Towards a fertility modifier for hybrid growth models

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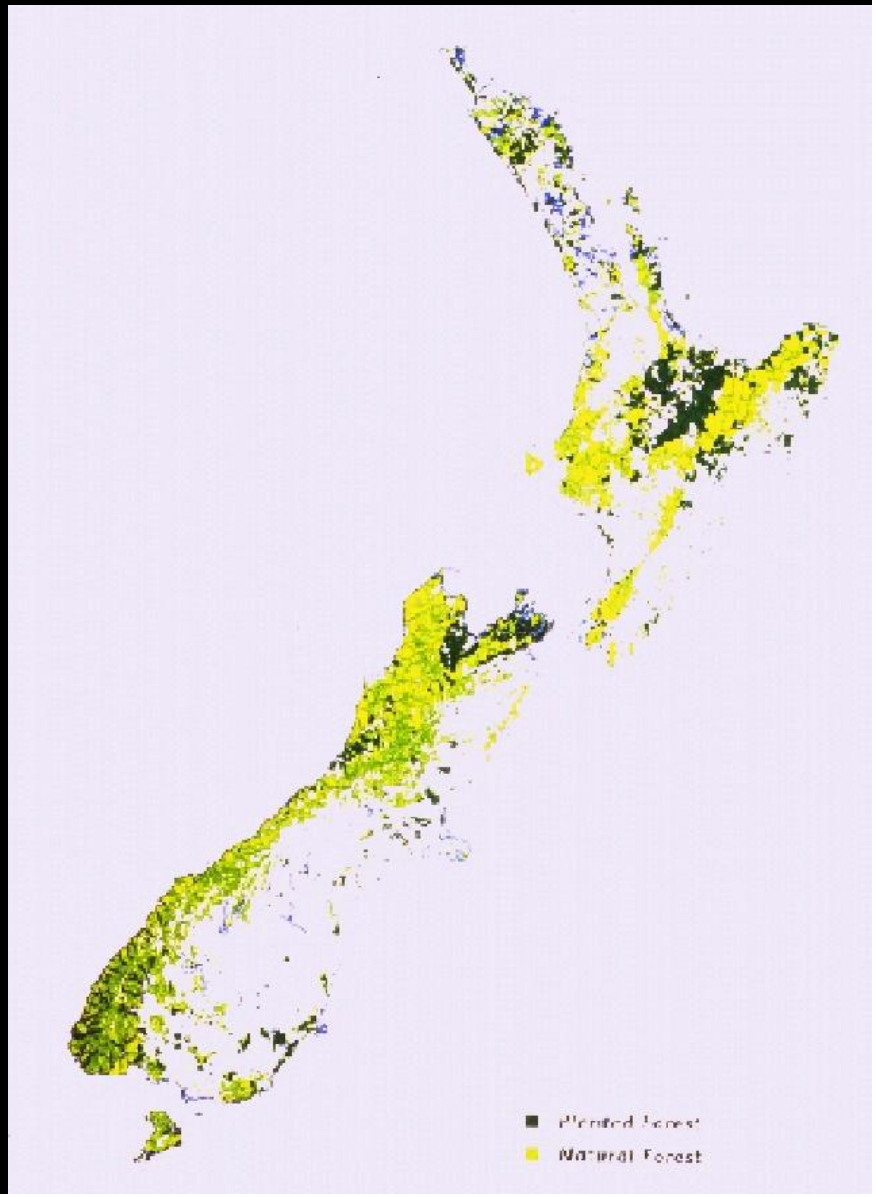
Outline

- Introduction
- Hybrid modeling
- Phosphorus
  - Soil measurements
- Nitrogen and Phosphorus
  - A simple approach
  - A step by step approach

New Zealand

- Current areas of Forest:
  - Indigenous - 6.3 million Ha.
  - Exotic (mostly *P. radiata*) - 2 million Ha.
  - 27% of NZ
- Much P deficiency



P deficiency

An example “hybrid” model

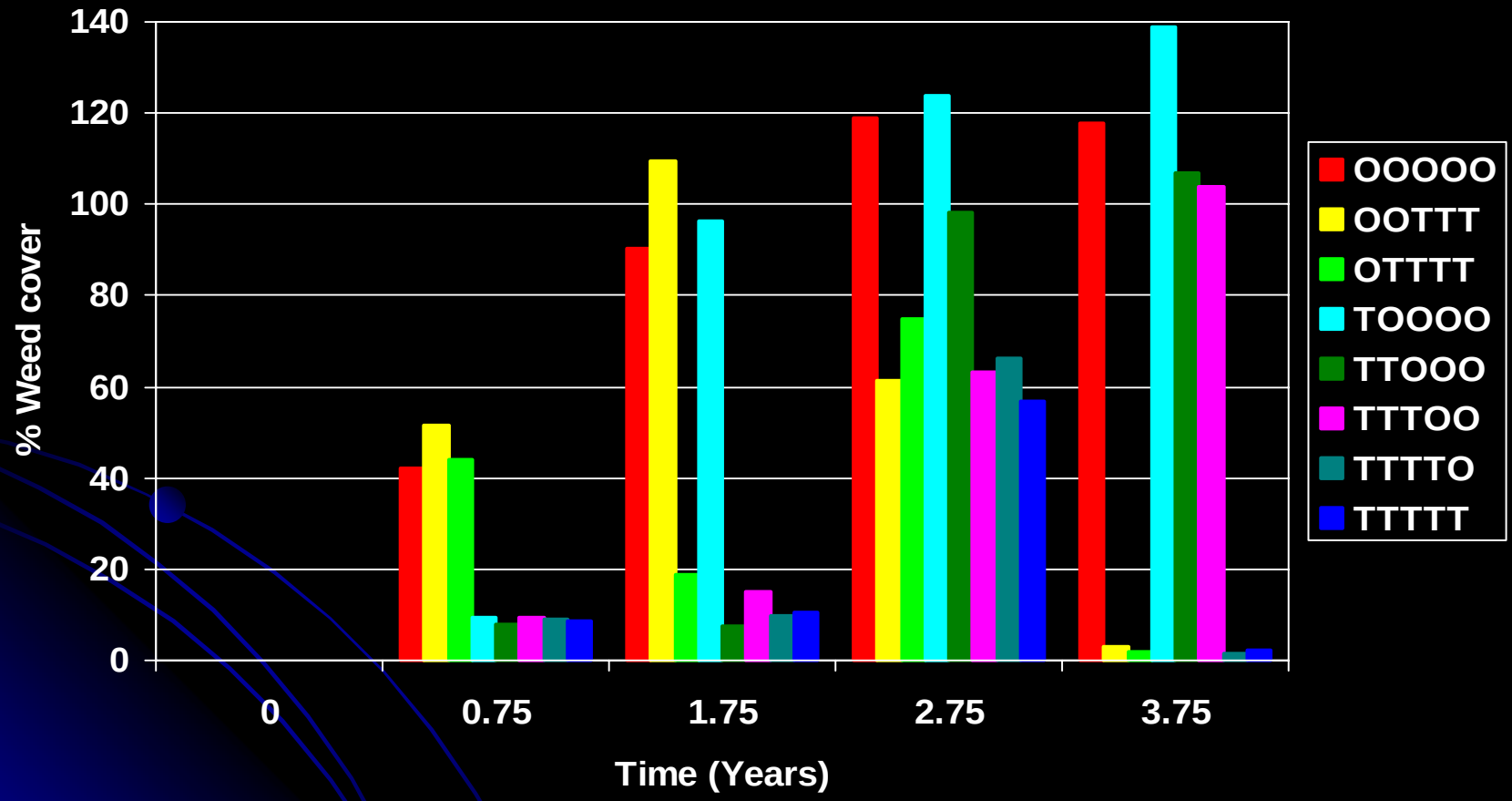
3-PG Model (Landsberg & Waring 1997)

$$NPP = \varepsilon \sum_{t=1}^{t} APAR_t \min\left[f_\theta \; f_D\right] f_T \; f_F \; f_S$$

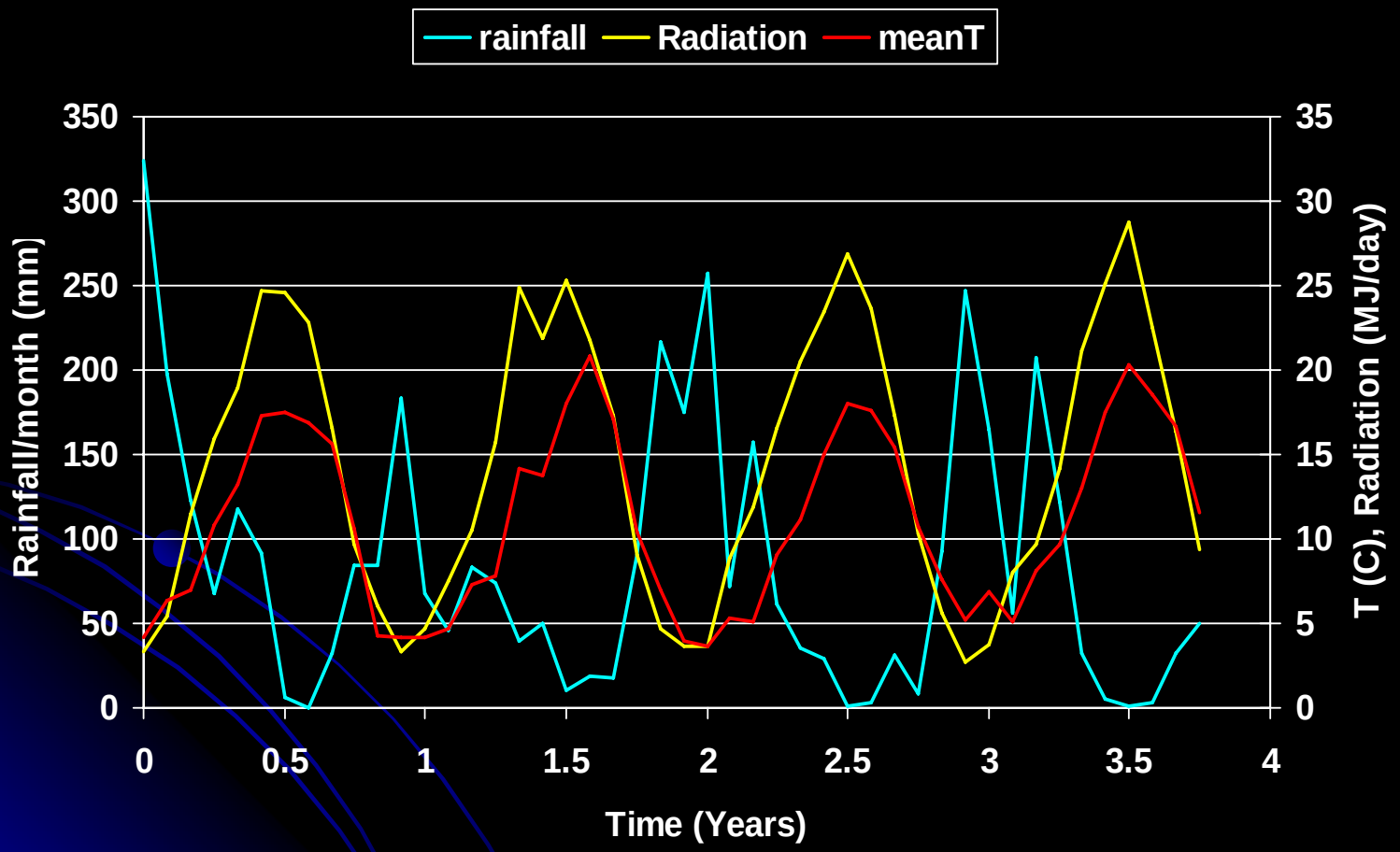
Allocation varies with fertility

Starker CPT study

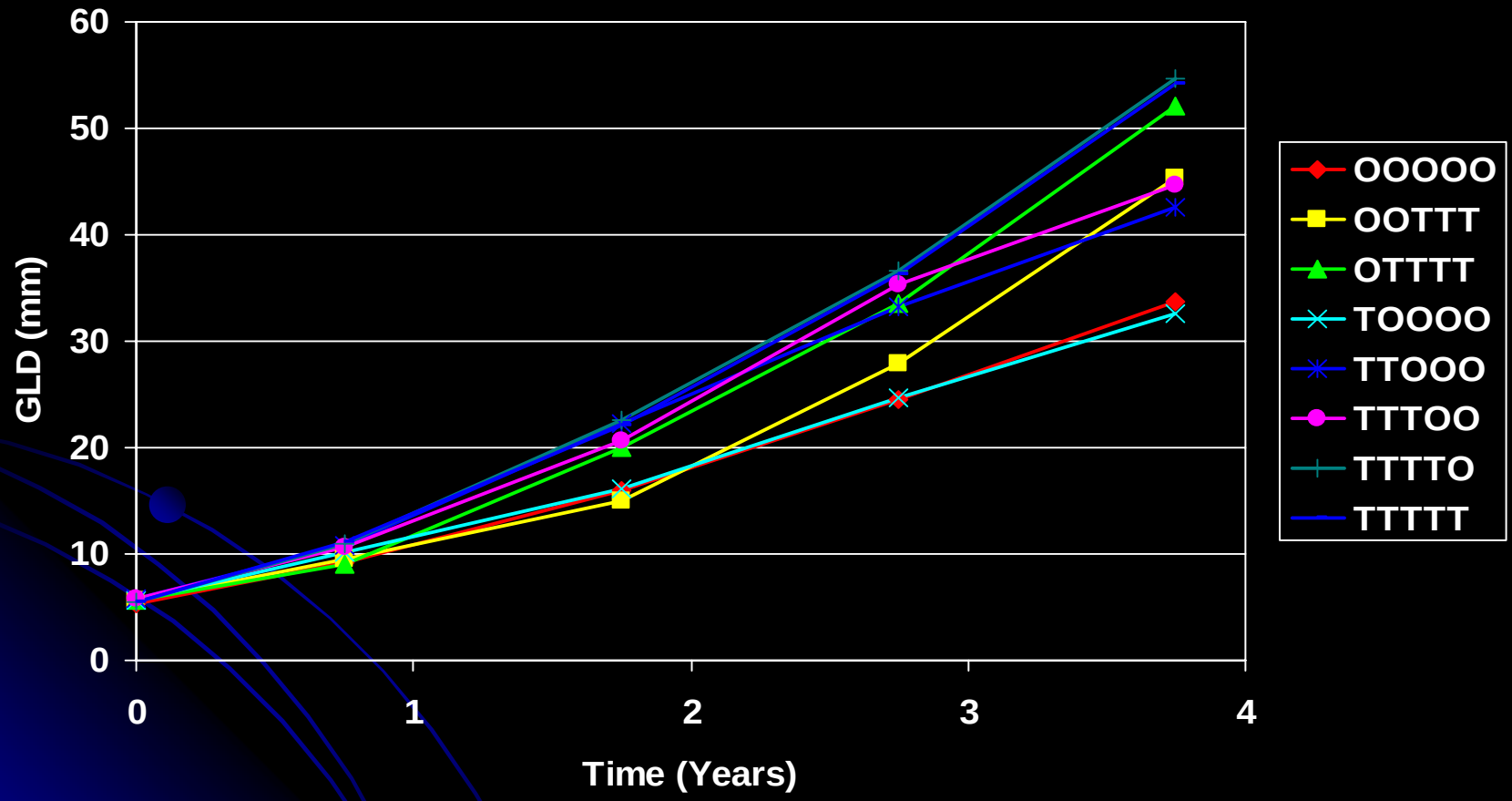
Estimated weed cover within 2 m diameter zones around trees



Climate by month

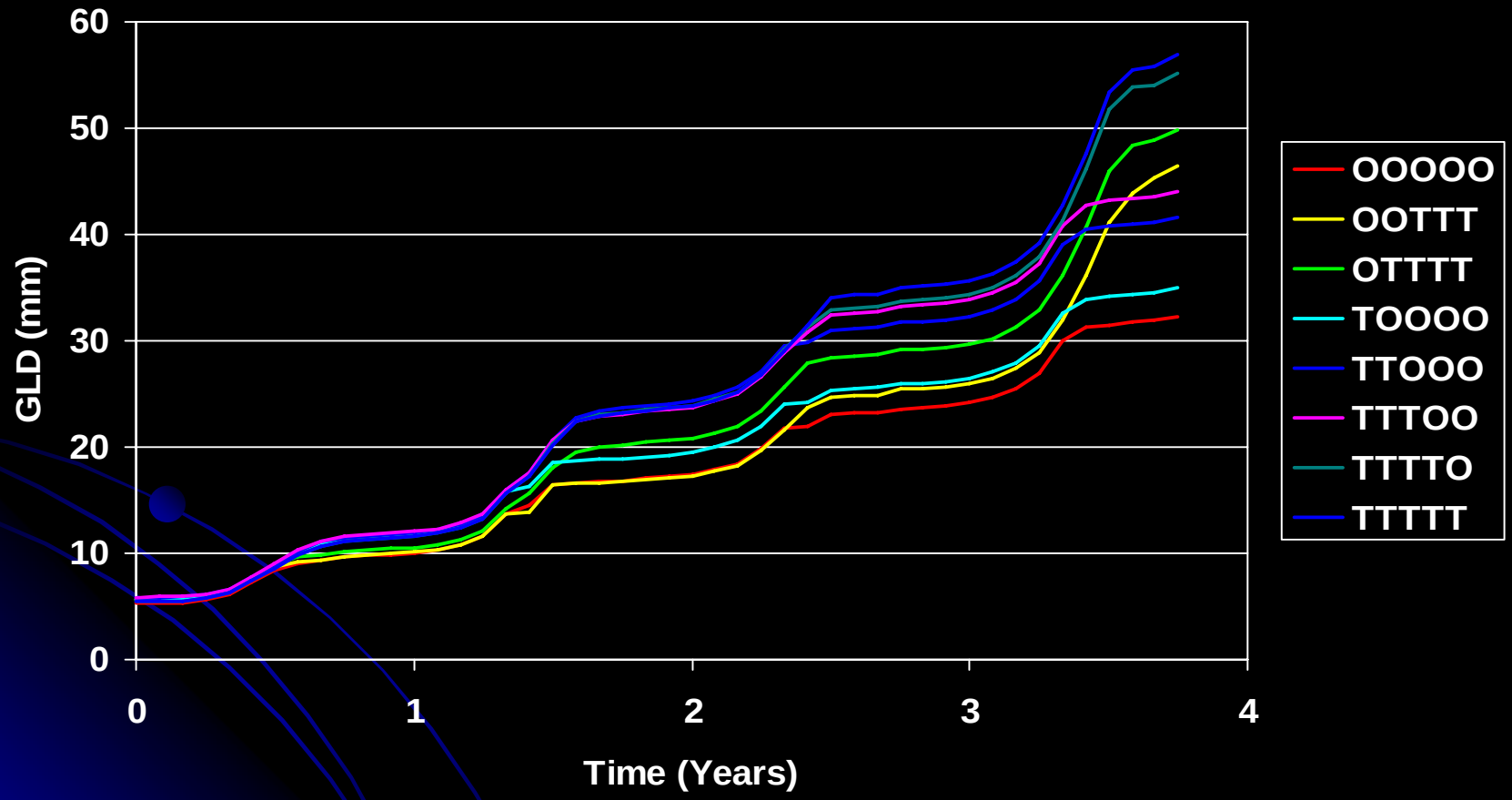


Observed Ground Line Diameter

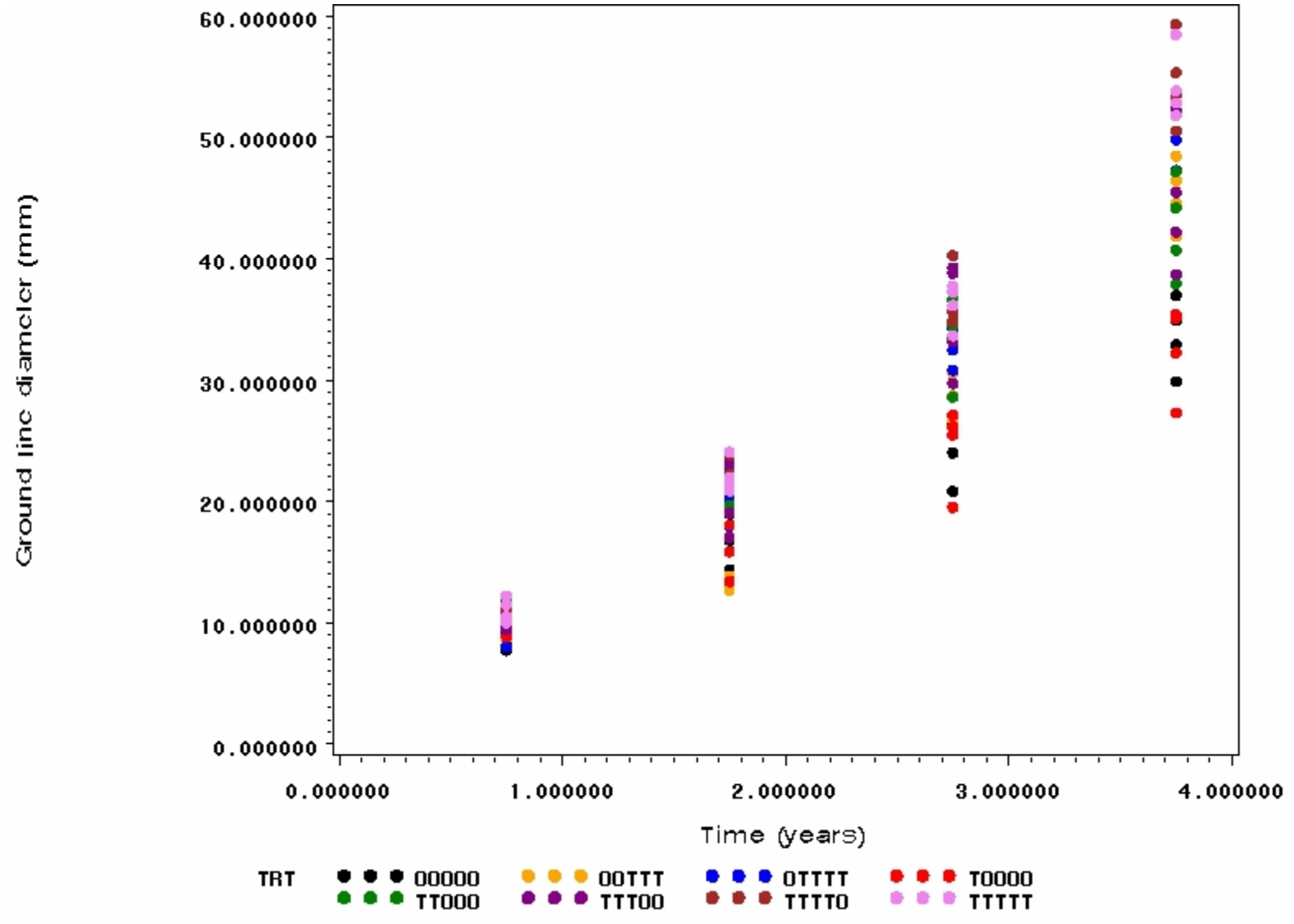


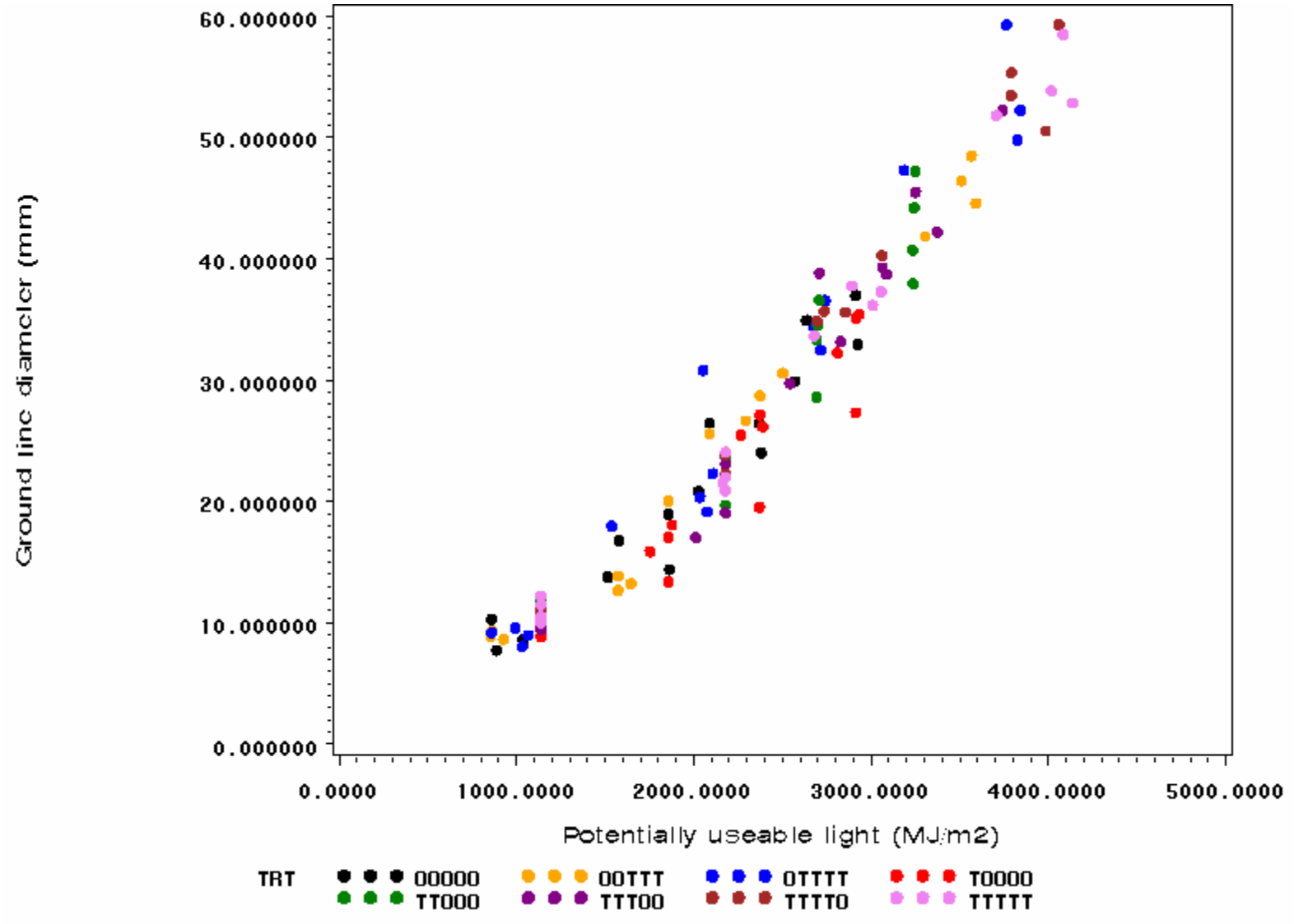
N.B.: Analysis of Douglas fir only

Modeled ground line diameter



N.B.: Analysis of Douglas fir only


Ground line diameter (mm)
60.000000
50.000000
40.000000
30.000000
20.000000
10.000000
0.000000
0.000000
1.000000
2.000000
3.000000
4.000000
Time (years)
TRT
00000
TT000
00TTT
TTT00
0TTTT
TTTT0
T0000
TTTTT


Ground linc diamclcr (mm)
60.000000
50.000000
40.000000
30.000000
20.000000
10.000000
0.000000
0.0000
1000.0000
2000.0000
3000.0000
4000.0000
5000.0000
Potentially useable light (MJ/m2)
TRT
00000
TT000
00TTT
TTT00
0TTTT
TTTT0
T0000
TTTTT

Model form

$$Y_T = Y_0 + \alpha R_T^{\beta}$$

$$R_T = \sum_{t=1}^{t} R_t \; f_T \; \min\left[f_D \; f_\theta \right]$$

Summed across months

What kinds of sub-models are needed to represent fertility in hybrid models?

Overview

- Demand
  - Nutrient assays
  - Understanding of processes
- Supply
  - Weathering
  - Rainfall
  - Mineralisation
  - Retranslocation

1. Soil measurement of P deficiency – with Malcolm Skinner

- Bray P
  - Immediate supply
- Release from weathering can be significant
- Hypothesis
  - Response to P fertilisation will be correlated with both immediate supply and weathering
  - Repeated extractions from the same soil sample can mirror weathering

Methods

- 35 experiments throughout New Zealand
- N * P factorial
  - Sometimes site preparation was a factor
- N+P contrasted with no fertilisation
- Height and gld measured at age 4
- Soil samples
  - Depth 0-10 cm
  - Ten Bray P extractions from each

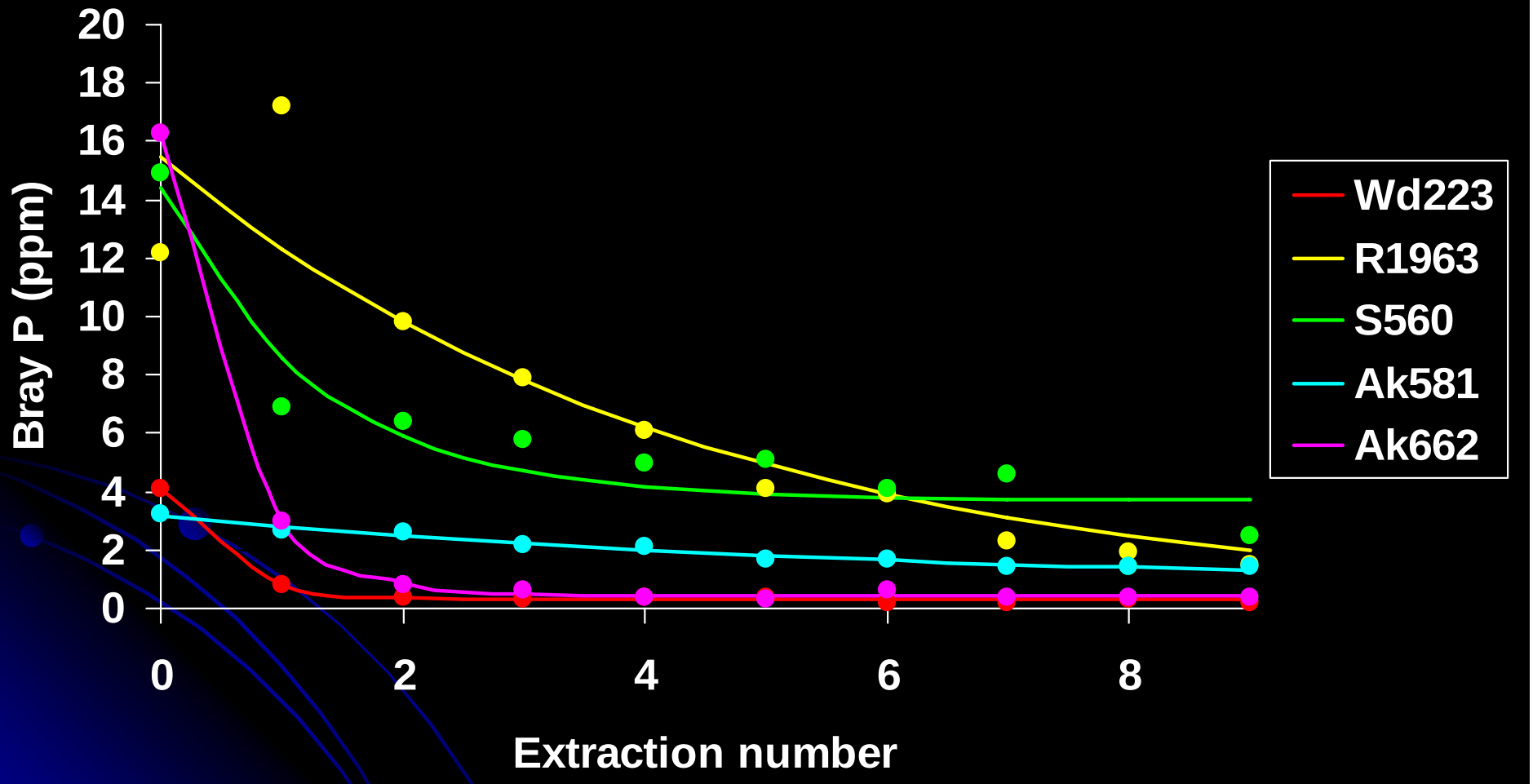
Methods

- Exponential decay fitted to extractions

$$BrayP = \beta + (\alpha - \beta)e^{-\gamma N}$$

  - N=extraction numbered from 0-9
- Response represented as a ratio of d^2h
  - No fertilisation / fertilisation
- Response to P regressed against coefficients from exponential equation
- Effect of number of extractions tested

Results – example fits



Measured fertility ratios : 0.02 0.87 0.64 1.00 0.04

Results – Fertility ratio (FR)

- First Bray P only

$$FR = m * BrayP + b$$

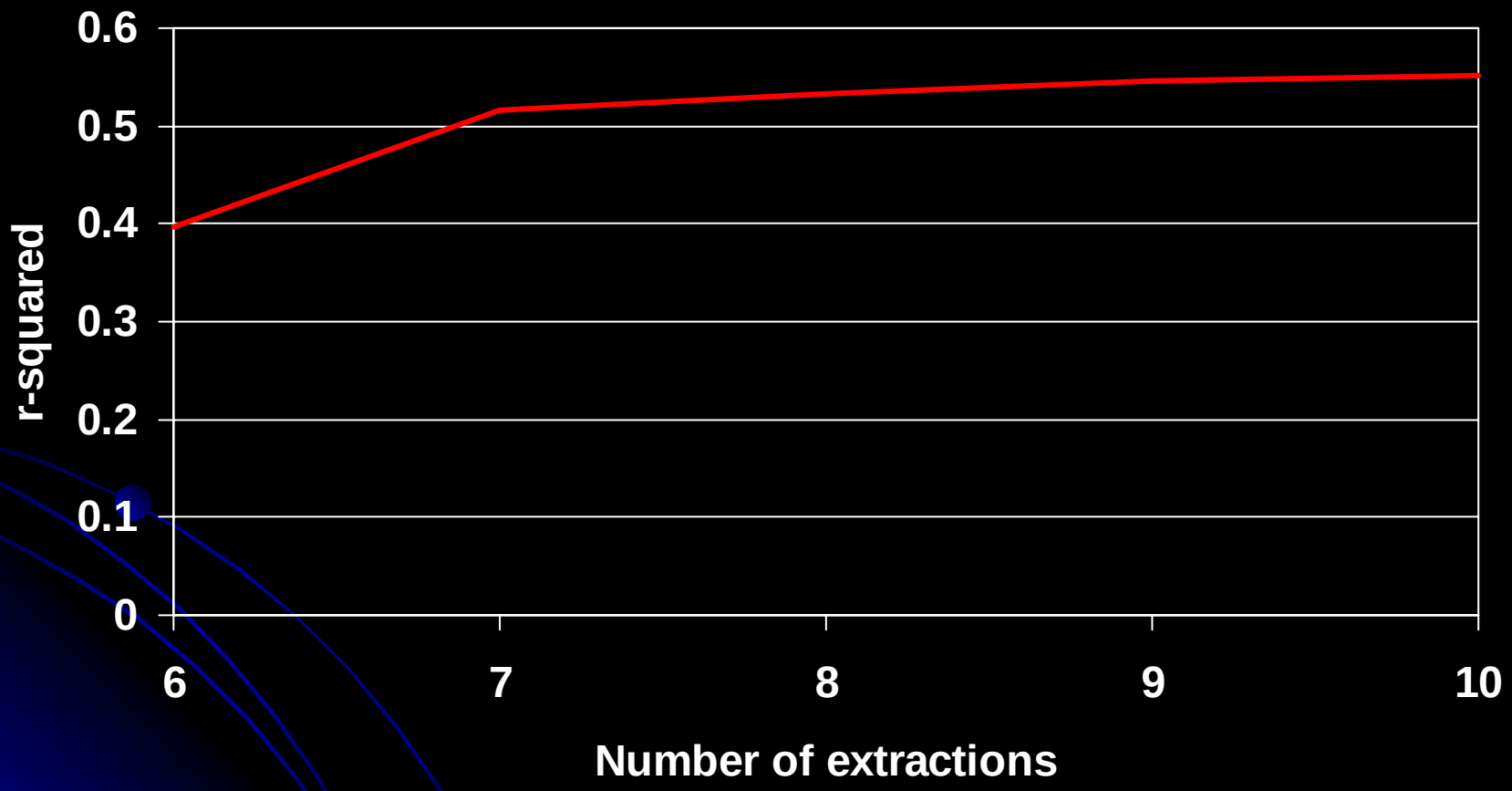
  - R^2=0.24

- Y intercept and concavity of exponential

$$FR = 0.7466 - 0.3926\gamma + 0.0124\alpha\gamma$$

  - R^2=0.55

How many extractions?



Cautions

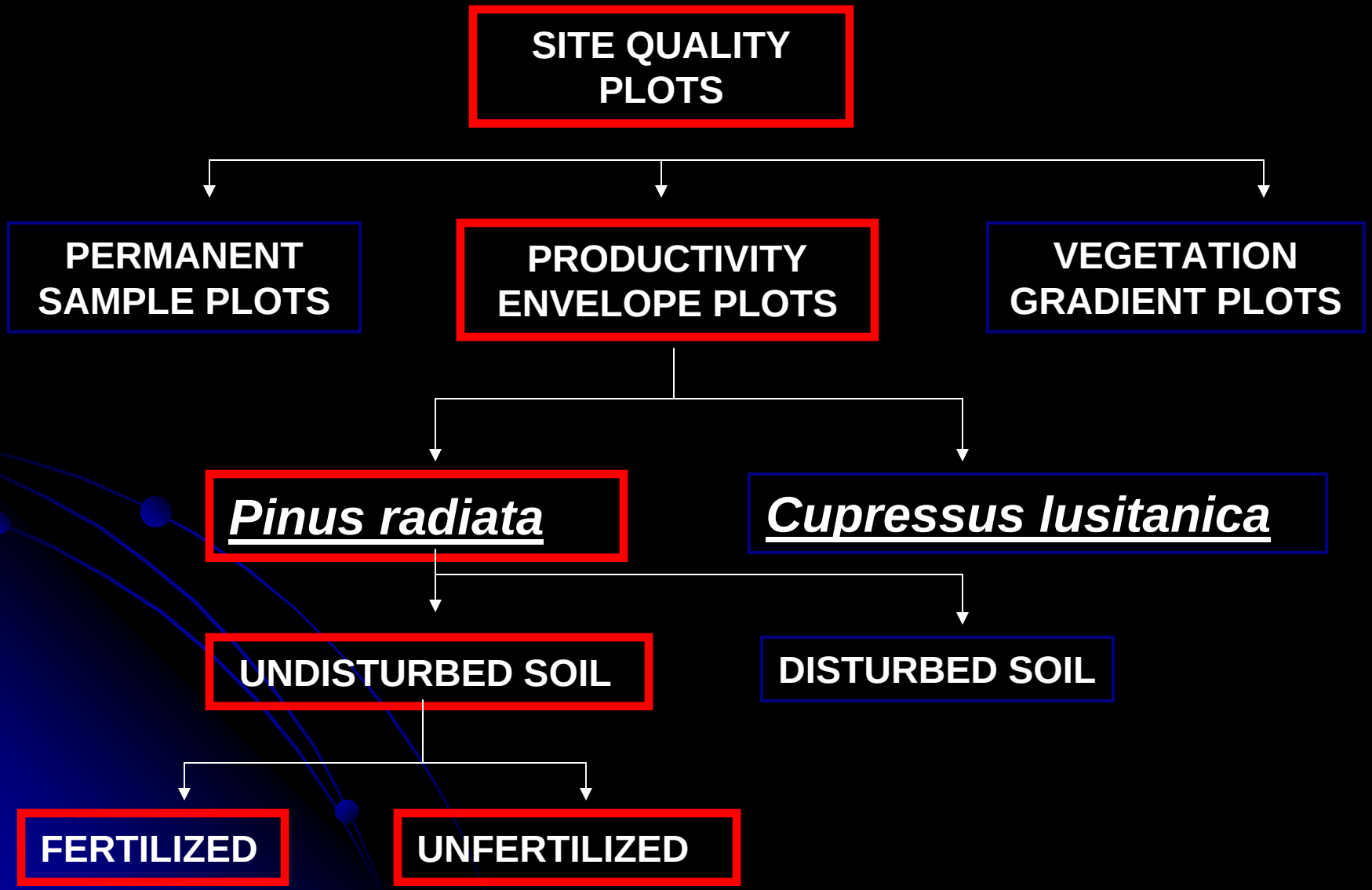
- Ratio is of stem measurements
  - Allometry changes with plant size
  - Allocation ≠ allometry
- No account of changes in C allocation to roots with fertility
  - Assumed with 3-PG
- Represents P only

2. N, P & C:N ratio

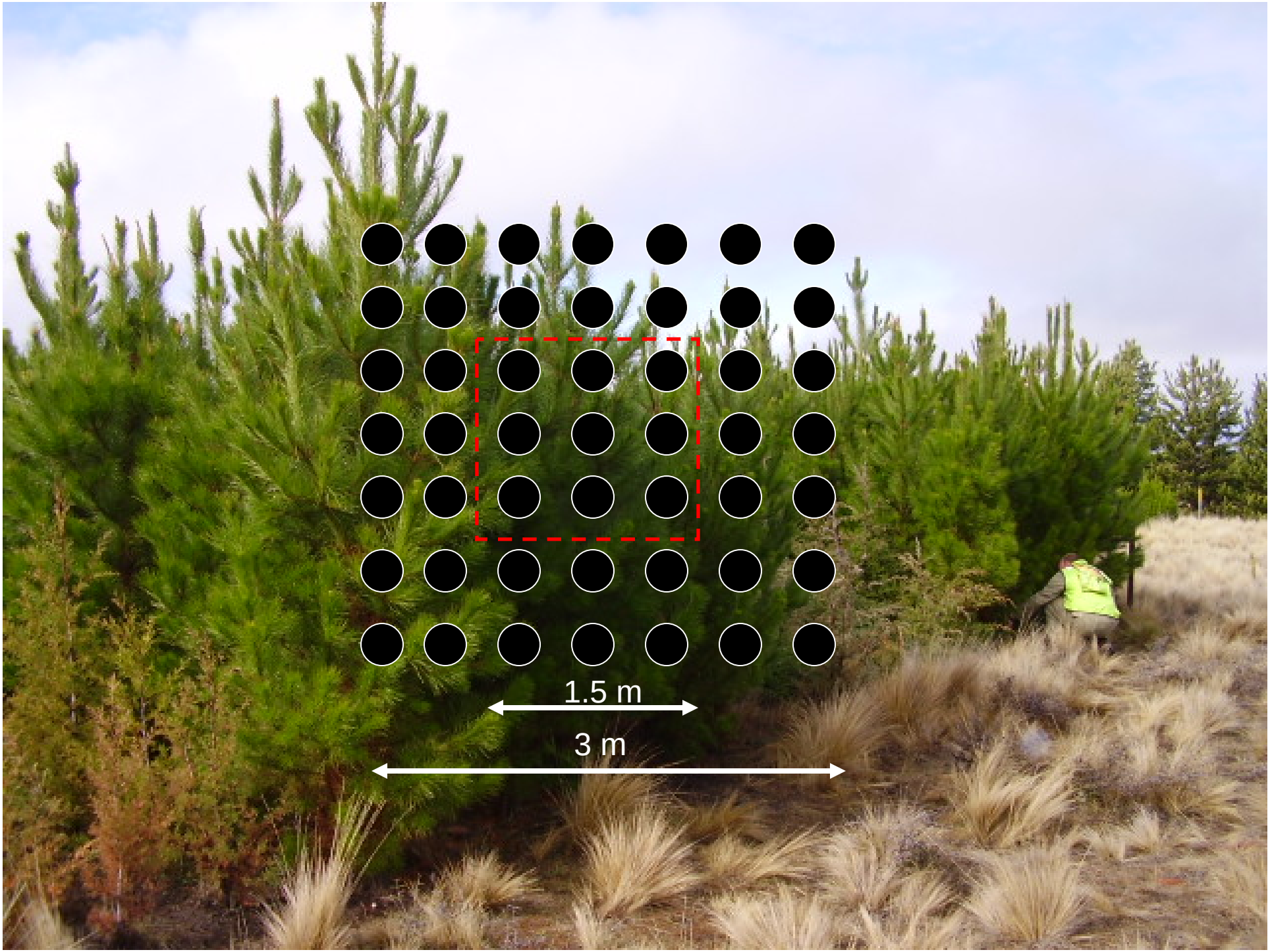
with Horacio Bown, Peter Clinton, Mike Watt & Brian Richardson

- N is sometimes critical in NZ
- N:P ratio may be significant
- Form of N can affect results
- Retranslocation must be accounted for
- Simple vs step by step approaches

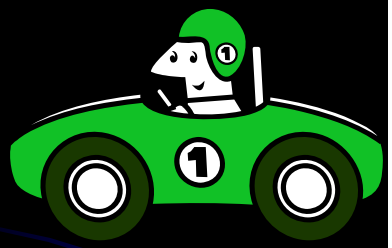
A simple approach



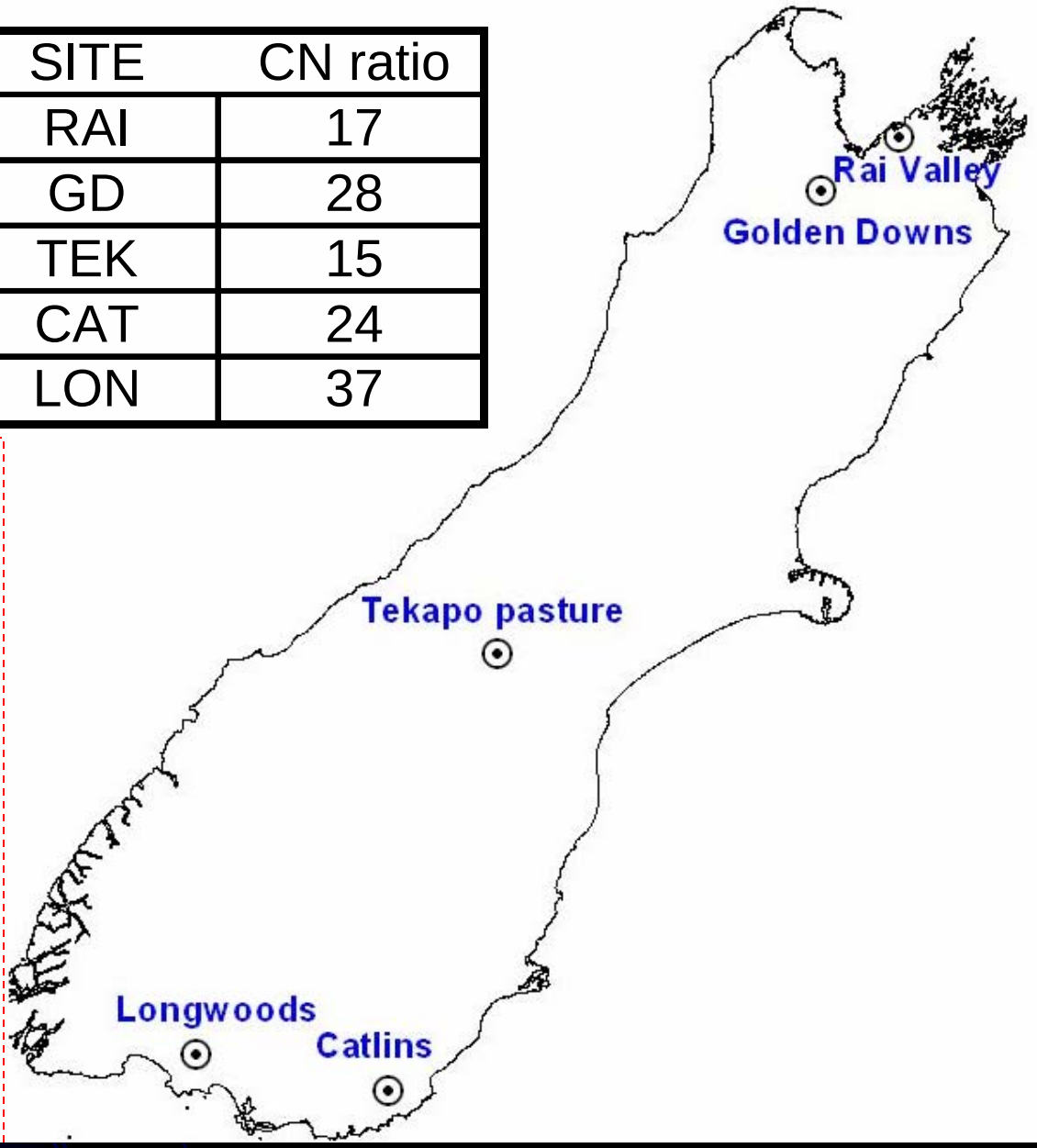
- Site quality plots comprise 35 sites across NZ
- 5 sites selected for the purposes of the study
- selected within the SI to cover gradient fertility
- Within each site 2 plots were selected
- established between July and September 2001
- harvested between August and September 2005

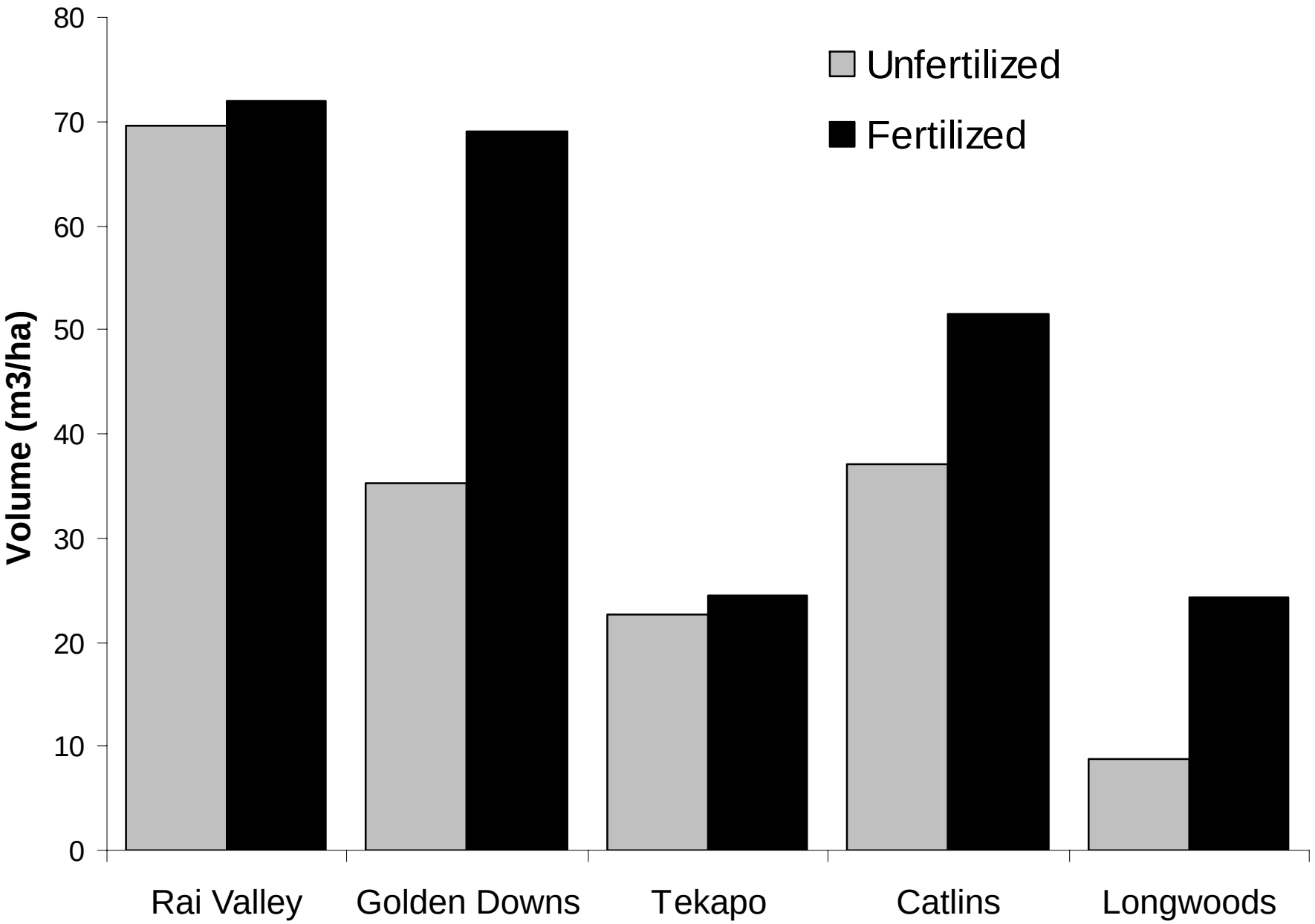

1.5 m
3 m

SITE	CN ratio
RAI	17
GD	28
TEK	15
CAT	24
LON	37

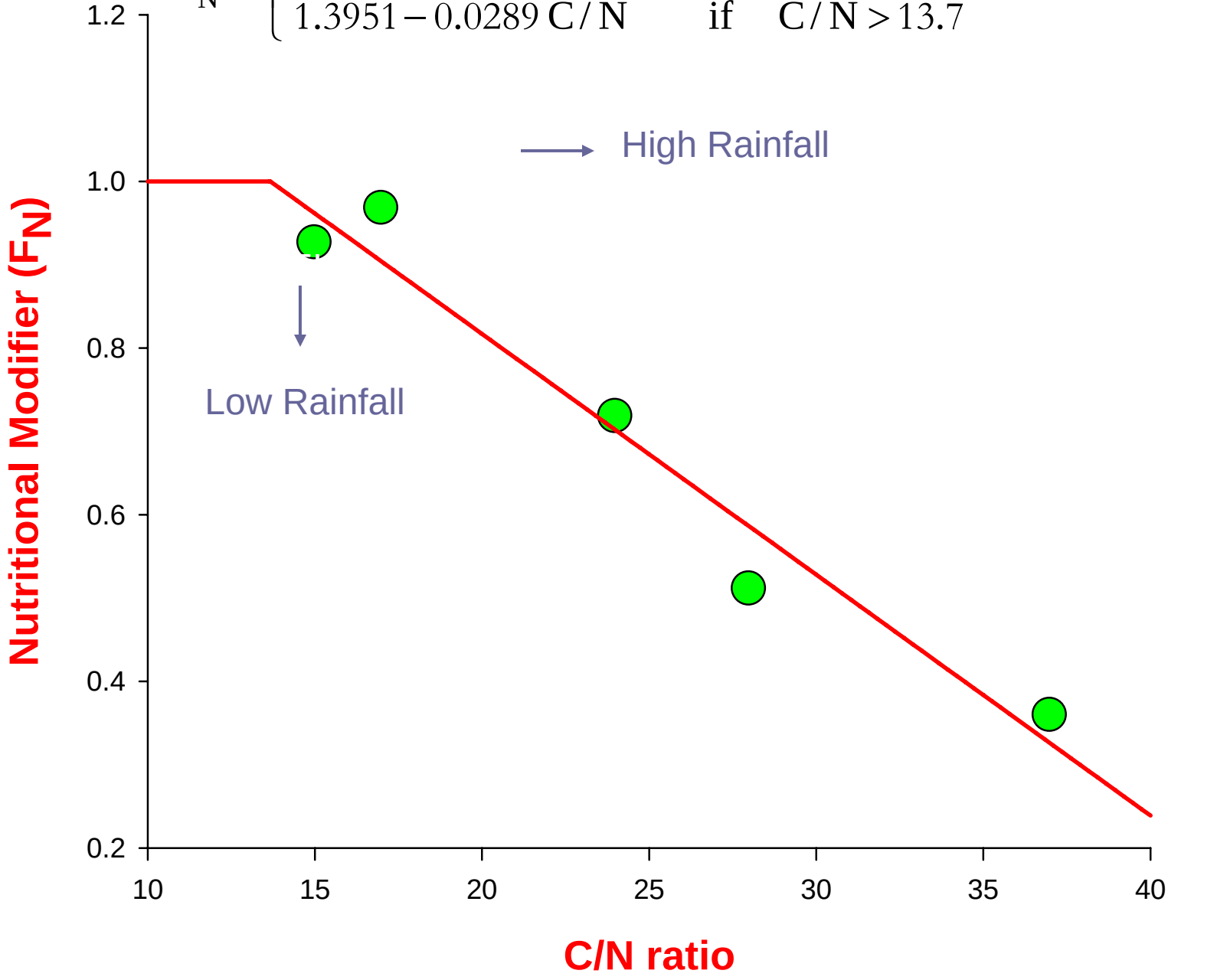


Horacio & Mike visited all 5 sites 12 times over a year. 12 trips of 2,500 km, or 30,000 km = return ticket to South America !!!!




Volume (m3/ha)
80
70
60
50
40
30
20
10
0
Unfertilized
Fertilized
Rai Valley
Golden Downs
Tekapo
Catlins
Longwoods

$$F_N = \begin{cases} 1 & \text{if} \quad C/N \le 13.7 \\ 1.3951 - 0.0289\, C/N & \text{if} \quad C/N > 13.7 \end{cases} \qquad R^2 = 0.95$$



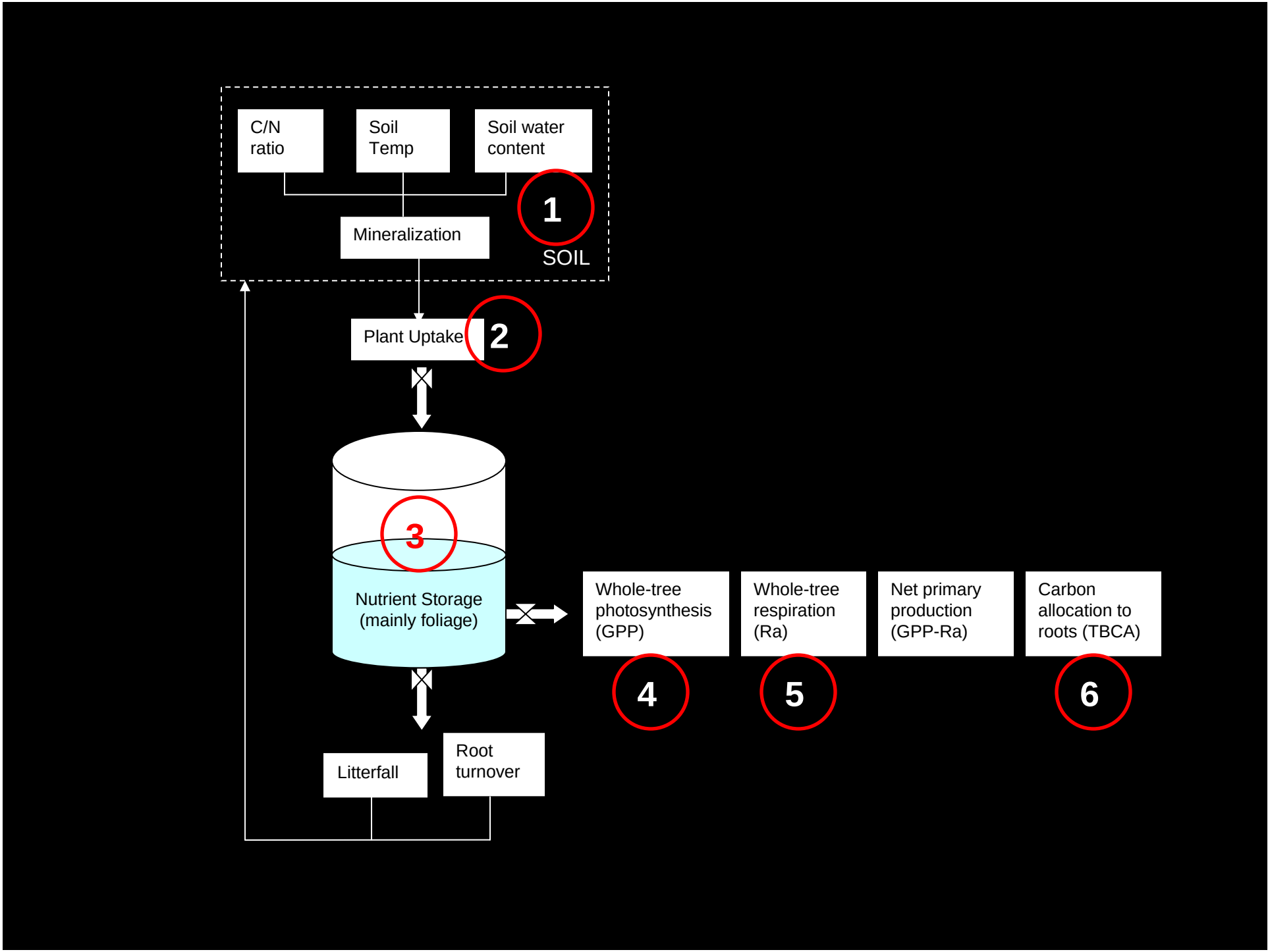
Advantages of simple approach

- Simple to use
- Physiologically sound?
- In the short run, you would expect interaction between water and nutrient availability
- In the long run, the interaction can be neglected (Compare Rai valley and Tekapo)
- Fertilization can be easily handled as a reduction in the C/N ratio

A step-by-step approach

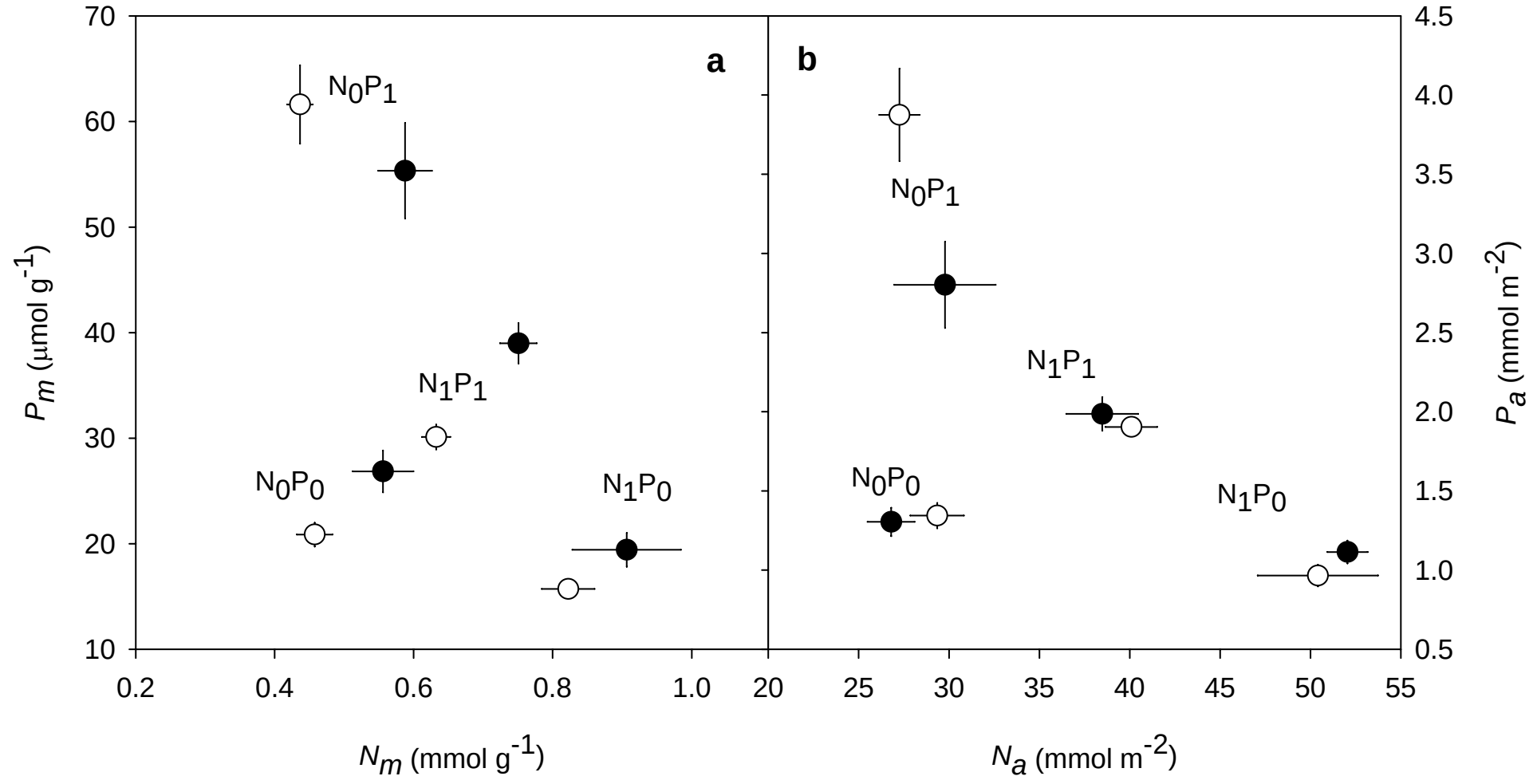
1. Construct a nutrient balance model

2. Drive photosynthesis and carbon allocation on a monthly step


C/N ratio
Soil Temp
Soil water content
1
Mineralization
SOIL
Plant Uptake
2
3
Nutrient Storage (mainly foliage)
Whole-tree photosynthesis (GPP)
Whole-tree respiration (Ra)
Net primary production (GPP-Ra)
Carbon allocation to roots (TBCA)
4
5
6
Litterfall
Root turnover

Field and glasshouse studies

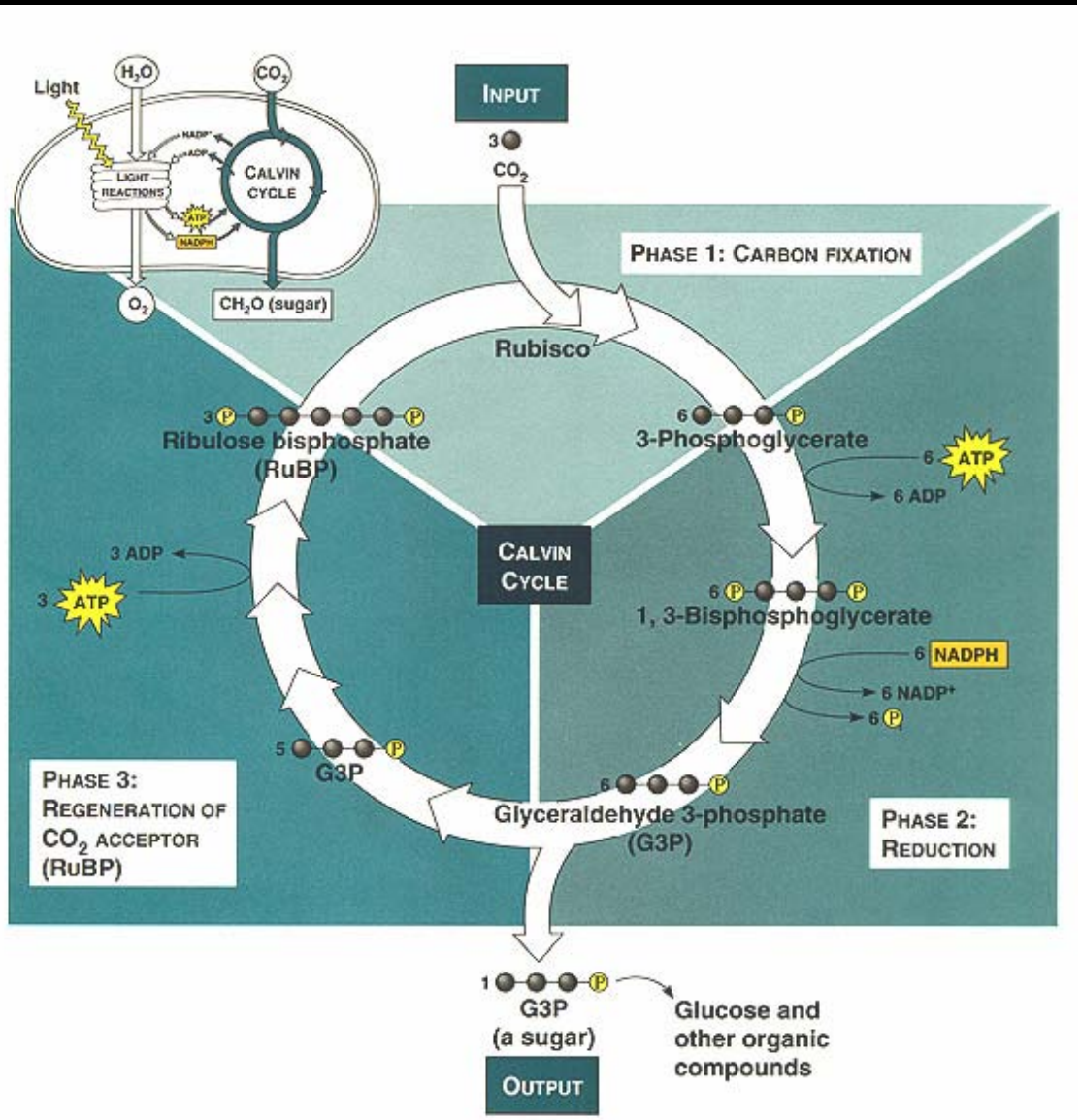
1	Soil mineralization model	→	Field
2	Tree uptake model	→	Field
3	Storage and Retranslocation model	→	Glasshouse & Field
4	Photosynthesis model	→	Glasshouse
5	Respiration model	→	Glasshouse
6	Model of carbon allocation to roots	→	Glasshouse & Field

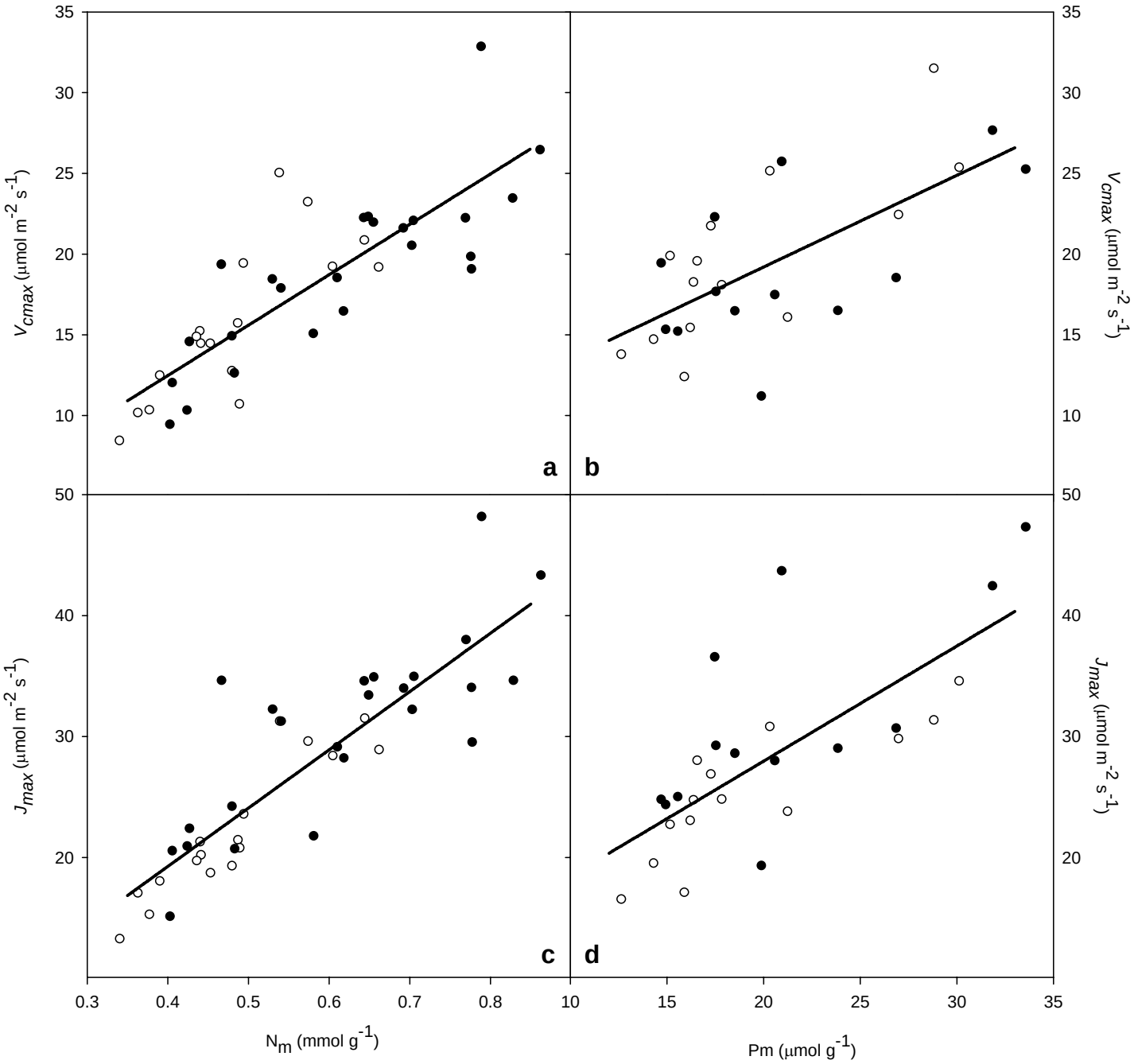


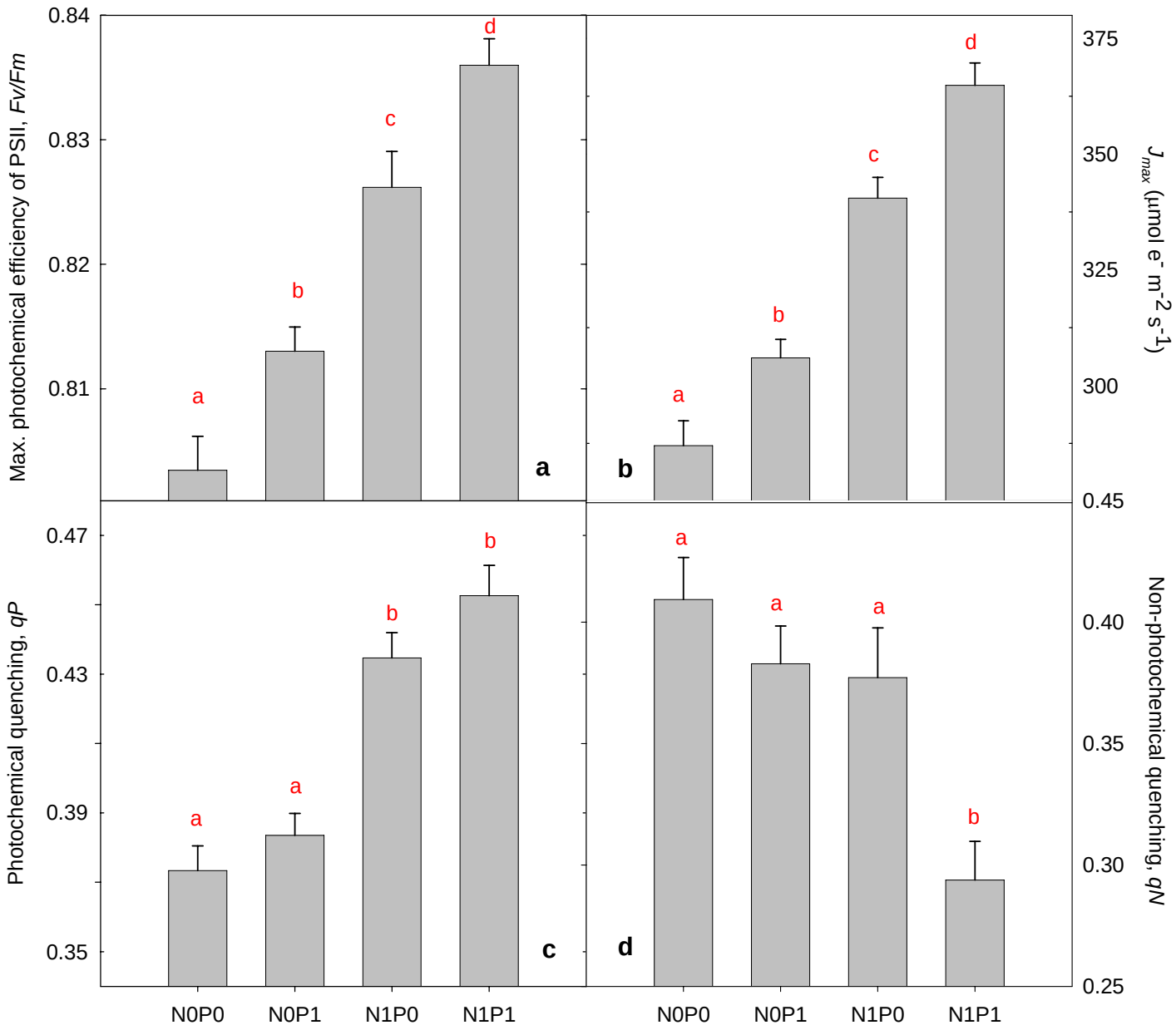
Treatments were made up as a combination of two levels of nitrogen (N0=1.43 and N1=7.14 mM) and two levels of phosphorus (P0=0.084 and P1=0.420 mM).

Calvin cycle

- Vcmax
  - maximum carboxylation rate of Rubisco
  - Rubisco content
- Jmax
  - Regeneration rate of RuBP
  - Thylakoid protein content




a
b
c
d
V_{cmax} (μmol m^{-2} s^{-1})
J_{max} (μmol m^{-2} s^{-1})
N_m (mmol g^{-1})
Pm (μmol g^{-1})


Max. photochemical efficiency of PSII, Fv/Fm
0.84
0.83
0.82
0.81
a
b
c
d
a
b
J_{max} (µmol e$^-$ m^{-2} s^{-1})
375
350
325
300
0.45
a
b
c
d
b
Photochemical quenching, qP
0.47
0.43
0.39
0.35
a
a
b
b
c
Non-photochemical quenching, qN
0.40
0.35
0.30
0.25
a
a
a
b
d
N0P0
N0P1
N1P0
N1P1
N0P0
N0P1
N1P0
N1P1

Conclusion

- Research aimed at devising a nutritional modifier for hybrid models
  - Supply/Demand
- Repeated Bray P analysis
- C:N ratio
- Step by step approach
  - Nutrient balance model