FOR/FES-599

3-PG FOREST GROWTH MODEL

Dr. Richard H. Waring

Dr. Carlos A. Gonzalez-Benecke

Lecture 8

Soil Fertility :
Effects on Photosynthesis
And
The Partitioning of Growth

Nutrients

Plants require 13 nutrients for optimum growth

13 Essential Nutrients

Primary Nutrients	Micronutrients
Nitrogen (N) Phosphorus (P) Potassium (K)	Zinc (Zn) Iron (Fe) Copper (Cu) Manganese (Mn) Boron (B) Molybdenum (Mo) Chlorine (Cl)
Secondary Nutrients Sulfur (S) Calcium (Ca) Magnesium (Mg)	

Trick to remember nutrients:

"See (C) HOPKiNS (name) CaFe Managed By Mine CuZins, Mo and Claude"
C H O P K N S CaFe Mg B Mn CuZn Mo Cl

Plants receive Carbon, Hydrogen and Oxygen from water and air.

Nutrients

Nutrient balance important to sustain max growth and vigor

TABLE 4.1
Optimum Nutrient Weight Proportions in Leaves of Seedlings Grown in Solution Culture, Relative to N[a]

Species	N	P	K	Ca	Mg
Alnus incana	100	16	41	10	14
Betula pendula	100	14	55	6	10
Eucalyptus globulus	100	10	37	10	9
Picea abies[b]	100	16	50	5	5
Picea sitchensis[b]	100	16	55	4	4
Pinus sylvestris[b]	100	14	45	6	6
Populus simonii	100	11	48	7	7
Salix viminalis	100	14	45	7	7
Tsuga heterophylla[b]	100	16	70	8	5

[a]From Ingestad (1979) and Ericsson (1994).
[b]Expressed on basis of nutrient contents of entire seedlings.

Nutrients

An increase in (balanced) nutrient content affects photosynthetic capacity, growth rate, and partitioning to roots, shoots, & stem

Table 2. Performance of willow (*Salix aquatica*) under specified environments

Variable	High light High nutrients	Low light High nutrients	High light Moderate nutrients
Relative growth rate, % day^{-1}	16.1[a]	6.8[b]	5.5[b]
Unit leaf rate, mg shoot dm^{-2} leaf day^{-1}	4.3[a]	1.3[b]	3.0[c]
Leaf wt.:total wt.	0.56[a]	0.53[a]	0.37[b]
Root wt.:total wt.	0.20[a]	0.15[b]	0.38[c]
Specific Leaf wt. g dm^{-2}	0.48[a]	0.28[b]	0.80[c]
Net photosynthesis mg CO_2 g leaf hr^{-1}	26.2[a]	6.9[b]	16.4[c]
Net photosynthesis mg CO_2 dm^{-2} hr^{-1}	12.5[a]	1.9[b]	13.1[a]
Shoot dark resp. mg CO_2 g^{-1} hr^{-1}	5.7[a]	4.0[b]	2.1[c]
Net leaf carbon flux mg C dm^{-2} leaf hr^{-1}	1.52[a]	0.39[b]	0.90[c]
Leaf N flux mg N dm^{-2} leaf hr^{-1}	0.14[a]	0.04[b]	0.03[c]

Values with different superscripts differ significantly at $P=0.05$

Waring et al. 1985.
Oecologia 66:157-160.

Nitrogen and Photosynthetic Capacity

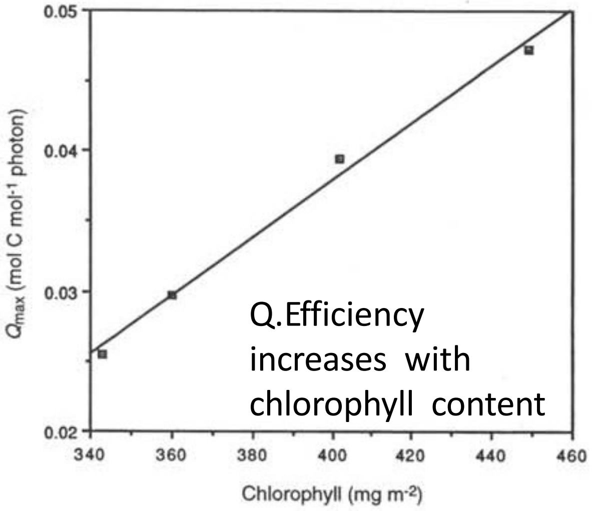
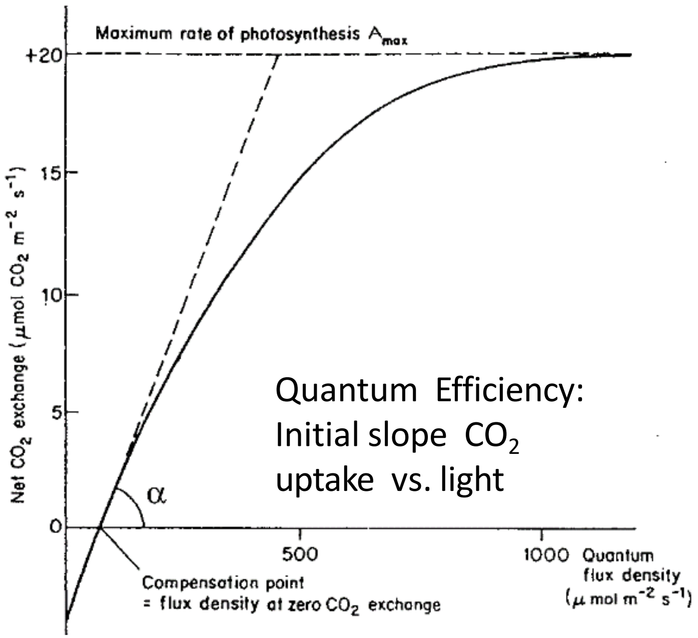


Figure 4. Mean values of chlorophyll concentrations from the upper canopy leaves of four hardwood species (Table 3) were linearly related to the maximum quantum efficiency (Q_{max}) determined on the same leaves in August (Table 2). $y = -0{\cdot}044 + 0{\cdot}0002x$; $R^2 = 0{\cdot}99$. Sample size varied from 5 to 10 leaves with the higher numbers collected from the dominant oaks and maples.

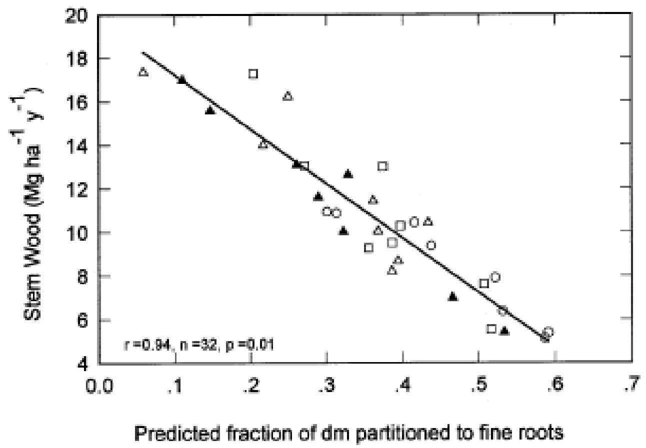


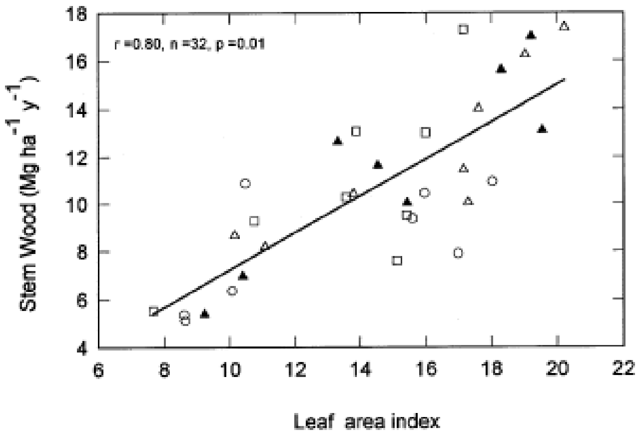
Photosynthetic capacity increases linearly with N availability, up to a point.
Photo: Harvard Forest in october taken from ultra-light aircraft

Waring et al. 1995. Plant, Cell, & Env. 18:1201-1213.

Nitrogen and Growth

Nitrogen availability controls how growth is partitioned

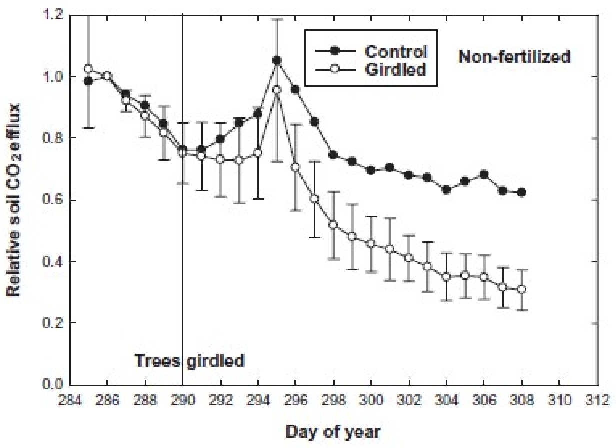




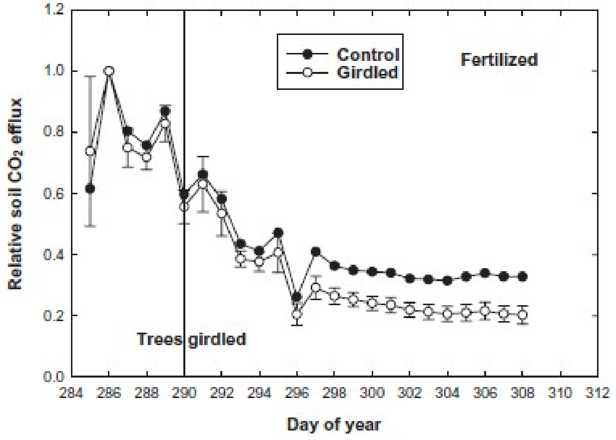
Beets, P.N. & D. Whitehead. Carbon partitioning in *Pinus radiata* in relation to foliage nitrogen status. Tree Phys. 16:131-138

Nitrogen and CO_2

When phloem transport is stopped, soil CO2 efflux from unfertilized trees is reduced much more than from those fertilized indicating that N fertilization reduces the proportion of photosynthate going to roots



(c)



Johnson et a. 2007. Physiological girdling of pine trees via phloem chilling: proof of concept. Plant, Cell & Env. 30:128-135. (No. 98, www.fsl.orst.edu/~waring)

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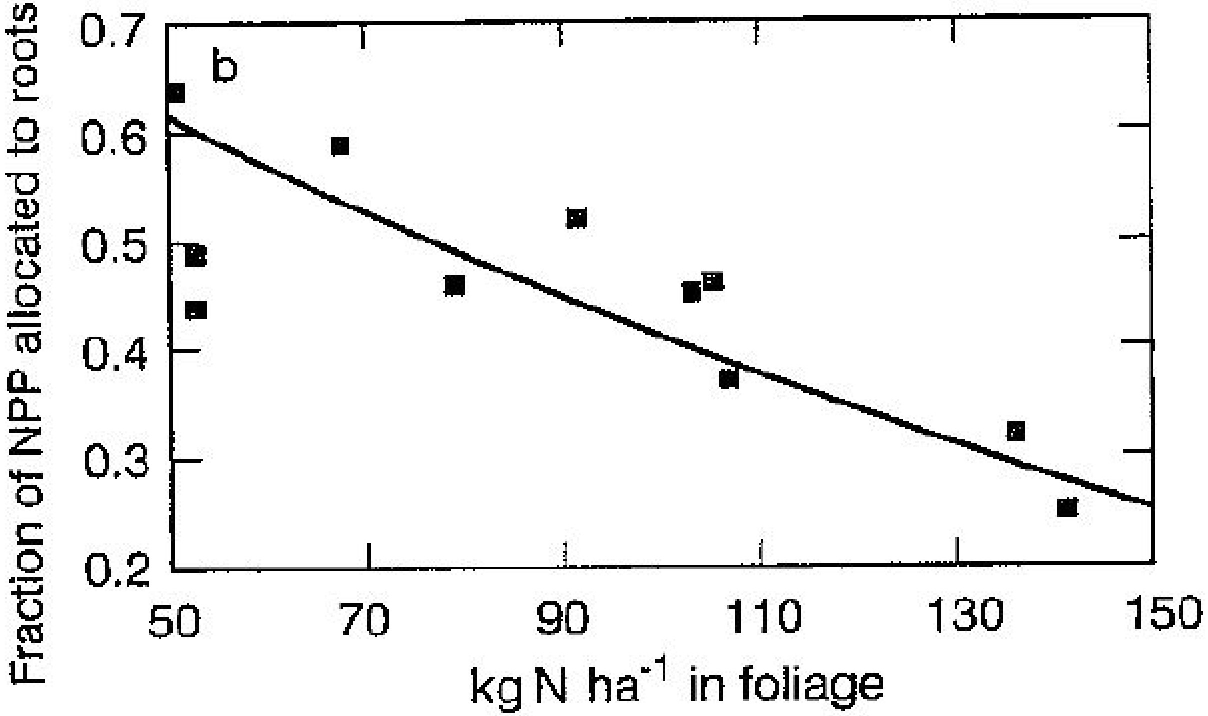
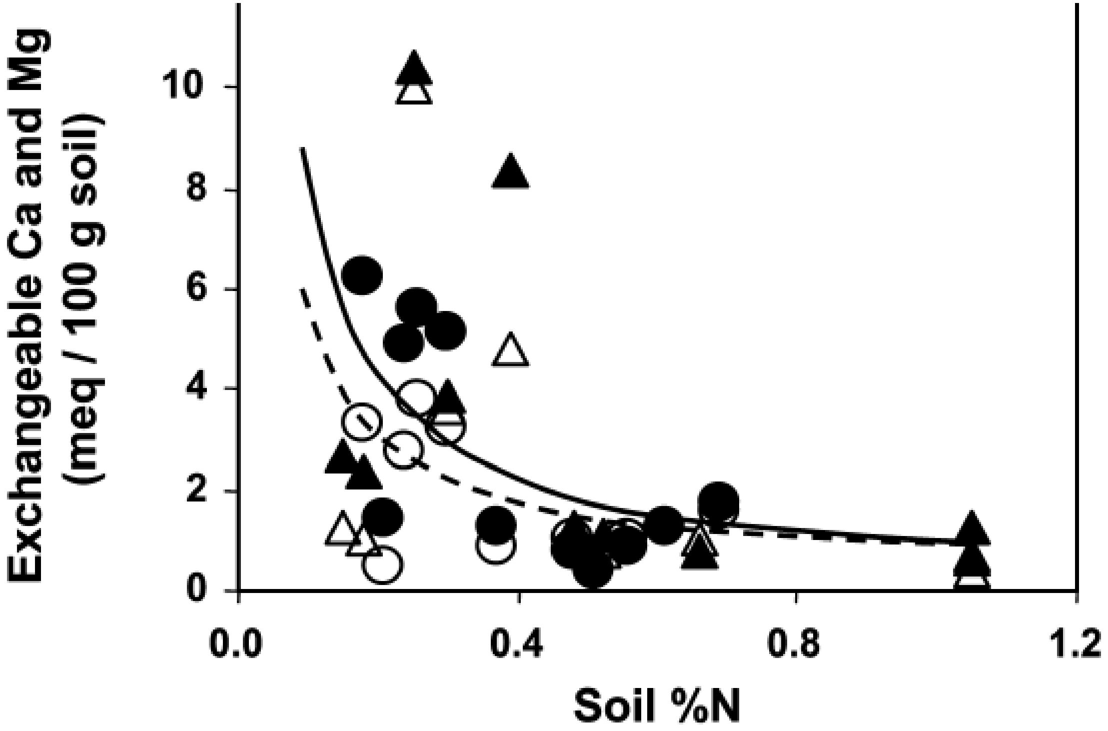
Nitrogen

FIGURE 3.15. (a) Increasing the availability of nitrogen to *Pinus radiata* plantations in New not change the concentration of N in foliaget but it caused a proportional shift in carbon allocation c from fine roots into stem ,vood. Root production was estimated from a con1ponent analysis as a res Beets and Whitehead 1996.) (b) As the total content of nitrogen in the radiata pine canopy increr to nearly I50kg N ha-¹ ,the fraction of N PP allocated to all roo1s showed a decrease from a maxin: 0.65 to a minitnun1 of about 0.25. Graph was made fron1 a composite of information coHected t Madg,vick (1988) and fro1n Beets and Whitehead (1996). (Modified fron1 *Forest Ecology and A* Volume 95 J_ J. Landsberg and R. H. Waring, " A generalized model of forest productivity usir concepts of radiation-use efficiency, carbon balance and partitioning." pp. 209-228, I997 with kin

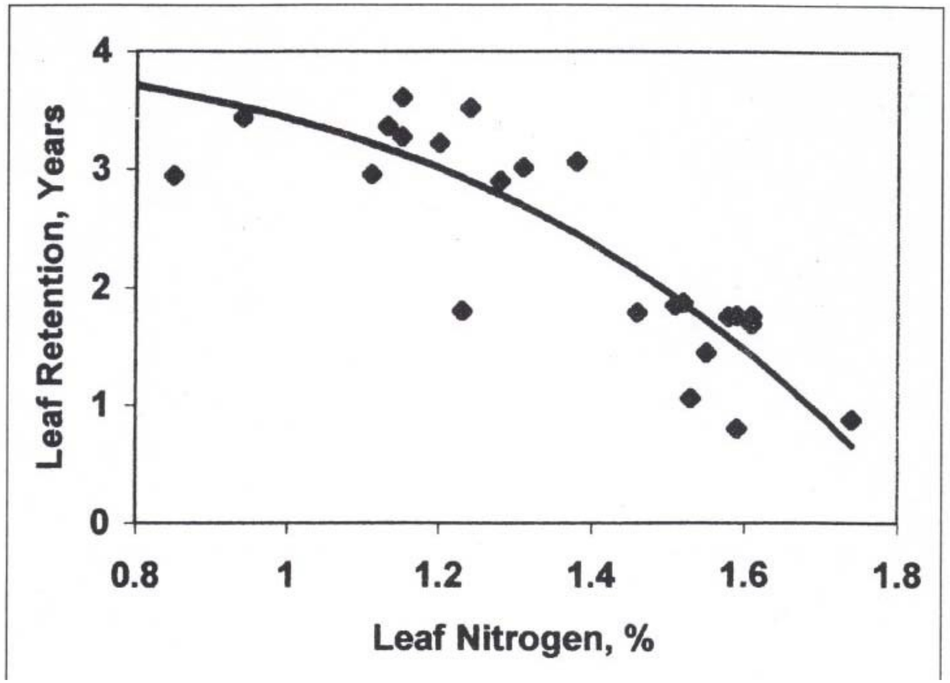


Nitrogen



Perakis et al. 2006. Ecosystems 9:63-74.
(no. 94, [www.fsl.orst.edu/~waring)](http://www.fsl.orst.edu/~waring)

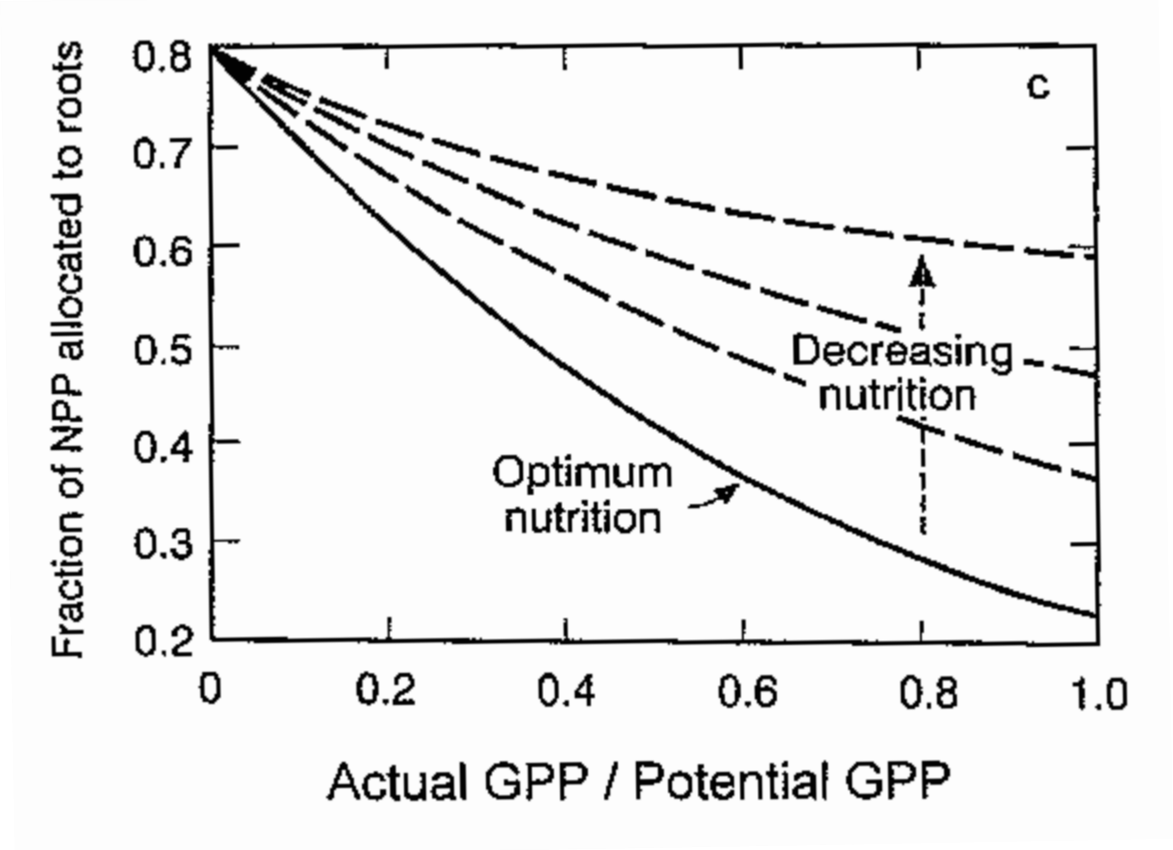
Figure 1. When leaf nitrogen concentration was above 1.4 percent, leaf retention was reduced to two years or less in areas with severe Swiss needle cast disease.



Waring et al. 2000. Western Forester Nov/Dec. pages 10-11.

3-PG Model

3-PG Model links constraints on photosynthesis and soil nutrient availability to partitioning of NPP



Conclusions

- Through evolution, nitrogen was generally scarce compared to other nutrients. When available, nitrogen increases quantum efficiency and encourages above-ground growth while reducing root growth & mycorrhizal activity. As a result, fertilization with only N, make plants more vulnerable to other nutrient deficiencies and to drought.

- 3-PG models computes NPP at monthly time steps, with between 20-60% going to roots.