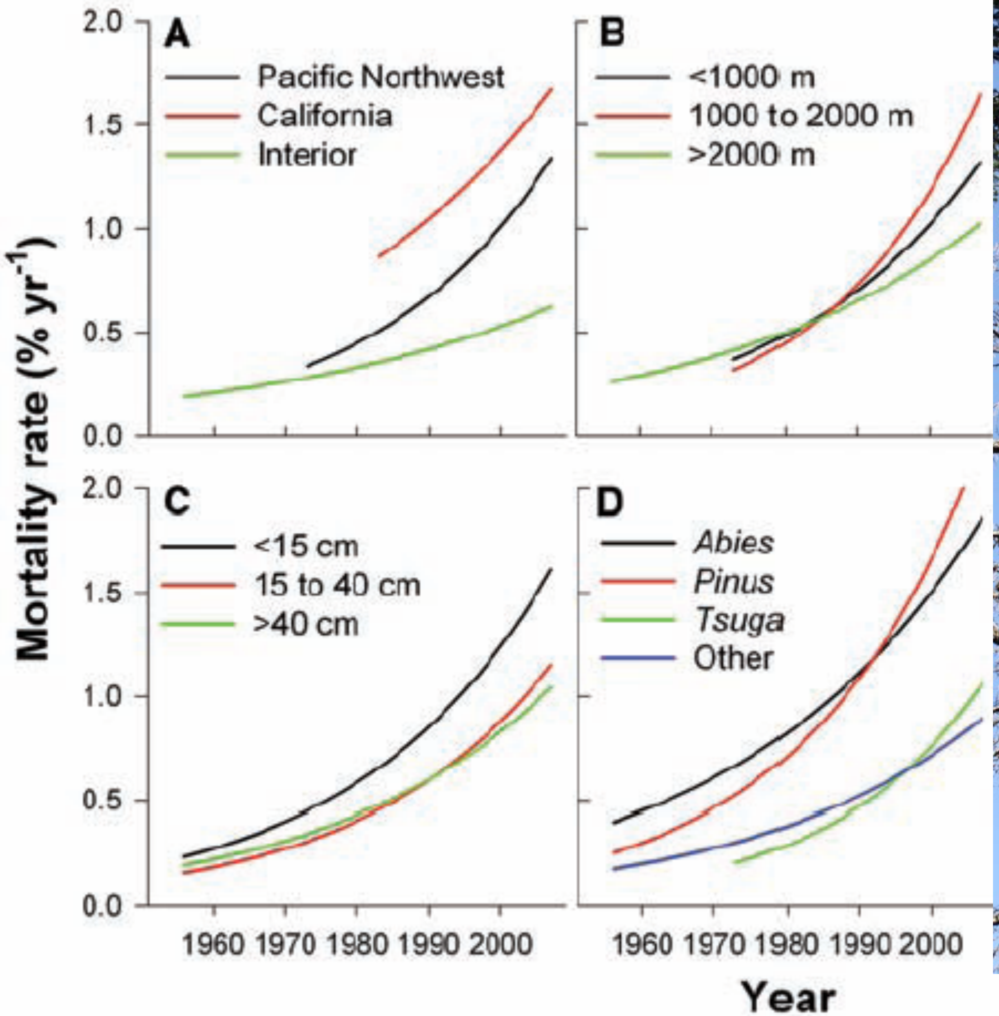
How to predict tree decline and mortality from process based models?

H. Davi, M. Cailleret, M. Nourtier, M. Gillmann, R. Huc, A. Chanzy

Van Mantgem et al., 2009



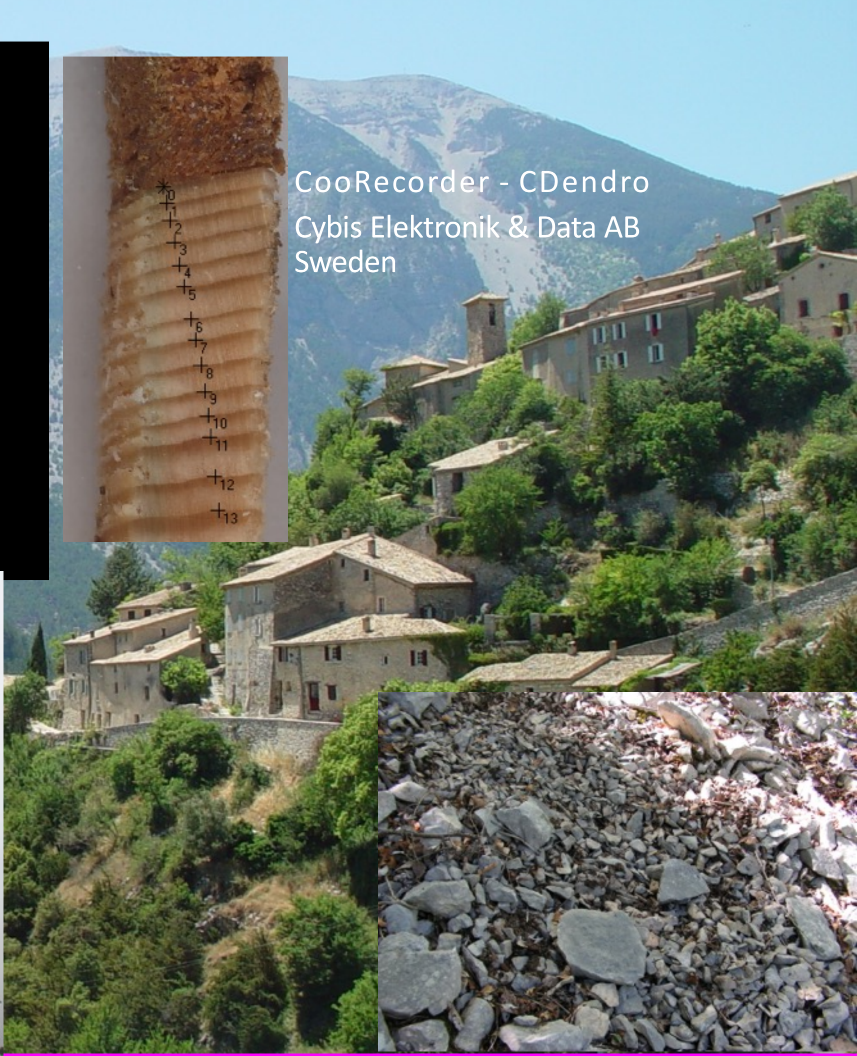
How explain, predict and prevent mortality?

The Mont Ventoux : a mountain in the Mediterranean area

Recent Silver fir decline: two spatial scales

2 intensive study sites
- tree transpiration by sapflow measurements
- deep soil water capacity by electric resistivity

21 stands gathering 450 trees
- tree ring record
- needle loss



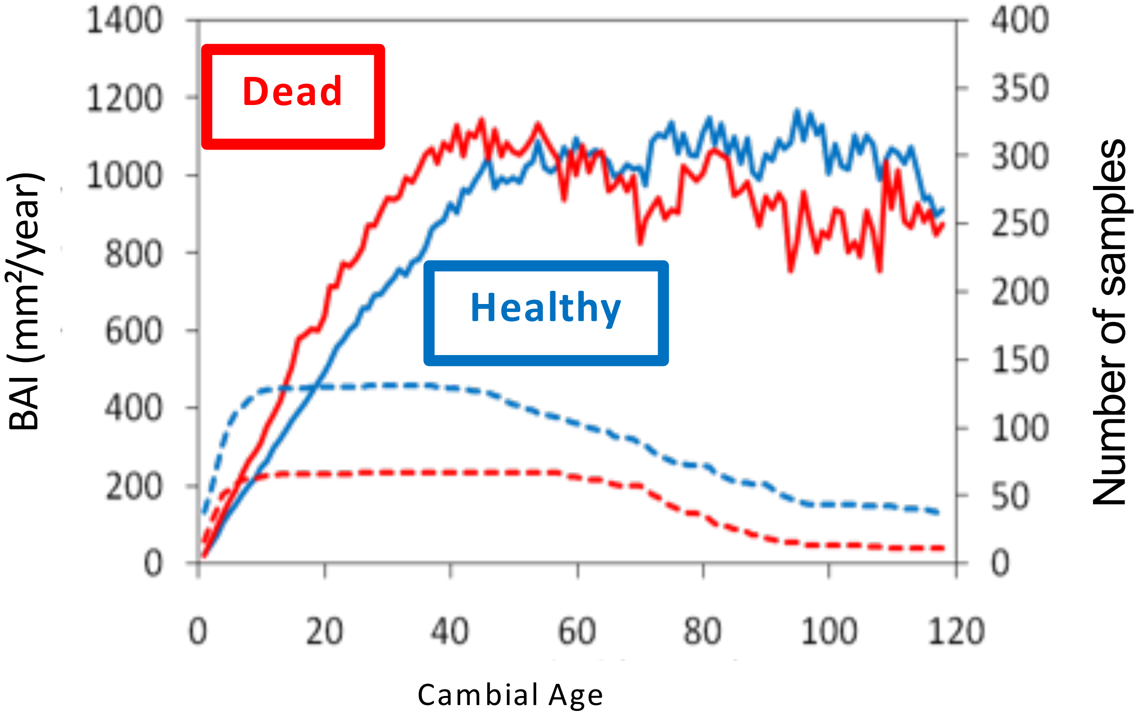
CooRecorder - CDendro
Cybis Elektronik & Data AB
Sweden

Silver at its xeric limit
High water stress

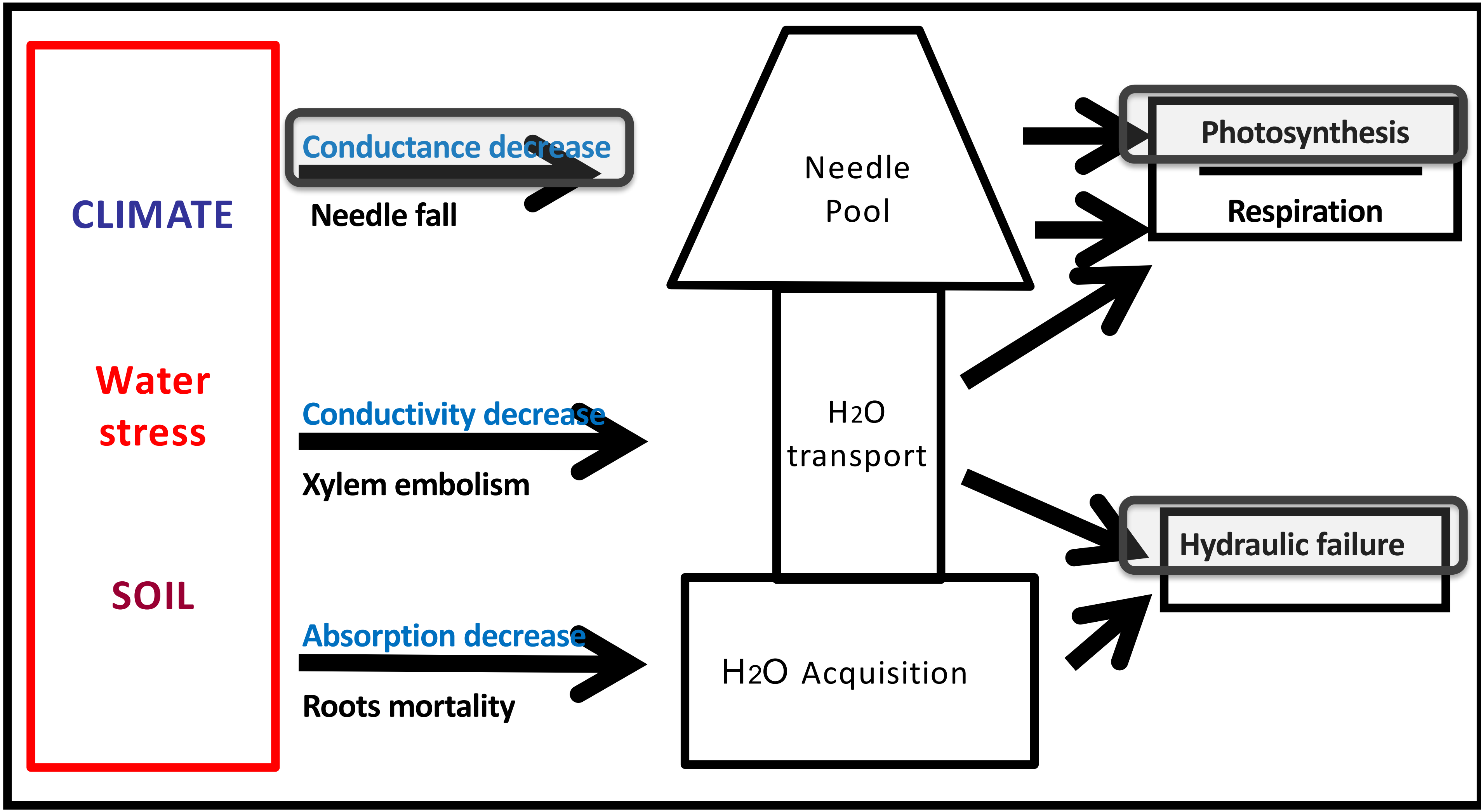
Karstic soils with high stone content

Main *in situ* results :

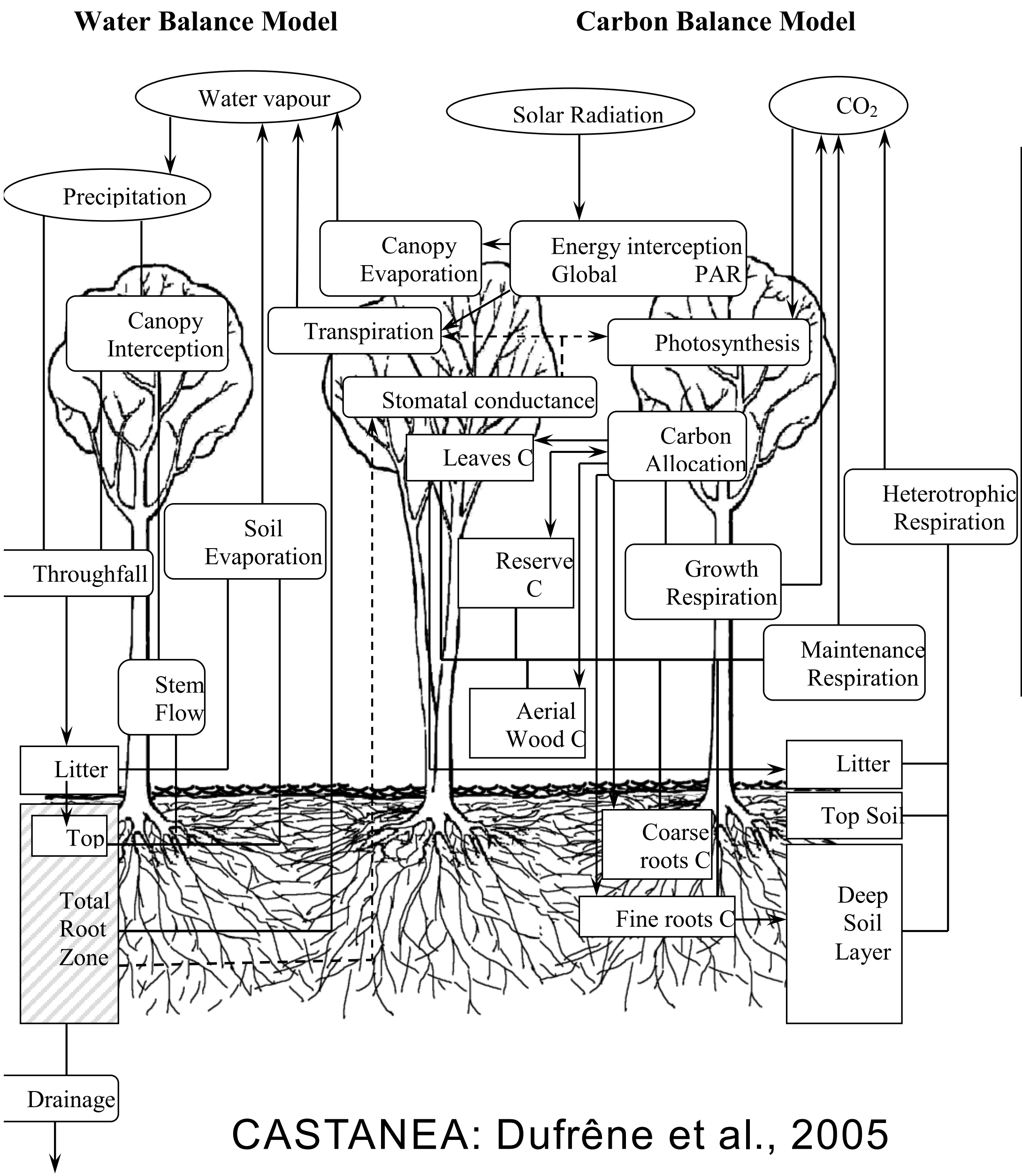
- Juvenile growth rate of dead trees is higher
- Tree mortality is not related to needle deficit as growth patterns of dead trees and trees with crown damages differed
- Post effects of drought on transpiration are probably due to fine roots mortality not to hydraulic failure



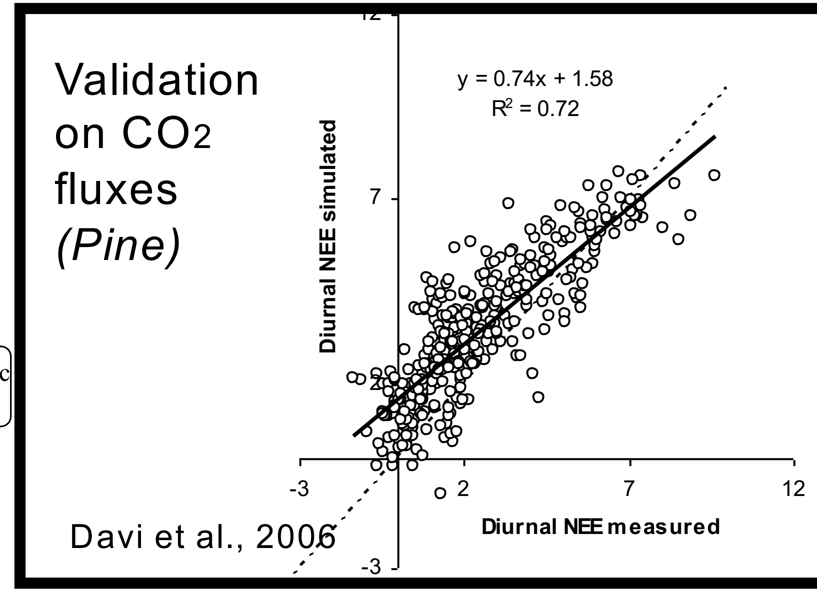
Cailleret et al., submitted
Nourtier et al., submitted
Cailleret et al., see a poster here



- Temporal scale of response (hour, year, decade)
- hydraulic .vs. carbon starvation



CASTANEA: Dufrêne et al., 2005



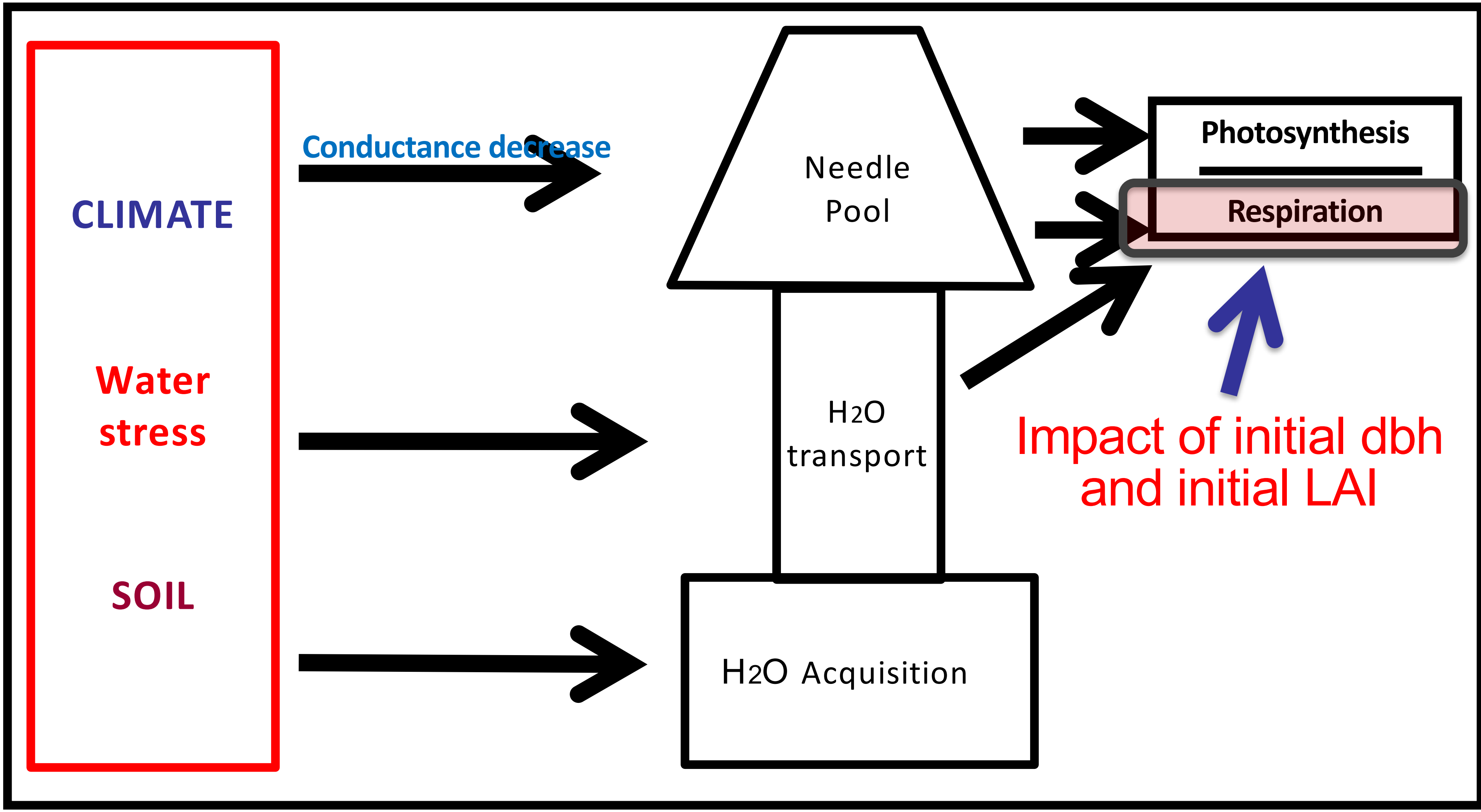
Objectives: Depict the various processes involved in carbon starvation and answer the tree questions revealed by the *in situ* results

Methods:

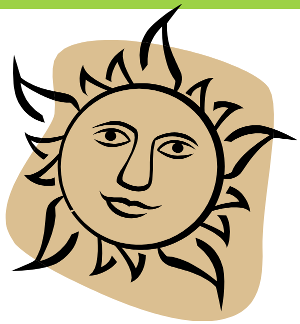
- Add new mechanisms to the model
- Use sensitivity analysis

Q1: Impact of juvenile growth and soil conditions on tree vulnerability

- ✓ simulation from 1967 to 2007 (trees: 50->90 years old)
- ✓ 6 initial dbh: 12->32 cm
- ✓ 10 Soil Water Capacity: 20 ->140 mm
- ✓ 3 altitudes: 1000, 1200, 1500m



Model I: $\text{Model}_{\text{Basis}}$



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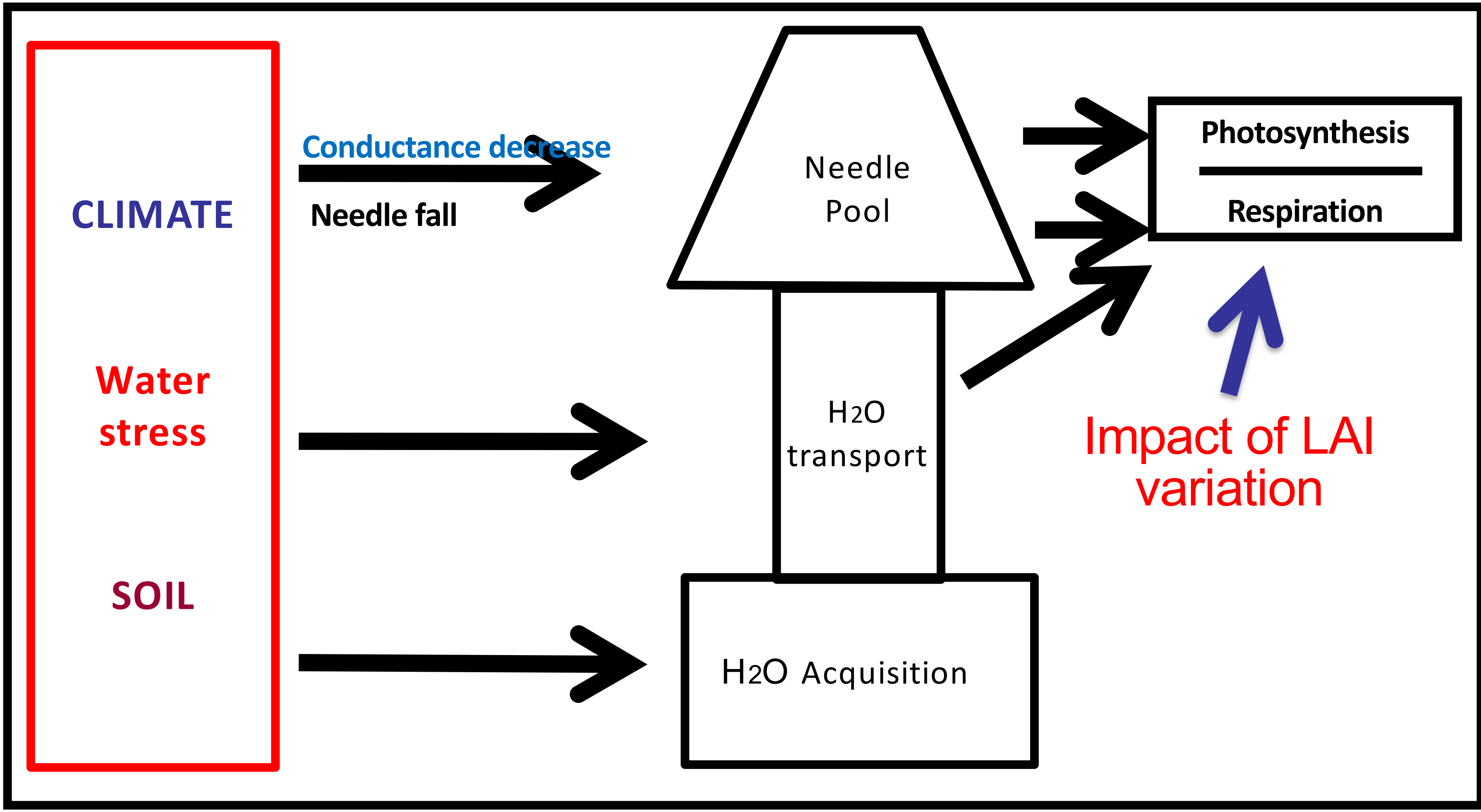
Q2: Role of needle loss or production in provoking or avoiding death

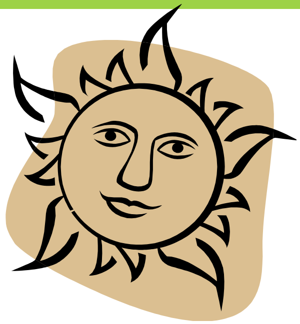
- ✓ **same simulation** with a second version (Davi et al., 2009)
- ✓ needle production and mortality depends on reserves



Model II= Model$_{LAI\ var}$

Davi et al., 2009

Add needle loss and production = f(C reserves)



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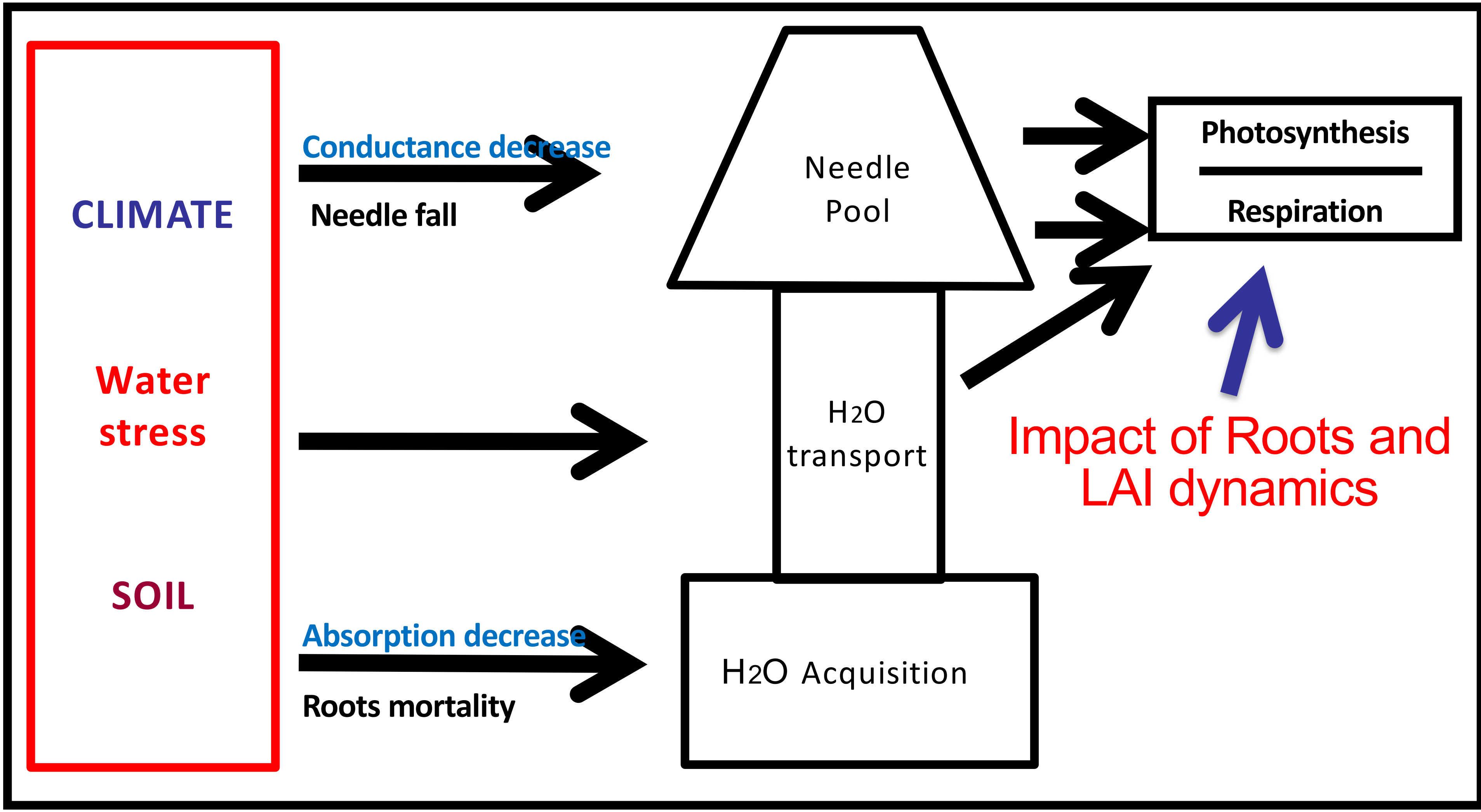
Q3: Impact of roots distribution and dynamics on water uptake and mortality

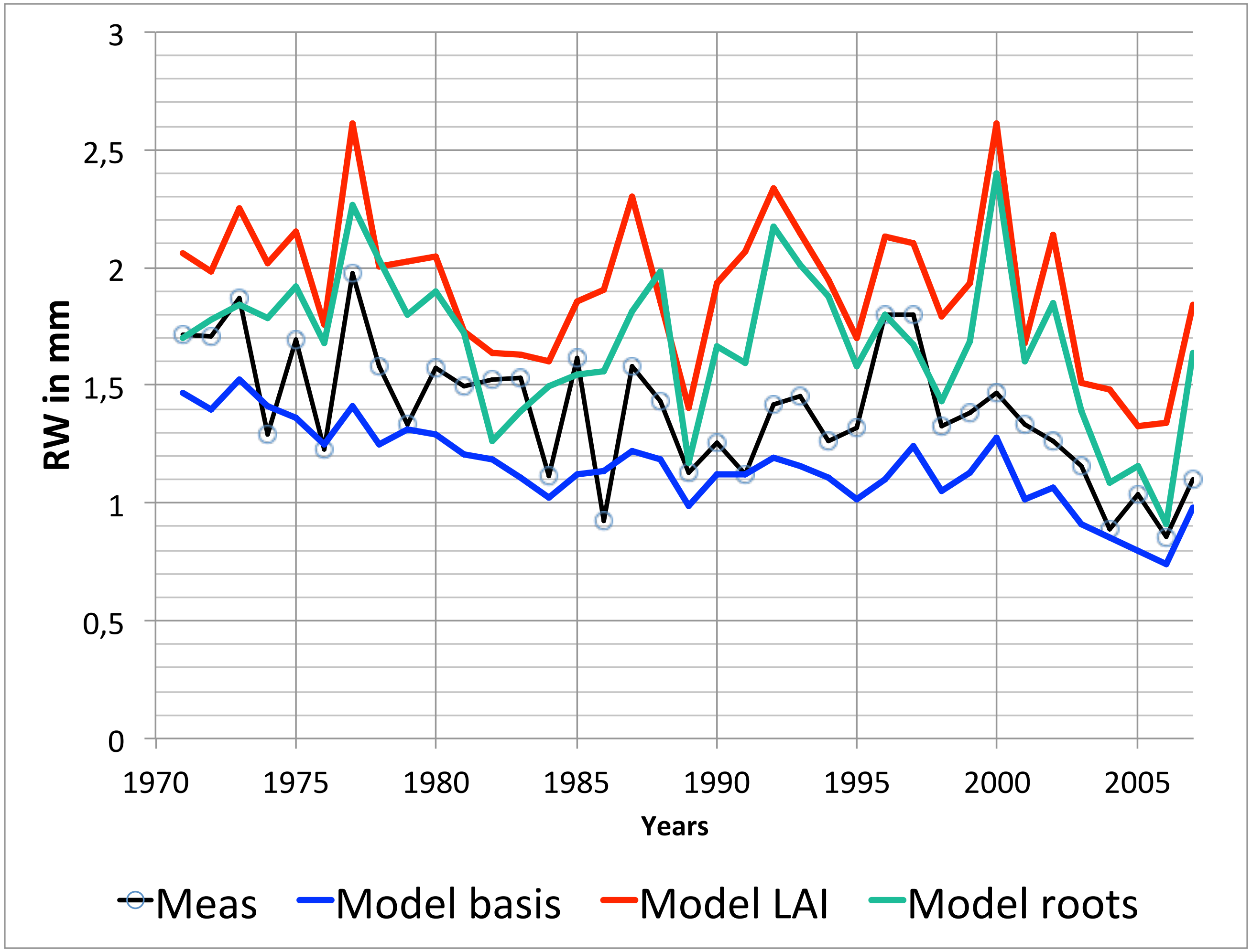
- ✓ **same simulation** with a third version (Nourtier et al., in prep)
- ✓ two soil layers: SWC=f(depth of soil, % stone content)
- ✓ impact of fine roots dynamics on water uptake



Model III= $Model_{roots}$

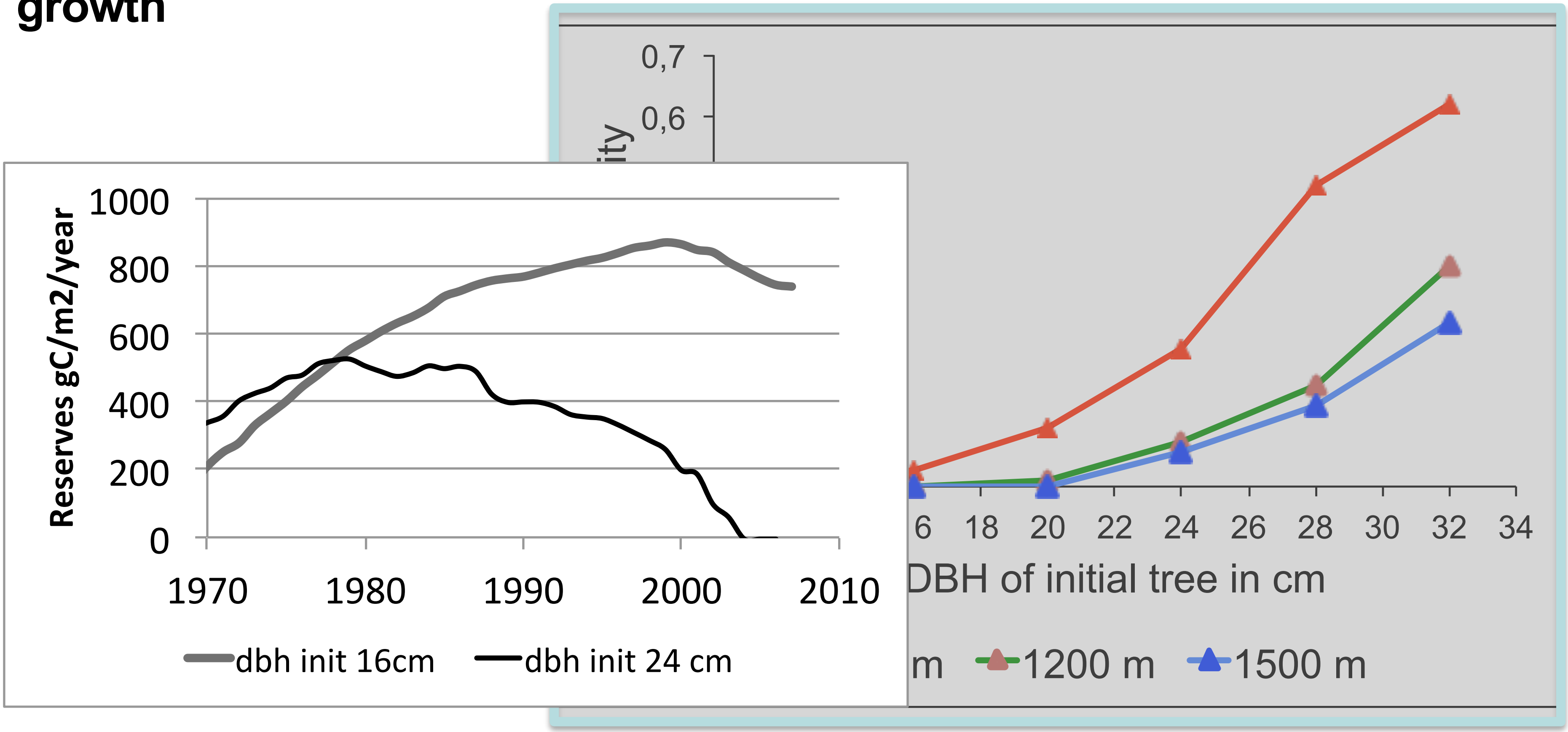
Add roots mortality f(Ψsoil) and water acquisition f(roots)

Average simulation
.vs.
Average measure of
Ring Width



- Too low average and variability in basis model
- Too high average variability with LAI and roots models

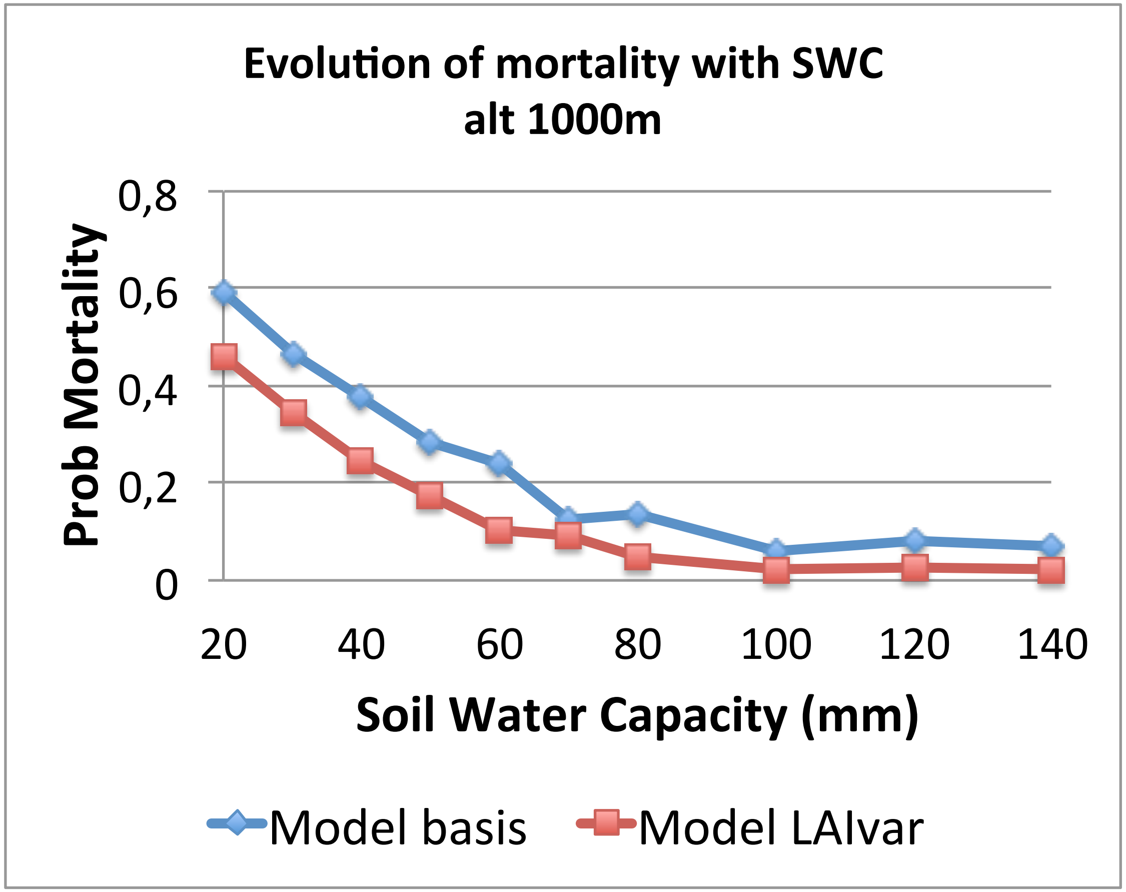
1. Effect of Juvenile growth



- High mortality probability when initial dbh and LAI are high
- Mortality rate decreases with altitude (not linearly)

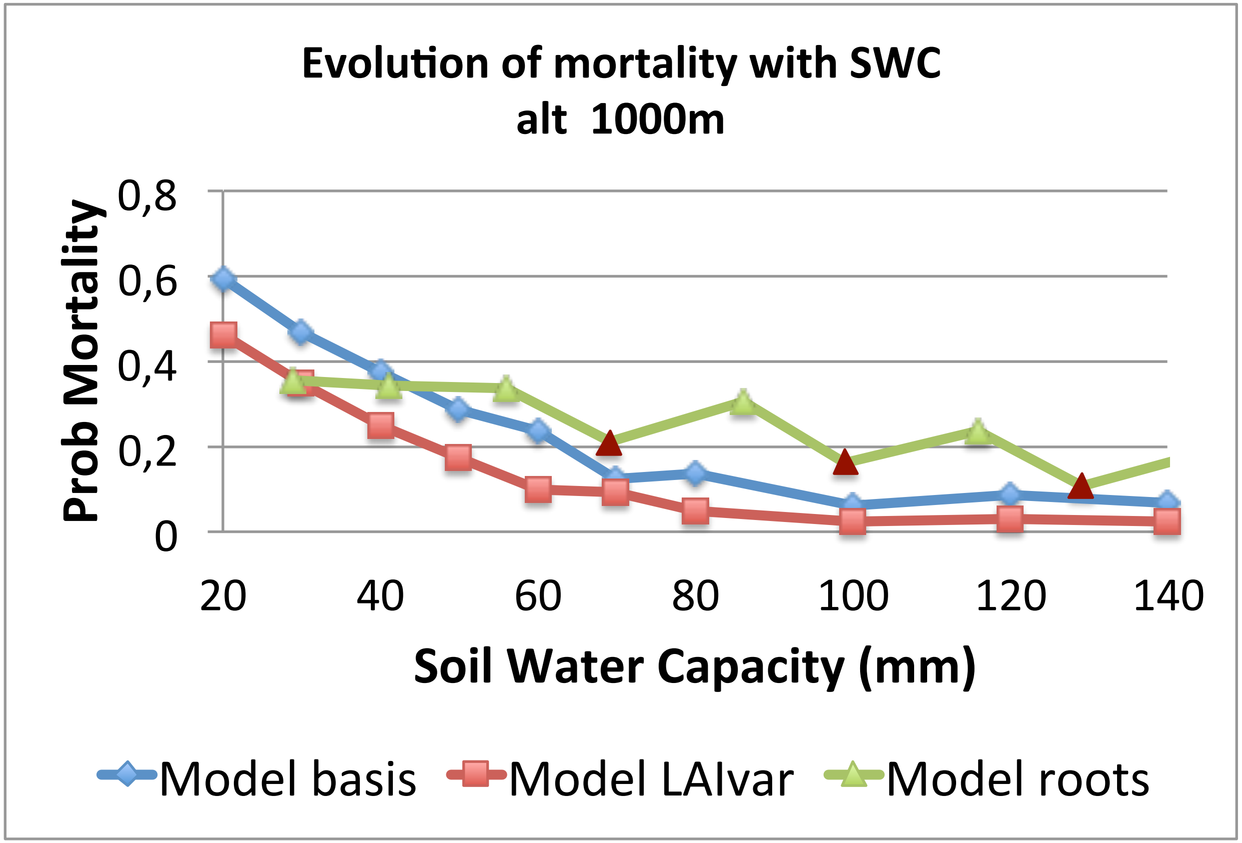
High respiration rate & investment in roots and leaf => low reserves

2. Effect of Leaf Area Index (LAI) plasticity



LAI plasticity => decrease mortality rate

3. Effect of roots dynamics



- Lower mortality at low SWC
- Higher mortality at high SWC
- Mortality differs according the « type » of SWC: % stones change (black triangle) or soil depth change

Carbon starvation does not only sum up to stomata closure and lower carbon uptake

- High juvenile growth provokes high respiratory costs & fine roots production
- Plasticity of needle production limits mortality
- Roots mortality affecting water uptake increases mortality

Back to measurements

- Validation of CASTANEA model on Silver fir flux site in Lavaronne (Italia)
- Impact of pathogens (ongoing PhD)
- Role of hydraulic failure: low in Silver fir (high stomata control), test on another species
- **Carbon allocation to fine roots must be better known**

Acknowledgement

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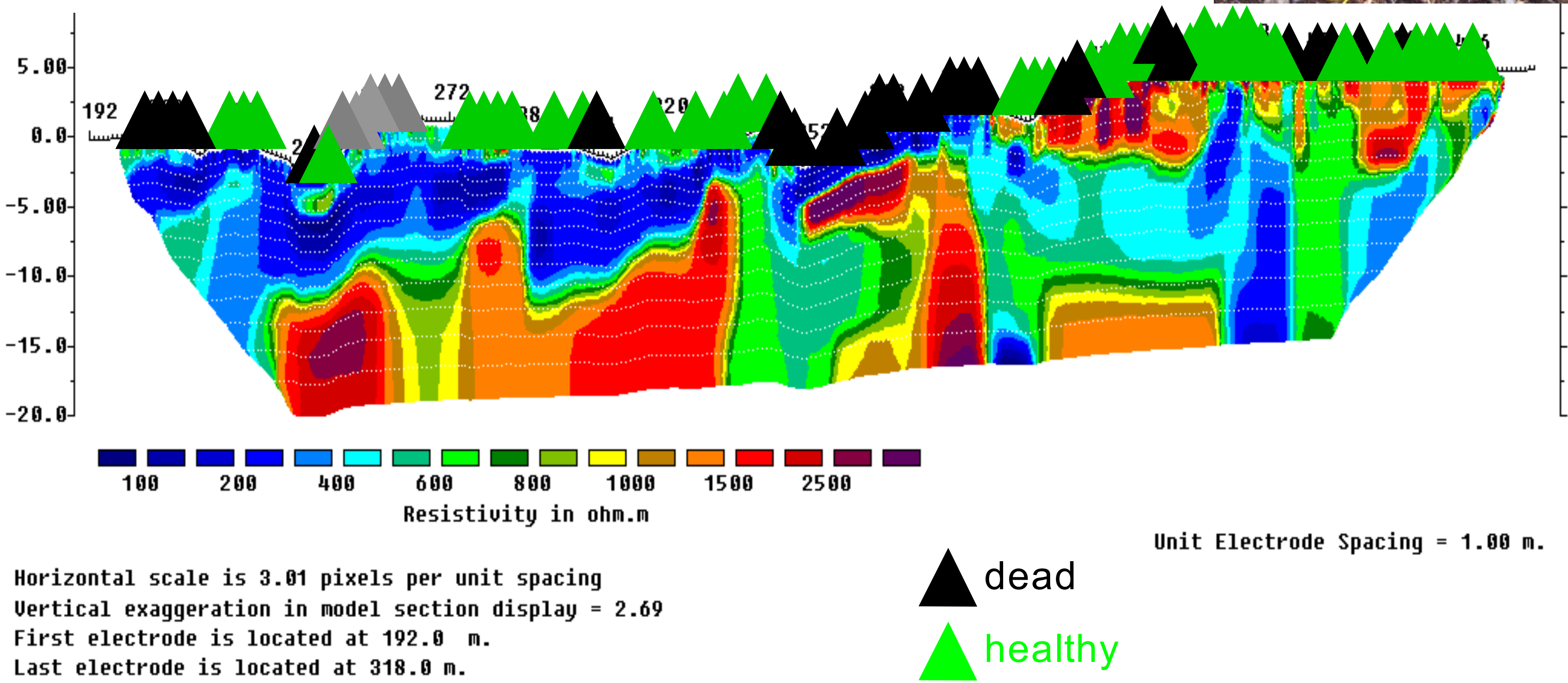
- PHD: A. Amm, M. Cailleret, Y. Xie, M. Nourtier
- Permanent: P. Dreyfus, A. Chanzy, F. Baret, C. Pichot, T, N. Bréda

Main *in situ* results : 3. Role of deep soil (>2m)

Using tomography (electrical resistivity)



Healthy were not necessarily located on the « best soils »

Equations of Mortality
1000 random Reserves value from Gaussian law

$$\mathrm{Prob}\left(\mathrm{Mortality}\right)=\frac{\sum Tree(reserves<0)}{\sum Tree}$$

Soil 2 layers

Transpiration is reduced when the quantity of active root is not sufficient to supply water demand by the crown.

$$T_{(l)} = T.\frac{R_{R(l)} - R_{R\,wp}}{R_{R\,top} + R_{R\,depth} - R_{R\,wp}}$$

$$g_1 = (g_{1\max} - g_{1\min}).reduc + g_{1\min}$$

$$reduc = \frac{R_R - R_{R\,wp}}{S_{stress}.\left(R_{R\,fc} - R_{R\,wp}\right)}$$

$$g_1 = \max(g_1.B_{fr}/B_{fr\,th};g_{1\min})$$

Soil 2 layers

The loss of root is calculated for each layer ($MR_{(l)}$) for the soil water potential ($\psi_{(l)}$) of the same layer.

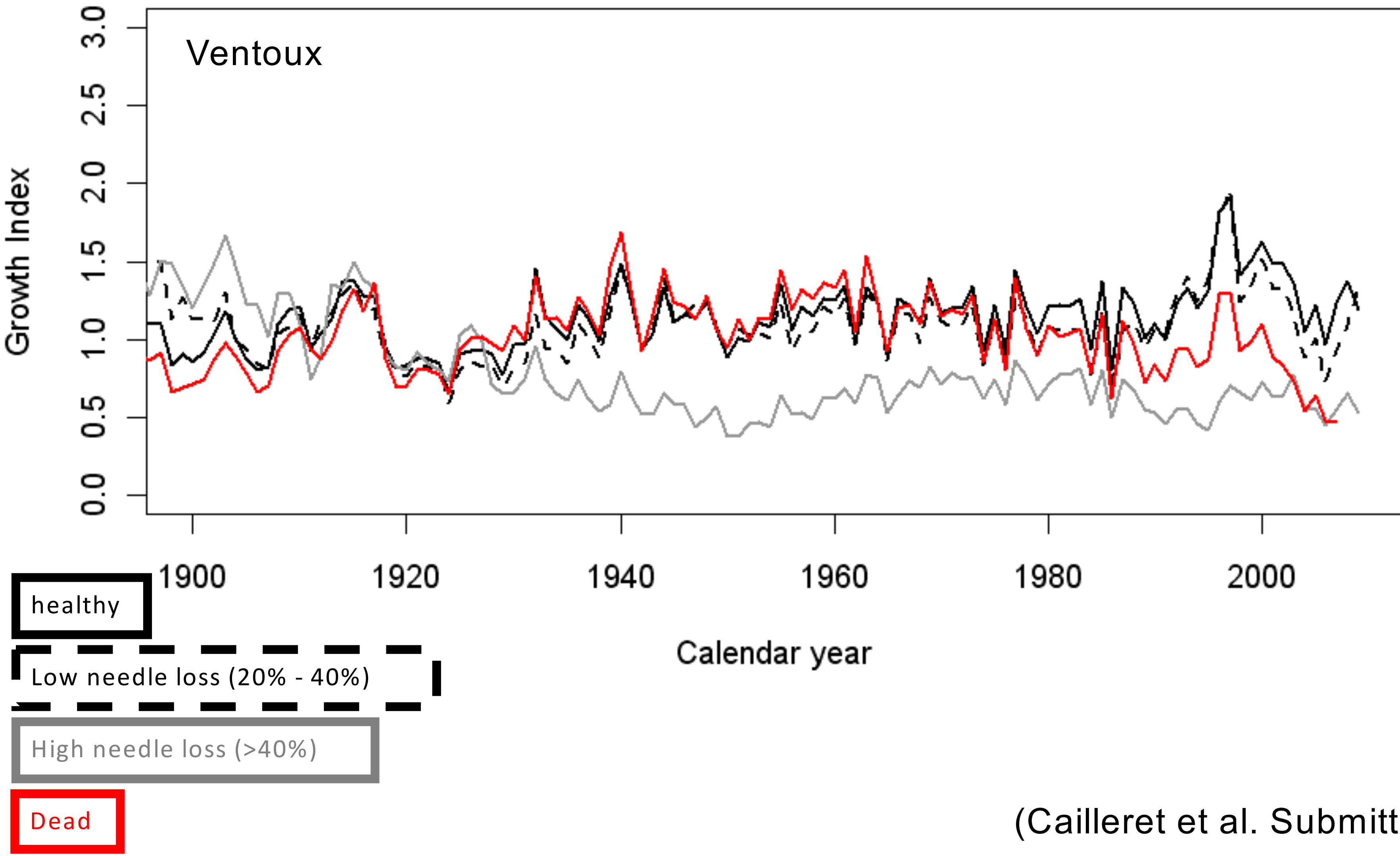
$$\psi_{(l)} = \psi_{max}.(R_{R\,(l)} / R_{R\,fc\,(l)})^{-3.5}$$

During a drought event, the loss of roots by this mechanism is not cumulative. The proportion of root death stops to increase above the maximum rate: 16 % at -2 MPa.

$$MR_{(l)} = 1 / e^{0.93.(\psi_{(l)} - \psi_{50})}$$

where ψ_{50} correspond to the soil water potential for which 50 % of the silver fir roots are embolised according to the vulnerability curves established

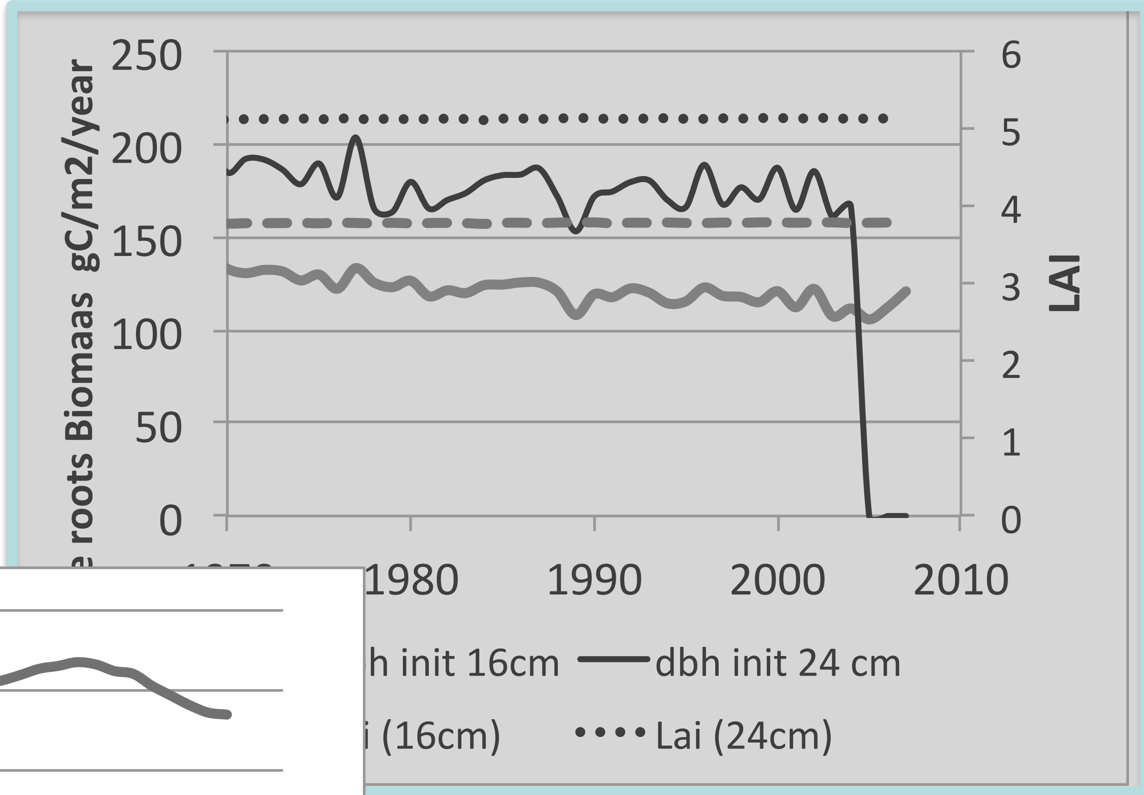
Main *in situ* results : 2. Mortality differs from needle loss

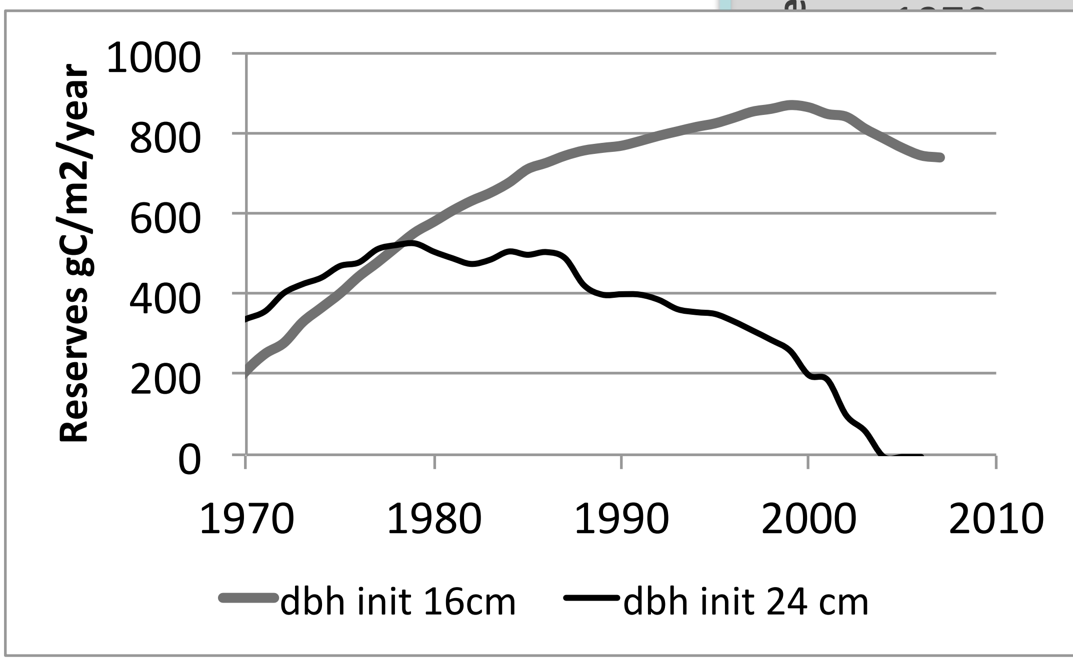


(Cailleret et al. Submitted)

1. Effect of Juvenile growth

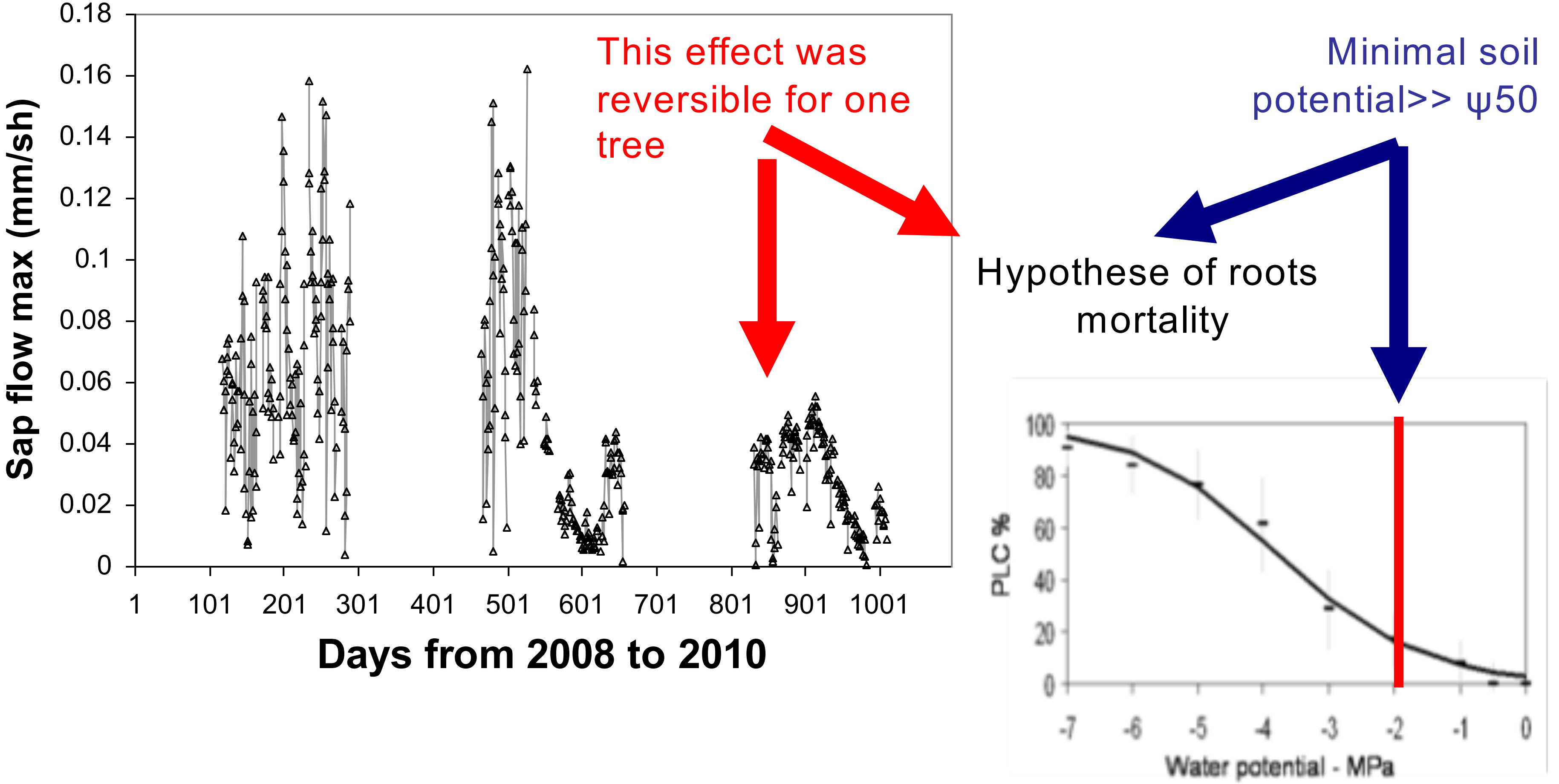
Ex SWC=60mm





High respiration rate & investment in roots and leaf => low reserves

Main *in situ* results : 3. Post effects of drought on transpiration



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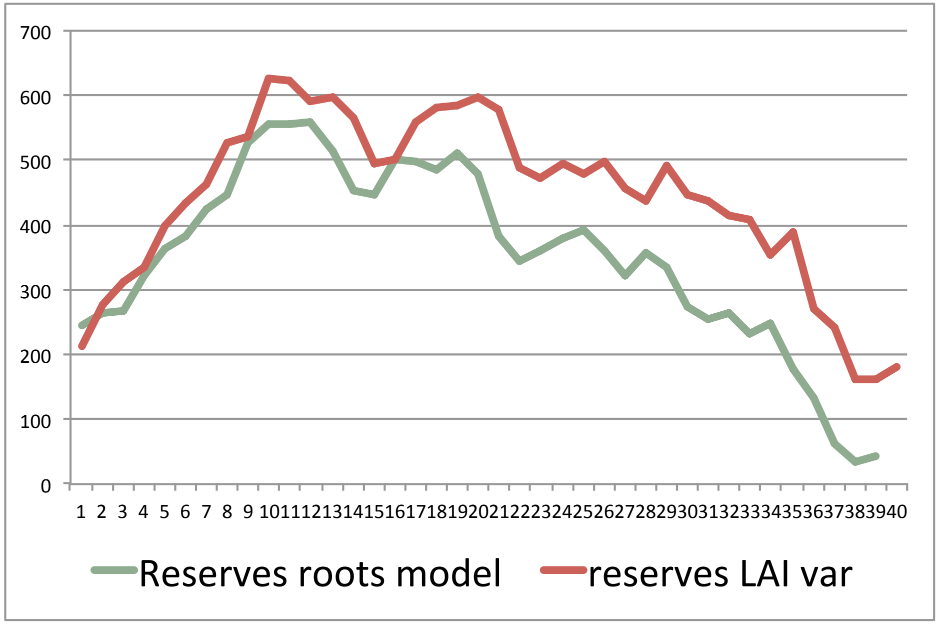
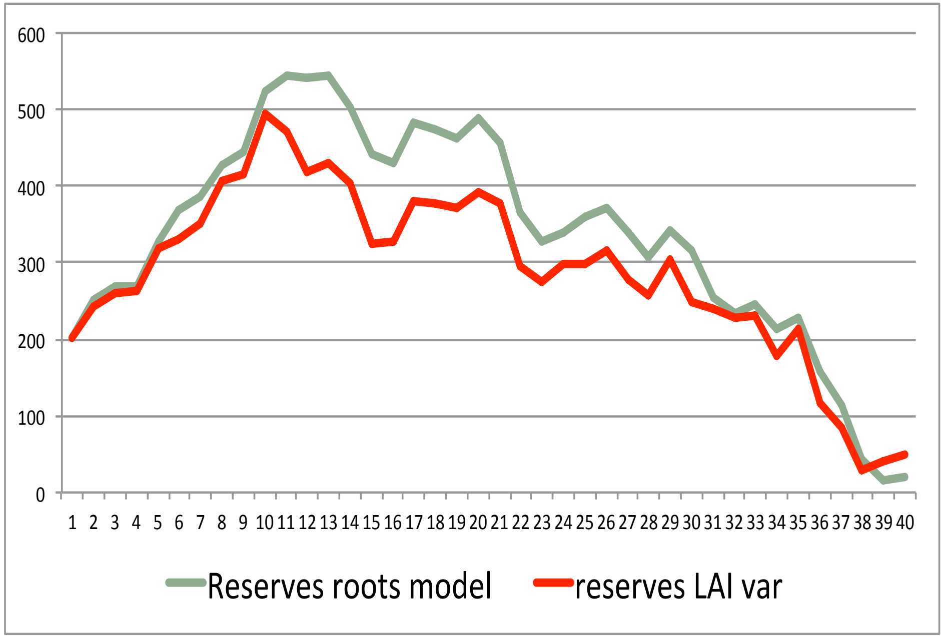
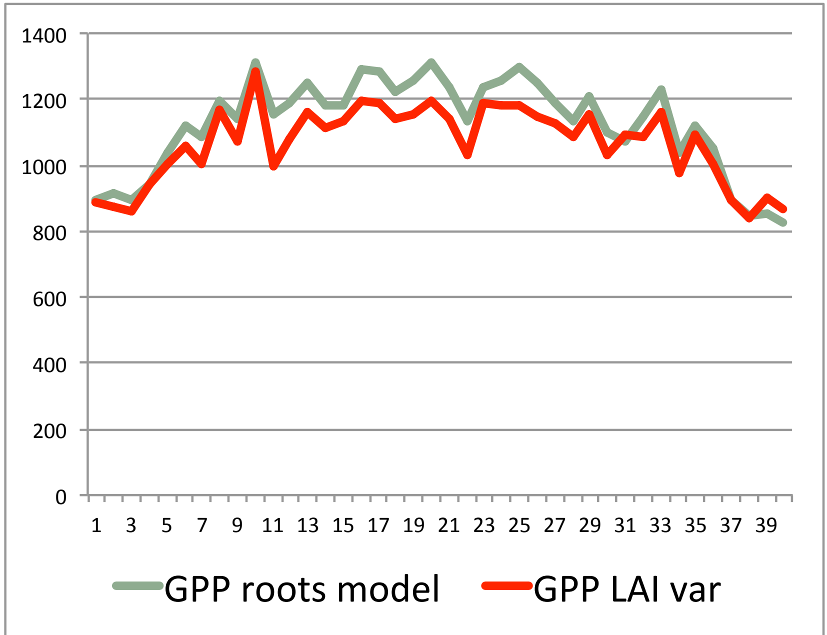


SWC= 40mm

SWC= 30mm: higher photosynthesis with roots dynamics





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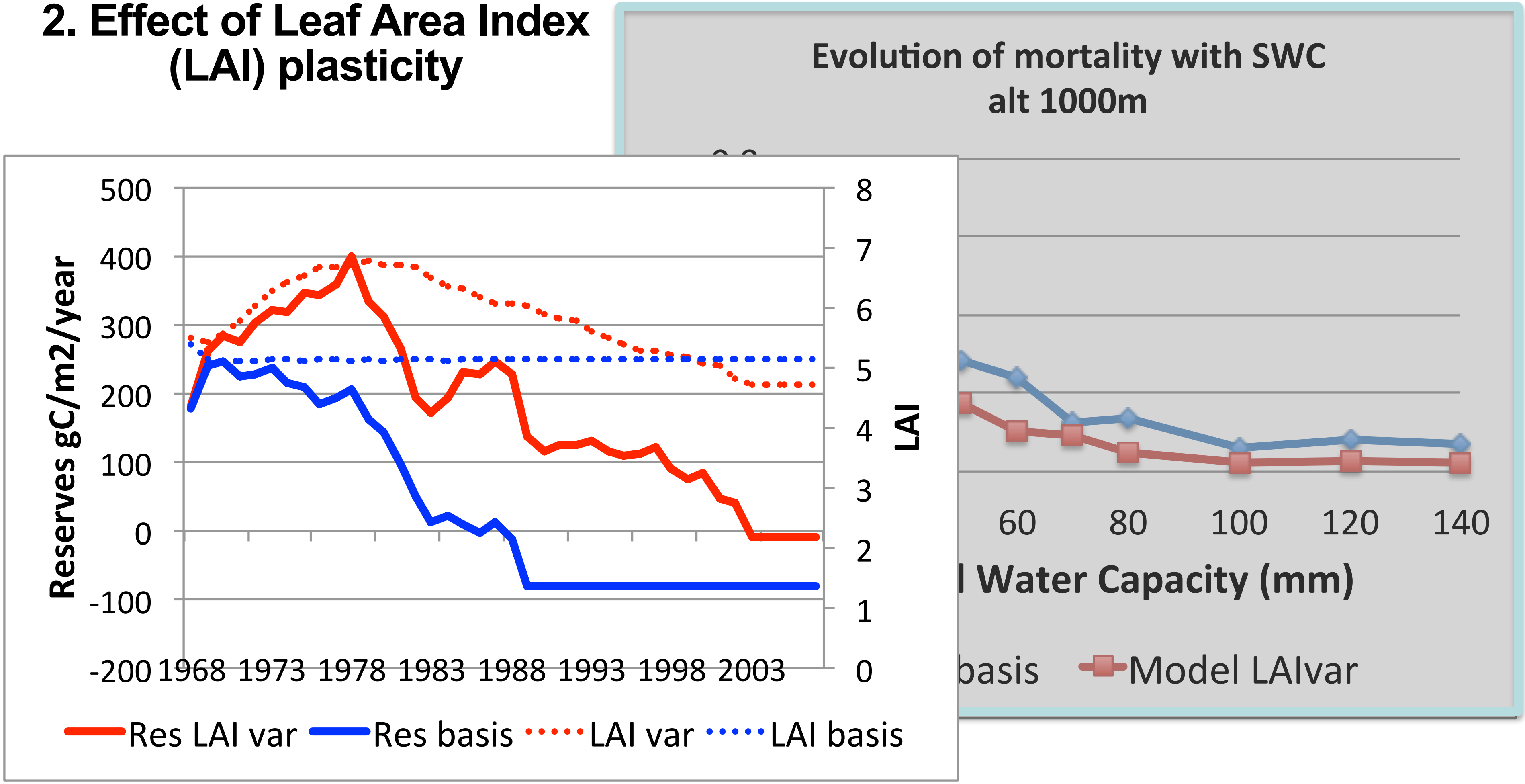

SWC= 40 mm
dbh_{init}= 24 cm

LAI plasticity => decrease mortality rate