Drought-induced mortality and forest decline

Jordi Martínez Vilalta
Outline of the presentation

What do I mean by 'forest decline'?  
Is it really happening?  
What are the causes?  
Is drought involved? drought & plants  
Hydraulic adjustments  
Implications at larger scales  
Synthesis
What do I mean by 'forest decline'?

A rapid decrease in the vigour of dominant forest tree species that has the potential to result in a vegetation shift.
Is it really happening?

- 88 well documented cases around the globe associated with drought and/or warming

Allen et al. (For. Eco. Manag., in press)
Drought-induced mortality and forest decline

Is it really happening?

Van Mantgem et al. (Science, 2009)
Is it really happening?
Potential demographic effects...

MacDowell et al. (*New Phytologist*, 2008)
Drought-induced mortality and forest decline

Is it really happening? examples from NE Spain

1994

Quercus ilex

2005

Pinus sylvestris
Is it really happening? The case of Scots pine

Martínez-Vilalta & Piñol (For Eco Man, 2002)

Bigler et al. (Ecosystems, 2006)
What are the causes?

The causes are **multiple and complex**
Is drought really involved?


Breshears et al. (*Front Ecol Environ.*, 2009)
Drought-induced mortality and forest decline

Drought & plants

↑↑ VPD

↑ Resp?

CO₂, H₂O, H₂O_vap, N

Drought & plants
Drought-induced mortality and forest decline

$CO_2$  $H_2O_{vap}$

$\uparrow$ Resp?

$H_2O$  $N$

Drought & plants

$\uparrow\uparrow$ VPD
Drought-induced mortality and forest decline

\[ \text{CO}_2 \quad \text{H}_2\text{O}_{\text{vap}} \]

↑ Resp?

↑↑↑↑ VPD

Drought & plants

H2O
N
Drought-induced mortality and forest decline

Drought & plants

CO$_2$  H$_2$O$_{vap}$

↑ Resp?

↑↑ VPD
Drought-induced mortality and forest decline

Drought & plants

Sack & Holbrook (ARPB 2006)
Drought-induced mortality and forest decline

Drought & plants

Radially oriented cellulose microfibrils

Guard cells become turgid

Guard cells go limp

Stoma closed → Stoma open → Stoma closed
Drought-induced mortality and forest decline

Drought & plants

CO₂ ↗

H₂O_{vap} ↗

H₂O ↘

N ↘

Drought & plants
Drought-induced mortality and forest decline

Drought & plants

\[ \text{CO}_2 \quad \text{H}_2\text{O}_{vap} \]

Pathway of water movement

- Root Hair
- Cortex
- Xylem
- Casparian Strip
- Endodermis
Drought & plants

Hydraulic failure or carbon starvation?

McDowell et al. (New Phyt, 2008)
Hydraulic failure or carbon starvation?

Holm oak forests in NE Spain

Martínez-Vilalta et al. (Tree Phys, 2003)

Martínez-Vilalta et al. (Oecologia, 2002)
Hydraulic failure or carbon starvation?

Holm oak forests in NE Spain

Ogaya et al. (*For Eco Man*, 2003)

Martínez-Vilalta et al. (*Ecol Model*, 2002)
Hydraulic failure or carbon starvation?

Adams et al. (PNAS, 2009)
Or something else? Unsolved issues...

Pinus ponderosa

Sala & Hoch (PCE2009)
Drought-induced mortality and forest decline

Or something else? Unsolved issues...

Minimum Midday Water Potential (MPa)

JD Miranda et al. (in prep.)
Or something else? Unsolved issues...

JL Quero et al. (in prep.)
Hydraulic adjustments. The case of Scots pine

Poyatos et al. (*Oecologia*, 2007)

*Pinus sylvestris*
Hydraulic adjustments. The case of Scots pine

\[ E = G_S \cdot A_L \cdot D = K_S \cdot A_S \cdot \nabla \Psi \]

Martínez-Vilalta et al. (*New Phyt*, 2009)
Hydraulic adjustments. The case of Scots pine

Poyatos et al. (*Oecologia*, 2007)
Drought-induced mortality and forest decline

Implications at larger scales

The case of Scots pine

Martínez-Vilalta et al. (Global Change Biol, 2008)
Implications at larger scales. The case of Scots pine

Galiano, Martínez-Vilalta & Lloret (in prep.)
Implications at larger scales.

The case of Scots pine

Vilà, Martínez-Vilalta, Vayreda & Retana (in prep.)

Cummulative mortality (%)
Implications at larger scales: climate change & water availability

Change in annual runoff for the period 2090-2099 relative to 1980-1999:

IPCC (2008)
Implications at larger scales
Drought-induced mortality and forest decline

Implications at larger scales

LETTERS

Drought sensitivity shapes species distribution patterns in tropical forests

Bettina M. J. Engelbrecht, Liza S. Comita, Richard Condit, Thomas A. Kursar, Melvin T. Tyree, Benjamin L. Turner & Stephen P. Hubbell

Choat et al. (in prep.)
Synthesis: forests in flow

Widespread events of tree dieback associated (partially at least) with increased drought stress.

Mechanism of drought-induced tree death not completely understood: it may involve hydraulic failure in the xylem, carbon starvation, impairment of phloem transport and/or interactions with biotic agents.

Hydraulic adjustments are likely to happen, but plasticity is limited.

Drought effects interact with ongoing changes in forest structure. Together, these factors will cause demographic changes at the population level that will result in community shifts and important modifications of ecosystem function.
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