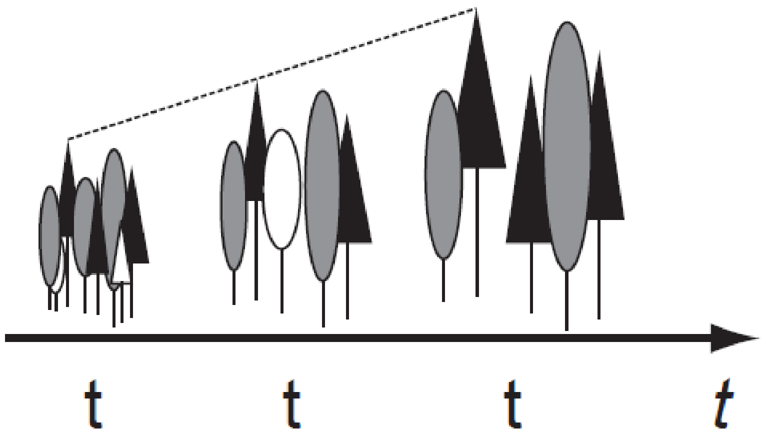
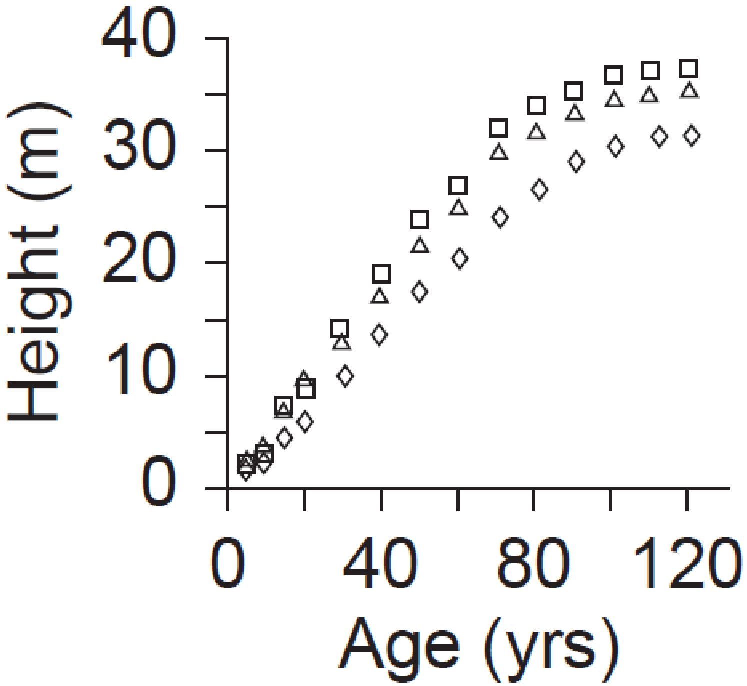
Methods to study the evolution of tree and stand variables over time

Where do we get the data for growth studies?

- In permanent and interval plots
  - Plots established with the objective of measuring growth in stands managed according to “current” practices
    - Permanent plots follow the stand during a long period, eventually the whole life of the stand

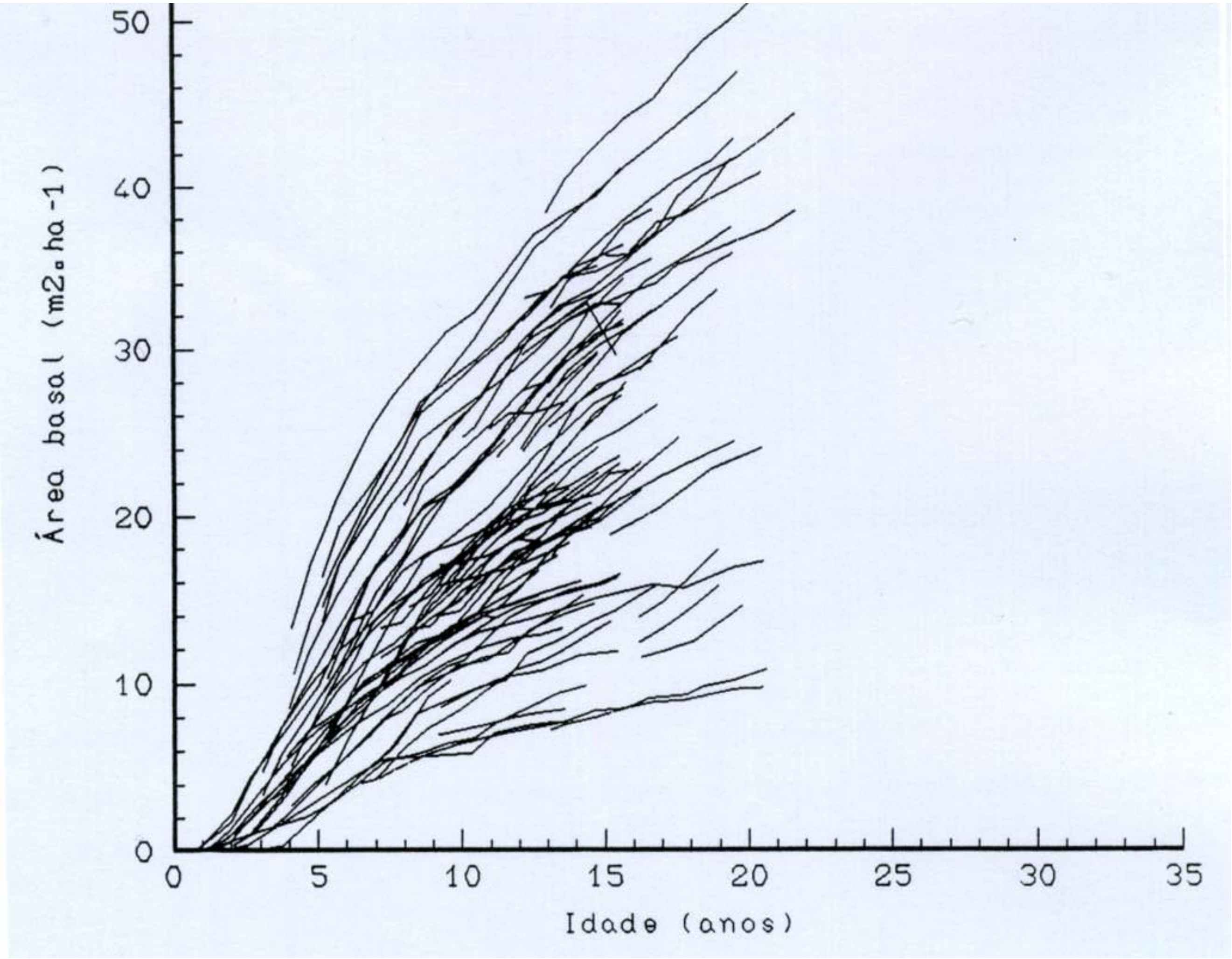
Permanent plots



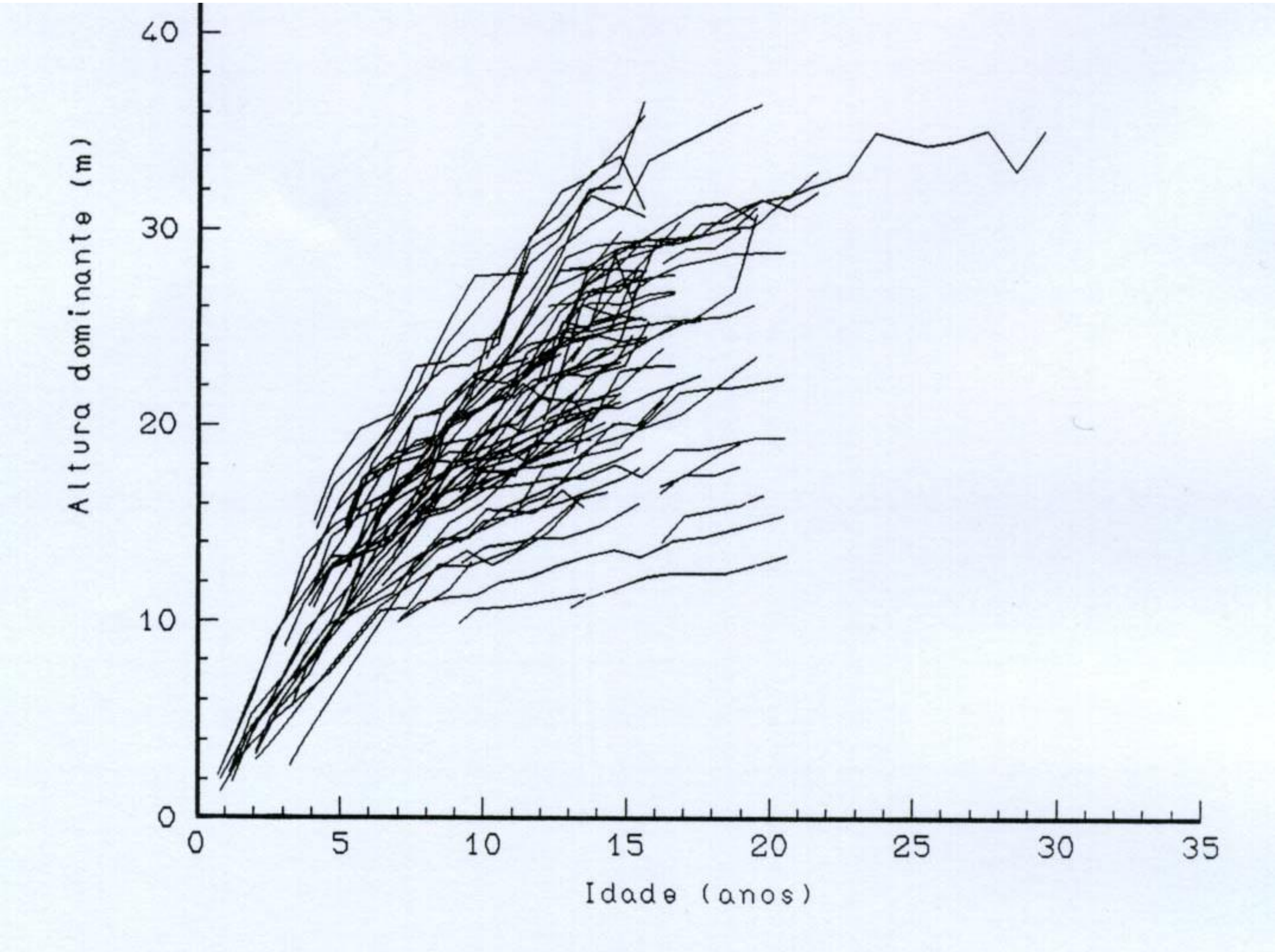


Adapted from Gadow and Hui 1999

Examples of permanent plot data
G - eucalyptus



Examples of permanent plot data
h_{dom} - eucalyptus



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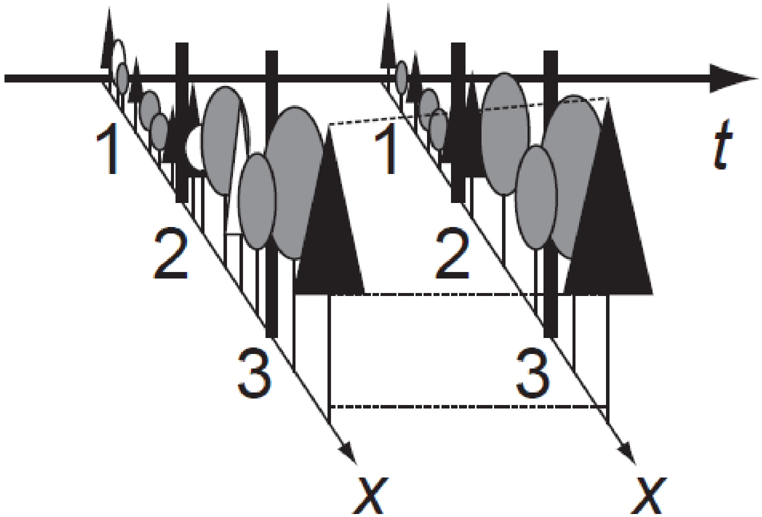
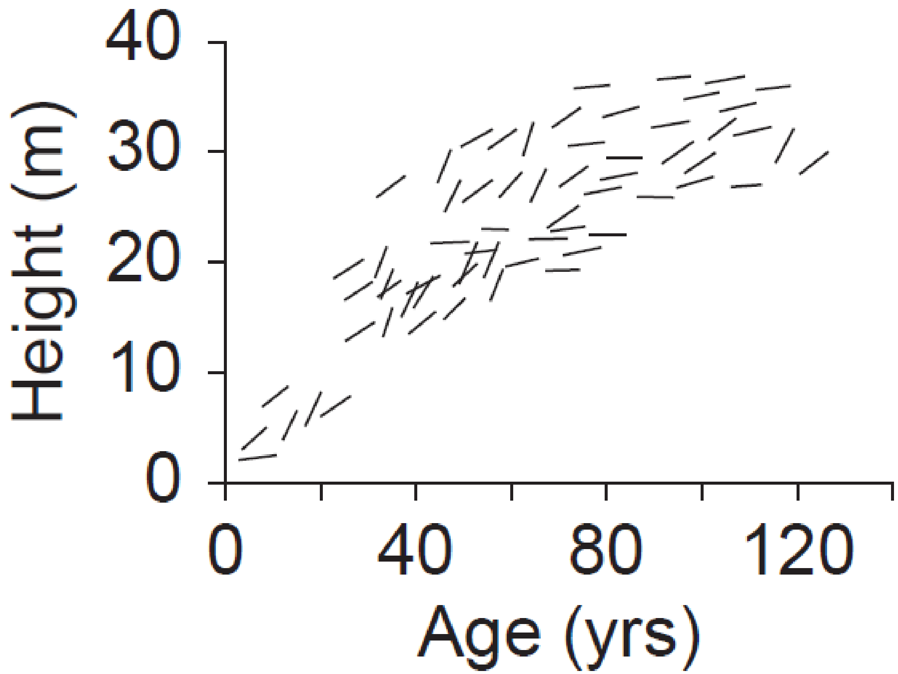
Interval plots





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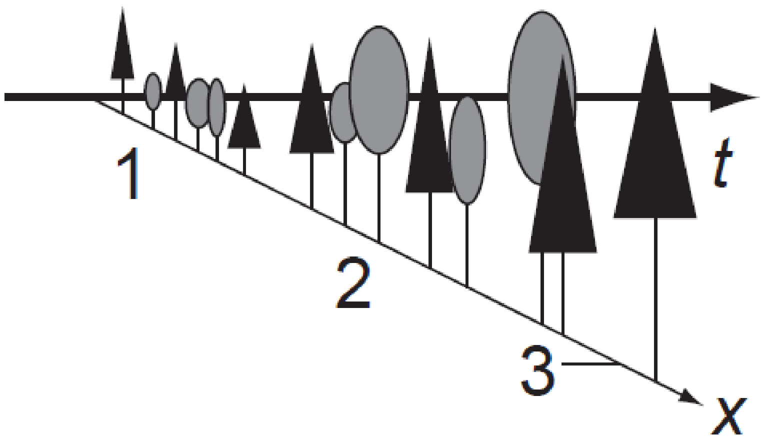
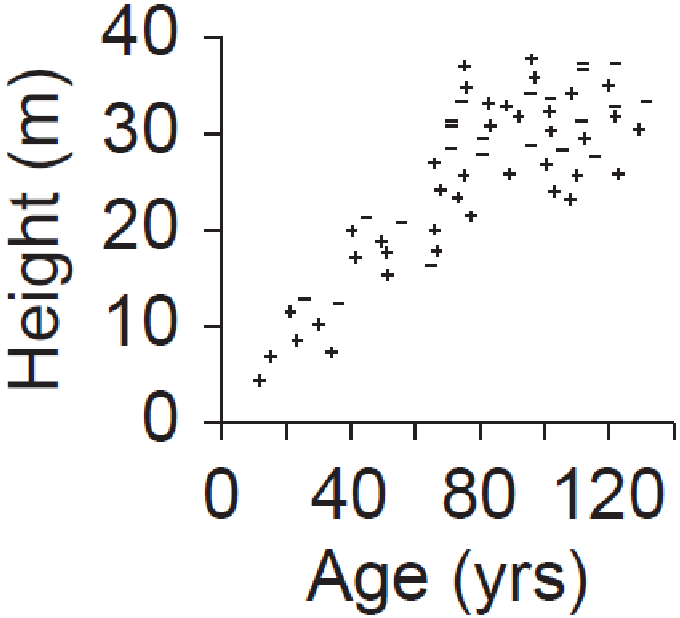
- In temporary plots
  - Plots that are measured just at one point in time

Temporary plots

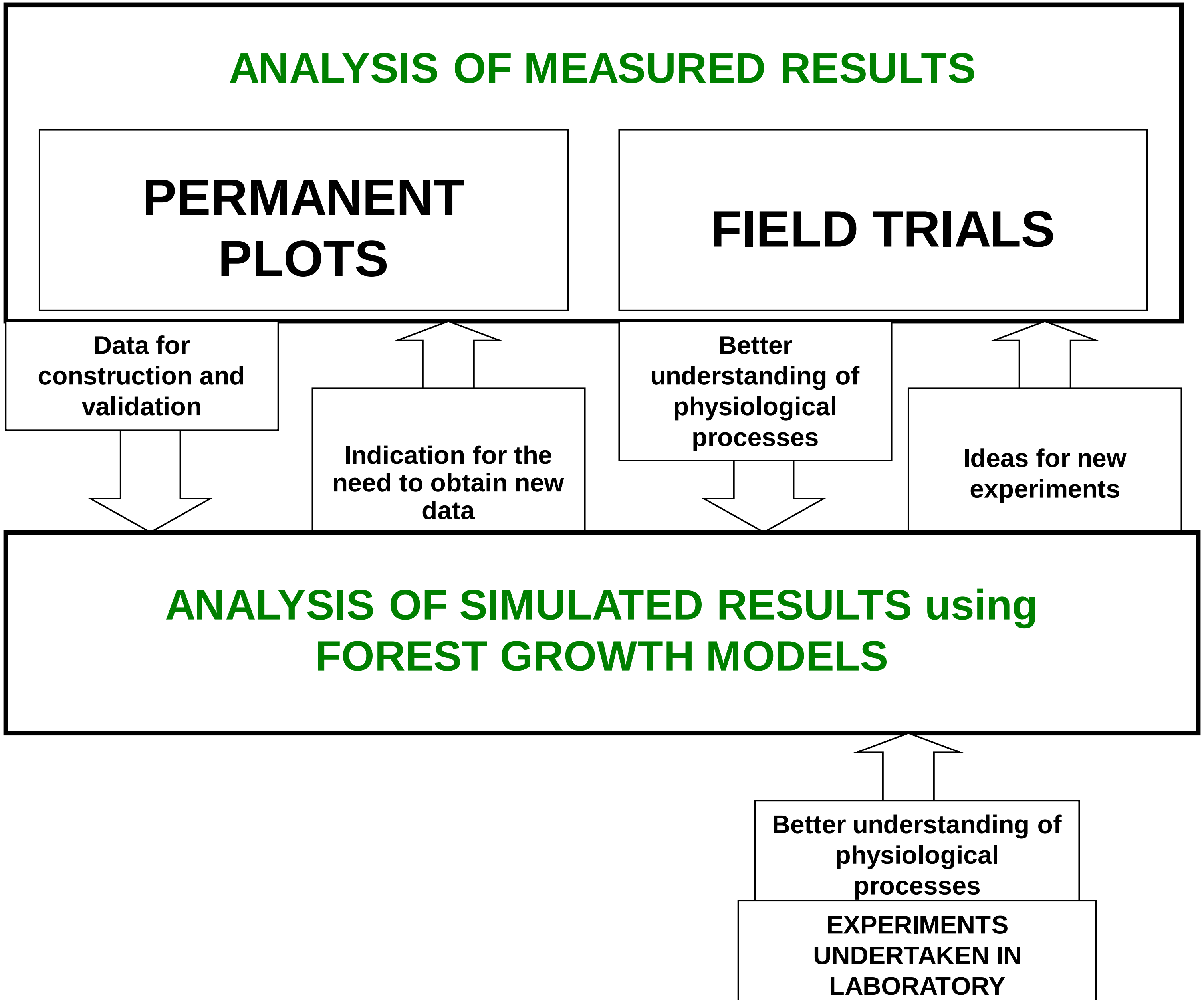




Adapted from Gadow and Hui 1999

Where do we get the data for growth studies?

- In designed silviculture and genetic trials
  - Trials purposively established to study the impact of silvicultural treatments and/or genetic material on tree and stand growth
- From continuous forest inventory data
- From stem analysis


ANALYSIS OF MEASURED RESULTS
PERMANENT PLOTS
FIELD TRIALS
Data for construction and validation
Indication for the need to obtain new data
Better understanding of physiological processes
Ideas for new experiments
ANALYSIS OF SIMULATED RESULTS using FOREST GROWTH MODELS
Better understanding of physiological processes
EXPERIMENTS UNDERTAKEN IN LABORATORY

Stem analysis

- Stem analysis is the study of tree growth from the analysis and measurement of the growth rings
- It is restricted to the species whose wood exhibits clear growth rings and to the regions with a climate that implies a clear stop on growth
- Two types of stem analysis:
  - Partial – analysis of increment cores at dbh level
  - Total – analysis of several tree discs along the stem

Partial stem analysis
Stand table projection

- It is usually used for short term projections of forest inventory data:
  1. During the forest inventory an increment bore is taken in some "sample" trees
  2. Diameter growth of wood in the last k years (usually 5 years) is measured in the increment bore from each tree and converted to diameter growth
  3. Estimate the diameter growth (idj) of the average tree of each diameter class (j)

Increment borer

Partial stem analysis
Stand table projection

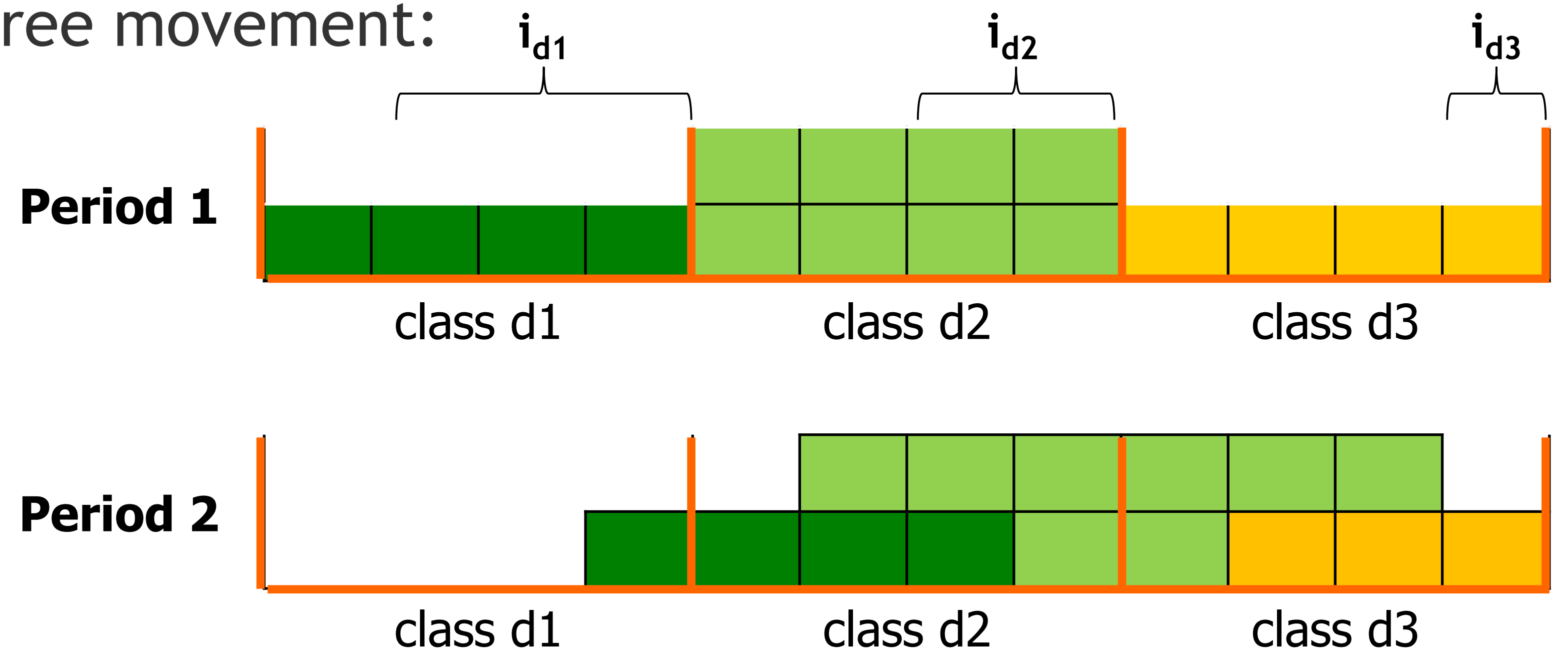
- It includes several steps:
  1. Start by computing the stand table (number of trees per diameter class) from forest inventory data
  2. Estimate mortality in each diameter class and compute the future number of trees
  3. Compute the growth index or ratio between id_j and the width of the class – this index allows the computation of the number of trees that stay in the class and the ones that move 1 or 2 classes

Partial stem analysis
Stand table projection

- Computation of growth index:
  - Assumes that trees inside a dbh class have an uniform distribution
  - Estimate the diameter increment in k years of each dbh class (i_d)
  - All trees inside a dbh class [d_1; d_2[with $d>d_2-i_d$, after k years will be in the next class

Partial stem analysis
Stand table projection

- Tree movement:



- Note that now the trees are not equally distributed but this assumption will hold for the next period projection

Partial stem analysis
Stand table projection

class j (5 cm)	Nj_{1996} after mortality	d increment id_5 (cm)	Growth index		Movements			Nj_{2001}
			P_1	P_2	stay	1 class	2 classes	
ingrowth						100		
5	102	3.80	0.76	0	24.48	77.52	0	
10	59	3.80	0.76	[illegible]	14.1[illegible]	44.8[illegible]	[illegible]	
15	53	3.85	0.77	0	12.1[illegible]	40.81	0	
20	59	3.85	0.77	0	[illegible]	[illegible]	0	
25	58	3.85	0.77	0	[illegible]	[illegible]	0	
30	22	3.90	0.78	0	4.84	17.16	0	
35	1	3.90	0.78	0	0.22	0.78	0	
40	0							
45	[illegible]							
Tota[illegible]	[illegible]							

=3.80/5cm

=102-24.48

=102*(1-0.76)

Future number of trees alive in each class

Increment in diameter for the period

Partial stem analysis
Stand table projection

- We should also take into account the ingrowth
  - trees that achieve the lower limit of the first diameter class and must be added to the stand

Partial stem analysis

Stand table projection

class j (5 cm)	Nj_{1996} after mortality	d increment id_5 (cm)	Growth index		Movements			Nj_{2001}
			P_1	P_2	stay	1 class	2 classes	
ingrowth						**100**		
5	102	3.80	0.76	0	24.48	77.52	0	124
10	59	3.80	0.76	0	14.16	44.84	0	92
15	53	3.85	0.77	0	12.19	40.81	0	57
20	59	3.85	0.77	0	13.57	45.43	0	54
25	58	3.85	0.77	0	13.34	44.66		59
30	22	3.90	0.78	0	4.84	17.16	0	50
35	1	3.90	0.78	0	0.22	0.78	0	17
40	0							1
45								
Total	354							454

=24+100

Partial stem analysis
Stand table project

- To estimate volume (or biomass) increment:
  - Estimate the height of the average tree in each dimater class using a height-diameter curve
  - Estimate the respective volume with a volume equation
  - Estimate the volume in each point in time using the stand tables
  - Obtain the volume (biomass) growth by difference

Partial stem analysis

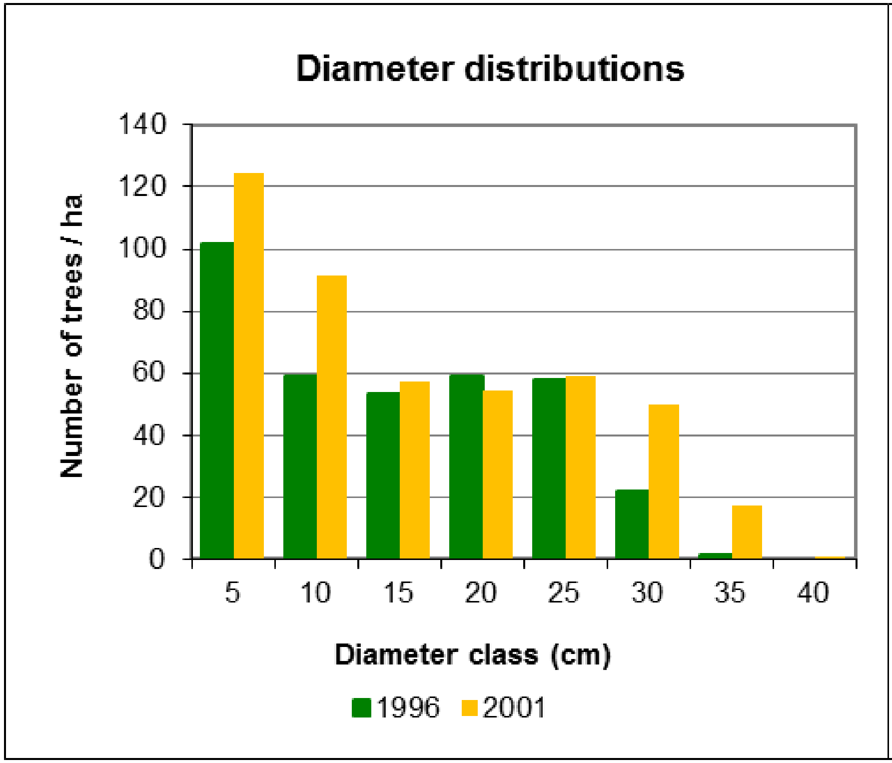
Stand table projection

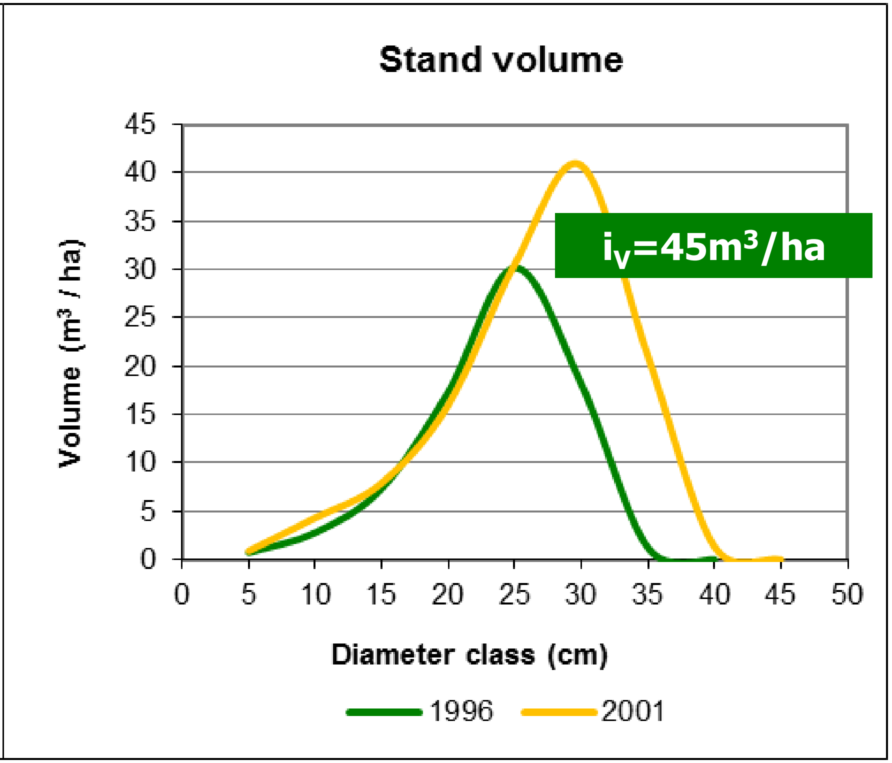
class j (5 cm)	Nj_{1996} after mortality	Nj_{2001}	h_j m	v_j m^3/tree	V_{j1996} m3/ha	V_{j2001} m3/ha	
ingrowth							
5	102	124	6.8	0.0070	0.71	0.87	=0.0070*124
10	59	92	12.1	0.0470	2.77	4.30	
15	53	57	16.2	0.1387	7.35	7.91	
20	59	54	19.7	0.2939	17.34	15.98	
25	58	59	22.5	0.5204	30.18	30.58	
30	22	50	24.9	0.8237	18.12	40.77	
35	1	17	27.0	1.2080	1.21	20.99	
40	0	1	28.7	1.6763	0.00	1.31	V growth m^3/ha
45						0	
Total	354	454			78	123	45

Tree height with a height-diameter curve: $h=d/(0.64212+0.01874*d)$

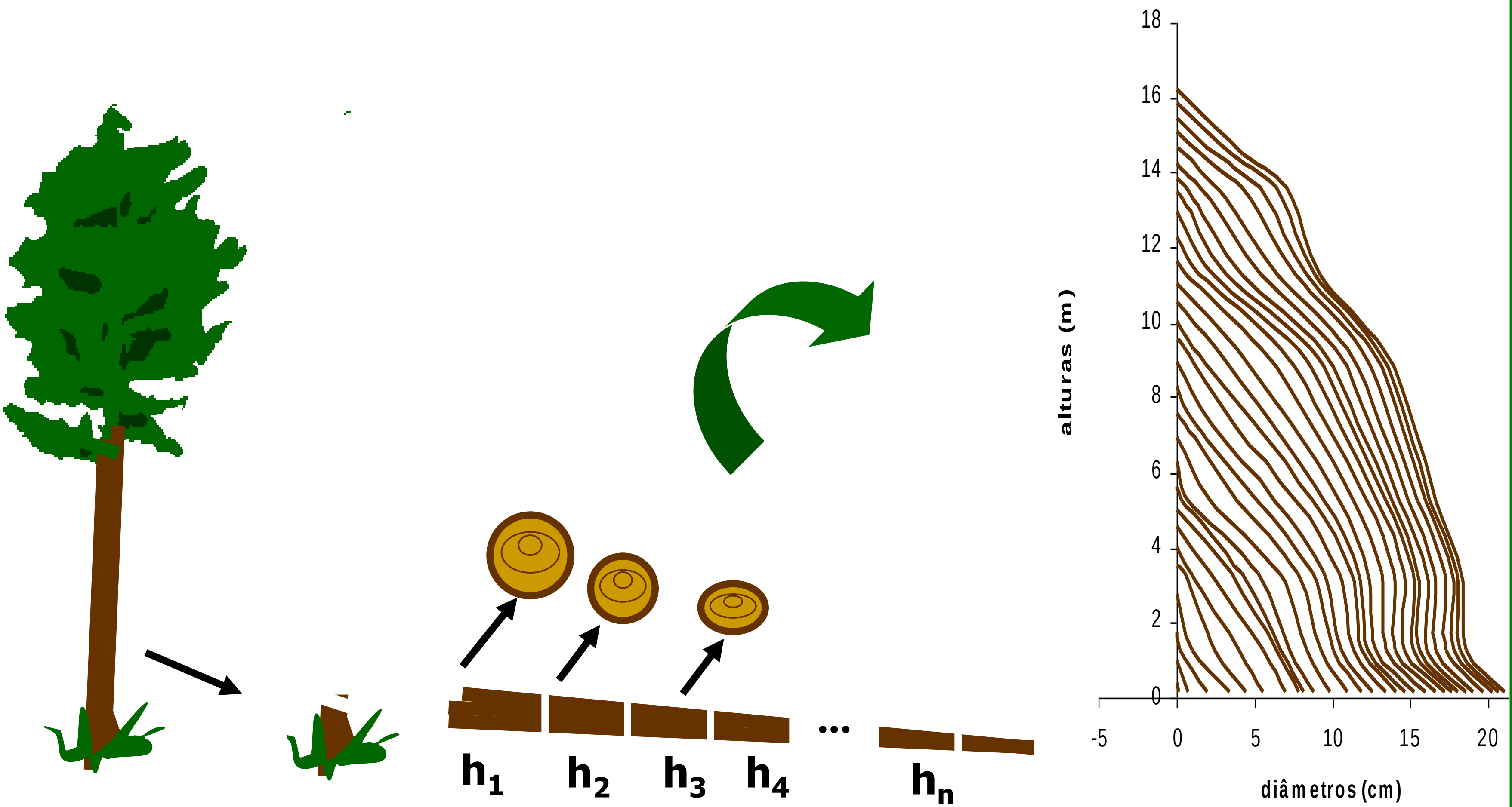
Total volume with a volume equation: $v = 0.00005126\ d^{2.0507}\ h^{0.8428}$

Partial stem analysis
Stand table projection





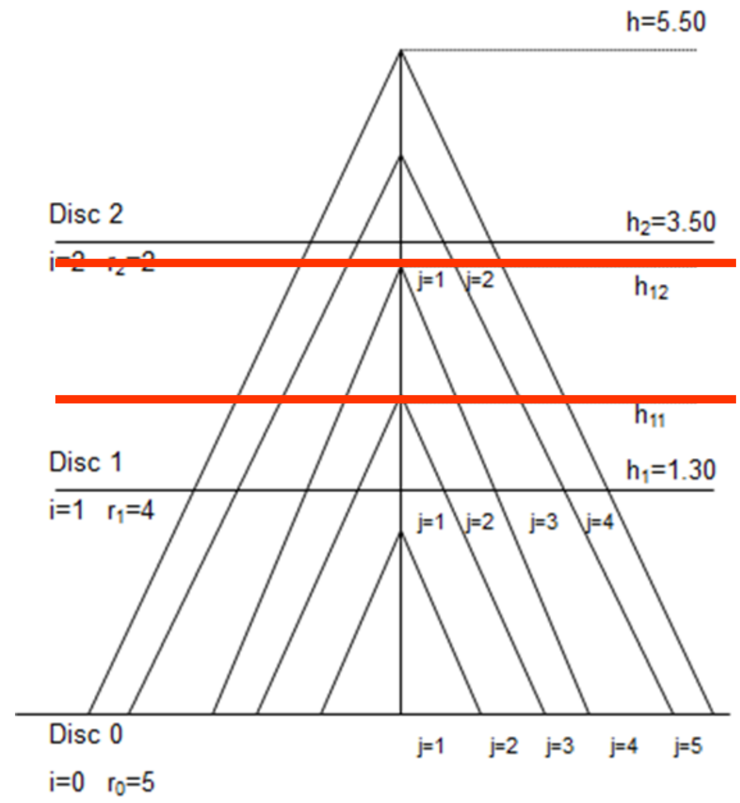
Stem analysis



Stem analysis - example

height	N rings	age
0	5	0
1.30	4	1+ ...
3.50	2	3+ ...
5.50	0	5

- Tree is 5 years old
- Between Disc 1 and Disc 2, the correction is needed to estimate the heights at the end of the years: h_{11} and h_{12}
- The method most used for this correction is the Carmean method



Stem analysis
Carmean's correction

- Carmen's method is based in two assumptions:
  1. Constant annual increment in height between two discs
  2. Each disc occurs at the mid-point between two whorls

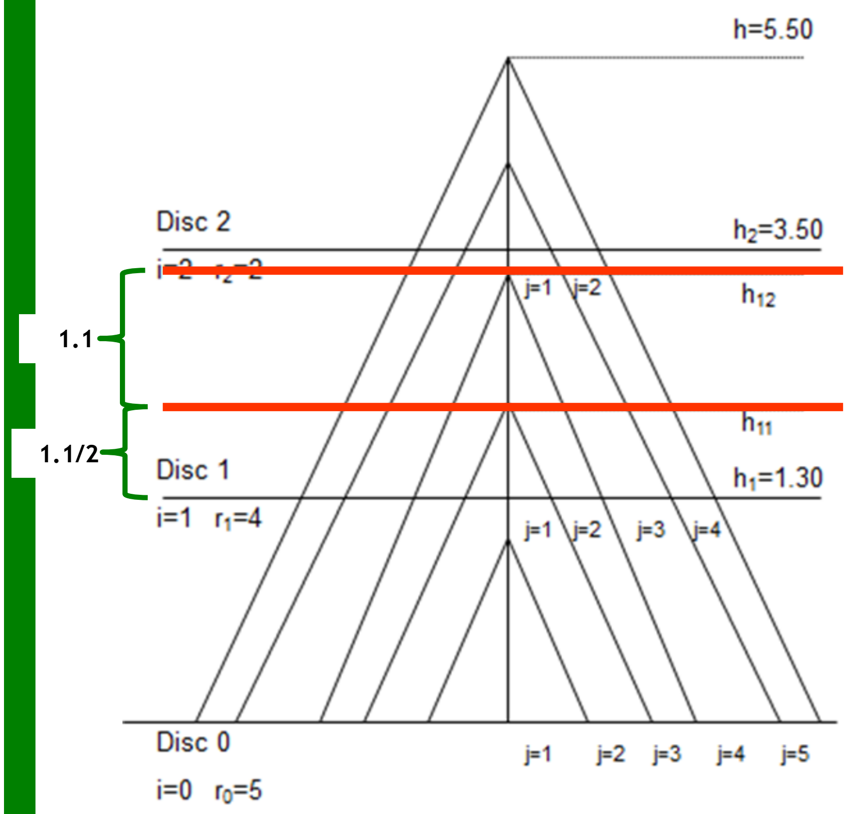
Stem analysis
Carmean's correction

- The application of the method to the whorls between two discs implies:
  - Compute the annual increment $i_h=(h_2-h_1)/(nrg_1-nrg_2)$, where h_i and nrg_i are the height and the number of rings of $disc_i$
- Compute the height of the first whorl as:
  - $h_{i1}=h_i+i_h/2$
- The heights of the following whorls are computed as:
  - $h_{ij}=h_i+i_h/2+(j-1)*i_h=h_{i(j-1)}+i_h$

Stem analysis
Carmean's correction

Let's compute h11 and h12:

- Annual height growth:
  i_h=(h2-h1)/(4-2)=(3.50-1.30)/2=1.1
- h_{11}=1.30+1.1/2=1.85
- h_{12}=h11+i_h=1.85+1.1=2.95



Stem analysis
Carmean's correction

- It is possible to obtain a general formula for the height of any whorl h_{ij}:

$$h_{ij} = h_i + \frac{1}{2}\ \frac{h_{i+1} - h_i}{r_i - r_{i+1}} + (j-1)\ \frac{h_{i+1} - h_i}{r_i - r_{i+1}}$$

$\frac{h_{i+1} - h_i}{r_i - r_{i+1}}$ is the annual growth between discs *i* and *i+1*

$$h_{11} = 1.30 + \frac{1}{2}\ \frac{3.50 - 1.30}{4-2} + (1-1)\ \frac{3.50 - 1.30}{4-2} = 1.30 + \frac{1}{2}\ 1.10 = 1.30 + 0.55 = 1.85$$

$$h_{12} = 1.30 + 0.55 + (2-1)\ 1.10 = 2.95$$

Stem analysis
Carmean's correction