Adapting forests to climate change in the French Mediterranean mountains :

how far forest management can facilitate species succession, consider growth potential modification, and ensure the continuity of some ecosystem services

Dreyfus *Ph.* [1], ***Ladier*** *J.* [2], ***Huard*** *F* [3]., ***Courdier*** *F.* [1]

[1]: **INRA** Mediterranean Forests Ecology – *Avignon (France)*

[2]: **ONF** R & D - *Avignon*

[3]: **INRA** AgroClim - *Avignon*

Tackling climate change requires much **research** effort : ***no immediate answers ...***

Meanwhile, **forest managers have to decide right now**
and try to maintain forest and ecosystem services
(both short term and long term) :

- *water-saving silviculture* ?

- ***change target species ?***

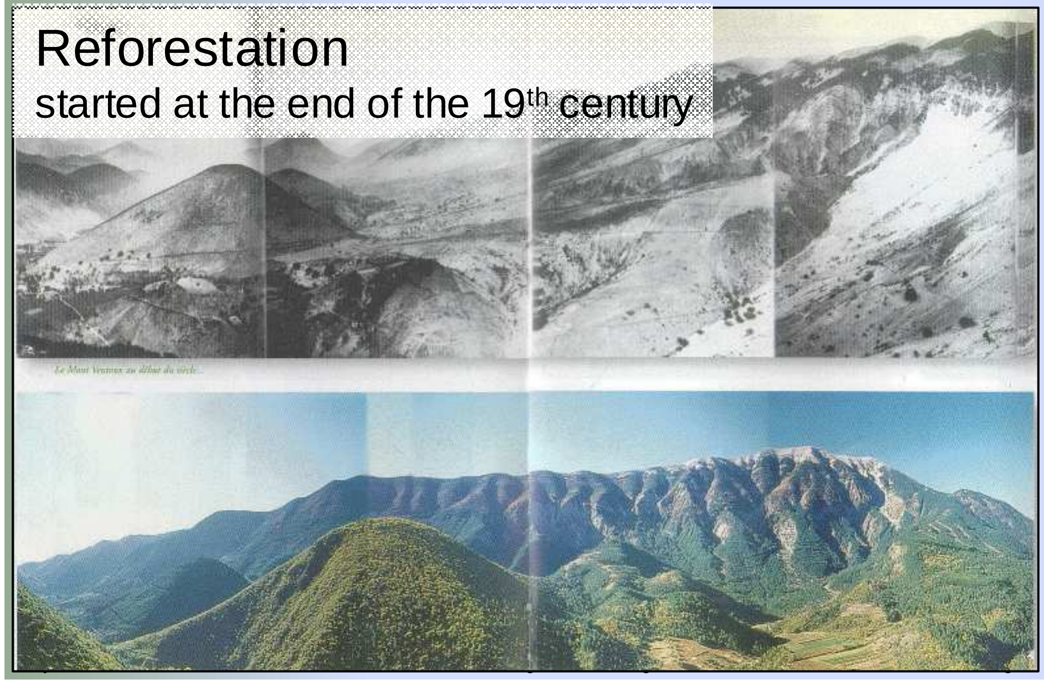
... Use already **available tools** (though imperfect) and knowledge
in a view to **favor better-adapted species**

- \- a **Case Study** *from the French Mediterranean mountains*
  simulation of site conditions change,
  species migration and influence of forest management
- \- the **Tool Box** *used for these simulations*

A case study

Mont Ventoux

mount Ventoux



Reforestation
started at the end of the 19th century

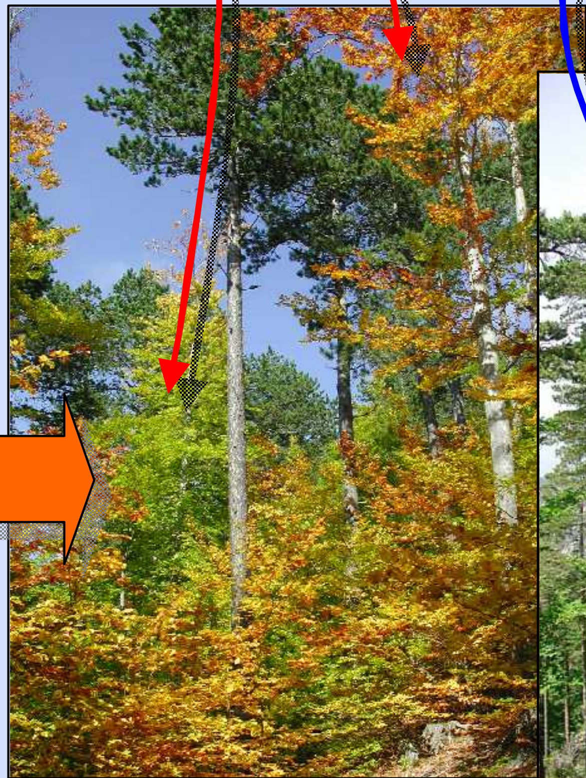
Photo J. Baubion

1st major trend: **« Forest Maturation »**

from ***Old Pine plantations*** towards ***New Uneven-Aged Mixed stands***

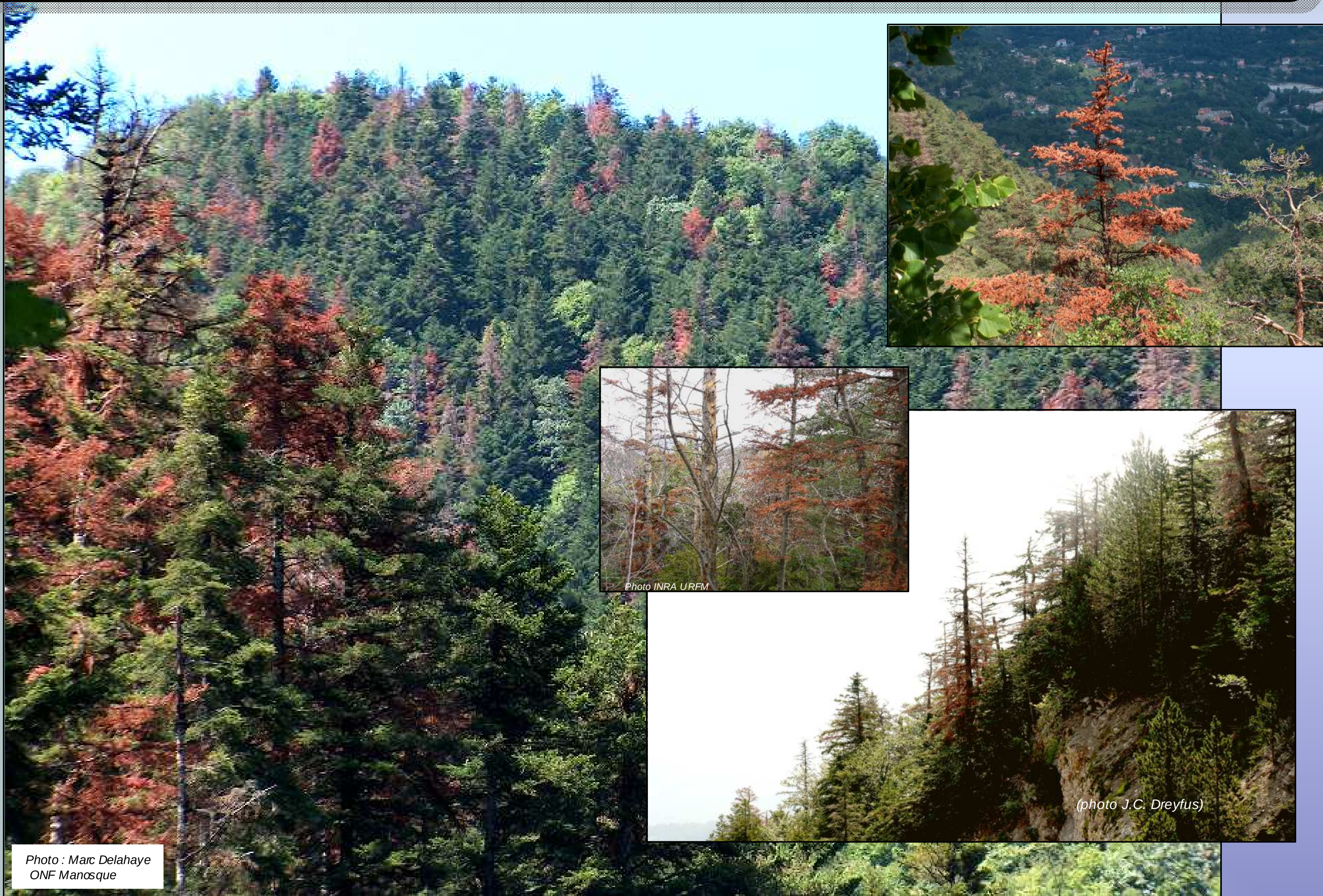
through (re-)colonization by ***Fagus silvatica*** and ***Abies alba*** (northern slopes)

Pinus nigra nigra
or ***Pinus sylvestris***
or ***Pinus uncinata***



2nd major trend: Increase in Climate-induced Mortality

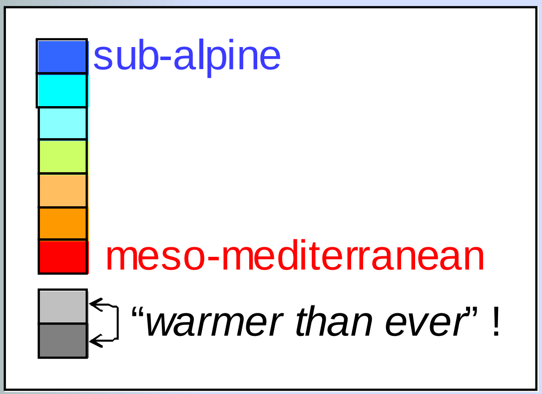
for Silver fir (*Abies alba*), Scots pine (*Pinus sylvestris*) ...

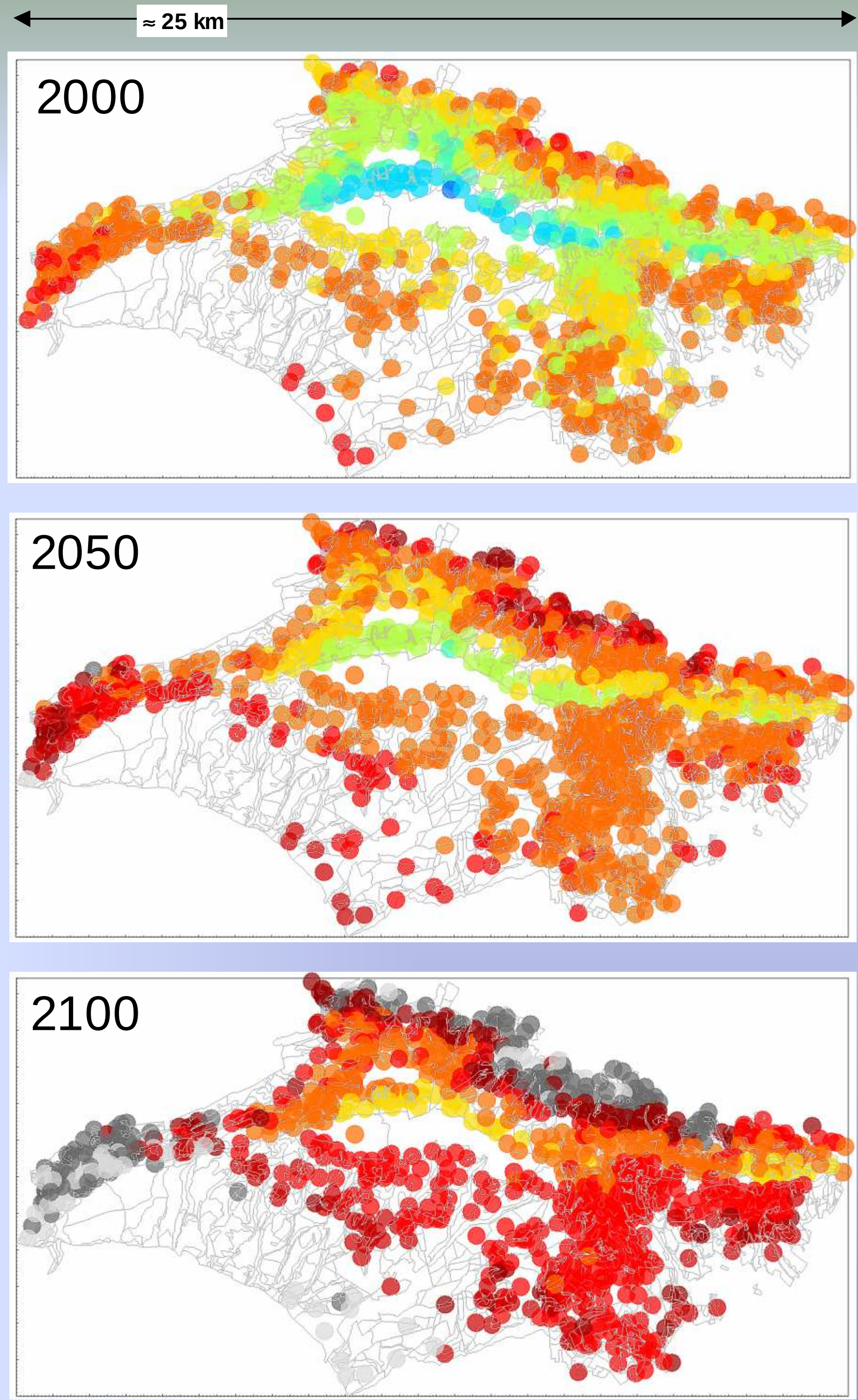


Simulating the evolution of site conditions

Climate change
for ***A1B***
IPCC emissions scenario

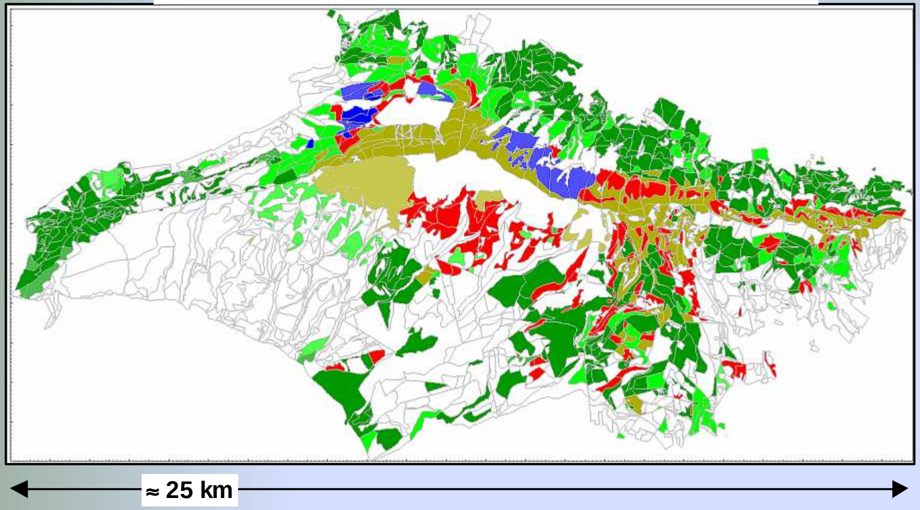
... namely the **evolution of "bioclimatic levels"** moving upward due to CC



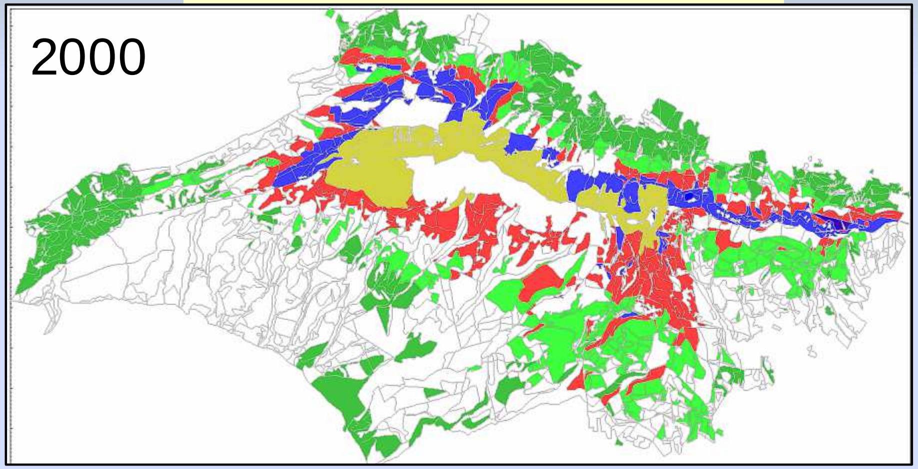


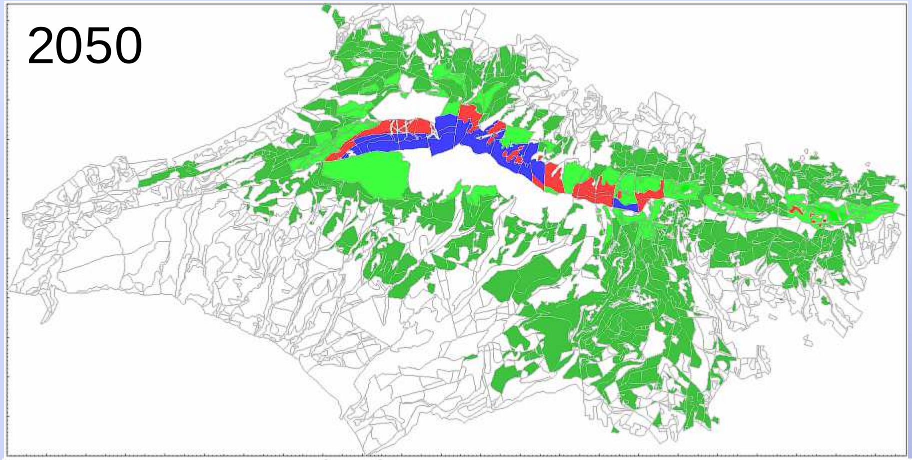
Simulating the evolution of the "Best-Adapted Species"

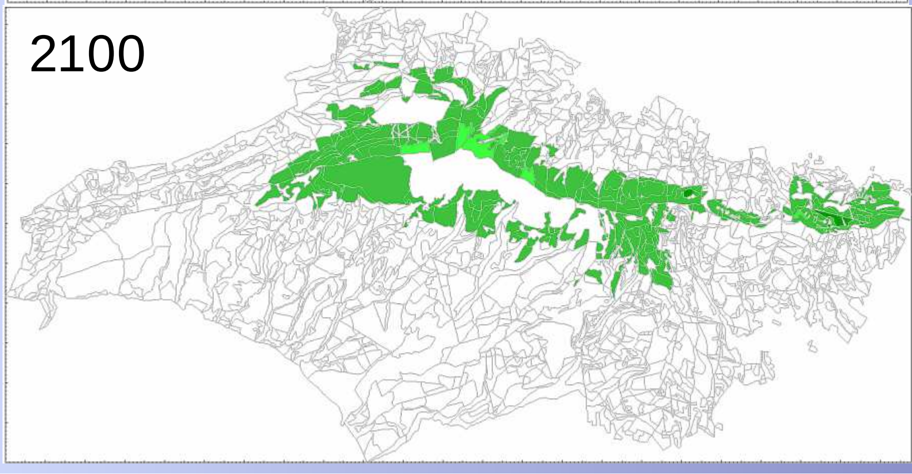
Initial (2000) main species



"Best-Adapted Species"







"Best-Adapted Species" ... ?
= optimal altitude
nearest to current stand altitude

"optimal altitude"
= middle of the altitude range
in year 2000, South-East of France

Pinus nigra nigra ***Fagus silvatica***
Pinus sylvestris ***Abies alba***
Pinus uncinata

(N.B.: aspect-compensated altitude)

Defining 2 forest management Strategies

"**Conservative**" *vs* "**Adaptive**"

"Conservative"

Target Species

remains

the **"main species"** (G/ha)

in **2000**

in each stand,
for each thinning:

stronger reduction for other species

"Adaptive"

Target Species

= **future "Best-Adapted Species"**

= ***Pinus nigra***

(and *Pinus sylvestris*)

in each stand, for each thinning:

canopy removal for stands of other species when the current altitude of the stand is **in the upper part of *P. nigra* range**, or slightly above

⇔ **promote regeneration**
(seedlings growth and survival)
of light-demanding *P. nigra*

⇔ ***P. nigra* extension upward**

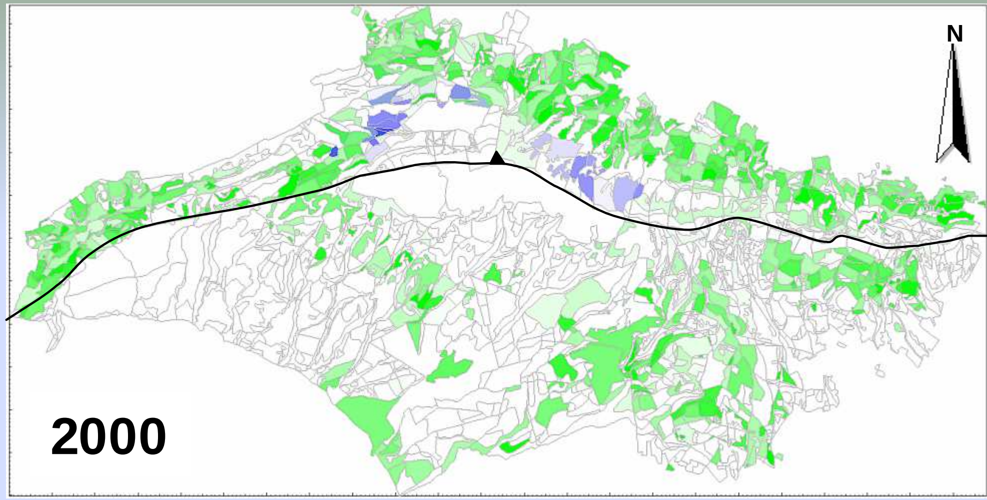
Conservative

Abies alba

Pinus nigra,

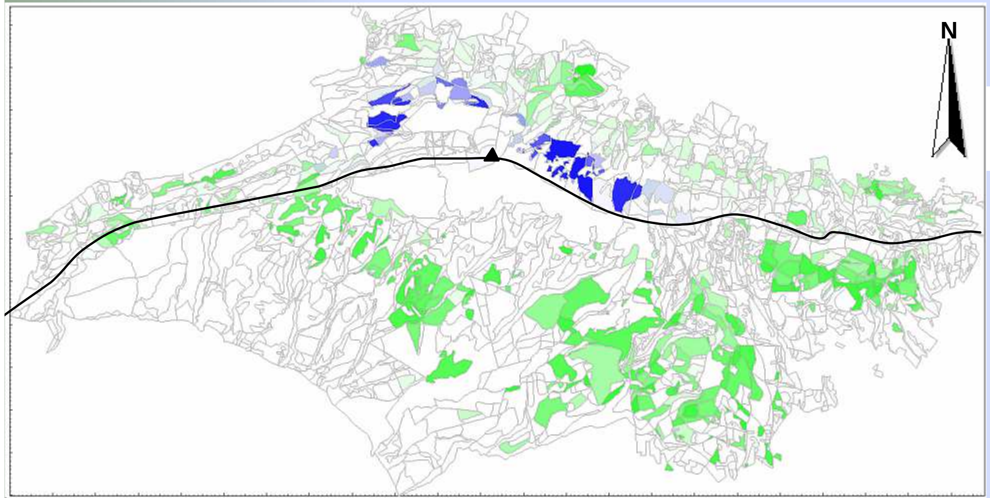
+ P. sylvestris

(P. uncinata, F. silvatica not shown*)*

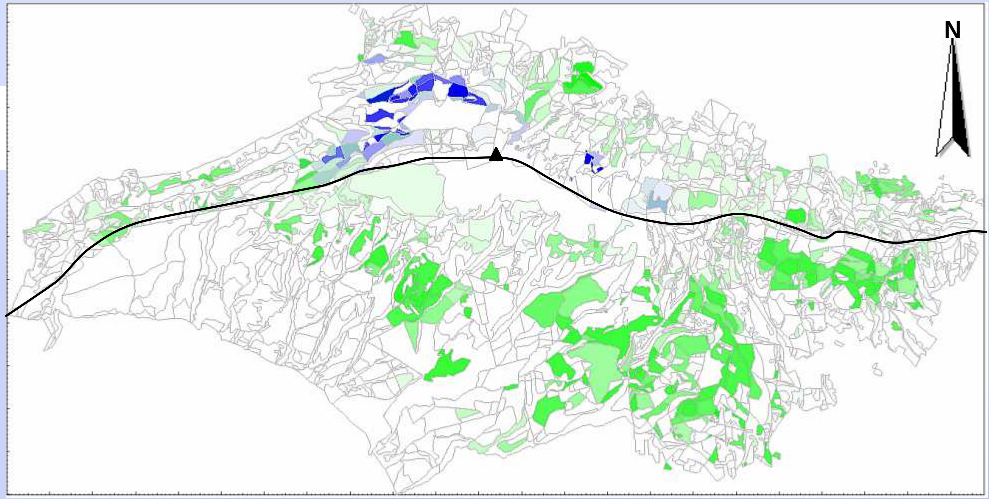


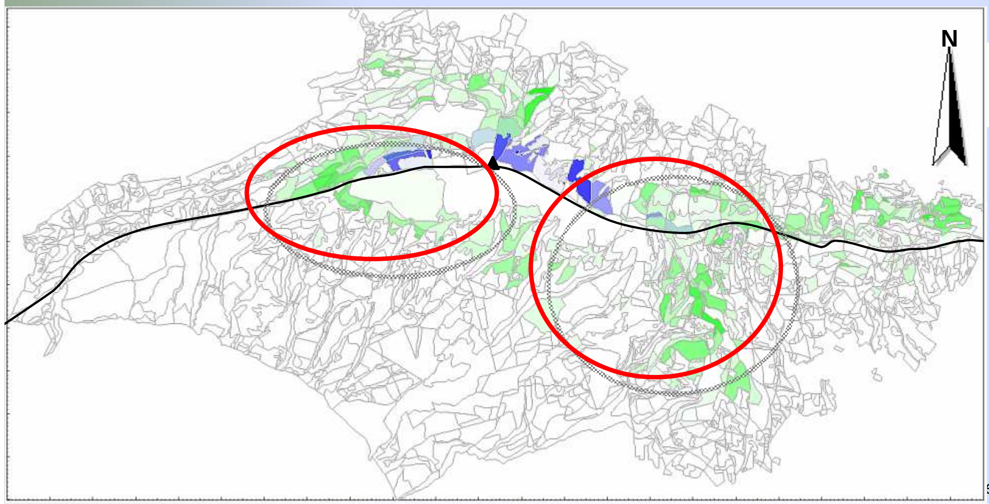
Adaptive

shade level
= G/ha trees > 0.5 Hdom
(white: 0)

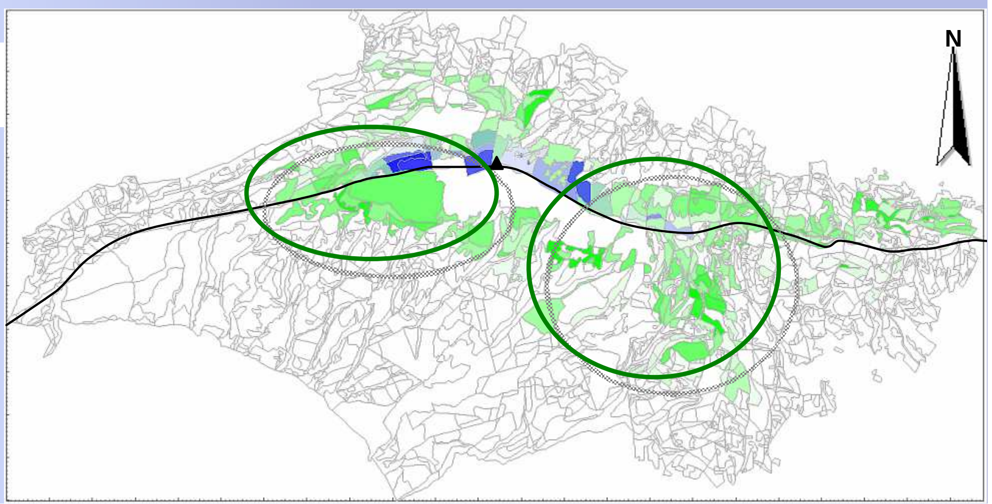


2050





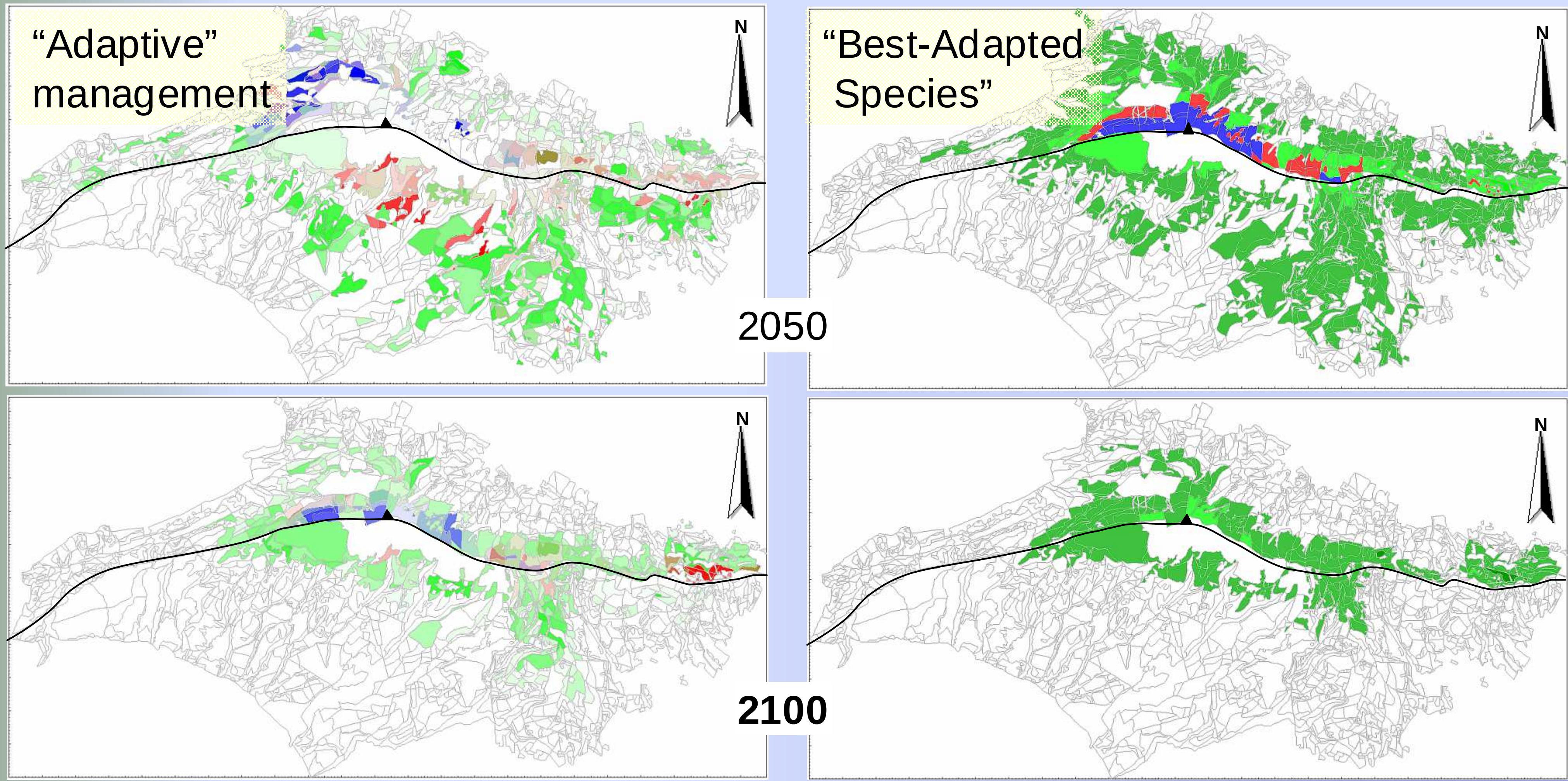
2100



edge

2100: "*Adaptive*" forest management would lead near to the "*Best-Adapted Species*" distribution

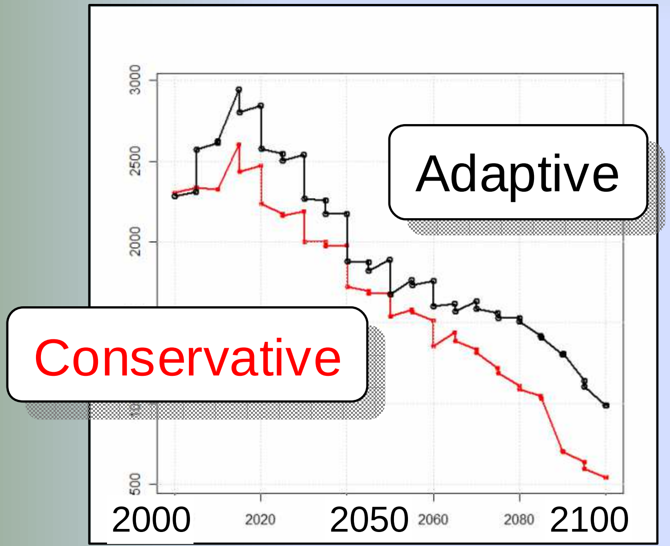
Pinus nigra, Pinus sylvestris, Pinus uncinata, Fagus silvatica, Abies alba



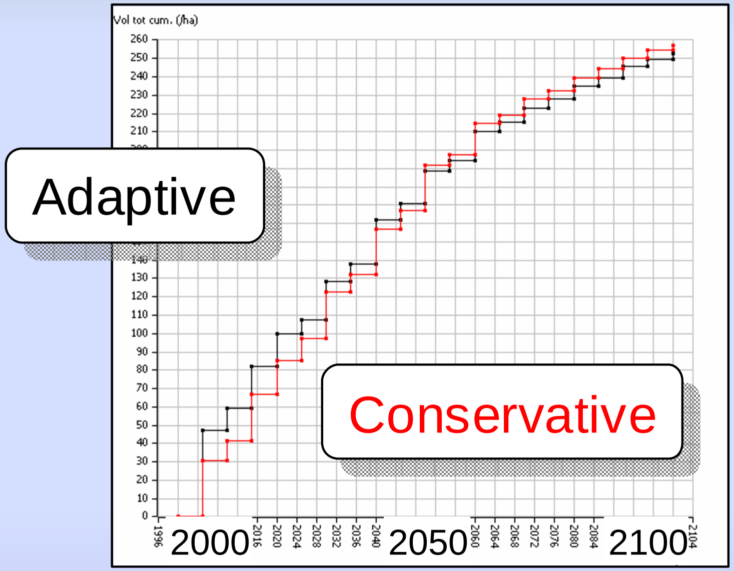
Nota Bene : at lower elevation, other species:
Quercus pubescens (humilis), Q. ilex, Cedrus atlantica

Ecosystem services ...

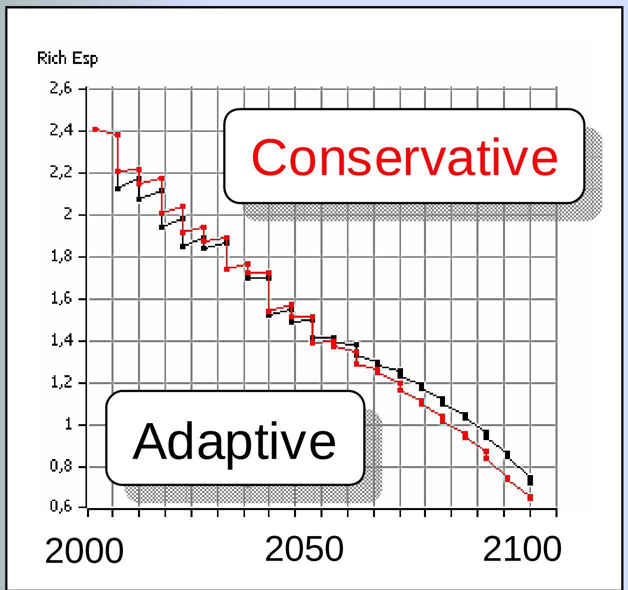
Area in Black pine

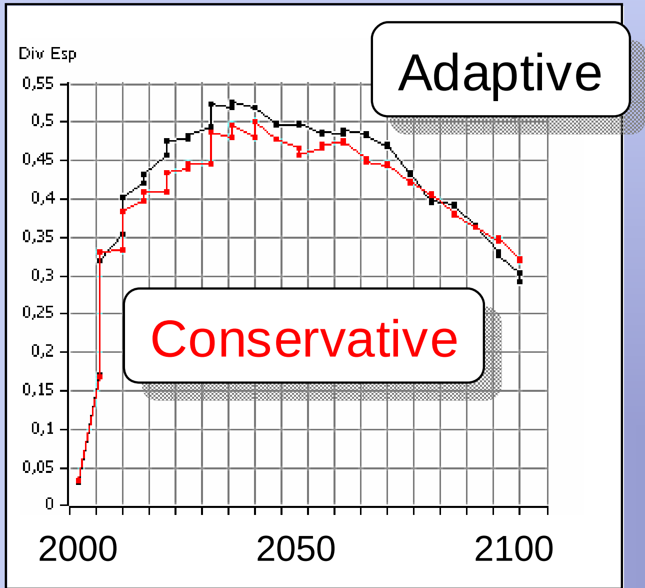


Wood production: cumulated harvest



Potential biodiversity: tree species richness and diversity *(5 main species)*





The “tool box” =

Site model

+

Forest dynamics model

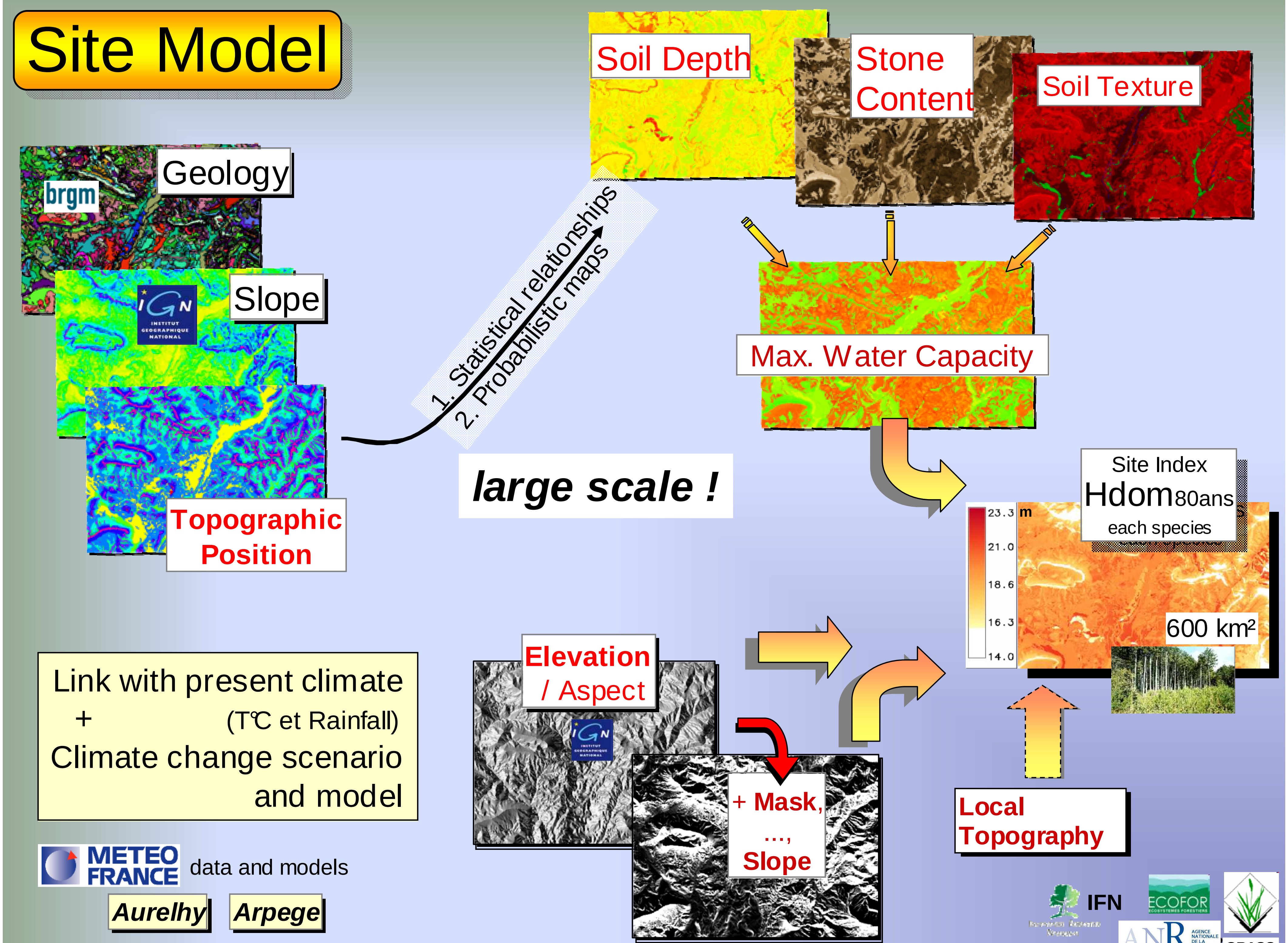
+

Simulation platform

for forest dynamics & forest management

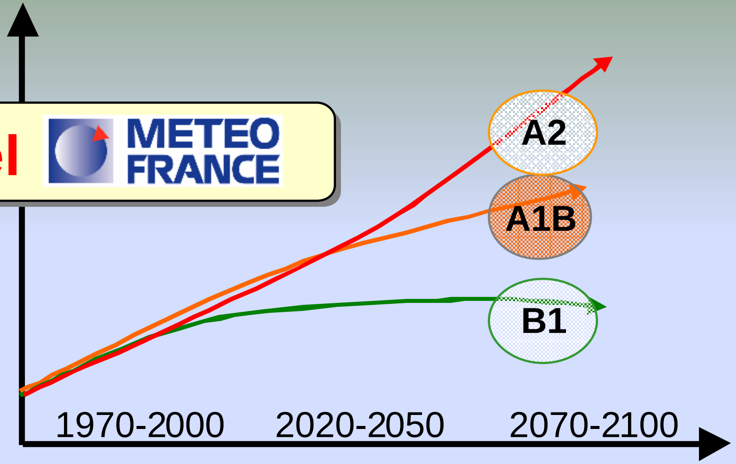
+

... Additional hypotheses

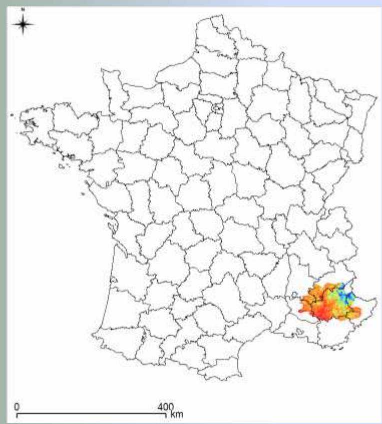

Site Model
Soil Depth
Stone Content
Soil Texture
Geology
brgm
Slope
IGN
Topographic Position
1. Statistical relationships
2. Probabilistic maps
Max. Water Capacity
large scale !
Site Index
Hdom80ans
each species
23.3 m
21.0
18.6
16.3
14.0
600 km²
Link with present climate
+ (T℃ et Rainfall)
Climate change scenario
and model
Elevation / Aspect
+ Mask, …, Slope
Local Topography
METEO FRANCE
data and models
Aurelhy
Arpege
IFN
ECOFOR
ANR
GRASS

Accounting for Climat Change

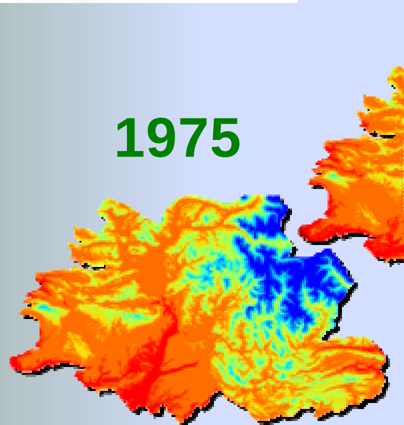
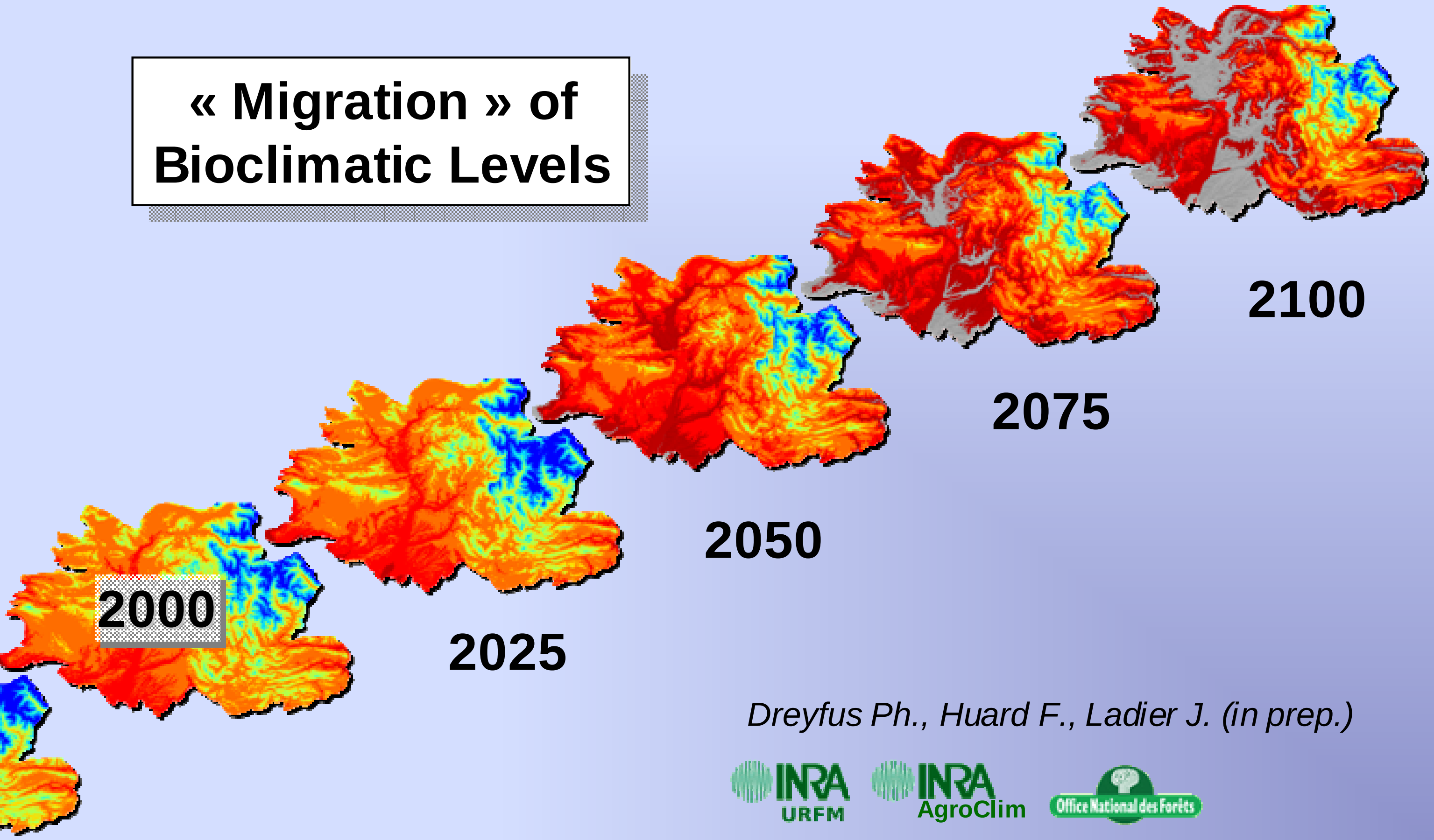
SITE, climate : IPCC scenario **A1B, Arpege model** METEO FRANCE



=> **translation** (proxy) **to Elevation shift** :
current relationship between elevation (DEM res. 50 m)
and **temperature** **+ rainfall**
(normal values, base = AURELHY 1 km METEO FRANCE



« Migration » of Bioclimatic Levels

Dreyfus Ph., Huard F., Ladier J. (in prep.)

INRA URFM INRA AgroClim Office National des Forêts

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Forest dynamics model

= based on rather simple (simplistic ?) assumptions: effects of competition and site

Recruitment (efficient dispersal to +/- long distance)

⇔ entrance of new individuals within the system

Number of recruited seedlings (h ≈ 30 cm) per 100m² & per year

= f(Distance to the nearest seed-stand, power (= BA) of this source, ...)

Growth (in H and Ø)

silviculture

ΔH, ΔØ = f(POT(species, age, **site**) x REDs (**competition/density**, competition status))

asymetric, symetric

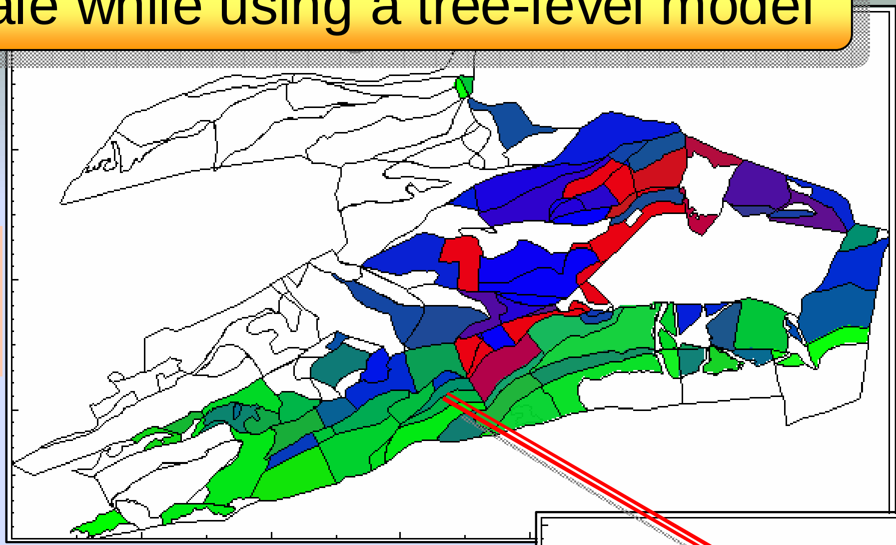
(light)

Regular Mortality

Annual Prob. of Mortality = f(competition/density, individual relative size)

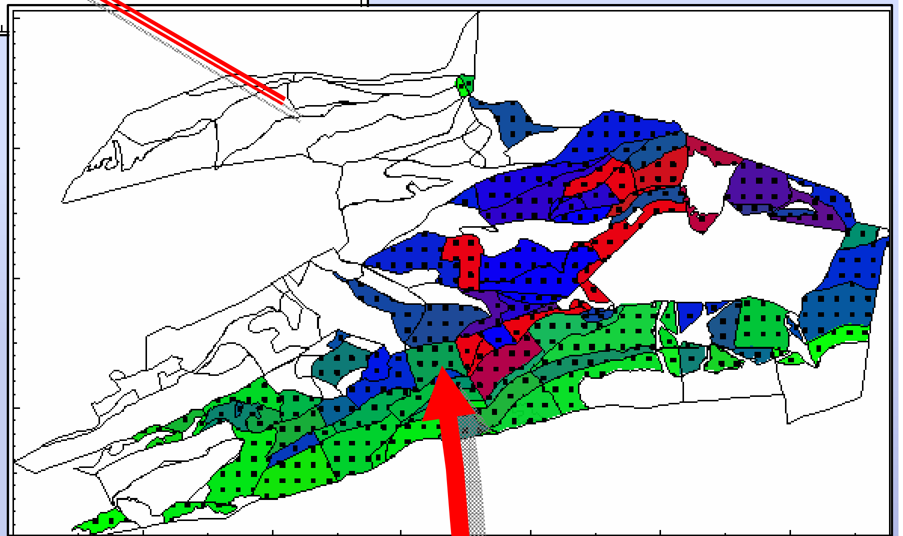
Dreyfus Ph. 2012. Joint simulation of stand dynamics and landscape evolution using a tree-level model for mixed uneven-aged forests. *Annals of Forest Science*. DOI: 10.1007/s13595-011-0163-2, 69:283–303

Addressing landscape-scale while using a tree-level model

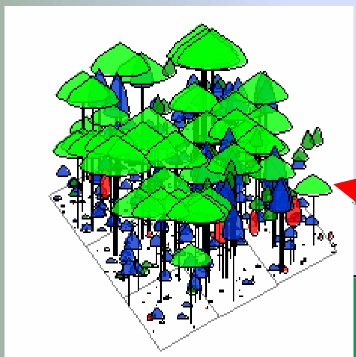


Forest / Landscape scale simulation ...

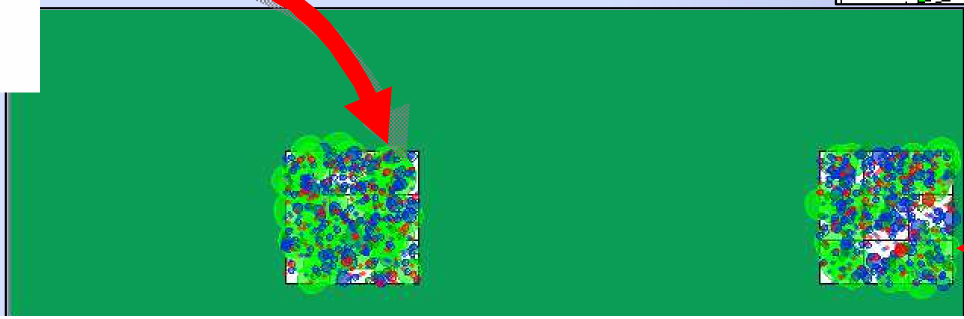
dispersal: between-stand interactions



... incomplete **grid of 10 m x 10 m cells in each stand**



growth/mortality: between-tree interactions



⇔ Spatial sampling of the forest (like plots in a forest inventory)

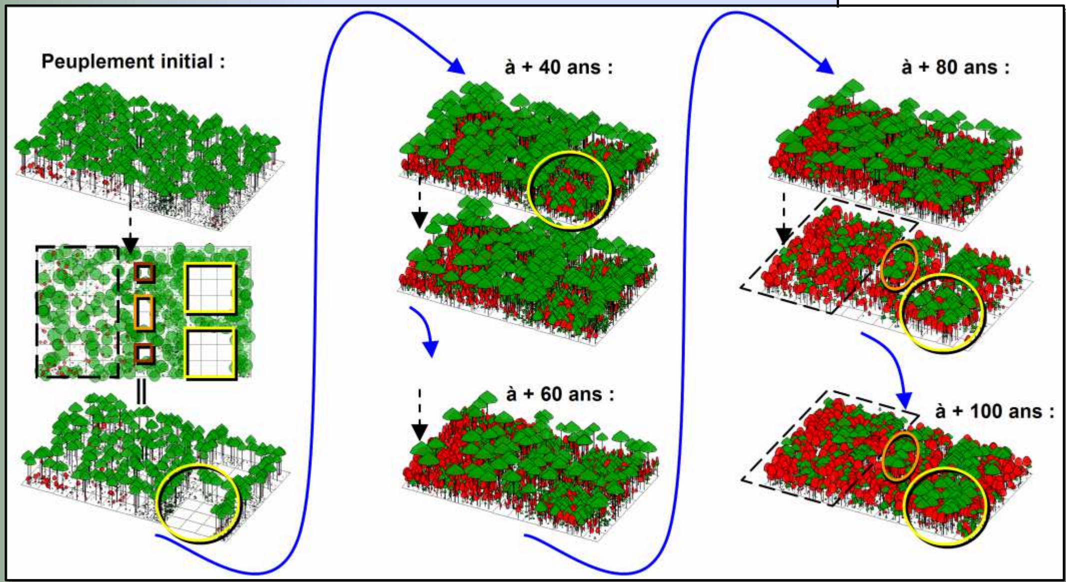
(no upscaling method required)

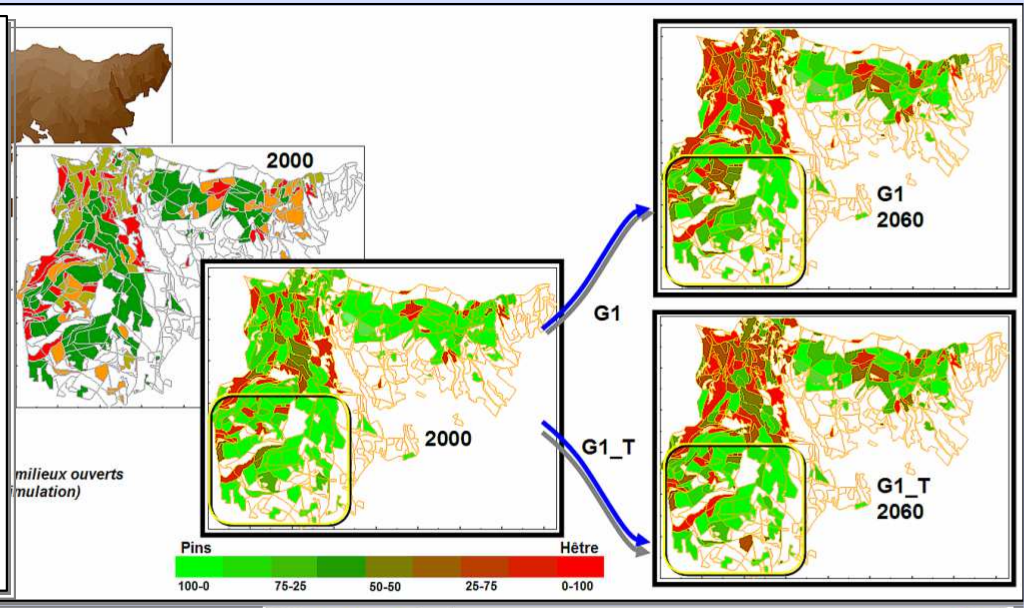
Simulation Software: CAPSIS platform

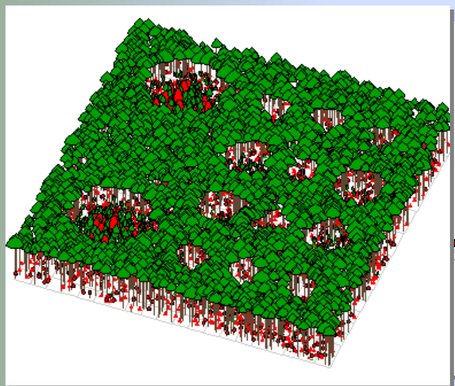
- collaborative, multi-OS (Java)
- **stand and/or forest scale simulations**

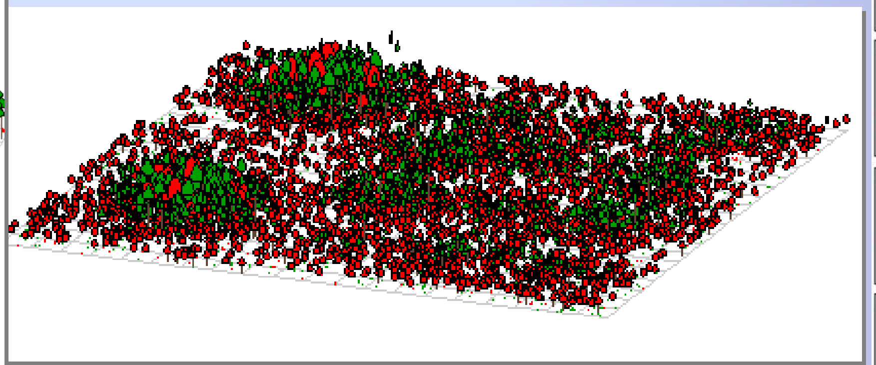
http://www.inra.fr/capsis/

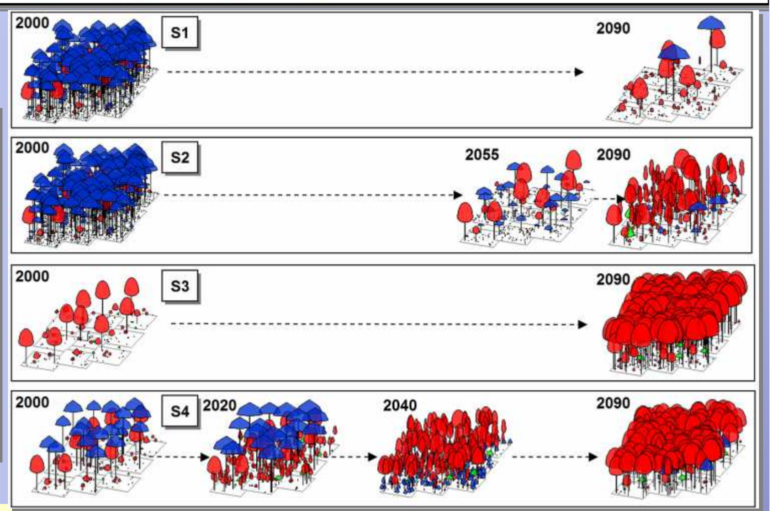
Dufour-Kowalski S., Courbaud B., Dreyfus P., Meredieu C., **de Coligny F.**, 2012.
Capsis: an open software framework and community for forest growth modelling.
Annals of Forest Science (2012) 69:221–233, DOI: 10.1007/s13595-011-0140-9











+ **input from / output to GIS** (vector layer of managed stands, raster of site factors)

Conclusion ...

1 **How far forest management can steer forest composition and structure ?**

- **No unique answer** ... Various situations ...

  e.g., in this case study : max. elevation = 1900 m

  while in other situations *Abies alba* could spread higher

  (and under other species : *Larix decidua)*

- **No miracle**

  but improve sustainability through better adapted species

  when able to help their migration (and quickly enough compared to CC)

*Strong need for **decision tools** appropriate **for a changing context***
to use instead of static tools (like traditional silviculture or management guidelines)

2

Some tools exist
... OR we know how to build them (more or less) quickly

- **Take advantage of existing tools and methods**

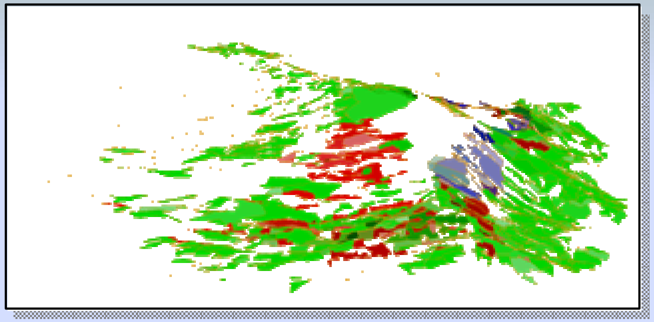
when building anticipative forest management,
... do no only wait for new research results
(might also help detection of what is missing and point out research needs)

- and **Update these tools continuously** : new scientific results ...

- massive mortality evaluation,
& rate of annual mortality when out of range
- water saving thinning treatments
- effects of extreme events
- genetic adaptation
- ...

THANK YOU FOR YOUR ATTENTION ...

Philippe Dreyfus



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