Do increasing respiratory costs explain the decline with age in forest growth rate?

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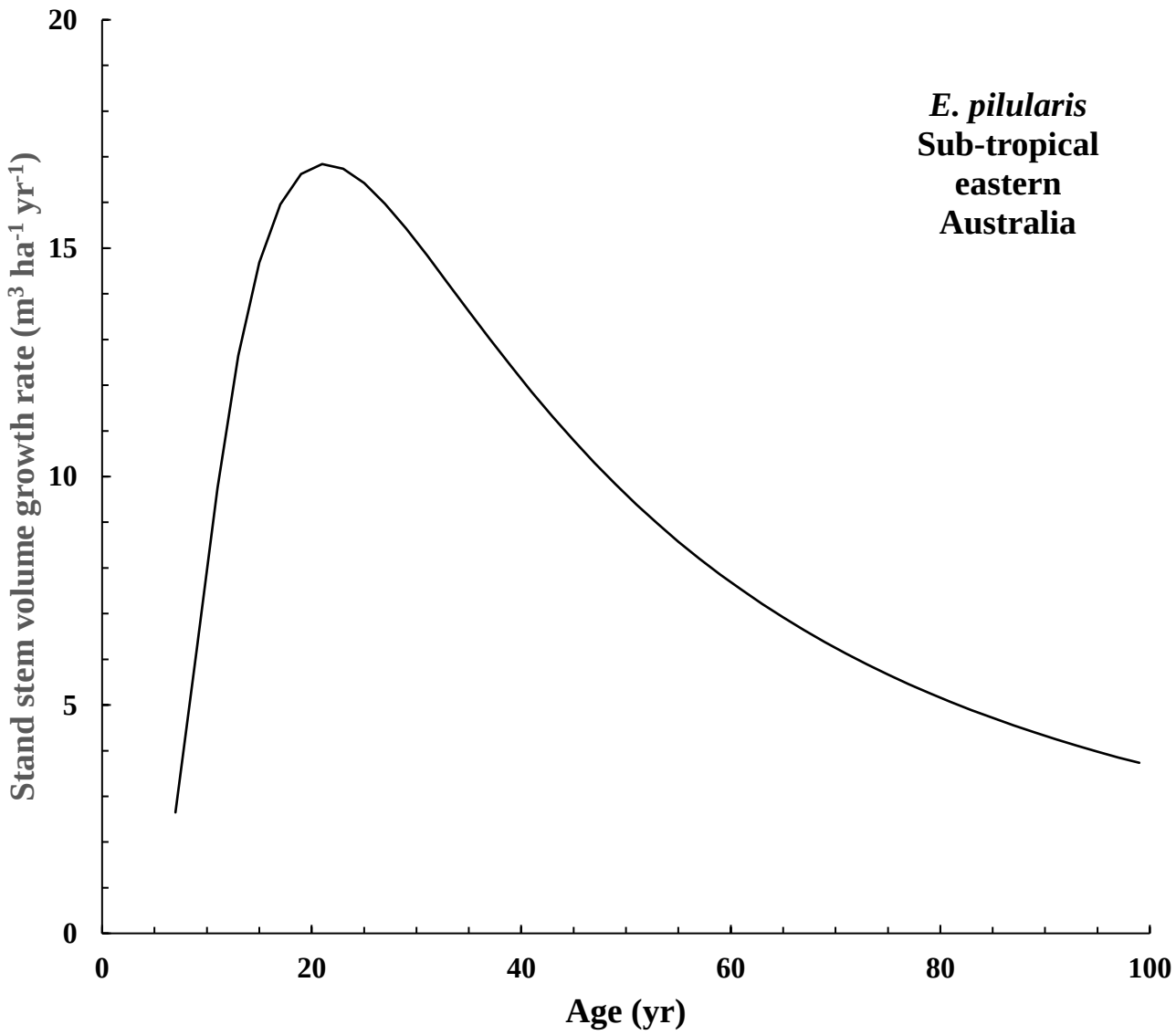

20
15
10
5
0
Stand stem volume growth rate (m3 ha-1 yr-1)
0
20
40
60
80
100
Age (yr)
E. pilularis
Sub-tropical
eastern
Australia

Hydraulic Limitation Theory

- **As trees grow taller, gravity and friction increase resistance to water flow from roots to leaves**
- **Increased water stress in leaves**
- **Stomata shut more frequently from time to time during the day and in hot weather**
- **Less photosynthesis over a year**
- **Growth rate declines progressively as trees get taller and taller with age**

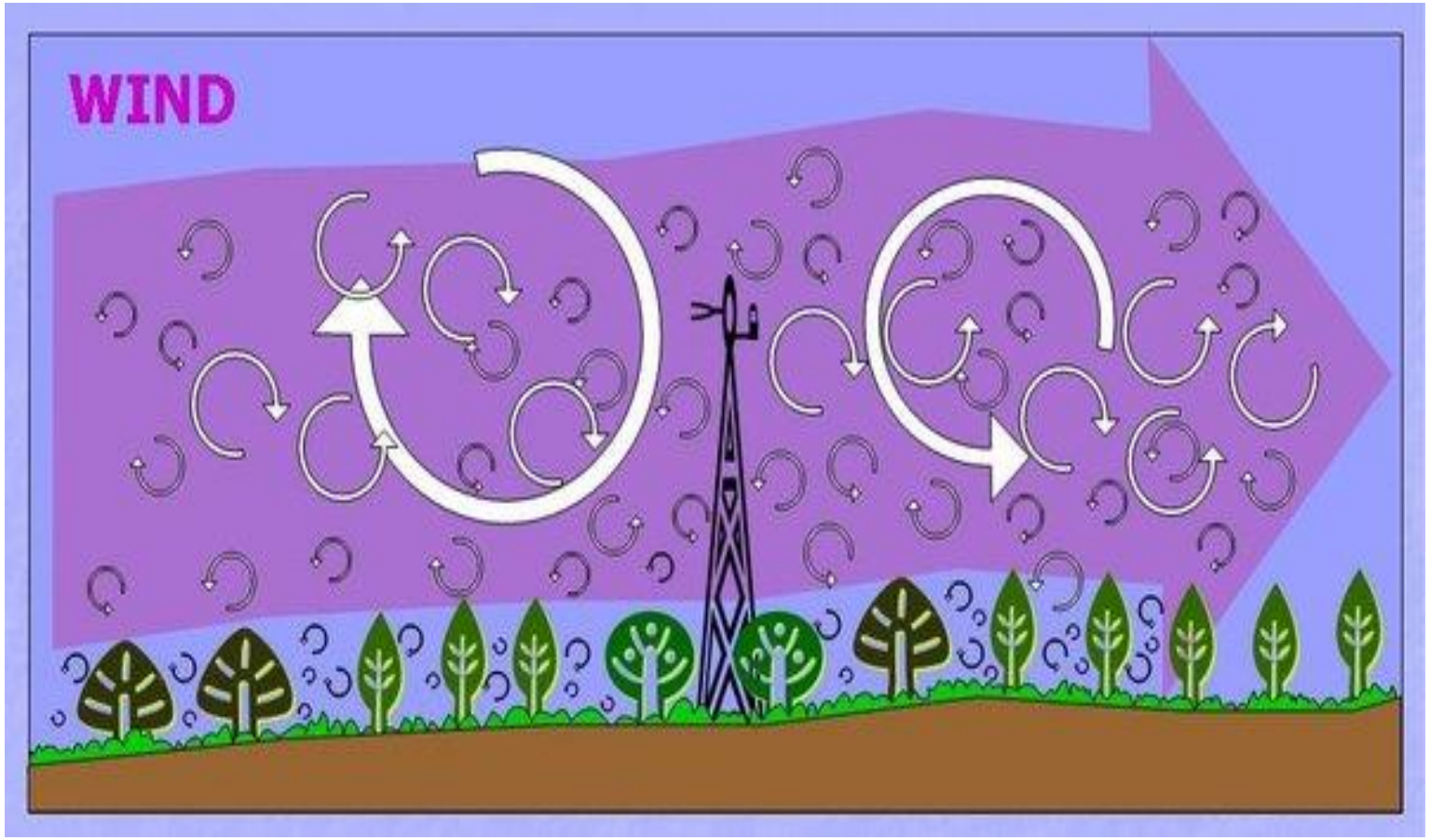
Net biomass growth = **Total canopy photo-synthetic production** – **Respiratory losses to keep trees alive and grow new tissue**

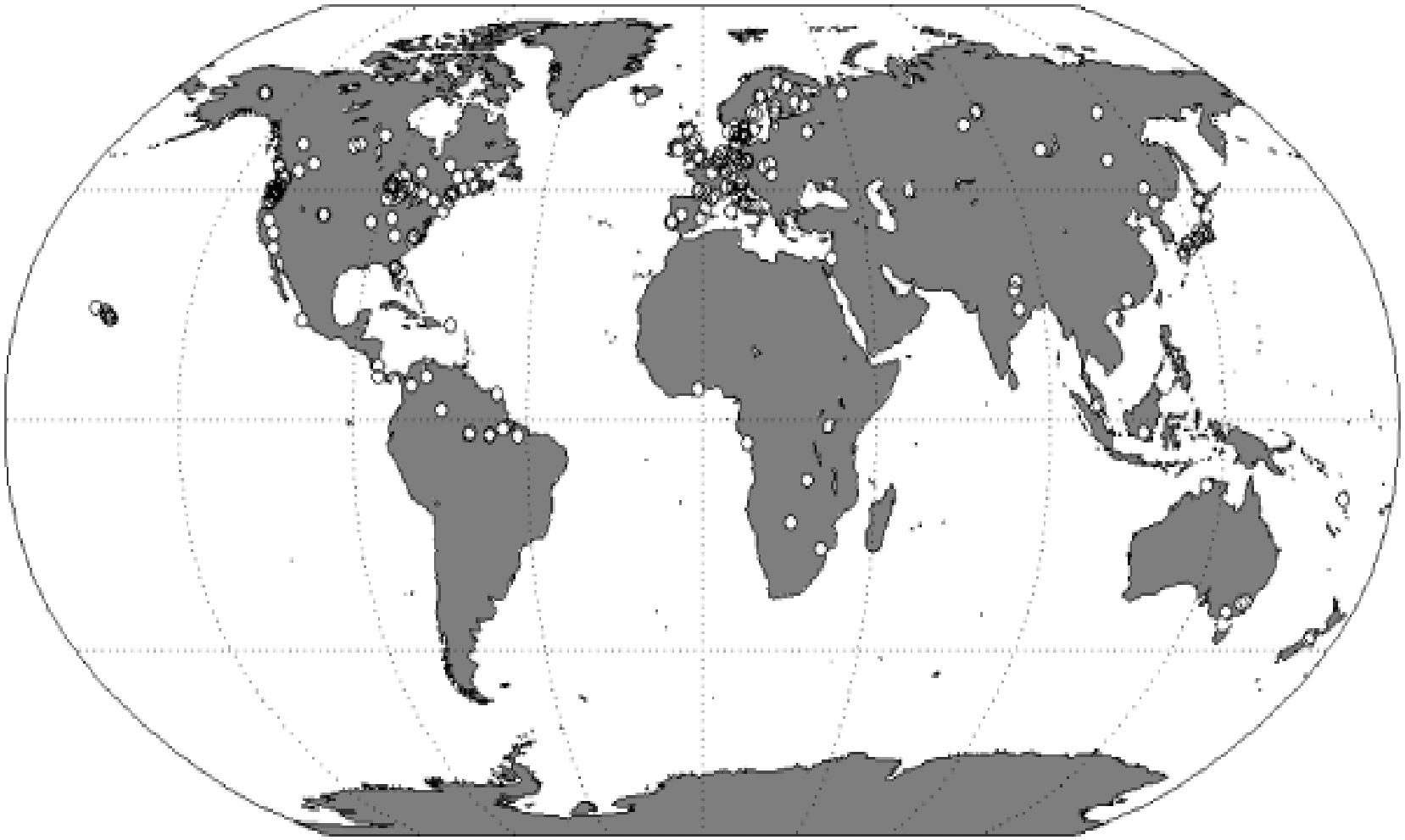
$$\mathbf{NPP} = \mathbf{GPP} - \mathbf{R_A}$$

Net primary production | **Gross primary production** | **Autotrophic respiration**

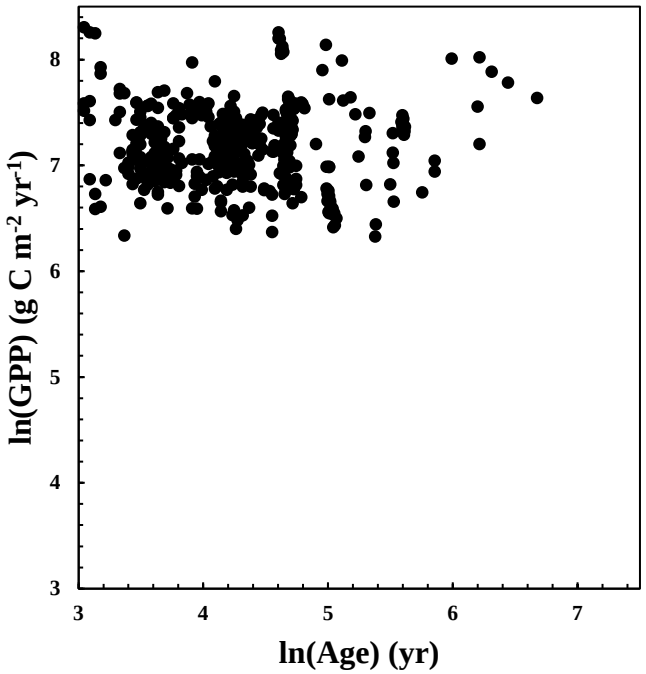
Units used commonly are g C m^{-2} yr^{-1} that is, grams of carbon in biomatter per square metre of land area occupied by the forest per year

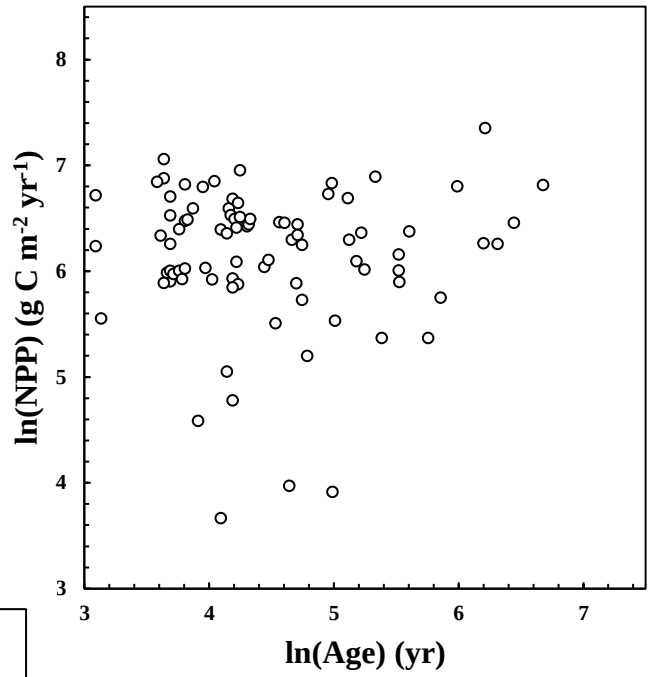
Eddy covariance

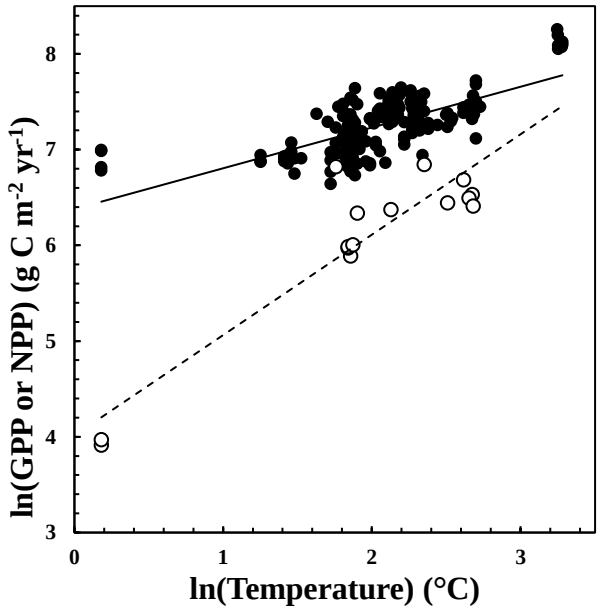


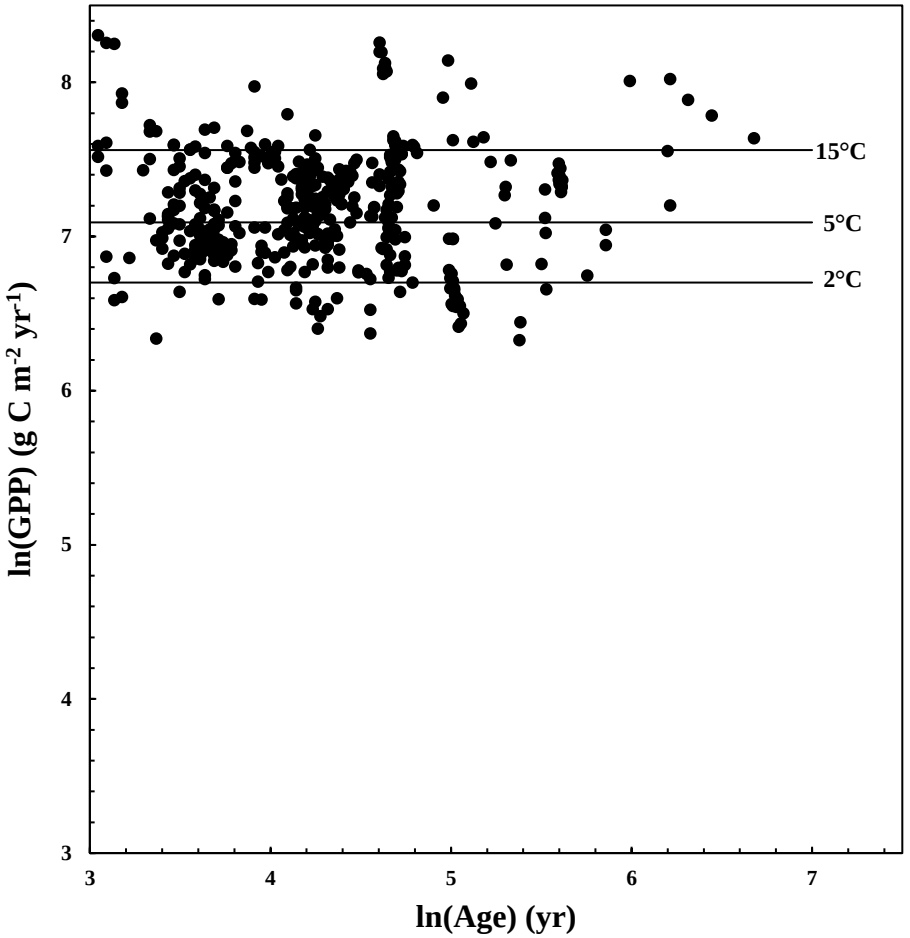


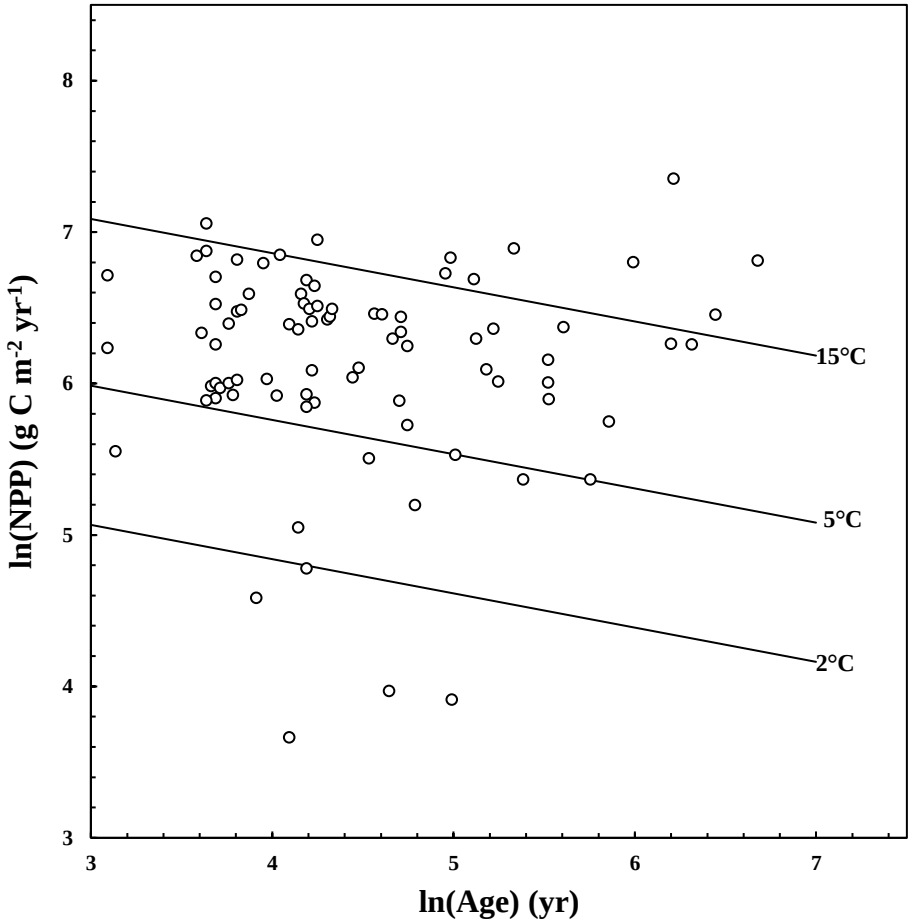
From Fig. 2 of: S Luyssaert and 65 others (2007) CO_2 balance of boreal, temperate and tropical forests derived from a global database. Global Change Biology 13:2509–2537

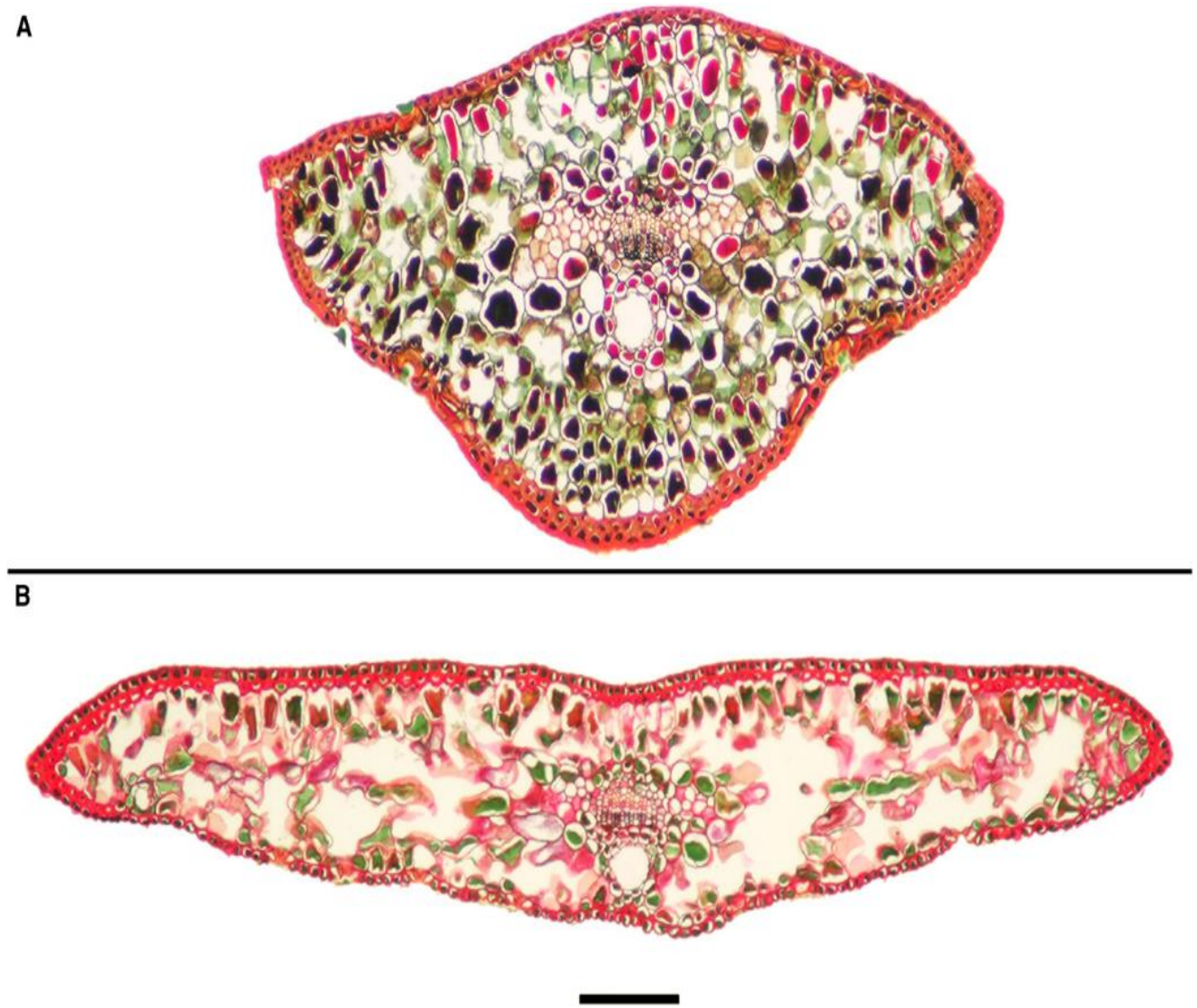

ln(GPP) (g C m-2 yr-1)
ln(Age) (yr)
3
4
5
6
7
8


ln(NPP) (g C m-2 yr-1)
ln(Age) (yr)
3
4
5
6
7
8


ln(GPP or NPP) (g C m-2 yr-1)
ln(Temperature) (°C)
0
1
2
3
4
5
6
7
8


ln(GPP) (g C m-2 yr-1)
ln(Age) (yr)
15°C
5°C
2°C
3
4
5
6
7
8


ln(NPP) (g C m-2 yr-1)
ln(Age) (yr)
15°C
5°C
2°C
3
4
5
6
7
8


A
B

$$\mathbf{NPP = GPP - R_A}$$

Possible sources of increased respiration as trees grow larger with age

- **Maintenance of more live tissue in stems and woody roots**
- **Costs incurred in developing more complexly structured tissues to maintain photosynthetic rates**
- **Costs of conversion of sapwood to heartwood as their total length or volumes increase**
- **Increasing transport costs of carbohydrates and hormones through an ever increasing length of the phloem**
- **Shortening of fine root lifespan, so increased costs involved with their turnover**
- **Metabolic inefficiency of tall trees unable to compensate fully for increased water stress in canopies**
- **Metabolic inefficiency of competitively unsuccessful small trees that survive but do not grow**