Climate and drought effects on forest carbon balance: lesson from three case studies

Denis Loustau, Damien Bonal

Climate and drought effects on forest carbon balance: lesson from three case studies

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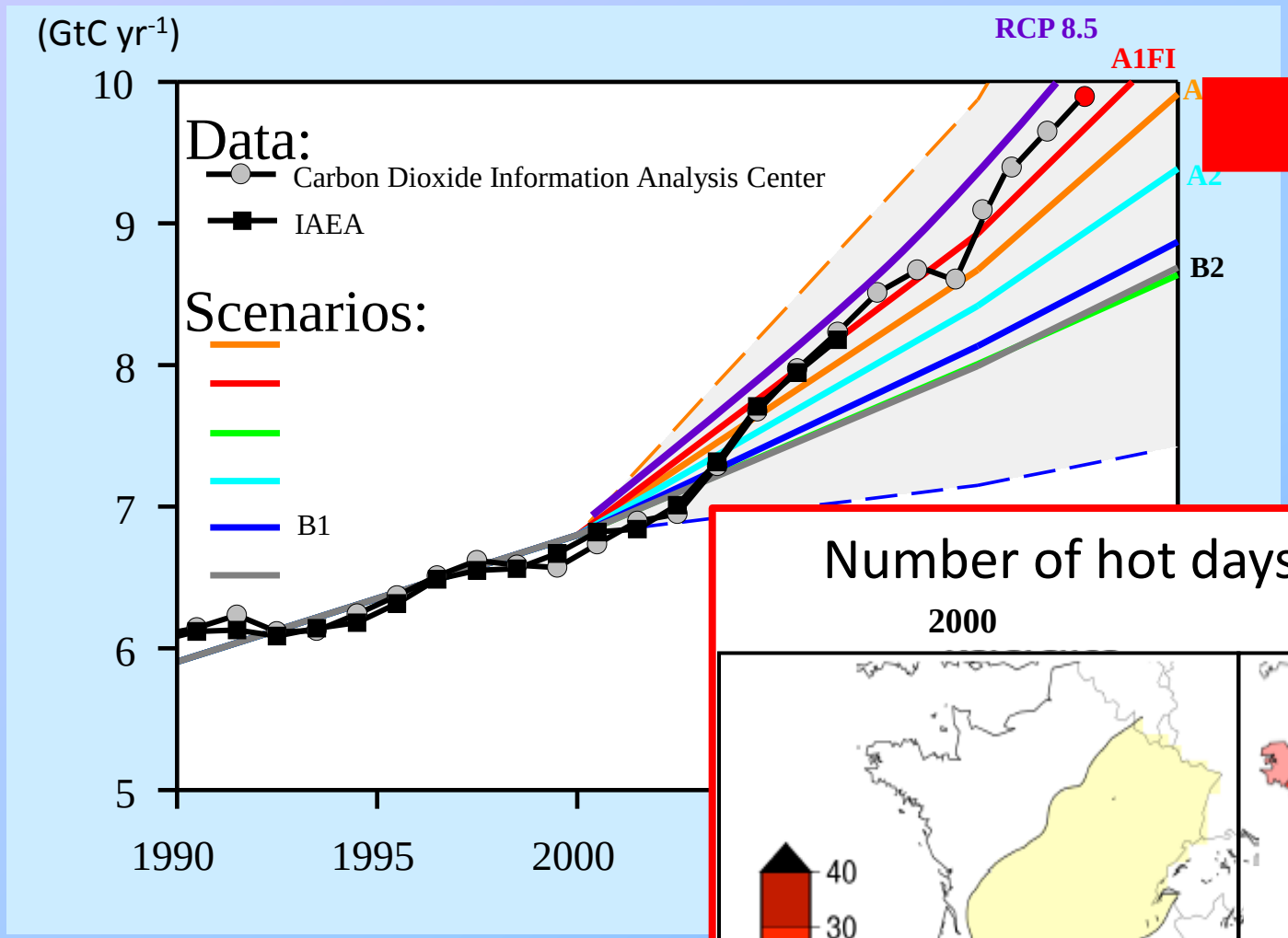
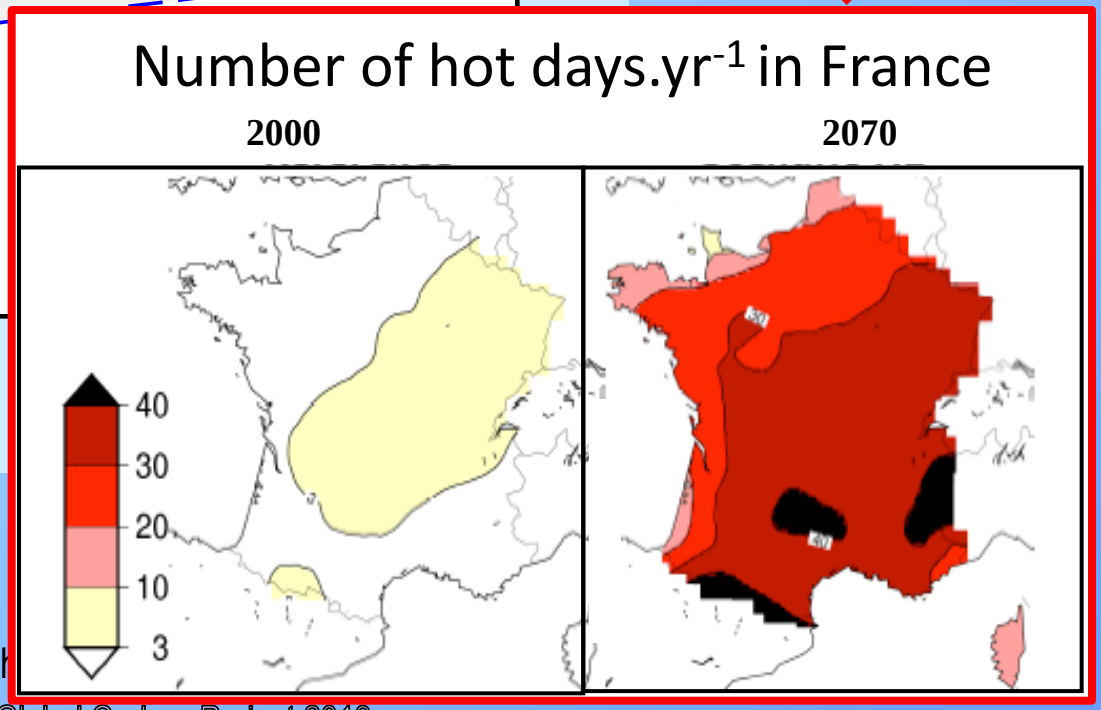
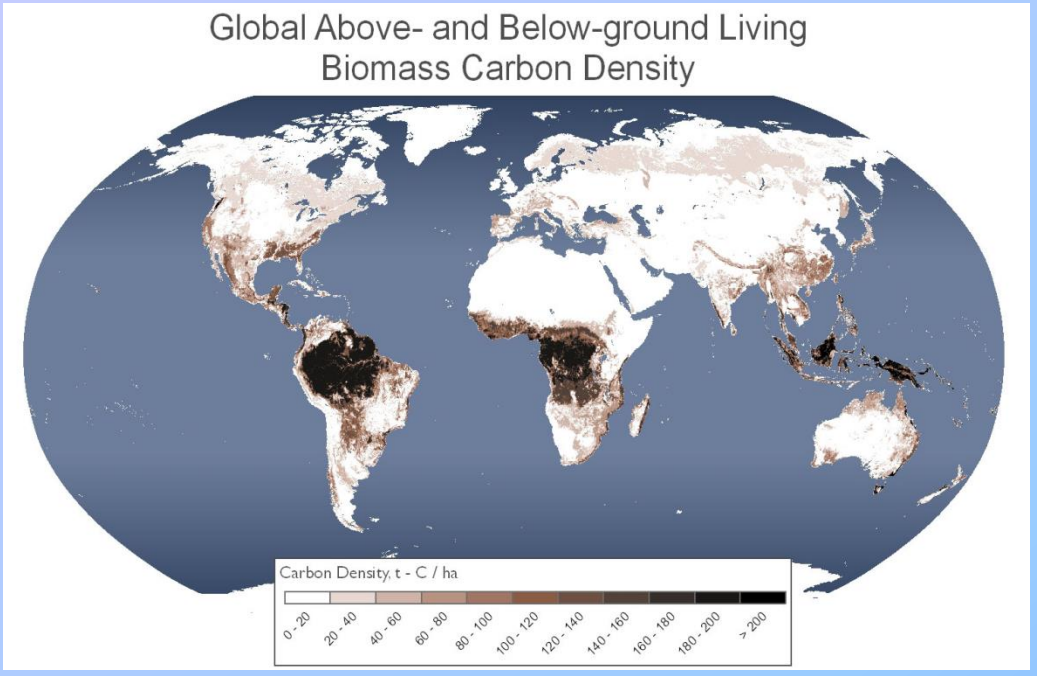
Global fossil fuel emissions



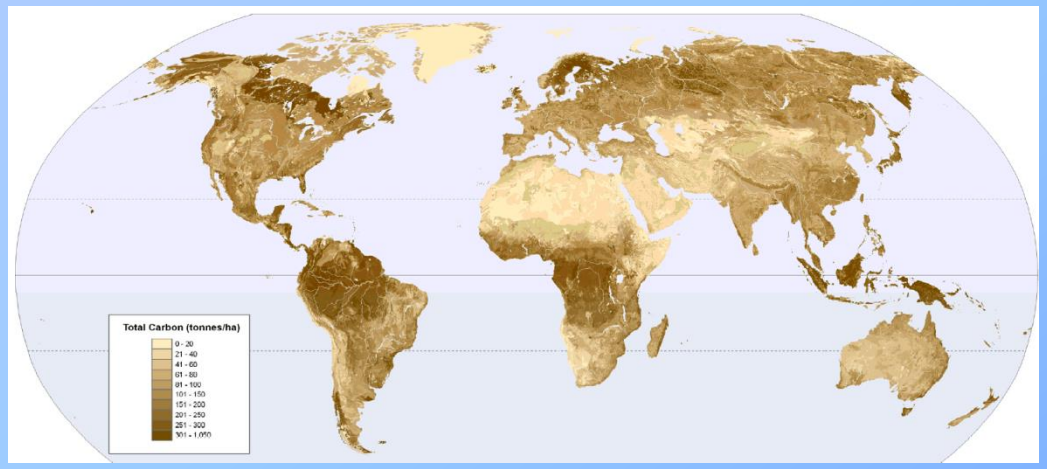


- With leap year adjustment: 2012 growth
- Source: Le Quéré et al 2013; CDIAC Data; Global Carbon Project 2013

Threatened areas include the largest terrestrial carbon stocks.



Ruesch, et al. 2008. New IPCC Tier-1 Global Biomass Carbon Map For the Year 2000.



Scharlemann, J., Hiederer, R., Kapos, V. (2009). *UNEP-WCMC* & EU-JRC, Cambridge, UK.

- Biomass in tropics

(Philips et al. 2009, 2010, Lewis et al, 2011)

- Soil carbon (permafrost & boreal zone)

(Schuur et al. 2008, Muskett et Romanovsky, *Natural Science,* 2011)

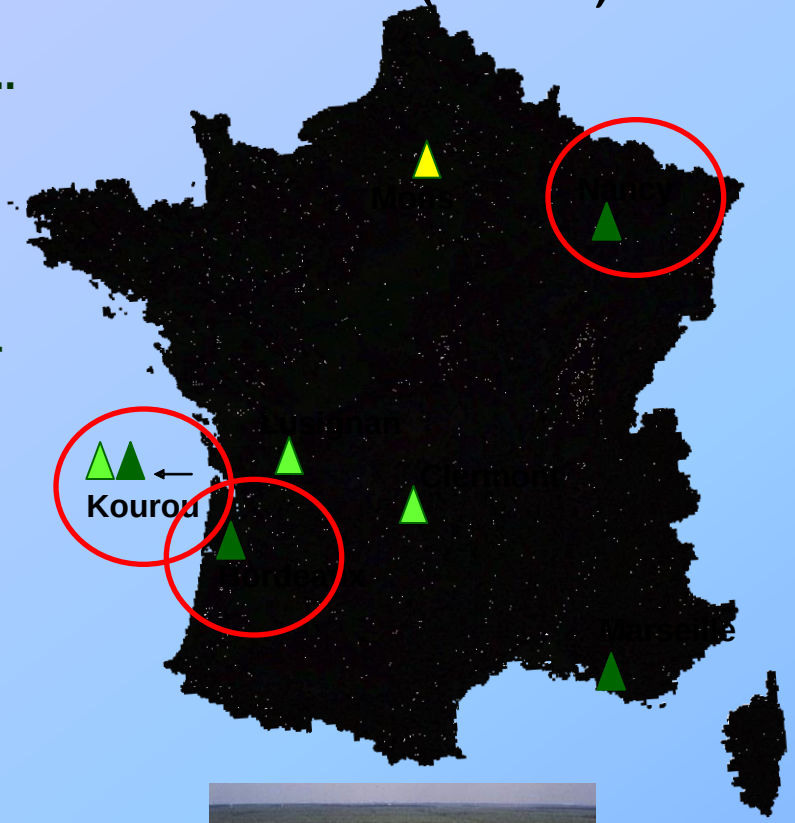
Climate and drought effects on forest carbon balance: case studies

1. Tropical forests
2. Broadleaved forests
3. Fast growing pine forest

INRA long term forest network

(1996-)

- ✓ **Fluxes of CO2, O3, N,..**
- ✓ **Phenology**
- ✓ **Radiative balance**
- ✓ **Energy balance**
- ✓ **Hydrology**
- ✓ **Soil carbon and water**
- ✓ **Growth and Biomass**



Broadleaved temperate forest (Nancy)

Broadleaved tropical forest (Kourou)

Coniferous forests (Bordeaux, Marseille)

Bioenergy forests (Estrées-Mons)

1. Amazonian forest: stand scale impacts.

The Guyaflux site in French Guiana (Europe)
(French overseas department)

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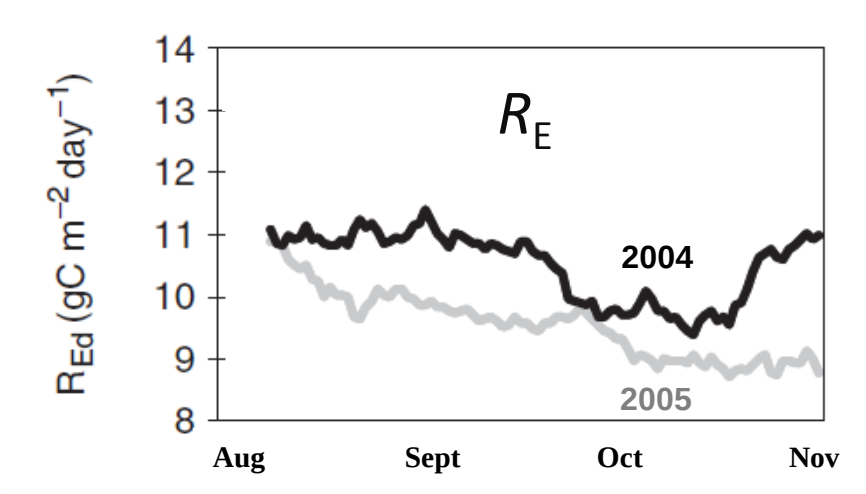
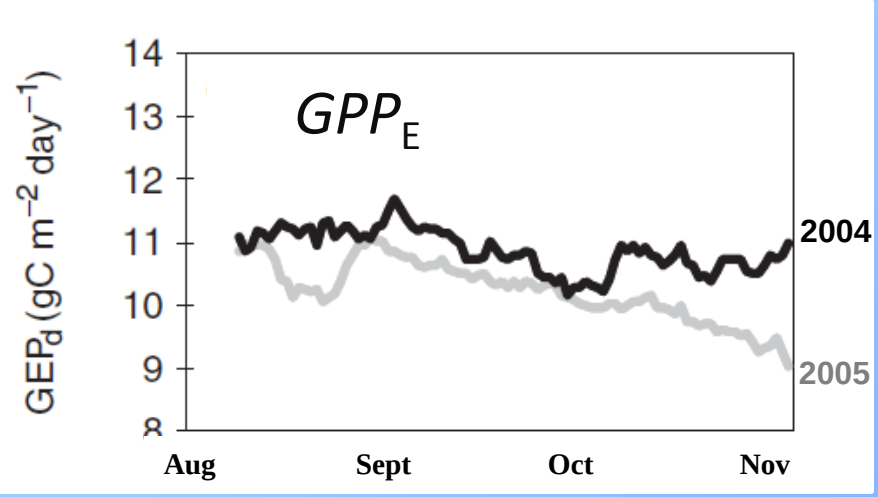
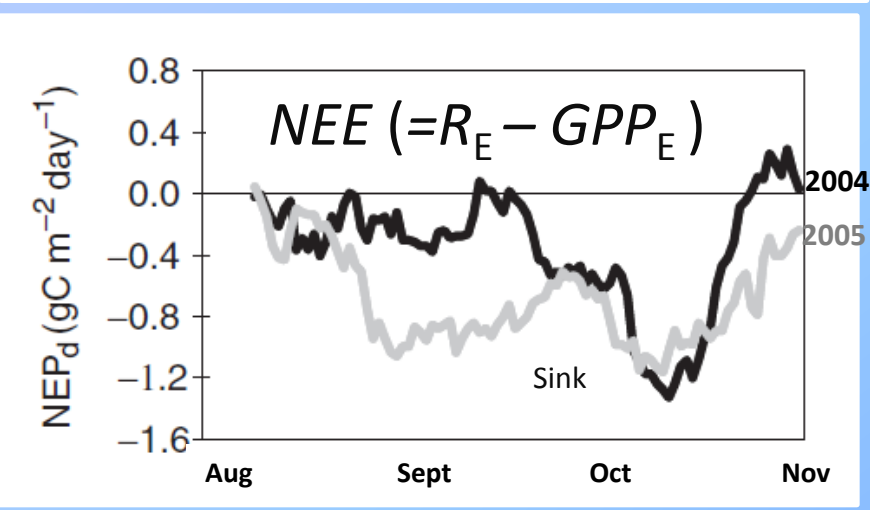
Integrated Carbon Observation System

1. Amazonian forest: immediate impacts at stand level.





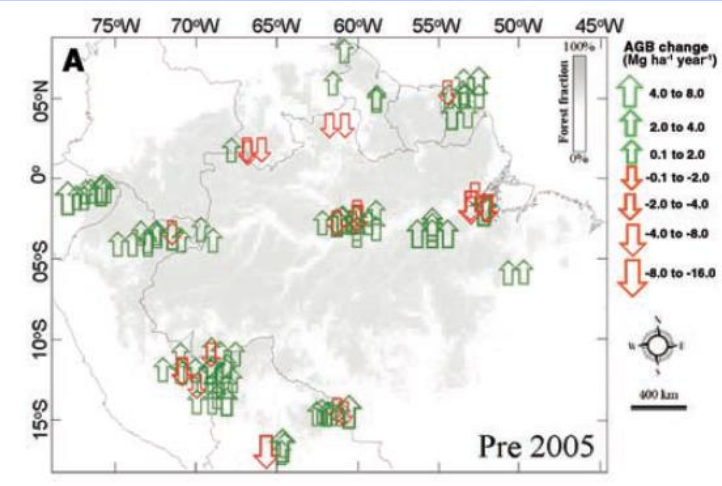


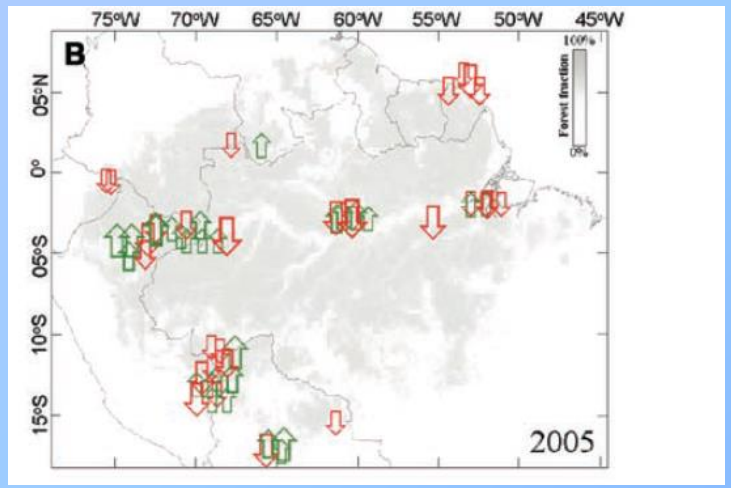
Carbon Flux and Balance

gC m^{-2} for 92 days	Dry 2004	Dry 2005
R_E	975.6	888.6
GPP	1008.4	953.2
NEE	32.7	64.6

- Counter-intuitive increase in net CO_2 uptake during drought
  - explained by a larger decrease in ecosystem respiration -.

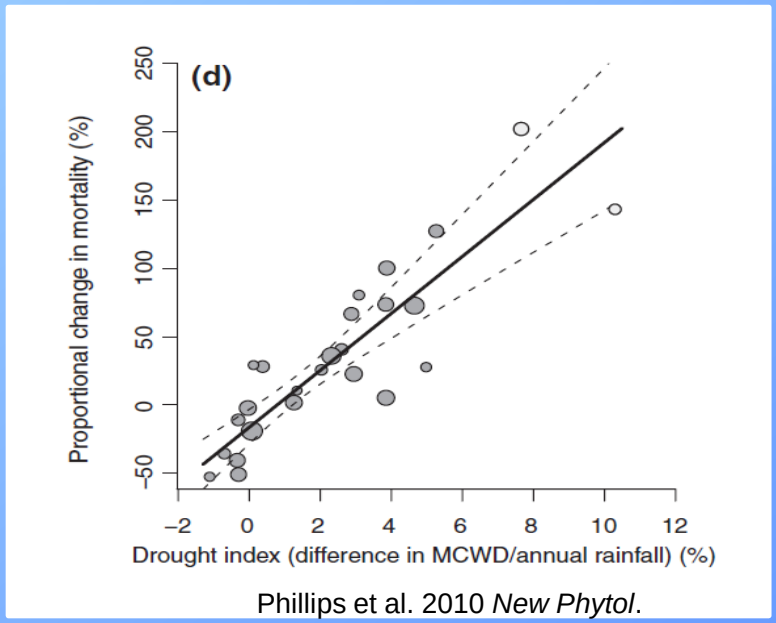
1. Amazonian case: delayed drought impacts at large-scale.





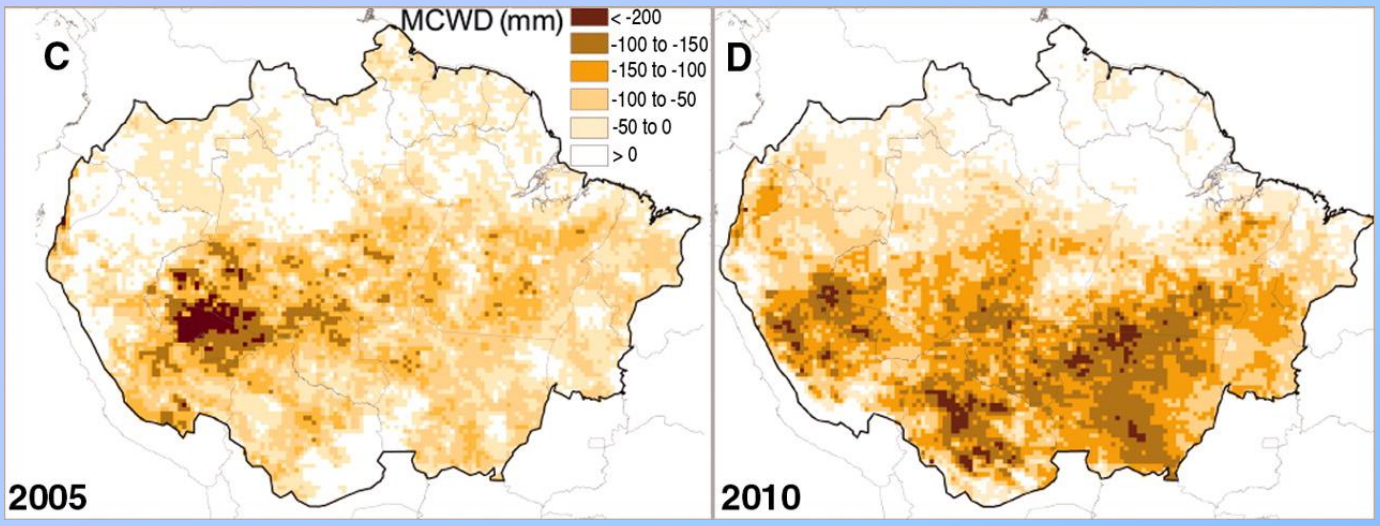
- Large scale inventories have shown Amazonian rainforests were converted into a source of carbon by the <u>2005</u> drought (Philipps et al. 2009, *Science*)

- The increase in tree mortality correlates with drought intensity.



Phillips et al. 2010 *New Phytol*.

1. Amazonian case: large-scale potential impacts.

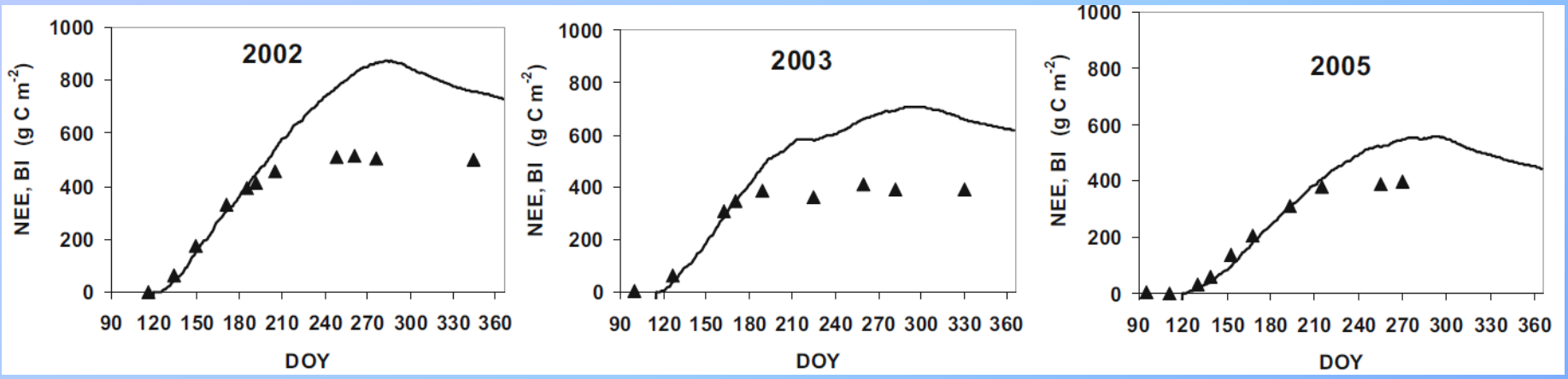


S L Lewis et al. Science 2011;331:554-554

- 2010 drought had a larger extend and severity;
- Repeated drought events have been leading the Amazonian rainforest from a weak sink (Mahli, Grace, Lewis,…) to a source;

2. Drought effects observed in temperate forest: instantaneous impacts.

- 35 y-old beech forest in N-E France carbon cycle monitored since 1996.



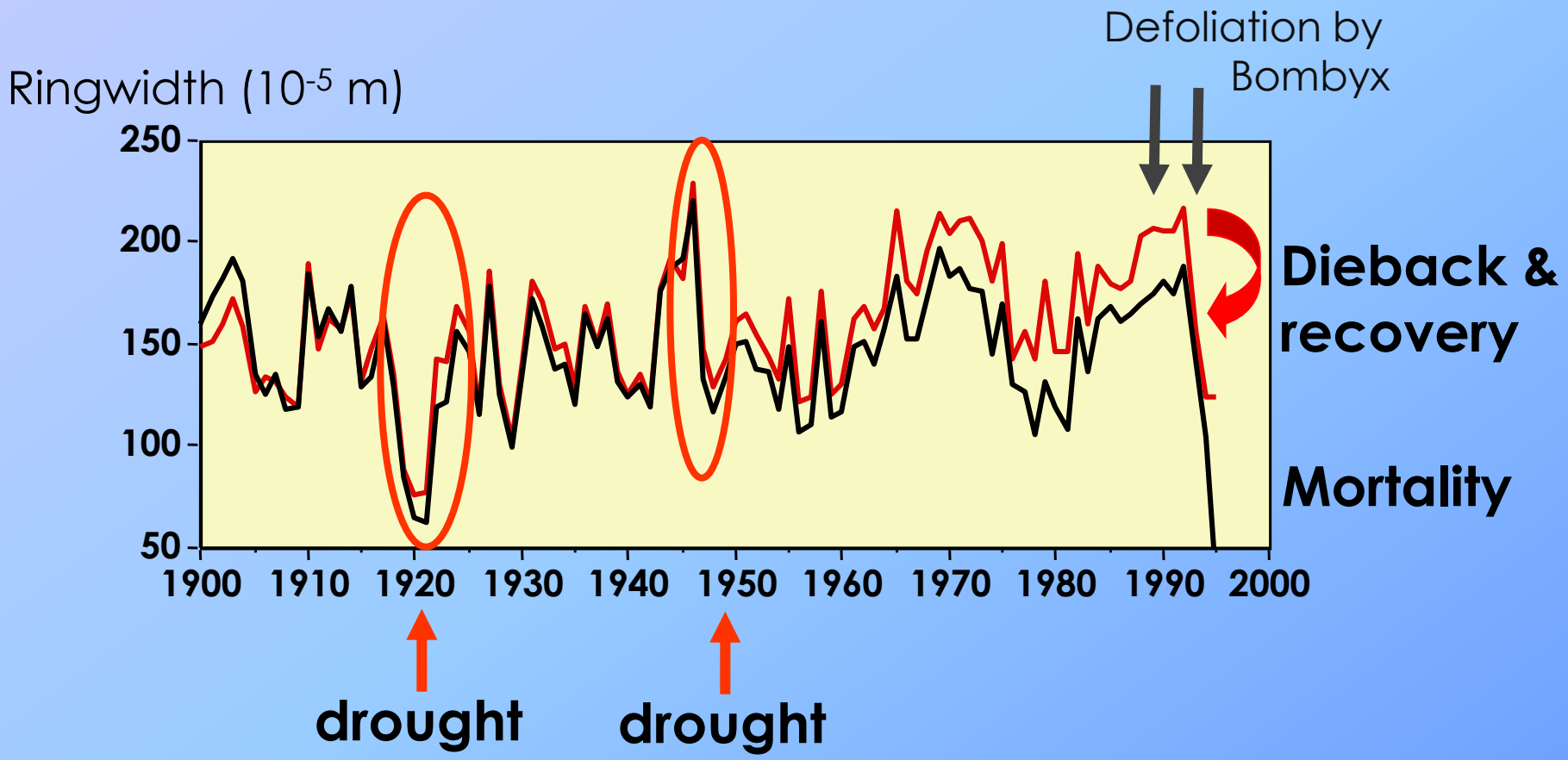
Wet year | Driest year | Dry year

- Annual stem growth (▲) is more resilient to concurrent soil water deficit than CO2 exchanges (——)

- But next year growth is severely depleted (Granier , unpublished)

2. Drought effects observed in temperate forest: Long-term predisposition to mortality by previous drought.

Oak Forests in Haguenau (Alsace) –
Bréda & Badeau, 2008, Geosciences

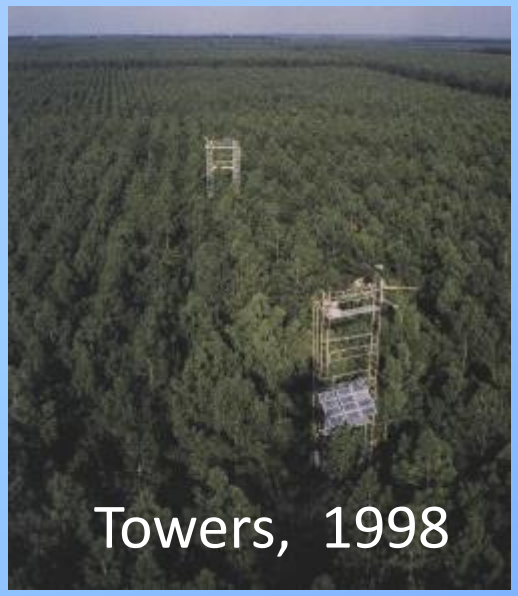


- Droughts render individuals more vulnerable to subsequent stresses (defoliation by caterpillar)

3. Drought effects observed in temperate forest: Interaction with management in fast growing pine forests.

Chronosequence of Pine sites, SW France.

- Ecological and tree inventories from 1987
- Water balance 1988 -2008
- CO_2 flux from 1996 to 2008
- ^{14}C Soil carbon dating in 2002


Towers, 1998


Ground view 1999


Top view 2006

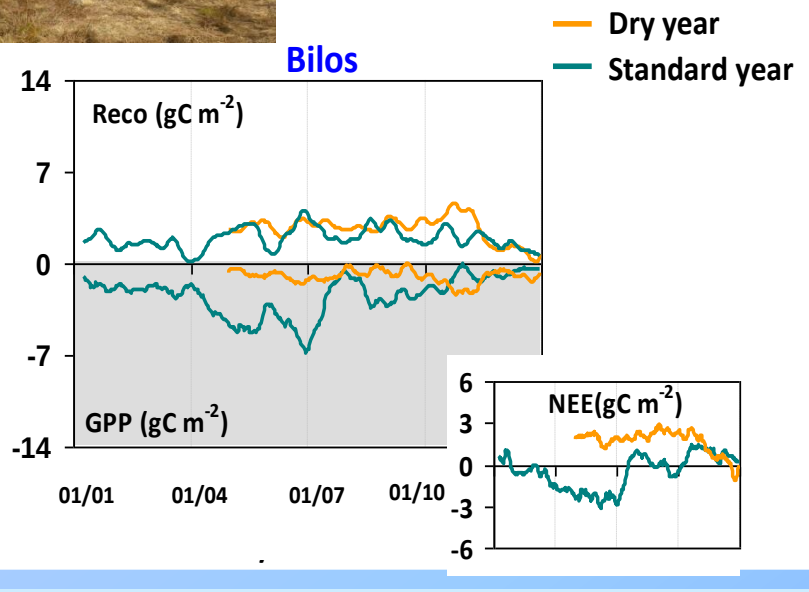
REGION AQUITAINE

ECOFOR ECOSYSTEMES FORESTIERS

ICOS

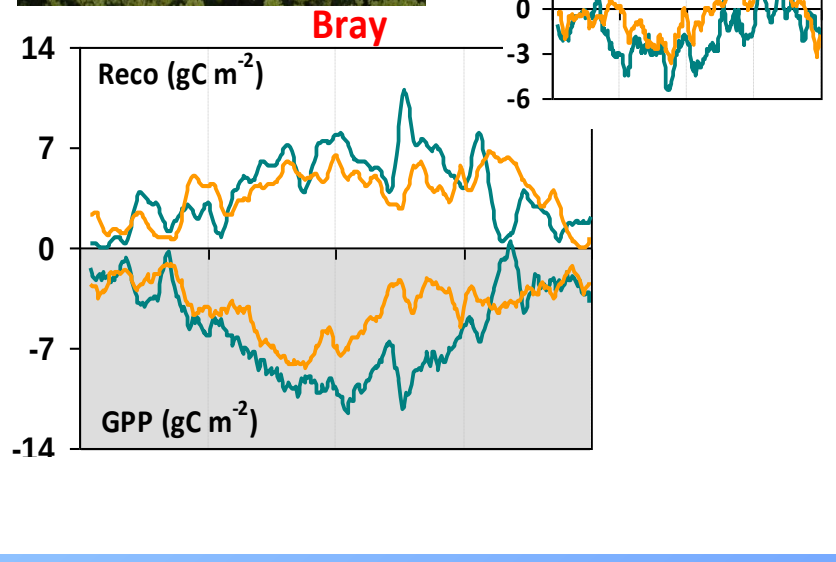
3. Drought effects observed in temperate forest: Interaction with management in fast growing pine forests.

Regenerating stand



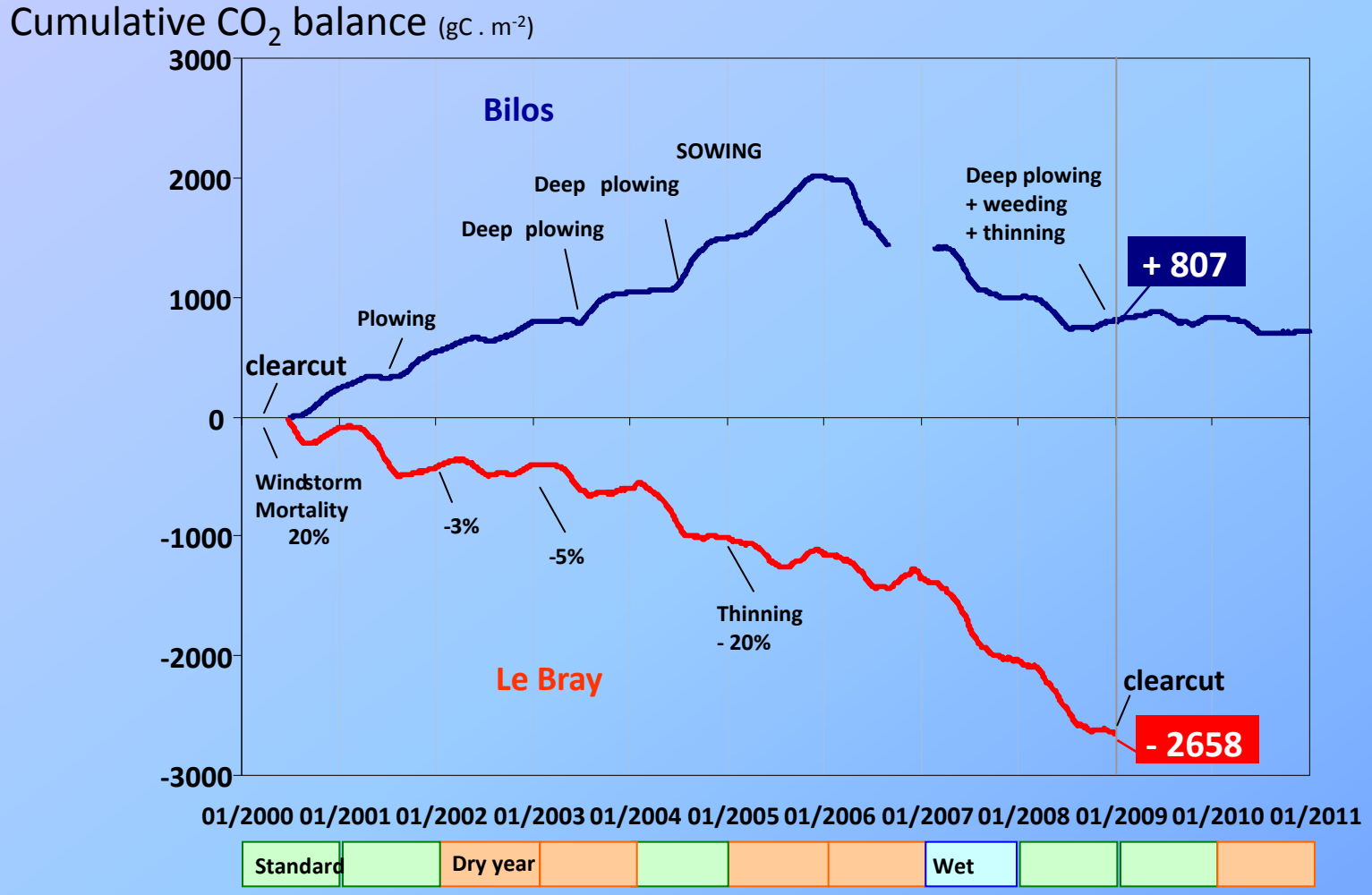
- Drought turns NEE from sink into source
- Heterotrophic respiration is maintained
- Soil is still partly wet !

Mature stand



- Ecosystem NEE depleted but not reversed
- Respiration is strongly affected
- Soil is 100% dry

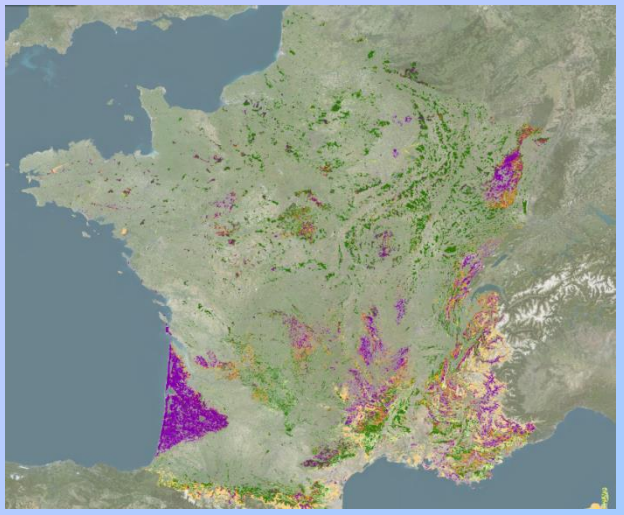
3. Drought effects observed in temperate forest: Interaction with management in fast growing pine forests.



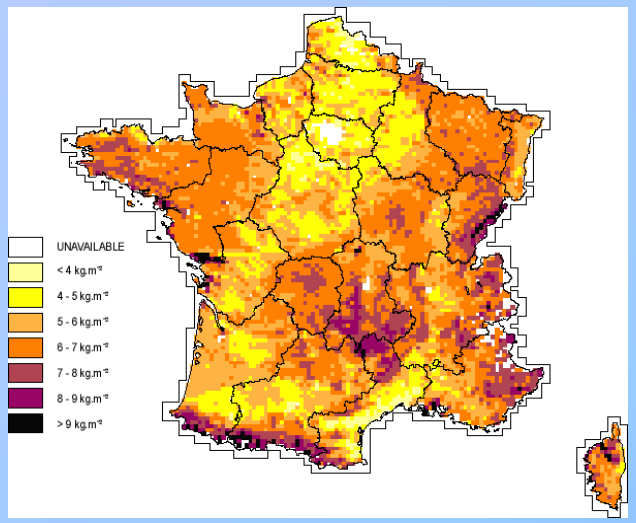
- No significant post-drought effects
- Drought maintains young forest as a net source of carbon
- Temporal fluctuations in mature stand NEE are controlled by climate

Numerical investigations for the French Pine Forests case

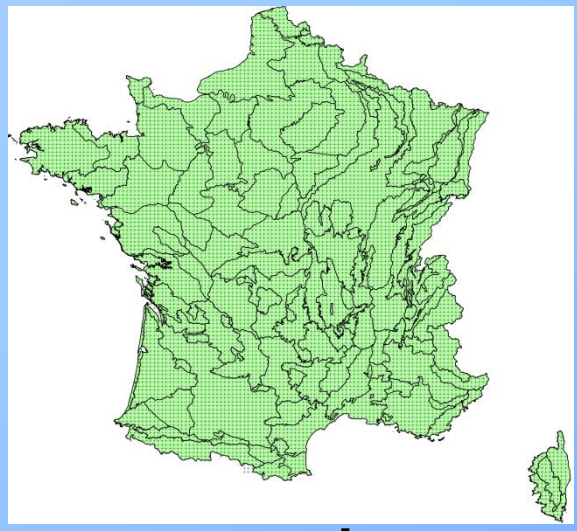
Species & age distribution



Soil Inventory



Climate



GO+ model

- Biophysics
- Biogeoclemistry
- Carbon, water cycles
- Tree growth & production
- Management
- Harvest

X

Gridded data sets

- Soil class
- Forest area (species, age)
- Climate

=

1. Transitory mode: predictions mapped over country area

- Management scenarios
- Soil class
- 1970-2100

3. Drought effects modelling in temperate forest:
Mapping the interaction between climate and management in fast growing pine forests.

		Tillage	NPK	Stocking	Thinnings	Parts harvested	Age at clearcut
Pine Extensive	**(P60)**	**0**	**0**	**1600**	**4**	**Stem**	**60**
Pine Standard	**(P45)**	**X**	**+**	**1600**	**6**	**Stem**	**45**
Pine Intensive	**(P30)**	**XXX**	**+++**	**1600**	**1**	**Stem Crown Stump**	**30**





3. Drought effects modelled in temperate forest: Mapping the interaction between climate and management in fast growing pine forests.

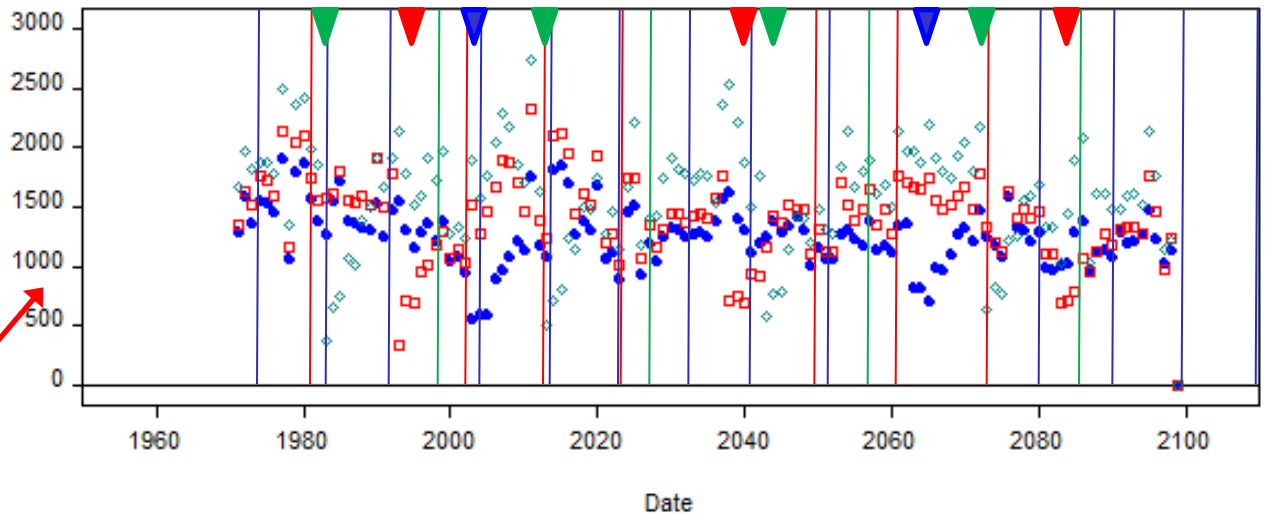
Tillage /fertilisation/plantation:

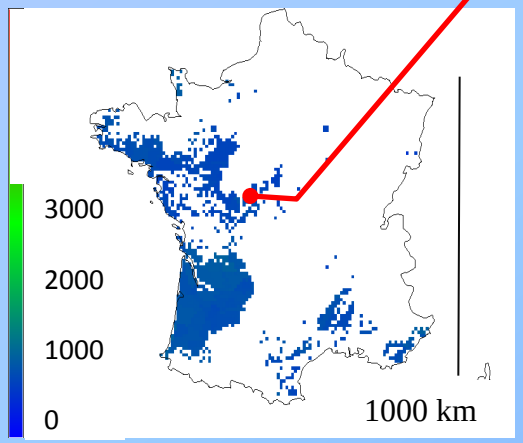
Thinning / disking :

Gross Primary Production ($gC.m^{-2}.yr^{-1}$)

Management class:

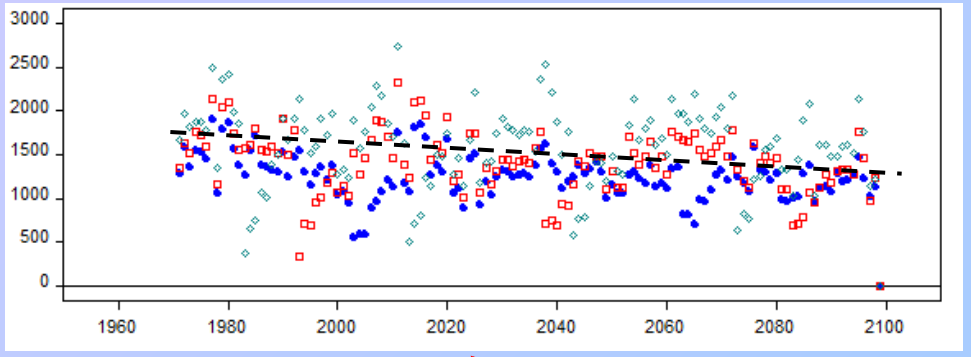
- P30
- P45
- P60

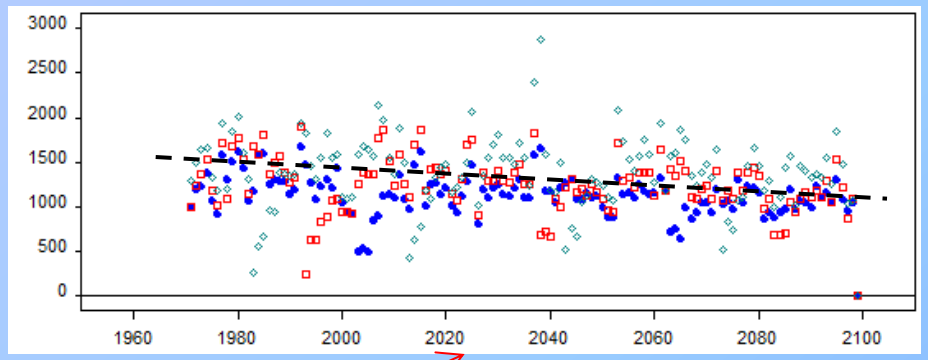




Predicted GPP according to management class 1970-2100 (as forced by A2 Scenario downscaled by model ARPEGE).

(Loustau et al., AGU 2013)



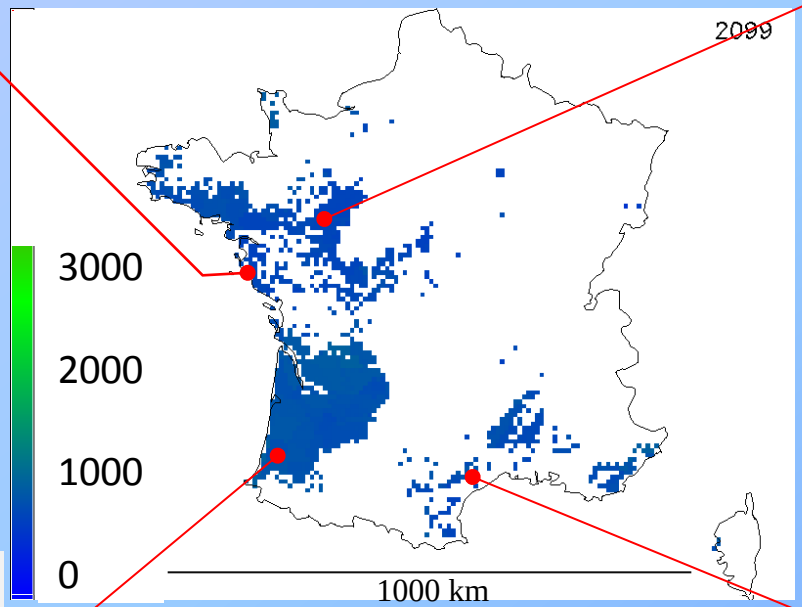


Atlantic

Centre

1. Transitory mode predictions: mapping over country area (9600 grid points)

- **Management scenarios**
- **Soil class 80**
- **1970-2100**

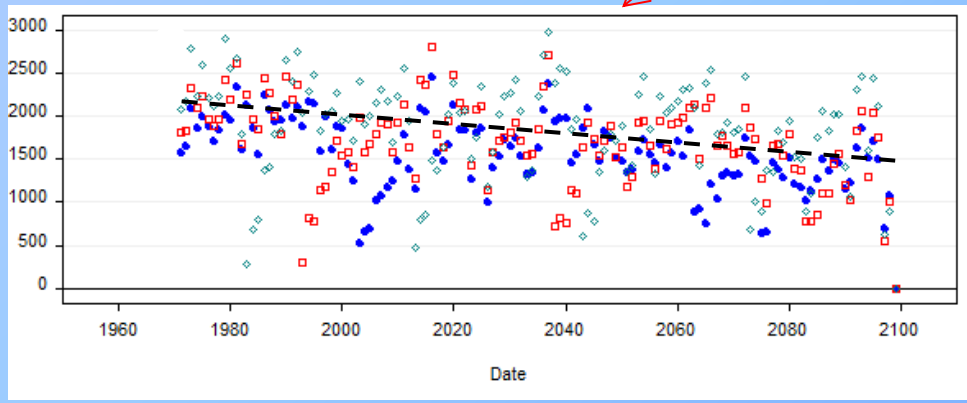


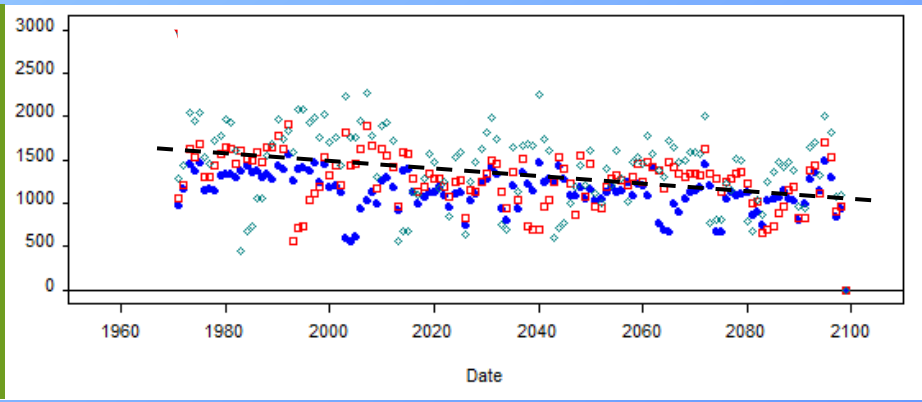
Gross Primary Production ($gC.m^{-2}.yr^{-1}$)

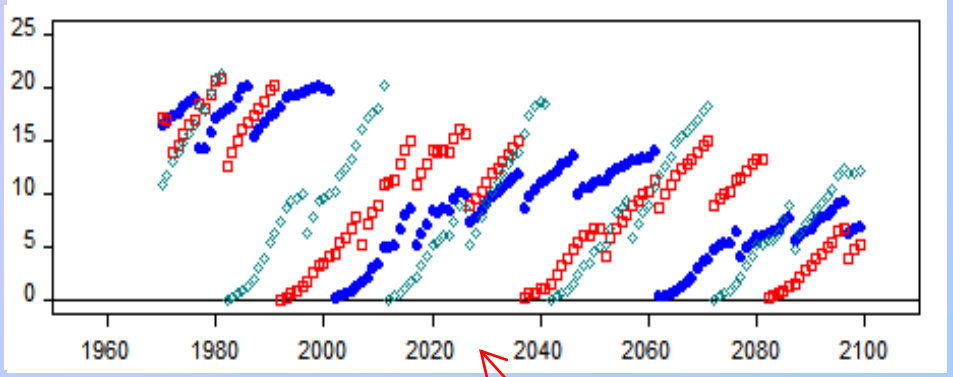
Managt class:
- P30
- P45
- P60

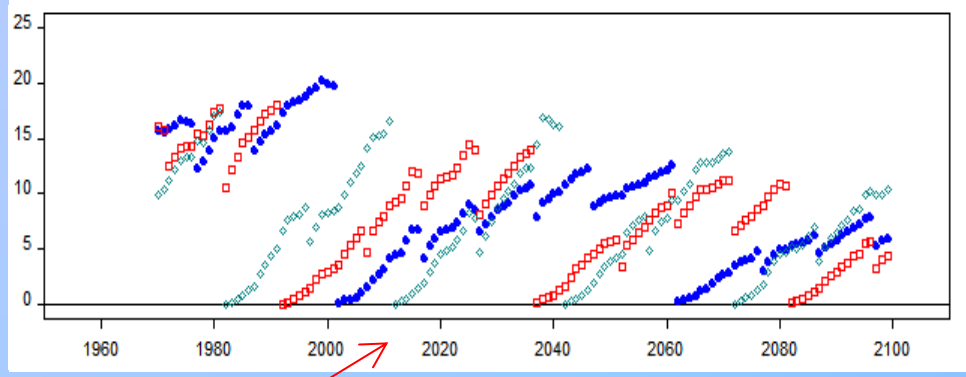
Pyrenean Foremounts

Mediterrannean









Atlantic

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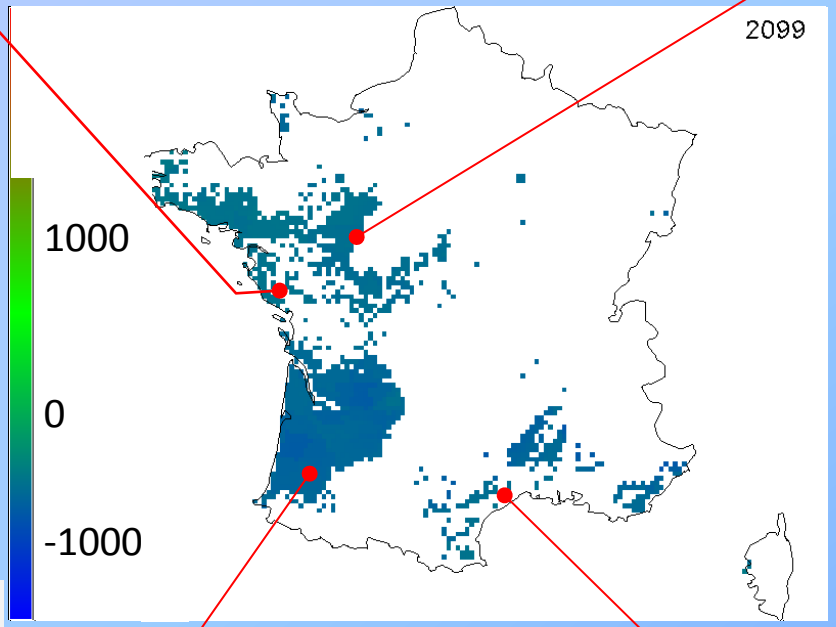
- NEE map
- Standing Biomass plots

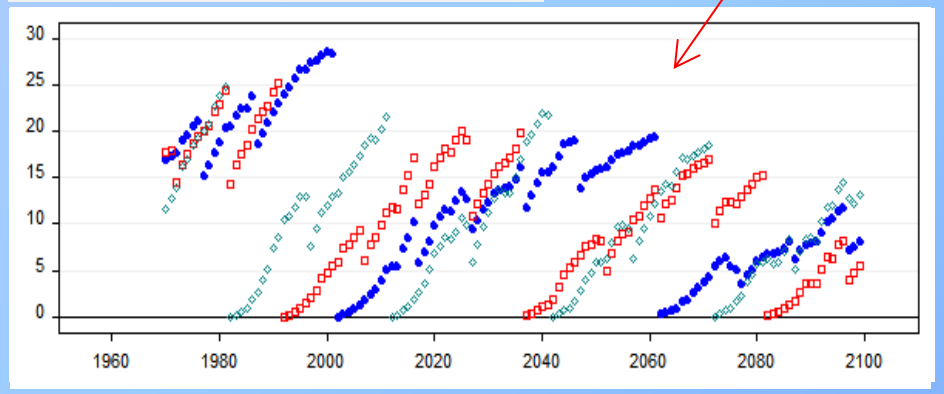


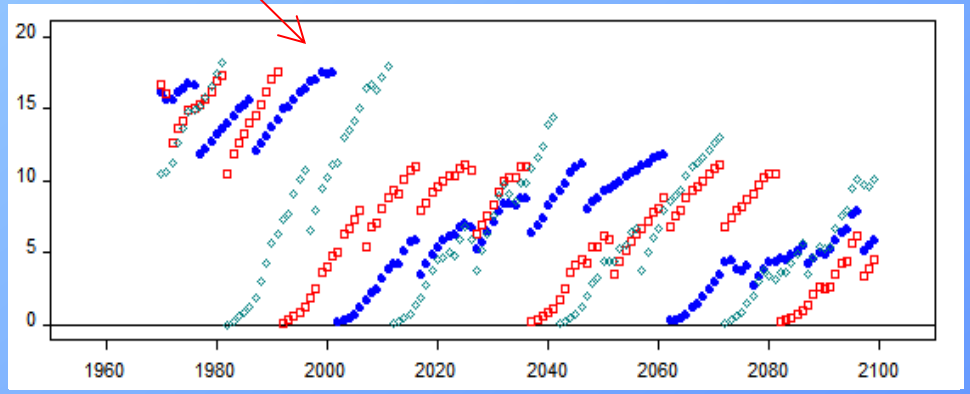
Plots of Biomass Stock (kg dm .m^{-2})

- P30
- P45
- P60

Pyrenean Foremounts

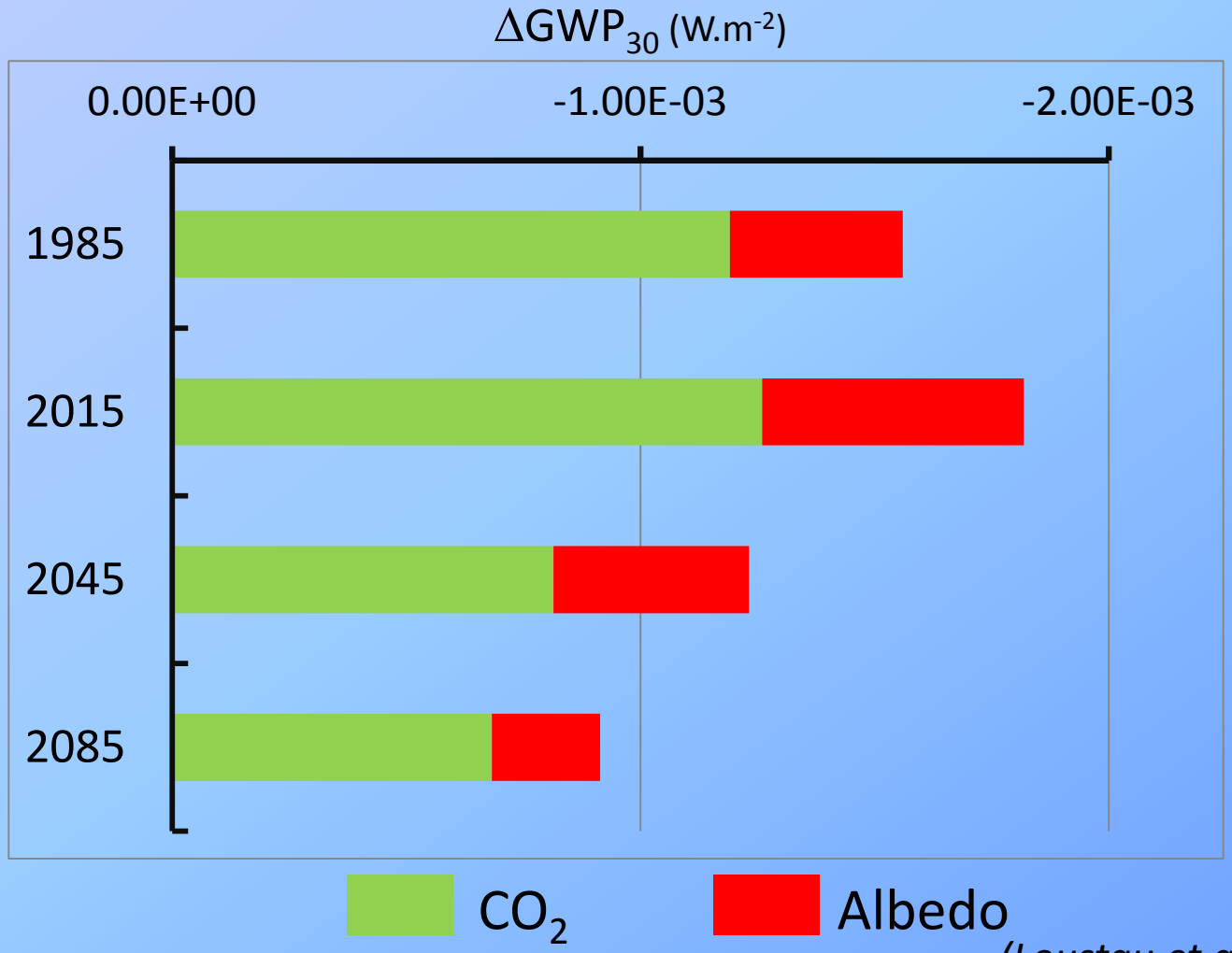
Mediterrannean





3. Drought effects modelled in temperate forest: Management impacts on climate are weakened under future drier climates

Global warming potential of management intensification from P60 → P30



(Loustau et al., EGU 2014)

Main points to take home.

- All forest types are exposed to droughts
- Trees respond at a range of time scale from hour to century
- How far does drought weaken the biosphere carbon sink is unknown.
- Release of carbon from declining forests will feed-forward the climate disturbance

INRA
SCIENCE & IMPACT

INRA ISPA

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- Virginie Moreaux*
- Alexandre Bosc
- Delphine Picart
- Christophe Moisy

INRA EEF

- Damien Bonal
- Nathalie Bréda
- Bernard Longdoz
- André Granier

SUPPORT

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