Impact of Swiss Needle Cast on Stand Growth and a Synthesis of Silvicultural Treatments for Mitigation

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Oregon State University

Growth impacts and silvicultural mitigation

- Growth impacts (Doug Maguire)
  - Growth and mortality
  - Foliage dynamics and measures of SNC severity
  - Soil and foliar chemistry
- Silvicultural mitigation (Doug Mainwaring)
  - Thinning effects
  - Fertilization
  - Fungicides

Growth impacts

1) What is the growth impact of SNC?
2) Does SNC accelerate Douglas-fir mortality?
3) How can we rate SNC severity?
4) Do stands recover from SNC? Does disease severity fluctuate?
5) What tools are available for estimating SNC growth impacts?
6) Are there predisposing conditions that suggest mitigation measures?

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Growth Impact of Swiss needle cast

Objectives

1) To establish the magnitude of growth losses resulting from varying severity of Swiss needle cast

2) To identify tree and/or foliage attributes that can serve as indices of SNC severity and corresponding growth losses

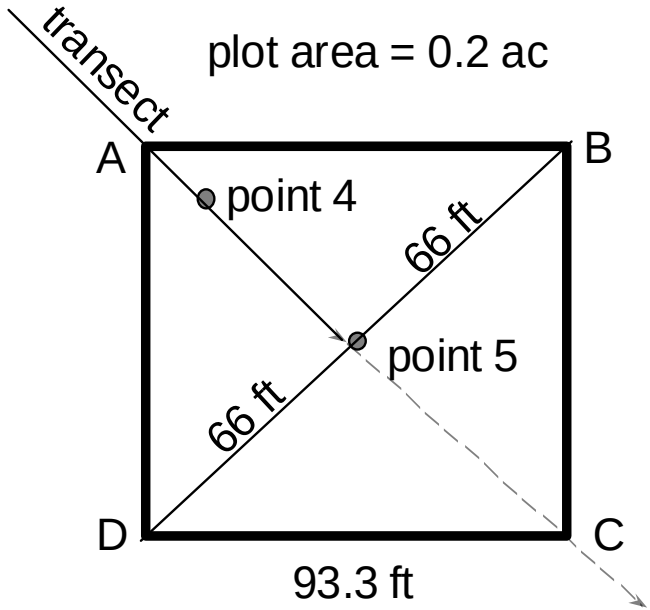
Growth Impact of Swiss needle cast

Objectives (cont'd)

3) To develop quantitative links among attributes monitored in aerial surveys, plantation surveys, and intensively measured growth plots

4) To monitor symptom severity and growth losses over time

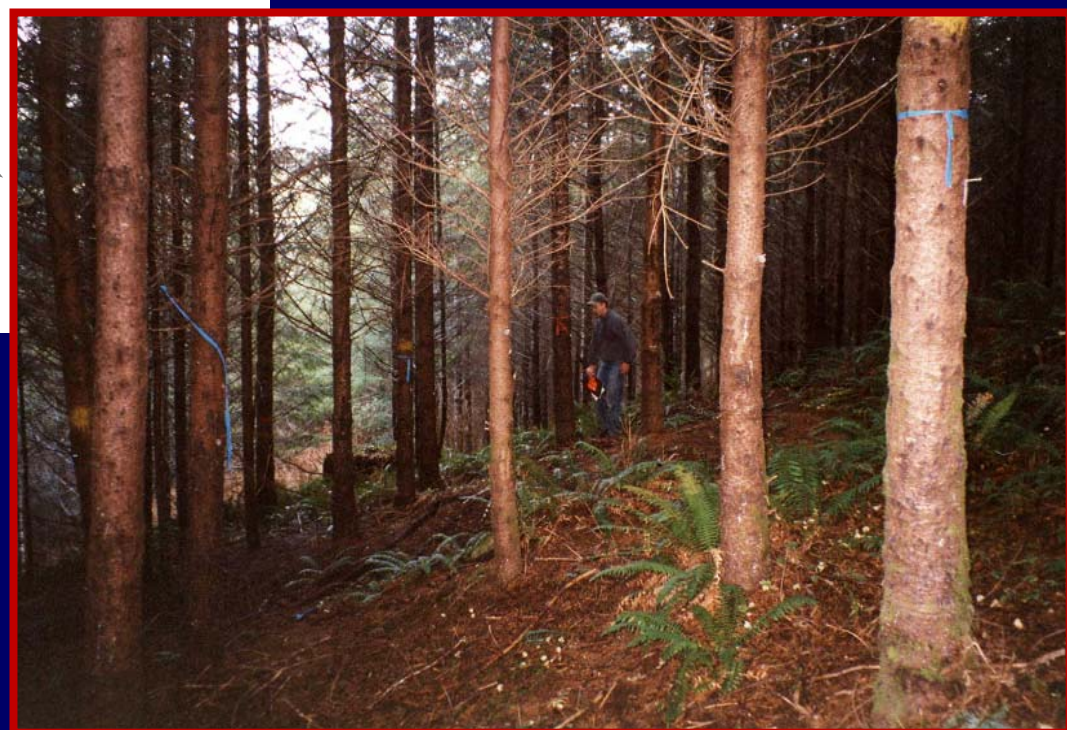
SNCC Growth Impact Study



Retrospective

vs.

Permanent plots



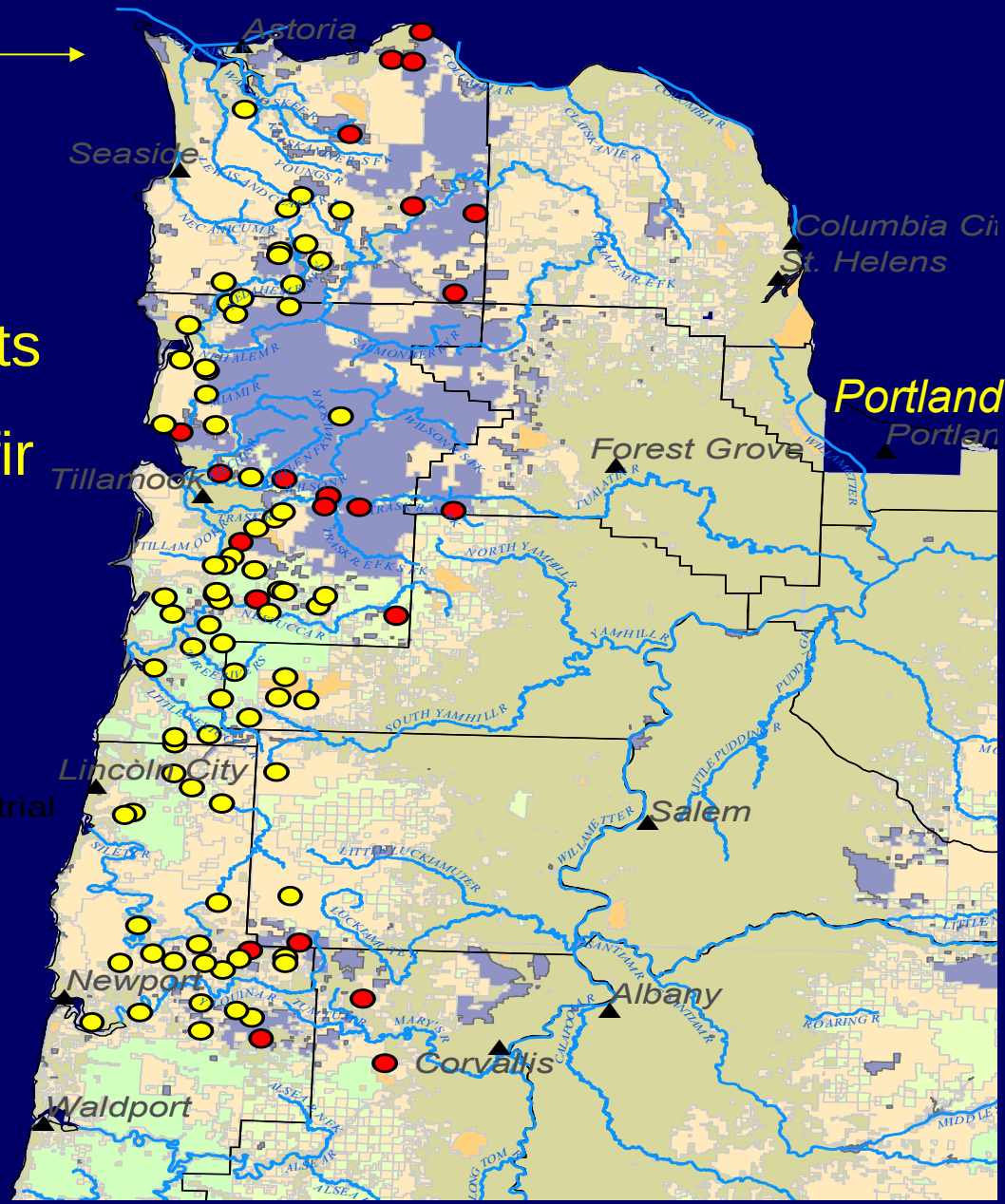
Astoria →

- 76 Growth impact plots

  90% Douglas-fir
  10-30 yrs old

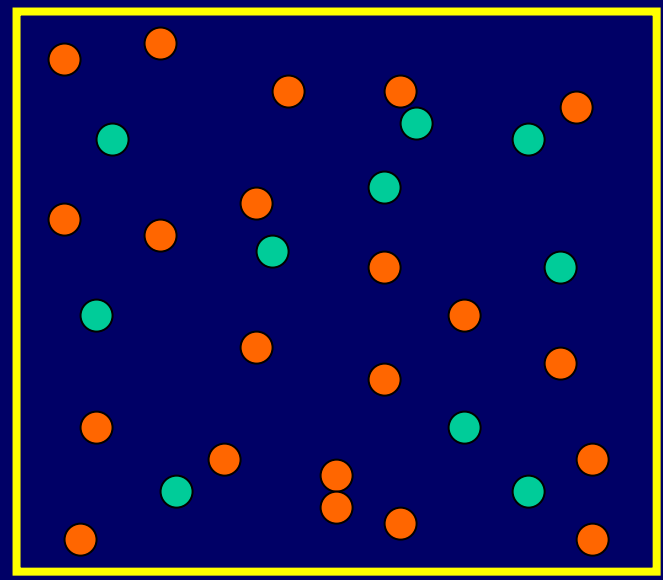
- 22 Pre-commercial thinning plot sets

Newport →

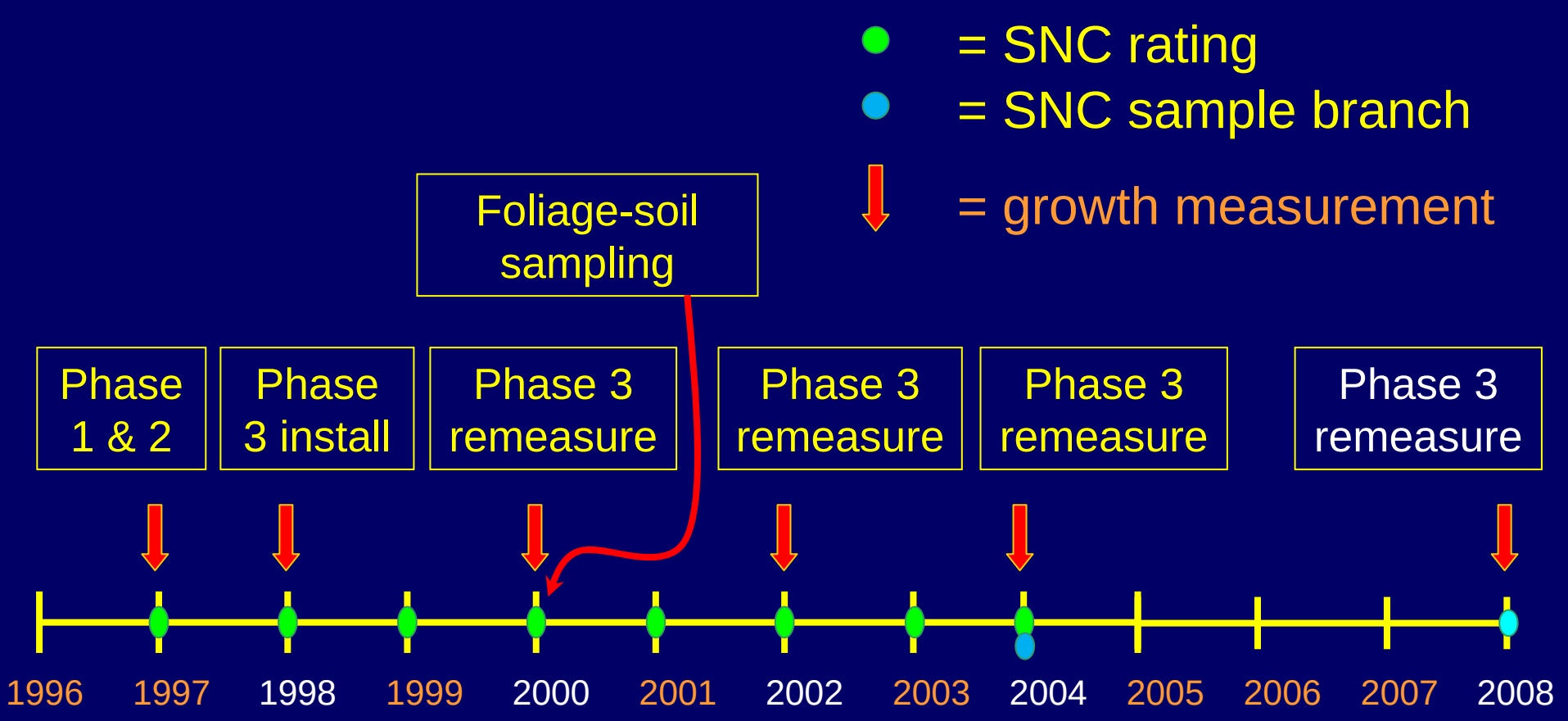


SNCC Growth Impact Study

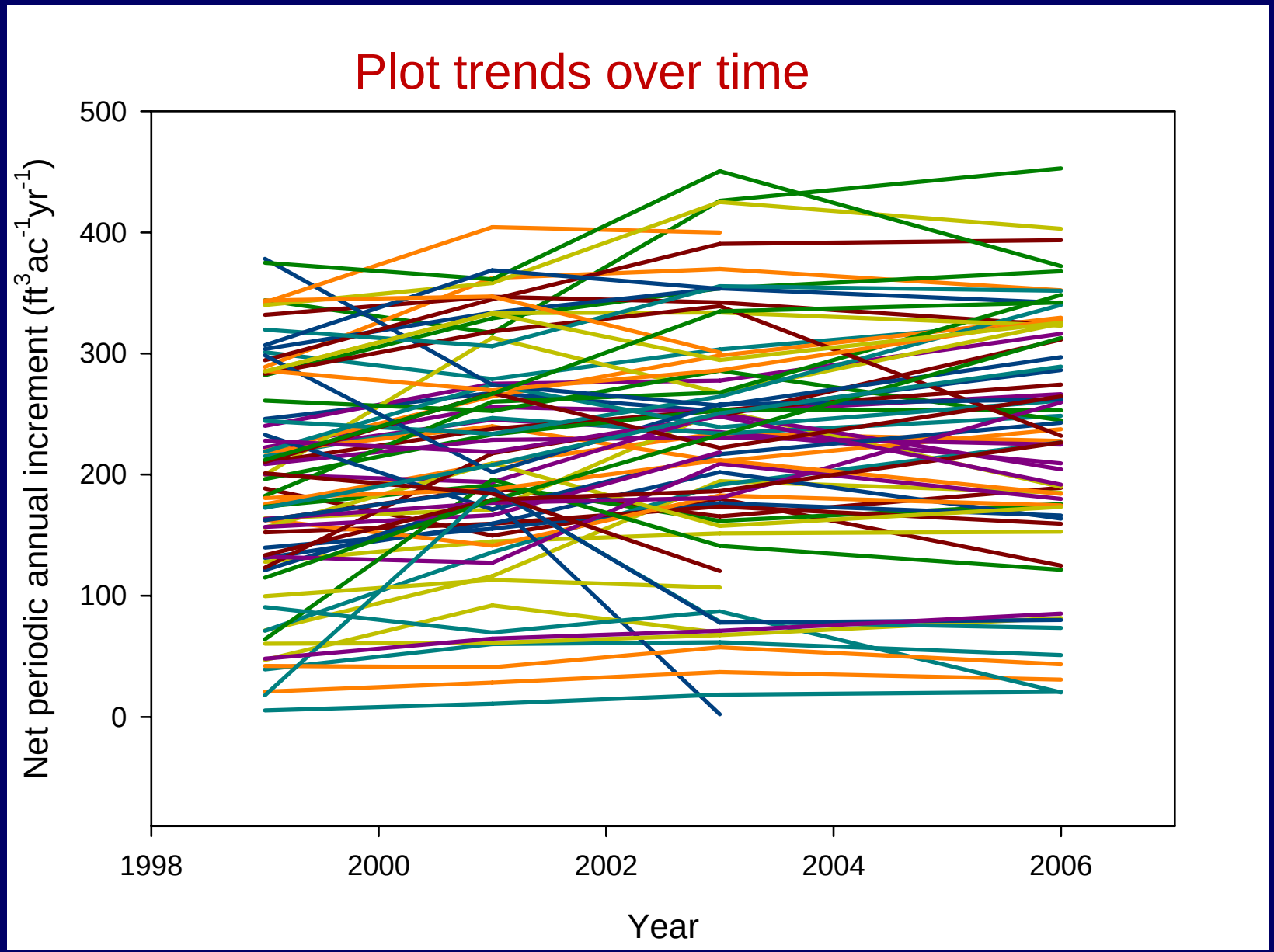
- Dbh on all trees >1.37m in height
- Tagged all trees with dbh>6cm ( )
- 40-tree height sample for Douglas-fir
- SNC ratings on 10 dominant or codominant DF trees per plot ( ):
  - foliage retention
  - color
  - crown density
  - crown transparency



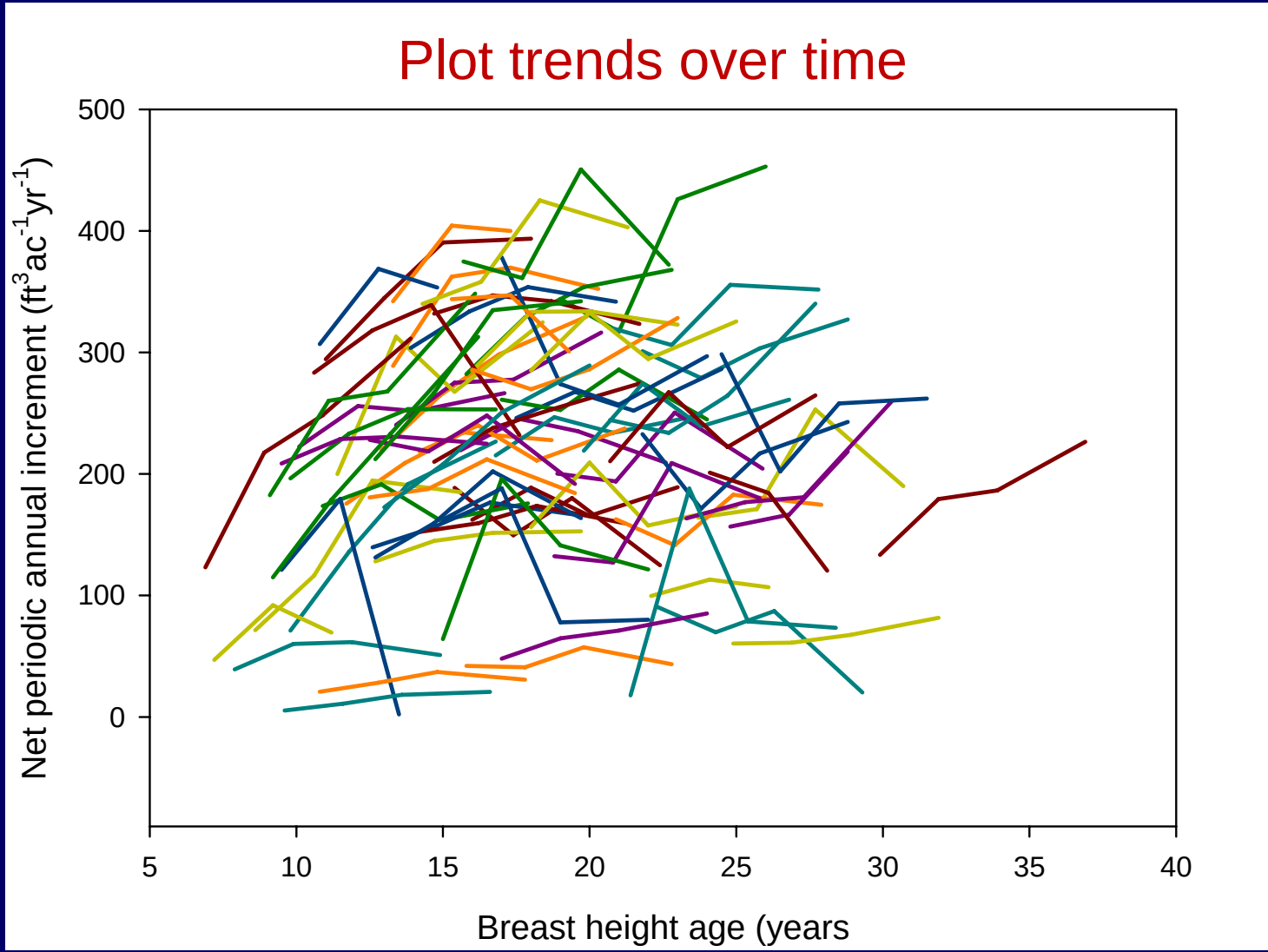
Growth Impact Study
Remeasurement schedule



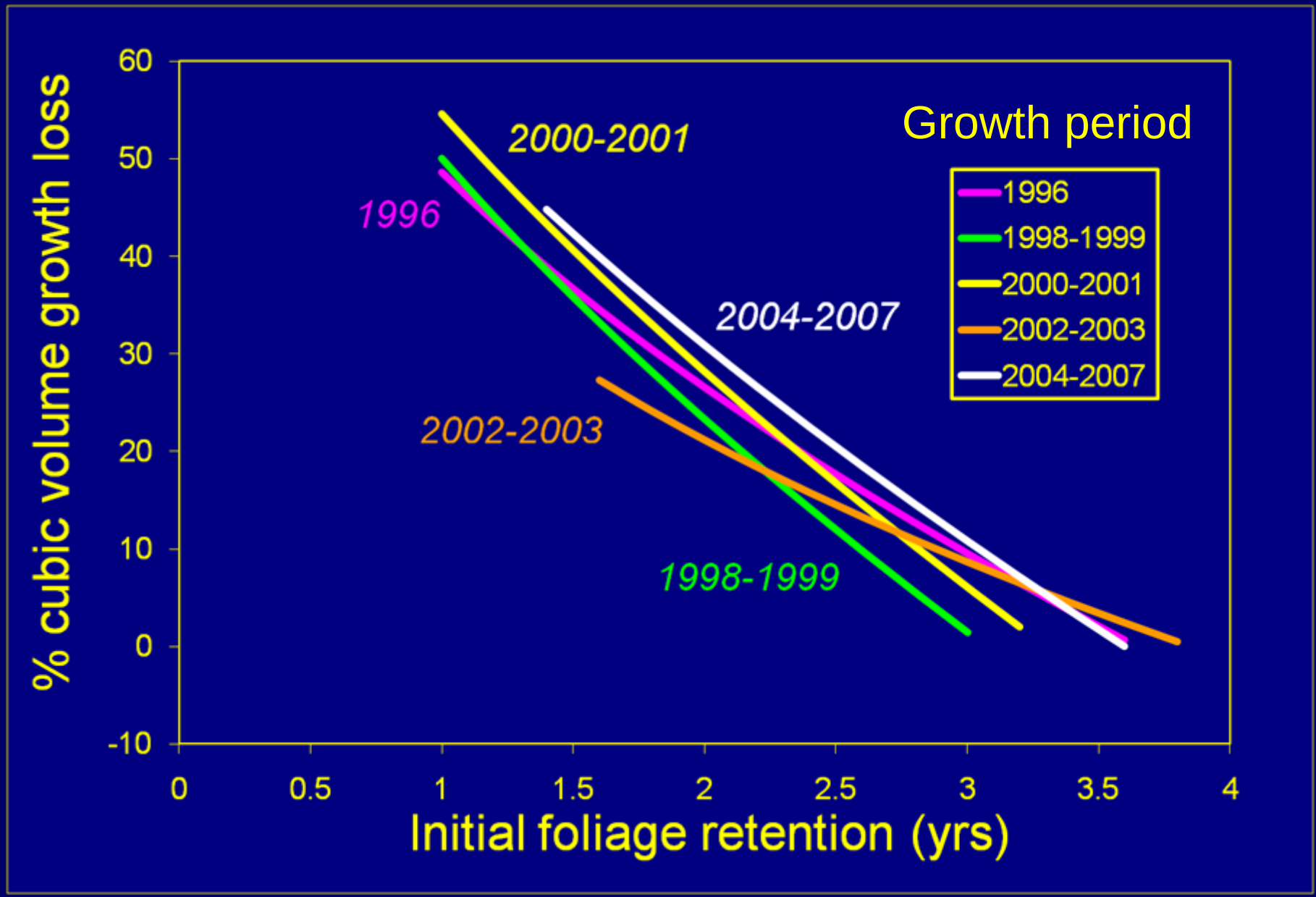
Net periodic annual increment over year of growth



Net periodic annual increment over breast height age



Predicted growth losses for successive growth periods



Comprehensive dataset and model

Douglas-fir stocking *Site quality*

$$\ln(PAI_{NET}) = \beta_0 + \beta_1 \ln(BA_{DF}) + \beta_2 \ln(SI) + \beta_3 \ln(A) + \beta_4 \ln(FR-0.5) + \varepsilon$$

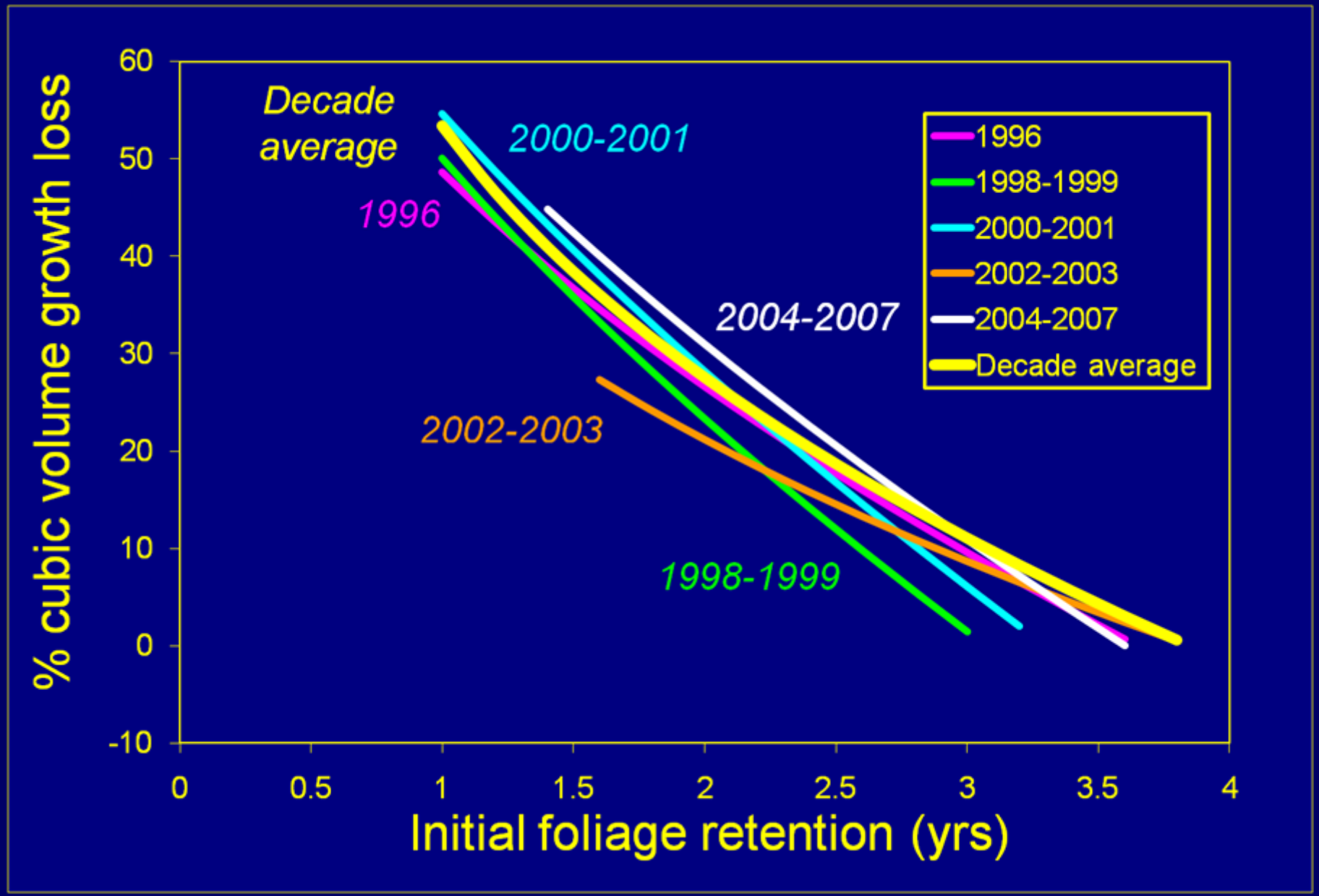
Stand age *SNC severity*

Where

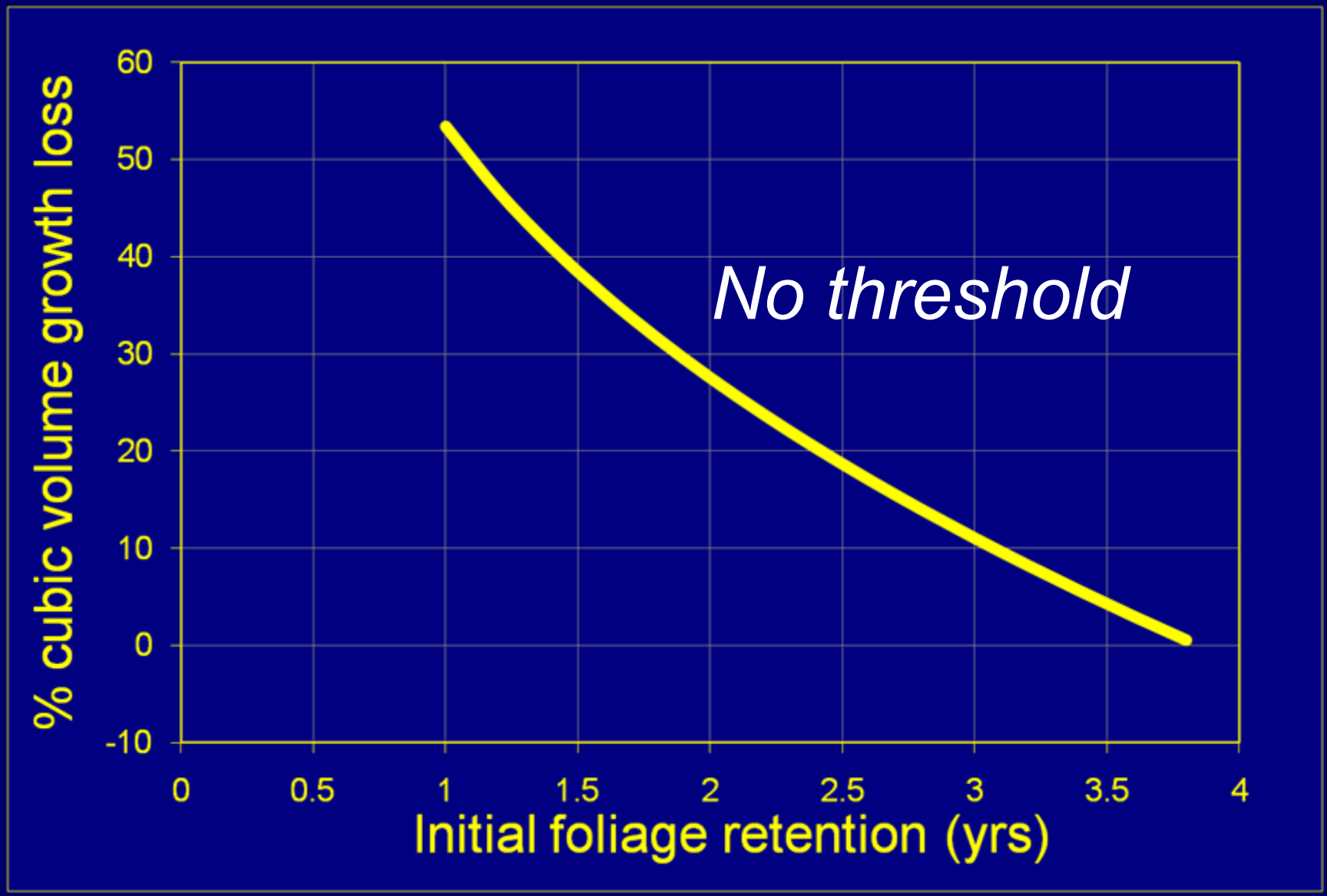
PAI_{NET} = Net periodic annual increment ($m^3 ha^{-1} yr^{-1}$)
BA_{DF} = Initial Douglas-fir basal area ($m^2 ha^{-1}$)
SI = Bruce's site index (m at 50 years)
A = Plot average breast height age (years)
FR = Plot average foliage retention (years)
β_k = Parameters estimated from the data
ε = Error term with variance-covariance matrix having compound symmetry for observations within a plot over time

$$\ln(PAI_{NET}) = \beta_0 + \beta_1 \ln(BA_{DF}) + \beta_2 \ln(SI) + \beta_3 \ln(A) + \beta_4 \ln(FR-0.5) + \varepsilon$$

Parameter	Parameter estimate	Standard error
β_0	-3.7607	0.7626
β_1	0.02367	0.006929
β_2	1.0998	0.2015
β_3	0.6417	0.07530
β_4	0.4018	0.07657


% cubic volume growth loss
60
50
40
30
20
10
0
-10
0
0.5
1
1.5
2
2.5
3
3.5
4
Initial foliage retention (yrs)
Decade average
2000-2001
1996
2004-2007
2002-2003
1998-1999
1996
1998-1999
2000-2001
2002-2003
2004-2007
Decade average

Average growth loss by initial foliage retention, 1998-2008



Growth impacts and silvicultural mitigation

- What is the growth impact of SNC?
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- How can we rate SNC severity?
- Do stands recover from SNC? Does disease severity fluctuate?
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Foliage retention (SNC) does not influence Douglas-fir mortality rate.

$$\sin^{-1}(\sqrt{pmort}) = \beta_0 + \beta_1 \ln(BA_{DF}) + \beta_2 BA_{OC} + \beta_3 BA_{HARD} + \varepsilon$$

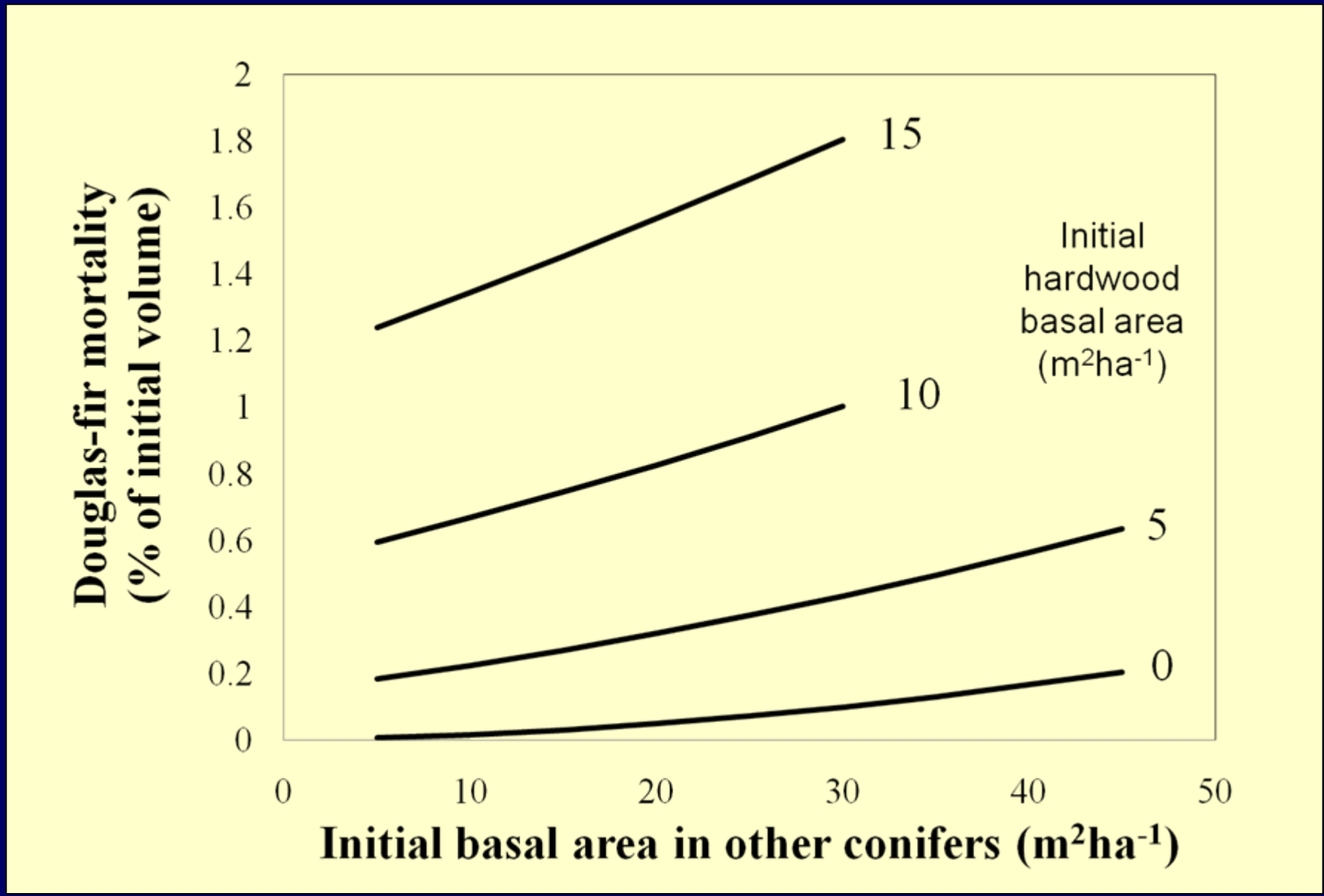
Where

pmort = mortality as proportion of initial cubic volume
BA_{DF} = Initial Douglas-fir basal area ($m^2 ha^{-1}$)
BA_{OC} = Initial basal area in other conifers ($m^2 ha^{-1}$)
BA_{HARD} = Initial basal area in hardwoods ($m^2 ha^{-1}$)
β_k = Parameters estimated from the data
ε = Error term with variance-covariance matrix having compound symmetry for observations within a plot over time

$$\sin^{-1}(\sqrt{pmort}) = \beta_0 + \beta_1 \ln(BA_{DF}) + \beta_2 BA_{OC} + \beta_3 BA_{HARD} + \varepsilon$$

Parameter	Parameter estimate	Standard error
β_0	-0.01037	0.01430
β_1	0.01051	0.004626
β_2	0.000924	0.000427
β_3	0.006885	0.001232

Periodic annual Douglas-fir mortality



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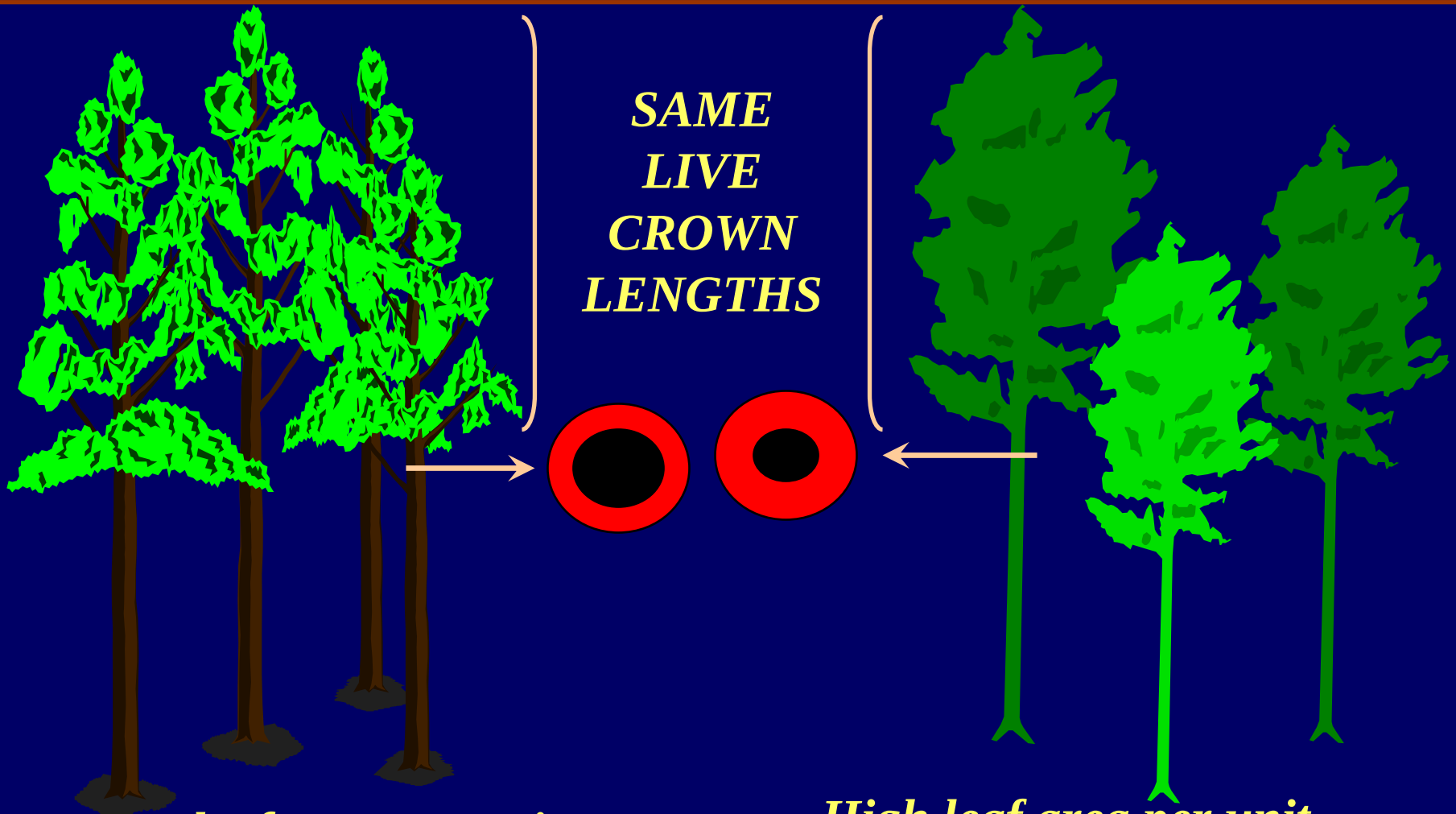
SNC severity - Foliage retention (yrs)

4.0

2.4

0.9

DYNAMIC EQUILIBRIUM (with tree growth or under defoliation)

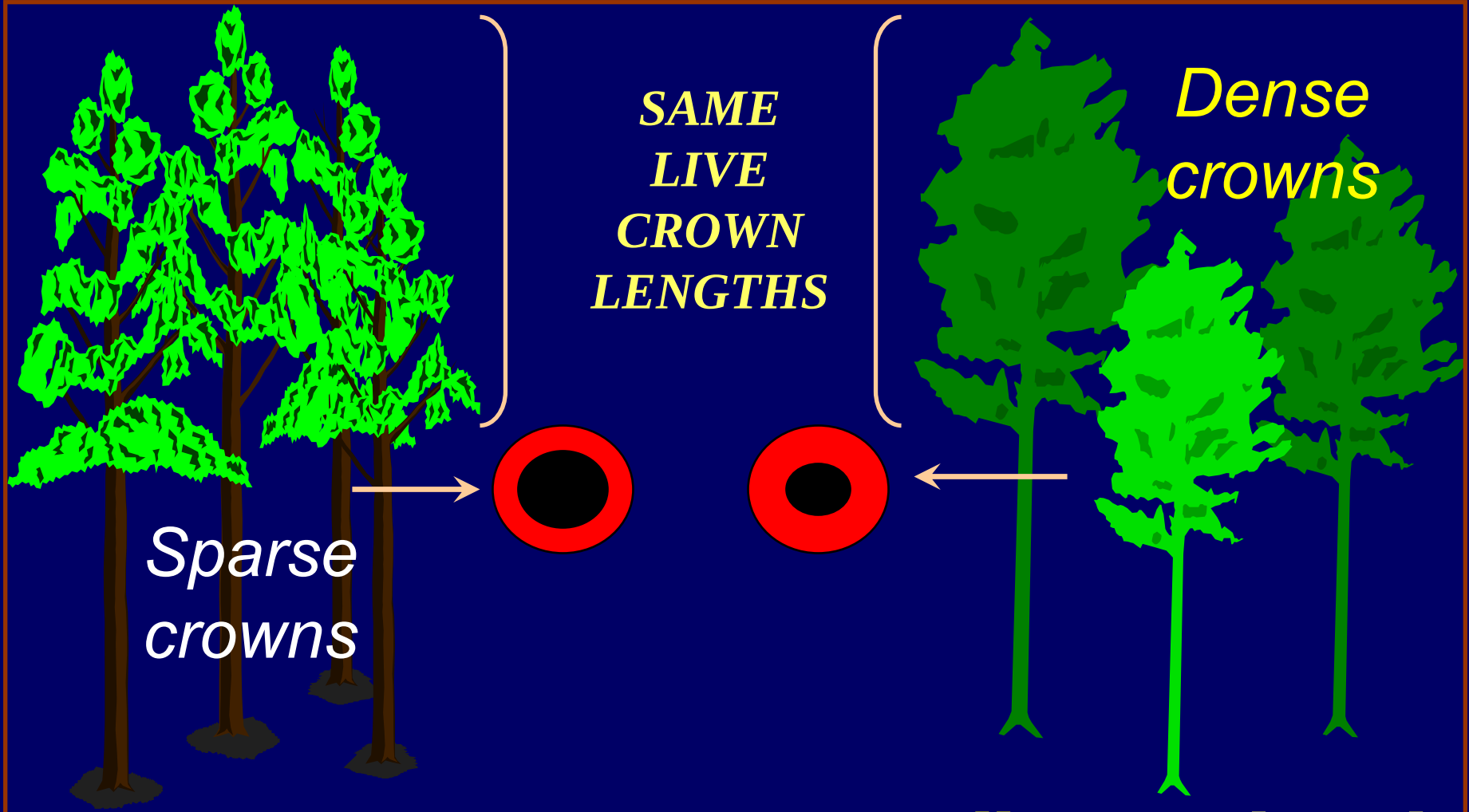


Low leaf area per unit crown length

→ Relatively small sapwood area at crown base

High leaf area per unit crown length

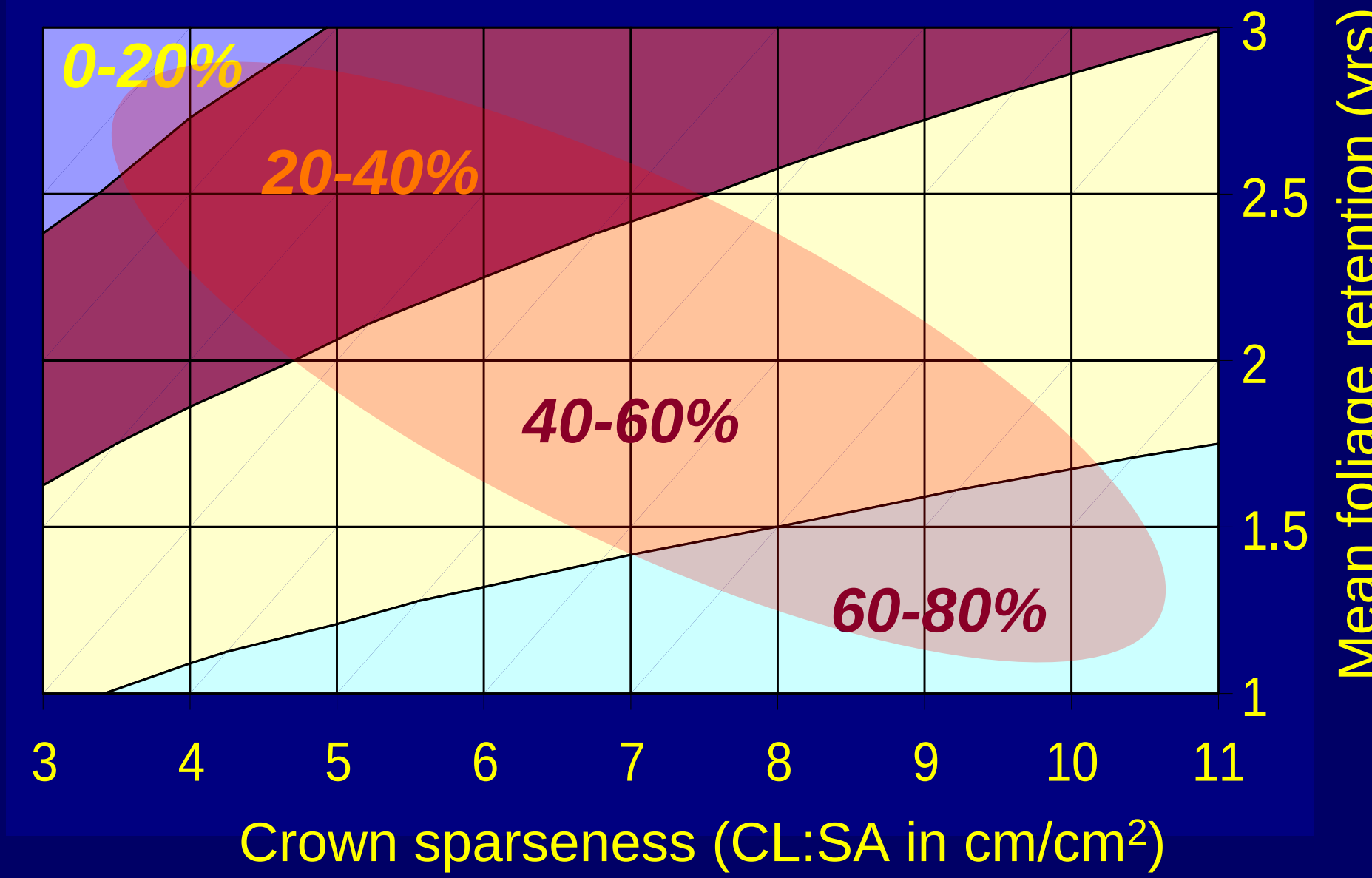
→ Relatively large sapwood area at crown base



***Large* crown length to sapwood area ratio**

***Small* crown length to sapwood area ratio**

Cubic volume growth loss by foliage retention and crown sparseness

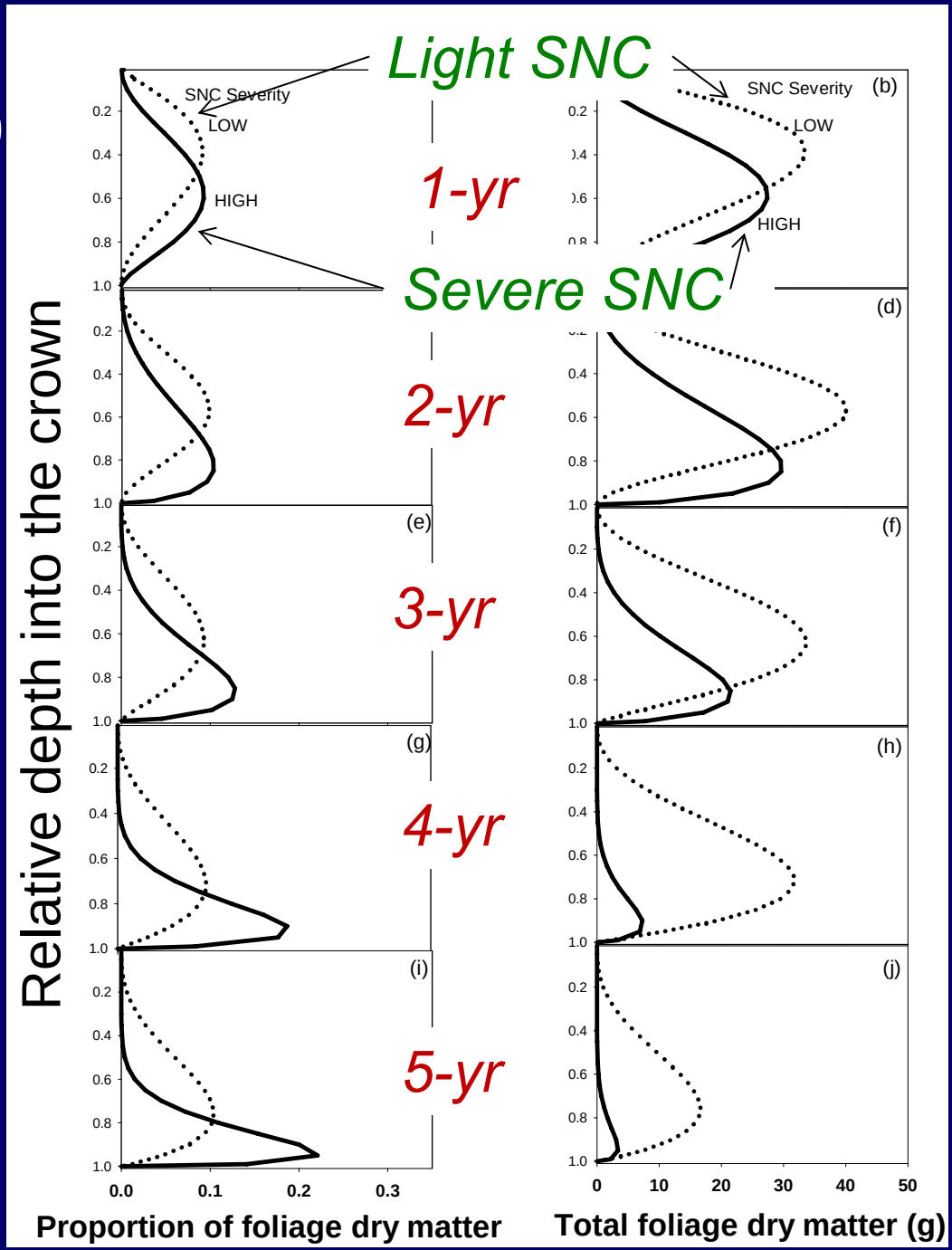


How does foliage retention relate to foliage amount?

Correlated with:

Amount of foliage in different age classes (area under curves at right)

Vertical distribution of foliage by age class



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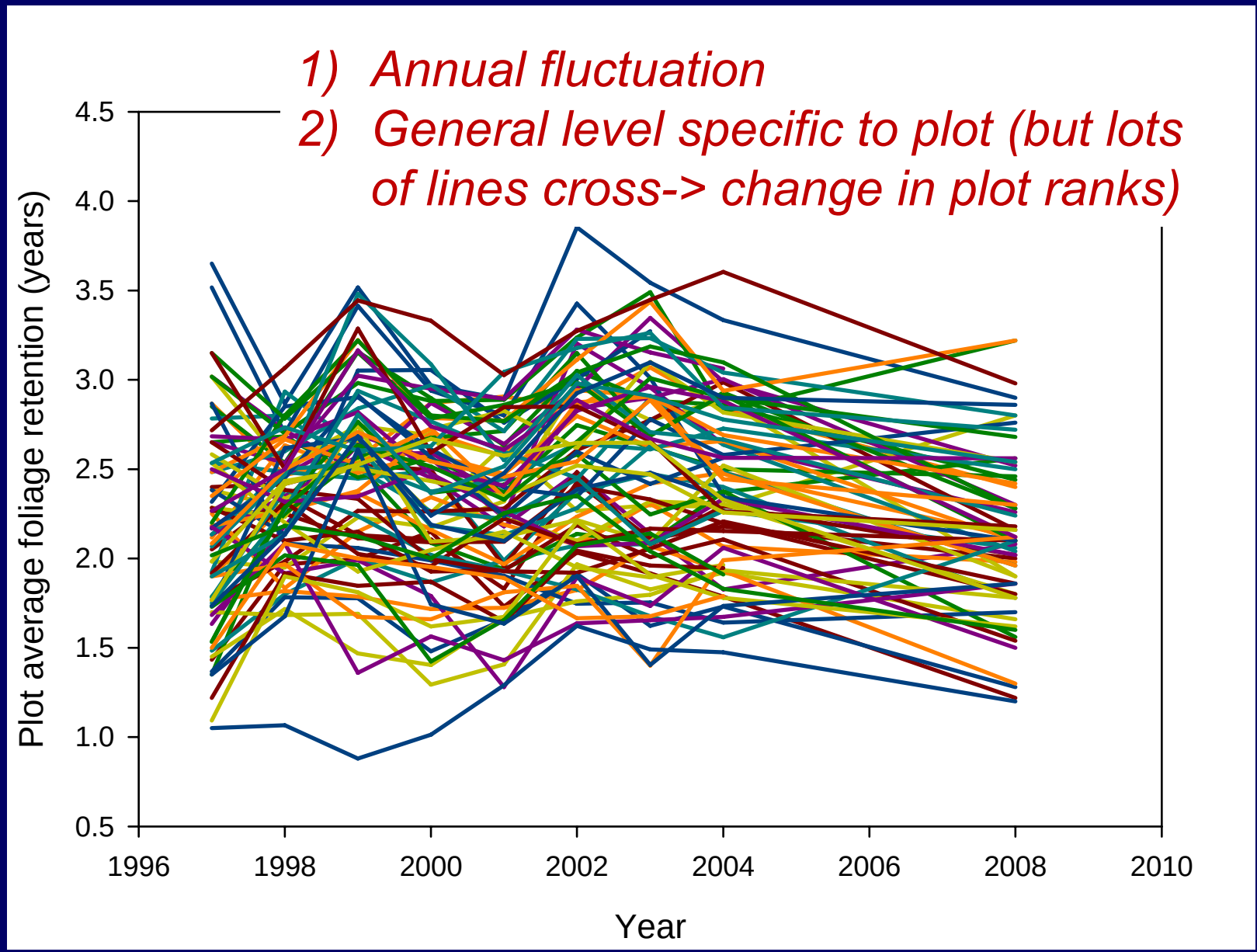
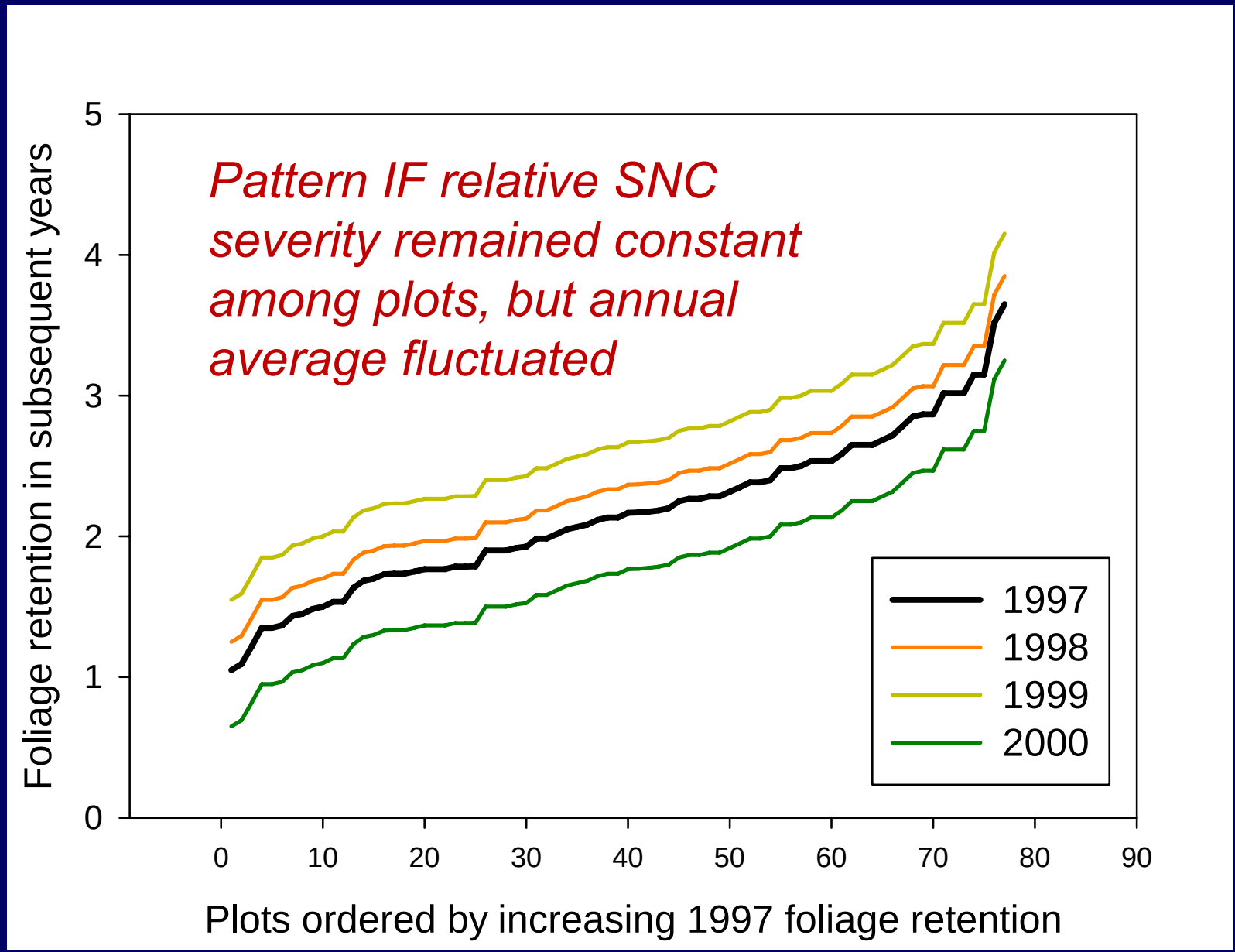
Trend foliage retention for each GIS plot from 1997-2008



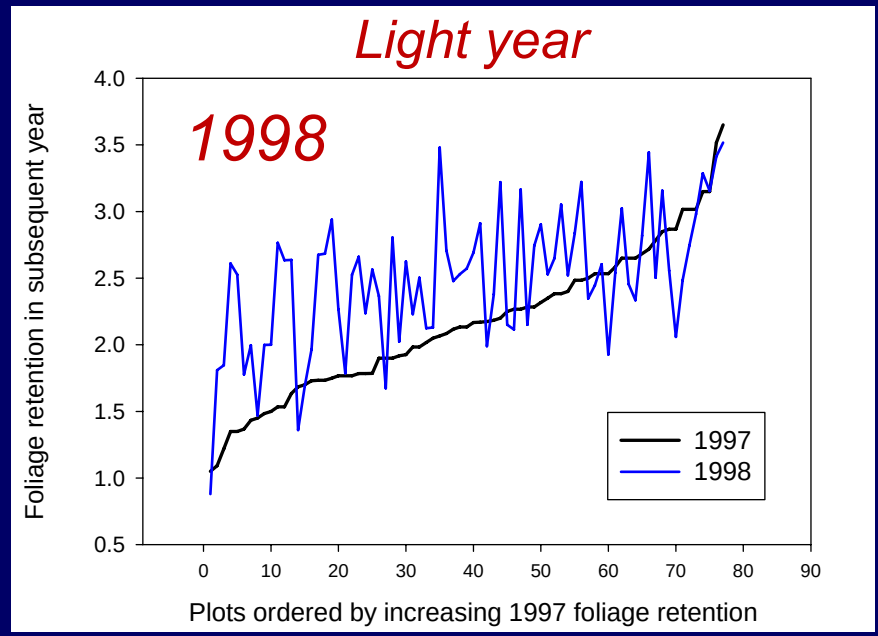
Level of foliage retention among years, ordered plots

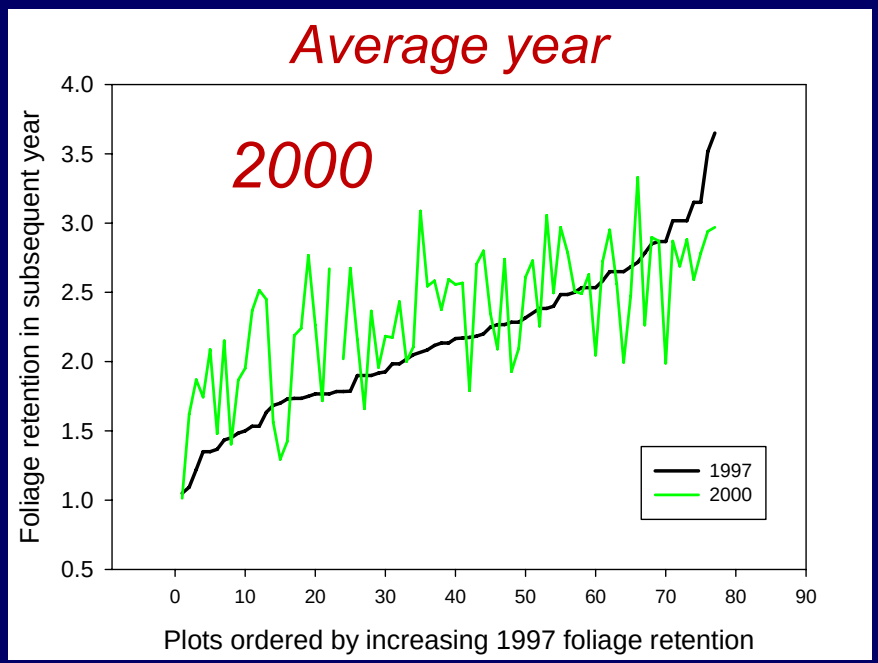


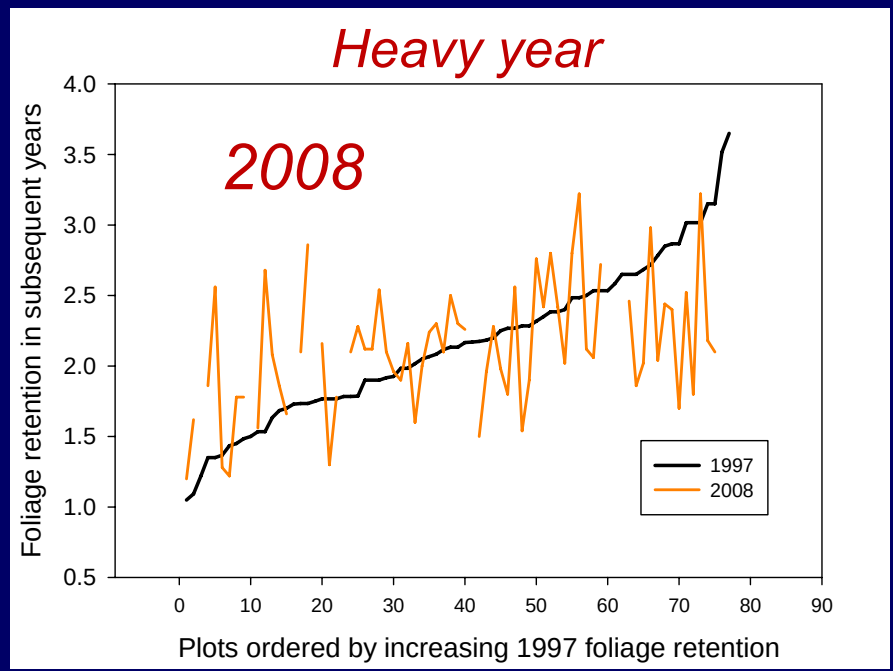
In general:

Plots of high SNC severity became slightly better, SNC;

Plots with low SNC severity became slightly worse







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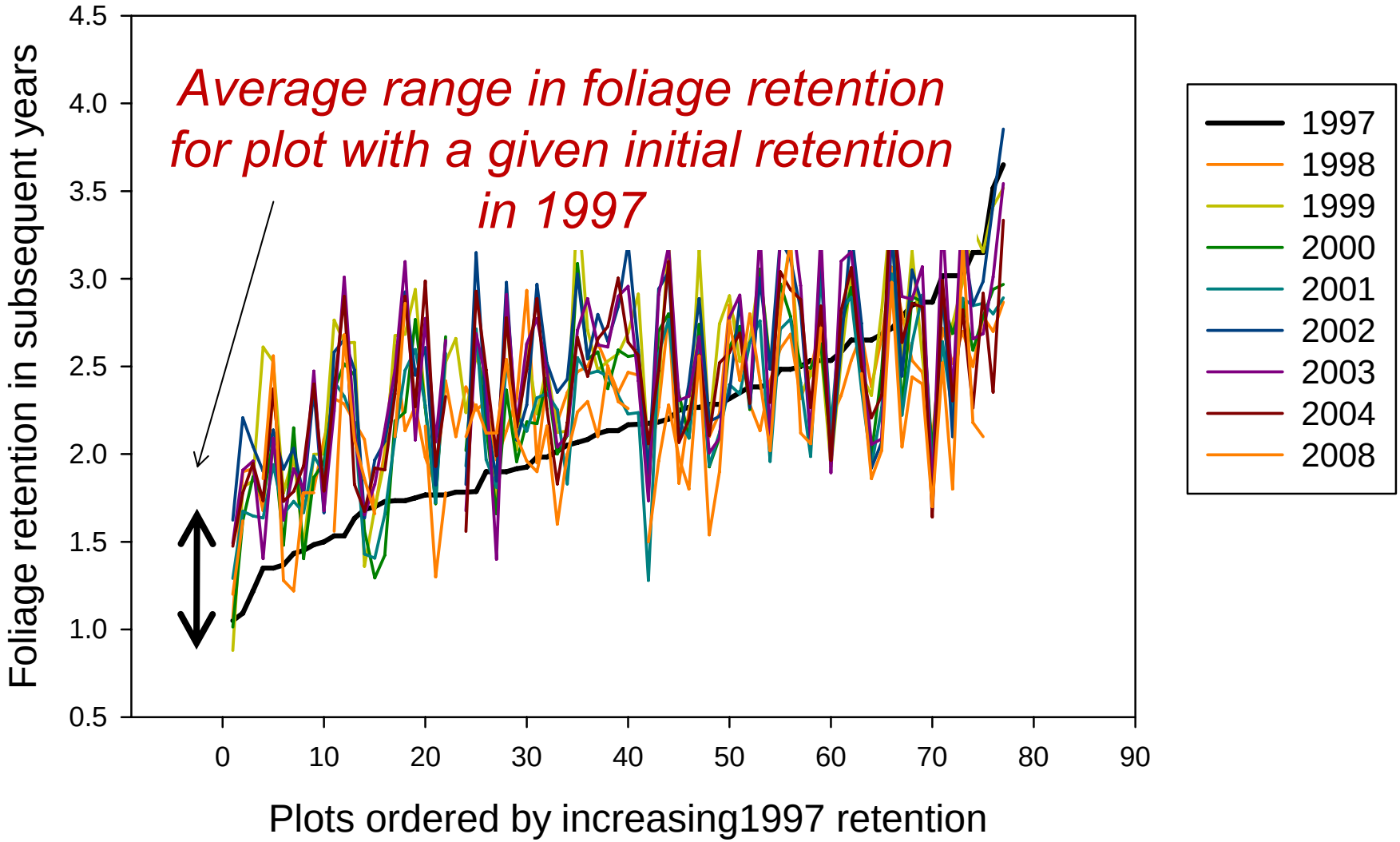
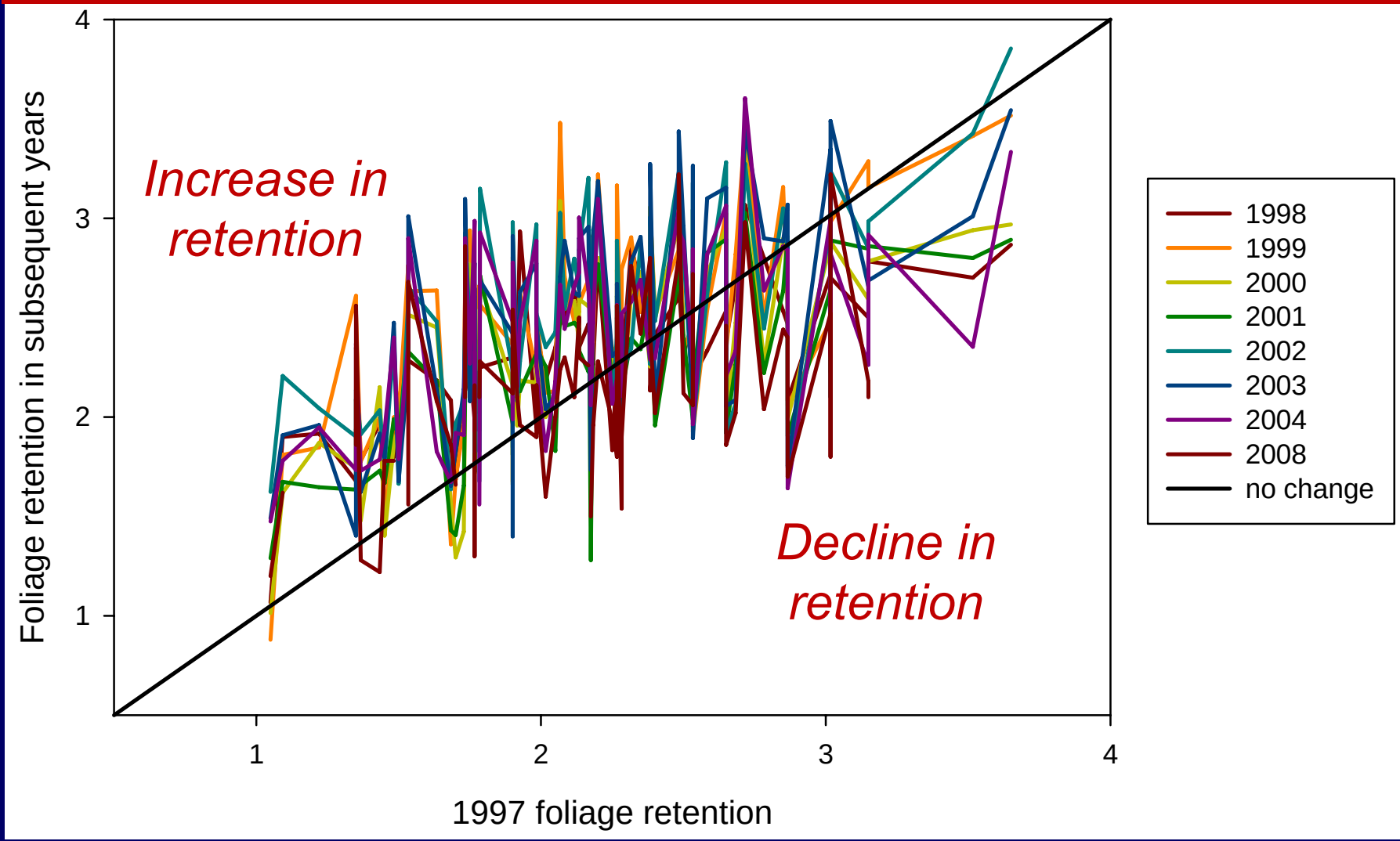


- Foliage retention exhibits annual fluctuations, but all plots do not vary in same direction or amount each year.
- Plot rank in disease severity changes over time.



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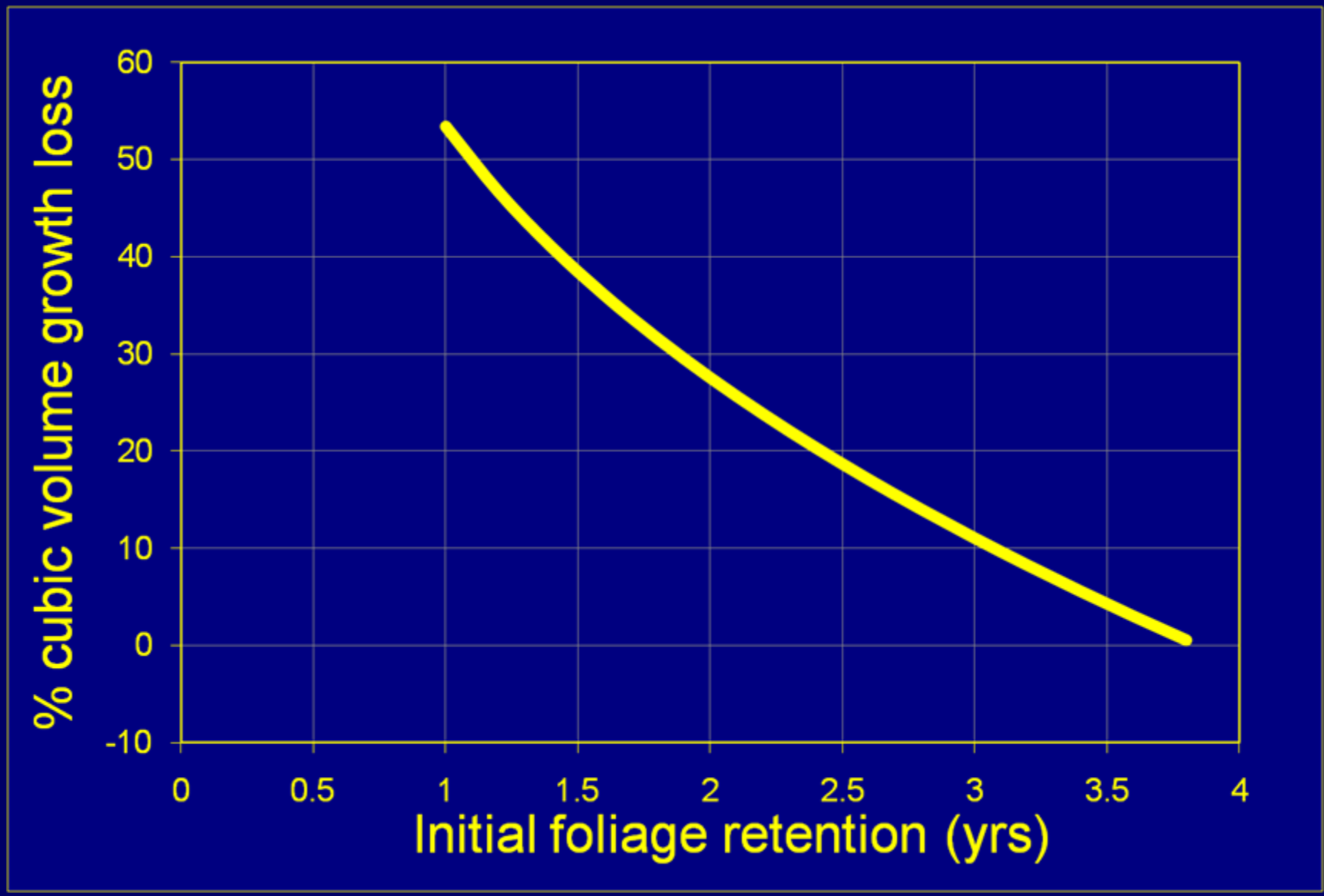
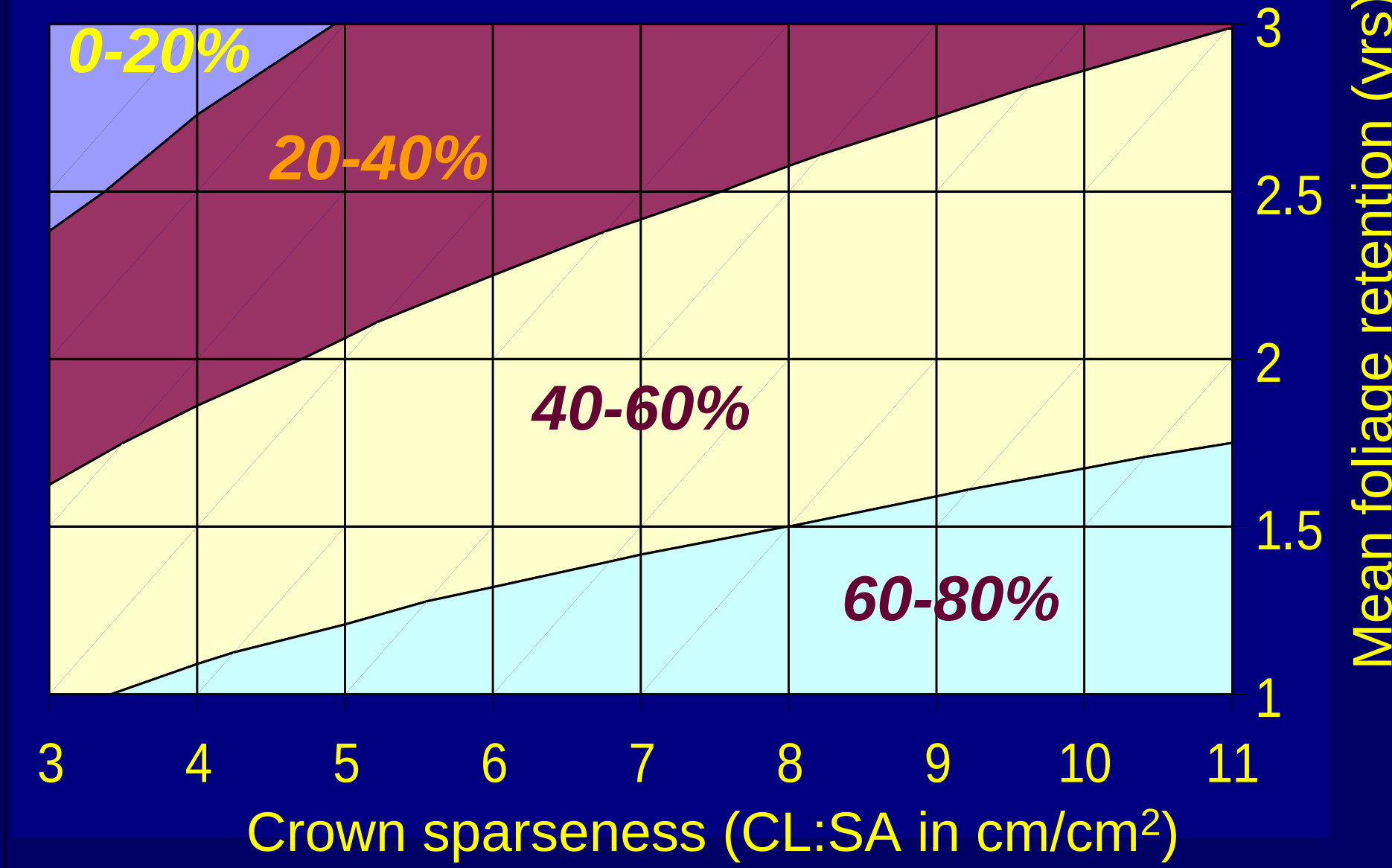
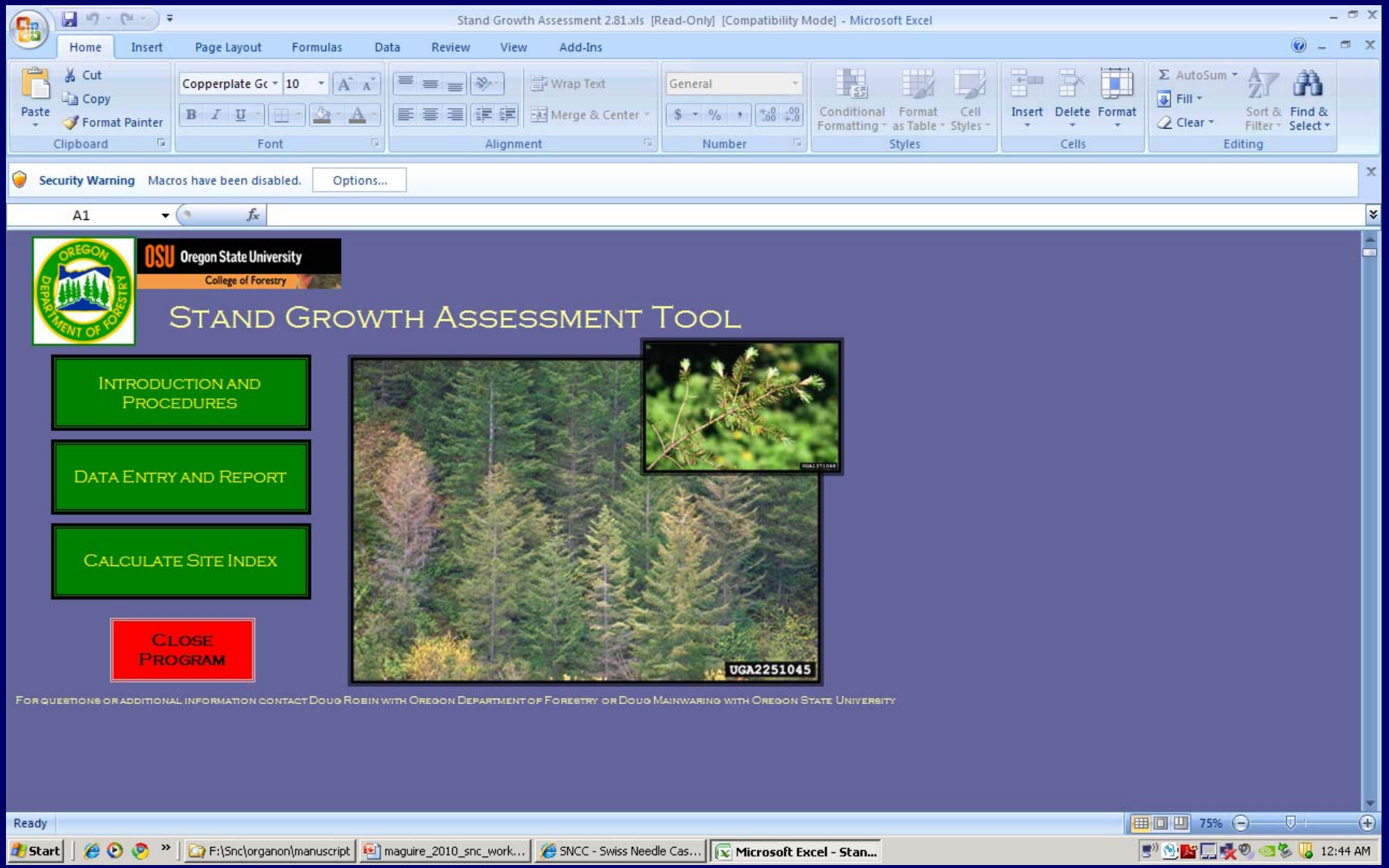
Average growth loss by initial foliage retention, 1998-2008



Cubic volume growth loss by foliage retention and crown sparseness

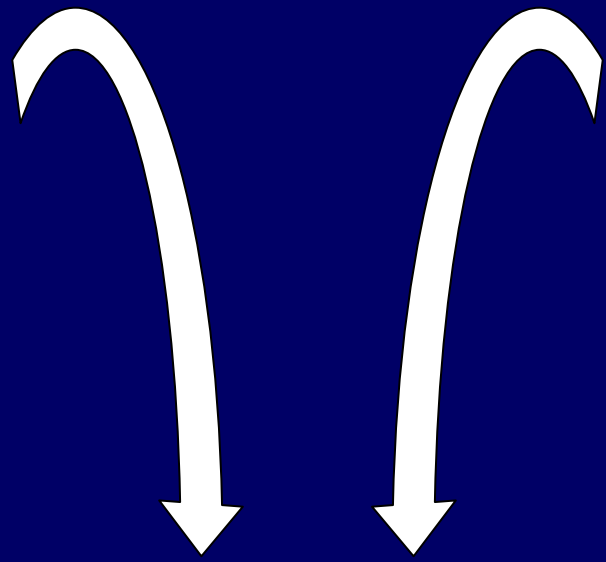


Stand Growth Assessment Tool



Stand Growth Assessment Tool

Measured stand growth

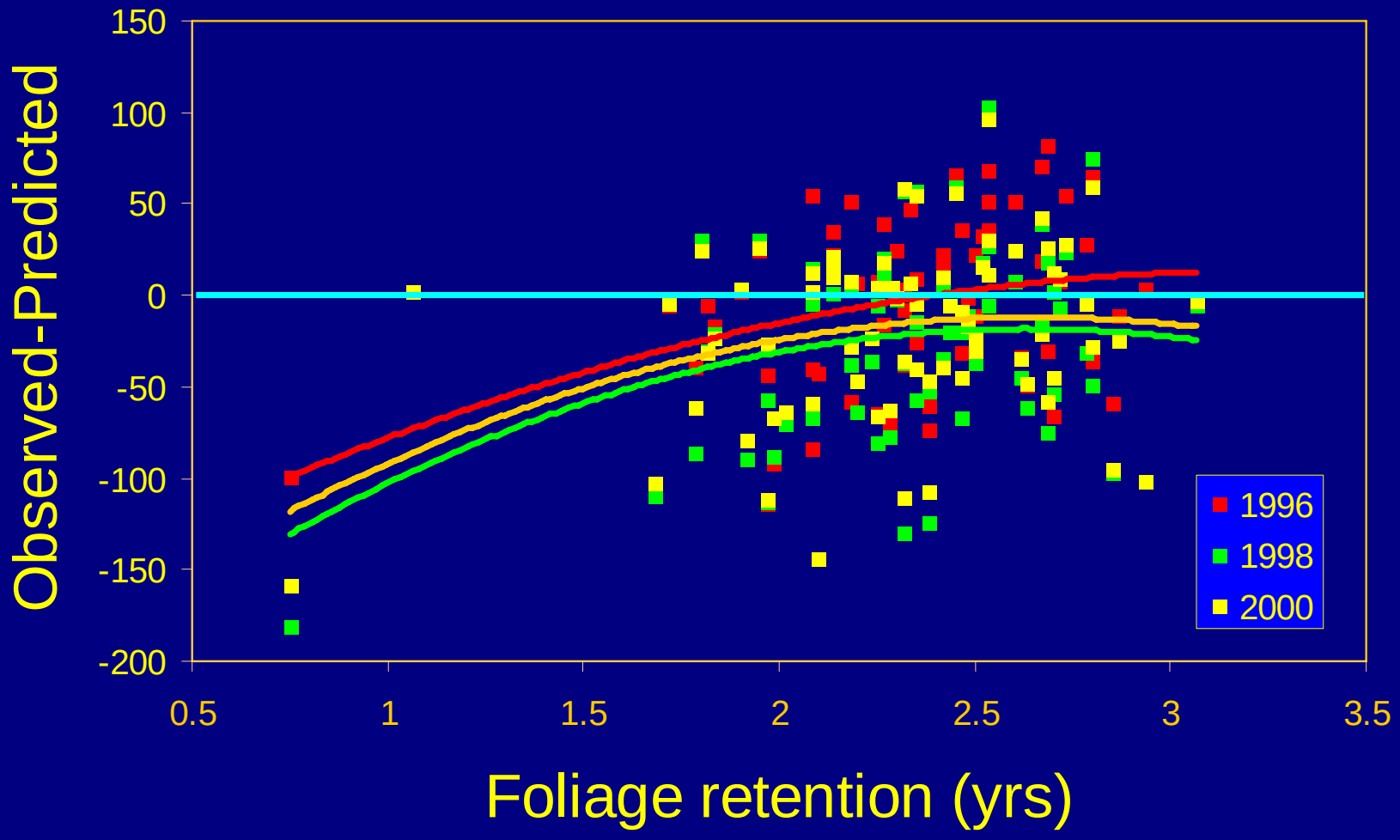


Expected stand growth

Diagnostic:

- Severity of SNC
- Relative priority for treatment

Comparison of observed PAIs to ORGANON predictions

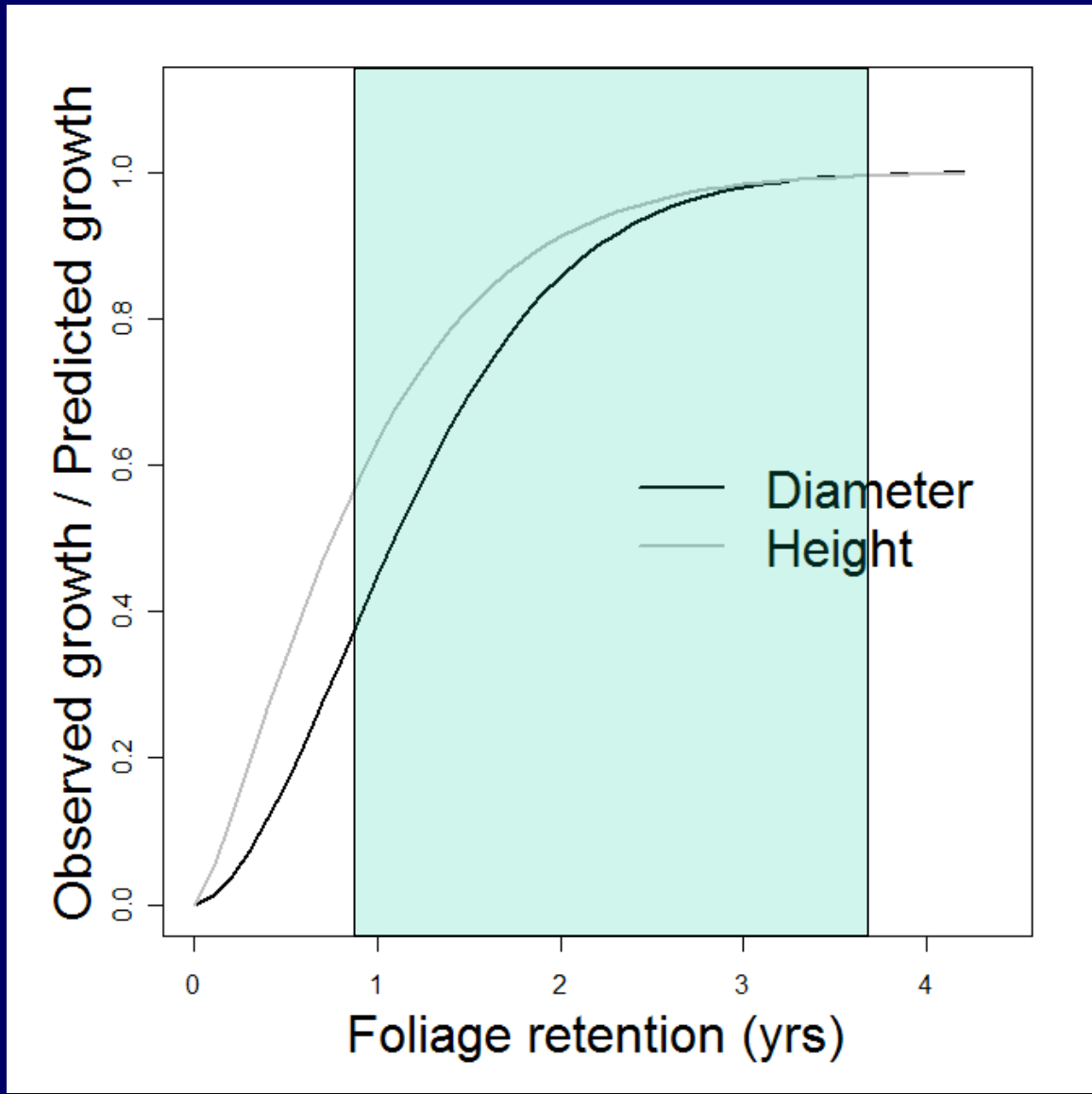


Growth does not meet expectation under severe SNC

Growth multiplier for diameter and height growth in the SMC variant of ORGANON.

Diameter:
$1-\exp(0.5952FR^{1.7121})$

Height:
$1-\exp(1.0021FR^{1.2802})$



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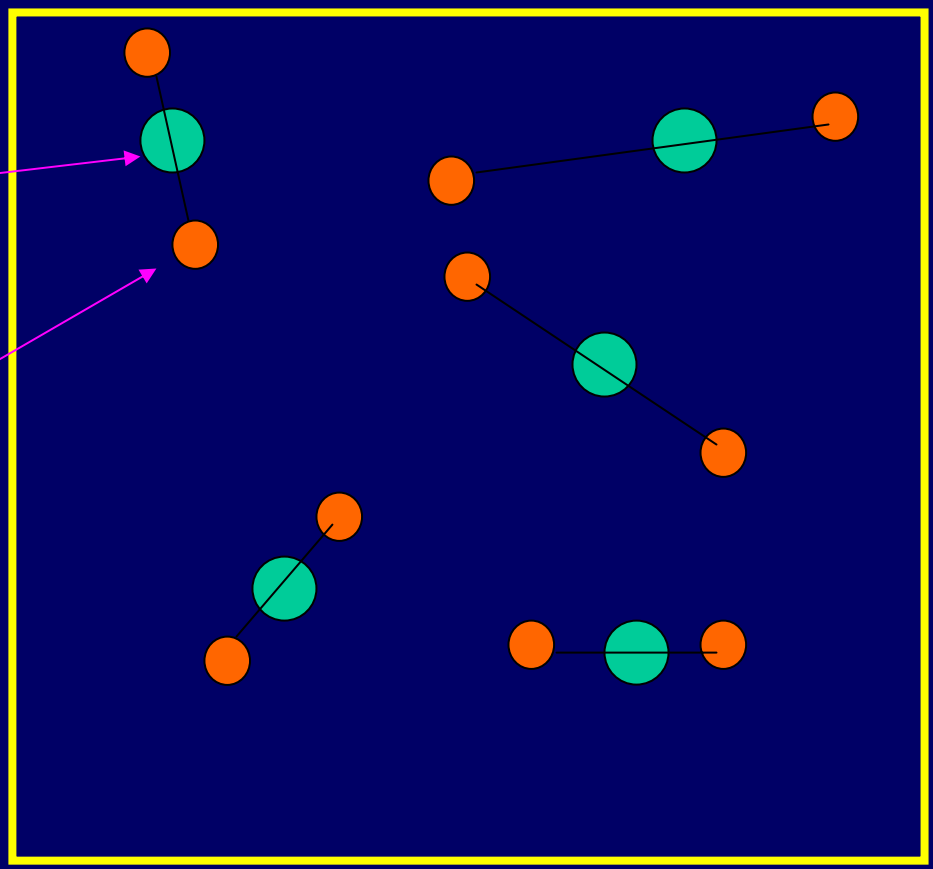
Soil and Foliar Chemistry

25 sites, half at each SNC extreme, early 2000

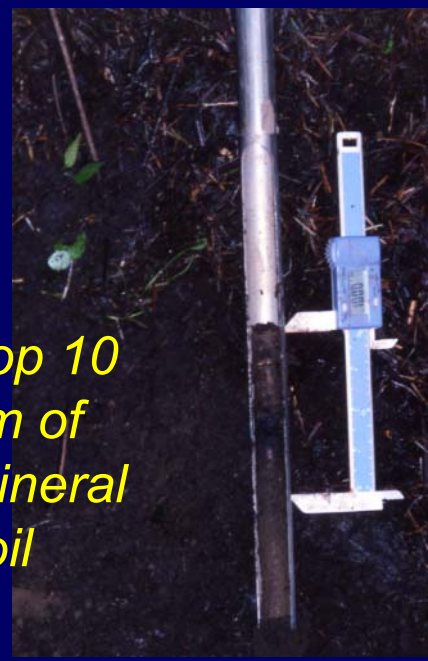
Soil cores located relative to 5 random SNC-rated trees:

tree

soil core



Random distance and azimuth from tree



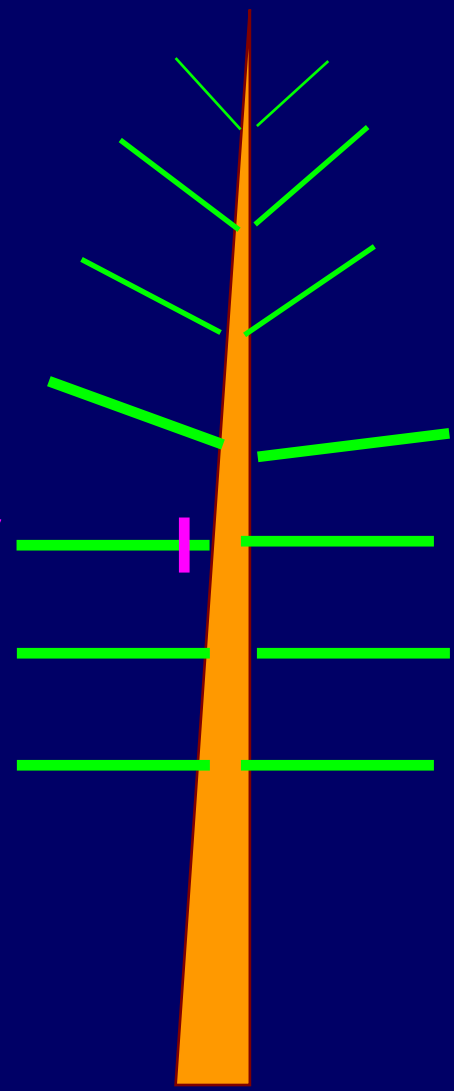
Top 10 cm of mineral soil

Sampling for foliar chemistry

5-YR-OLD SAMPLE BRANCH

(5TH WHORL DOWN FROM TREE TIP)

SAMPLE BRANCH



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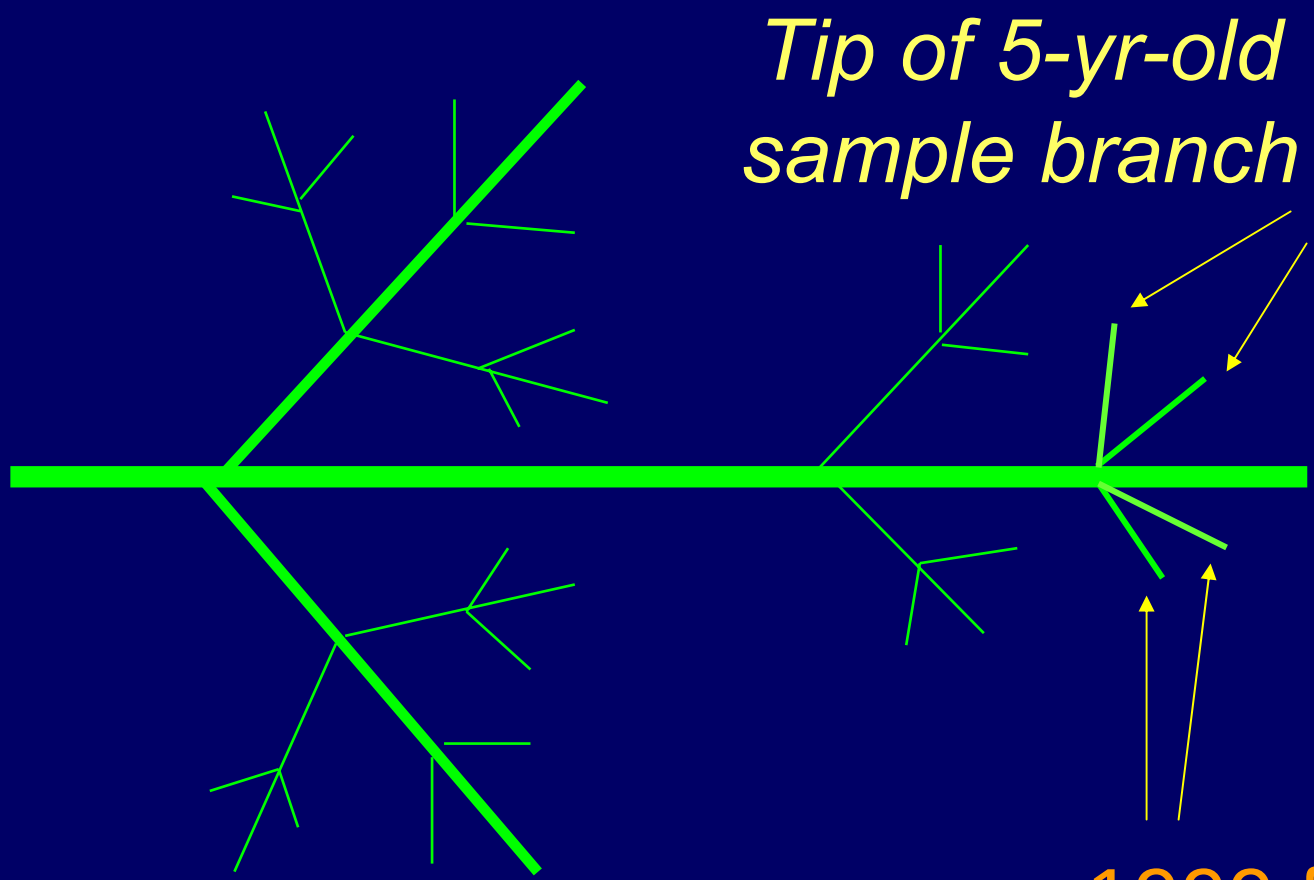
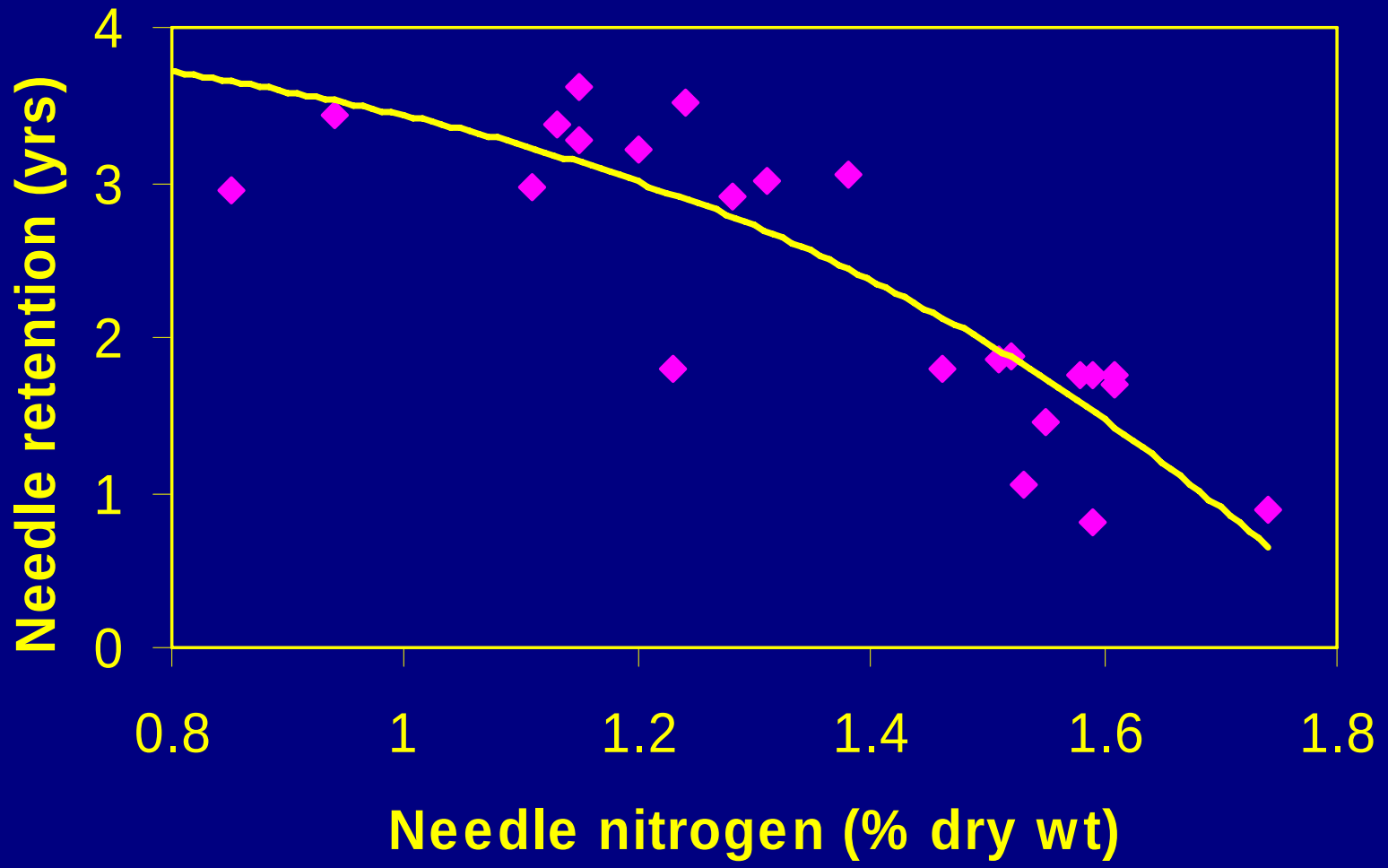
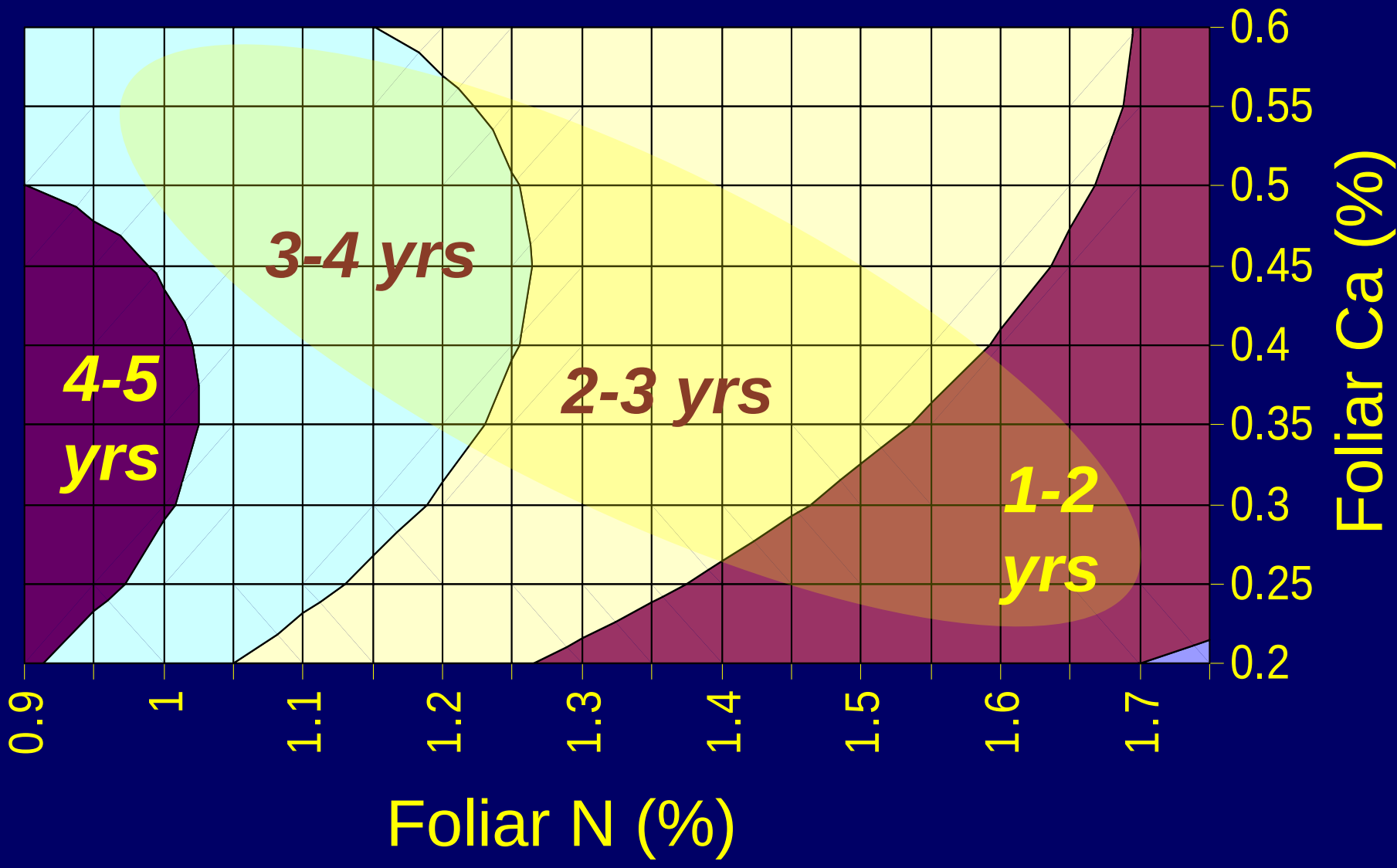


Needle Retention as a Function of Needle N Concentration



Needle retention by foliar N and Ca



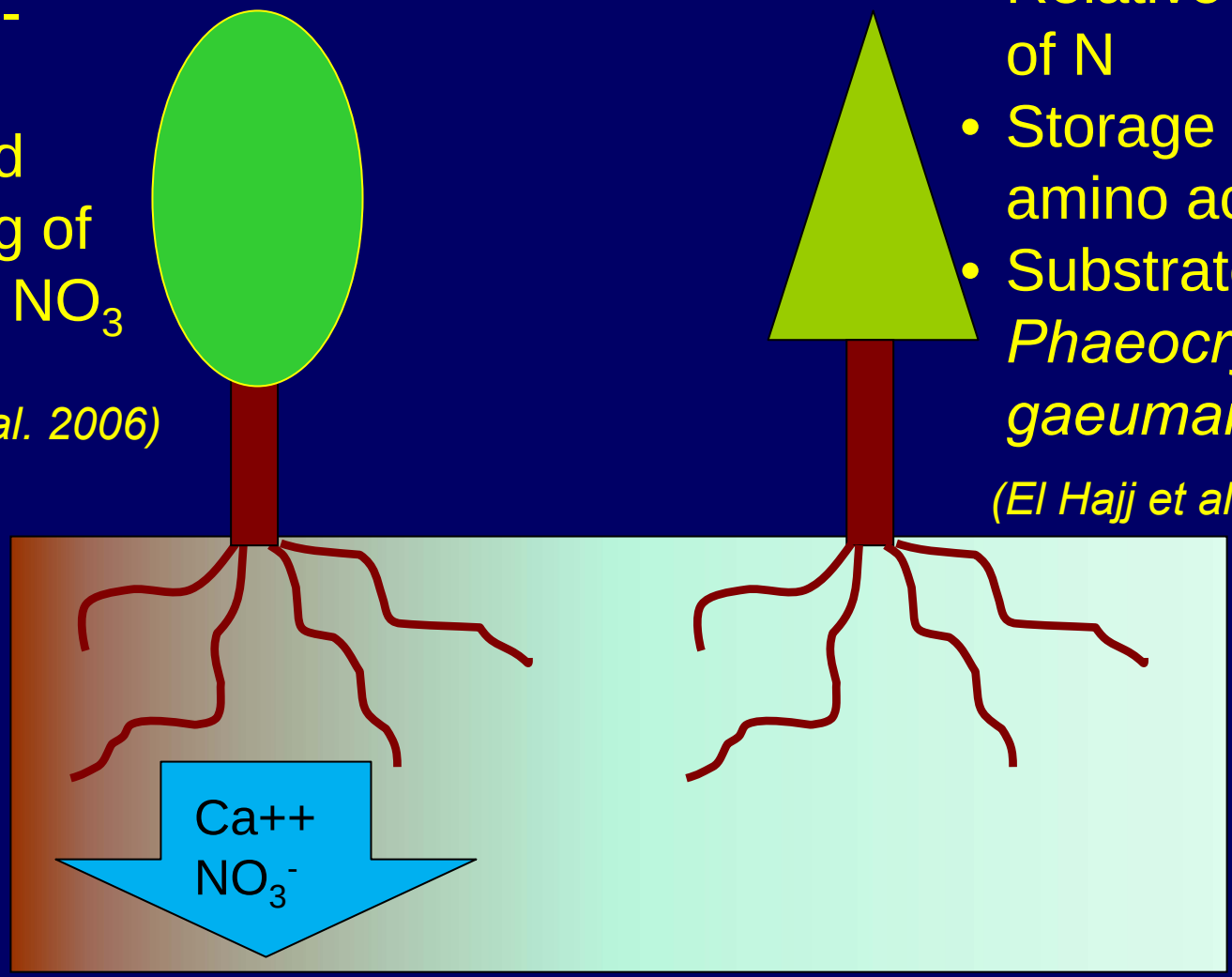
Growth Impact of Swiss needle cast

- ***S and NO_3 have consistently negative relationship to foliage retention***
- ***Ca has consistently positive relationship to foliage retention***
- Foliar S, foliar (or soil) Ca, and soil NO_3 "explain" 91% of the variation in foliage retention

One hypothesis

- Alder N-fixation
- Coupled leaching of Ca and NO_3

(Perakis et al. 2006)

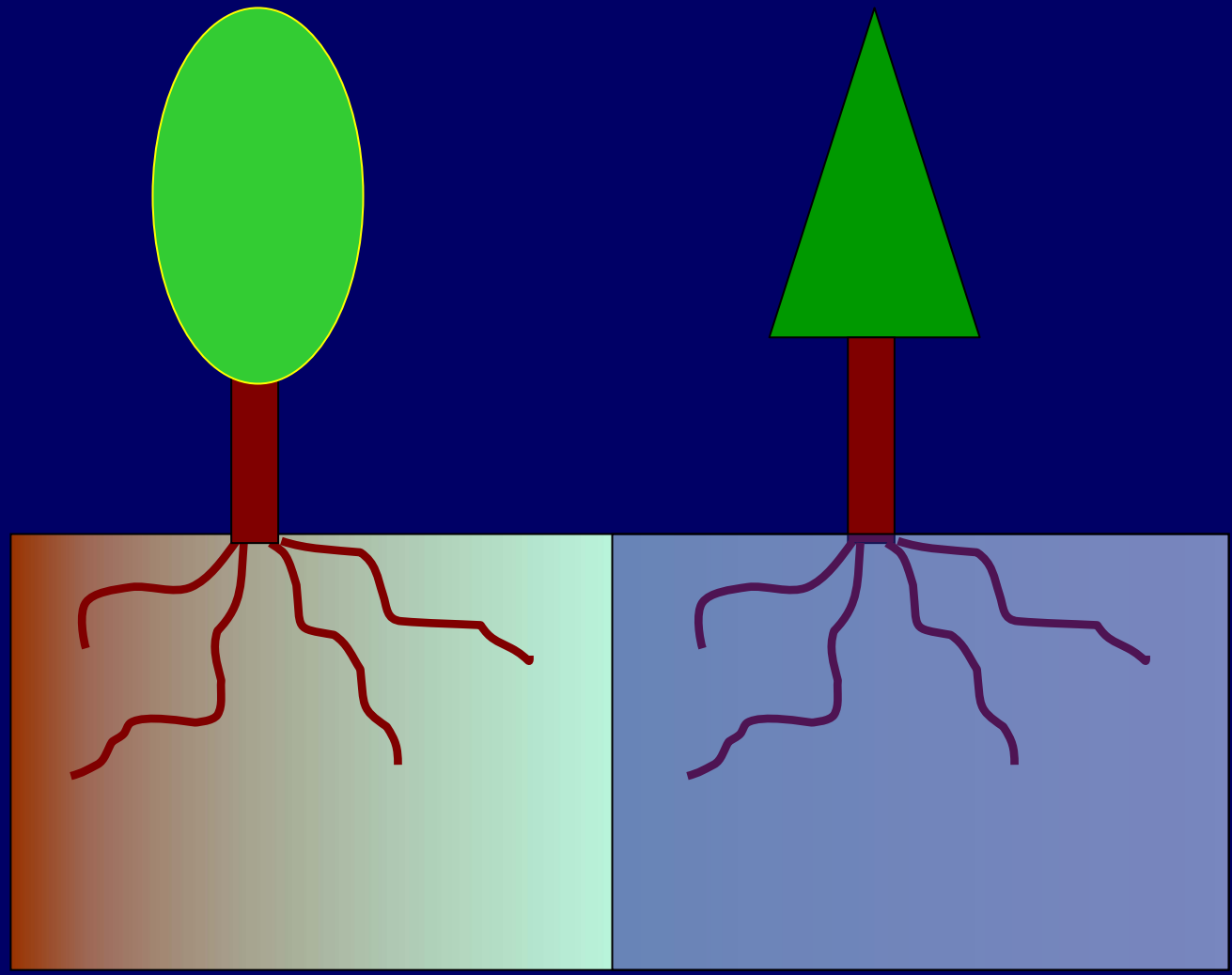


- Relative excess of N
- Storage as free amino acids
- Substrate for *Phaeocryptopus gaeumannii*

(El Hajj et al. 2004)

Can fertilization ameliorate SNC?

(Main Doug has the rest of the story . . .)



Climatic influences

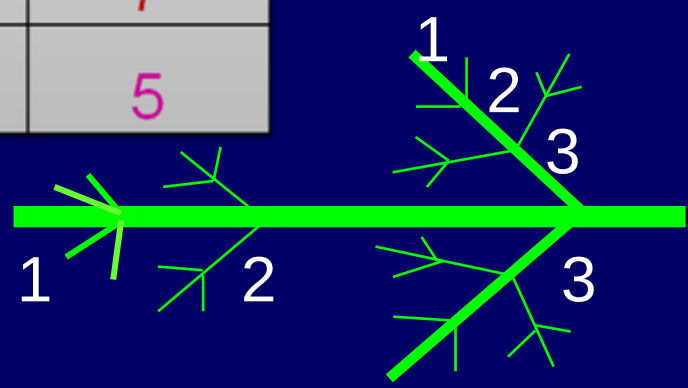
Climatic influences on foliage retention

- Geographic variation: Risk defined by local climatic factors (Rosso, Hansen, Coop, Stone, Latta)
- Annual variation: Driven by long-term site average and annual fluctuations in climatic conditions (Zhao)
  - Lagged climatic variables:
    - Winter temperature
    - Spring/summer wetness
    - Late summer heat
- Dynamics of individual needle cohorts that contribute to foliage retention (Zhao)

Foliage retention by age class or cohort

Year of observation	Foliage retention by age class			
	1	2	3	4
1997	9	9	8	5
1998				
1999	9	8	5	3
2000	9	9	5	0
2001	9	9	8	2
2002	9	8	7	7
2003	9	7	6	5

9 -> 90-100%
8 -> 80-89%
.
.
.
0 -> 0-9%



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2000	9	9	5	0
2001	9	9	8	2
2002	9	8	7	7
2003	9	7	6	5

1993 cohort

1994 cohort

1995 cohort

1996 cohort

1997 cohort

1998 cohort

2002 cohort

2001 cohort

2000 cohort

1999 cohort

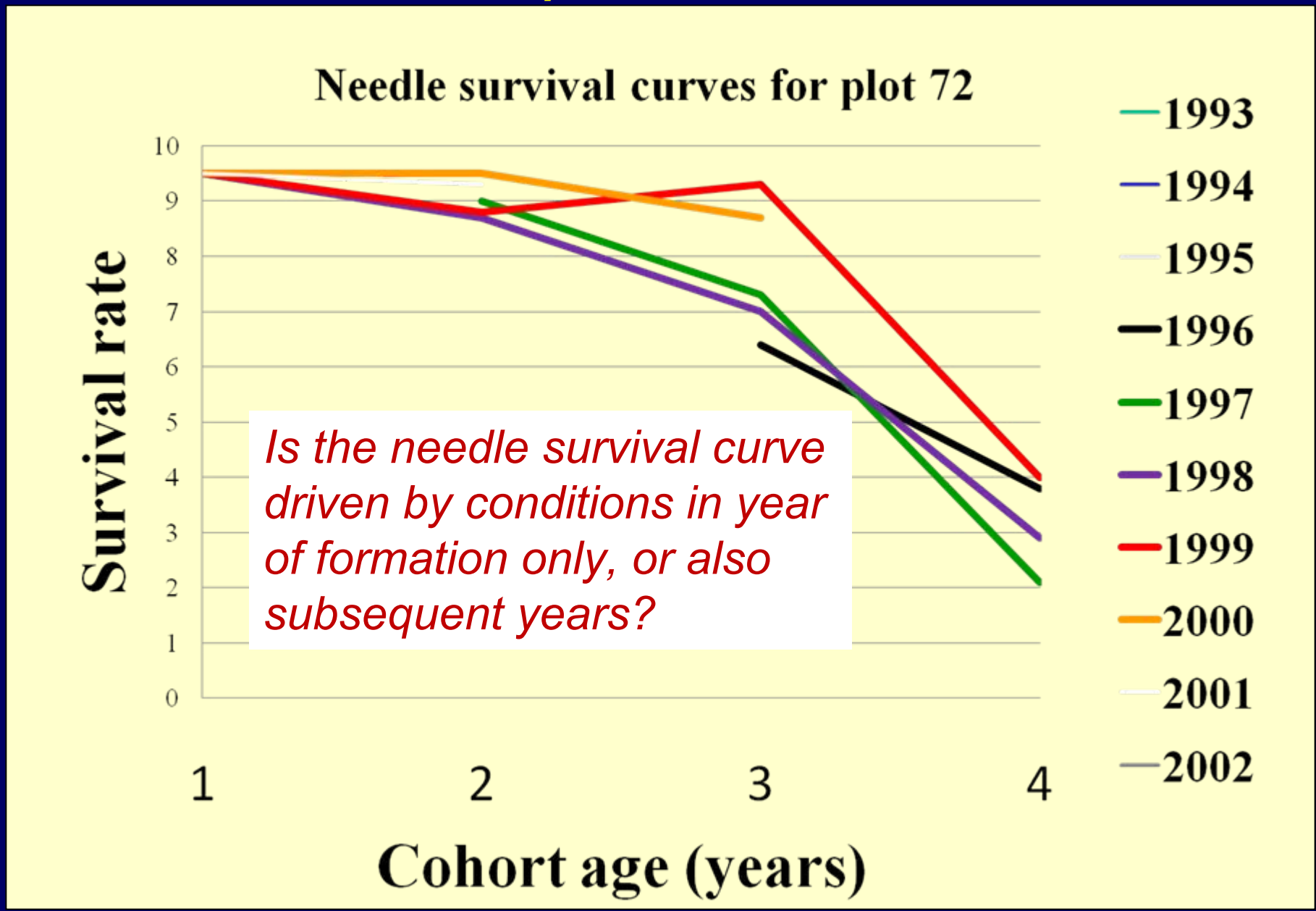
System of equations

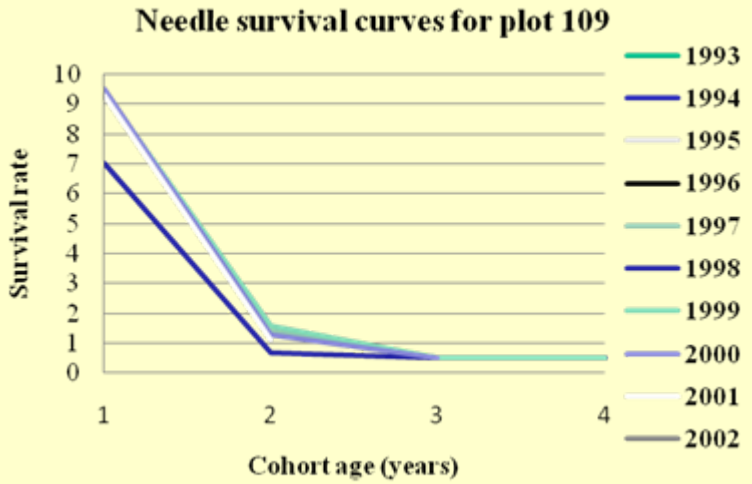
Foliage retention by age class as function of climatic variables with differing lag times

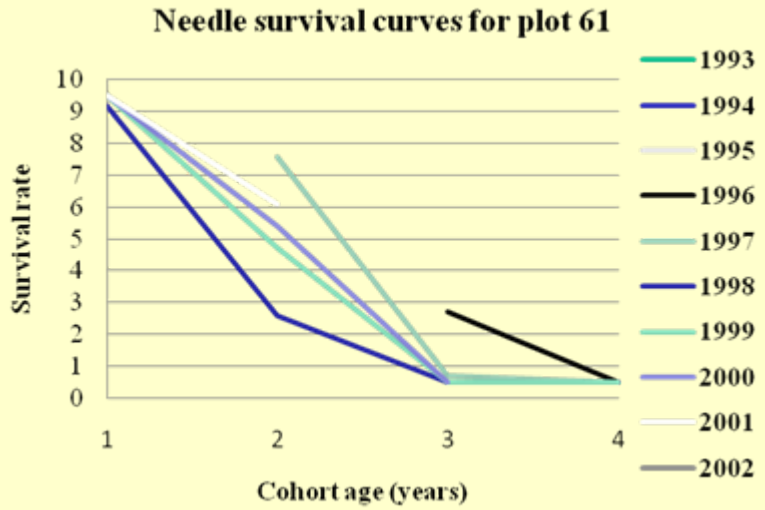
$$FR1_t = \beta_{10} + \beta_{11}SW_{t-1} + \beta_{12}WT_t + \beta_{13}SH_{t-1} + \varepsilon_1$$
$$FR2_t = \beta_{20} + \beta_{21}SW_{t-2} + \beta_{22}WT_{t-1} + \beta_{23}SH_{t-2} + \varepsilon_2$$
$$FR3_t = \beta_{30} + \beta_{31}SW_{t-3} + \beta_{32}WT_{t-2} + \beta_{33}SH_{t-3} + \varepsilon_3$$
$$FR4_t = \beta_{40} + \beta_{41}SW_{t-4} + \beta_{42}WT_{t-3} + \beta_{43}SH_{t-4} + \varepsilon_4$$

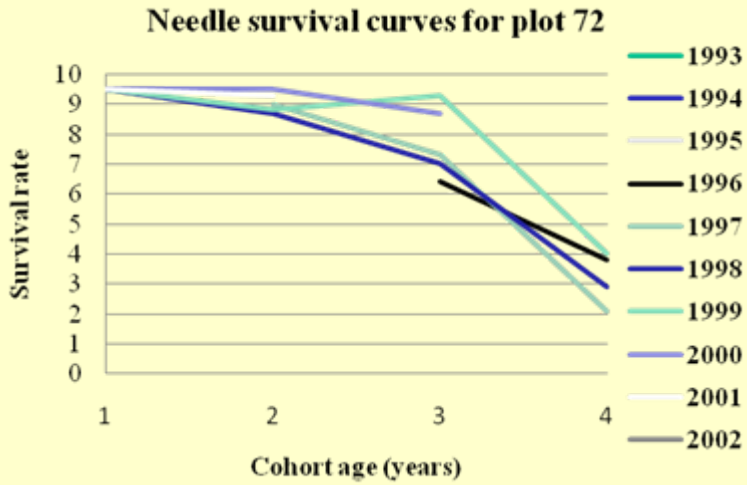
- FRk_t = Foliage retention of k-yr-old foliage at time *t*
- β_k = Parameter to be estimated from the data
- SW_t = Spring/summer wetness at time *t*
- WT_t = Winter temperature at time *t*
- SH_{t-1} = Summer heat at time *t*
- ε_1 = *Error term for equation k, assumed correlated with error term from other equations*

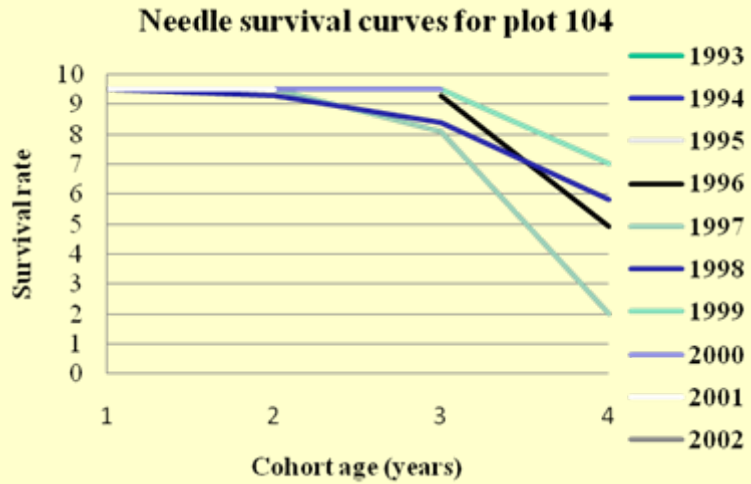
Needle survivorship models



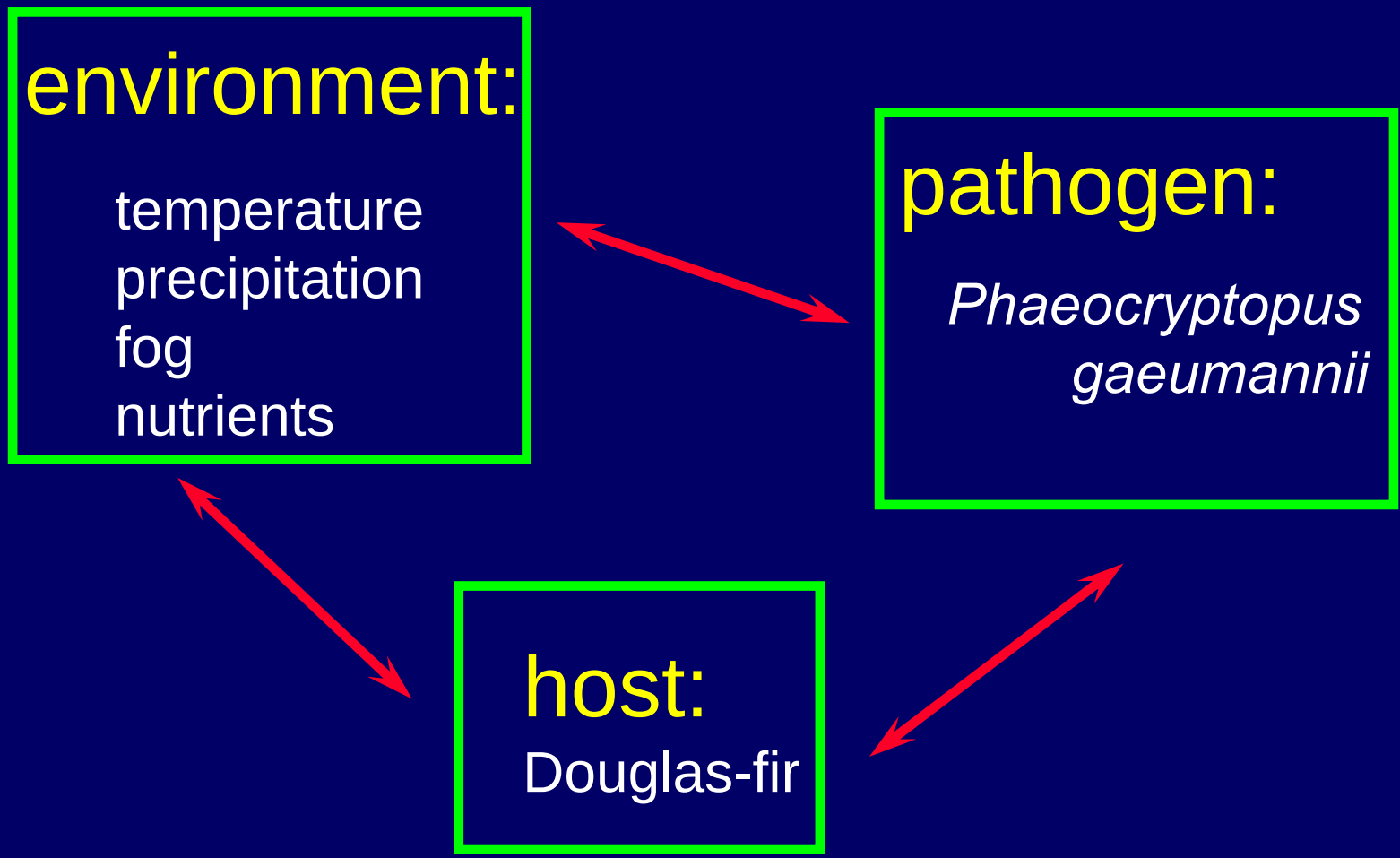

Needle survival curves for plot 109
Survival rate
Cohort age (years)
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002


Needle survival curves for plot 61
Survival rate
Cohort age (years)
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002


Needle survival curves for plot 72
Survival rate
Cohort age (years)
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

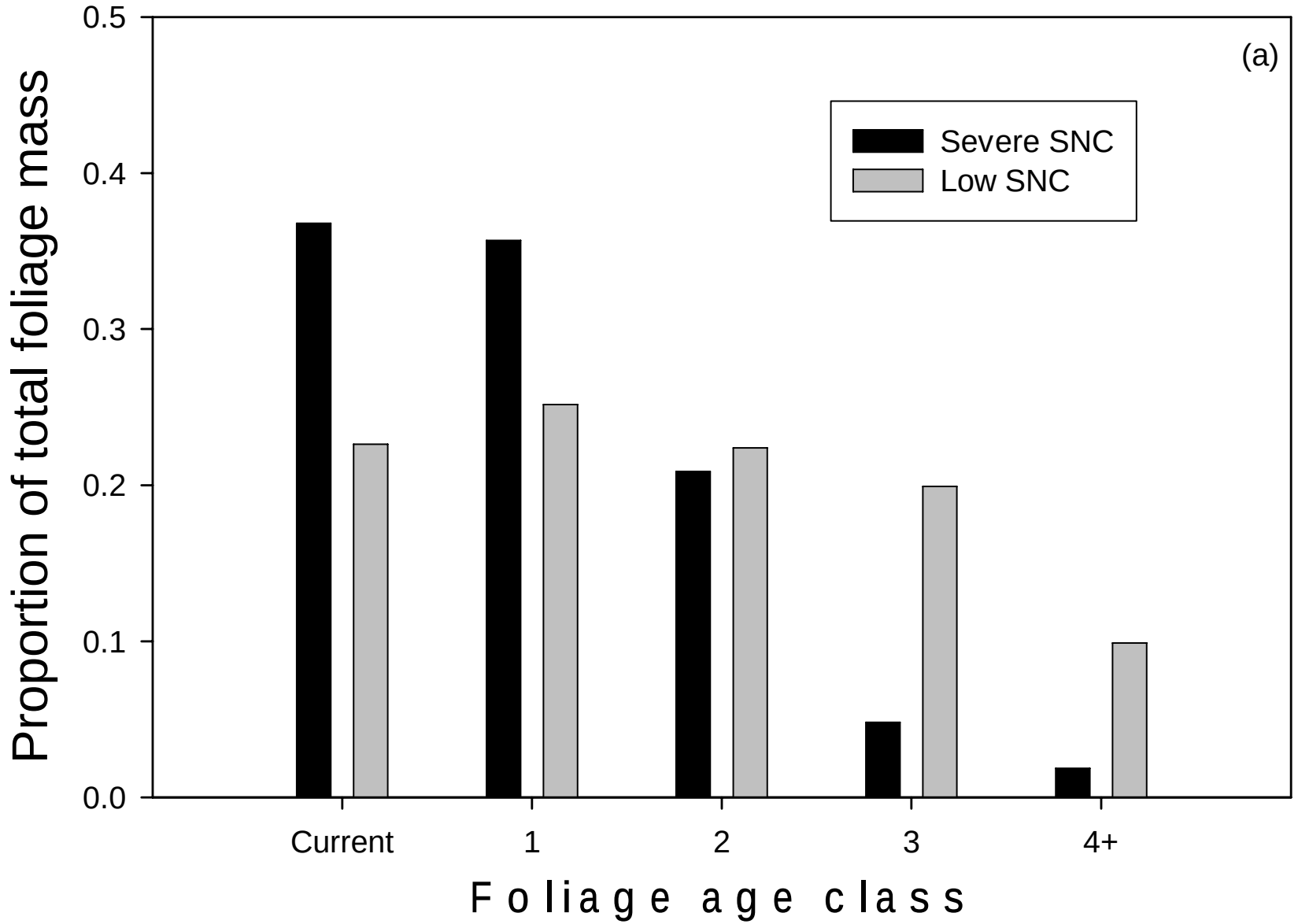

Needle survival curves for plot 104
Survival rate
Cohort age (years)
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

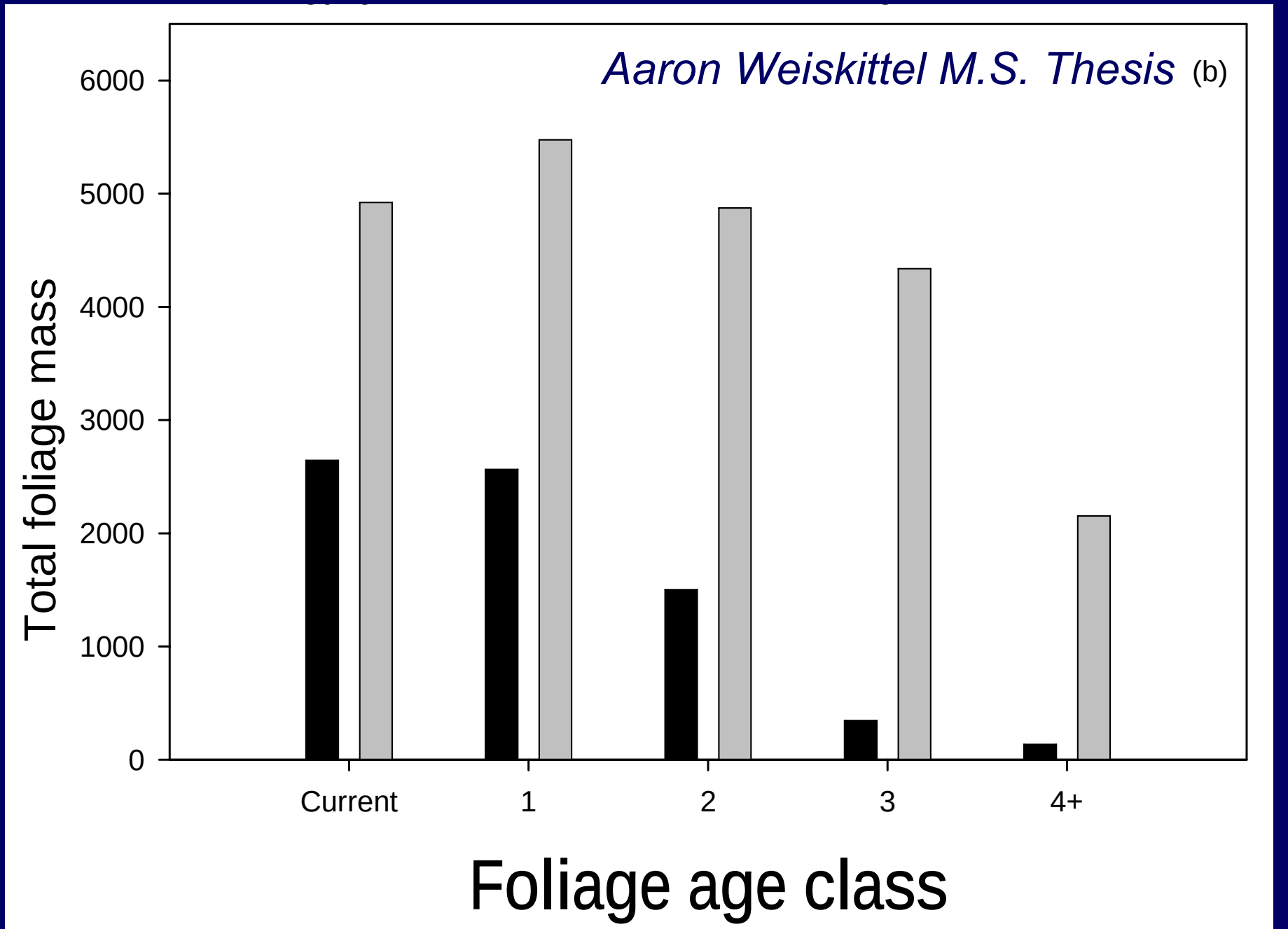
Disease triangle !



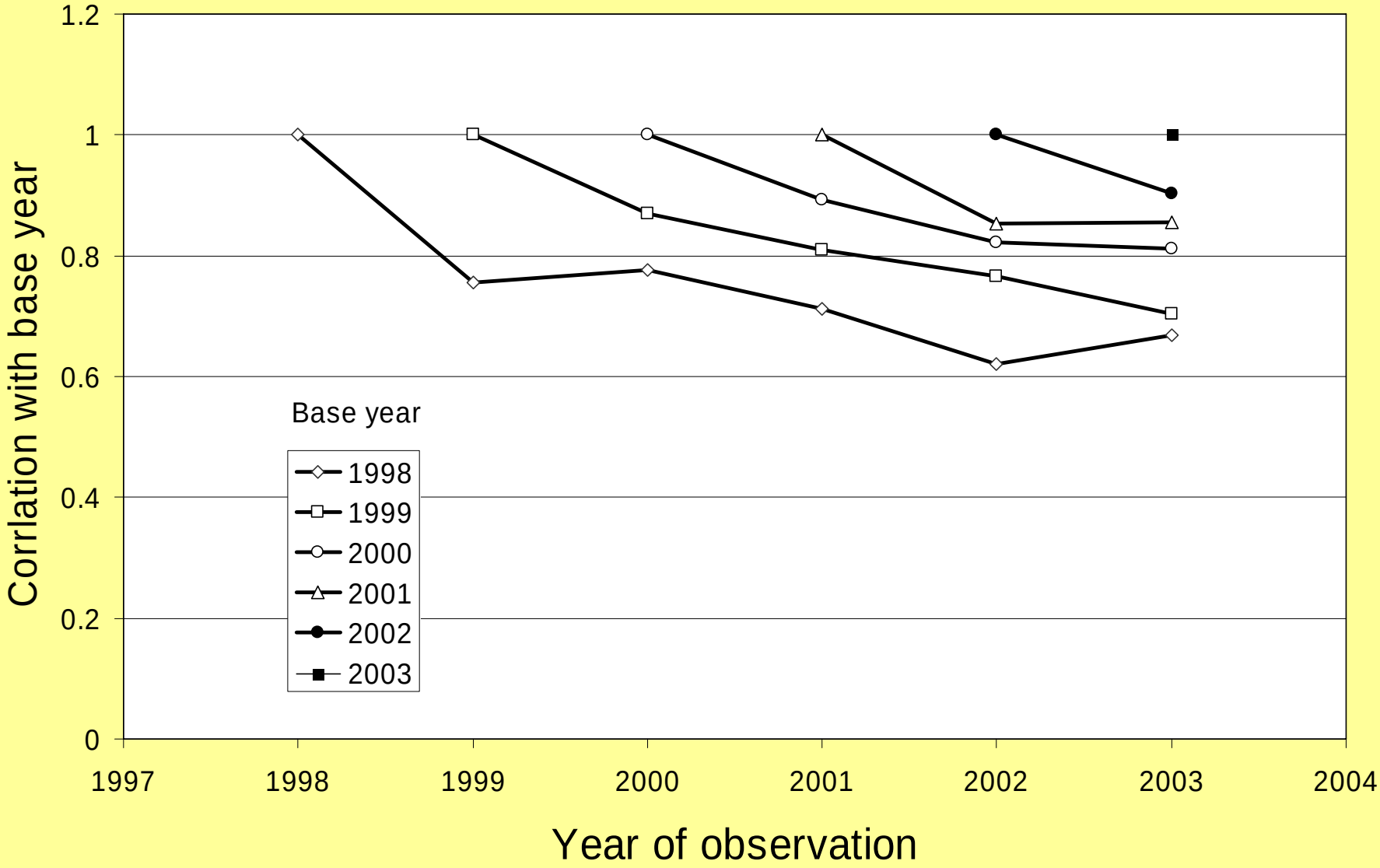

Thanks . . . now on to Main Doug . . .

Aaron Weiskittel M.S. Thesis

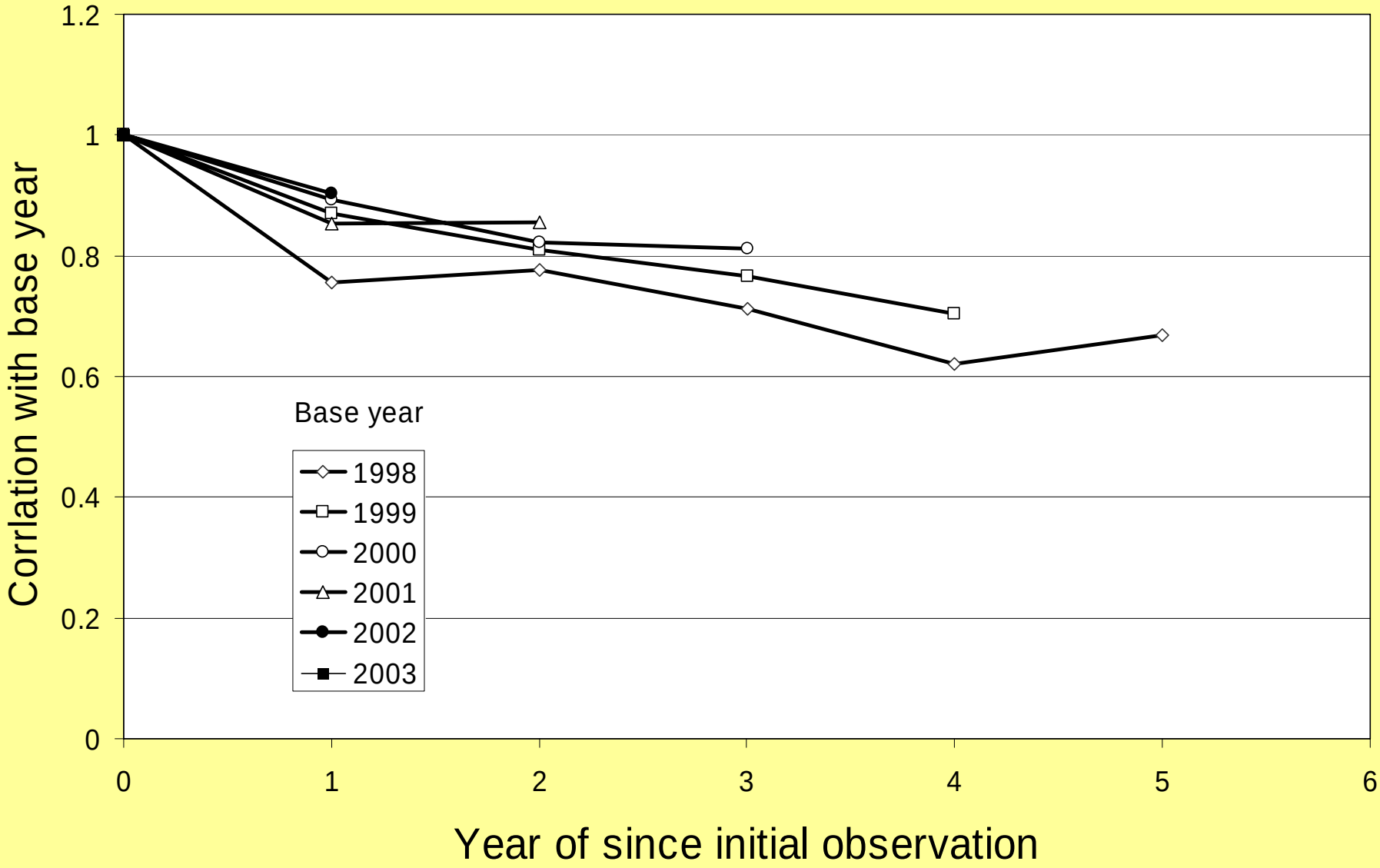



Aaron Weiskittel M.S. Thesis (b)
Total foliage mass
6000
5000
4000
3000
2000
1000
0
Current
1
2
3
4+
Foliage age class

Foliage retention rank correlations

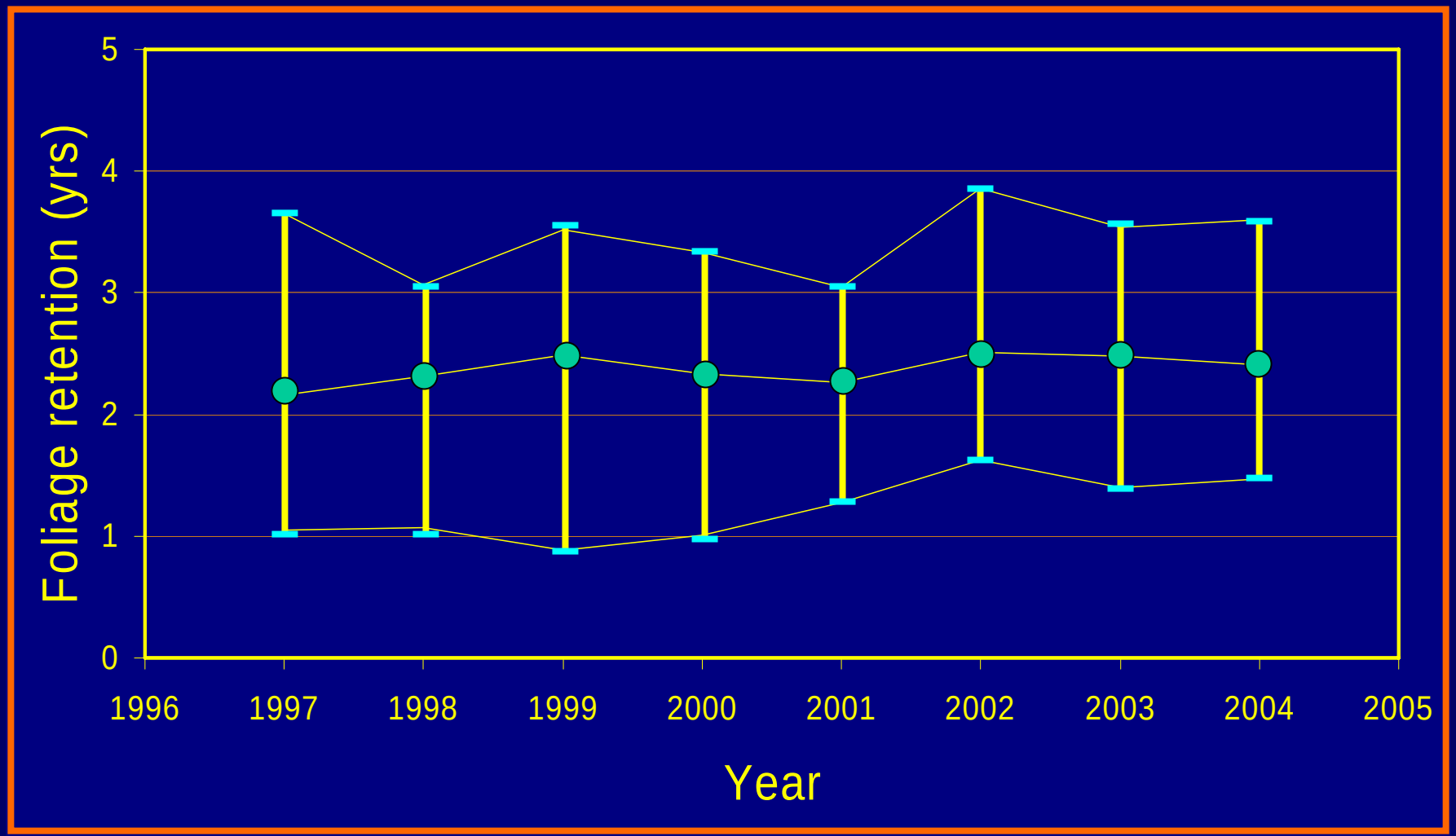


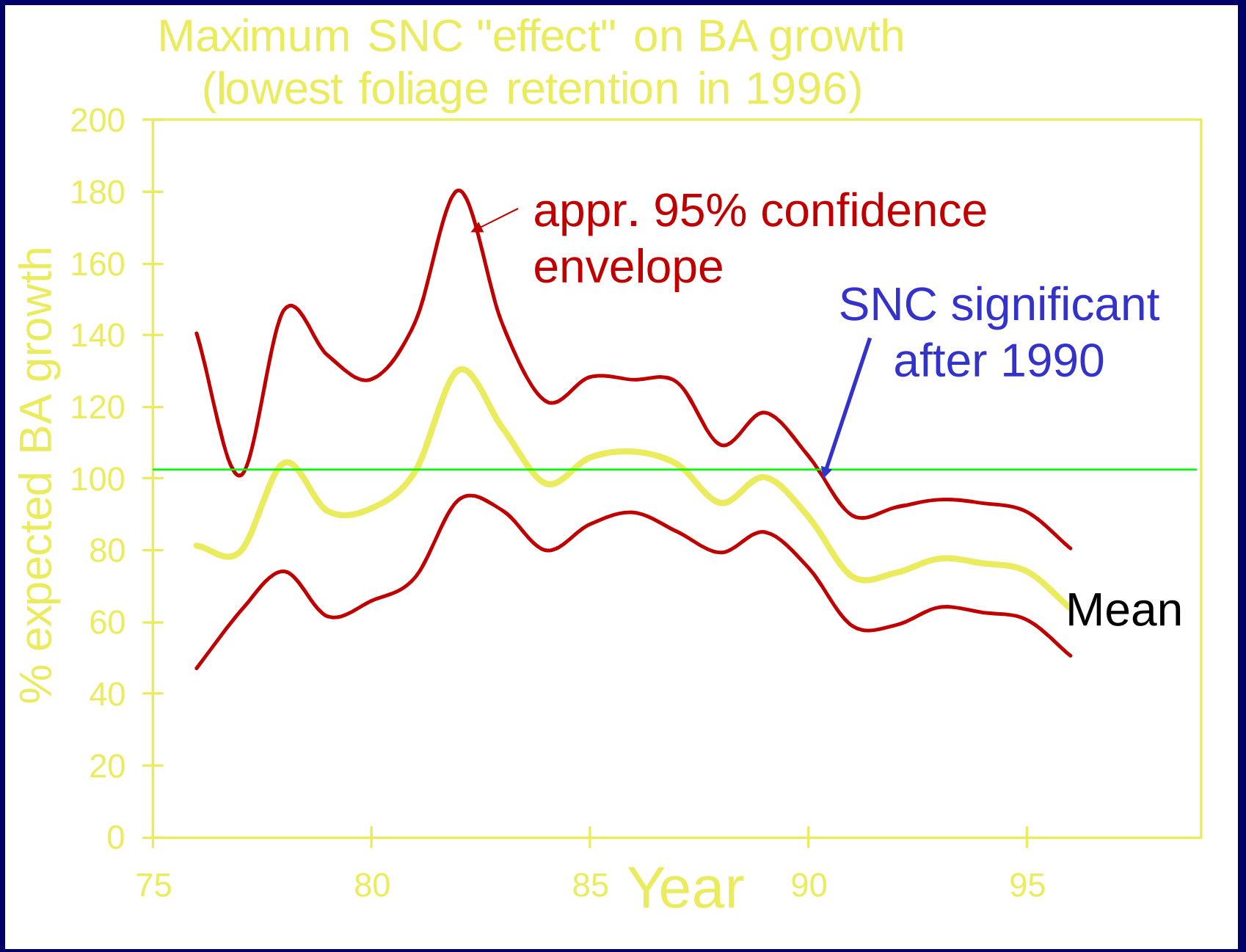
Foliage retention rank correlations



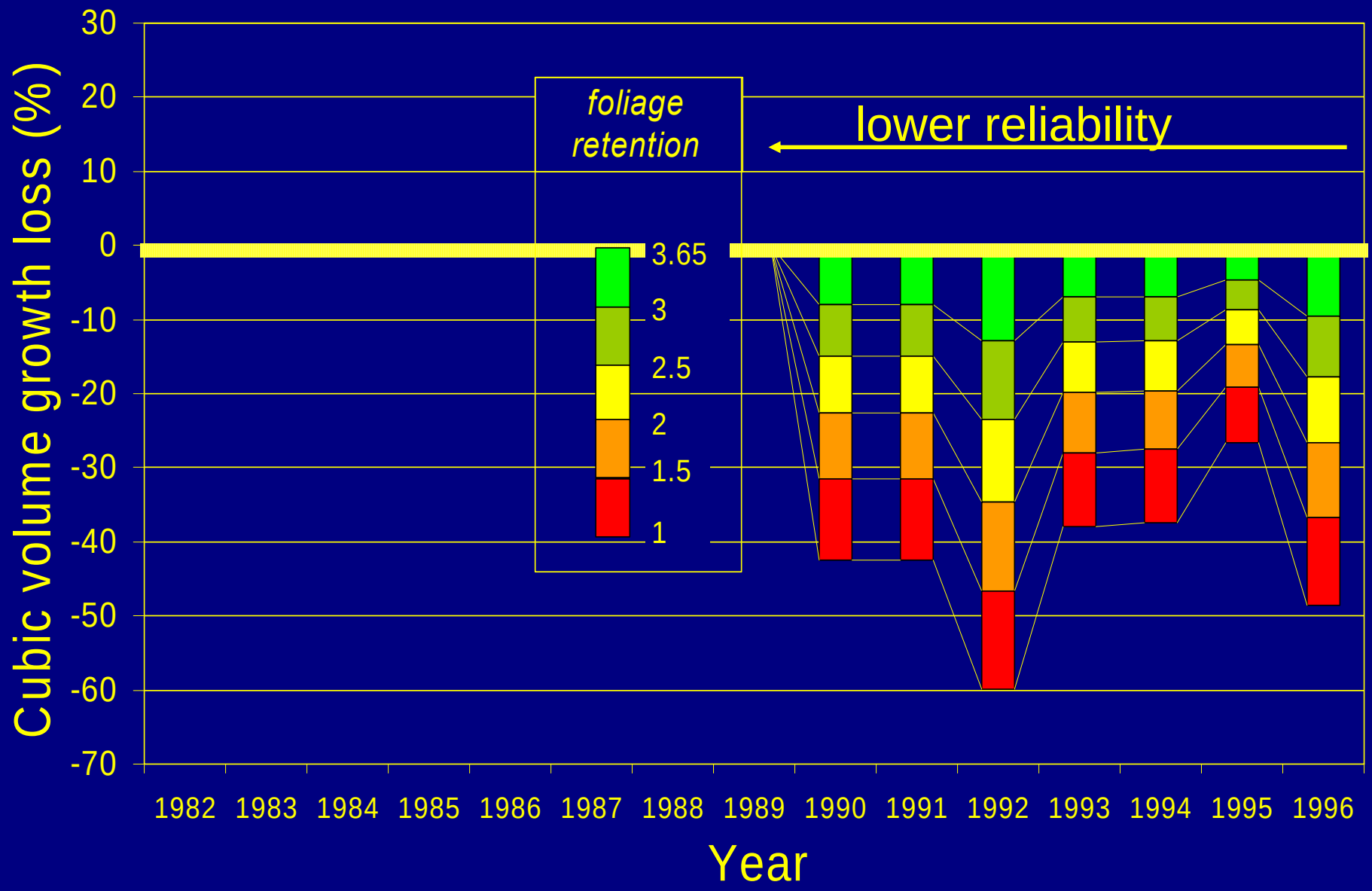
Growth Impact of Swiss needle cast

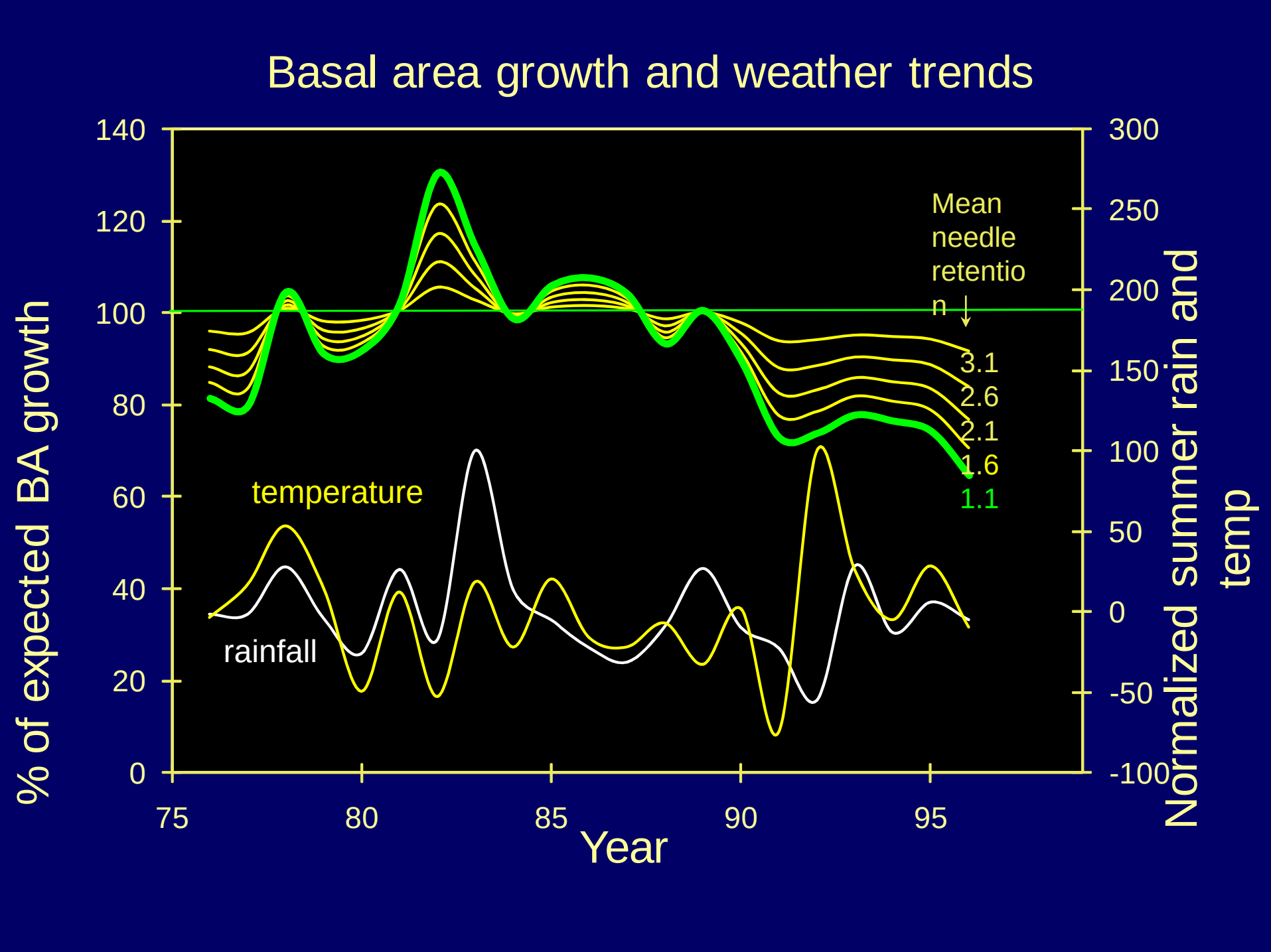
- What is the range in SNC severity?



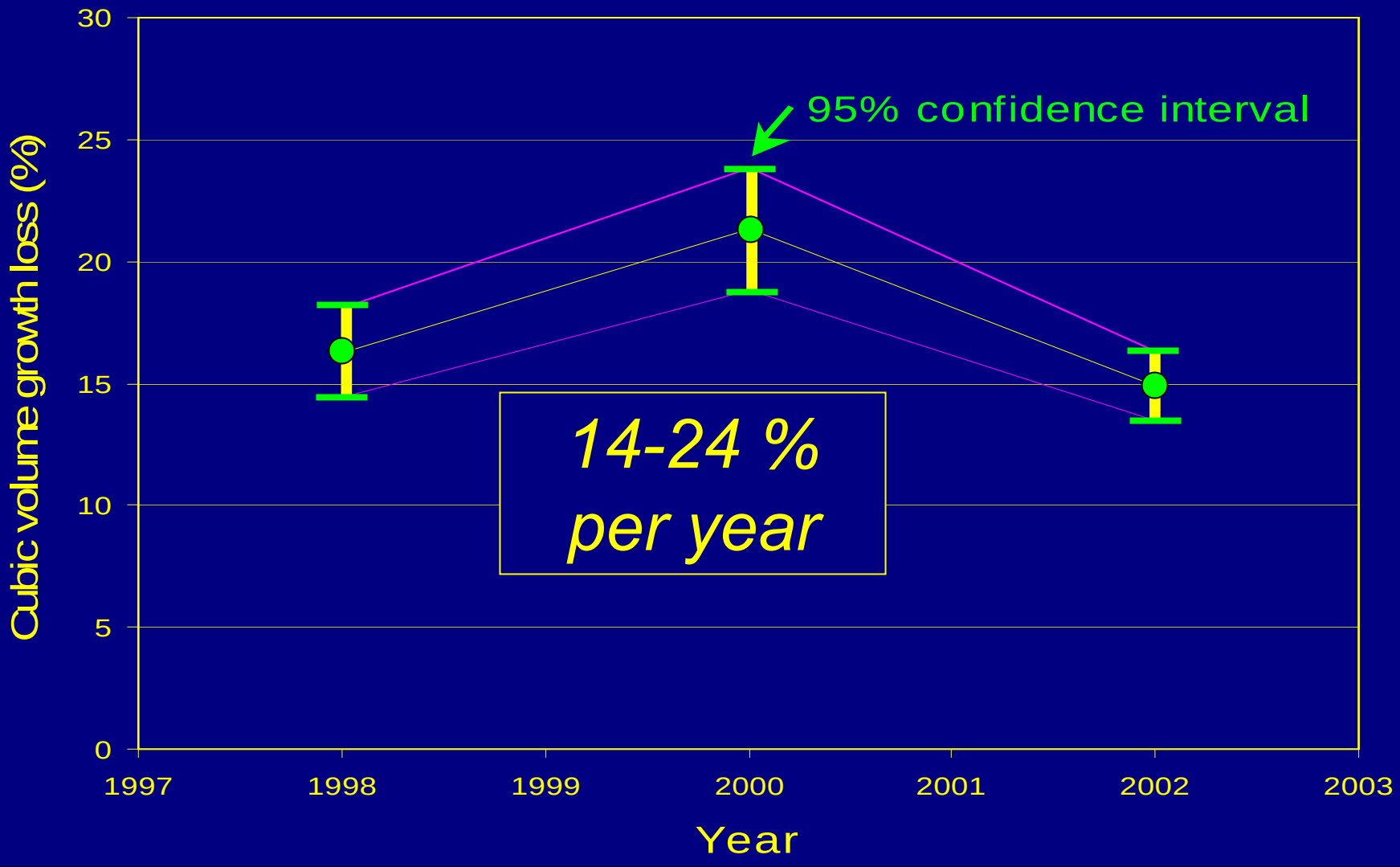

Maximum SNC "effect" on BA growth
(lowest foliage retention in 1996)
% expected BA growth
200
180
160
140
120
100
80
60
40
20
0
appr. 95% confidence
envelope
SNC significant
after 1990
Mean
75
80
85
Year
90
95

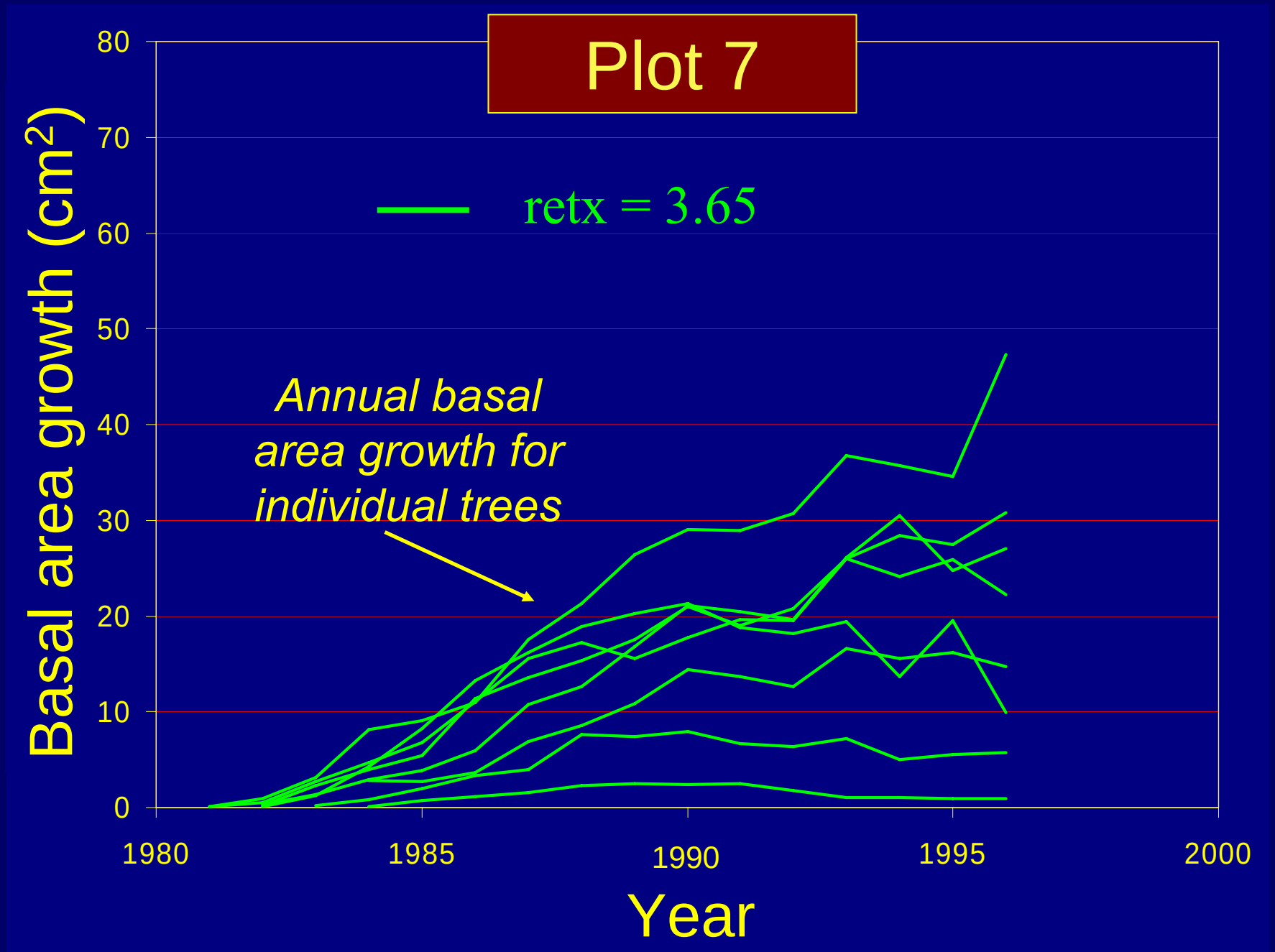
Growth losses estimated from retrospective analysis

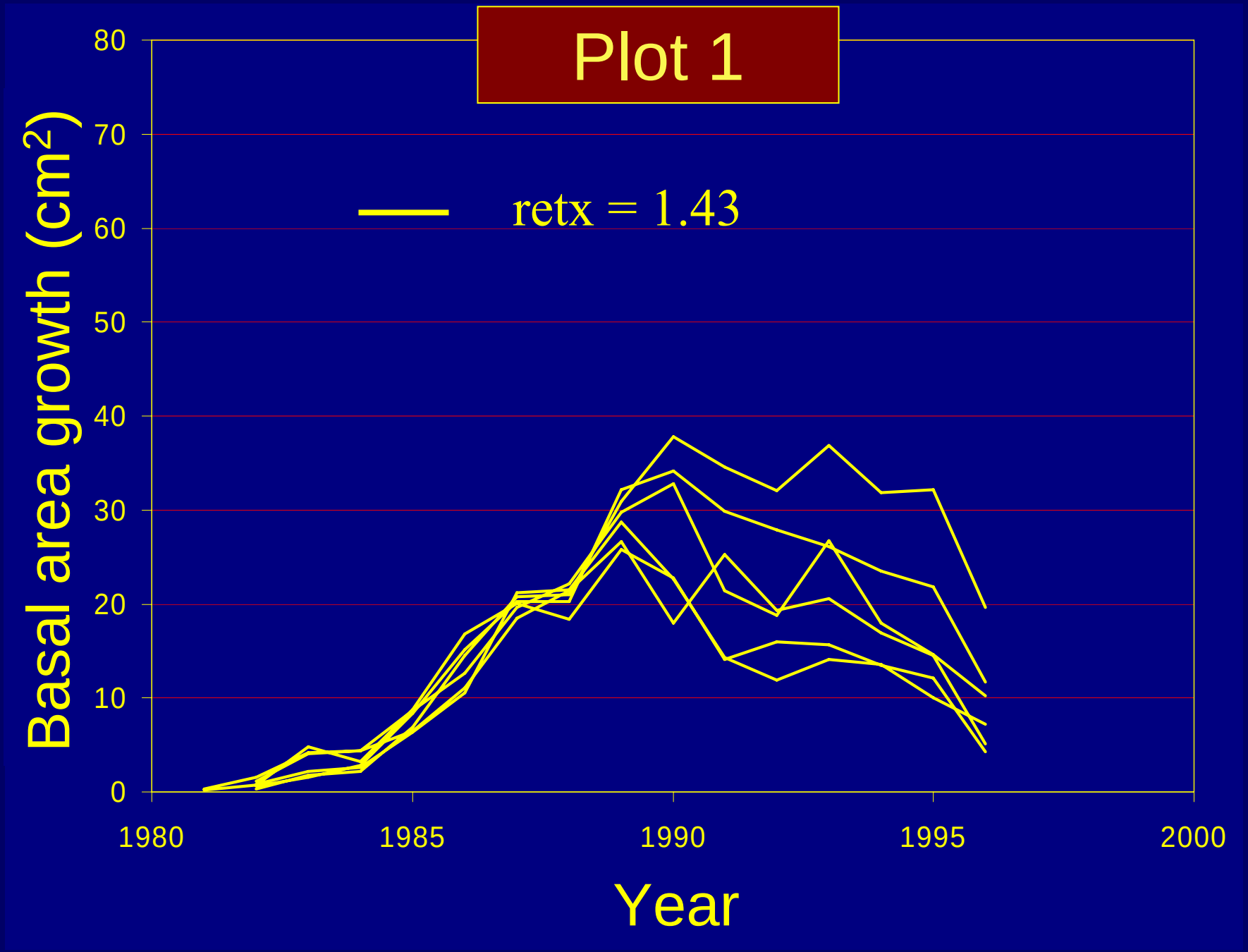


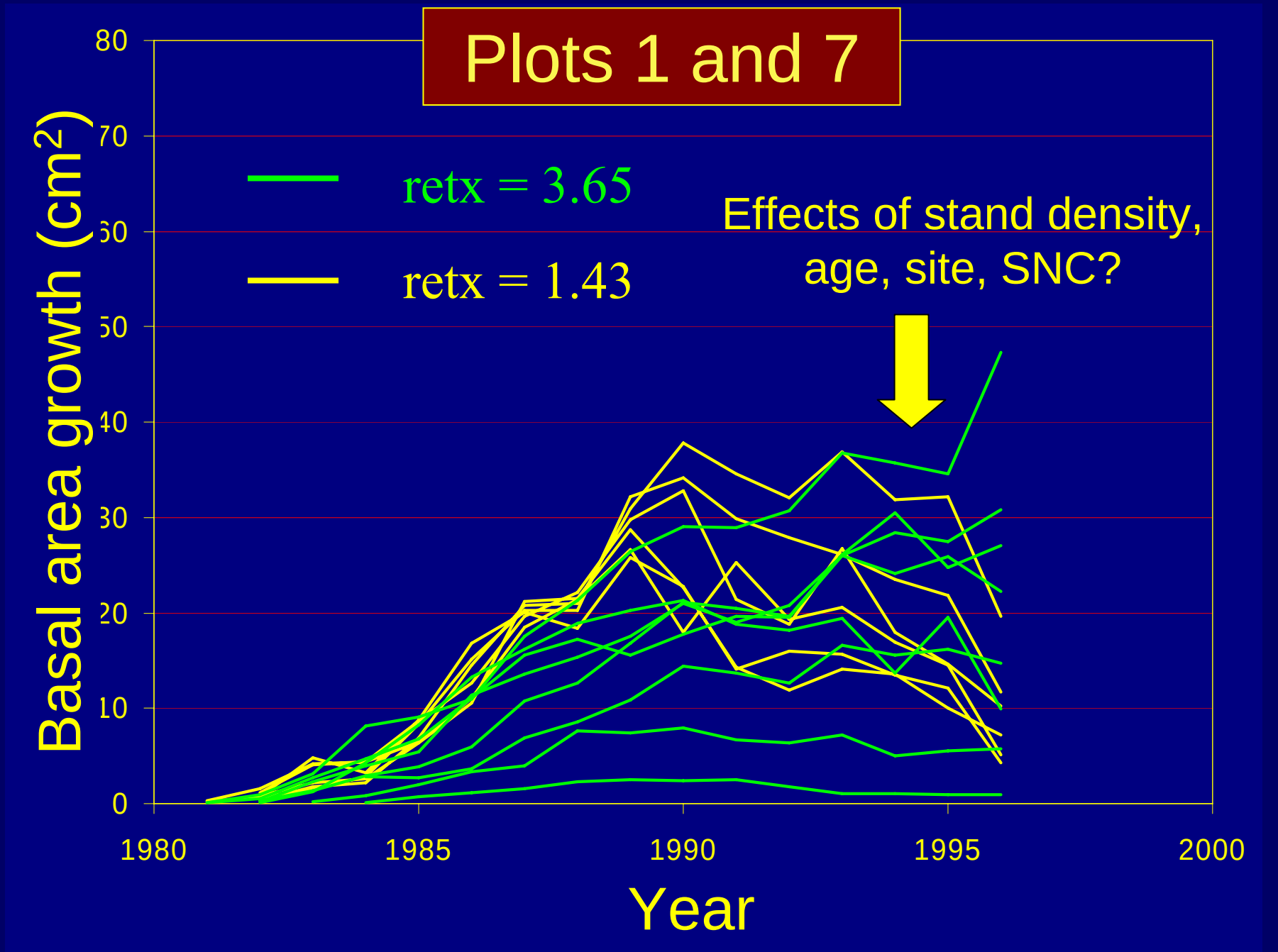

Basal area growth and weather trends
% of expected BA growth
Normalized summer rain and temp
Year
Mean needle retention
3.1
2.6
2.1
1.6
1.1
temperature
rainfall
140
120
100
80
60
40
20
0
300
250
200
150
100
50
0
-50
-100
75
80
85
90
95

Average growth loss for population of young Douglas-fir plantations

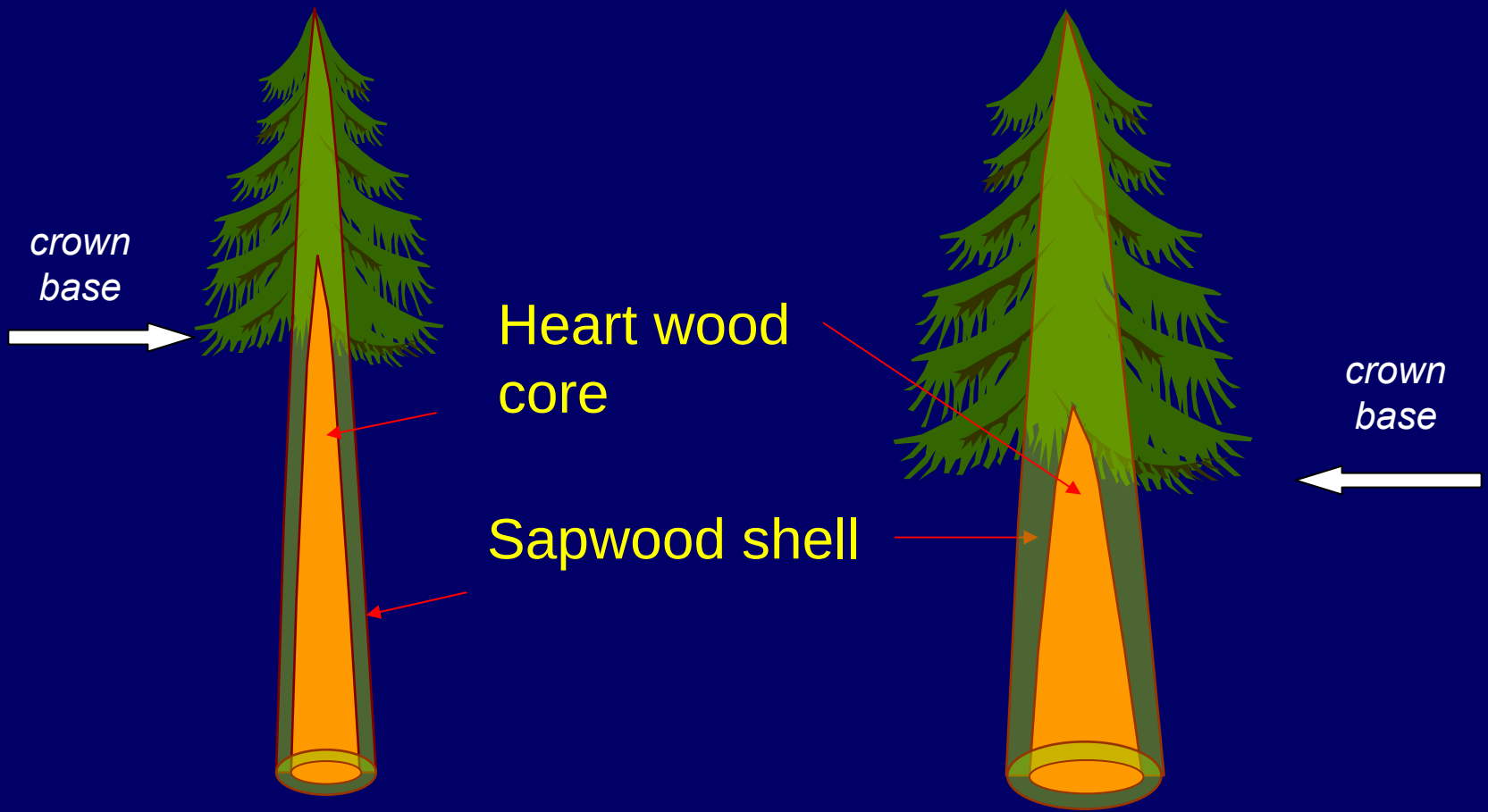



Plot 7
retx = 3.65
Annual basal area growth for individual trees
Basal area growth (cm2)
80
70
60
50
40
30
20
10
0
1980
1985
1990
1995
2000
Year

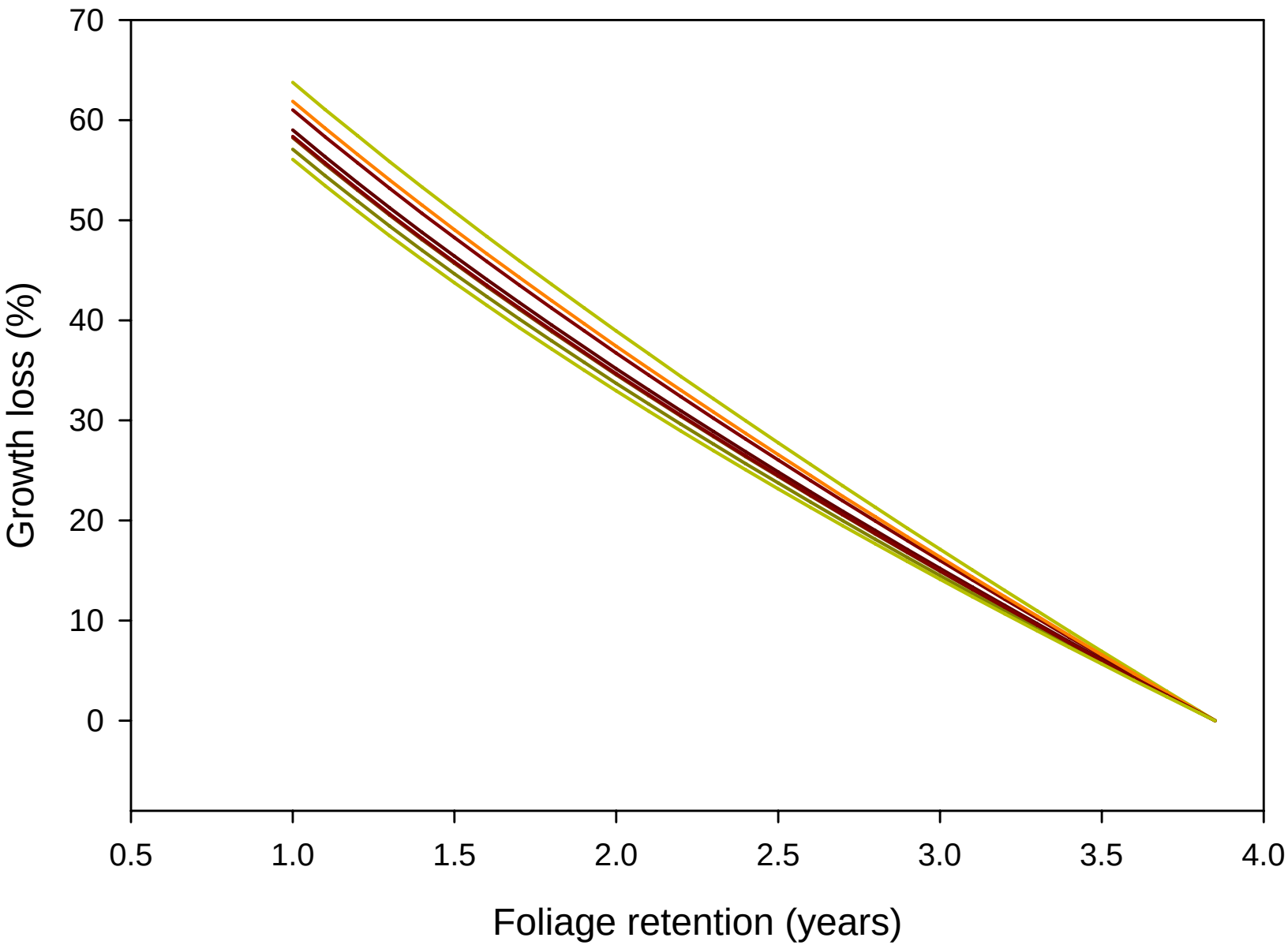

Plot 1
retx = 1.43
Basal area growth (cm2)
80
70
60
50
40
30
20
10
0
1980
1985
1990
1995
2000
Year


Plots 1 and 7
retx = 3.65
retx = 1.43
Effects of stand density, age, site, SNC?
Basal area growth (cm2)
0
10
20
30
40
50
60
70
80
1980
1985
1990
1995
2000
Year

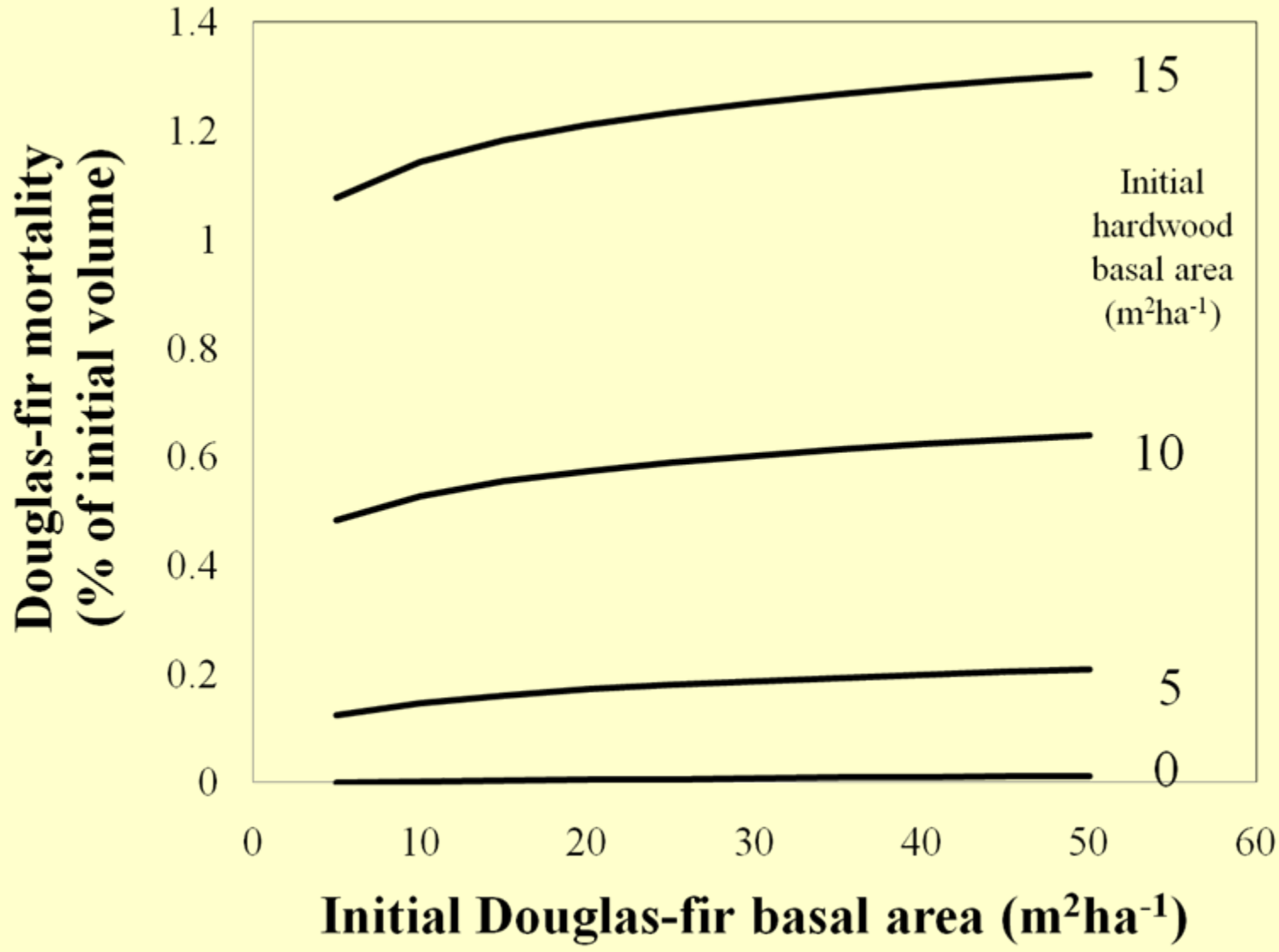
- Sapwood conducts water to service foliage for transpiration.
- Sapwood cross-sectional area is proportional to foliage amount.



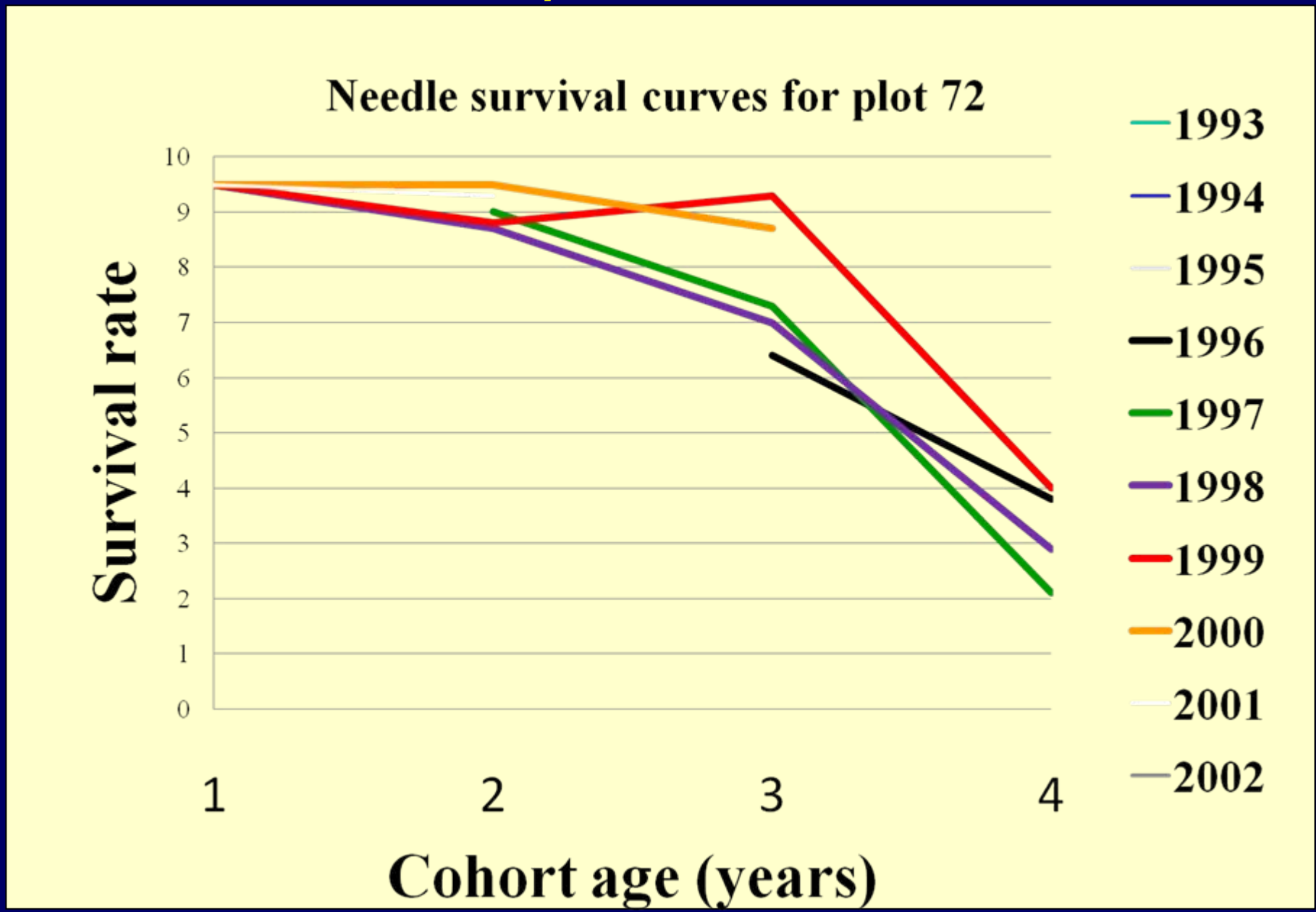
Swiss needle cast growth impact



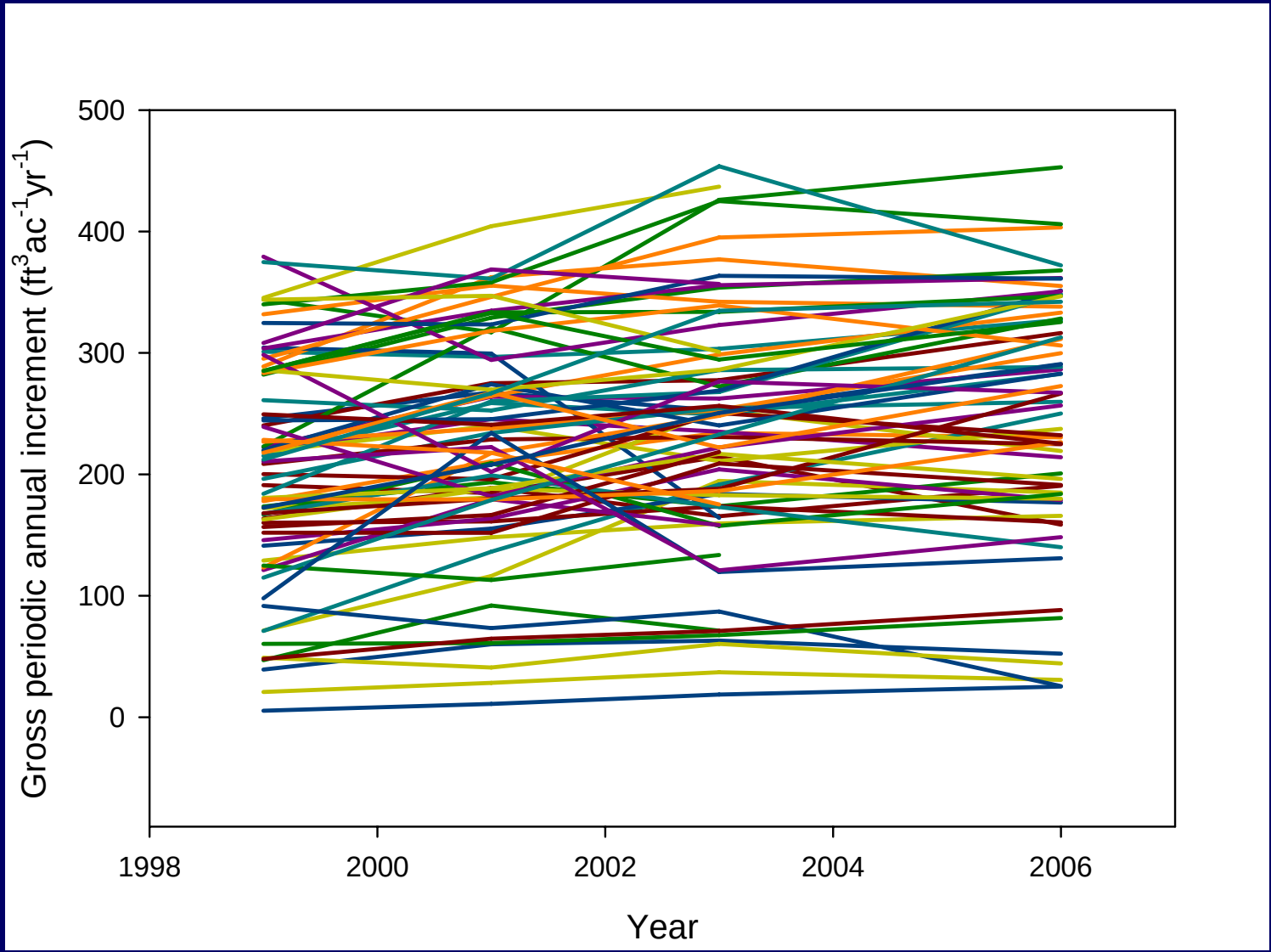
Periodic annual Douglas-fir mortality



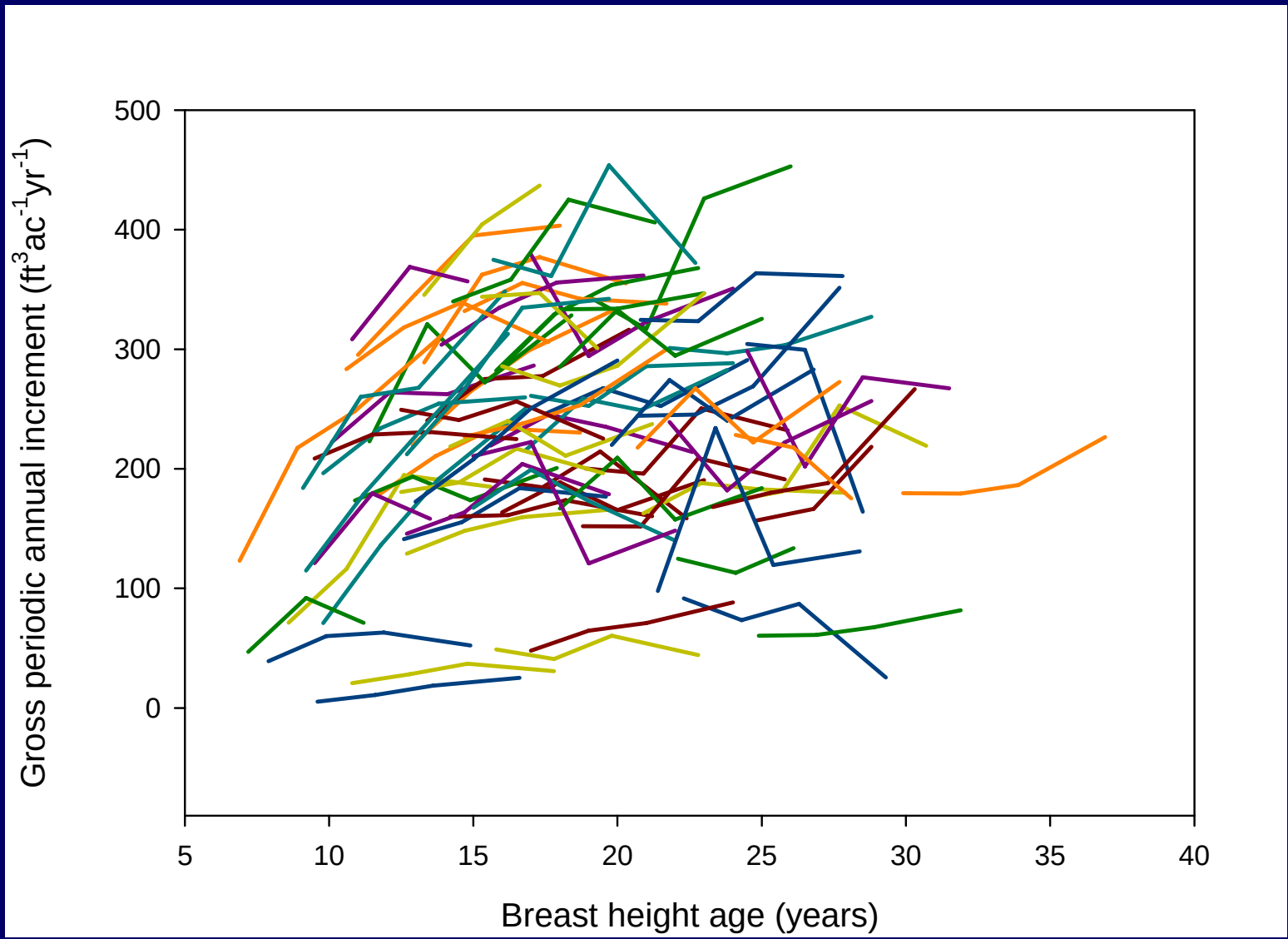
Needle survivorship models



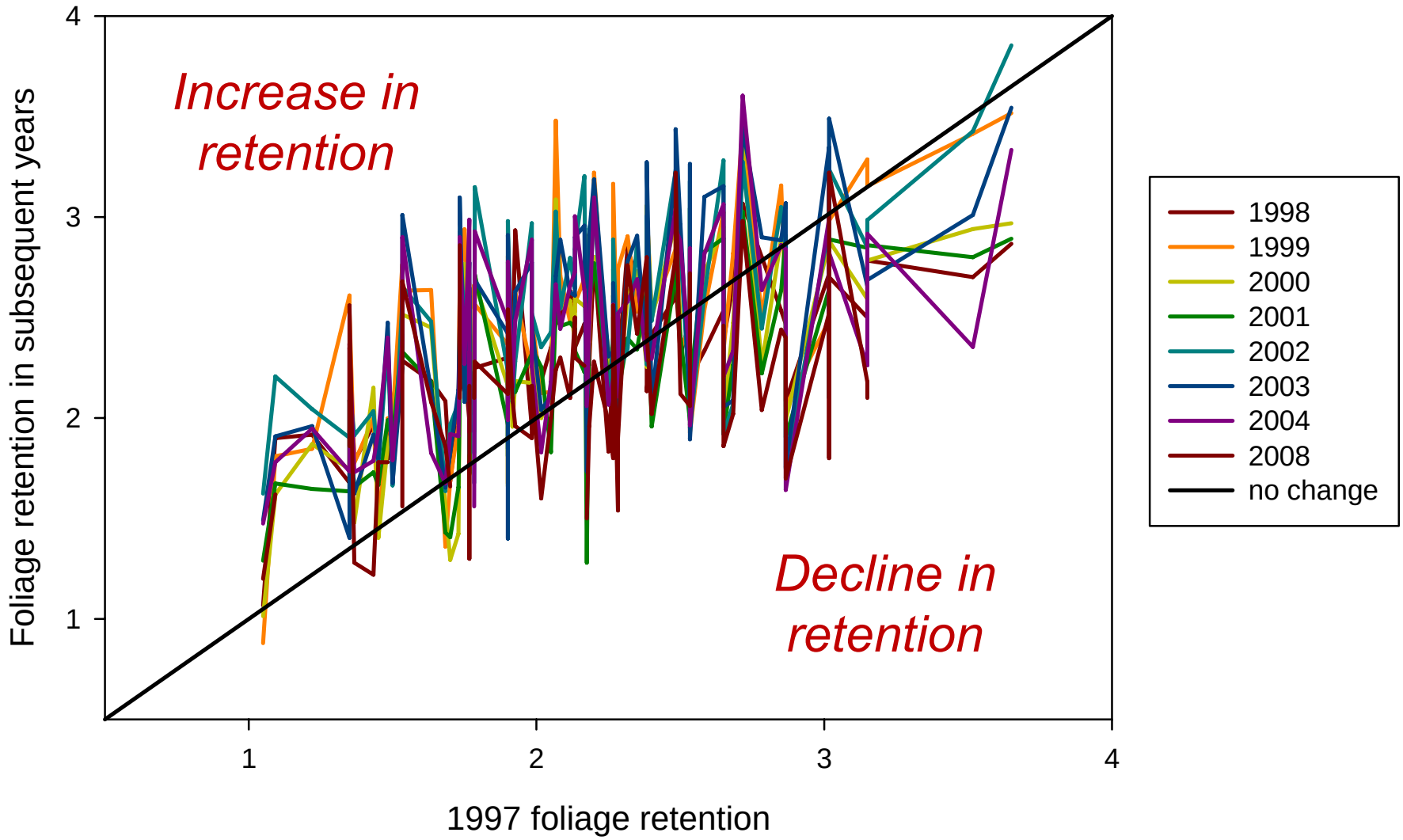
Gross periodic annual increment over year of growth



Gross periodic annual increment over breast height age



Level of foliage retention among years, ordered plots



Level of foliage retention among years