# Ancient trees in Amazonian floodplains: implications for tropical forest ecology and climate change

9th INTECOL INTERNATIONAL WETLANDS CONFERENCE

WETLANDS IN A COMPLEX WORLD

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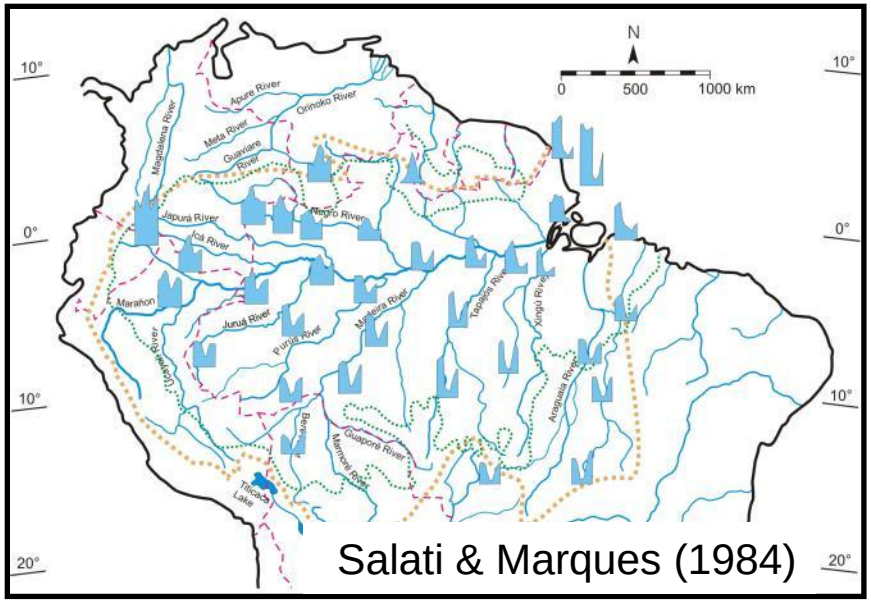
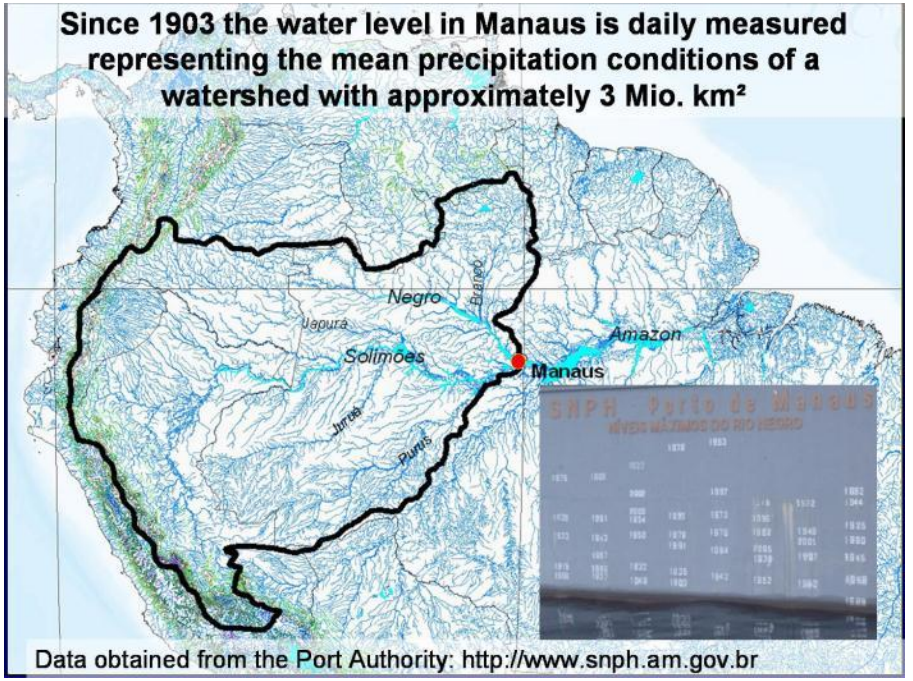
Annual rainfall patterns in the Amazon Basin



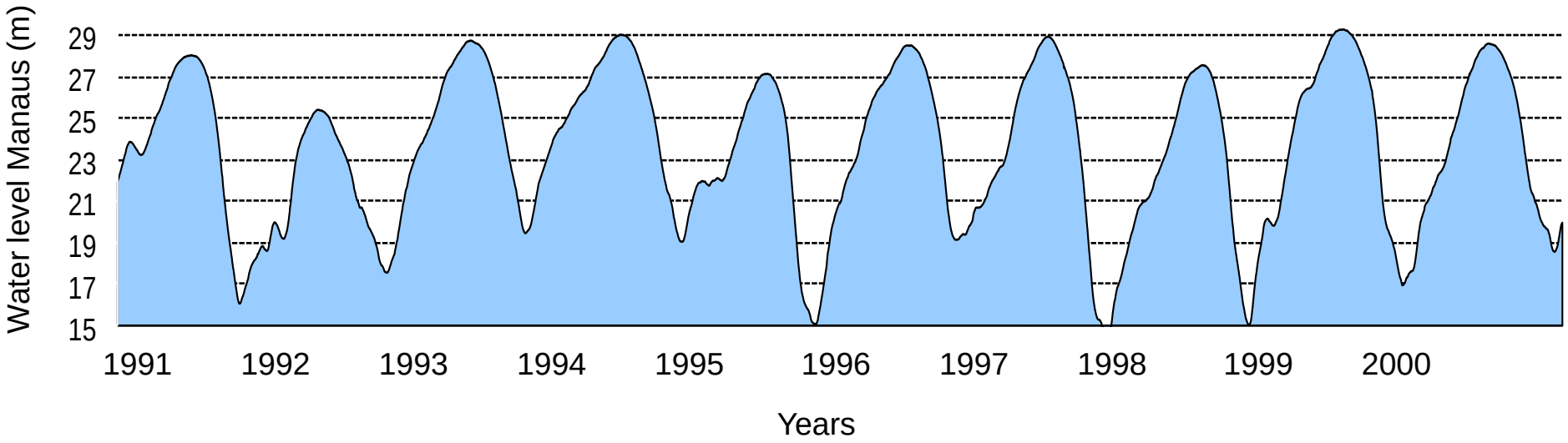

Salati & Marques (1984)

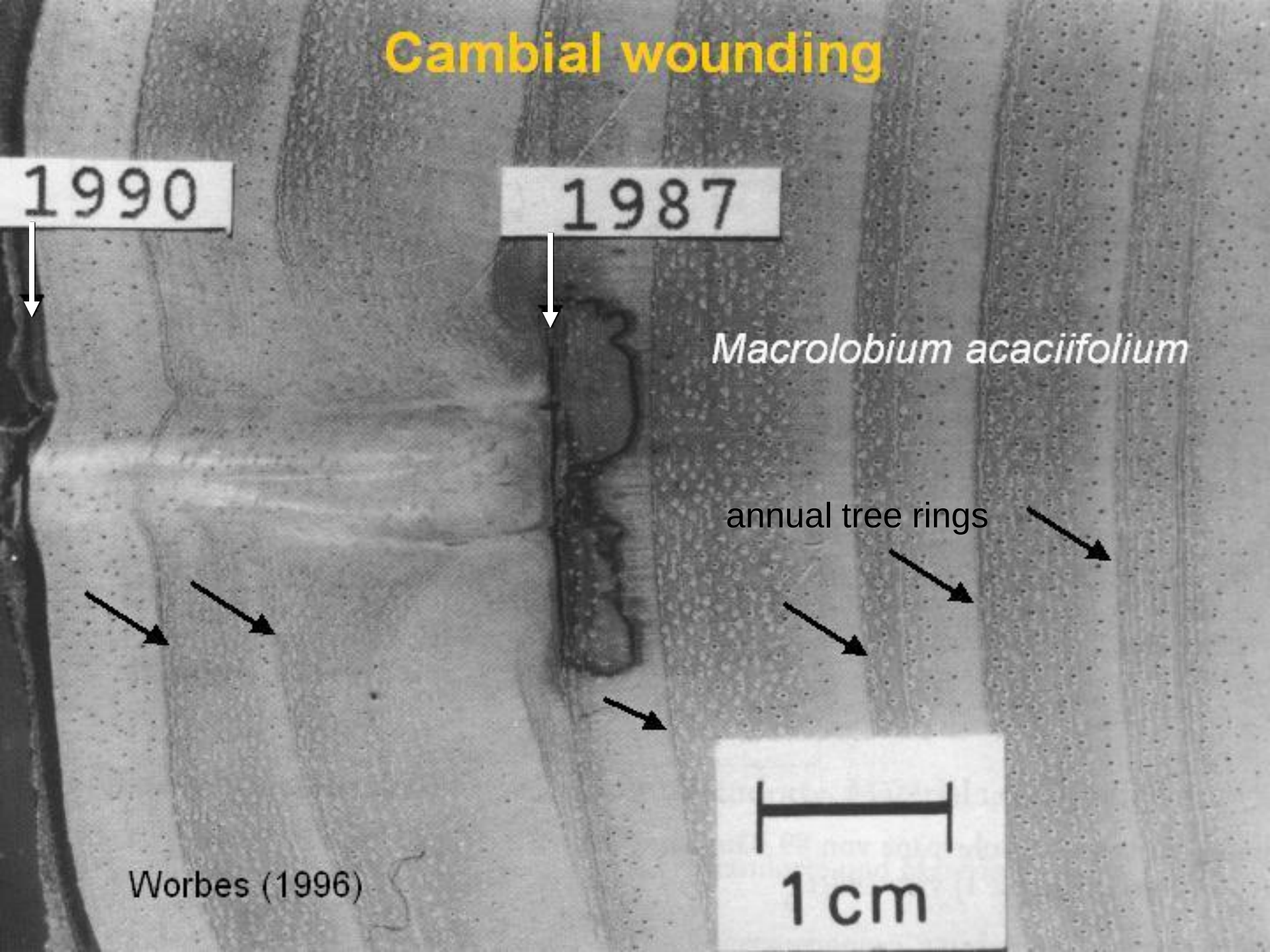



# The flood-pulse concept

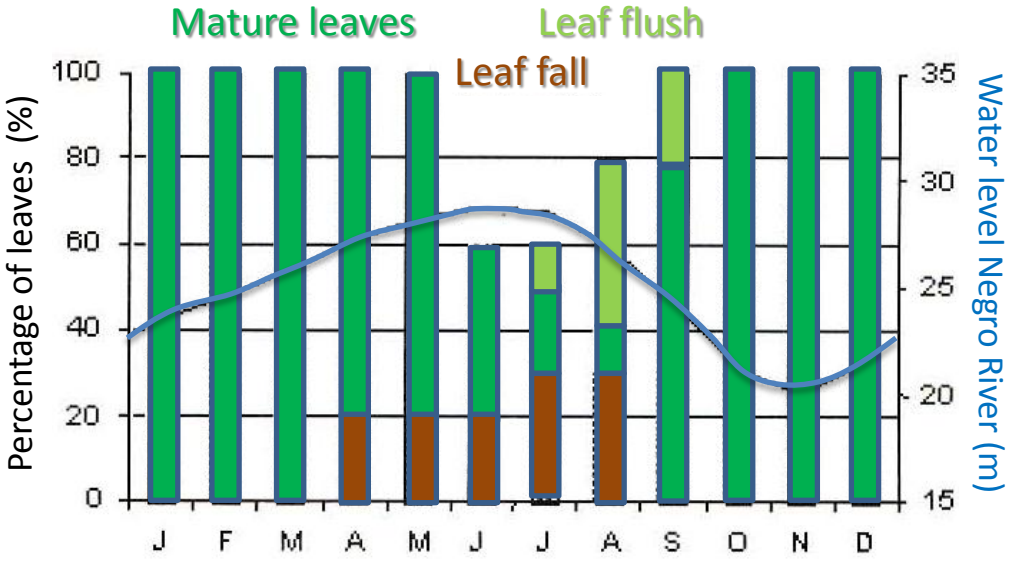
Junk *et al.* (1989)

- Regular
- Annual
- ± Pre-visible




Cambial wounding
1990
1987
Macrolobium acaciifolium
annual tree rings
1 cm
Worbes (1996)

# *Eschweilera tenuifolia* (O. Berg) Miers (Lecythidaceae)




Maia & Piedade (2002)

Endemic? to Amazonian igapó (blackwater and clearwater rivers)

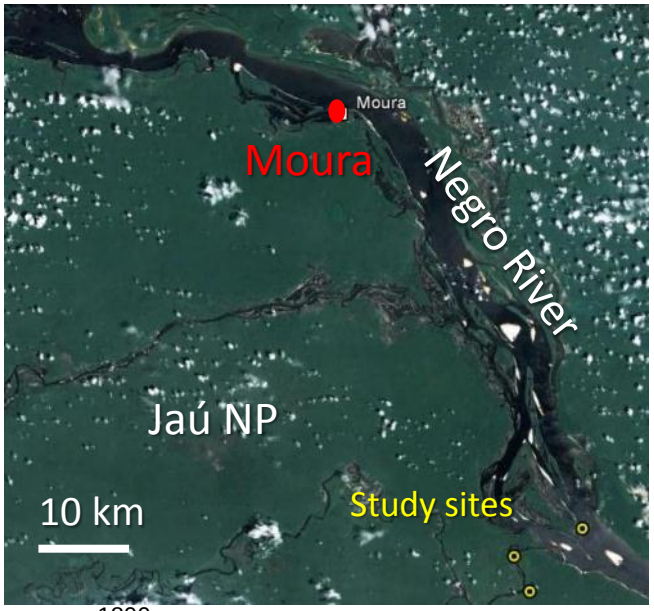
Low topographies

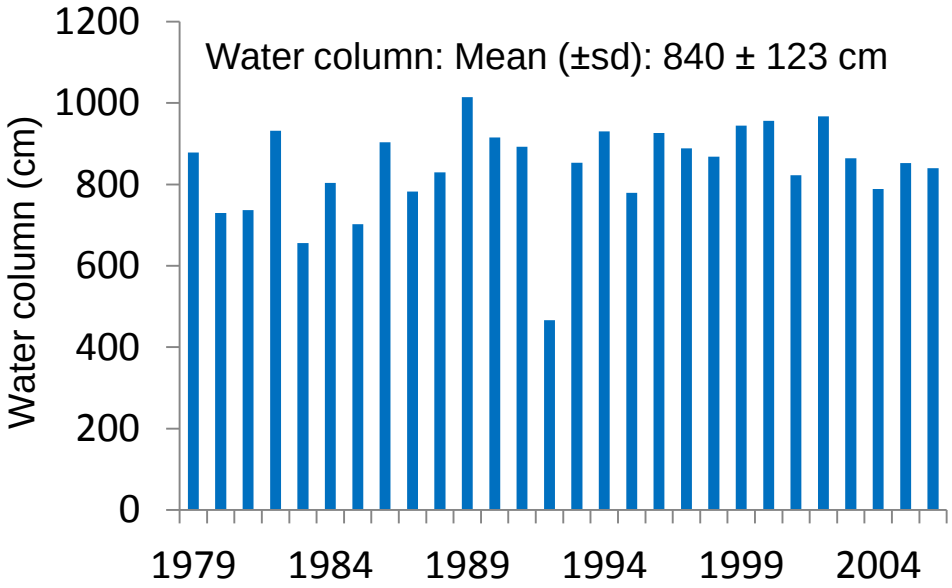
Evergreen species

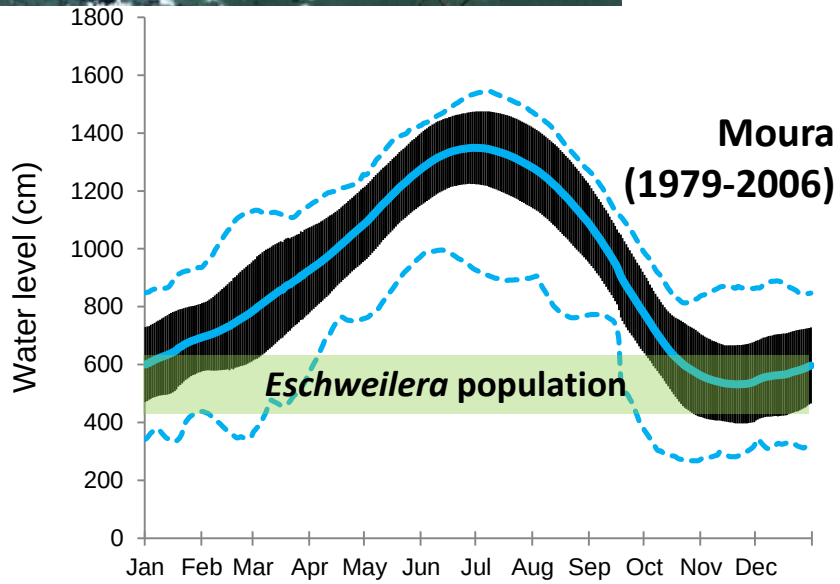
Wood density: 0.70 ± 0.05 g $cm^{-3}$

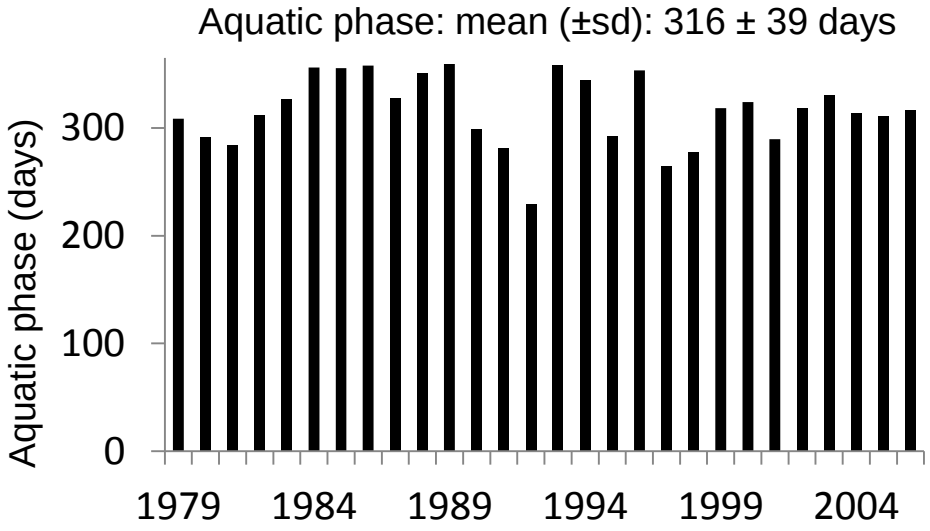
Tree height: 10-20 m

Diameter up to 2 m

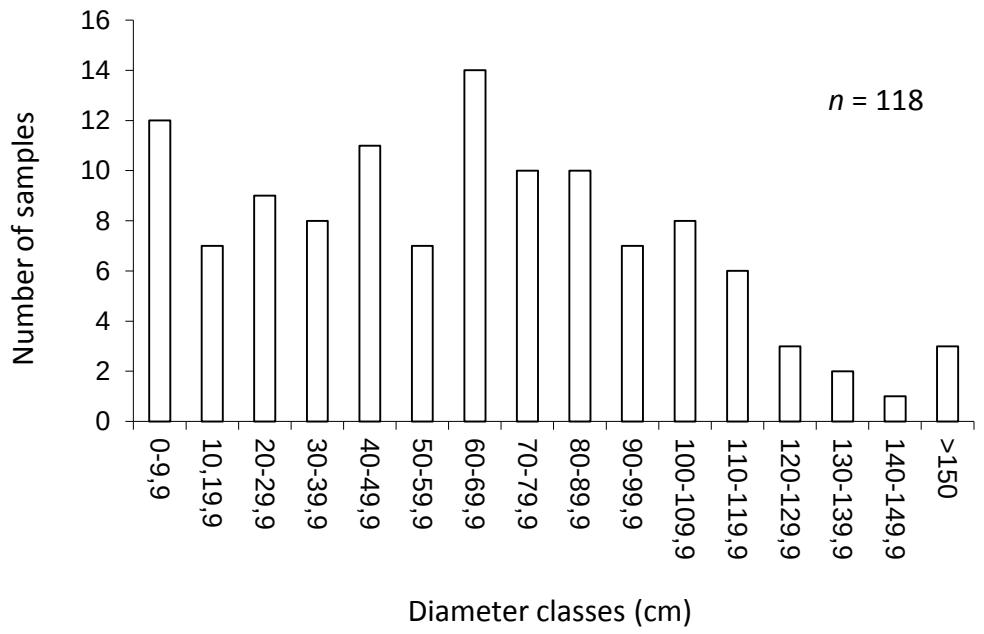



Data: Agência Nacional de Águas (ANA)

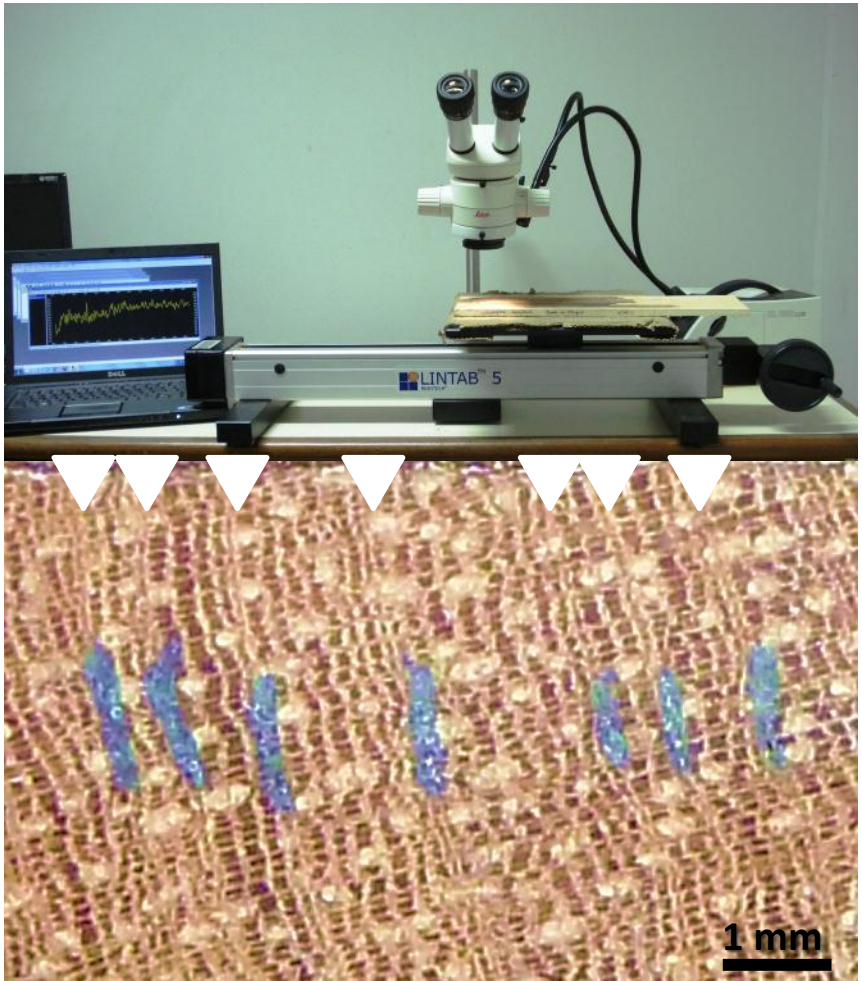

Number of samples
16
14
12
10
8
6
4
2
0
n = 118
0-9,9
10,19,9
20-29,9
30-39,9
40-49,9
50-59,9
60-69,9
70-79,9
80-89,9
90-99,9
100-109,9
110-119,9
120-129,9
130-139,9
140-149,9
>150
Diameter classes (cm)

# Field measurements

- Diameter at breast height
- Tree height
- Water depth

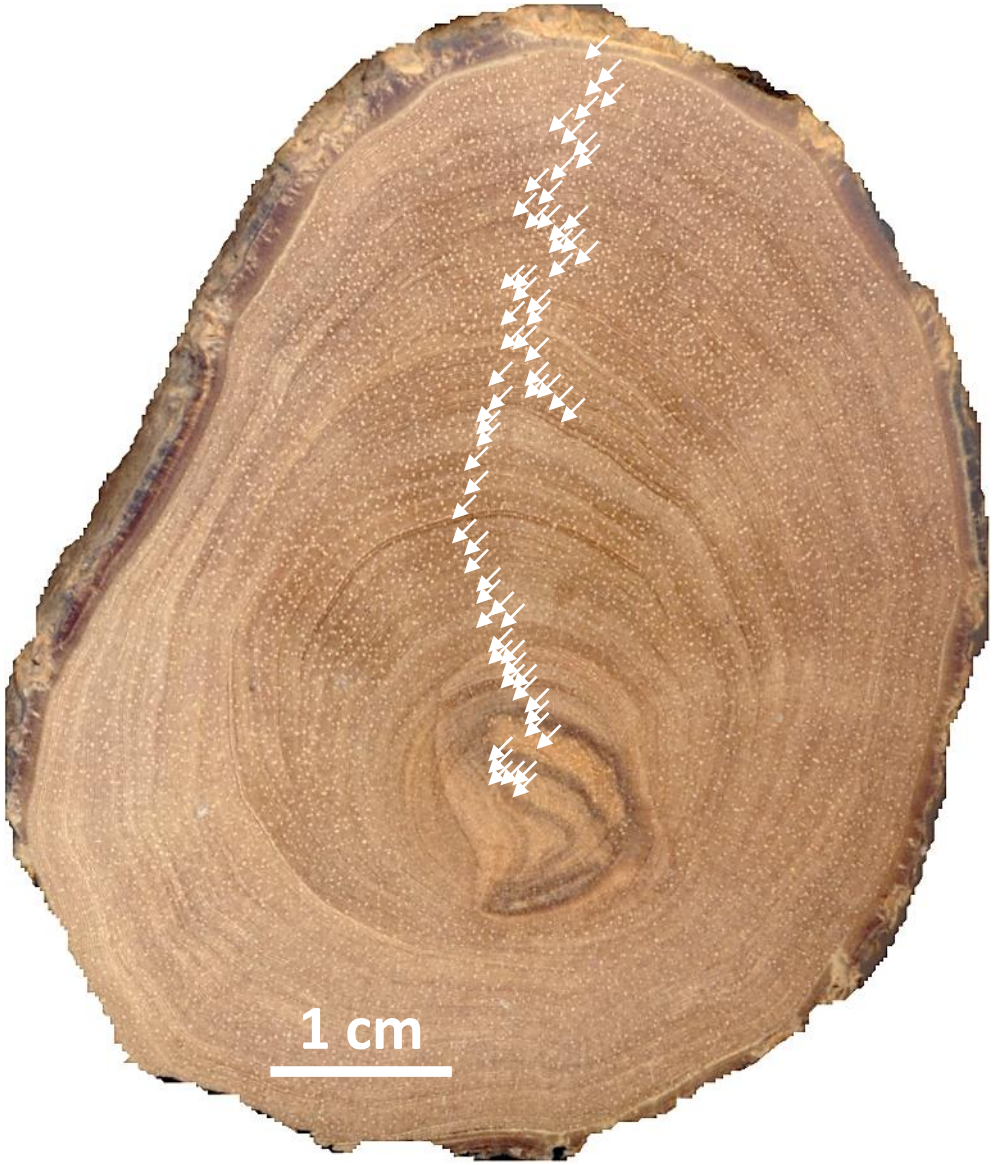
# Wood sampling

- Diameter increment rates

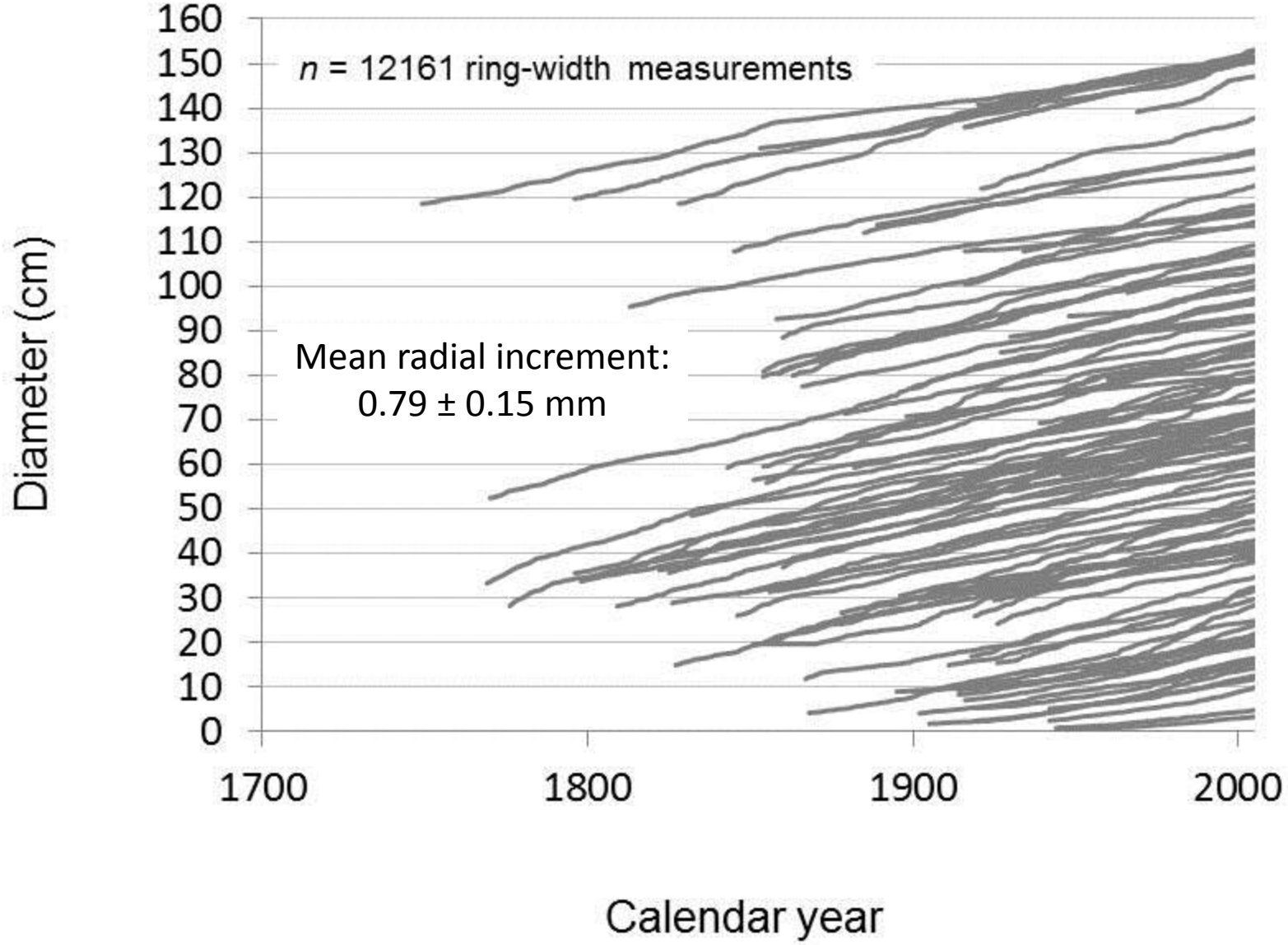


Stem disk from *Eschweilera tenuifolia*

Diameter: 4,5 cm
Age: 59 years



# Constructed cumulative diameter growth curves of *Eschweilera tenuifolia*



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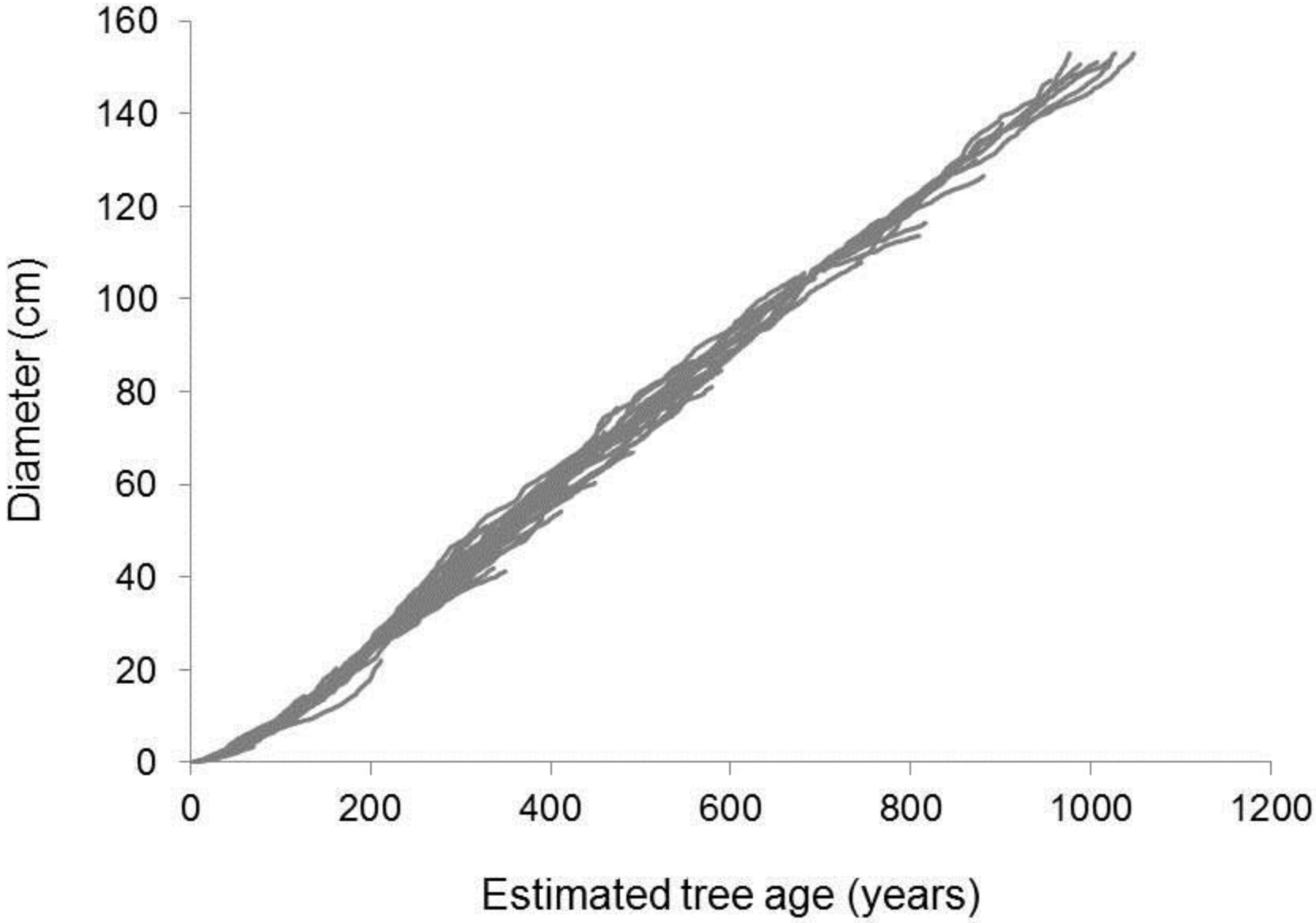
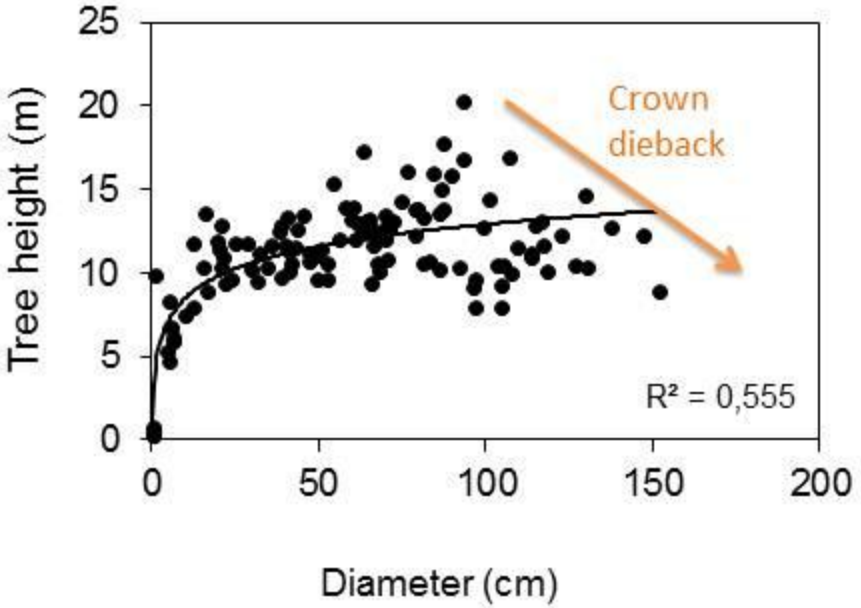
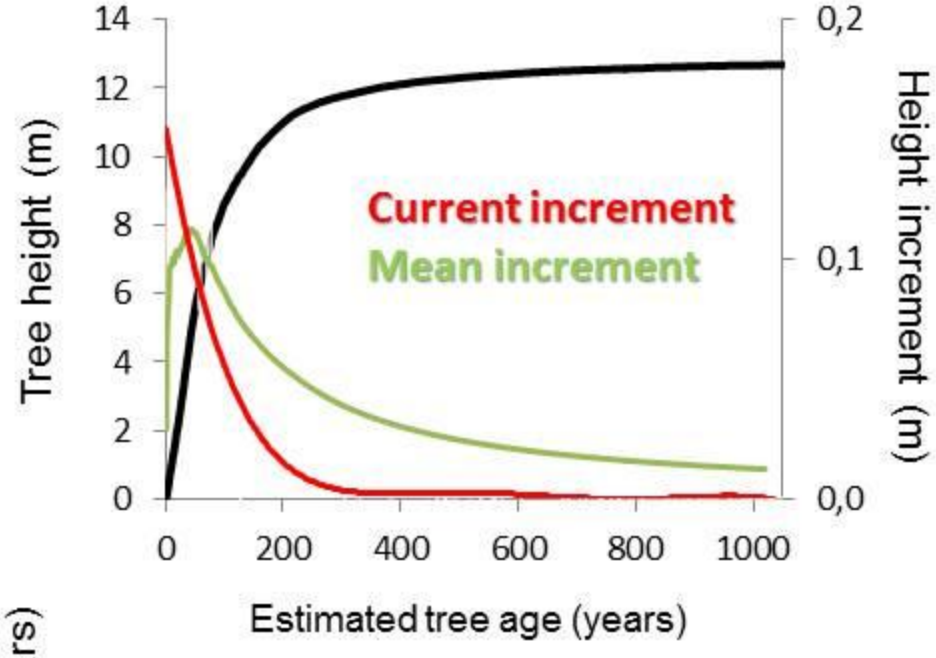
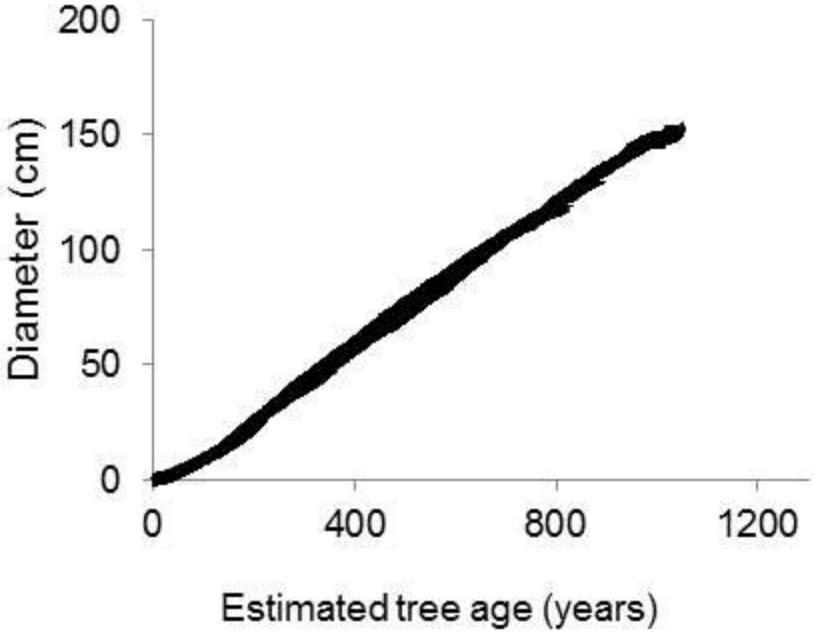
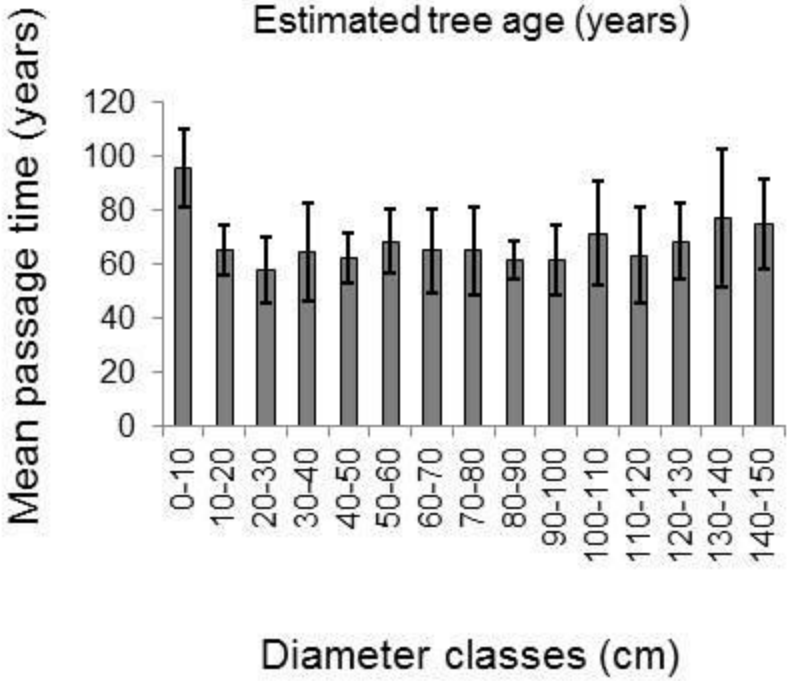


# Growth modeling of *Eschweilera tenuifolia*

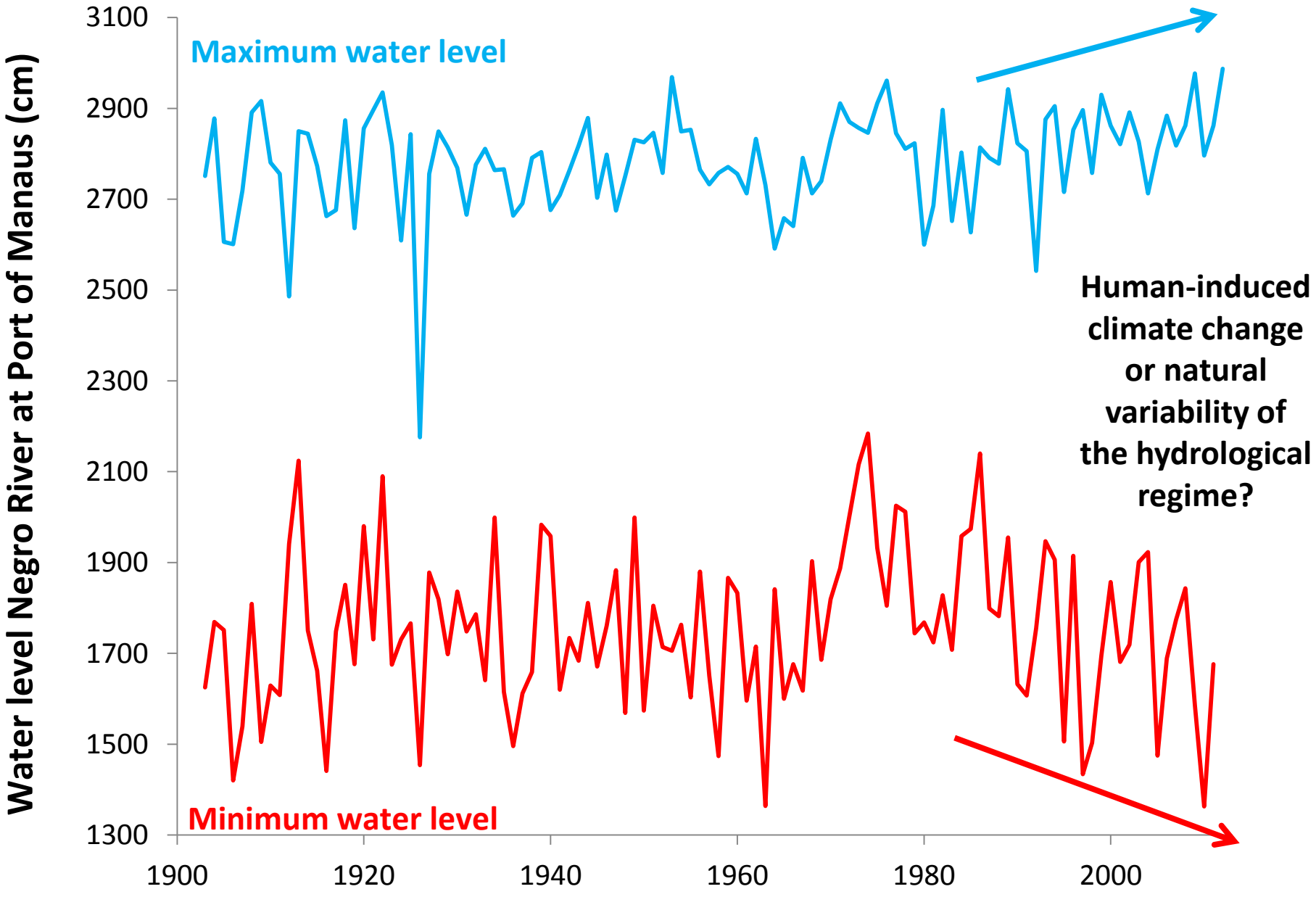


**A 110-yr record of annual maximum and minimum water levels at the Port of Manaus reflecting the rainfall condition in a 3 Mio km² watershed of the Negro and Solimões basins**




Data: Agência Nacional de Águas - ANA

# How old are tropical trees?

# Age estimates based on radiocarbon ($^{14}C$) dating, mathematical model (mortality rates) and repeated diameter measurements

| Method | Tree species | Diamater (cm) | Age (yrs) | Locaiton |
|---|---|---|---|---|
| $^{14}C$ dating | *Bertholletia excelsa* | 129,5 | 1050 | Terra firme, Brazil |
| | *Bertholletia excelsa* | 265 | 440 ± 60 | Terra firme, Brazil |
| | *Cariniana micrantha* | 180 | 1380 | Terra firme, Brazil |
| | *Eusideroxylon zwageri* | 121 | 885 ± 20 | Terra firme, Malaysia |
| | *Carapa guianensis* | 17 | 920 | Terra firme, Brazil |
| Mortality rates | *Swartzia simplex* | - | 2000 | BCI, Panama |
| Repeated diameter measurements | *Pouteria manaosensis* | 54,7 | 1867 | Terra firme, Brazil |
| | *Maquira coriacea* | 160 | 620 | Várzea, Peru |
| | *Neea divaricata* | 22,5 | 529 | Terra firme, Ecuador |
| | *Bertholletia excelsa* | 170 | 292 | Terra firme, Bolivia |

$^{14}C$ dating - Chambers *et al.* (1998); Camargo *et al*. (1994); Kurokawa *et al*. (2003); Viera (2003)

Mortality rates - Condit *et al.* (1995)

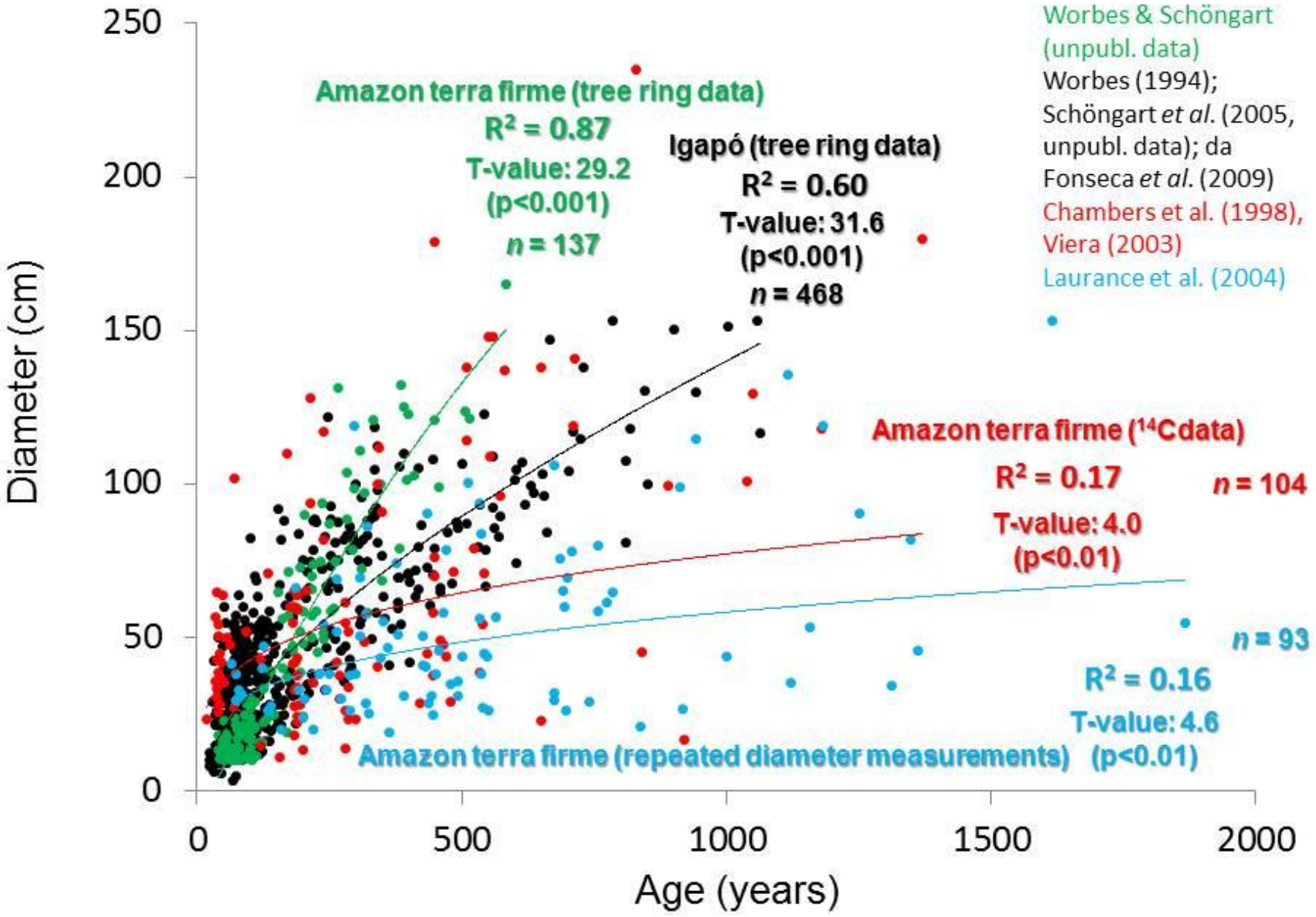
Repeated diameter measurements – Korning & Balslev (1993); Nebel *et al*. (2001); Zuidema & Boot (2002), Laurance *et al.* (2004)

# Maximum tree age of angiosperms determined by tree-ring analysis

| Tree species | Diameter (cm) | Age (yrs) | Location |
|---|---|---|---|
| *Cariniana micrantha* | 165 | 584 | Terra firme, Brazil |
| *Macrolobium acaciifolium* | 126,8 | 562 | Igapó, Brazil |
| *Caryocar villosum* | 124,4 | 546 | Terra firme, Brazil |
| *Hymenolobium mesoamericanum* | 128 | 530 | La Selva, Costa Rica |
| *Manilkara huberi* | 78,8 | 457 | Terra firme, Brazil |
| *Bertholletia excelsa* | 200 | 427 | Terra firme, Bolivia |
| *Daniella oliveri* | 63,5 | 368 | West Africa |
| *Piranhea trifoliata* | 60 | 289 | Várzea, Brazil |
| *Guibourtia tessmannii* | 84 | 260 | Gabon, Africa |
| *Celtis zenkeri* | 63 | 220 | Cameroon, Africa |

Fichtler *et al*. 2003; Worbes *et al*. 2003; Schöngart *et al*. 2004, 2005, 2006; Brienen & Zuidema (2005); Worbes & Schöngart (*unpubl.*)

**Comparison of age-diameter relationships of igapó trees compared to non-flooded terra firme trees evaluating different methods to estimate tree age**



*Pinus longaeva*


*Sequoiadendron giganteum*

## Maximum ages of trees in temperate, boreal and semi-arid zones

| Tree species | Country | Method | Age (yrs) |
|---|---|---|---|
| **Gymnosperms** | | | |
| *Pinus longaeva* | USA | *XD* | 4789-4844 |
| *Fitzroya cupressoides* | Chile | *XD* | 3622 |
| *Sequoiadendron giganteum* | USA | *XD* | 3033-3266 |
| *Juniperus occidentalis* | USA | *XD* | 2675 |
| *Pinus aristata* | USA | *XD* | 2435 |
| *Sequoia sempervirens* | USA | *RC* | 2200 |
| *Pinus balfouriana* | USA | *XD* | 2110 |
| **Angiosperms** | | | |
| *Weinmannia trichosperma* | Chile | *RC* | 730 |
| *Liriodendron philippiana* | Chile | *RC* | 657 |
| *Quercus alba* | USA | *XD* | 289-407 |
| *Quercus gambelli* | USA | *XD* | 401 |
| *Quercus stellata* | USA | *XD* | 373 |
| *Quercus bicolor* | USA | *XD* | 285 |

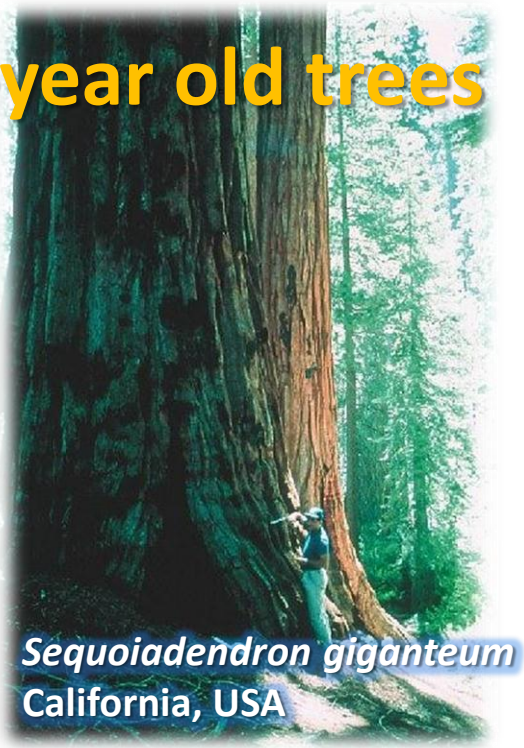
Method: *XD* = *cross-dating*; *RC* = ring-counting

Loehle (1988); Lara (1991); Lusk (1999); Brown (1994)

# Over 1000-year old trees


*Pinus albicaulis* , Montana, USA


*Pinus longaeva*
White Mountains, USA


*Sequoiadendron giganteum*
California, USA

http://web.utk.edu/~grissino/
http://www.rmtrr.org/oldlist.htm


*Thuja occidentalis*
Niagara, USA


*Taxodium distichum*,
South Carolina, USA

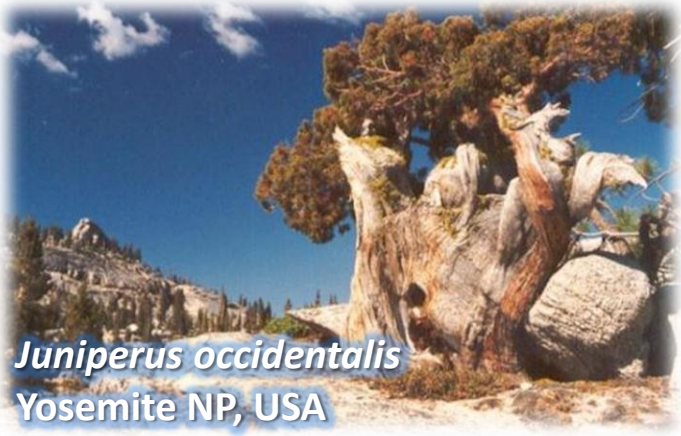
**Marginal sites**

**Limiting environmental factores**

**Monodominant or monospecific stands**

**Low competition**

**Trees with longitudinal twisted stems, crown dieback, hollow voids or heart rot and bark-covered knobs**


*Juniperus occidentalis*
Yosemite NP, USA

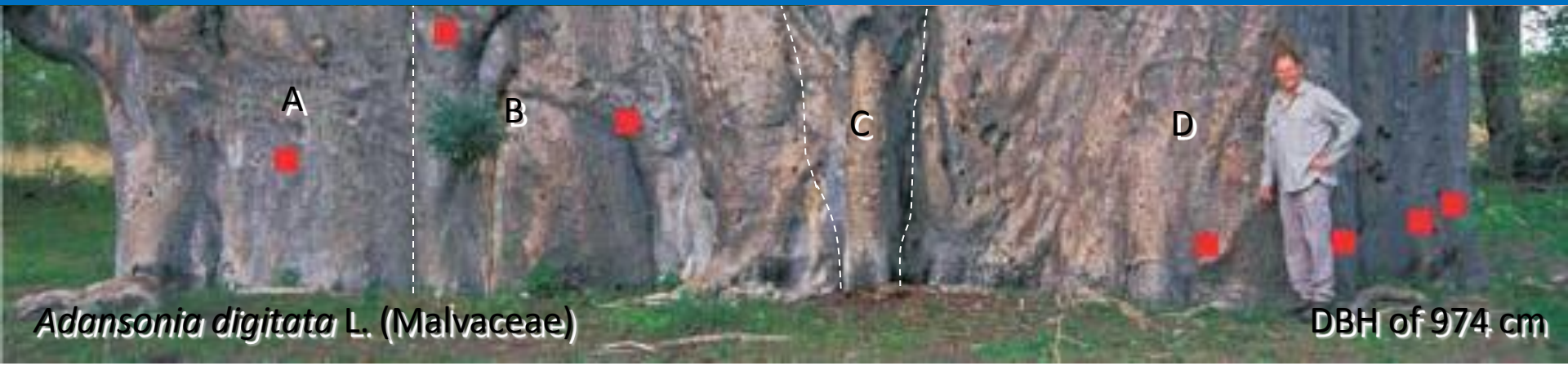
(Loehle 1988; Stahle 1996; Stahle *et al*. 2012)

# Site conditions and morphological characteristics of *Eschweilera tenuifolia*

- ✓ Marginal sites
- ✓ Limiting environmental factores
- ✓ Monodominant or monospecific stands
- ✓ Low competition
- ✓ Trees with longitudinal twisted stems, crown dieback, hollow voids or heart rot and bark-covered knobs

# Radiocarbon dating of a very large African baobab (Namíbia)

| Sample No. and stem | Fraction Modern | $\delta^{13}C$ (‰) | Radiocarbon date ($^{14}C$ years BP) | 1-σ age ranges (cal years AD) | Relative area (%) | Mean cal BP age (cal years BP) | Sample age (cal years) |
|---|---|---|---|---|---|---|---|
| 1 A | 0.8555 (± 0.0042) | −23.60 | 1255 (± 35) | 680–780 | 68.2 | 1220 (± 50) | 1275 (± 50) |
| 2 B | 0.9559 (± 0.0036) | −24.89 | 360 (± 30) | 1460–1530 | 39.0 | 455 (± 35) | 510 (± 35) |
| | | | | 1570–1630 | 29.2 | | |
| 3 B | 0.9551 (± 0.0024) | −26.14 | 370 (± 20) | 1450–1520 | 51.0 | 465 (± 35) | 520 (± 35) |
| | | | | 1600–1620 | 17.2 | | |
| 4 B | 0.8778 (± 0.0023) | −25.56 | 1045 (± 20) | 990–1020 | 68.2 | 945 (± 15) | 1000 (± 15) |
| 5 C | 0.9334 (± 0.0032) | −24.31 | 555 (± 25) | 1325–1345 | 26.4 | 545 (± 15) | 600 (± 15) |
| | | | | 1390–1420 | 41.8 | | |
| 6 C | 0.9466 (± 0.0030) | −24.24 | 440 (± 25) | 1430–1460 | 68.2 | 505 (± 15) | 560 (± 15) |
| 7 D | 0.8981 (± 0.0026) | −25.66 | 865 (± 20) | 1165–1210 | 68.2 | 765 (± 25) | 820 (± 25) |
| 8 D | 0.8734 (± 0.0071) | −24.54 | 1090 (± 55) | 890–1020 | 68.2 | 995 (± 65) | 1050 (± 65) |
| 9 D | 0.9361 (± 0.0053) | −23.54 | 530 (± 45) | 1320–1350 | 13.3 | 535 (± 25) | 590 (± 25) |
| | | | | 1390–1440 | 54.9 | | |
| 10 D | 0.9419 (± 0.0025) | −24.69 | 480 (± 20) | 1420–1440 | 68.2 | 520 (± 10) | 575 (± 10) |




The “Grootboom” site is located at 19°38’57.5” S, 20°39’23.7” E, 1149 m asl
Mean annual rainfall in the area is 451 mm!

Patrut *et al*. (2005)

# Summary and conclusion

- Dendrochronology is a powerful method for age determination also for tropical trees.
- Trees of *Eschweilera tenuifolia* are the oldest ones so far described for the Amazonian floodplains and among the oldest found in the tropics.
- Only at marginal sites where species occur in monodominant (monospecific) stands growing under low competition and limited by environmental factors, tropical trees reach maximum ages above 1,000 years.
- This finding questions age estimates based on radiocarbon dating and repeated diameter measurements indicating tree ages over 1,000 years for the Central Amazonian non-flooded terra firme where up to 250 tree species $ha^{-1}$ grow under high competition at the “optimum” of forest occurrence.
- The 1,000-yr old *Eschweilera tenuifolia* trees indicate that flooding at the study sites did not increase over the last millennium, however, changes of the hydrological regimes caused by climate change and/or hydrological power plants might have a severe impact on these tree populations in the future.

# Acknowledgements

**Technicians (INPA)**

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