SECTION 3. TRAIT STANDARDS

For trait data entered into the LEDA Traitbase there are some rules that need to be followed:

- For any trait data entered into the LEDA Traitbase it is required to record ALL obligate fields.
- For the general standards information on the data reference (literature, database), geographical references (study area, area code), and description of the sample site (habitat type, sample area size, soil substrate, method of measurement) is required.
- For each of the trait standards the required information that is stated for each trait.
- Trait data obtained from greenhouse or garden experiments are only accepted when all obligate fields can be completed.
- LEDA preferred records from literature with known origin source for e.g. a published paper (= original reference).
- For trait data that are obtained from literature the original data source (original reference) should be filled in separately for each trait when the data is originating from a review paper (i.e. data used in one paper that is originating from another source).

Note: To secure the data quality in the LEDA Traitbase, the criteria for refusing data for the LEDA Traitbase are: The lacking of any obligate information required for the general and/or trait standard, as well as missing information on the number of replicates and the standard deviation or standard error of the mean values of the concerning trait value(s).

1. WHOLE PLANT TRAITS

1.1. PLANT GROWTH FORM

I.C. Knevel

Introduction

Life form and growth form are often used as synonyms and hence many different classifications are used in literature to describe plant growth form, mainly as a result of the mixing of the concepts life form and growth form, often used as synonyms. Life form is defined as having the same kind of morphological and/or physiological adaptation to a certain ecological factor, whereas growth form includes growth morphology and architecture (Barkman 1988).

One way of describing plants is based on how much they branch, the direction in which branches grow and how far they grow, however trees will often change their branching pattern as they grow. Raunkiaer (1934) noted that the traditional classification of plants into trees, shrubs, herbs, and other categories based on habit does not take into account much of the ecology or lifestyle of the plants (Fig. 3.1). Raunkiaer devised an ecological system of classifying plants using the position of the perennating bud, which provides various degrees of protection during dry or cold seasons, based on the idea that plants in different climates will use different methods to protect their buds (growing points) during unfavourable periods of the year, using a system of description of vegetation using life-forms. The life-form is defined as the vegetative form of a plant based on the position of the growth points or buds during adverse times of year. In the classification 11 different categories are distinguished, including phanerophyte, chamaephyte, geophyte, therophyte, liana, hemi-epiphyte, epiphyte, errant vascular hydrophyte (see Fig. 3.1) as well as vascular semi-parasite and vascular parasite categories.

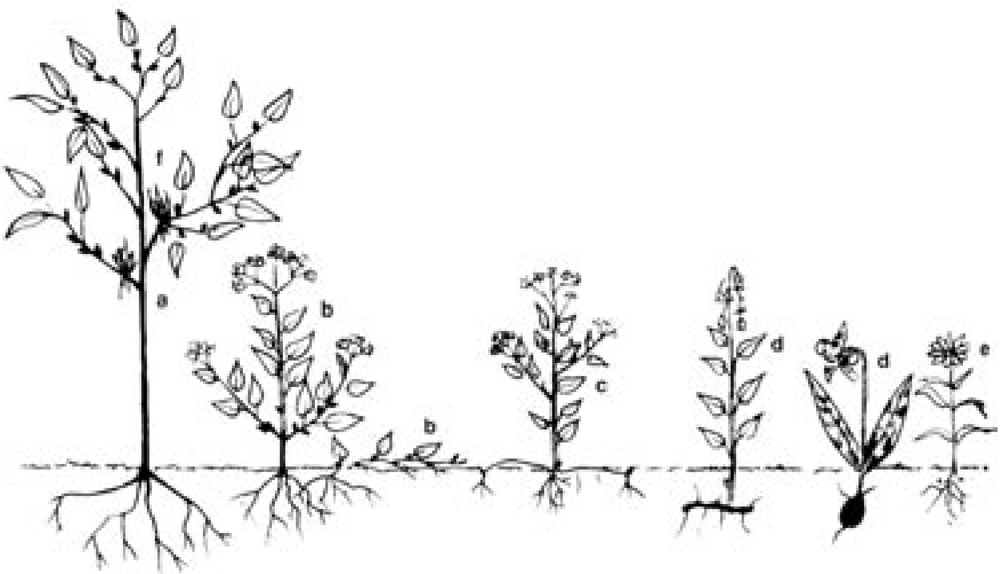

Figure 3.1. *Some of the growth form categories used in LEDA: a. phanerophyte, b. chamaephyte, c. hemicryptophyte, d. geophyte, e. therophyte, f. epiphyte (Picture: see Source list).*

Trait definition

Life form:

A classification of the way plants are adapted morphologically for surviving stressful seasons or unfavourable conditions (perennating). The aerial parts of a plant may die back under these unfavourable circumstances and the food for the new shoots for next growing season is stored in underground organs such as bulbs, tubers, corms and rhizomes, or in the case of woody plants, the food would be stored in the buds situated on their woody stems (Hickery 2003). For example Raunkiaer life form classification (Raunkiaer 1934) based up on the position of the perennating bud(s). Types of plants that have the same kind of morphological and/or physiological adaptation to a certain ecological factor.

Plant form:

Is defined as types of plants with the same growth morphology or architecture (Barkman 1988).

Plant Growth form:

The LEDA plant growth form is a combination of the life form classification of Raunkiaer completed with other specialised forms which are based upon their morphology (e.g. epiphyte) or living conditions (e.g. habitat).

What to collect

As the growth form seems to be a generality within species, one observation per species (from literature) would be sufficient. The life-form of the mature plant used in LEDA is classified based on the system of Raunkiaer (1934). Broadly speaking, this approach classifies plants according to the positions of their perennating buds (hence the level of protection that buds are given), during seasons or periods that are unfavourable for growth. The classification is completed with growth forms that have other specialised forms which are based upon their morphology or living conditions. An outline of the classification which is adopted by the LEDA Traitbase is provided below:

1. Phanerophyte	Woody or herbaceous evergreen perennial, taller than 50 cm, whose shoots do not die back. Including trees and larges shrubs (buds 3 m above ground), smaller shrubs (nanophanerophytes - buds located between 0.5 to 3 m) and herbaceous phanerophytes.
2. Chamaephyte	Woody or herbaceous evergreen perennial from 25 to 50 cm tall or whose shoots die back periodically. Can have buds that are located above soil level, but never above 50 cm. This group includes dwarf shrubs and some perennial herbs.
3. Hemicryptophyte	Have herbaceous stems that often die-back during unfavourable seasons, and surviving buds placed on (or just below) soil level (remnant shoot system). This group includes many biennial and perennial herbs, including those in which buds grow from a basal rosette.
4. Cryptophyte	Plants whose buds develop underground or under water.
4.1. Geophyte	Perennial (or biennial) herbaceous plants in which the stem die back to a remnant shoot system with storage organs (bulbs, corms, rhizomes, tubers) that are imbedded in the soil.
4.2. Helophyte	Plants in which surviving buds are buried in water-saturate soil, or below water-level, but that have flowers and leaves that are fully emergent during the growing season. The group includes many marsh and emergent aquatic herbs.
4.2.1. Halophyte	Plants living in or tolerant to saline conditions.
4.3. Hydrophyte	Are fully aquatic herbs in which surviving buds are submerged or buried in soil beneath water. Their stems and vegetative shoots grow entirely underwater and leaves can be submerged or floating, but only the flower-bearing parts may be emergent.

5. Therophyte	Annual - or plant that dies after seed production and completes its entire life cycle within one year and survives the unfavourable season as a seed. This group includes all annual herbs.
6. Liana	Plant that germinates on the ground and maintains soil contact while using another plant for support. Grape vines are typical lianas.
7. Hemi-epiphyte	Plant that germinates on other plants and then establishes soil contact; or plant that germinates on ground but later loses contact with the soil. (Note - not occurring in NW Europe).
8. Epiphyte	Plant that germinates and root on other plants (their growing-buds occur on another plant).
9. Vascular semi-parasite	Green plant growing attached to other living, green plants. Many plants photosynthesise but also supplement their nutrients by parasitising other plants.
10. Vascular parasite	Non-green plant growing on living, green plants.
11. Mesophyte	Land plant growing under moderate moist conditions.

Minimal requirements
LEDA prefers records from literature with known origin source for e.g. a published paper (= original reference).

Data structure
To collect: 1 observation per species for plant growth form
Obligate:
- Type of variable: nominal
- Unit: category
- Plant growth form categories:
  1. Phanerophyte
  2. Chamaephyte
  3. Hemicryptophyte
  4. Cryptophyte
     4.1. Geophyte
     4.2. Helophyte
        4.2.1. Halophyte
     4.3. Hydrophyte
  5. Therophyte
  6. Liana
  7. Hemi-epiphyte
  8. Epiphyte
  9. Vascular semi-parasite
  10. Vascular parasite
  11. Mesophyte

Optional:
- o Comment field: Any information of importance to the trait

1.2. CANOPY HEIGHT

D. Kunzmann and I.C. Knevel

Introduction

Canopy height is associated with competitive vigour, whole plant fecundity and generation time after disturbance. Between canopy height and tolerance or avoidance of, for instance, environmental stress there are important trade-offs. On broad interspecific comparisons height tends to correlate allometrically with other size traits such as aboveground biomass, rooting depth, lateral spread and leaf size (Cornelissen *et al*. 2003). Note that in the LEDA Traitbase canopy height is not the same as plant height. Plant height is defined as the highest point of the plant (i.e. inflorescence) and note therefore that plant height can be greater than canopy height.

Trait definition

Canopy height: Is defined as the distance between the highest photosynthetic tissue and the base of the plant (Weiher *et al*. 1999; see Glossary – Appendix E).

How to measure

The canopy height is measured in metres as the difference between the highest photosynthetic tissue (the foliage) of the individual and the base of the plant. Within a plant species the canopy height can be highly variable. Therefore a minimum of 25 representative healthy, adult individuals should be randomly selected for measurement per species per site. The randomly selected individuals should be situated with their foliage exposed to the light (i.e. sunny spot; Cornelissen *et al*. 2003). For the determination of the height of trees, a (telescopic) stick with length units marks (e.g. metre) will be the most straightforward way to measure tree height. Height sticks provide a direct method for measuring tree height and are the most reliable instrument for measuring tree height (Brack & Wood 1997). Each stick is usually 1.5 m long and constructed of tubular duralumin or fibreglass, and graduated in decimetres. Use of height sticks is generally confined to trees less than 25 m tall. For taller trees situated on flat areas or on slopes, an estimate of tree height can be obtained by indirect measurements using trigonometric principles in combination with hypsometers or other (optical) instruments for measuring height (i.e. Vertex, Releskop, Suunto clinometer, Blume Leiss, Haga, Criterion laser dendrometer, and Abney level; see Fig. 3.2 (Brack & Wood 1997)).

For estimations of tree height in flat areas you assume that the tree is truly vertical (i.e. point A is directly above point B; Fig. 3.3a), the operator's eye (point O) is above the level of the base of the tree (point C), and the distance to the tree is the horizontal distance from the operator to the geometric centre of the tree at the appropriate position on the trunk (OC; see Fig. 3.3a). To estimate the height of the tree the observer stands at any distance (OC) from the tree that is convenient for observation of both the tip and base of the tree. The distance OC is measured and the angles between the horizontal plain and the tree top (AOC = α) and between the horizontal plain and the tree base (COB = β) are determined using a hypsometer. The total tree height (H; A-B in Fig. 3.3) is subsequently calculated as $H = OC \times [TAN(\alpha) + TAN(\beta)]$. In the case described above it is assumed

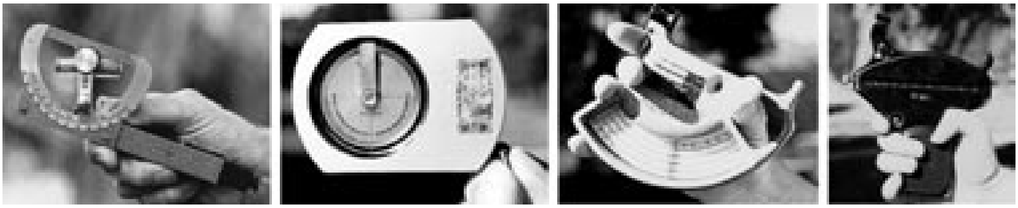

Figure 3.2. *Instruments used for indirect tree height measurement, with from left to right the Abney level, Suunto, Blume Leiss, and Haga (Brack and Wood 1997).*

that the operator is above the level of the tree base. On sloping grounds this may not be the case and it may also be difficult to determine the horizontal distance to the tree (OC; see Fig. 3.3b). In this situation you calculate the horizontal distance OC (from slope distance OB and angle BOC) and subtract the length BC from AC: H = AC - BC = OC x [TAN(α) - TAN(β)] where OC = OB x COS(β). Alternatively an object of known height is placed against the tree trunk, and the height (H) is calculated using the formula H= h x [tan (α) - tan (γ)] / [tan (β) - tan (γ)], where α is the angle between the horizontal plane and the tree top, b; is the angle between the horizontal plane and the top of an object of known height (h) that is positioned vertically next to the trunk of the tree, and γ is the angle between the horizontal plane and the tree base (which is the similar as the base of an object or person).
If the slope is not severe, the horizontal distance OC can be measured by holding a measuring tape at point B and stretching it out horizontally until it is exactly above point O (Fig. 3.3b).

Special cases

- For species with leaves entirely or largely confined to a basal rosette, canopy height is based on height of the rosette leaves, as these species often have little photosynthetic tissue higher up (*Capsella bursa-pastoris, Onopordum acanthium*; Cornelissen *et al*. 2003).
- In the case of epiphytes canopy height is defined as the shortest distance between the upper foliage boundary and centre of their basal point of attachment.
- The canopy height measurements of species that use external support structures (liana, climbers, epiphytes) is different. For lianas and climbers the canopy height is measured with the support structure height; canopy height is defined as the shortest distance between the upper foliage boundary and the soil surface. The canopy height of epiphytes is measured without the support structure, i.e. just the height of the epiphyte from.
- The canopy height for water plants with emerged leaves is measured as the distance between the highest point of photosynthetic tissue and the water surface. For submerged water plant without emerged leaves the canopy height is measured as the distance between the highest photosynthetic tissue and the soil surface.

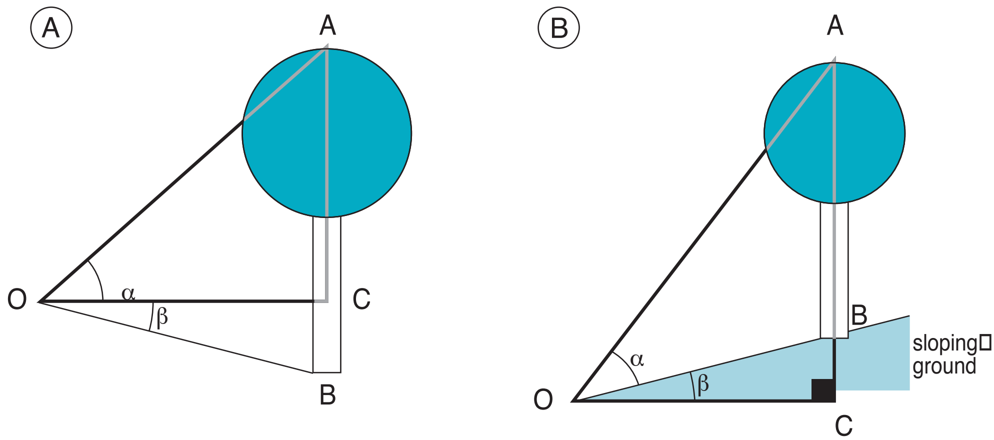

Figure 3.3. *Trigonometric principles to estimate tree height in flat (A) and sloped (B) areas (after Brack and Wood 1997).*

Minimal requirements
To estimate the canopy height the database BIOPOP1 used drawings from the German flora (Rothmaler 2000; see Poschlod *et al*. 2003). These data will be incorporated into the LEDA Traitbase, however note that the statistical quality of this method is low, due to the fact that the ranges of minimum and maximum height are only field observations with an unknown number of replicates.
To obtain the canopy height of the species missing from the BIOPOP list, the standardised measuring protocol of canopy height (as described above) should be used.
When in any published source the canopy height is a real measurement (i.e. not derived from drawings), information on the number of sampled individuals, mean or median with the standard deviation or standard error is obligatory. Missing information on one of the above mentioned criteria will result in rejection of the data. In the cases of estimation by drawings and of published data sets LEDA accepted the unknown number of replicates as a single observation. For canopy height field data with 25 replicates per species per site are preferred, but data from garden experiments are accepted with additional information about the sample site (see general standards). For small populations or rare species a lower number of replicates are accepted with a minimum of 3 replicates per species per site. In the LEDA Traitbase the canopy height will be expressed in metres. Data expressed in other units needs to be converted to metres before entering the data into the database to be able to compare the data.

Data structure
To collect: 1 height measurement of 25 different individuals = 25 heights in total per species (per site)
Obligate:
- Type of variable: numerical
- Number of individuals per sample (sample size, n): 25
- Number of replicates per individual (N): 1
- Unit: m

- Values: N, mean, median, minimum, maximum, standard deviation, standard error
- Trait specific method used:
    1. Obtained by measurements (standardised protocol)
    2. Obtained from measurements of published data
    3. Estimated from drawings
- Validity range: 0-70 (for European plants)
- External support structure:
    1. Yes
    2. No
    3. Unknown

    Note: For external support structure 'yes' is only used for lianas, climbers (both measured with support structure) and epiphytes (measured without their support structure).

Optional: o Comment field: Any information of importance to the trait

1.3. PLANT LIFESPAN AND AGE OF FIRST FLOWERING

J.M. van Groenendael

Introduction

Plant lifespan, i.e. the average length of life of a plant under certain stated conditions, is a complicated trait that overlaps with a number of other traits in the LEDA Traitbase (e.g. age of first flowering). The first problem is to define 'the plant'. In the strictest definition a plant is the genetic individual with the lifespan as the time from zygote formation to death of the genet. In the Traitbase the plant is more practically defined as 'the tissue that occupies a space from which it draws its resources and that is vacated when the plant dies'. This definition works fine for non-clonal individuals (i.e. many tree species, annuals) or clonal individuals where ramets stay very close together forming a recognisable unit still forming the complete genet. The latter includes, among others, tussock forming species and rosette forming plants where a ramet replaces another ramet that died after flowering or during winter. For these units a lifespan can be defined and potentially life-time reproductive output by coupling with seed production per inflorescence. Lifespan now becomes a mean number of years of appearance of the adult.

Problems of defining lifespan arise for clonal plants which form longer connections between units that can establish new tissue that occupies a separate space away from the original seedling establishment position. Connections may wither or be permanent as in Populus or Acacia, respectively. The lifespan estimate for one tissue unit now is no longer an estimate for the genet lifespan. For practical reasons this is not so important. Ecologically speaking the important issue is resource capture by a unit and turning resources into offspring, but from any other point of view, like real individual longevity and total reproductive output, this is problematic.

For all true monocarpic species, that is for all species in which the genet dies after reproduction, age of first flowering is identical with plant lifespan. For all other species age of first flowering is not identical with lifespan and needs to be defined separately.

Trait definition

Plant lifespan: Is the length of time a plant exists.
Age of first flowering: Is the earliest age at which a plant can flower in the field.

What and how to collect

Most floras provide information on the monocarps (summer- winter annuals, biennials, polyannuals) and lump all others into perennials. In the LEDA trait base, the perennial category will be roughly divided into three sub-units based on the lifespan of the plant unit in years, assuming that lifespan of less than 5 years and more than 50 years can be defined and the rest will automatically land in the middle category.

Categories

For plant lifespan the main indication will be the choice of the 8 categories below (Fig. 3.4):

1. Annuals
2. Summer annuals
3. Winter annuals
4. Strict monocarpic biennials and poly-annuals
5. Perennials
6. Poly-annuals < 5 years (short-lived perennials)
7. Poly-annuals 5-50 years (medium-lived perennials)
8. Poly-annuals >50 years (long-lived perennials)

For Age of first flowering the main indication will be the choice of the 3 categories below:

1. Within 1 year
2. Between 1 and 5 years
3. Over 5 years

Special cases

- Clonal plants. Note that for clonal species lifespan becomes more complicated. If for example, a clonal plant stays more or less in the same place then the age of the plant becomes the age of the 'apparent individual'. In this case the categories 4 to 6 will be used. However, if a clonal plant spreads over long distances (lateral spread of ≥ 0.25m per year; see also Section 3, Chapter 4.7), the age of the 'apparent individual' becomes increasingly doubtful as an estimate for the lifespan. These species will also fall in the categories 4 to 6, however a marker should indicate that the lifespan category given relates to a clonal fragment and is therefore probably an underestimation of the total genet lifespan.

Data structure

To collect: 1 Observation per species for lifespan and 1 observation per species for age of first flowering

Obligate:
- Type of variable: nominal
- Number of samples: 1 observation per species
- Number of replicates: -

- Method:
    1. Obtained by measurements
    2. Observations
    3. From published data
- Unit: categories
- Plant lifespan categories:
    1. Annuals
    2. Summer annuals
    3. Winter annuals
    4. Strict monocarpic biennials and poly-annuals
    5. Perennials
    6. Poly-annuals < 5 years (short-lived perennials)
    7. Poly-annuals 5-50 years (medium-lived perennials)
    8. Poly-annuals >50 years (long-lived perennials)
- Age of first flowering categories:
    1. < 1 year
    2. 1 and 5 years
    3. > 5 years

Optional:
- o Original value plant lifespan: years
- o Value: minimum, maximum (in years)
- o Comment field: Any information of importance to the trait

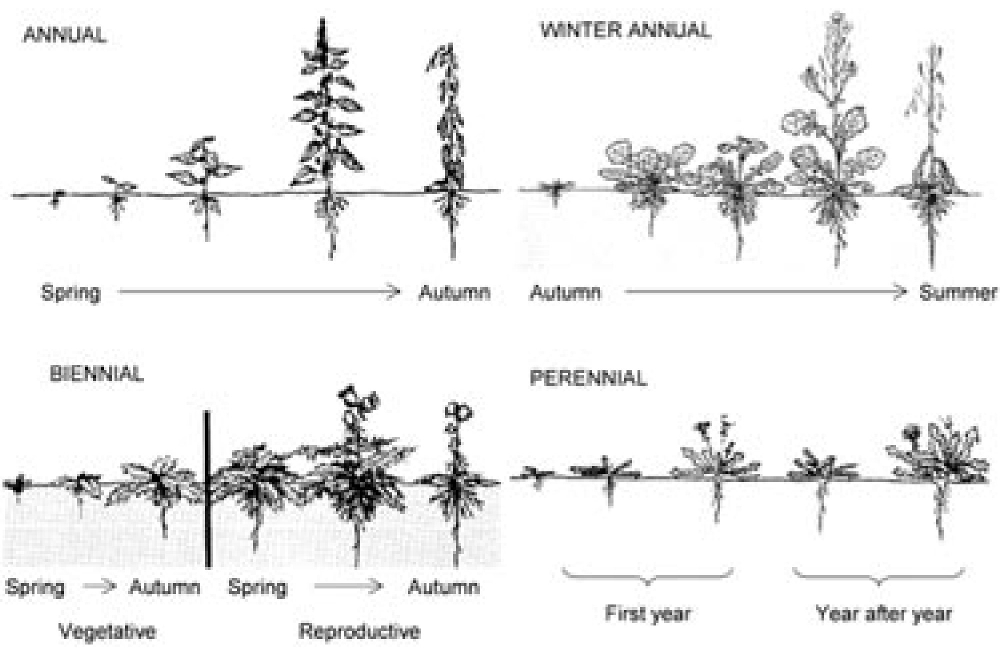

Figure 3.4. *An example of the life cycle of an annual, winter annual, biennial and perennial plant species (after Fermania 2000).*