Vegetation Ecology 2nd edition Web Resources to Chapter 12

Plant functional types and traits at the community, ecosystem and world level

by A.N. Gillison

Web Resource 12.1: Functional redundancy

It is widely considered, though as yet poorly evaluated, that ecosystem resilience depends on functional or 'ecological' redundancy (the number of species contributing similarly to an ecosystem function) and response diversity (how functionally similar species respond differently to disturbance) (Laliberté *et al.* 2010; Mayfield *et al.* 2010; Messier *et al.* 2010). By definition, species within a defined functional group are ecologically equivalent and therefore some degree of redundancy to the system can be inferred (Martinez 1996; Mooney 1997; Franks *et al.* 2009). Although rarely supported by hard biological evidence, the concept can be readily aligned with engineering principles (Naeem 1998). Support for the redundancy and related 'insurance' hypotheses is based on the assumed relative independence of traits relevant to disturbance response and those involved in ecosystem effects (Lawton & Brown 1993; Walker 1992). The concept has attracted considerable debate, with theoretical support arising primarily from localized studies and then with very limited criteria for assessing and evaluating vascular plant species performance *in situ* (Cowling *et al.* 1994; Mouchet *et al.* 2010). Beyond the level of single species, Gamfeldt *et al.* (2008) assert that due to multifunctional complementarity among species, overall functioning is more susceptible to species loss than are single functions. As described in the main text of this chapter, the influence of single functional traits such as Specific Leaf Area (SLA) can be shown to vary with specific environmental factors. It seems certain that, while arguably orthogonal to certain other traits, plants with similar SLAs may be coupled with other widely differing functionally significant traits (e.g. leaf inclination, hypostomatous *versus* isostomatous condition, leaf longevity, life form). Under such circumstances, assumptions about redundancy based on minimal sets of traits become increasingly difficult to support.

Web Resource 12.2: Sampling plant functional types and traits

Scale and purpose should drive sampling method, preferably aligned with a standardized protocol. In reality, different ecologists apply different sampling techniques in different situations, a feature exacerbated by the inherent complexity of trait variables and their biophysical environment, and wide variation in scale

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and purpose of study. Current sampling methodology is thus essentially idiosyncratic, resulting in a lack of uniformity that limits meaningful comparisons between different data sets. Practitioners tend to use two main categories of data sampling (proximal and remote) applied according to either gradient- or non-gradient-based approaches. 'Hands-on' plot-based, field sampling of functional traits can vary from micro-level stratification to accommodate different sizes (plots) of individual growth forms or life-forms as well as single leaves (*cf.* Albert *et al.* 2010a,b). Increasingly, data are accessed by remote means via meta-data summaries often assembled by multiple agencies or spatially explicit, simulated data (Körner & Jeltsch 2008). Global scale databases such as TRY (Kattge *et al.* 2011) are becoming increasingly common. Nonetheless, because of differing methods of data collection, often using different units of measurement for the same trait (Table S.12.2) databases compiled from varying sources lack uniformity and are prone to error.

Truncated samples of a species' environmental range can lead to misguided models of a species performance. A fundamental question therefore is whether sampling should be governed by a random or subjective design with or without reference to prevailing environmental gradients. Random sampling with little attention to gradients is common (Batalha & Martins 2004; Watanabe *et al.* 2007), as is the subjective location of sample units such as leaves, growth forms and life-forms (Lloret & Montserrat 2003; Markesteijn *et al.* 2007; Powers & Tiffin 2010; Warman *et al.* 2011). Certain gradient-based sampling approaches take advantage of the fact that biota are rarely distributed at random being subject instead to variation along environmental gradients, that, in turn should be the focus of sample design. Here gradient-oriented transects or 'gradsects' are supported by statistical theory (Gillison & Brewer 1985) and are well established in many countries, especially the USA, as a rapid and more cost-effective alternative to purely random or systematic (e.g. grid) survey technique (Wessels *et al.* 1998; Sandmann and Lertzmann 2003; USGS-NPS 2003; Mallinis *et al.* 2008; Murray *et al.* 2008).

Clearly methodology matters (Gaucherand & Lavorel 2007; Lavorel *et al.* 2008) and to achieve progress will require broad consensus on sampling protocols. There are moves to standardize units (Weiher *et al.* 1999; Gillison 2002; Ackerly 2009; Blonder *et al.* 2011) and for standardized toolkits and generic protocols (Grime *et al.* 1997; Hodgson *et al.* 1999; Gillison 2002; Cornelissen *et al.* 2003; Garnier *et al.* 2004, 2007; Hulshof & Swenson 2010; Vandewalle *et al.* 2010). The challenge for universality remains.

Web Resource 12.3: Plant stoichiometry and metabolic scaling theory

Compensatory changes in species populations in response to environmental fluctuations can maintain an approximate steady state between rates of resource supply and resource consumption (Ernest & Brown

2001). Until recently, the underlying dynamics of this implied homeostatic control have received only limited attention. Under widely varying foliar C:N:P ratios, vascular plants consistently exhibit a high degree of '**stoichiometric homeostasis**' that describes the extent to which the internal elemental content is regulated in relation to the elemental supply available (Sterner & Elser 2002; Minden 2010). This in turn tends to be reflected in plant adaptive responses to varying growth conditions (Elser *et al.* 2010; Yu *et al.* 2010). However, consensus about the level of stoichiometric control clearly varies with the level of enquiry. For example, in an analysis of ten functional traits of 87 tropical, dry forest tree species, Powers & Tiffin (2010), found that, while C:N, N:C ratios varied significantly among PFTs, they were also closely correlated with leaf N and leaf C content suggesting that the ratios provide little information that is not already contained in the total element concentrations.

Plant traits related to size and growth rate are particularly important because they determine the productive capacity of vegetation and the rates of decomposition and nitrogen mineralization (Chapin *et al.* 2003). **Metabolic scaling theory** considers how size affects metabolic properties from cells to ecosystems. In this context, plant stoichiometry exhibits size scaling, as foliar nutrient concentration decreases with increasing plant size, especially for phosphorus. Thus, in line with the LES strategy, small plants, frequently with small leaves, have lower N:P ratios. Foliar nutrient concentration is also reflected in other tissues (root, reproductive, support), permitting the development of empirical models of production that scale from tissue to whole-plant levels (Gordon & Jackson 2000; Elser *et al.* 2010; Minden 2010). At global level a current trend is to couple latitude as well as environmental phosphorus concentration with plant stoichiometry (see also Reich & Oleksyn 2004; Ballantyne *et al.* 2008). Research thus far suggests that an improved knowledge of the stoichiometric role in the plant size-nutrient-environment nexus can lead to a better understanding of global change factors such as carbon dioxide, temperature and nitrogen deposition (Elser *et al.* 2010; Reich & Oleksyn 2004).

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Web Resource 12.4: Table 1 Plant functional terminology

Term	Definition	Reference
Function	Those features of the plant that are apparent adjustments to the environment, e.g. deciduousness, shade tolerance, and fire resistance.	Fosberg (1961) Knight & Loucks (1969)
Function (of leaf structure)	The action that a structure is capable of performing.	Press (1999)
Functional attribute	That which responds in a demonstrable and predictable way with a change in the physical environment.	Gillison (1981)
Functional attribute	An assemblage of functional elements used in the VegClass PFT classification system. PFTs are constructed from functional attributes according to a standard rule set and grammar. Functional attributes are, in turn, constructed from functional elements (*q.v.*).	Gillison (2002, 2012)
Functional attribute	Plant functional types (PFTs) can be seen as assemblages of species having certain plant functional attributes (PFA) in common.	Skarpe (1996)

Term	Definition	Reference
Functional attribute	The different expressions of a trait, which should rather be called states.	van der Maarel (2005), p. 41
Functional attribute	The value or modality taken by a trait at a point of an environmental gradient.	Violle *et al.* (2007)
Functional clique	A set of species with the property that every pair in the set has some food source in common.	Yodziz (1982)
Functional diversity	The extent of trait differences in a unit of study.	de Bello *et al.* (2009)
Functional diversity	Functional diversity (FD) comprises the kind, range, and relative abundance of functional traits present in a given community.	Díaz *et al.* (2007)
Functional diversity	This can refer to two rather different concepts: the diversity of the ecological functions performed by different species, and the diversity of species performing a given ecological function.	Heywood, & Watson (1995)

Term	Definition	Reference
Functional diversity	Functional diversity is the range and distribution of functional trait values in a community. It can be described, among other indicators, by community-level weighted means of trait values (CWM) and functional divergence. In its broadest sense, functional diversity can be defined as the distribution of trait values in a community (Díaz & Cabido 2001; Tilman 2001).	Lavorel *et al.* (2008)
Functional diversity	The number of functional groups in an ecological system.	Martinez (1996)
Functional divergence	The degree to which abundance distribution in niche space maximises divergence in functional characters within the community.	Mason *et al.* (2005)
Functional divergence	The degree to which the distribution of species abundances in niche space maximises total community variation in functional characters.	Mason *et al.* (2005)
Functional diversity	The distribution of the species and abundance of a community in niche space, including: functional richness, functional evenness and functional divergence.	Mason *et al.* (2005)

Term	Definition	Reference
Functional diversity	The different types of processes in a community that are important to its structure and dynamic stability.	Moore (2001)
Functional divergence	Functional divergence defines how far high species abundances are from the centre of the functional space.	Mouchet *et al.* (2010)
Functional diversity	The total branch length of a functional dendrogram.	Petchey & Gaston (2002)
Functional diversity	The functional component of biodiversity as the distribution of species in a functional space whose axes represent functional features.	Rosenfeld (2002)
Functional diversity	The number of functional groups in a community.	Smith & Huston (1989); Collins & Benning (1996)
Functional diversity	The variety of different responses to environmental change.	Steele (1991)
Functional diversity	The range and value of those species and organismal traits that influence ecosystem functioning.	Tilman (2001); Garnier *et al.* (2004)
Functional effect traits	Species traits that feed back to ecosystem functioning.	Garnier *et al.* (2007)

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Term	Definition	Reference
Functional element	A Plant Functional Element (PFE) is a subdivisional unit (e.g. mesophyll leaf size class) within a Plant Functional Attribute (PFA) (e.g. 'Leaf Size'). By means of a specific rule set, PFEs and PFAs are combined to form a Plant Functional Type (PFT) or functional *modus*. Used in the VegClass classification system.	Gillison (1981, 2012)
Functional evenness	The evenness of abundance distribution in filled niche space. Applies only to the distribution of abundance just as species evenness applies only to the abundances of the species that are present.	Mason *et al.* (2005)
Functional evenness	Functional evenness corresponds to how regularly species abundances are distributed in the functional space.	Mouchet *et al.* (2010)
Functional group	Functional groups are suites of species with similar roles in an ecosystem and, importantly, mediate the relationship between biodiversity and the functioning of ecosystems.	Davis *et al.* (2004)

Term	Definition	Reference
Functional group	Plant functional groups are aggregations of plant species that show a similar response to variation in environmental conditions or have a similar effect on ecosystem processes (Gitay & Noble 1997; Lavorel *et al* . 1997).	Dorrepaal (2007)
Functional group	Collection of species sharing a single important attribute.	Hunt *et al.* (2004)
Functional group	Groups of species that respond similarly to environmental settings and share common functional attributes.	Lehsten *et al.* (2009)
Functional group	A group of species that utilize similar resources; synonymous with guild.	Moore (2001)
Functional group	Variation among taxa in individual functional traits can be classified using discrete (e.g. functional group) or continuous categories.	Reich *et al.* (2003a)
Functional group	A set of species that have similar traits and thus are likely to be similar in their effects on ecosystem functioning.	Tilman (2001)
Functional group	A group of species that perform similar roles in an ecosystem process.	Virginia & Wall (2001)

Term	Definition	Reference
Functional group	The most commonly used technique for quantifying functional diversity consists of clustering species with shared taxonomic, physiological and morphological traits into functional groups, assuming that groups with similar traits differ in their response to and effect on resources.	Wright *et al.* (2006)
Functional group diversity	The number of functional groups that exist within a given community or ecosystem (measure of functional diversity as basically closely related to species richness).	Tilman (2001)
Functional groups	Aggregations of species that perform similar ecosystem processes, such as grazers, suspension or filter feeders, leaf shredders, predators and decomposers.	Covich (2001)
Functional groups	Classifed according to whether species respond in a similar way to a specified perturbation.	Cramer (1997)
Functional groups	A non-phylogenetic grouping of organisms that respond in a common manner to a syndrome of environmental factors or have a common effect on ecosystem functioning.	Franks *et al.* (2009)

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Term	Definition	Reference
Functional Groups	Species (taxa) with similar responses to a given factor They are characterized by a set of common biological attributes that correlate with their behaviour.	Lavorel *et al.* (1998)
Functional groups	A vascular plant adaptive syndrome. Functional groups are arbitrary assemblages since species are classified on the basis of similarity criteria set by the ecologist.	Solbrig (1994)
Functional groups	Polyphyletic suites of species that share ecological characteristics and play equvalent roles in natural communities and ecosystems. Commonly, organisms with convergent anatomical, morphological, physiological, behavioural, biochemical, or trophic characteristics are grouped together.	Steneck (2001)
Functional groups	A set of species that have similar effects on a specific ecosystem-level biogeochemical process.	Vitousek & Hooper (1993)

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Term	Definition	Reference
Functional identiy	Functional identity (FI) as the mean vector of plant functional traits, i.e. the centroid in the multidimensional trait space, calculated among all PGS that are able to tolerate the climatic constraints of a grid cell. FI is similar to the concept of community-aggregated traits (sensu Garnier *et al*. 2004).	Reu *et al.* (2011)
Functional markers	Traits used to capture the functioning of plant species and communities.	Garnier *et al.* (2004)
Functional *modus*	A combination of functional attributes and elements. A specific Plant Functional Type (PFT).	(Gillison 1981, 2002, 2012)
Functional redundancy	The number of functionally similar entities within a functional group.	Martinez (1996)
Functional redundancy	The presence or addition of species to a community possessing the same functional traits, or of the same functional type as a species already residing in the community, does not necessarily add to the functional richness of the community; rather, it defines the community's functional redundancy.	Mayfield *et al.* (2010)

Term	Definition	Reference
Functional Response Type (PRT)	A group of plants similar in a set of traits and similar in their response to given environmental factors.	Louault *et al.* (2005)
Functional richness	The amount of niche space occupied by the species within a community.	Mason *et al.* (2005)
Functional richness	The amount of functional space occupied by a species assemblage.	Mouchet *et al.* (2010)
Functional richness	Functional richness (FR) as the number of different PGS in a grid cell	Reu *et al.* (2011)
Functional significance (of structure)	The role, significance or consequence of a structure.	Press (1999)
Functional taxa	Functional taxa for specific ecosystems (ecological sectors) are defined as broad trophic groups of organisms in common vertical habitat zones, and with common inputs and outputs (ecosystem commodities and services).	Bahr (1982)
Functional types	Sets of plants exhibiting similar responses to environmental conditions and having similar effects on the dominant ecosystem process.	Díaz Barradas *et al.* (1999)

Term	Definition	Reference
Functional types	Functionally similar plant types which can be used in global ecological modelling.	Box (1996)
Functional types	Classified PFTs according to: herbaceous plants, shallow-extracting woody plants, and deeper-extracting woody plants.	Breshears & Barnes (1999)
Functional types	Defines plant functional types along an environmental gradient from cold to dry according to phenology, thermal, drought and shade tolerance.	Bugmann (1996)
Functional types	Used 'morpho-functional traits' canopy height, leaf dry matter content, flowering period, flowering start, leaf dry weight, leaf area and specific leaf area.	Caccianiga *et al.* (2006)
Functional types	Groupings of plant species with similar functional attributes in vegetation.	Campbell *et al.* (1999)
Functional types	Based on growth forms combined with response to to above- and below-snow depth. Basically uses trees, shrubs, herbs, bryophytes and lichens.	Chapin *et al.* (1996)
Functional types	Plant functional types described according to seven characteristics of each tree species: three demographic, two phenological one indicator of drought-tolerance and one structural.	Condit *et al.* (1996)

Term	Definition	Reference
Functional types	Classified according to 13 climate/vegetation based PFTs (Tropical evergreen, etc.).	Cramer (1997)
Functional types	According to the similarities in the trait syndromes of their individuals, species can be grouped into plant functional types (PFT) representing distinct functional strategies.	de Bello *et al.* (2009)
Functional types	Sets of plants exhibiting similar responses to environmental conditions and having similar effects on the dominant ecosystem processes.	Diaz & Cabido (1997)
Functional types	Non-phylogenetic groupings of species that show close similarities in their response to environmental and biotic controls.	Duckworth *et al.* (2000)
Functional types	Archetypal plant species that differ from each other in terms of their trait values.	Falster *et al.* (2011)
Functional types	Species that respond in a similar way to a specified perturbation.	Gitay & Noble (1997)
Functional types	A general term that groups plants according to their function in ecosystems and their use of resources.	http://www.arcticatlas.org/glossary/pft/ Accessed 17 Oct 2012

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Term	Definition	Reference
Functional type	A collection of species sharing an important collection of attributes.	Hunt *et al.* (2004)
Functional type	Plant functional types (PFTs) are groups of species sharing traits that govern their mechanisms of response to environmental perturbations such as recurring fires, inundation, grazing, biological invasions and global climate change.	Keith *et al.* (2007)
Functional types	Groups of plants with similar biological traits displaying significant optima or maxima on a gradient plane of resource supply and disturbance intensity. The biological traits refer to expansion, vegetative regeneration, generative reproduction, dispersal and seed bank longevity.	Kleyer (1999)
Functional types	Groups of plant species that share similar functioning.	Kooistra *et al.* (2007)
Functional types	Species with similar roles in ecosystem processes by responding in similar ways to multiple envronmental factors.	Lavorel *et al.* (1997)

Term	Definition	Reference
Functional types	PFTs can be either defined *a priori* (i.e. based on growth form) or *a posteriori* from an analysis of a relevant trait. Plant Functional Types (PFTs) are defined as non-phylogenetic groupings of species which perform similarly in an ecosystem based on a set of common biological attributes. They can be defined in relation to either the contribution of species to ecosystem processes or the response of species to changes in environmental variables.	Lavorel *et al.* (1997)
Functional types (hydraulic)	Species groups with similar water-use strategies.	Mitchell *et al.* (2008)
Functional types	Groups of plants similar in terms of traits and similar in their responses to certain environmental conditions (e.g. soil conditions, temperature, moisture, disturbance regimes) and/ or in their effects on ecosystem processes (e.g. biomass production, litter decomposition).	Müller *et al.* (2007)

Term	Definition	Reference
Functional types	Plant Functional Types (PFTs) place a species in a group, the members of which have similar combinations of functional attributes and respond similarly, or are similarly sensitive to environmental disturbance.	Navarro *et al.* (2006)
Functional type	A group of plants that, irrespective of phylogeny, are similar in a given set of traits and similar in their association to certain variables, which may be factors to which the plants are responding or effects of the plants in the ecosystem.	Pillar & Sosinski (2003)
Functional types	Plant functional types (PFTs) or species as community components after fuzzy weighting by the traits.	Pillar *et al.* (2009)
Functional type	Members of a PFT share similar morphological, physiological and/or life history traits, with the differences between members of a PFT being smaller than those between types.	Ramsay *et al.* (2006)
Functional types	Non-phylogenetic functionally similar groups that share ecological traits and play similar roles in the community.	Ramsay *et al.* (2006)

Term	Definition	Reference
Functional types (ecosystem)	Ecosystem functional types (EFTs) are characterized at patch, patch-mosaic and regional scales according to dominant structural and functional characteristics.	Reynolds *et al.* (1997)
Functional types	A group of species that share morphological and physiological characteristics that result in a common ecological role.	Sala *et al.* (2001)
Functional types (vegetation)	Those areas of the vegetated land surface which have similar ecological attributes, such as composition in terms of plant functional types. Structure (i.e. distribution of leaf area with height), phenology, (i.e. distribution of of leaf area over time), and potential biomass and productivity (corresponds closely to the biome concept).	Scholes *et al.* (1997)
Functional types	Used to connote species or groups of species that have similar responses to a suite of environmental conditions.	Shugart (1997)
Functional types	Assemblages of species having certain plant functional attributes (PFA) in common.	Skarpe (1996)

Term	Definition	Reference
Functional types	Defined according to plant strategies into discrete classes along a light-water continuum.	Smith & Huston (1989)
Functional types	Sets of species showing similar responses to the environment and similar effects on ecosystem functioning.	Smith *et al.* (1993); Weithoff (2003)
Functional types (optical)	Optically distinguishable functional types.	Ustin & Gamon (2010)
Functional types	A group of plant species sharing certain morphological-functional characteristics.	van der Maarel (2005), p. 39
Functional types	The combined strategies, 'groupings' of similar or analagous genetic characteristics which recur widely among species or populations and cause them to exhibit similarities in ecology.	van der Maarel (2005). p. 41
Functional vicariance	A concept of functional similarity referring to species that appear ecologically similar and are closely related taxonomically but occur in different, usually distant regions.	Box & Fujiwara (2005)
Guild	A set of sympatric species whose expressed preferences for a common set of key resources can be resolved to fit a single axis.	Adams (1985)

Term	Definition	Reference
Guild	Developed a classification of climatic guilds based on wood structure and deciduousness.	Borchert (1994)
Guild	A group of species using the same resources.	Cramer (1997); Gitay & Noble (1997)
Guild	Grouping of organisms that use the same investigator-defined resource.	Hawkins & MacMahon (1989)
Guild	A group of species that utilize similar esources (usually food).	Moore (2001)
Guild	A group of species that exploits the same class of environmental resources in a similar way.	Root (1967); Moran & Southwood (1982)
Guild	Organisms that use similar resources in similar ways. Depending on the application, guilds can be synonymous with functional groups.	Steneck (2001)
Guild	A group of species that are similar in some way that is ecologically relevant, or might be.	Wilson (1999), p. 508
Plant ecology strategy schemes	Plant ecology strategy schemes (PESSs) that arrange species in categories or along spectra according to their ecological attributes.	Westoby (1998)

Term	Definition	Reference
Plant Growth Strategy (PGS)	In the JeDi model, a plant growth strategy (PGS) is defined as the combination of such functional traits that determine its growth behaviour and capacity to reproduce as well as its tolerances to climatic constraints.	Reu *et al.* (2011)
Strategy	How a species sustains a population.	Westoby (1998)
Synusia	A group of species of roughly the same size, sometimes of similar form, occupying the same layer in a vegetation stand, for example the synusia of ground-layer herbs in a forest.	Box & Fujiwara (2005)
Synusia	A synusia is a minor community, such as a layer or bark community, within a complex community, dominated by a single life-form or by closely related life-forms.	Cain (1950)
Trait	A well-defined, measurable property of organisms, usually measured at the individual level and used comparatively across species.	McGill *et al.* (2006)
Trait	A surrogate of organismal performance.	Violle *et al.* (2007)

Term	Definition	Reference
Trait (effect)	An effect trait reflects the effects of a plant on environmental conditions: community or ecosystem properties.	Violle *et al.* (2007)
Trait (functional effect)	Species traits that affect ecosystem properties	Garnier *et al.* (2004) (also Díaz & Cabido (2001); Lavorel & Garnier (2002)
Trait (functional response)	Species traits that vary consistently in response to changes in environmental factors.	Garnier *et al.* (2007)
Trait (biological)	Biological traits, defined as measurable phenotypic characteristics for which relationships with biological function have been described, provide the basis of this functional classification.	Gaucherand & Lavorel (2007)
Trait (functional)	Any measurable feature at the individual level affecting its fitness directly or indirectly.	Albert *et al.* (2010b)
Trait (functional)	Any phenotypic character that influences organismal fitness through biochemical, physiological, morphological, developmental, or behavioural mechanisms.	Geber & Griffen (2003)

Term	Definition	Reference
Trait (functional)	Plant functional traits are considered as reflecting adaptations to variation in the physical environment and trade-offs (ecophysiological and/or evolutionary) among different functions within a plant.	Lavorel *et al.* (2007)
Trait (functional)	A trait that is strongly correlated with the growth and/or survival of organisms.	Lusk *et al.* (2008)
Trait (functional)	A functional trait is one that strongly influences organismal performance.	McGill *et al.* (2006)
Trait (functional)	Any attribute that has potentially significant influence on establishment, survival, and fitness.	Reich *et al.* (2003a)
Trait (functional)	Any characteristic of the plant that may have 'functional' (i.e. adaptive or 'strategic') significance.	Semenova & van der Maarel (2000)
Trait (functional)	The characteristics that combine to form a PFT.	van der Maarel (2005), p. 41.
Trait (functional)	The characteristics of organisms with demonstrable links to the organism's fitness.	Vandewalle *et al.* (2010)

Term	Definition	Reference
Trait (functional)	Any morphological, physiological or phenological feature measurable at the individual level, from the cell to the whole-organism level, without reference to the environment or any other level of organization.	Violle *et al.* (2007)
Trait (functional)	Any trait which impacts fitness indirectly via its effects on growth, reproduction and survival.	Violle *et al.* (2007)
Trait (functional)	Morpho-physiophenological traits which impact fitness indirectly via their effects on growth, reproduction and survival, the three components of individual performance.	Violle *et al.* (2007)
Trait (performance)	A performance trait is a direct measure of fitness. In plants, only three types of performance traits are recognized: vegetative biomass, reproductive output (e.g. seed biomass, seed number), plant survival.	Violle *et al.* (2007)
Trait (response)	A response trait is any trait the attribute of which varies in response to changes in environmental conditions.	Violle *et al.* (2007)

Term	Definition	Reference
Trait convergence	A trait convergence assembly pattern is identified when sites nearby on the ecological gradient consistently contain species with similar traits and changes in these traits are related to the gradient.	Pillar *et al.* (2009)
Trait divergence	A trait divergence assembly pattern is identified when the turnover in trait based community components is related to the gradient but the communities contain species with dissimilar traits.	Pillar *et al.* (2009)
Trait, adaptive ecophysiological	An ecophysiological trait can be considered adaptive if it has a direct impact on fitness in natural environments.	Ackerly *et al.* (2000)
Trait syndrome	The set of trait values (or levels) of an individual – its trait syndrome – results from functional trade-offs between different plant functions and from adaptive and plastic responses to its biotic and abiotic environments.	Albert *et al.* (2010b); (see also functional *modus* in this table)
Vital attribute	An attribute of a species which is vital in determining its role in vegetation replacement sequences.	Noble & Slatyer (1980)

Web Resource 12.5: Table 2 Plant traits used in functional analyses – examples

Trait syndrome	Trait	Unit	Source
Phylogenetic	Monocots, dicots, ferns		Decocq & Hermy (2003)
Life-form	'Growth form' used as life-form *sensu* raunkiær (ordinal 5 states)		Bernhardt-Römermann *et al.* (2011)
Life-form *sensu* Raunkiær	After Raunkiær (1934)		Numerous
Physiognomic	'Life form': tree/shrub, grass, forb		Campbell *et al.* (1999); Reich *et al.* (2007)
	'Life form': trees, shrubs, epiphytes, vines, and forbs, as well as distinguishing between deciduous and evergreen,		Foster & Brooks (2005)
	'Life form' – tree, liana and palm ("functional categories")		Bouroncle & Finegan (2011)
	Grasses, legumes, upright forbs, rosettes		Ansquer *et al.* (2009)
	Growth forms: deciduous shrubs, evergreen shrubs, graminoids, forbs, mosses and lichens		Bret-Harte *et al.* (2008); Albert *et al.* (2010a,b)
	Growth form (epiphyte, herb, shrub, treelet, vine)		Mayfield *et al.* (2005, 2006)
	Growth form (ordinal 5 states)		Nygaard & Ejrnæs (2004)
	Plant inclination (1:prostrate, 2:semi-erect, 3:erect)		Pillar *et al.* (2009)
	Shoot growth form		Poschlod *et al.* (2003)
	Prostrate habit		Díaz *et al.* (2007)

Trait syndrome	Trait	Unit	Source
Structure, including biomass	Above-ground live biomass	g.m^{-2}	Garnier *et al.* (2007)
	Biomass allocation to leaves	%	Ackerly *et al.* (2000)
	Shoot mass	g·plant^{-1}	Reader (1998)
	Above-ground total dead plant matter	g·m^{-2}	Garnier *et al.* (2007)
	Height of mean outer canopy	m	Gillison (2002)
	Height of mean outer canopy	mm	Caccianiga *et al.* (2006)
	Height outer canopy	cm	Díaz *et al.* (2004)
	Height estimated max at maturity	m	Laliberté *et al.* (2010); Kooyman *et al.* (2011)
	Height maximum canopy (L<0.5 m; H>0.5m)	m	Campbell *et al.* (1999); Cerabolini *et al.* (2010)
		mm	
	Height (ordinal 3 states)	mm	Lavorel *et al.* (1998)
	Height (ordinal 5 states)	m	Ramsay *et al.* (2006)
	Height maximum (ordinal: 3 states) herbs & shrubs ≤ 150cm, shrubs (>150–300cm), trees (>300cm)	cm	Moretti & Legg (2009)
	Height canopy (ordinal: 9 states)	–	Nygaard & Ejrnæs (2004)
	Height canopy (ordinal: 6 states)	cm	Díaz *et al.* (1998)
	Canopy structure (leafy, rosette)		Lavorel *et al.* (1998)
	Maximum height species		Prach *et al.* (1997)
	Basal area	m^{2}·ha^{-1}	Gillison (2002)
	Litter depth	cm	Gillison (2002)
	Litter biomass	Mg·ha^{-1}	Quetiér *et al.* (2007)
	Litter decay rate	g·kg·d^{-1}	Garnier *et al.* (2007)
	Necromass persistence (ordinal 3 states)		Caccianiga *et al.* (2006)
	Total canopy cover %	%	Gillison (2002)

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Trait syndrome	Trait	Unit	Source
	Canopy cover woody plants	%	Gillison (2002)
	Canopy cover non-woody plants	%	Gillison (2002)
	Canopy roughness (see ref. for eqn.)		Aguiar *et al.* (1996)
	Canopy structure (ordinal 6 states – floating, leafy, rosette, semi-rosette, stems assimilating, submerged)		Nygaard & Ejrnæs (2004)
	Canopy layering (canopy, shrub, ground)		Ramsay *et al.* (2006)
	Tree shape (ratio 1:2)	ordinal	Gitay *et al.* (1999)
	Cover-abundance woody plants < 2 m tall	Domin scale index	Gillison (2002)
	Height of plant at maturity (H_{max})	m	Markesteijn *et al.* (2007): Poorter *et al.* (2008)
	Height (5 ordered multistates)	m	Díaz Barradas *et al.* (1999)
	Crown diameter	m	Ackerly (2004)
	Canopy diameter (avg) (5 ordered multistates)	m	Díaz Barradas *et al.* (1999)
	Number of stems	number	Ackerly (2004)
	Crown exposure juvenile (5 state scale)	–	Poorter & Bongers (2006)
	Perennial plant cover (PPC)	%	Jauffret & Lavorel (2003)
	Max crown diameter (shrub, sub-shrub)	binary	Esther *et al.* (2010)
	Mean canopy openness (sun)	%	Markesteijn *et al.* (2007)
	Mean canopy openness (shade)	%	Markesteijn *et al.* (2007)
	Average crown exposure at 2 m height	–	Markesteijn *et al.* (2007)
	Lateral spread > 1 m		Prach *et al.* (1997)
	Lateral spread (ordinal, 5 states)		Moretti & Legg (2009)
	Lateral spread (6 ordinal states)		Caccianiga *et al.* (2006)
	Lateral spread (ordinal 3 states)		Bernhardt–Römermann *et al.* (2011)

Trait syndrome	Trait	Unit	Source
	Lateral spread (ordinal 4 states)		Lavorel *et al.* (1998)
	Lateral spread (ordinal 5 states)		Nygaard & Ejrnæs (2004)
	Ramification at ground level (ordinal 3 ordered multistates)		Díaz *et al.* (1998)
	Specific branch area (SBA)	–	Urban (2003)
	Thorniness (ordinal 3 states)		Díaz *et al.* (1998)
Bryophytes	Terrestrial, arboreal combined	Domin cover-abundance scale	Gillison (2002)
Lichens	Fruticose, crustose, foliose terrestrial, arboreal combined	Domin cover-abundance scale	Gillison (this chapter)
Phenology	Annual, perennial		Lavorel *et al.* (1998); Campbell *et al.* (1999)
	Evergreen, deciduous, semideciduous, brevideciduous, etc.		Eamus (1999); Reich *et al.* (2007)
	Persistence (ordinal 3 states) (aestival green; partial evergreen; evergreen)		Moretti & Legg (2009)
	Life history: (categorical, 3 states)		Moretti & Legg (2009)
	Winter dormancy		Aguiar et al. (1996)
	Time of first flowering	month	Moretti & Legg (2009)
	Time of flowering start (March–August 5 states)		Caccianiga *et al.* (2006)
	Onset of flowering (ordinal 12 states)	–	Nygaard & Ejrnæs (2004)
	Leaf (ordinal 4 states)	–	Nygaard & Ejrnæs (2004)
	Flowering duration	months	Caccianiga *et al.* (2006)
	Mid-point flower emergence		Gitay *et al.* (1999)
	Mid-point fruit maturation		Gitay *et al.* (1999)

Trait syndrome	Trait	Unit	Source
	Month peak leaf flush	month	
	Duration of leaf flush	months	
	First leaf drop	month	
	Ordinal (5 state timing by season)		Diaz *et al.* (1998)
	Reproductive (ordinal 4 states)		Díaz *et al.* (1998)
	Start and stop flowering		Moretti & Legg (2009)
	Age of first flowering (ordinal 3 states)		Bernhardt-Römermann *et al.* (2011)
	Shoot (seasonality of max. production of photosynthetic tissue) (ordinal 4 states)		Díaz *et al.* (1998)
Stem	Assimilating (mainly water plants)		Nygaard & Ejrnæs (2004)
	Bark thickness	mm	Paine *et al.* (2011)
	Density	$kg{\cdot}m^{-3}$	Falster *et al.* (2010)
	Density	$g{\cdot}cm^{-3}$	Laliberté *et al.* (2010); Kooyman *et al.* (2011); Maharjan *et al.* (2011)
	Density of sapwood	$g{\cdot}m^{-3}$	Paine *et al.* (2011)
	Density of branch sapwood	$g{\cdot}m^{-3}$	Paine *et al.* (2011)
	Diameter (ordinal, 4 state)		Díaz Barradas *et al.* (1999)
	Diameter (max.)	m	Maharjan *et al.* (2011
	Diameter breast high		
	Mean maximal vessel diameter	cm	Gitay *et al.* (1999)
	Basal area	$m^2{\cdot}ha^{-1}$	Gillison (2002)
	Height	m	Maharjan *et al.* (2011
	Height	cm	Bernhardt–Römermann *et al.* (2011)
	Modulus of elasticity	$kg{\cdot}cm^{-2}$	Maharjan *et al.* (2011);
	Number		Ackerly (2004)
	Wood specific gravity	$g{\cdot}cm^{-3}$	

Trait syndrome	Trait	Unit	Source
	Woodiness (3 state ordinal)	$mg \cdot m^{-3}$	Diaz *et. al*. (2004)
	Bark consistency (smooth, fibrous, corky)		Díaz Barradas *et al.* (1999)
	Spininess	binary	Díaz Barradas *et al.* (1999)
	Underground stem (lignotubers, others)	binary	Díaz Barradas *et al.* (1999)
	Sprout insulation (ordinal: 4 states)		Moretti & Legg (2009)
	Furcation index	%	Gillison (1981, 2002)
	Twig : cross-sectional area	mm^2	Ackerly (2004)
	Twig : length	mm	Ackerly (2004)
	Twig : annual extension	mm	Ackerly (2004)
Leaf	Absorptance	%	Ackerly *et al.* (2000)
	Anatomy: (hygromorphic, mesomorphic, scleromorphic)		Lososová & Láníkova (2010)
	Angle, inclination	degrees	Ackerly (2004); Posada *et al.* (2007, 2009)
	Inclination (ordinal 4 states)		Gillison (1981, 2002)
	Area (= size)	mm^2	Ackerly *et al.* (2002); Díaz *et al.* (2004); Cerabolini *et al.* (2010)
	Area	cm^2	Ackerly *et al.* (2000); Kooyman *et al.* (2011); Paine *et al.* (2011)
	Area ordinal 6 states	cm^2	Ramsay *et al.* (2006)
	Area (length × width rescaled into 6 classes)	cm^2	Pillar *et al.* (2009)
	Area : leaf: sapwood area	$m^2 \cdot m^{-2}$	Ackerly (2004)
	Area based leaf N (N_{area}),	$g \cdot m^{-2}$	Ackerly & Reich (1999)

Trait syndrome	Trait	Unit	Source
	Area density at canopy depth *h*	m^2–leaf·m^{-3} space	Schieving & Poorter (1999)
	Area-based assimilation rates (a_{area})	mmol·m^{-2}·s^{-1}	Ackerly & Reich (1999)
	Ash	g·g^{-1}	Adler *et al.* (2004)
	Calcium content	% dwt	Cornelissen & Thompson (1997)
	Carbon	%	Caccianiga *et al.* (2006); Niinemets *et al.* (2007)
	Carbon	% (g·g^{-1})	Ellis *et al.* (2000); Adler *et al.* (2004); Foster & Brooks (2005);
	Carbon content	%	Cerabolini *et al.* (2010)
	Carbon concentration	mg·g^{-1}	Osunkoya *et al.* (2010)
	Carbon isotope ratio $\delta^{13}C$	‰	Craine & Lee (2003)
	C:N	ratio	Pringle *et al.* (2010)
	Cellulose	g·g^{-1}	Adler *et al.* (2004)
	Chlorophyll concentration per per unit leaf area	μmol·m^{-2}	Poorter & Bongers (2006)
	Chlorophyll concentration per per unit leaf area	μg·mm^{-2}	Paine *et al.* (2011)
	Chlorophyll concentration per per unit leaf mass	μmol·g^{-1}	Loranger & Shipley (2010)
	Colour (ordinal 3 state)		Díaz Barradas *et al.* (1999)
	Compound *vs* simple		Gitay *et al.* (1999); Maharjan *et al.* (2011)
	Cosine of leaf inclination		Posada *et al.* (2009)
	Colour (ordinal 3 states)		Díaz Barradas *et al.* (1999)

Trait syndrome	Trait	Unit	Source
	Cumulative leaf area at canopy depth *h*	m^2–leaf·m^{-2} ground	Schieving & Poorter (1999)
	Deciduous, evergreen		Maharjan *et al.* (2011
	Density	g·cm^{-3}	Markesteijn *et al.* (2007); Niinemets *et al.* (2007)
	Density	mg·cm^{-3}	Bussotti (2008)
	Distribution (rosette, semi–rosette, regular)		Bernhardt-Römermann *et al.* (2011)
	Dry mass per unit area	gm·cm^{-3}	Niinemets *et al.* (2007)
	Dry matter content	%	Caccianiga *et al.* (2006); Cerabolini *et al.* (2010)
	Dry matter content (LDC)	g·g^{-1}	Markesteijn *et al.* (2007)
	Dry matter content (LDMC: the ratio of leaf dry mass to saturated fresh mass)	mg·g^{-1}	Garnier *et al.* (2001); Laliberté *et al.* (2010); Bernhardt–Römermann *et al.* (2011)
	Dry to fresh mass ratio	g·g^{-1}	Niinemets *et al.* (2007)
	Dry weight	mg	Caccianiga *et al.* (2006); Cerabolini *et al.* (2010)
	Effective leaf area	mm^2	Ackerly (2004)
	Fraction of total biomass	g·g^{-1}	Niinemets *et al.* (2007)
	Fraction of total leaf N	N·g·g^{-1}	Niinemets *et al.* (2007)
	Fresh weight	mg	Cerabolini *et al.* (2010) Maharjan *et al.* (2011)
	Hairiness	binary	Jauffret & Lavorel (2003)
	Hairiness (ordinal 3 states)		Díaz Barradas *et al.* (1999)
	Height above ground	cm	Adler *et al.* (2004)

Trait syndrome	Trait	Unit	Source
	Inrolling of lamina (continuous) 1–(inrolled width). expanded width^{-1}		Díaz *et al.* (2004)
	Internode length		Ackerly (2004)
	Internode to leaf area ratio (ILAR)	$mm^2\ cm^{-2}$	Markesteijn *et al.* (2007)
	Angle (from horizontal)	degrees	Schieving & Poorter (1999)
	Leaf area index (LAI)	$m^2 \cdot m^{-2}$	Moles *et al.* (2005)
	Leaf area ratio (LAR) (total leaf area. whole plant mass)	$cm^2 \cdot g^{-1}$	Walters and Reich (1999); Reich *et al.* (2003a)
	Plant dry mass	mg	Ishizaki *et al.* (2003)
	Latex (time elapsed after cutting & % of the cut length exuding latex after 15 s)	index 0–100	Pringle *et al.* (2010)
	Leaf area ratio	$m^{-2} \cdot g^{-1}$	Ishizaki *et al.* (2003)
	Leaf mass density per individual of species *j* at depth *h*	$g \cdot m^{-3}$	Schieving & Poorter (1999)
	Leaf mass ratio (LMR) total leaf mass / whole-plant mass)	$g \cdot g^{-1}$	Walters and Reich (1999); Reich *et al.* (2003a)
	Leaf area ratio	$m^2 \cdot g^{-1}$	Ishizaki *et al.* (2003)
	Leaf area ratio (LAR)	$cm^2 \cdot g^{-1}$	Reich *et al.* (2003a)
	Leaf specific mass (LSM)	$Mg.mm^{-2}$	Witkowski & Lamont (1991)
	Leaf mass per area	$g \cdot m^2$	Ishizaki *et al.* (2003)
	Leaf weight ratio (photosynthetic tissue/ non–photosynthetic tissue)		Díaz *et al.* (1998)
	Length	cm	Adler *et al.* (2004); Markesteijn *et al.* (2007); Maharjan *et al.* (2011)
	Length	–	Gitay *et al.* (1999)
	Length leaf sheath	cm	Adler *et al.* (2004)

Trait syndrome	Trait	Unit	Source
	Life span	Month	Reich *et al.* (1997); Ackerly & Reich (1999); Blonder *et al.* (2011)
	Life span	weeks	Reader (1998)
	Life span (ordinal 3 state)	year	Díaz *et al.* (1998, 2004)
	Life span (ordinal 3 state annuals, bi–annuals, perennials)		Bernhardt-Römermann *et al.* (2011)
	Lignin	$g \cdot g^{-1}$	Adler *et al.* (2004)
	Longevity (evergreen, deciduous)		Campbell *et al.* (1999)
	Magnesium content	% dwt	Cornelissen & Thompson (1997)
	Malacophyllous		Jauffret & Lavorel (2003)
	Margin (ordinal 3 states)		Díaz Barradas *et al.* (1999); Gitay *et al.* (1999)
	Mass	g	Loranger & Shipley (2010)
	Mass (M_L)		Pyankov *et al.* (1999)
	Mass per area (LMA)	$g \cdot m^{-2}$	Markesteijn *et al.* (2007); Shiodera *et al.* (2008); Blonder *et al.* (2011)
	Mass per area (LMA)	$mg.cm^{-3}$	Bussotti (2008)
	Mass density lamina	$g \cdot m^{-3}$	Blonder *et al.* (2011)
	Mass per unit of leaf area	$g \cdot m^{-2}$	
	Mass per unit of leaf area (LMA)	$kg \cdot m^{-2}$	Falster *et al.* (2010)
	Mass-based leaf nitrogen concentration (N_{mass})	$mg \cdot g^{-1}$	Ackerly & Reich (1999); Shiodera *et al.* (2008)
	Mass-based, light-saturated assimilation rates (a_{mass})	$nmol \cdot g^{-1} \cdot s^{-1}$	Ackerly & Reich (1999)
	Mesophyll area per leaf area (A_{mes} / A_L	$m^2 \cdot m^{-2}$	Pyankov *et al.* (1999)

Trait syndrome	Trait	Unit	Source
	Mesophyll density (D_{mes})	cm^{-2}	Pyankov *et al.* (1999)
	Mid-rib, lamina, mid-rib + lamina, petiole		Niinemets *et al.* (2007)
	N to weight ratio	$mg \cdot g^{-1}$	Cornelissen *et al.* (1997)
	N:P ratio	ratio	Paoli (2006); Ordoñez *et al.* (2009)
	Nitrogen concentration	%	Cerabolini *et al.* (2010)
	Nitrogen concentration	% ($g \cdot g^{-1}$)	Adler *et al.* (2004); Foster & Brooks (2005), Paine *et al.* (2011)
	Nitrogen concentration	$mg \cdot g^{-1}$	Paoli (2006); Reich *et al.* (1997); Paoli (2006); Laliberté *et al.* (2010); Maharjan *et al.* (2011)
	Nitrogen per leaf mass	$g\text{-}N \cdot g^{-1}$	Blonder *et al.* (2011)
	Nitrogen concentration	$mmol \cdot g^{-1}$	Garnier *et al.* (2007)
	Nitrogen concentration at depth *h*	$Mol\text{-}N \cdot kg^{-1}$ leaf	Schieving & Poorter (1999)
	Nitrogen concentration per leaf area	$g \cdot m^{-2}$	Reich *et al.* (1997); Ackerly (2004); Liu *et al.* (2010)
	Nitrogen concentration per leaf area	$mmol \cdot m^{-2}$	Markesteijn *et al.* (2007)
	Nitrogen concentration per unit mass	$mg \cdot g^{-1}$	Cornelissen *et al.* (1997); Reich *et al.* (1997): Ellis *et al.* (2000); Markesteijn *et al.* (2007); Liu *et al.* (2010)
	N concentration per unit area	$mg \cdot cm^{-2}$	Ellis *et al.* (2000)
	Nitrogen content (area)	$\mu m \cdot cm^{-2}$	Osunkoya *et al.* (2010)

Trait syndrome	Trait	Unit	Source
	Nitrogen content	% dwt	Thompson *et al.* (1997); Cornelissen *et al.* (2001); Caccianiga *et al.* (2006)
	Nitrogen content per unit leaf area at depth *h*	$Mol\text{-}N\cdot m^2$ leaf	Schieving & Poorter (1999)
	Nitrogen isotope ratio $\delta^{15}n$	‰	Craine & Lee (2003); Foster & Brooks (2005)
	Number of chloroplasts per mesophyll cell (N_{chl}/M_{cell})	number	Pyankov *et al.* (1999)
	Number on the leader shoot	number	Shiodera *et al.* (2008)
	Number per 10 cm stem (ordinal 5–state)	number	Díaz Barradas *et al.* (1999)
	Penetrometer resistance (CPU gauge; model 9500, aikoh engineering co.)	g	Shiodera *et al.* (2008)
	Penetrometer resistance (force to punch)	Fp, $kN\cdot m^{-1}$	Onoda *et al.* (2011)
	Penetrometer resistance (specific force to punch)	Fps, $MN\cdot m^{-2}$	Onoda *et al.* (2011)
	Phosphorus concentration (leaf)	%	Paoli (2006)
	Phosphorus concentration per unit leaf area	$mmol\cdot m^{-2}$	Markesteijn *et al.* (2007)
	Phosphorus concentration per unit leaf area (P_{area})	$mg\cdot g^{-1}$	Cornelissen e*t al.* (1997); Markesteijn *et al.* (2007); Ordoñez *et al.* (2009); Maharjan *et al.* (2011)
	Phosphorus concentration per unit leaf mass (P_{mass})	$mg\cdot g^{-1}$	Cornelissen *et al.* (1997); Markesteijn et al (2007)
	Phosphorus content	% dwt	Cornelissen & Thompson (1997); Thompson *et al.* (1997); Cornelissen *et al.* (2001);
	Phosphorus content	$mg\cdot kg^{-1}$	Adler *et al.* (2004)

Trait syndrome	Trait	Unit	Source
	Potassium content	% dwt	Cornelissen & Thompson (1997)
	Resistance to traction (4 classes estimated by pulling by hand until broken)	–	Pillar *et al.* (2009)
	Sclerophylly (bifacial leaf)	$g{\cdot}dm^{-2}$	Camerik & Werger (1981)
	Seedling leaf area index (LAI)		Marks & Lechowicz (2006)
	Shape (classes) (also index)	$cm{\cdot}cm^{-1}$	Markesteijn *et al.* (2007)
	Shape (classes – 4)		Ramsay *et al.* (2006)
	Shape (states – 3)	ordinal	Gitay *et al.* (1999)
	Shape (width/length rescaled into 6 classes)	–	Pillar *et al.* (2009)
	Shear (specific work to shear)	$J.m^{-2}$	Onoda *et al.* (2011)
	Silica content	% dwt	Cornelissen & Thompson (1997)
		$mg{\cdot}kg^{-1}$	Adler *et al.* (2004)
	Size	cm^2	Paoli (2006); Ackerly & Reich (1999)
	Size	mm	Bernhardt–Römermann *et al.* (2011)
	Size (ordinal 9 state picophyll to megaphyll)	–	Gillison (2002)
	Size (ordinal mesophyll, microphyll, nanophyll, leptophyll)	–	Skarpe (1996)

Trait syndrome	Trait	Unit	Source
	Specific leaf area (SLA)	$cm^2 \cdot g^{-1}$	Reich *et al.* (1997); Ackerly & Reich (1999); Ackerly *et al.* (2000); Anderson *et al.* (2000); Reich *et al.* (2003a,b); Paoli (2006); Markesteijn *et al.* (2007); Loranger & Shipley (2010); Osunkoya *et al.* (2010)
	Specific leaf area (SLA)	$m^2 \cdot kg^{-1}$	Garnier *et al.* (2001); Vendramini *et al.* (2002); Poorter & Bongers (2006); Laliberté *et al.* (2010)
	Specific leaf area (SLA)	$mm^2 \cdot mg^{-1}$	Cornelissen & Thompson (1997; Ackerly *et al.* (2002); Díaz *et al.* (2004); Caccianiga *et al.* (2006); Cerabolini *et al.* (2010); Liu *et al.* (2010); Bernhardt-Römermann *et al.* (2011)
	Specific leaf area (SLA)	$cm^2 \cdot g^{-1}$	Reich *et al.* (1997); Ellis *et al.* (2000); Reich *et al.* (2003a); Maharjan *et al.* (2011); Paine *et al.* (2011)
	Specific leaf area index (LAI)	$cm^2 \cdot g^{-1}$	Aguiar *et al.* (1996);
	Specific leaf mass (SLM)	$mg \cdot dm^{-2}$	Pyankov *et al.* (1999)
	Specific leaf weight (SLW)	$g \cdot cm^{-2}$	
	Specific leaf weight (SLW)	$g \cdot m^{-2}$	Jurik (1986)
	Specific petiole length (SPL)	$cm \cdot g^{-1}$	Markesteijn *et al.* (2007)

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Trait syndrome	Trait	Unit	Source
	Spininess	binary	Díaz Barradas *et al.* (1999)
	Stomatal density (number of stomata)	cm^{-2}	
	Stomatal density (number of stomata)	mm^{-2}	Loranger & Shipley (2010)
	Stomatal pore thickness	m	Blonder *et al.* (2011); Nobel (1999).
	Structural carbon percent or protein free leaf percentage (C^s)		Niinemets *et al.* (2007)
	Succulence (ordinal 3 states)		Díaz *et al.* (1998)
	Succulence	$g.dm^{-2}$	Camerik & Werger (1981)
	Succulence	$g–H_2O·cm^{-2}$	
	Sulfur concentration	$mg·g^{-1}$	Laliberté *et al.* (2010)
	Surface area (A_L)	dm^2	Pyankov *et al.* (1999)
	Tensile strength	$g.cm^{-1}$	Quetiér *et al.* (2007)
	Tensile strength	$N.cm^{-1}$	Cornelissen & Thompson (1997)
	Tensile strength	$N.mm^{-2}$	Adler *et al.* (2004)
	Tensile strength, traction (manual) continuous and categorical (ordinal)		Pillar *et al.* (2009)
	Tear (specific force to tear)	$MN·m^{-2}$	Onoda *et al.* (2011)
	Tear (force to tear)	$kN·m^{-1}$	Onoda *et al.* (2011)
	Texture (1: membranous; 2: herbaceous; 3: coriaceous or fibrous)		Pillar *et al.* (2009)
	Texture: (papery, herbaceous, coriaceous)		Maharjan *et al.* (2011)
	Texture (malacophyll, semi-sclerophyll, sclerophyll)		Díaz Barradas *et al.* (1999)
	Texture (mesophyll, sclerophyll, succulent)		Ramsay *et al.* (2006)

Trait syndrome	Trait	Unit	Source
	Thickness	mm	Vendramini *et al.* (2002); Diaz *et al.* (2004); Adler *et al.* (2004); Loranger & Shipley (2010)
	Thickness	μm	Pyankov *et al.* (1999); Markesteijn *et al.* (2007)
	Threshold leaf nitrogen content per unit leaf area for positive g_{max}	Mol-N·m^2	Schieving & Poorter (1999)
	Tissue density	g·cm^{-3}	Craine & Lee (2003); Paine *et al.* (2011)
	Total cumulative leaf area of the canopy	m^2-leaf·m^{-2}-ground	Schieving & Poorter (1999)
	Total cumulative leaf nitrogen in the canopy	Mol-N·m^2 ground	Schieving & Poorter (1999)
	Total base content	% dwt	Cornelissen & Thompson (1997)
	Toughness (lto)	N·cm^{-2}	
	Toughness (tensile strength)	N·mm leaf width^{-1}	Díaz *et al.* (2004)
	Toughness (tensile strength)	N	Paine *et al.* (2011)
	Toughness (tensile strength)	N·mm^{-1}; N·cm^{-2}	Cingolani *et al.* (2005); Markesteijn *et al.* (2007)
	Toughness (push pull gauge)	g	Pringle *et al.* (2010)
	Trichomes	hairs/4mm disc	Pringle *et al.* (2010)
	Type (tender, sclerophyllous, succulent)		Vendramini *et al.* (2002)
	Venation: distance between vein and evaporative leaf surface (half thickness)	m	Blonder *et al.* (2011)
	Venation: mass density veins	g·m^{-3}	Blonder *et al.* (2011)
	Venation: vein density	m^{-1}	Blonder *et al.* (2011)

Trait syndrome	Trait	Unit	Source
	Venation: vein loopiness	m^{-2}	Blonder *et al.* (2011)
	Venation: vein bundle radius	m	Blonder *et al.* (2011)
	Water content (LWC)	$g–H_2O \cdot cm^{-2}$	Hulshof & Swenson (2010)
	Water content (LWC)	$g \cdot g^{-1}$	Vendramini *et al.* (2002)
	Water content	%	Pringle *et al.* (2010)
	Width	cm	Markesteijn *et al.* (2007); Maharjan *et al.* (2011)
	Width	mm	Adler *et al.* (2004)
Roots	Depth	cm	Eamus (1999);
	Depth (ordinal, 4 state)		Díaz Barradas *et al.* (1999)
	Diameter	mm	Roumet *et al.* (2006)
	Fine roots	% root length	Roumet *et al.* (2006)
	Specific root length (SRL)	$m \cdot g^{-1}$	Roumet *et al.* (2006)
	Root to shoot ratio		Reader (1998)
	Mass	$g \cdot plant^{-1}$	Reader (1998)
	Mass fraction (RMF)	$g–root \cdot g–plant^{-1}$	Reich *et al.* (2003b)
	Morphology (tap-root, horizontal, vertical – horizontal)		Díaz Barradas *et al.* (1999)
	Number in 20 cm layer		Aguiar *et al.* (1996)
	Above-ground, adventitious	PFE	Gillison (2002)
	N concentration in fine roots	%	Craine & Lee (2003)
	N concentration in roots	%	Craine & Lee (2003)
	Tissue density	$g \cdot cm^{-3}$	Craine & Lee (2003); Roumet *et al.* (2006)

Trait syndrome	Trait	Unit	Source
	Construction cost	g–glucose·g^{-1}	Roumet *et al.* (2006)
	Carbon isotope ratio $\delta^{13}C$	‰	Craine & Lee (2003); Foster & Brooks (2005)
	Mycorrhizal colonization	% root length colonized	Roumet *et al.* (2006)
	Nitrogen isotope ratio $\delta^{15}N$	‰	Craine & Lee (2003)
	N	mg·kg^{-1}	Reader (1998)
	N mass	mg·g^{-1}	Liu *et al.* (2010)
	N length	mg·m^{-1}	Liu *et al.* (2010)
	N concentration	%	Roumet *et al.* (2006)
	P	mg·kg^{-1}	Reader (1998)
	Specific root length (SRL)	m·g^{-1}	Reich *et al.* (2003b)
	Phreatophyte (ordinal 4 states)		Nygaard & Ejrnæs (2004)
Inflorescence	Length	mm	Ackerly (2004)
	Height	cm	Adler *et al.* (2004)
Flower	Color (light, dark)		Maharjan *et al.* (2011)
	Size (3 ordered multistates)		Maharjan *et al.* (2011)
	Arrangement (solitary/ non)		Gitay *et al.* (1999)
Fruit	13 types		Mayfield *et al.* (2005, 2006)
	Size (ordinal 6 states)		Mayfield *et al.* (2005, 2006)
	Size	mm	Gitay *et al.* (1999)
	Length	cm	Maharjan *et al.* (2011)
	Fleshy, dry		Maharjan *et al.* (2011)
	Width	cm	Maharjan *et al.* (2011)
	Color (light, dark)		Maharjan *et al.* (2011)

Trait syndrome	Trait	Unit	Source
	Dehiscence (ordinal 4 states)		Díaz Barradas *et al.* (1999)
	Type (ordinal 7 state)		Díaz Barradas *et al.* (1999)
	Type (ordinal 3 states)		Gitay *et al.* (1999)
Seed	Number		Díaz *et al.* (1998); Gitay *et al.* (1999); Maharjan *et al.* (2011)
	Length	cm	Maharjan *et al.* (2011)
	Width	cm	Maharjan *et al.* (2011)
	Size (5 ordinal states); (8 ordinal)		Mayfield *et al.* (2005, 2006)
	Size (length) (ordered multistates 5)	mm	Díaz *et al.* (1998)
	Size (small <0.3 mg, large >0.3 mg)	mg	Campbell *et al.* (1999);
	Seeds < 0.5 mg	mg	Prach *et al.* (1997)
	Mass (size)	kg	Falster *et al.* (2010)
	Mass	mg	Ackerly (2004)
	Mass (3 ordered multistates)	mg	Lavorel *et al.* (1998)
	Mass dry	mg	Kooyman *et al.* (2011)
	Mass (ordinal: 8 states)	mg	Moretti & Legg (2009)
	Seed bank type (canopy, soil)	–	Esther *et al.* (2010)
	Seed bank (persistent)		Prach *et al.* (1997)
	Max seed production (low, moderate, high)	–	Esther *et al.* (2010)
	Shape continuous (variance among length, width and depth when length = 1; for a spherical seed, variance = 0)	–	Díaz *et al.* (1998, 2004)
	Longevity, dormancy		Roumet *et al.* (2006); Nygaard & Ejrnæs (2004)
	Elaiosomes		

Trait syndrome	Trait	Unit	Source
	Mass	mg	Laliberté *et al.* (2010)
Seedling	Type: (ordinal, 4 states)		Maharjan *et al.* (2011)
Dispersal	Dispersal syndrome (limited, unlimited)	binary	Esther *et al.* (2010)
	Dispersal mode (ordinal 3 states)		Díaz *et al.* (1998); Gitay *et al.* (1999)
	Anemochorous		Prach *et al.* (1997); Lavorel *et al.* (1998); Decocq & Hermy (2003); Jauffret & Lavorel (2003); Maharjan *et al.* (2011
	Autochory	numeric	Lavorel *et al.* 1998; Nygaard & Ejrnæs (2004)
	Allochory	numeric	Nygaard & Ejrnæs (2004)
	Explosive		Maharjan *et al.* (2011
	Barochorous		Decocq & Hermy (2003); Jauffret & Lavorel (2003)
	Myrmecochory		Beattie & Culver (1981); Decocq & Hermy (2003); Nygaard & Ejrnæs (2004)
	Endozoochorous		Jauffret & Lavorel (2003); Nygaard & Ejrnæs (2004); Maharjan *et al.* (2011
	Exozoochorous	numeric	Nygaard & Ejrnæs (2004)
	Zoochory		Prach *et al.* (1997); Lavorel *et al.* 1998;
	Animal, water, wind (13 states)		Mayfield *et al.* (2005, 2006)
	Mode	nominal	Laliberté *et al.* (2010)

Trait syndrome	Trait	Unit	Source
Cellular	Solubles	$g \cdot g^{-1}$	Adler *et al.* (2004)
	Latex	–	
	Resins	–	
	Secondary metabolites	–	
	Vulnerability to cavitation	–	
	Thickness of outer cell wall	μm	Markesteijn et al (2007)
	Upper epidermis thickness	μm	Markesteijn *et al.* (2007)
	Palisade parenchyma thickness	μm	Markesteijn *et al.* (2007)
	Spongy parenchyma thickness	μm	Markesteijn *et al.* (2007)
	Lower epidermis thickness	μm	Markesteijn *et al.* (2007)
	Palisade to spongy parenchyma ratio	$\mu m \cdot \mu m^{-1}$	Markesteijn *et al.* (2007)
	Xylem conduit diameter	μm	Markesteijn *et al.* (2007)
	No. Of palisade parenchyma layers		Markesteijn *et al.* (2007)
	Vessel diameter	μm	Ackerly (2004)
	Secondary thickening	–	Campbell *et al.* (1999)
	Volume of the average chloroplast (V_{chl})	μm^3	Pyankov *et al.* (1999)
	Volume of the average mesophyll cell ($V_{mes\ cell}$)	μm^3	Pyankov *et al.* (1999)
Decomposition	Litter dry weight loss	% dwt (8 wk; 20 wk)	Cornelissen & Thompson (1997)
Reproductive	Pollination mode (ordinal 3 states)		Díaz *et al.* (1998)
	Pollination syndrome	nominal	Laliberté *et al.* (2010)
	Seed		Bernhardt-Römermann *et al.* (2011)
	Pollen vector (wind, animals)		Moretti & Legg (2009)
	Pollen vector (wind, insect)		Prach *et al.* (1997)
	Extra-floral nectaries		
	Pollinators (ordinal 2 states)		Díaz Barradas *et al.* (1999);

Trait syndrome	Trait	Unit	Source
	Pollination (13 states)		Mayfield *et al.* (2005, 2006)
	Reproductive age (ordinal)		Laliberté *et al.* (2010)
	Maximum propagule longevity	ordinal	Laliberté *et al.* (2010)
	Breeding system (monoecious/ dioecious)		Gitay *et al.* (1999)
Vegetative	Clonal growth	nominal	Laliberté *et al.* (2010); Bernhardt-Römermann *et al.* (2011)
	Vegetative reproduction (binary)		Lavorel *et al.* 1998; Nygaard & Ejrnæs (2004)
	Resprouting capacity	binary	McIntyre *et al.* (1999); Esther *et al.* (2010)
	Resprouting ability	nominal	Laliberté *et al.* (2010)
	Capacity for lateral spread		McIntyre *et al.* (1999)
	Clonal growth organ		Meusel (1970);
	Mean distance between ramets connected below ground or at ground level		Diaz *et al.* (2004)
	Regeneration after fire (ordinal 4 states)		Díaz Barradas *et al.* (1999)
	Active bud position (basal or below ground; above ground)		Campbell *et al.* (1999)
	Rhizomes, stolons		Aguiar et al. (1996); Díaz *et al.* (2007)
	Vegetation regeneration	binary	McIntyre *et al.* (1999)
	Vegetation regeneration (“clonality”) (ordinal; 3 states)		Caccianiga *et al.* (2006)
Survival strategies	Competitor (C); stress tolerant (S); ruderal (R)		Grime (1979);
	C-S-R strategy (3 quantitative, 3 ordinal)		Prach *et al.* (1997); Moretti & Legg (2009)

Trait syndrome	Trait	Unit	Source
	C-S-R strategy (4 ordinal states)		Decocq & Hermy (2003)
	C (ordinal 12 states)		Nygaard & Ejrnæs (2004)
	S (ordinal 12 states)		Nygaard & Ejrnæs (2004)
	R (ordinal 12 states)		Nygaard & Ejrnæs (2004)
	Fecundity (high/low)	binary	McIntyre *et al.* (1999)
	Timing of seed release		McIntyre *et al.* (1999)
	Recruitment frequency (high/low)	binary	McIntyre *et al.* (1999)
	Germination seasonality		McIntyre *et al.* (1999)
	Sprout insulation (e.g. to fire) (ordinal, 4 states)		Moretti & Legg (2009)
	Drought avoidance	binary	Díaz *et al.* (1998)
	Drought avoidance – tolerance		
	Shade tolerant, shade bearer		Decocq & Hermy (2003); Maharjan *et al.* (2011)
	Nonpioneer light demander		Maharjan *et al.* (2011)
	Nutrient uptake strategy	nominal	Laliberté *et al.* (2010)
	Pioneer		Maharjan *et al.* (2011)
	Vital attributes (see paper)		Noble & Slatyer (1980)
	Saprophytic, parasitic		Decocq & Hermy (2003)
Growth rate, maintenance & productivity	Cost of leaf growth (3 ordered multistates)	g-glucose·g $(dwt)^{-1}$	Díaz Barradas *et al.* (1999)
	Cost of leaf maintenance	g-glucose·g $(dwt)^{-1}$ day^{-1}	Díaz Barradas *et al.* (1999)
	Total biomass (14 weeks growth)	g	Osunkoya *et al.* (2010)
	Diameter growth rate		
	Fecundity (4 ordinal states)		Decocq & Hermy (2003)
	Investment into support tissue (ordinal 3 states)		Díaz *et al.* (1998)
	Growth rate	$g \cdot g^{-1} \cdot week^{-1}$	Decocq & Hermy (2003)

Trait syndrome	Trait	Unit	Source
	Net primary productivity	$g{\cdot}m^{-2}{\cdot}yr^{-1}$	Moles *et al.* (2005)
	Above-ground net primary productivity anpp	$g{\cdot}m^{-2}{\cdot}d^{-1}$	Garnier *et al.* (2007)
	Specific above-ground net primary productivity sanpp	$g{\cdot}kg^{-1}{\cdot}d^{-1}$	Garnier *et al.* (2007)
	Relative growth rate (RGR max (d^{-1})	RGR max (d^{-1})	Cornelissen & Thompson (1997); Cornelissen *et al.* (2001)
	RGR	$g{\cdot}g^{-1}{\cdot}day^{-1}$	Reich *et al.* (2003a)
	RGR	$g{\cdot}g^{-1}{\cdot}month^{-1}$	Osunkoya *et al.* (2010)
	RGR	$g{\cdot}g^{-1}{\cdot}week^{-1}$	Reader (1998)
	Sexual maturity	years	Decocq & Hermy (2003)
	Age (4 ordered multistates)	year	Díaz Barradas *et al.* (1999)
Taxonomic, phylogenetic	Species density		Paoli (2006)
	Species frequency		Paoli (2006)
	Angiosperm, gymnosperm		Reich *et al.* (2007)
	Legume and targeted species archetypes of LHS PFTs abundance		Quetiér *et al.* (2007)
Folivory, herbivory	Palatability index	low, med. high	Jauffret & Lavorel (2003)
	Palatability	bioassay	Pringle *et al.* (2010)
	Forage quality (ordinal 3 states)		Campbell *et al.* (1999)
Defence	Stinging hairs	presence	McIntyre *et al.* (1999)
	Spine length	presence	McIntyre *et al.* (1999)
	Spininess	presence	McIntyre *et al.* (1999)
	Secondary compounds	presence	McIntyre *et al.* (1999)
	Waxiness	presence	McIntyre *et al.* (1999)

Trait syndrome	Trait	Unit	Source
	Physical defence	nominal	Laliberté *et al.* (2010)
Grazing-related	Uprooting potential	high, low	McIntyre *et al.* (1999)
	Inflorescence prominence	absolute or relative measure	McIntyre *et al.* (1999)
Fire-related	Serotinous obligate seeder shrubs	species frequency (0.5x0.5m quads x 60)	Keith *et al.* (2007)
	Non-serotinous obligate seeder shrubs	species frequency (0.5x0.5m quads x 60)	Keith *et al.* (2007)
	Resprouter shrubs	species frequency (0.5x0.5m quads x 60)	Keith *et al.* (2007)
	Fire ephemeral herbs	species frequency (0.5x0.5m quads x 60)	Keith *et al.* (2007)
	Non-rhizomatous resprouting herbs and graminoids	species frequency (0.5x0.5m quads)	Keith *et al.* (2007)
	Rhizomatous resprouting graminoids, herbs and ferns	species frequency (0.5x0.5m quads x 60)	Keith *et al.* (2007)

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Trait syndrome	Trait	Unit	Source
Growth	Growth rate	$cm \cdot yr^{-1}$	Poorter & Bongers (2006)
	Age (4 ordered multistates)		Díaz Barradas *et al.* (1999)
Physiological	Ash (mineral ash)	$mg \cdot g^{-1}$	Osunkoya *et al.* (2010)
	Carbon storage in reserve organs	binary	Díaz *et al.* (1998)
	(Dark) leaf respiration rate per unit leaf mass at depth *h*	$mol\text{-}CO \cdot kg^{-1}\text{-}leaf \cdot s^{-1}$	Schieving & Poorter (1999)
	(Dark) respiration rate per individual of species *j*	mol-CO, s^{-1} per individual	Schieving & Poorter (1999)
	Dark respiration	$mmol\text{-}CO_2\ m^{-2}\ s^{-1}$	Foster & Brooks (2005)
	(Gross) photosynthetic nitrogen-use efficiency	mol.CO, $mol^{-1}.N.S^{-1}$	Schieving & Poorter (1999)
	Apparent quantum yield (phi)		Posada *et al.* (2009)
	Capacity of the gross photosynthesis-light curve at depth *h*	$mol\text{-}CO_2{}^{-2}\ leaf.s^{-1}$	Schieving & Poorter (1999)
	Condensed tannin	$mg\ g^{-1}$	Shiodera *et al.* (2008)
	Condensed tannin-free total phenolics	$mg.g^{-1}$	Shiodera *et al.* (2008)
	Conduit diameter	μm	Chave *et al.* (2009)
	Daily instantaneous photosynthetic photon flux density (PPFD)	$mol.m^{-2}\ d^{-1}$	Posada *et al.* (2009)
	Dark respiration (R(d))		Posada *et al.* (2009)
	Drought resistance		
	Drought tolerance	binary	Esther *et al.* (2010)
	Peak carbon assimilation rate	$mol.CO_2 \cdot g^{-1} \cdot s^{-1}$	Blonder *et al.* (2011)
	Photosynthetic pathway	nominal	Laliberté *et al.* (2010)

Trait syndrome	Trait	Unit	Source
	Gross photosynthetic rate per individual of species *j*	mol-CO, s–[1] per individual	Schieving & Poorter (1999)
	Gross photosynthetic rate per unit leaf area at depth *h*	mol-CO, m–[2] leaf s–[1]	Schieving & Poorter (1999)
	In situ photosynthetic nitrogen-use efficiency (PNUE)	$\mu mol \cdot m^{-1} \cdot s^{-1}$	Schieving & Poorter (1999); Ackerly (2004)
	Intercellular co_2 concentration (C_i)	ppm	Sandquist & Cordell (2007)
	Transpiration	$mmol \cdot m^{-2}\ S^{-1}$	Ackerly (2004)
	Transpiration efficiency	$g \cdot mm^{-1} \cdot yr^{-1}$	Aguiar *et al.* (1996)
	Leaf construction cost (grams of glucose + minerals required to synthesize 1 g skeleton (CC_{area})	$g \cdot m^{-2}$	Osunkoya *et al.* (2010)
	Leaf respiration (R_d-leaf)	$nmol \cdot g^{-1} \cdot s^{-1}$	Walters and Reich (1999); Reich *et al.* (2003a)
	Light compensation state (lcp)	$m^{-2} \cdot s^{-1}$	Walters and Reich (1999); Reich *et al.* (2003a)
	Mass based dark respiration R_{mass}	$nmol \cdot g^{-1} \cdot s^{-1}$	Reich *et al.* (1997); Poorter & Bongers (2006)
	N fixation (presence of N fixer)		Cadotte *et al.* (2009)
	Photosynthesis A_{max}	$\mu mol \cdot m^{-2} \cdot s^{-1}$	Ellis *et al.* (2000); Osunkoya *et al.* (2002)
	Net assimilation rate per area (NAR_{area})	$g \cdot m^{-2} \cdot day^{-1}$	Reich *et al.* (2003b)
	Net assimilation rate per mass (NAR_{mass})	$g \cdot g^{-1} \cdot day^{-1}$	Reich *et al.* (2003b)
	Net photosynhthesis	$nmol \cdot g^{-1} \cdot s^{-1}$	Reich *et al.* (1997, 2003a)
	Net photosynthesis area based (A_{net})	$\mu mol \cdot m^{-2} \cdot s^{-1}$	Reich *et al.* (1997); Marks & Lechowicz (2006)

Trait syndrome	Trait	Unit	Source
	Net photosynthetic capacity A_{max} (mass)	nmol·g^{-1}·s^{-1}	Walters and Reich (1999); Reich *et al.* (2003b)
	Net rate of carbon gain (gross photosynthesis − respiration)	mol-CO_2·s^{-1} per individual	Schieving & Poorter (1999)
	N^-fixation		Campbell *et al.* (1999)
	Nitrogen isotope ratios $\delta^{13}N$		Sandquist & Cordell (2007)
	Nitrogen per unit mass N_{mass}	%	Paoli (2006); Poorter & Bongers (2006)
	Nitrogen per unit mass N_{mass}	mg·g^{-1}	Osunkoya *et al.* (2010)
	Nitrogen per unit area N_{area}	mg·cm^{-2}	Osunkoya *et al.* (2010)
	Optimal allocation of foliar N (ONA)		Posada *et al.* (2009)
	Oxygen isotope ratios $\delta^{18}O$		Sandquist & Cordell (2007)
	Ozone sensitivity of plants (ordinal high, medium, low)		Bussotti (2008)
	Photosynthetic capacity (a_{max})		Posada *et al.* (2009)
	Photosynthetic capacity	μmol·m^{-2}·s^{-1}	Valladares *et al.* (2000)
	Photosynthetic pathway (CAM, C_3, C_4)		Díaz *et al.* (1998)
	Photosynthetic pathway (C_3, C_4)		Skarpe (1996)
	Photosynthetic energy use efficiency	mol-CO_2 g^{-1}	Osunkoya *et al.* (2010)
	Photosynthetic n use efficiency	mmol–CO_2 mol.N^{-1}	Osunkoya *et al.* (2010)
	Photosynthetic water use efficiency (WUE)	Mmol-CO_2 .$mmol^{-1}$-H_2O	Ackerly (2004); Osunkoya *et al.* (2010)
	Pre-dawn water potential Ψpd	Mpa	Sandquist & Cordell (2007)

Trait syndrome	Trait	Unit	Source
	Relative growth rate (RGR)	$mg \cdot g^{-1} \cdot d^{-1}$	Walters and Reich (1999); Reich *et al.* (2003b)
	Relative growth rate (RGR)	$mg \cdot g^{-1} \cdot wk^{-1}$	Valladares *et al.* (2000)
	Sap flow (heat balance method)	$kg.H_2O \cdot hr^{-1}$	Williams *et al.* (1998); Schaeffer & Williams (1998)
	Sapwood area conductivity	$mm^2.kPa^{-1} \cdot S^{-1}$	Chave *et al.* (2009)
	Sla at canopy depth *h*	m^2-leaf.kg^{-1} leaf	Schieving & Poorter (1999)
	Stable carbon isotope ratio $\delta^{13}C$	‰	Brooks *et al.* (1997); Sandquist & Cordell (2007); Osunkoya *et al.* (2010)
	Stomatal conductance (gs)	$mmol \cdot m^{-2} \cdot s^{-1}$	Poorter & Bongers (2006)
	Stomatal conductance (gs)	$mol \cdot m^{-1} \cdot s^{-1}$	Sandquist & Cordell (2007)
	Stomatal conductance (g_s).	mol-$H_2O \cdot m^{-2} \cdot s^{-1}$	Ackerly & Reich (1999); Ackerly (2004); Blonder *et al.* (2011)
	Stomatal conductance (g_{max})	$mmol.H_2O \cdot m^{-2} \cdot s^{-1}$	Foster & Brooks (2005)
	Maximum per area transpiration rate	mol-$H_2O \cdot m^{-2}\ s^{-1}$	Blonder *et al.* (2011)
	Thickness of photosynthetic tissue	-0.95 (Pmax) - - $1.3\alpha^0$	Duarte. (1999)
	Total xylem sap flow per leaf area		Marks & Lechowicz (2006)

Trait syndrome	Trait	Unit	Source
	True quantum yield	mol-CO_2 , mol^{-1} quanta	Schieving & Poorter (1999)
	Water potential predawn Ψ august	MPa	Ackerly (2004)
	Water potential midday Ψ june	MPa	Ackerly (2004)
	Water potential midday Ψ august	MPa	Ackerly (2004)
	Water potential miminum seasonal Ψ	MPa	Ackerly (2004)
	Water potential predawn Ψ june	MPa	Ackerly (2004)
	Summer leaf water potential (4 ordered multistates)	MPa	Díaz Barradas *et al*. (1999)
	Winter leaf water potential (4 ordered multistates)	MPa	Díaz Barradas *et al*. (1999)
	Water use efficiency (WUE)	$mmol \cdot mol^{-1}$	Poorter & Bongers (2006)
	Leaf water use efficiency	mol-CO_2 $\cdot mol^{-1}$ H_2O	Blonder *et al.* (2011)
	Xylem area conductivity	$kg \cdot m^{-1}$ kPa^{-1} S^{-1}	Chave *et al.* (2009)
	Xylem pressure	MPa	Ackerly (2004)
Fungal (mycorrhizal)	Hyphal length	–	Van der Heijden & Scheublin (2007)
	Mycelium structure	–	Van der Heijden & Scheublin (2007)
	Stability of hyphal networks	–	Van der Heijden & Scheublin (2007)
	Hyphal life span	–	Van der Heijden & Scheublin (2007)
	Speed of root colonization	–	Van der Heijden & Scheublin (2007)
	Spore production	–	Van der Heijden & Scheublin (2007)

Trait syndrome	Trait	Unit	Source
	Formation of auxiliary cells	–	Van der Heijden & Scheublin (2007)
	Formation of vesicles	–	Van der Heijden & Scheublin (2007)
	Efficiency of uptake, N, P, Cu, Fe	–	Van der Heijden & Scheublin (2007)
	Temporal and spatial variation in fungal activity	–	Van der Heijden & Scheublin (2007)
	Fungal carbon acquisition	–	Van der Heijden & Scheublin (2007)
	Host preference, compatibility	–	Van der Heijden & Scheublin (2007)
	Presence of va mycorrhizae	–	Prach *et al.* (1997); Cornelissen *et al.* (2001)
	Arbuscular mycorrhizal fungi (AMF)	–	van der Heijden *et al.* (1998); Cornelissen *et al.* (2001); Urcelay & Díaz (2003)
	Ericoid mycorrhizal (functional type)		Cornelissen *et al.* (2001)
	Ectomycorrrhizal (functional type)		Cornelissen *et al.* (2001)
	Ecto/am (functional type)		Cornelissen *et al.* (2001)
	Mycorrhizal infection	%	Reader (1998)
Spectral, remote sensing	Canopy spectral reflectance (albedo) composite digital and empirical	(see ref.)	Aguiar *et al.* (1996)
	Spectral signatures used to construct optical types	–	Ustin & Gamon (2010)
Indicator species values	Light (ordinal 9 states)	–	Nygaard & Ejrnæs (2004) (After Ellenberg *et al.* 1992)
	Moisture (ordinal 9 states)	–	Nygaard & Ejrnæs (2004)
	Nitrogen (ordinal 12 states)	–	Nygaard & Ejrnæs (2004)

Trait syndrome	Trait	Unit	Source
	Ph (ordinal 9 states)	–	Nygaard & Ejrnæs (2004)
Genetic	Quantitative trait locus	–	Remington & Purugganan (2003)

Web Resource 12.6: Table 3 Comparative list of plant functional complexity (PFC), species and *modal* PFT richness in humid to humid-seasonal lowland tropical, subtropical and temperate forests in 28 countries *

No.	Country	Location	Georeference	Plot ID	Forest type	Species rich.	PFT rich.	PFC value
1	Indonesia (Sumatra)	Tesso Nilo, Riau Province,	0º 14’ 51” S 101º 58’ 16” E	TN02	Complex primary forest, logged 1997	202	68	338
2	Indonesia (Sumatra)	Pancuran Gading, Jambi Province	1º 10’ 12” S 102º 06’ 50” E	BS10	Lowland forest interplanted with ‘jungle’ Rubber (*Hevea brasiliensis*)	112	47	236
3	India	Arunachal Pradesh Tipi – Pakke Sanctuary.	27º 2’ 3” N 92º 36’ 58” E	NBL06	Complex lowland forest selectively logged	107	74	314
4	Indonesia (Borneo)	Gunung Banalang, Long Puak, Pujungan, East Kalimantan	2º 43’ 32” N 115º 39’ 46”E	BUL02	Disturbed complex ridge forest	104	44	232

No.	Country	Location	Georeference	Plot ID	Forest type	Species rich.	PFT rich.	PFC value
6	Papua New Guinea	Kuludagi / West New Britain Province	5º 38’ 46” S 150º 06’ 14” E	KIMBE2	Complex, primary lowland forest	99	52	234
7	Costa Rica	Braulio Carillo Parque Nacional	10º 09’ 42” N 83º 56’ 18” W	CR001	Partially disturbed forest, palm dominated. Many epiphytes	94	71	336
5	Cameroon	Awae Village	3º 36’ 05” N 11º 36’ 15” E	CAM 01	Late secondary forest. Previously logged	94	43	232
8	Brazil	Pedro Peixoto, Acré (West Amazon basin)	10º 01’ 13” S 67º 09’ 39” W	BRA19	Secondary forest (Capoeira) 3–4 years after abandonment	78	43	230
9	Brazil	Alcalinas Canamá N.W. Mato Grosso (West Amazon basin)	10º 04’ 06” S 58º 46’ 00” W	PN24	Primary lowland forest on shallow granitic soils	75	54	298

No.	Country	Location	Georeference	Plot ID	Forest type	Species rich.	PFT rich.	PFC value
10	Perú	Jenaro Herrera, Ucayali river (West Amazon basin)	4º 58’ 00” S 73º 45’ 00”W	PE02	‘High terrace’ lowland forest - selective logging	72	39	208
11	Vietnam	Cuc Phuong National Park Ninh Binh Province	20º 48’ 33” N 105 42’ 44” E	FSIV02	Lowland forest partly disturbed; on limestone	69	46	256
12	Perú	Von Humboldt forest reserve, Pucallpa, (W. Amazon basin)	8º 48’ 01” S 75º 03’ 54” W	PUC01	Primary forest selectively logged, 1960	63	31	258
13	Fiji	Bua, Vanua Levu	16º 47’ 36” S 178º 36’ 45” E	FJ55	Disturbed lowland forest on ridge	60	37	158
14	Thailand	Ban Huay Bong, Mae Chaem watershed	18º 30’ 42” N 98º 24’ 13” E	MC18	Humid-seasonal, deciduous dipterocarp forest fallow system	58	44	200

No.	Country	Location	Georeference	Plot ID	Forest type	Species rich.	PFT rich.	PFC value
16	Kenya	Shimba Hills near Mombasa	4º 11' 33" S 39º 25 34" E	K01	Semi-deciduous forest in game park area. Disturbed (logged)	56	33	214
15	Malaysia (Borneo)	Danum Valley, Sabah	4º 53' 03" N 117º 57' 48" E	DANUM3	Primary forest subject to reduced impact logging, Nov 1993	54	39	208
17	Guyana	Iwokrama forest reserve	4º 35' 02" N 58º 44' 51" W	IWOK01	Primary wamp forest in blackwater system	52	34	192
19	Georgia	Gezgeti, Mt Kazbegi Central Caucasus Mts	42º 40' 01" N 44º 36' 27" E	CAUC05	*Betula litwinowii* Krummholz	47	35	198
20	Bolivia	Las Trancas, (Santa Cruz)	16º 31' 40" N 61º 50' 48" W	BOL02	Semi-evergreen, lowland vine forest. Logged 1996	46	33	302

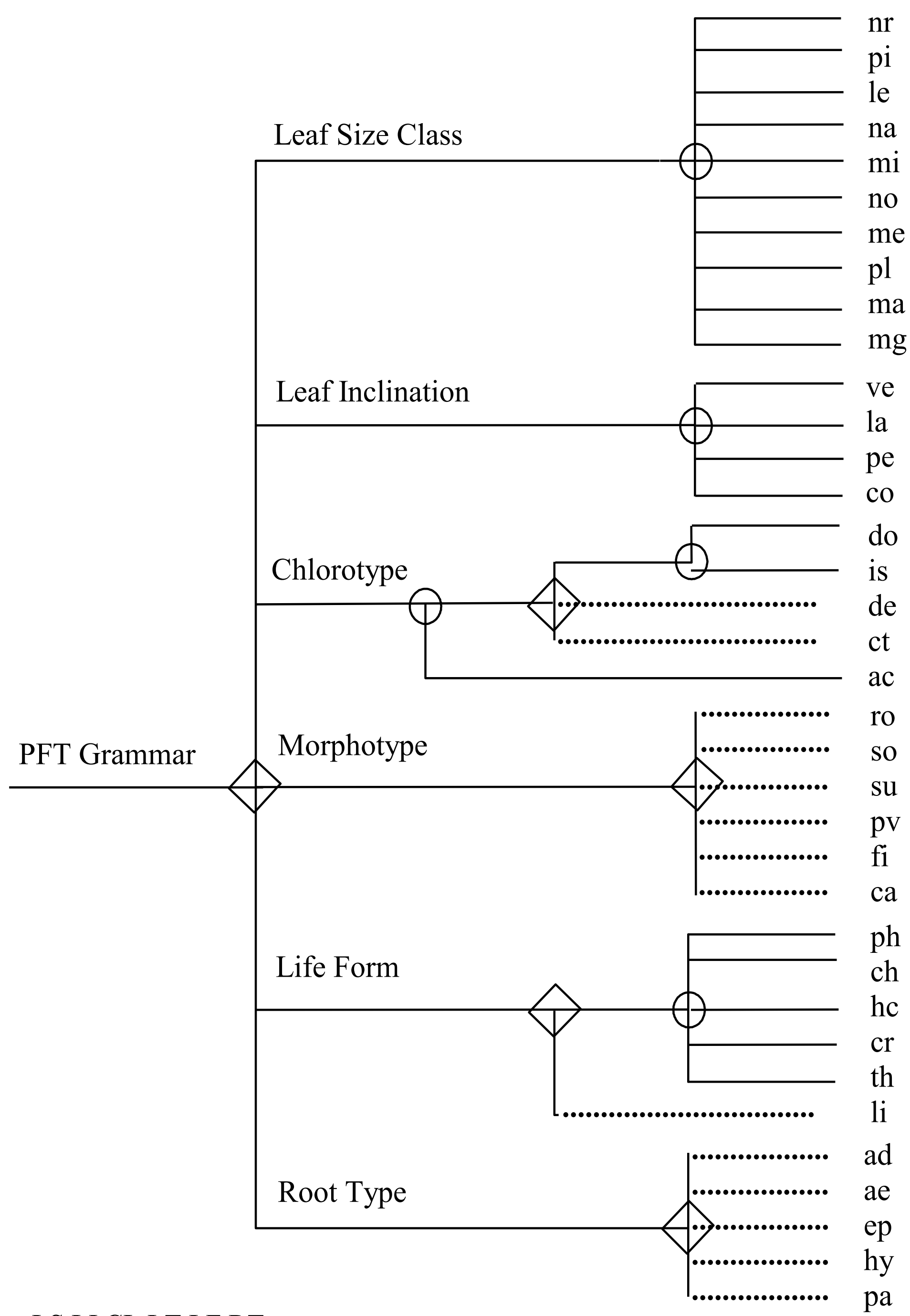
No.	Country	Location	Georeference	Plot ID	Forest type	Species rich.	PFT rich.	PFC value
21	Australia	Atherton tableland North Queensland	17º 18’ 28” S 145º 25’ 20” E	DPI012	Upland humid forest managed for sustainable timber extraction	4.	25	187
22	Panama	Barro Colorado island	9º 09’ 43” N 79º 50’ 46” W	BARRO1	Semi-evergreen vine forest, ground layer grazed by native animals	43	30	238
23	Brazil	Reserva Biologica da Campiña Km 50 near Manaus (East Amazon basin)	2º 35’ 21” S 60º 01’ 55” W	BRA24	Moderately disturbed, microphyll, evergreen vine forest on siliceous sands	42	27	276
18	Philippines	Mt Makiling, Luzon	14º 08’ 46” N 131º 13’ 50” E	PCLASS1	Regen. forest planted in 1968 with *Swietenia macrophylla*, *Parashorea*, *Pterocarpus indicus* .	42	26	194

No.	Country	Location	Georeference	Plot ID	Forest type	Species rich.	PFT rich.	PFC value
24	Outer Mongolia	Bear Cub Pass, Khentii Mountains	48º 58’ 35” N 107º 09’ 18” E	MNG04	Mixed larch and birch forest	40	25	188
25	Vanuatu	Yamet, near Umetch, Aneityum Island	20º 12’ 32” S 169º 52’ 33” E	VAN11	Coastal primary forest, logged with *Agathis macrophylla* (Kauri) overstorey	38	22	217
26	Mexico	Zona Maya, Yucatan peninsula	19º 02’ 26” N 88º 03’ 20” E	YUC02	Logged secondary lowland forest	37	26	288
27	Indonesia (Borneo)	Batu Ampar, Central Kalimantan	0º 47’ 48” N 117º 06’ 23” E	BA07	Primary forest, heavily logged 1991/92	35	23	286
28	West Indies (France)	Near Mont Pelée, Martinique	0º 47’ 48” N 117º 06’ 23” E	MQUE1	Humid, lowland forest on volcanic slopes, heavily disturbed	32	24	279

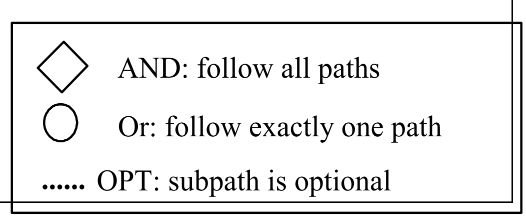
No.	Country	Location	Georeference	Plot ID	Forest type	Species rich.	PFT rich.	PFC value
29	Mozambique	Supita, near Mopeia	17º 56’ 20.6” S 35º 43’ 33.8” E	MOZ19	Semi-deciduous microphyll vine forest. Community reserve	31	24	144
30	Argentina	Iguazú Parque Nacional de las Cataratas	25º 39’ 00” S 54º 35’ 00” W	IGUAZU01	Lowland vine forest, disturbed	28	24	302
31	French Guyana	B.E.C. 16 km from Kourou	14º 49’ 23” N 61º 7’ 37” W	FRG05	*Tierra firme* simple evergreen forest on white sand	28	18	146
32	Indonesia (Borneo)	Mandor Nature Reserve, North of Pontianak	0º 17’ 12” N 109º 33’ 00” E	PA02	Low microphyll evergreen forest in blackwater system on siliceous sand	25	21	228
33	Austria	Heilligenkreutz	48º 03’ 19” N 16º 7’ 48” E	AUSTRIA 01	Disturbed riparian forest	23	16	116
34	England	Newbridge, River Dart NP Devon	50º 31’ 23” N 03º 50’ 7.5” W	ENG13	Deciduous oak forest	20	19	160
35	Spain	Pedro Alvarez Reserve,Tenerife	28º 32’ 4” N 16º 19’ 0” W	TENERIFE 04	‘Laurisilva’ upland forest	12	9	46

* Data summary from plots with richest vascular plant species and Plant Functional Type (PFT) and Plant Functional Complexity (PFC) values extracted from a series of global, ecoregional surveys and restricted to closed forests. All data collected using a standard ‘VegClass’ sampling protocol (Gillison 1988, 2002). Forest conditions range from relatively intact to highly disturbed. *Source:* International Centre for Agroforestry Research, Alternatives to Slash and Burn Programme (ICRAF/ASB); Center for International Forestry Research (CIFOR); WWF AREAS project and CBM (Center for Biodiversity Management).

Web Resource 12.7: Grammar and rule set for compiling Plant Functional Types.



X = LS LI CL LT LF RT
LS = nr |pi |le |na |mi |no |me |pl |ma |mg
LI = ve |la |pe |co
CL = ((do |is) [de] [ct]) |ac
LT = [ro] [so] [su] [pv] [fi] [ca]
LF = (ph |ch |hc |cr |th) [li]
RT = [ad] [ae] [ep] [hy] [pa]



Web Resource 12.7: Fig. 1 Grammar and rule set for compiling Plant Functional Types. Using this method, an individual of the seasonally deciduous sub-tropical tree *Dipterocarpus tuberculatus* might be classified as macrophyll-dorsiventral-composite-deciduous-phanerophyte with a resulting PFT ma-do-co-de-ph. Lower left inset is Backus-Naur notation for the complete PFT grammar. From Gillison & Carpenter (1997)