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Session 14: Biotic Responses of Trees and Understory Vegetation to Contemporary Climate Change

ClimTree 2013 – Zurich – 1-5 September 2013

International Conference on Climate Change and Tree Responses in Central European Forests

UNIVERSITÉ de Picardie Jules Verne

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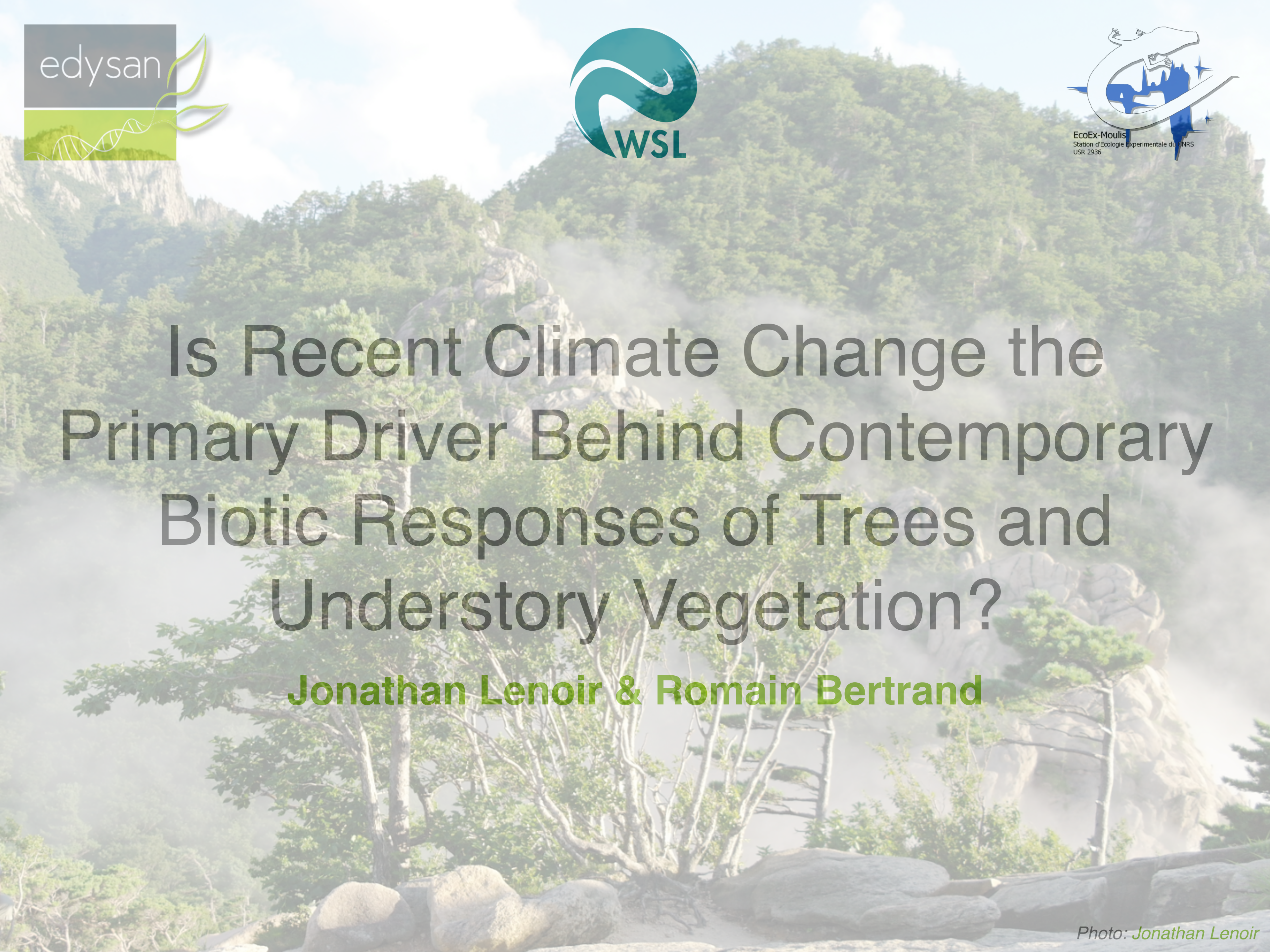
Photo: Jonathan Lenoir



Is Recent Climate Change the Primary Driver Behind Contemporary Biotic Responses of Trees and Understory Vegetation?

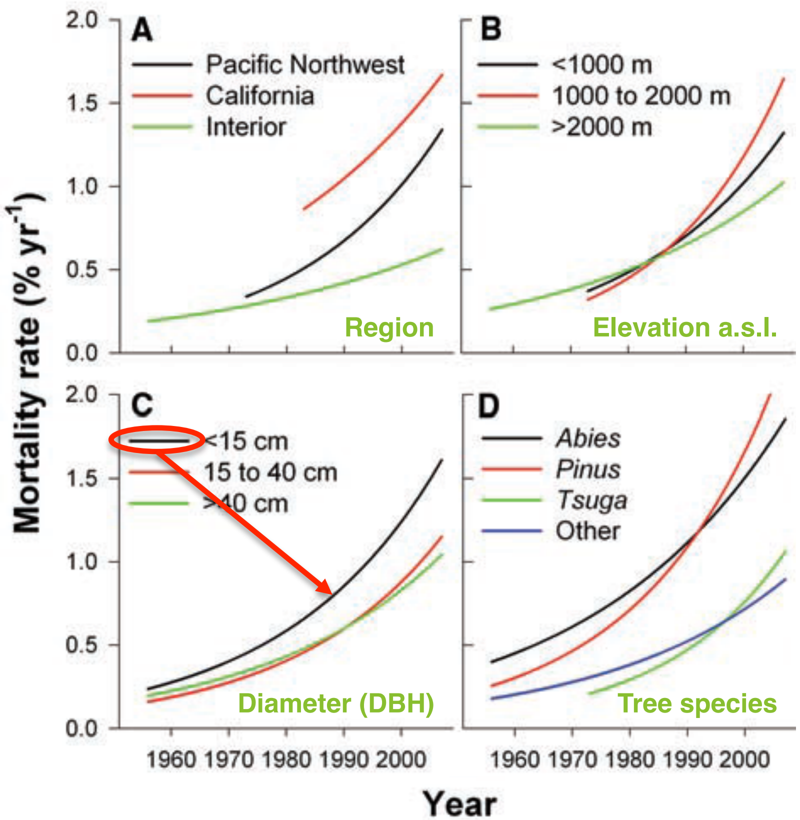
Jonathan Lenoir & Romain Bertrand

Photo: Jonathan Lenoir

Trees and understory vegetation have shown strong biotic changes since the 1970s

Observed changes in population dynamics over time:

➢ Tree mortality rates are increasing (van Mantgem *et al.*, 2009)



Widespread Increase of Tree Mortality Rates in the Western United States

Phillip J. van Mantgem,[1]*†‡ Nathan L. Stephenson,[1]*† John C. Byrne,[2] Lori D. Daniels,[3] Jerry F. Franklin,[4] Peter Z. Fulé,[5] Mark E. Harmon,[6] Andrew J. Larson,[4] Jeremy M. Smith,[7] Alan H. Taylor,[8] Thomas T. Veblen[7]

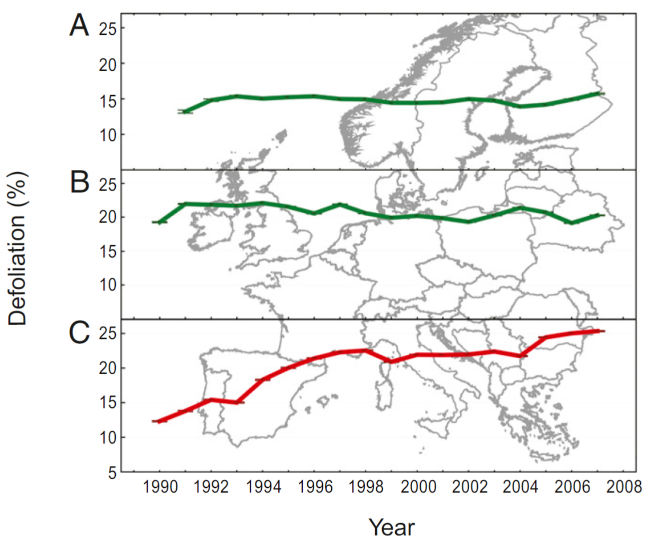
SCIENCE VOL 323 23 JANUARY 2009

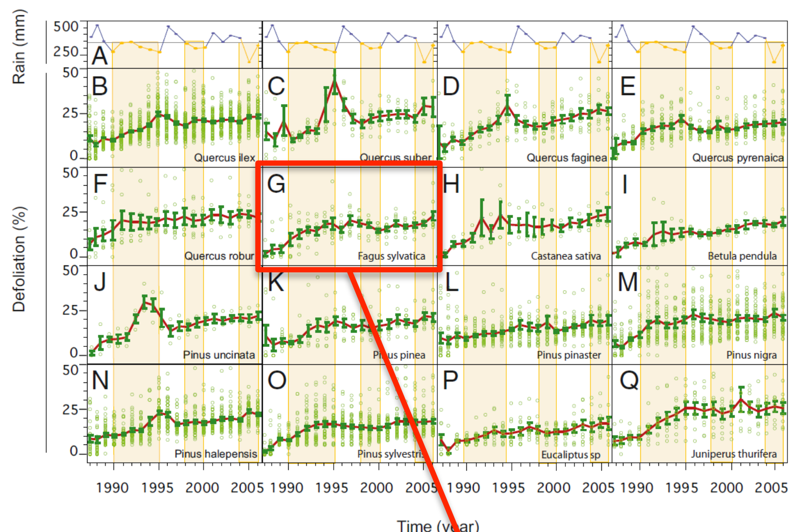
was not caused by endogenous increases in competition. Because mortality increased in small trees, the overall increase in mortality rates cannot be attributed solely to aging of large trees.

Trees and understory vegetation have shown strong biotic changes since the 1970s

Observed changes in population dynamics over time:

- Percentages of crown defoliation at the southern range limit of European trees are increasing (Carnicer *et al.*, 2011)

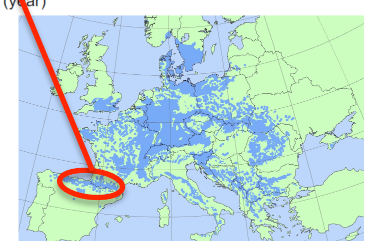


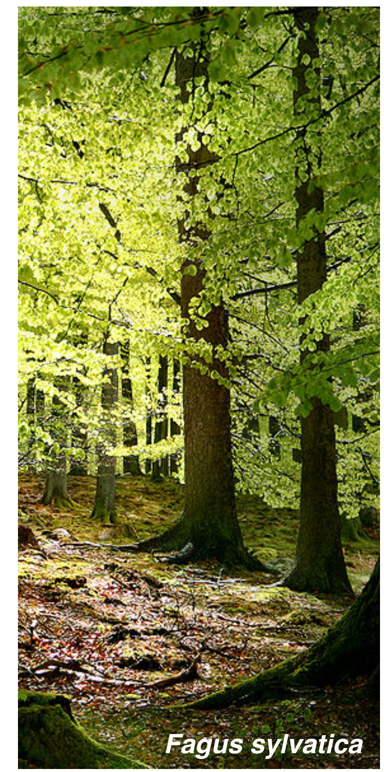


Widespread crown condition decline, food web disruption, and amplified tree mortality with increased climate change-type drought

Jofre Carnicer[a,b,1,2], Marta Coll[a,1], Miquel Ninyerola[c], Xavier Pons[d], Gerardo Sánchez[e], and Josep Peñuelas[a,2]

1474–1478 | PNAS | January 25, 2011 | vol. 108 | no. 4



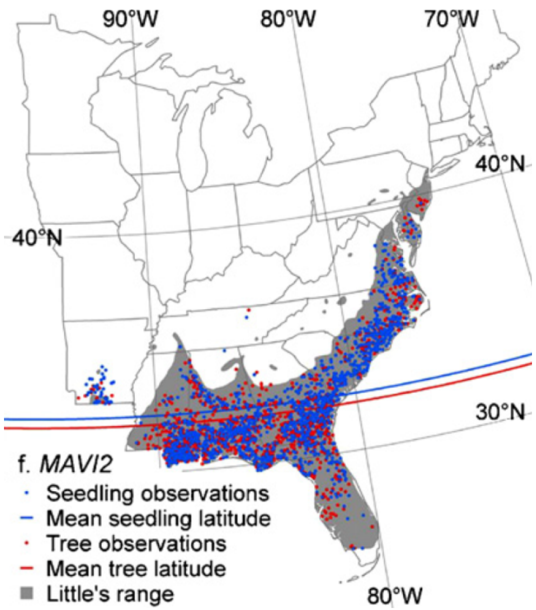


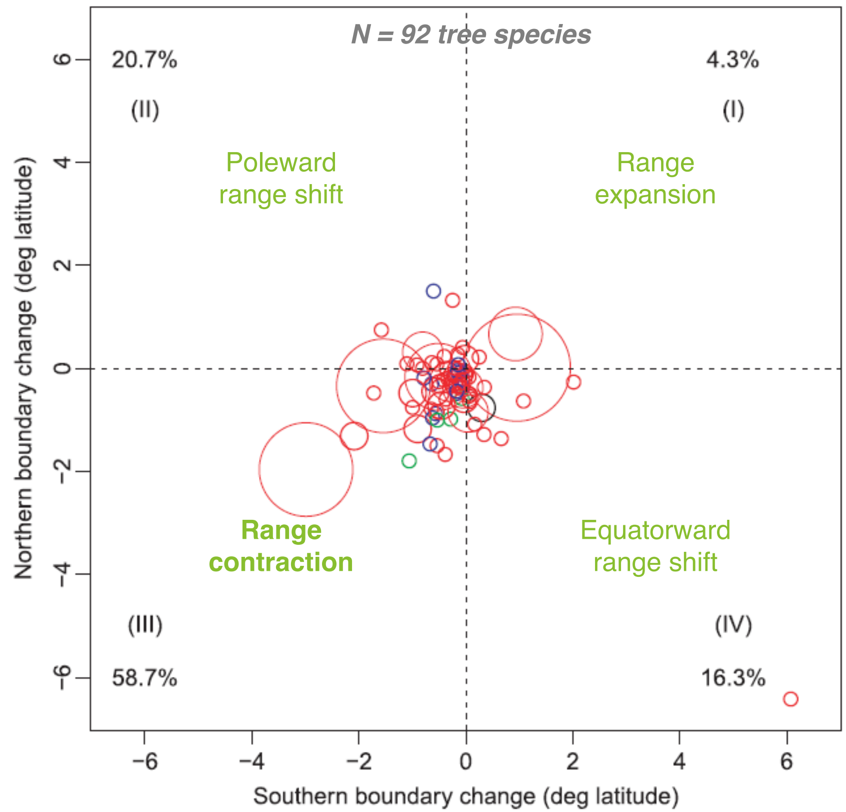
Map: www.euforgen.org, Photo: en.wikipedia.org/wiki/Fagus_sylvatica

Trees and understory vegetation have shown strong biotic changes since the 1970s

Observed changes in species distribution over time:

- Trees are contracting their ranges poleward (Zhu *et al*., 2012)





Failure to migrate: lack of tree range expansion in response to climate change

KAI ZHU*, CHRISTOPHER W. WOODALL† and JAMES S. CLARK*‡

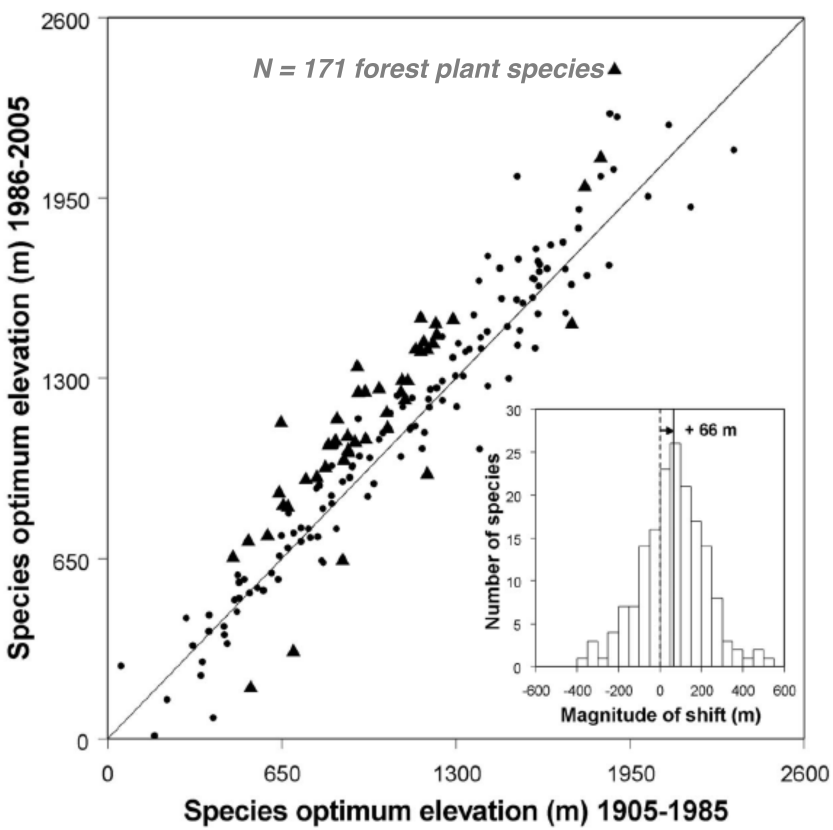
Global Change Biology (2012) **18**, 1042–1052

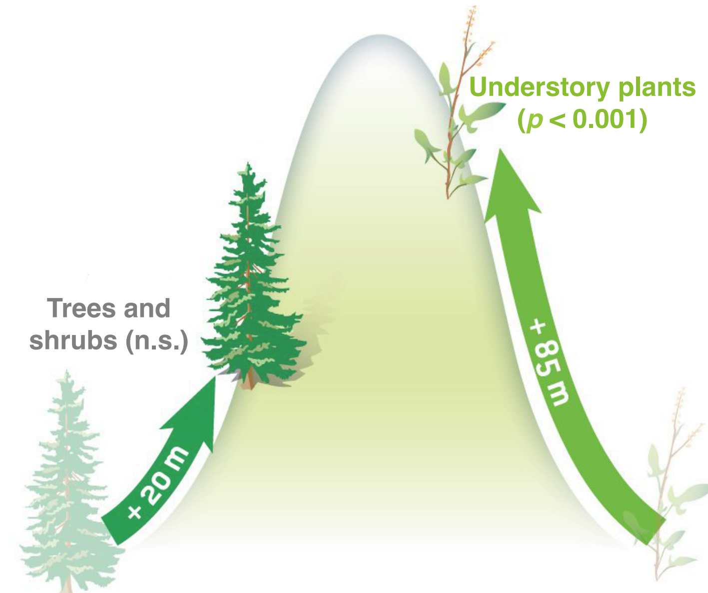
Map: Woodlall (2009), Photo: en.wikipedia.org/wiki/Magnolia_virginiana

Trees and understory vegetation have shown strong biotic changes since the 1970s

Observed changes in species distribution over time:

➢ Understory plants are shifting upward (Lenoir *et al.*, 2008)





A Significant Upward Shift in Plant Species Optimum Elevation During the 20th Century

J. Lenoir,[1*] J. C. Gégout,[1] P. A. Marquet,[2,3,4] P. de Ruffray,[5] H. Brisse[6]

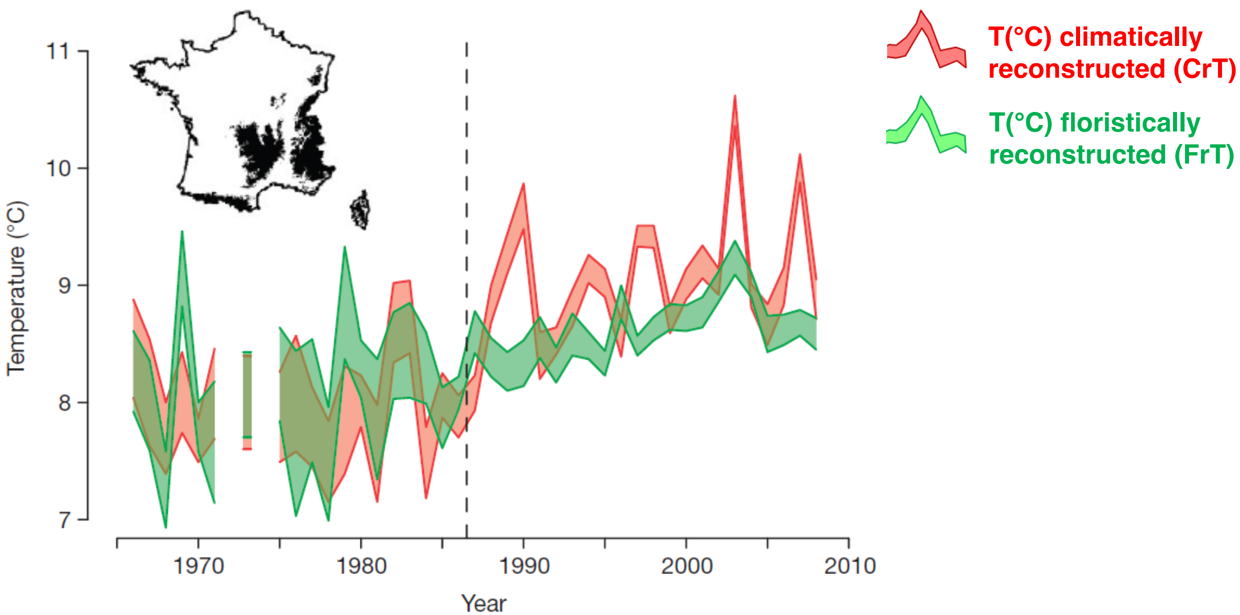
27 JUNE 2008 VOL 320 SCIENCE

Illus.: Etienne Hurault

Trees and understory vegetation have shown strong biotic changes since the 1970s

Observed changes in community composition over time:

➢ Mountain forests are more thermophilous (Bertrand *et al.*, 2011)



Changes in plant community composition lag behind climate warming in lowland forests

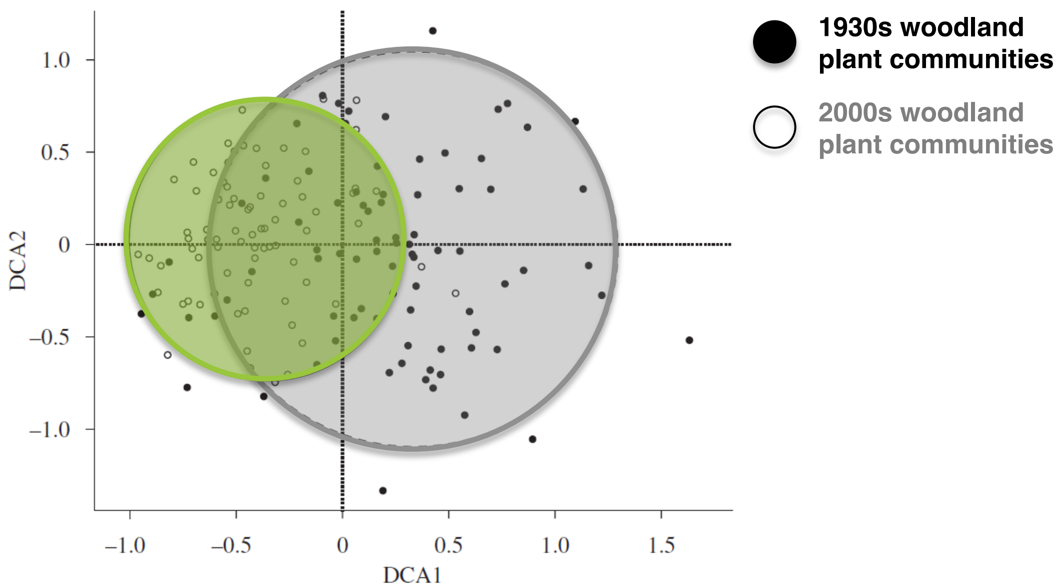
Romain Bertrand[1,2], Jonathan Lenoir[3], Christian Piedallu[1,2], Gabriela Riofrío-Dillon[1,2], Patrice de Ruffray[4], Claude Vidal[5], Jean-Claude Pierrat[1,2] & Jean-Claude Gégout[1,2]

24 NOVEMBER 2011 | VOL 479 | NATURE | 517

Trees and understory vegetation have shown strong biotic changes since the 1970s

Observed changes in community composition over time:

➢ Woodlands are homogenizing (Keith *et al*., 2009)



Taxonomic homogenization of woodland plant communities over 70 years

Sally A. Keith, Adrian C. Newton, Michael D. Morecroft, Clive E. Bealey and James M. Bullock

Proc. R. Soc. B (2009) **276**, 3539–3544

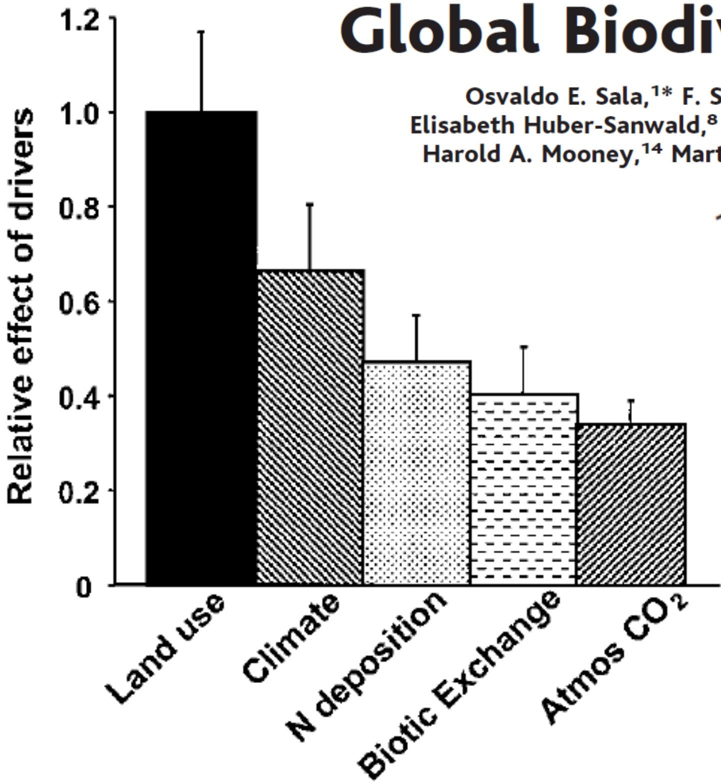
And several global-change drivers have been attributed to these biotic responses

Among the most cited global-change drivers potentially causing the observed biotic changes for trees or understory plants:

- Climate warming (Lenoir *et al*., 2008; Bertrand *et al*., 2011)
- Droughts (Van Mantgem *et al*., 2009; Carnicer *et al*., 2011)
- Acidification (Thimonier *et al*. 1994; Riofrío-Dillon *et al*., 2012)
- Eutrophication (Thimonier *et al*. 1994; Keith *et al*., 2009)
- Forest-canopy closure (Keith *et al*., 2009; Verheyen *et al*., 2012)
- Non-native species invasions (Hale *et al*., 2006)
- Herbivory pressure (Rooney, 2009)

But, what is the respective contribution of each of these global-change drivers?

Does the current relative contribution of each global-change driver on the observed biotic changes for trees and understory plants reflects future predictions?



Global Biodiversity Scenarios for the Year 2100

Osvaldo E. Sala,[1*] F. Stuart Chapin III,[2] Juan J. Armesto,[4] Eric Berlow,[5] Janine Bloomfield,[6] Rodolfo Dirzo,[7] Elisabeth Huber-Sanwald,[8] Laura F. Huenneke,[9] Robert B. Jackson,[10] Ann Kinzig,[11] Rik Leemans,[12] David M. Lodge,[13] Harold A. Mooney,[14] Martín Oesterheld,[1] N. LeRoy Poff,[15] Martin T. Sykes,[17] Brian H. Walker,[18] Marilyn Walker,[3] Diana H. Wall[16]

10 MARCH 2000 VOL 287 SCIENCE

So far, very few attempts to answer this timely question for trees and understory vegetation

But, see Carnicer *et al*. (2011) for trees and Verheyen *et al*. (2012) for understory vegetation:

- Forest-canopy closure contribute more than nitrogen deposition to explain eutrophication signal in understory plant communities

Variable	Value	SE	d.f.	*t*-value	*P*-value
Intercept	−0.182	0.098	765	−1.848	0.065
No. years	−0.002	0.001	15	−1.601	0.130
N_{mean}	0.006	0.003	15	1.919	0.074
mL_o	−0.027	0.007	765	−3.616	<0.001

Driving factors behind the eutrophication signal in understorey plant communities of deciduous temperate forests

Kris Verheyen[1]*, Lander Baeten[1], Pieter De Frenne[1], Markus Bernhardt-Römermann[2], Jörg Brunet[3], Johnny Cornelis[4], Guillaume Decocq[5], Hartmut Dierschke[6], Ove Eriksson[7], Radim Hédl[8], Thilo Heinken[9], Martin Hermy[10], Patrick Hommel[11], Keith Kirby[12], Tobias Naaf[13], George Peterken[14], Petr Petřík[15], Jörg Pfadenhauer[16], Hans Van Calster[17], Gian-Reto Walther[18], Monika Wulf[13] and Gorik Verstraeten[1]

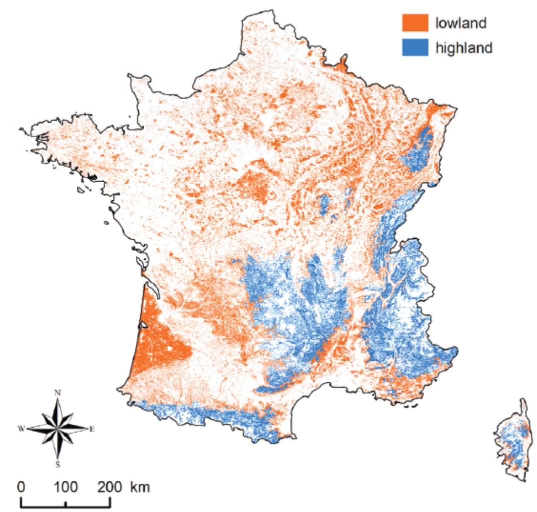
Journal of Ecology 2012, **100**, 352–365

Although forest-canopy closure is an important driver of changes in understory plant composition, the relative contribution of climate change was not assessed and could explain part of the signal edysan

Disentangling drivers of observed changes in forest understory plant community composition

Focusing on the observed thermophilization of forest understory vegetation in France in response to temperature increases (**dT/dt**), (Bertrand *et al*. 2011), Bertrand (2012) aims at assessing the amplifying/mitigating effects of changes in:

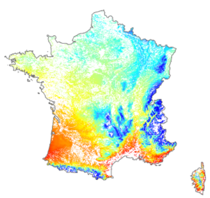
- Precipitation (**dP/dt**)
- Soil nitrogen (**dCN/dt**)
- Soil pH (**dpH/dt**)
- Understory light (**dL/dt**)
- Thermal tolerance (**dA/dt**)

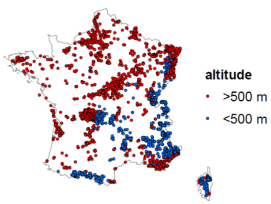


This assessment was done separately for lowland and highland forests due to the lowland-for-highland disparity in biotic changes

The response variable: a floristic index measuring temperature turnover or thermophilization

Difference in floristically reconstructed temperatures (**ΔFrT**) between 1965-1986 and 1987-2008 from a transfer function:

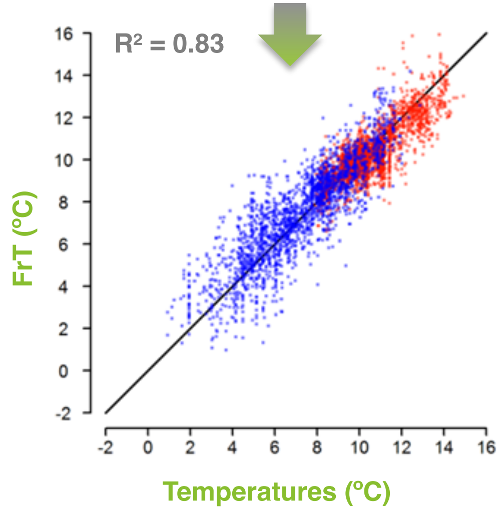




Y	Species
Temperature	Floristic table (0/1)

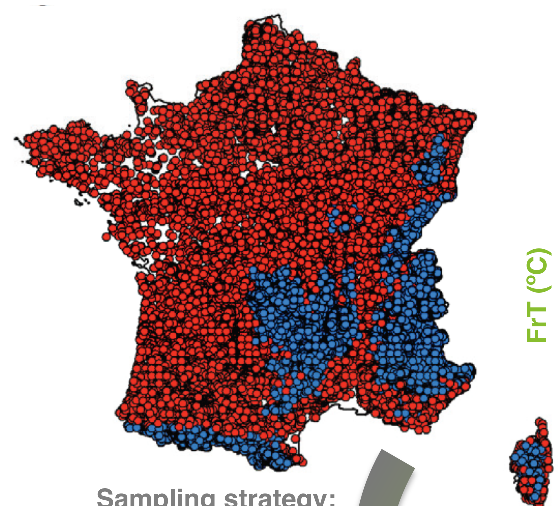
Relevés

WA-PLS + BRT

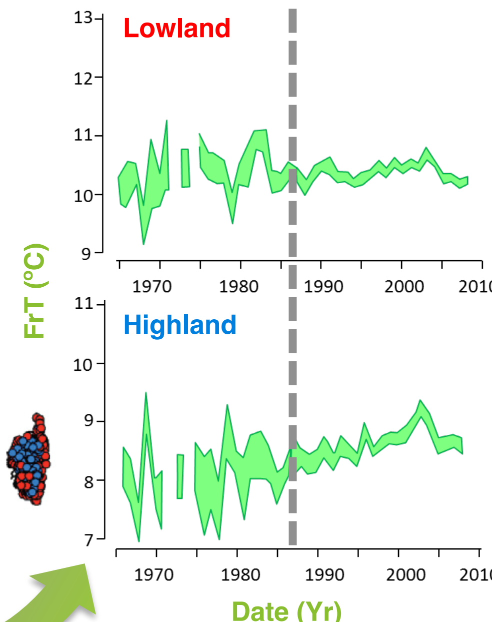


Calibration + Validation

Predictions



Sampling strategy: x1000 random samples stratified in space and time to get 1000 time trends



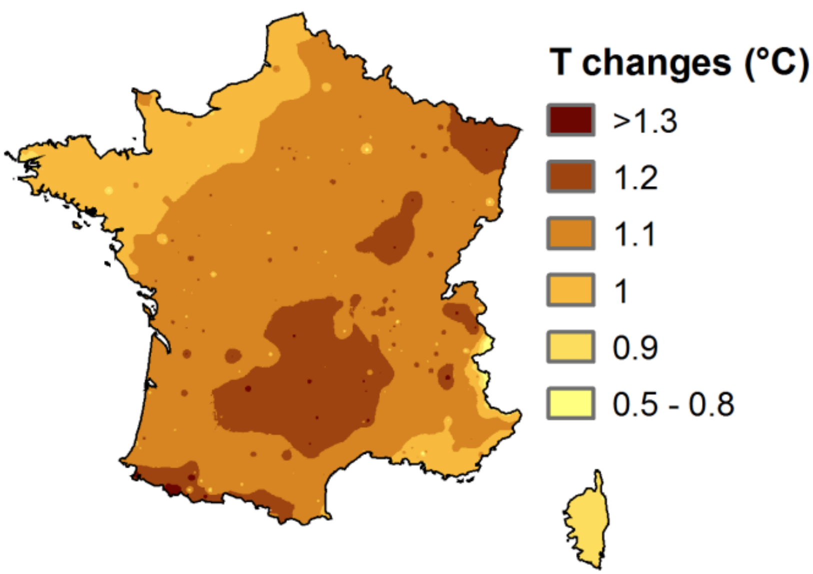
$$\Delta FrT = \overline{FrT}_{1987\text{-}2008} - \overline{FrT}_{1965\text{-}1986}$$

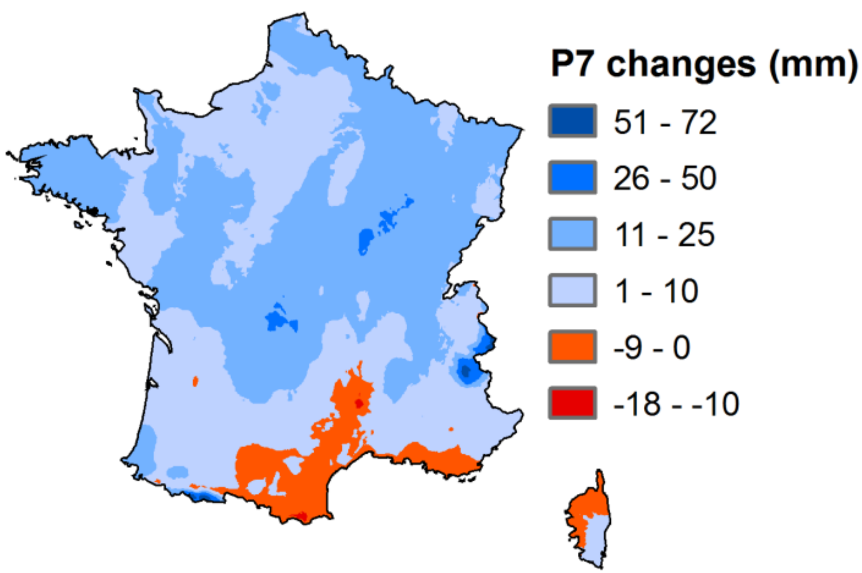
Sample size (N) = 1000 differences

The set of explanatory variables: temperature increase and other global-change drivers

Difference in mean climatic conditions between 1965-1986 and 1987-2008 for each of the 1000 time trends:

- Changes in mean annual temperature conditions (**ΔT**) and July precipitations (**ΔP**) obtained from yearly climatic data at 1-km resolution

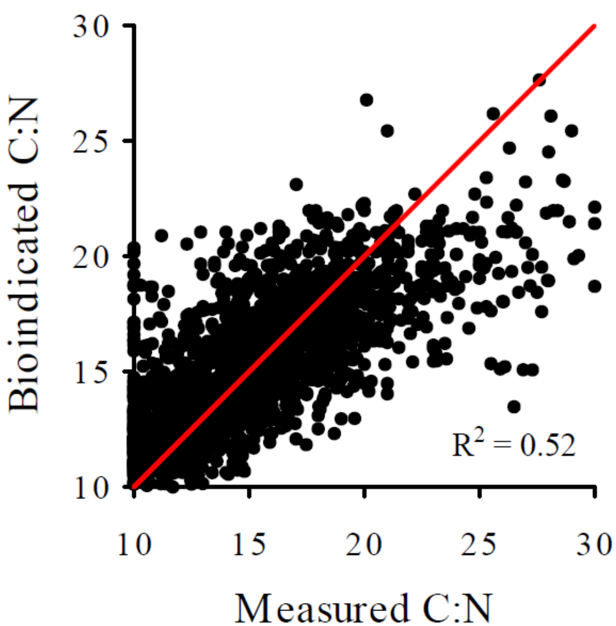


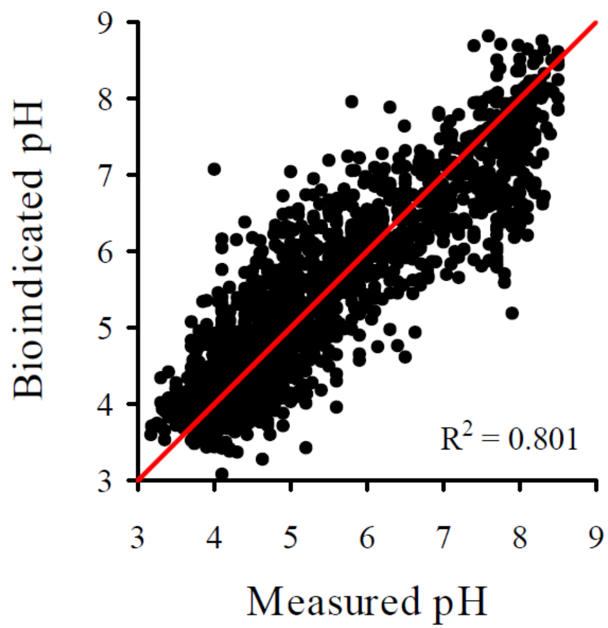


The set of explanatory variables: temperature increase and other global-change drivers

Difference in mean edaphic conditions between 1965-1986 and 1987-2008 for each of the 1000 time trends:

- Changes in CN ratio (**ΔCN**) and soil pH (**ΔpH**) obtained from differences in bioindicated values (cf. transfer functions based on WA-PLS)

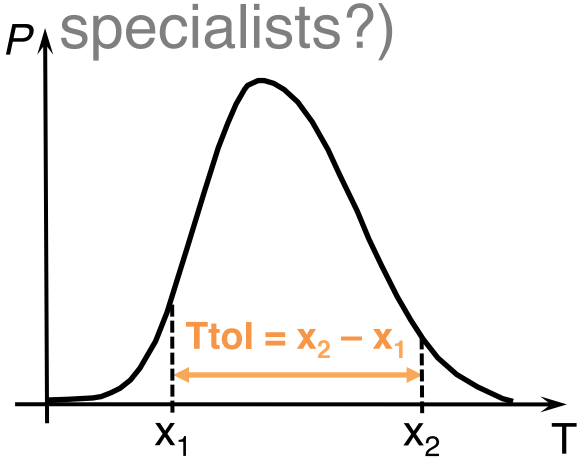




The set of explanatory variables: temperature increase and other global-change drivers

Difference in mean biotic conditions between 1965-1986 and 1987-2008 for each of the 1000 time trends:

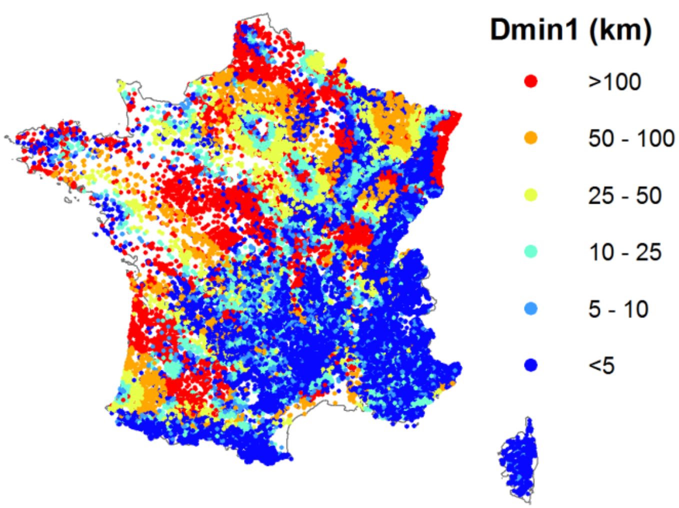
- Changes in light (**ΔL**) conditions obtained from differences in community mean values (cf. Ellenberg's ordinal scale)
- Changes in thermal tolerance (**ΔA**) at the community level obtained from differences in community mean values of species' thermal tolerances (**Ttol**) (cf. more generalists or specialists?)

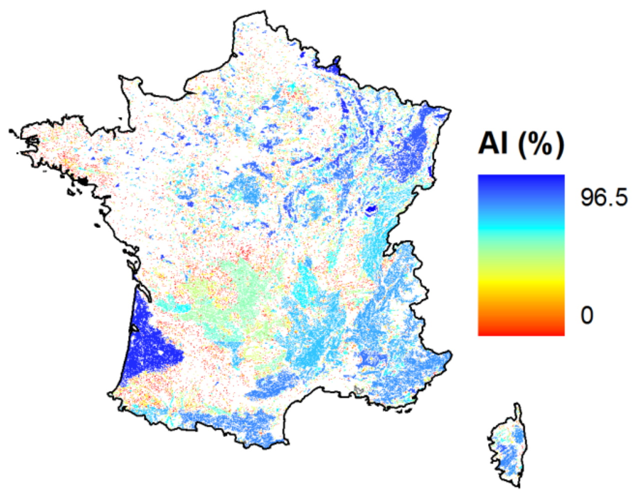


Accounting for understory plant accessibility to their forest habitats

Bertrand (2012) used 2 indices to account for habitat accessibility:

- The minimum distance (**Dmin1**) separating each given floristic relevé belonging to the period 1987-2008 to a forest habitat with analogous temperature conditions during 1965-1986
- The aggregation index (**AI**) of forest habitat within a radius of 20 km around each floristic relevé during 1987-2008





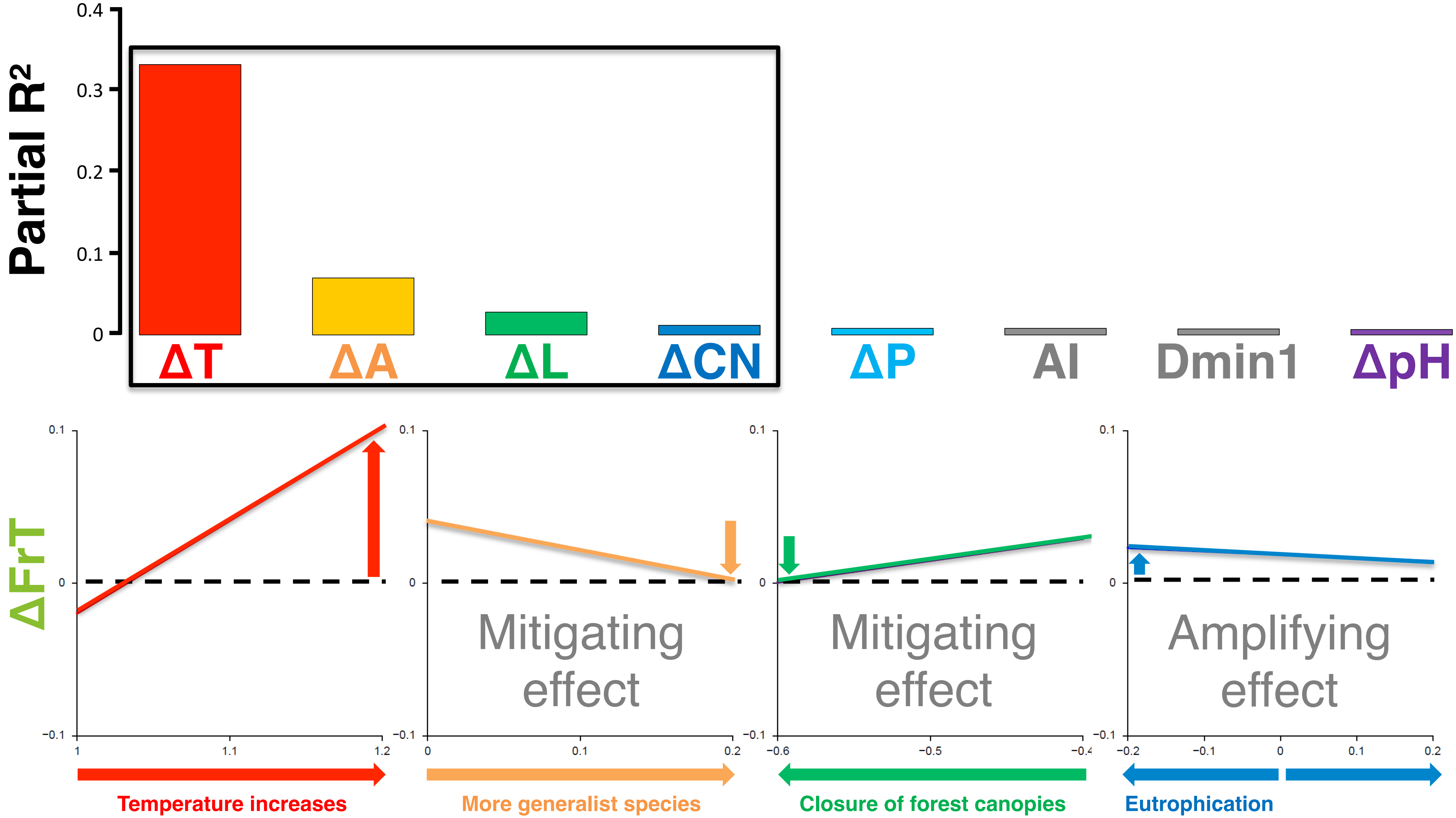
Assessing the relative contribution of temperature increase and other global-change drivers

Ordinary least square (OLS) regressions and variance partitioning were used to explain the observed thermophilization of understory plant communities in response to climate warming between 1965-1986 and 1986-2008 (**ΔFrT**):

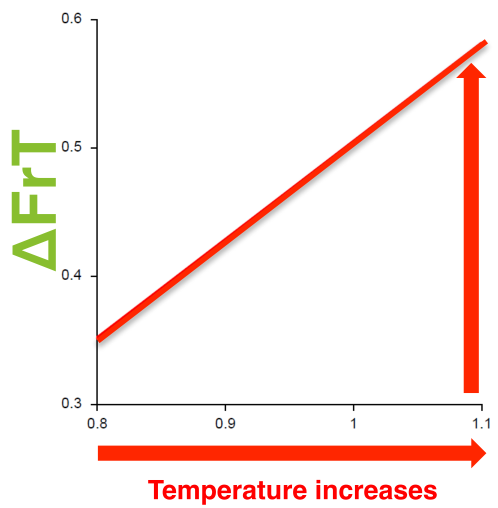
ΔFrT = *f(*ΔT, ΔP, ΔCN, ΔpH, ΔL, ΔA, Dmin1, AI*)*

- Sample size (N) = 1000
- R^2 between explanatory variables < 0.2

Mitigating and amplifying effects of secondary global-change drivers in lowland forests



Perfect filtering of understory vegetation changes due to climate warming solely in highland forests



NB: The transfer function used in Bertrand *et al*. (2011) is perfectly filtering out the effect of temperature increases alone on understory plant community composition, thus justifying the use of transfer functions for monitoring climate warming impacts on vegetation

Primary and secondary drivers of the observed thermophilization of understory vegetation

Take-home messages (Bertrand 2012):

- Climate warming is the primary global-change driver of the observed thermophilization of understory plant communities
- In lowland forests, two secondary drivers are mitigating this thermophilization effect of climate warming and contributing to the observed lag or climatic debt (Bertrand *et al*., 2011):
  - An increase in thermal tolerance due to more generalist species making up understory plant communities
  - A closure of forest canopies likely due to the abandonment of coppicing to the benefit of intense management practices in lowland European forests (Verheyen *et al*., 2012)

Thank you for your attention

Photo: Jonathan Lenoir