# FOR/FES-599

# 3-PG FOREST GROWTH MODEL

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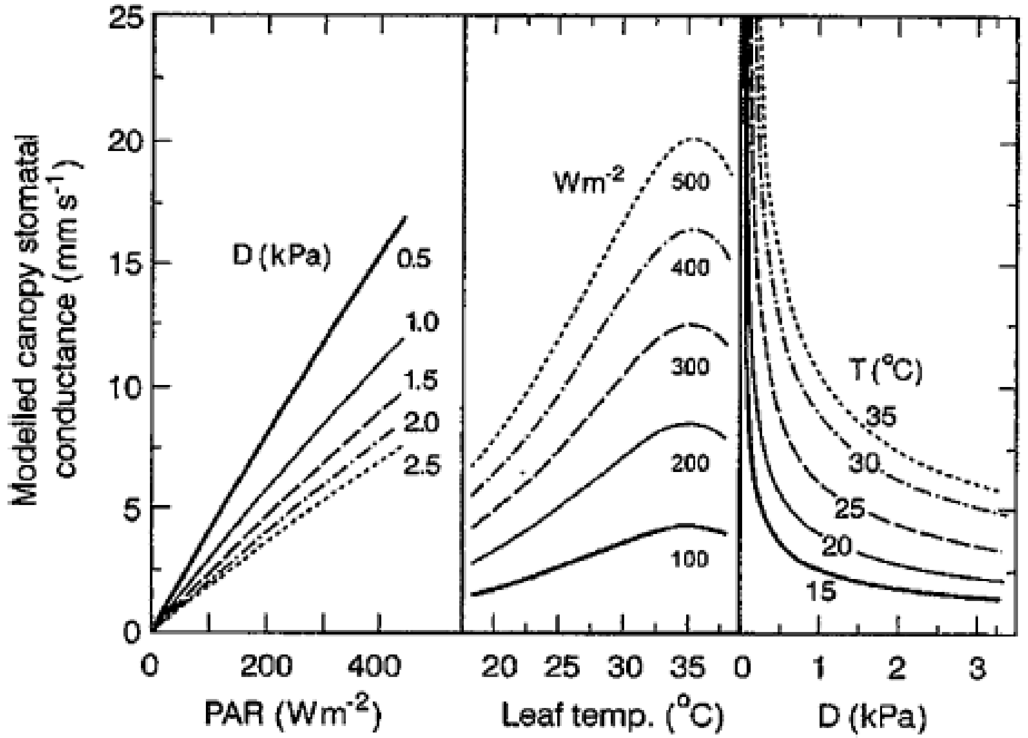
# Lecture 2

## Growth Modifiers

# Tropical Rainforest :
# Canopy Stomatal Conductance Relationships

$$g_s = g_{smax} \cdot f(D) \cdot f(\delta\psi) \cdot f(PAR) \cdot f(N) \cdot f(T) \cdot f(CO_2)$$




Lloyd et al.1995. *Plant, Cell & Environment*, *18* :1129-1145.

# Tropical Rainforest :
# Canopy Stomatal Conductance Relationships

Light-Use and Water-Use Efficiency response to $CO_2$

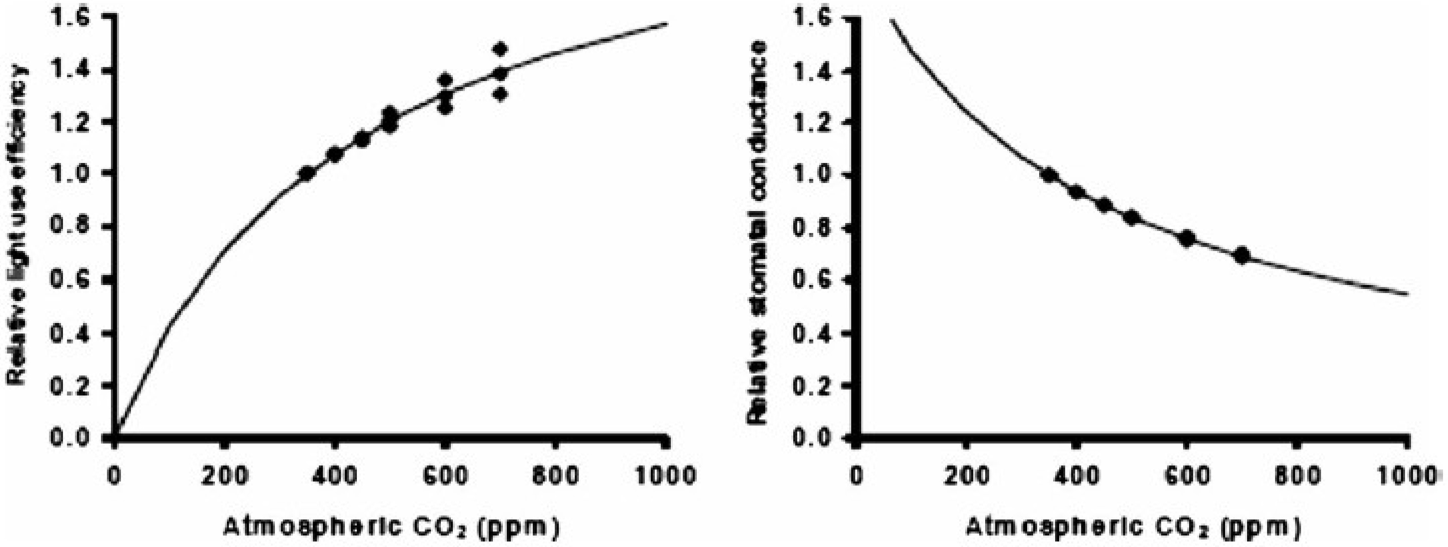
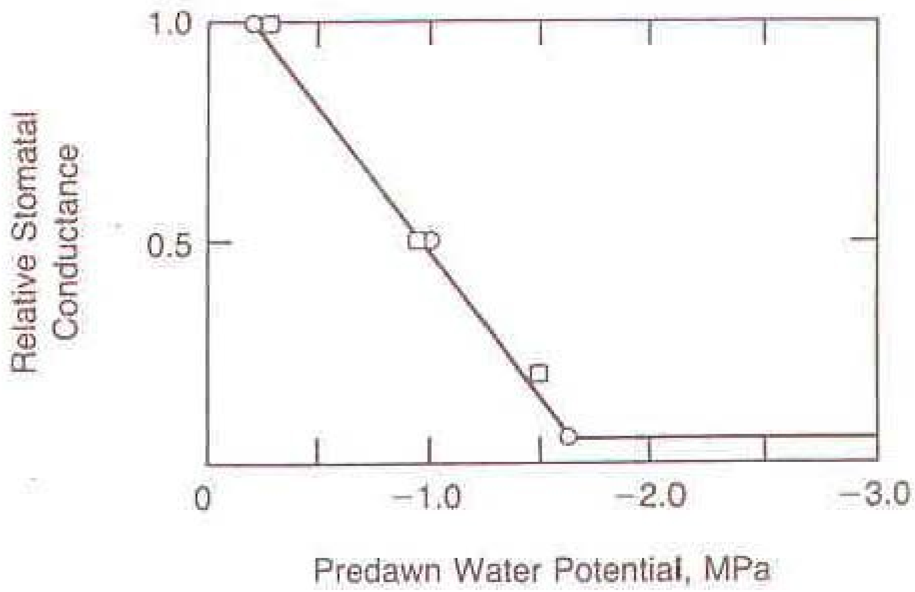



**Figure 5:** modeled relationship light-use efficiency (left) and relative leaf stomatal conductance (*gs*) (right) with ambient $CO_2$ concentrations. © The Modeling and Simulation Society of Australia and New Zealand Inc., with permission, taken from Almeida *et al.* (2009).

Pub. 114. Waring, R.H. and J.J. Landsberg. 2011. Generalizing plant water relations to landscapes. *Journal of Plant Ecology* 4:101-113

# Stomatal Conductance and Soil Drought




Waring, R.H., and W.E. Winner. 1995. Assessing the availability of resources and quantifying their constraints upon terrestrial primary productivity. IN: E. Fuentes and R. Lawford (eds.). p. 89-102. High latitude rainforests and river systems. Springer Verlag, New York.

# Stomatal Conductance and Soil Drought

## Soils differ in how they release water

Landsberg & Waring (1997)

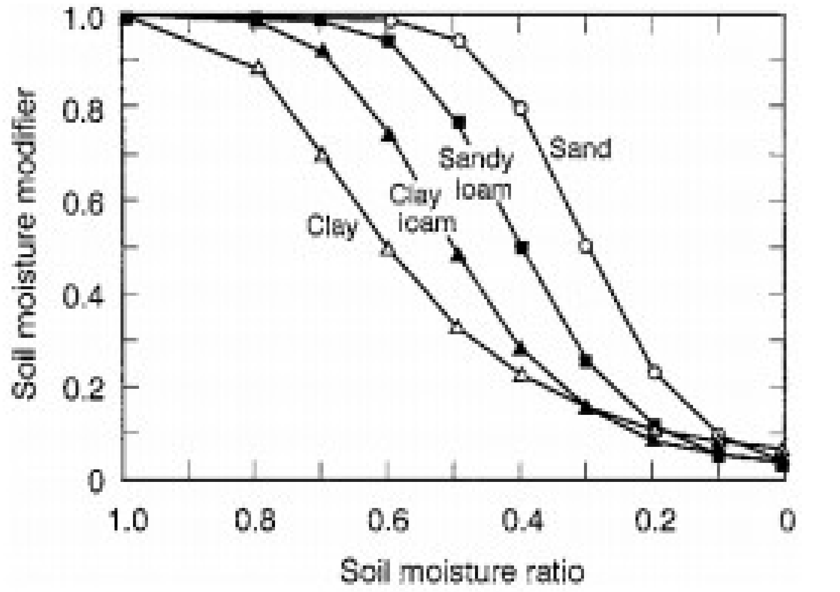
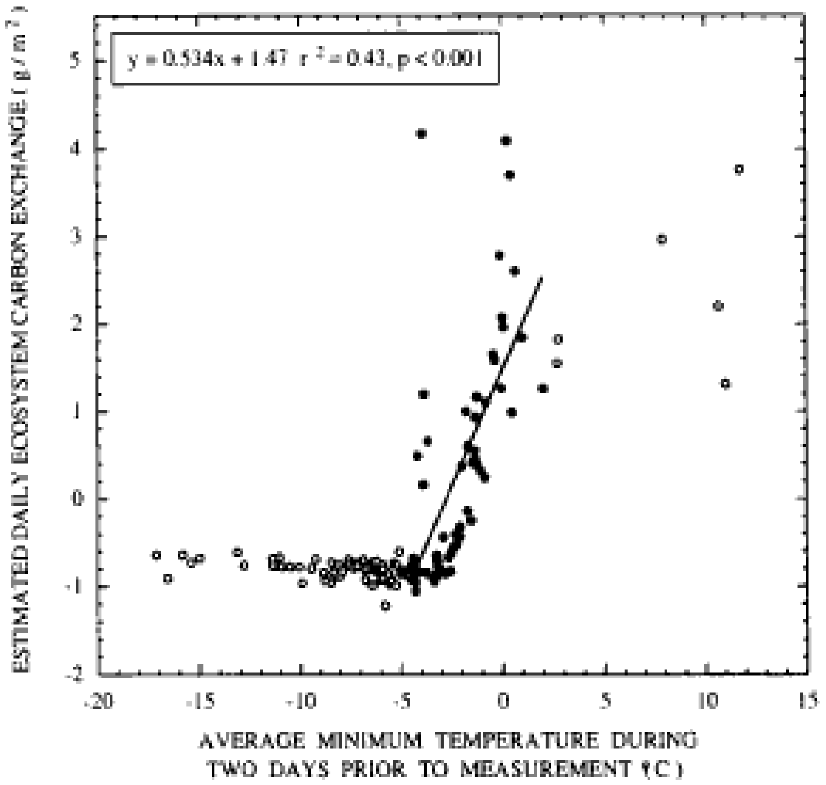



Fig. 2. Relationship between the soil water modifier ($f_\theta$) and the moisture ratio ($r_\theta$) for four soil types.

# Effect of Subfreezing Temperature on Stomata and GPP

Hadley (2000) Arctic, Antarctic and Alpine Res. 32:368-374.



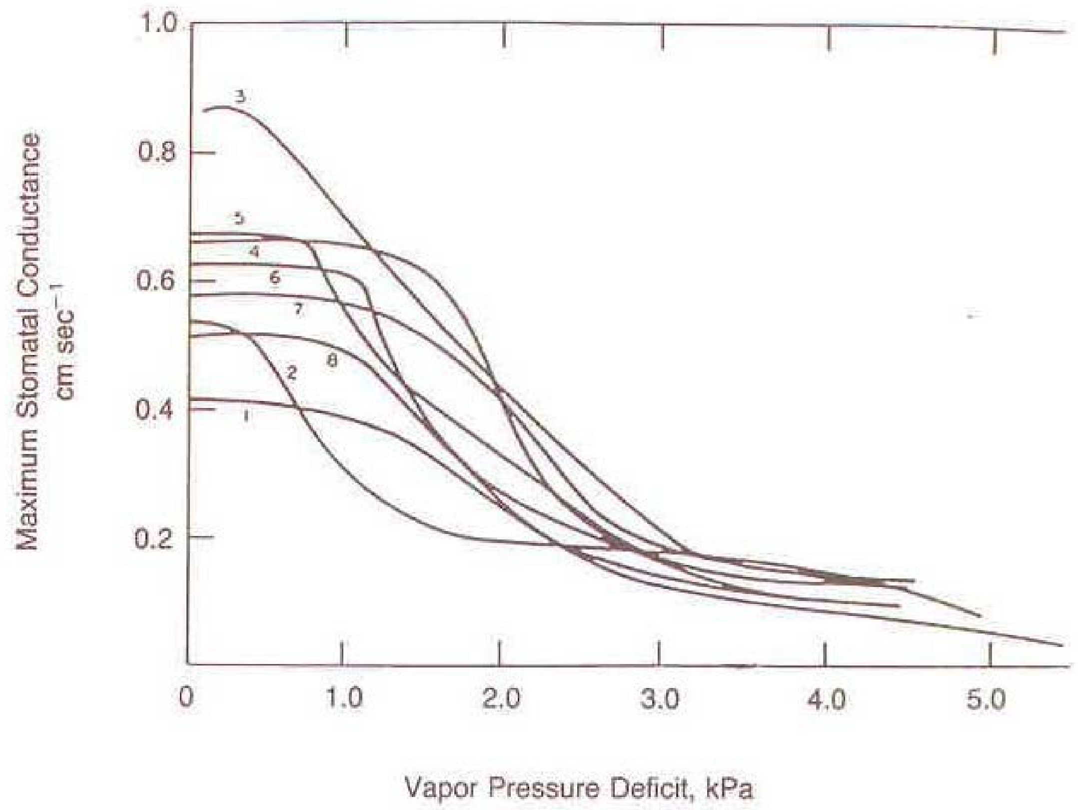
# Optimum Temperature

**Table 6.2.** Optimum Temperature for Photosynthesis Compared with Actual Mid-summer Temperatures for Five Genera of Native New Zealand and North American Tree Species. From Hawkins and Sweet, 1989

| Species | Optimum Temperature, °C | Mid-Summer Temperature, °C | Difference, °C |
|---|---|---|---|
| **New Zealand** | | | |
| *Agathis australis* | 27.0 | 22.2 | 4.8 |
| *Dacrycarpus dacrydiodes* | 27.0 | 17.9 | 9.1 |
| *Dacrydium cupressinum* | 27.0 | 16.8 | 10.2 |
| *Nothofagus solandri* | 27.0 | 17.0 | 10.0 |
| *Podocarpus totara* | 27.0 | 21.5 | 5.5 |
| **Mean** | 27.0 | 19.1 | +7.9 |
| **North America** | | | |
| *Larix decudua* | 17.0 | 19.0 | −2.0 |
| *Pinus radiata* | 23.0 | 21.0 | 2.0 |
| *Pseudotsuga menziesii* | 21.0 | 20.2 | 0.8 |
| *Sequoia sempervirens* | 19.0 | 17.0 | 2.0 |
| *Tsuga heterophylla* | 18.0 | 20.2 | −2.2 |
| **Mean** | 19.6 | 19.4 | +0.2 |

# VPD Response of Northwest Forest Species

Waring and Franklin, 1979. Science



# As Trees Grow, They Produce Less Foliage and More Branches

Waring et al. (2016) For. Ecol.& Manage.

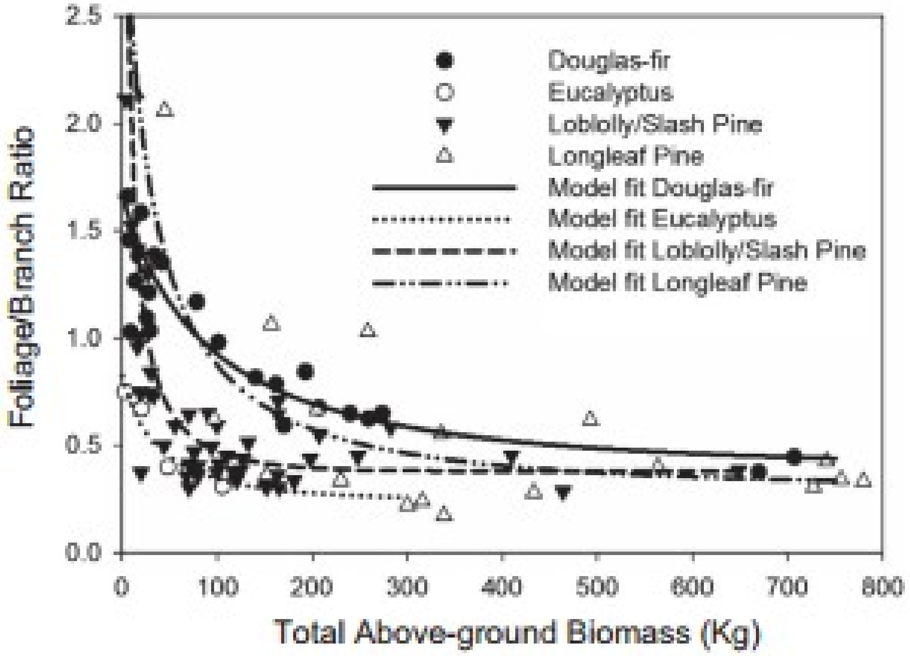
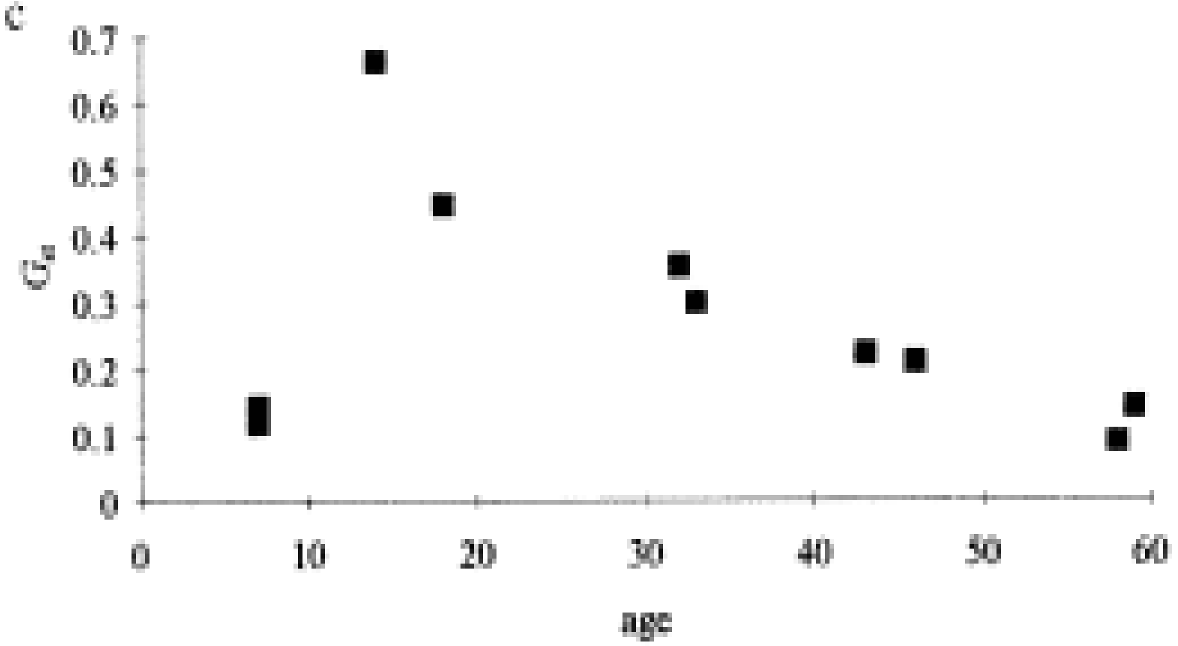



**Fig. 4.** As tree above-ground biomass increases, the ratio of needle to branch biomass in Douglas-fir decreases exponentially (Bartelin, 1996). Similar plots are presented for three species of southern pines: loblolly (*Pinus taeda*), longleaf (*P. palustris*), and slash (*P. elliottii*). *Eucalyptus grandis* data were obtained from Almeida (2012). Graph drafted by Carlos Gonzalez-Benecke using some original data (Gonzalez-Benecke et al., 2014, 2015).

# Hydraulic Conductance in Function of Age

As a result of the shift in the partitioning of growth in mass, photosynthesis is constrained by less efficient plumbing as expressed by a drop in total hydraulic conductance (Ga)



# All Modifiers Affect Canopy Production and Transpiration

$$NPP = Q_0 * \left(1 - e^{-k*LAI}\right) * \alpha_{Cx} * R * f_i$$

$$f_i = f_T \; f_F \; f_N \; f_D \; f_\theta \; f_{age} \; f_{C\alpha}$$

Temperature | Frost | Nutrition | VPD | ASW | Age | $CO_2$

$$(0 \le f_i \le 1)$$

## $Gc = Gcmax * f_j$

$$f_j = f_D \; f_\theta \; f_F \; f_{Cg}$$

VPD ASW Frost $CO_2$

$$(0 \leq f_i \leq 1)$$

# General References


- Waring, R.H. and J.J. Landsberg. 2011. Generalizing plant water relations to landscapes. *Journal of Plant Ecology* 4:101- 113.
- Waring, R., Landsberg, J. and Linder, S., 2016. Tamm Review: Insights gained from light use and leaf growth efficiency indices. *Forest Ecology and Management*, *379:*232-242.
- Landsberg, J., and Waring, R. 2017. Water relations in tree physiology: where to from here? *Tree Physiology* (in press). pdf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