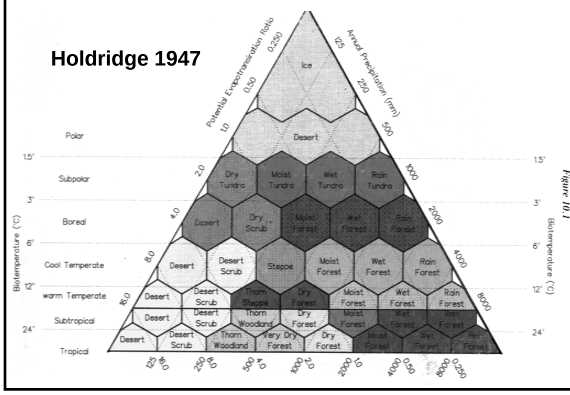
Comparative Plant Ecophysiology

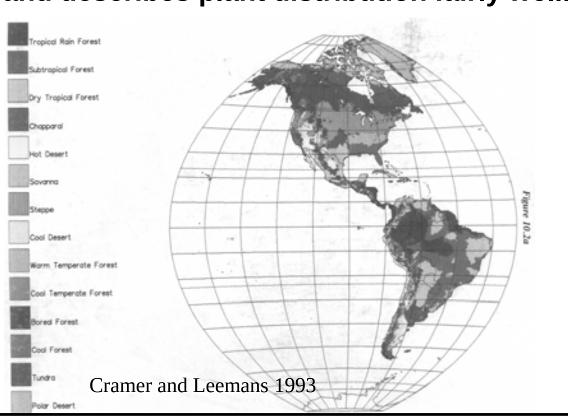
1. **Plant life forms and distribution**
2. **Plant traits and climate factors that form bases for eco- physiological comparison**
3. **Life form comparisons of:**
   - Stomatal conductance
   - Photosynthesis
   - Xylem Anatomy
   - Leaf traits
4. **Predictions of vegetation type**

Plant life form classification has a long history…

Holdridge 1947



…and describes plant distribution fairly well.



Cramer and Leemans 1993

But this approach is basically correlative and doesn't give insight into WHY, from a physiological or ecological basis, plant forms occur where they do.

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1. Plant life forms and distribution

Ecophysiologists ask the following:

1. **What are the physiological differences among plant life forms?**
2. **Do the differences in physiology make sense in terms of adaptation to environment?**
3. **Can we predict lifeform occurrence based on physiological function? (e.g., invasive species)**
4. **Could we put different values of physiological variables in each of Holdridge's hexagons?**

2. Plant traits that form bases for ecophysiological comparison

key comparative traits:

1. **Photosynthetic pathway (C3, C4, CAM)**
2. **Vascular anatomy (ring, diffuse, non-porous)**
3. **Stomatal morphology (elliptical vs. dumbbell)**
4. **Leaf longevity (evergreen vs. deciduous)**
5. **Leaf size and shape (needleleaf vs. broadleaf)**
6. **Lifespan (ephemeral, annual, biennial, perennial)**
7. **Stature (herb, shrub, tree)**
8. **Disturbance tolerance (e.g. fire)**
9. **Mode of seed dispersal**

Note that we exclude phylogenetic divisions (e.g. angiosperms vs. gymnosperms). The focus here is on functional units.

2. Plant traits that form bases for ecophysiological comparison

key climate/edaphic variables that may select for the previous listed plant traits:

1. **Temperature (low temperatures in particular)**
2. **Water availability**
3. **Soil nutrient status (favors evergreen?)**
4. **Light availability (deciduous vs. evergreen?)**
5. **Disturbance frequency**

2. Plant traits that form bases for ecophysiological comparison

1. Temperature (low temperatures in particular)

- One of the most lethal impacts on plant survival
- Low latitude plants grown in higher latitudes often die from single frost events. (citrus)
- Xylem structure, osmotic 'anti-freeze' capacity, cell membrane function all may play a role.

2. Plant traits that form bases for ecophysiological comparison

1. Temperature (low temperatures in particular)

- While reasons for overall low temperature tolerances are complex, general patterns are observed.

TABLE 1 Annual minimum temperatures for expected dominant physiognomies.

Minimum temperature (°C)	Physiognomy
>10	Broadleaved, evergreen, chilling sensitive
0 to 10	Broadleaved, evergreen, chilling resistant
−15 to 0	Broadleaved, evergreen, frost resistant
−40 to −15	Broadleaved, deciduous
<−40	Some broadleaved, but mostly evergreen and deciduous needles

(From Woodward, 1992.)

2. Plant traits that form bases for ecophysiological comparison

2. Water availability used to predict vegetation type

Premise:
- Models of hydrologic balance can predict LAI
- LAI is associated with vegetation mass and structure, if not life form.

2. Plant traits that form bases for ecophysiological comparison

2. Water availability used to predict vegetation structure (LAI)

Approach (Woodward 1992):

- Use Penman-monteith with assumed values of stomatal conductance and LAI to predict seasonal soil water depletion
- Use seasonal rainfall data to predict soil moisture recharge.
- Posit that vegetation will achieve the LAI that allows for annual recharge.
- Identify that LAI with vegetation type (e.g. shrub vs. forest)

2. Plant traits that form bases for ecophysiological comparison

2. Water availability used to predict vegetation structure (LAI)

Woodward's model:

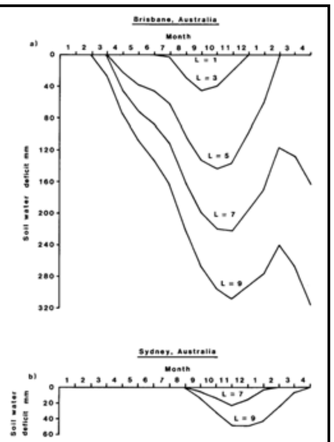

Fig. 4.5. Predicted monthly soil water deficit for soils at two sites Australia: (a) Brisbane; (b) Sydney.

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   - **Leaf traits**

3. Life form comparisons: stomatal conductance

Perhaps surprisingly, max leaf conductance does not appear to differ by life form. Leaf area index seems more important.

Table 22.3. Summary of maximum leaf conductance for woody vegetation (mmol $m^{-2} s^{-1}$, from Table 22.2)

	g_{max}	Number of species
Tundra shrub vegetation	253	14
Coniferous forests	234[a]	26
Temperate deciduous forests	190	22
Mediterranean shrub vegetation	219	41
Eucalyptus forests	218	6
Hot and cold desert shrublands	200	9
Semi-arid, subtropical and tropical shrub and woodlands	198	16
Humid tropical rainforests	249	17
Mean for all eight groups (n = 8)	218[b] ± 24	151

[a] Note that all data presented here relate to the projected leaf area which, in conifers, is ca. 2.6 times smaller than the overall surface area of needles.
[b] Analysis of variance showed that there is no significant difference between these eight groups of plant/vegetation types ($p = 0.726$).

Korner 1994

3. Life form comparisons: photosynthesis

Also perhaps surprising is a lack of predictable change in Amax with biome type.

Points out a limitation of using instantaneous measures of physiology

redictions and Measurements of the Maximum Photosynthetic Rate 499

Table 23.1. Biome type, global area ($km^2 \times 10^4$) and A_{max} observed and predicted ($\mu mol\ m^{-2} s^{-1}$)

No.	Biome Description	Area	A_{max} (obs.)	A_{max} (pred.)
1	Polar dry tundra	69.42	1.2	6.7
2	Polar moist tundra	251.91	9.5	22.6
3	Polar wet tundra	465.81	6.6	11.0
4	Polar rain tundra	171.97		3.5
5	Boreal desert	41.47	4.0	19.9
6	Boreal dry bush	188.73		23.7
7	Boreal moist forest	970.78	7.9	16.1
8	Boreal wet forest	441.08	6.0	8.0
9	Boreal rainforest	90.79	5.5	4.8
0	Cool temperate desert	149.91		20.4
1	Cool temperate desert bush	251.51	18.2	24.1
2	Cool temperate steppe	739.15	17.0	18.9
3	Cool temperate moist forest	821.35	10.9	20.7
4	Cool temperate wet forest	148.04	10.6	13.9
5	Cool temperate rainforest	24.56	5.7	11.3
6	Warm temperate desert	67.91	5.5	7.9
7	Warm temperate desert bush	181.85	8.7	16.0
8	Warm temperate thorn steppe	228.00	14.8	25.6
9	Warm temperate dry forest	329.80	14.0	27.3
0	Warm temperate moist forest	292.56	18.8	25.4
1	Warm temperate wet forest	20.45	8.0	7.1
2	Warm temperate rainforest	4.23	5.0	6.9
3	Subtropical desert	742.59	4.1	7.5
4	Subtropical desert bush	540.10	9.9	13.3
5	Subtropical thorn steppe	438.58	20.5	21.2
6	Subtropical dry forest	822.87	17.9	21.6
7	Subtropical moist forest	1512.81	17.7	25.5
8	Subtropical wet forest	284.70	19.0	25.2
9	Subtropical rainforest	12.58	9.0	16.7
0	Tropical desert	394.96		3.9
1	Tropical desert bush	157.96		3.9
2	Tropical thorn steppe	190.12		18.1
3	Tropical very dry forest	327.26	25.0	29.9
4	Tropical dry forest	663.06	17.3	23.7
5	Tropical moist forest	526.29	14.7	21.8
6	Tropical wet forest	22.14	9.4	17.3

Woodward and Smith 1994

Wide ranges of variability in xylem anatomy and hydraulics;

Some overall patterns appear

Consistent with freezing induced cavitation vulnerability

224 Chap. 8 Hydraulic Architecture of Woody Tropical Plants

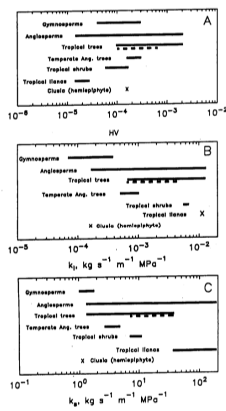

Figure 8.1. Ranges of hydraulic parameters (HV = Huber Value, k_l = leaf specific conductivity, k_s = specific conductivity) by phylogeny or growth form Horizontal bars demark the ranges read from the bottom axis of each parameter. Among tropical trees, Ficus spp are indicated by a dashed line. Ranges too short to be represented by horizontal bars are indicated by 'X'.

Variability with latitude within one genus

334 P. BAAS

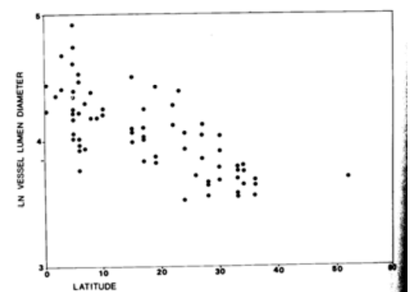

Figure 11.3. Correlation between vessel diameter and latitude of provenance in the genus *Symplocos* (reproduced from Van den Oever et al. 1981, with

Leaf size and shape

Needleleaf vs. broadleaf: Woodward hypothesizes that low boundary layer conductance of broadleaves leads to substantially lower leaf temperatures at night.

This may be a factor that favors needleleaf species in cold climates.

Orchard owners blow air on cold nights over trees to reduce boundary layers.

Present state of prediction uses general rules that are indirectly tied to physiology – the underlying physiology is complex

Table 1. Rules for predicting vegetation type from climate.

VEGETATION TYPE	
1. Tundra	Day-degrees <1000
2. Boreal Forest	Day-degrees >1000
3. Broadleaf deciduous (winter) forest	Day-degrees >2000 Minimum -15 to -50°C
4. Broadleaf evergreen (frost resistant) forest	Minimum 0 to -15°C
5. Brodleaf evergreen (chilling resistant) forest	Minimum 10 to 0°C
6. Broadleaf evergreen (chilling sensitive) forest	Minimum 10°C
VEGETATION STATURE	
1. Forest	LAI = >4
2. Shrub and grass	LAI = 2 to 3
3. Sparse vegetation	LAI = <1
DROUGHT PHENOLOGY	
1. Drought deciduous forest	Soil water <80 mm deficit

Three general approaches to veg prediction based on ecophysiology have been used:

1. Use GDD rules
2. Use models to predict LAI – use rules for LAI – veg type.
3. Competition models (gap needs, r vs k strategies)

Woodward produces a good looking map, but the rules translating LAI to vegetation type are way over simplified.

Conclusions:

Aside from vessel size and leaf size, it has been hard to predict occurrence of plant form directly from physiological principles

Ecological principles, particularly competition, may have the more important role.

For example, conifers grow readily in tropical climates, but are likely simply outcompeted.

Case studies illustrate both simple inferences and complex causes of life form distribution:

New Zealand: only 4% deciduous species. Mild winters (ocean influence) allow evergreen species to dominate.

Range of loblolly pine – limited by freezing – but not due to cavitation – rather, freezing rain topples trees.