | 3 | Public | Kapralov, Smith, and Filatov (2012) |
| 684 | Biomass Allocation Database | Hendrik Poorter | 6 | Public | Poorter et al. (2015) |
| 33 | Tropical Rainforest Traits Database | Lourens Poorter | 1 | Restricted | Poorter and Bongers (2006) |
| 71 | BIOPOP: Functional Traits for Nature Conservation | Peter Poschlod | 1 | Restricted | Poschlod et al. (2003) |
| 151 | Aluminium Tolerance Dataset | Peter Poschlod | 3 | Public | Abedi, Bartelheimer, and Poschlod (2012) |
| 615 | Yarramundi species trait data | Sally Power | 6 | Restricted | Unpublished |
| 263 | Costa Rican Tropical Dry Forest Trees | Jennifer Powers | 3 | Public | Powers and Tiffin (2010) |
| 205 | Leaf Allometry Dataset | Charles Price | 3 | Public | Price and Enquist (2007) |
| 506 | Functional traits of Cistus species leaf cohorts | Giacomo Puglielli | 6 | Public | Puglielli and Varone (2018) |
| 578 | Reproductive traits of neophytes in the Czech Republic | Petr Pyšek | 6 | Restricted | Moravcová, Pyšek, Jarošík, Havlíčková, and Zákřavský (2010) |
| 544 | Mediterranean Roadcut Trait Data | Valerie Raavel | 6 | Public | Raavel, Violle, and Munoz (2012) |
| 626 | Bolivian Bofedal TraitData | Valerie Raavel | 6 | Public | Raavel, Anthelme, Meneses, and Munoz (2018) |
| 59 | Frost Hardiness Database | Anja Rammig | 1 | Restricted | Unpublished |
| 639 | Mt Baldy seed traits | Courtenay Ray | 6 | Restricted | Unpublished |
| 206 | Maxfield Meadow, Rocky Mountain Biological Laboratory—LMA | Quentin Read | 3 | Public | Unpublished |
| 323 | Rocky Mountain Biological Laboratory WSR/gradient plant traits | Quentin Read | 4 | Public | Unpublished |
| 35 | Reich-Oleksyn Global Leaf N, P Database | Peter Reich | 1 | Restricted | Reich, Oleksyn, and Wright (2009) |
| 70 | Cedar Creek Savanna SLA, C, N Database | Peter Reich | 1 | Restricted | Willis et al. (2010) |
| 94 | Global A, N, P, SLA Database | Peter Reich | 1 | Restricted | Reich et al. (2009) |
| 96 | Global Respiration Database | Peter Reich | 1 | Restricted | Reich et al. (2008) |
| 494 | Poblet Ecophysiology | Víctor Resco de Dios | 6 | Public | Nolan, Hedo, Arteaga, Sugai, and Resco de Dios (2018) |
| 495 | Live fuel moisture data at a pine forest | Víctor Resco de Dios | 6 | Public | Soler Martin et al. (2017) |
| 571 | New Zealand Bark Thickness | Sarah Richardson | 6 | Public | Richardson et al. (2015) |

(Continues)

TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|---|---------------------------|---------|--------------|--|
| 572 | New Zealand Nothofagus leaf and stem traits | Sarah Richardson | 6 | Public | Richardson et al. (2013) |
| 573 | New Zealand Alpine Granite Leaf Nutrient Concentrations | Sarah Richardson | 6 | Public | Richardson et al. (2012) |
| 343 | Sphagnum tissue CNP | Bjorn Robroek | 4 | Public | Unpublished |
| 620 | Leaf and flower pressure volume curve data | Adam Roddy | 6 | Public | Roddy, Jiang, Cao, Simonin, and Brodersen (2019) |
| 442 | Plant Trait Dataset for Tree-Like Growth Forms | Arthur Vinicius Rodrigues | 5 | Public | Rodrigues et al. (2018) |
| 207 | Herbaceous Plants Traits From Southern Germany | Christine Roemermann | 3 | Public | Unpublished |
| 400 | Leaf Mass Area, Leaf Carbon and Nitrogen Content from Barrow, Alaska | Alistair Rogers | 5 | Public | Rogers, Serbin, Ely, Sloan, and Wullschleger (2017) |
| 401 | Arctic Leaf Photosynthetic Parameters Vcmax and Jmax Estimated from CO ₂ Response Curves | Alistair Rogers | 5 | Public | Rogers et al. (2017) |
| 402 | Arctic Photosynthetic parameter Vcmax Estimated Using the 1-Point Method | Alistair Rogers | 5 | Public | Rogers et al. (2017) |
| 325 | Rollinson DBH | Emily Rollinson | 4 | Public | Unpublished |
| 326 | Leaf nutrient concentrations | Victor Rolo Romero | 3 | Public | Rolo, López-Díaz, and Moreno (2012) |
| 396 | Rehabilitating Coastal dune forest | Victor Rolo Romero | 5 | Restricted | Rolo, Olivier, and van Aarde (2016) |
| 590 | Leaf Traits of Aquatic Plants | Dina Ronzhina | 6 | Public | Ronzhina and P'Yankov (2001) |
| 589 | Jena Experiment Traits | Christiane Roscher | 6 | Public | Gubsch et al. (2011); Lipowsky et al. (2015); Roscher, Schmid, Buchmann, Weigelt, and Schulze (2011) |
| 391 | Dataset for Rosell 2016 New Phytologist | Julieta Rosell | 5 | Restricted | Rosell (2016) |
| 392 | Dataset for Rosell et al. 2017 New Phytologist | Julieta Rosell | 5 | Restricted | Rosell et al. (2017) |
| 613 | Inner bark and wood NSC concentrations, density, height, phenology, bark photosynthesis, bark thickness | Julieta Rosell | 6 | Restricted | Unpublished |
| 633 | Bark Wood traits New Phytol 2014 and Oecologia 2015 | Julieta Rosell | 6 | Restricted | Rosell, Gleason, Méndez-Alonzo, Chang, and Westoby (2013) |
| 519 | Swiss National Park, Engadine | Christian Rossi | 6 | Restricted | Rossi (2017) |
| 208 | Response of Tree Growth to Light and Size, Barro Colorado Island, Panama | Nadja Rüger | 3 | Public | Rüger, Berger, Hubbell, Vieilledent, and Condit (2011) |
| 283 | Response of Tree Mortality to Light, Size and Past Growth, Barro Colorado Island, Panama | Nadja Rüger | 3 | Public | Rüger, Huth, Hubbell, and Condit (2011) |
| 284 | Response of Tree Recruitment to Light, Barro Colorado Island, Panama | Nadja Rüger | 3 | Public | Rüger, Huth, Hubbell, and Condit (2009) |
| 672 | DISEQU-ALP | Sabine Rumpf | 6 | Public | Rumpf et al. (2018) |
| 111 | Leaf and Whole-Plant Traits Database | Lawren Sack | 2 | Restricted | Nakahashi, Frole, and Sack (2005) |
| 675 | Salguero-Gomez Cistus albidus 2019 | Rob Salguero-Gomez | 6 | Public | Unpublished |
| 249 | California Coastal Grassland Database | Brody Sandel | 3 | Public | Sandel, Corbin, and Krupa (2011) |
| 543 | Functional traits related to flammability | Carolina Santacruz | 6 | Restricted | Unpublished |
| 407 | Leaf nutrient concentrations from Scalon et al. 2017 | Marina Scalon | 5 | Public | Scalon et al. (2017) |

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TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|---|--------------------------|---------|--------------|---|
| 209 | Leaf Area, Dry Mass and SLA Dataset | Brandon Schamp | 3 | Restricted | Unpublished |
| 211 | BIOTREE Trait Shade Experiment | Michael Scherer-Lorenzen | 3 | Public | Scherer-Lorenzen, Schulze, Don, Schumacher, and Weller (2007) |
| 350 | Trait Data for African Plants—A Photo Guide | Marco Schmidt | 4 | Public | Dressler, Schmidt, and Zizka (2014) |
| 531 | Paracou ITV | Sylvain Schmitt | 6 | Restricted | Unpublished |
| 532 | Uppangala Traits | Sylvain Schmitt | 6 | Restricted | Unpublished |
| 395 | Senckenberg leaf venation data of West African Plants | Julio Schneider | 5 | Restricted | Unpublished |
| 584 | Traits of Woody Plants in Hluhluwe-iMfolozi Park, South Africa | Simon D. Schowanek | 6 | Restricted | Unpublished |
| 587 | Raja Ampat tree dataset | Julian Schrader | 6 | Public | Unpublished |
| 593 | Branch anatomy | Bernhard Schuldt | 6 | Public | Schuldt, Leuschner, Brock, and Horna (2013) |
| 250 | FYNBASE—Database of Plant Traits From the South African Fynbos Biome | Frank Schurr | 3 | Restricted | Schurr et al. (2007) |
| 251 | The Xylem/Phloem Database | Fritz Schweingruber | 3 | Public | Schweingruber and Landolt (2005) |
| 356 | Aboveground morphological traits of grassland species | Marina Semchenko | 4 | Restricted | Abakumova, Zobel, Lepik, and Semchenko (2016) |
| 351 | Miombo tree species—SLA, leaf and seed size | Colleen Seymour | 4 | Public | Joseph, Seymour, Cumming, Cumming, and Mahlangu (2014) |
| 352 | Miombo tree species—Leaf nutrients | Colleen Seymour | 4 | Public | Seymour et al. (2014) |
| 485 | Catimbau National Park, Brazil | Julia Sfair | 6 | Restricted | Sfair, de Bello, de França, Baldauf, and Tabarelli (2018) |
| 374 | Traits of fertile (spore bearing) leaves of rainforest ferns from El Verde Field, Puerto Rico | Joanne Sharpe | 4 | Public | Unpublished |
| 375 | Traits of sterile (non-spore bearing) leaves of rainforest ferns from El Verde Field, Puerto Rico | Joanne Sharpe | 4 | Public | Unpublished |
| 574 | Traits of 48 native and alien Asteraceae in Germany (common-garden experiment) | Christine Sheppard | 6 | Restricted | Unpublished |
| 212 | Herbs Water Relations on Soil Moisture Gradients | Serge Sheremetev | 3 | Public | Sheremetiev and Chebotareva (2018) |
| 412 | The Global Leaf Traits Database | Serge Sheremetev | 5 | Public | Unpublished |
| 471 | Species Growth Forms (Angiosperms)—Update 9 | Serge Sheremetev | 6 | Public | Sheremetiev and Chebotareva (2018) |
| 483 | A Geological Age of an Angiosperm Genera and Families | Serge Sheremetev | 6 | Public | Sheremetiev and Chebotareva (2018) |
| 99 | Tropical Traits from West Java Database | Satomi Shiodera | 1 | Public | Shiodera, Rahajoe, and Kohyama (2008) |
| 50 | Leaf and Whole Plant Traits Database | Bill Shipley | 1 | Public | Shipley (2002) |
| 252 | Leaf Structure and Chemistry | Bill Shipley | 3 | Public | Auger and Shipley (2012) |
| 608 | Traits of understory plants of western Canadian forest | Tanvir Ahmed Shovon | 6 | Restricted | Shovon et al. (2019) |
| 616 | Div Resource Pot Experiment | Alrun Siebenkäs | 6 | Restricted | Siebenkäs, Schumacher, and Roscher (2015) |
| 133 | New York Old Field Plant Traits Database | Andrew Siefert | 2 | Restricted | Siefert (2011) |
| 327 | Eastern US Old Field Plant Traits Database | Andrew Siefert | 4 | Public | Siefert et al. (2014) |

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TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|--|------------------------|---------|--------------|---|
| 253 | Allometric Coefficients of Aboveground Tree Biomass | Carlos Sierra | 3 | Public | Zapata-Cuartas, Sierra, and Alleman (2012) |
| 393 | LABDENDRO Brazilian Subtropical Forest Traits Database [Dataset II] | Ana Carolina Silva | 5 | Restricted | Souza et al. (2017) |
| 568 | LABDENDRO Brazilian Subtropical Forest Traits Database [Dataset III] | Ana Carolina Silva | 6 | Restricted | Soboleski et al. (2017) |
| 466 | Leaf and stem traits of <i>Eremanthus erythropappus</i> | Mateus Silva | 6 | Public | Silva, Teodoro, Bragion, and van der Berg (2019) |
| 534 | Silva et al. 2019 | Vasco Silva | 6 | Restricted | Silva, Catry, et al. (2019) |
| 358 | Leaf Respiration Acclimation in Panama | Martijn Slot | 4 | Public | Slot, Rey-Sánchez, Winter, and Kitajima (2014) |
| 385 | Photosynthesis Temperature Response Panama | Martijn Slot | 5 | Restricted | Slot and Winter (2017) |
| 213 | Day and Night Gas Exchange of Deciduous Tree Seedlings in Response to Experimental Warming and Precipitation | Nick Smith | 3 | Public | Smith, Pold, Goranson, and Dukes (2016) |
| 424 | LCE: Leaf carbon exchange dataset for tropical, temperate, and boreal species of North and Central America | Nick Smith | 5 | Public | Smith and Dukes (2017) |
| 328 | Root Traits of Grassland Species | Stuart William Smith | 4 | Public | Smith, Woodin, Pakeman, Johnson, and van der Wal (2014) |
| 558 | Sonnier and Boughton ABS | Gregory Sonnier | 6 | Public | Unpublished |
| 454 | Leaf traits from ECOSHRUB Dovrefjell Norway | Mia Vedel Sørensen | 5 | Public | Unpublished |
| 77 | FAPESP Brazil Rainforest Database | Enio Sosinski | 1 (3) | Restricted | Unpublished |
| 84 | Causasus Plant Traits Database | Nadejda Soudzilovskaia | 1 | Restricted | Unpublished |
| 162 | Mycorrhizal Intensity Database Across the Former Soviet Union | Nadejda Soudzilovskaia | 3 | Public | Akhmetzhanova et al. (2012) |
| 329 | Plant traits from alpine plants on Mt. Malaya Khatipara | Nadejda Soudzilovskaia | 3 | Restricted | Soudzilovskaia et al. (2013) |
| 369 | Traits and ecological strategies of 66 subtropical tree species in the Brazilian Atlantic Forest | Alexandre Souza | 4 | Public | Forgiarini, Souza, Longhi, and Oliveira (2014) |
| 256 | Niwot Alpine Plant Traits | Marko Spasojevic | 3 | Public | Spasojevic and Suding (2012) |
| 418 | Ozark Tree leaf traits | Marko Spasojevic | 5 | Public | Spasojevic, Turner, and Myers (2016) |
| 674 | Staples et al. Australian Reforestation Tree Database | Timothy Staples | 6 | Public | Staples, Dwyer, England, and Mayfield (2019) |
| 547 | Traits of Alpine species in GLORIA regions Hochschwab, Schrankogel, Majella and Lefka Ori | Klaus Steinbauer | 6 | Restricted | Unpublished |
| 364 | Plant species high elevation dataset | Christien Steyn | 4 | Public | Steyn, Greve, Robertson, Kalwij, and le Roux (2016) |
| 577 | Marion Island Fine Scale | Tanya Strydom | 6 | Restricted | Unpublished |
| 610 | Ash Free Dry Mass of <i>Ceratophyllum submersum</i> | Ivana Svitkova | 6 | Restricted | Unpublished |
| 51 | Tropical Plant Traits From Borneo Database | Emily Swaine | 1 | Public | Swaine (2007) |
| 214 | Maximum Height of Chinese Tree Species (from <i>Silva Sinica</i>) | Nathan Swenson | 3 | Public | Zheng (1983) |
| 288 | CTFS Luquillo Forest Dynamics Plot | Nathan Swenson | 4 | Public | Swenson, Anglada-Cordero, and Barone (2010) |

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TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|--|-----------------------|---------|--------------|--|
| 581 | Charidemi Database | Ruben Tarifa | 6 | Restricted | Unpublished |
| 345 | CIRAD Selmet Tree LNC Sahel | Simon Taugourdeau | 4 | Public | Unpublished |
| 451 | NodDB—A global database of plants with root-symbiotic nitrogen fixation | Leho Tedersoo | 5 | Public | Tedersoo et al. (2018) |
| 662 | Thom 2019 | Dominik Thom | 6 | Public | Unpublished |
| 473 | Functional trait data Colombian dry Forest trees | Evert Thomas | 6 | Public | Thomas et al. (2017) |
| 625 | Tng et al. 2013 Traits | David Tng | 6 | Public | Tng et al. (2013) |
| 575 | Myricaria germanica | Sitzia Tommaso | 6 | Restricted | Sitzia, Michielon, Iacopino, and Kotze (2016) |
| 665 | Species patch metrics | Sitzia Tommaso | 6 | Public | Sitzia, Dainese, Krüsi, and McCollin (2017) |
| 492 | Xylem anatomical traits for different Cistus species | Jose M. Torres-Ruiz | 6 | Public | Torres-Ruiz et al. (2017) |
| 215 | Plant Functional Traits From the Province of Almeria (Spain) | Alexia Totte | 3 | Public | Unpublished |
| 338 | Leaf Traits and Seed Mass of Cover Crops | Hélène Tribouillois | 4 | Public | Tribouillois et al. (2015) |
| 598 | Soft traits of the Northern Swan Coastal Plain and Geraldton Sandplain kwongan vegetation, Western Australia | James Tsakalos | 6 | Restricted | Unpublished |
| 685 | Tree and Forest Biomass Distribution | Vladimir Usoltsev | 6 | Public | Usoltsev (2010) |
| 216 | Traits for Common Grasses and Herbs in Spain | Fernando Valladares | 3 | Public | Unpublished |
| 56 | Wetland Dunes Database | Peter van Bodegom | 1 | Restricted | van Bodegom, Sorrell, Oosthoek, Bakke, and Aerts (2008) |
| 90 | Ukraine Wetlands Plant Traits Database | Peter van Bodegom | 1 (2) | Restricted | Unpublished |
| 117 | Categorical Plant Traits Database | Peter van Bodegom | 2 | Public | Unpublished |
| 330 | Traits of Ukraine native and invasive plant species | Peter van Bodegom | 4 | Restricted | Unpublished |
| 617 | Forbs and grasses in North East Belgium | Elisa Van Cleemput | 6 | Public | Van Cleemput, Roberts, Honnay, and Somers (2019) |
| 332 | Photosynthetic parameters, respiration and leaf traits of a Peruvian tropical montane cloud forest | Marjan van de Weg | 4 | Public | van de Weg, Meir, Grace, and Ramos (2011) |
| 333 | LMA, leaf tissue density and N&P content along the Amazon-Andes gradient in Peru | Marjan van de Weg | 4 | Public | van de Weg, Meir, Grace, and Atkin (2009) |
| 618 | Montane grassland Functional Traits | Stephni van der Merwe | 6 | Restricted | Unpublished |
| 619 | Sub Antarctic tundra_Functional Traits | Stephni van der Merwe | 6 | Restricted | Unpublished |
| 331 | Traits of savannah trees in the Hluhluwe-iMfolozi Game reserve, South Africa | Fons van der Plas | 4 | Public | Van der Plas, Howison, Reinders, Fokkema, and Olf (2013) |
| 599 | Trait data Pibiri—Masha van der Sande | Masha van der Sande | 6 | Public | van der Sande et al. (2017) |
| 562 | 1000 Seedweight | Mark van Kleunen | 6 | Public | Chrobock, Kempel, Fischer, and van Kleunen (2011) |
| 563 | Germination | Mark van Kleunen | 6 | Public | Chrobock et al. (2011) |
| 564 | Competition | Mark van Kleunen | 6 | Public | Kempel, Chrobock, Fischer, Rohr, and van Kleunen (2013) |

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TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|--|--------------------|---------|--------------|---|
| 597 | shade (for TRY)_mvk | Mark van Kleunen | 6 | Public | Feng and van Kleunen (2014) |
| 461 | Western Pamirs | Kim André Vanselow | 6 | Public | Vanselow, Samimi, and Breckle (2016) |
| 627 | Functional traits of native and invasive species in tropical dry forest | Maribel Vasquez | 6 | Public | Vásquez-Valderrama (2016) |
| 264 | Functional Traits Of Bulgarian Grasslands | Kiril Vassilev | 3 | Restricted | Vassilev, Pedashenko, Nikolov, Apostolova, and Dengler (2011) |
| 217 | Canopy Traits for Temperate Tree Species Under High N-Deposition | Kris Verheyen | 3 | Public | Adriaenssens (2012) |
| 653 | Rasgos funcionales especies arboreas cuenca Amazonica | Jaime Villacís | 6 | Public | Unpublished |
| 122 | Plant Habit Database | Cyrille Violle | 2 | Public | Unpublished |
| 588 | Leaf trait records of rare and endangered plant species in the Pannonian flora | Anna Vojtko | 6 | Public | Unpublished |
| 218 | Plant Traits, Virginia, USA | Betsy von Holle | 3 | Public | Von Holle and Simberloff (2004) |
| 334 | A Global Data Set of Leaf Photosynthetic Rates, Leaf N and P, and Specific Leaf Area | Anthony Walker | 4 | Public | Walker et al. (2014) |
| 443 | The China Plant Trait Database | Han Wang | 5 | Public | Wang et al. (2018) |
| 219 | Seed Mass from Literature | Zhonglei Wang | 3 | Restricted | Unpublished |
| 630 | Watkins, Sjoman and Hitchmough CSR ordination of trees | Harry Watkins | 6 | Public | Unpublished |
| 258 | Global Wood Decomposition Database (version 1.1) | James Weedon | 3 | Public | Weedon et al. (2009) |
| 347 | Traits of 59 grassland species | Alexandra Weigelt | 4 | Public | Schroeder-Georgi et al. (2015) |
| 455 | Gift—Plant Growth Form Dataset | Patrick Weigelt | 5 | Restricted | Weigelt, König, and Krefl (2019) |
| 66 | Midwestern and Southern US Herbaceous Species Trait Database | Evan Weiher | 1 | Restricted | Unpublished |
| 335 | Plant traits from Wisconsin, USA | Evan Weiher | 4 | Restricted | Unpublished |
| 444 | Symbiotic N ₂ -Fixation Database | Gijsbert Werner | 5 | Public | Werner, Cornwell, Sprent, Kattge, and Kiers (2014) |
| 445 | Mycorrhizal Association Database | Gijsbert Werner | 5 | Public | Werner et al. (2018) |
| 79 | BIOME-BGC Parameterization Database | Michael White | 1 | Public | White, Thornton, Running, and Nemani (2000) |
| 259 | Angiosperm Shoot Ionomes Dataset | Philip White | 3 | Public | White et al. (2012) |
| 262 | LBA-ECO CD-09 Soil and Vegetation Characteristics, Tapajos National Forest, Brazil | Mathew Williams | 3 | Public | Williams, Shimabokuro, and Rastetter (2012) |
| 486 | Brassica tournefortii | Daniel Winkler | 6 | Public | Winkler, Gremer, Chapin, Kao, and Huxman (2018) |
| 487 | Sasa kurilensis | Daniel Winkler | 6 | Public | Winkler, Amagai, Huxman, Kaneko, and Kudo (2016) |
| 521 | Heterotheca brandegei traits | Daniel Winkler | 6 | Restricted | Winkler, Lin, Delgadillo, Chapin, and Huxman (2019) |
| 68 | The Functional Ecology of Trees (FET) Database—Jena | Christian Wirth | 1 (3) | Public | Wirth and Lichstein (2009) |
| 20 | GLOPNET—Global Plant Trait Network Database | Ian Wright | 1 | Public | Wright et al. (2004) |
| 57 | Categorical Plant Traits Database | Ian Wright | 1 | Public | Unpublished |
| 63 | Fonseca/Wright New South Wales Database | Ian Wright | 1 | Public | Fonseca, Overton, Collins, and Westoby (2000) |

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TABLE A1 (Continued)

| ID | Dataset name | Custodian | Version | Availability | Reference |
|-----|---|------------------|---------|--------------|---|
| 64 | Neotropic Plant Traits Database | Ian Wright | 1 | Public | Wright et al. (2006) |
| 65 | Overton/Wright New Zealand Database | Ian Wright | 1 | Public | Unpublished |
| 279 | Global Leaf Phenology Database | Ian Wright | 3 | Public | Zanne et al. (2014) |
| 340 | Global leaf size dataset | Ian Wright | 4 | Public | Wright et al. (2017) |
| 601 | Ian Wright NT savanna Traits | Ian Wright | 6 | Public | Wright et al. (2018) |
| 221 | Leaf Economic Traits Across Varying Environmental Conditions | Justin Wright | 3 | Public | Wright and Sutton-Grier (2012) |
| 112 | Panama Plant Traits Database | S. Joseph Wright | 2 | Public | Wright et al. (2010) |
| 612 | Ecophysiological parameters of tree and shrub leaves in forest-steppe plantings | Nikolai Yankov | 6 | Public | Kavelenova, Rozno, Kireyeva, and Smirnov (2007); Pomogaybin and Pomogaybin |
| 125 | <i>Quercus</i> Leaf C&N Database | Benjamin Yguel | 2 | Public | Yguel et al. (2011) |
| 322 | Shoot N/P stoichiometry of Inner Mongolia grassland species | Qiang Yu | 3 | Public | Yu et al. (2011) |
| 61 | Global Wood Density Database | Amy Zanne | 1 | Public | Chave et al. (2009) |
| 62 | Global Vessel Anatomy Database | Amy Zanne | 1 | Public | Zanne et al. (2010) |
| 554 | Leaf functional traits from Sino-US Dimension project (Chinese collaborators) | Yunpeng Zhao | 6 | Restricted | Unpublished |
| 621 | Metasequoia glyptostroboides from Shanghai China | Ji Zheng | 6 | Public | Zheng et al. (2018) |
| 337 | Tree Anatomy China | Jingming Zheng | 4 | Public | Zheng and Martínez-Cabrera (2013) |
| 596 | Wood anatomy and wood density—Australia | Kasia Ziemińska | 6 | Public | Ziemińska, Butler, Gleason, Wright, and Westoby (2013); Ziemińska, Westoby, and Wright (2015) |
| 569 | SW Michigan restored prairies | Chad Zirbel | 6 | Public | Zirbel, Bassett, Grman, and Brudvig (2017) |
| 570 | CLE_restored_prairie_greenhouse_traits | Chad Zirbel | 6 | Public | Unpublished |
| 223 | San Lorenzo Epiphyte Leaf Traits Database | Gerhard Zotz | 3 | Public | Petter et al. (2016) |