Quantifying and mapping climate change impact on forest flora diversity with a new bioclimatic model

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Quantifying and mapping Climate Change Impact on Forest Flora Diversity with a New Bioclimatic Model

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1 - Basic hypothesis

In Mediterranean ecosystems, water availability is one of the main constraints driving vegetation composition and growth. If pH and nutrient status are not too variable, vegetation should be a good indicator of water availability.
Most of the biomass is produced during spring, and summer is the most stressing period combining high temperatures and very low rainfall. In our study area (south-eastern France), summer drought lasts 2 to 6 months each year.

2 - Designing the Model

Figure 1

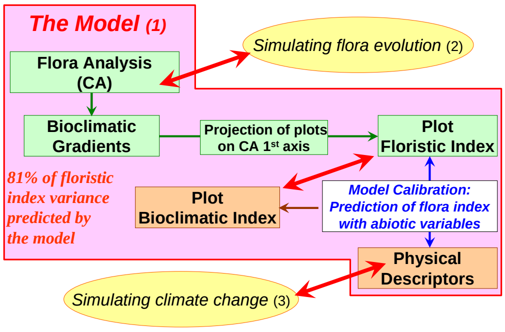


Figure 2

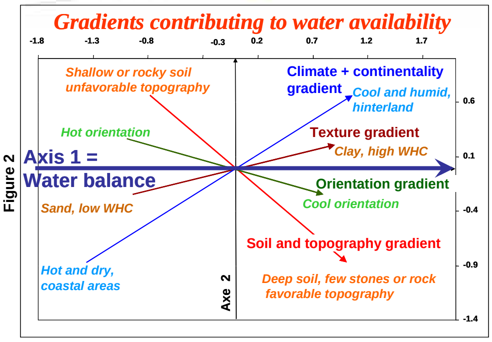
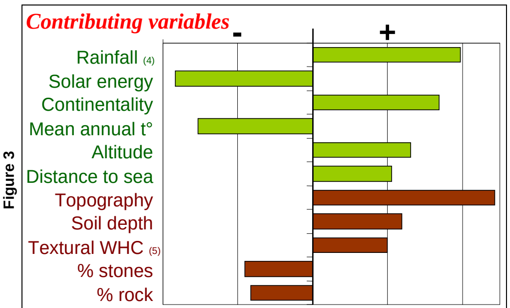


Figure 3



(4) 3 rainfall variables : summer, spring, autumn + winter. (5) Water Holding Capacity (mm/cm)

(1) Vennetier Michel, Ripert Christian, Maillé Eric, Blanc Laurence, Torre Frank, Roche Philip, Tatoni Thierry, Brun Jean-Jacques - 2008. *A new bioclimatic model based on the flora for Mediterranean forested areas*. Annals of Forest Science (accepted).

This bioclimatic statistical model aims at assessing water availability for plants and forest productivity with abiotic descriptors.
It was calibrated with the flora of 325 old forest plots in south-eastern France.
From the CA on flora, a **floristic index** (If) for each plot is computed (its coordinate on axis 1).
The assessment of the floristic index by the model gives the **bioclimatic index** (Ib) for each plot.
The rank of plants on axis one sort them according to a water stress gradient (fig.2)

In the CA map, based only on flora, environment variables are displayed for interpretation
All variables related to water balance are well represented. 4 gradients appear:
(i) climate and continentality, (ii) soil and topography, (iii) texture, (iii) orientation.

Axis 1 is clearly a synthetic water-balance gradient: plots and plants can be ordered on this axis.

The bioclimatic index can be slit into two components (fig. 3):
- one based on global variables (Ib-g) which can be mapped at regional scale with a GIS (in green, explaining 48% of If variance).
- one based on local variables (Ib-l) including topography as a main contributor (in brown, explaining 33% of If variance).

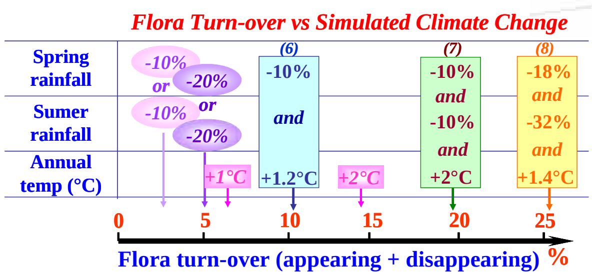
Fig. 5 + 6 display the map of Ib-g (for average local conditions) at respectively regional / local scale.

(2) Simulating flora turn-over : we simulated in each plot the disappearance/appearance of 1 to 6 plants, starting respectively from the highest/lowest coordinates on axis one. We also simulated the increase/decrease from 1 to 2 classes of Braun-Blanquet index for the same plants. For each simulation, the new flora index was computed for the plot.
(3) Simulating climate change: we simulated various climate change scenarios, introducing new climate data while computing the bioclimatic index for each plot.

Variations of the flora and bioclimatic indices, can be compared. As they are closely related, although computed separately, similar variations may indicate which range of flora turn-over correspond to simulated climate change. This theoretical approach is validated by field observations (fig. 7-9)

3 - Simulating Climate Change impact

Figure 4



(6) = 20th century observed change in the study area
(7) = 2000-2050 foreseen change in IPCC B2 scenario for the study area
(8) = Climate shift observed in the study area in the last 10 years

Comparing simulated variations of floristic and bioclimatic indices (fig. 4) to quantify flora turn-over :
The average number of plants for 400 m² is 25. 1 plant appearing or disappearing means a 4% turn-over.
Various climate change scenarios were simulated, including those observed in the 20th century and in the last 10 years.
Increasing/decreasing (+1/-1) Braun-Blanquet coefficient for 6 plants is equivalent to suppressing/adding 3 plants in our plots. The scenarios (6), (7) and (8) of fig. 4 match with +/- 1 B-B coef. respectively for 2, 5 and 13 plants.
These simulations are validated by field data (fig. 7 to 9).
They are mapped in fig. 5b as a consequence of climate change on Ib-g index and its close relation to flora composition

Figure 5-a

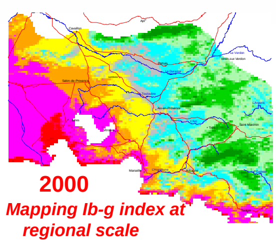
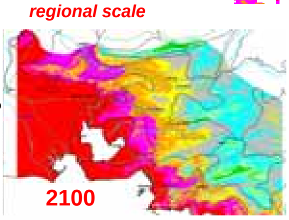
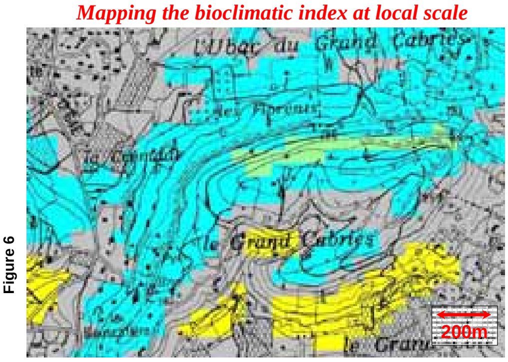


Figure 5-b



Mapping the bioclimatic index at local scale

Figure 6



Ib-G can be mapped and remains reliable at local scale for forest management (fig. 6). Up to 4 Ib-g classes among the 9 used for the regional map (fig. 5) can be found on a small hill.
When Ib_l is added, based on local forest site assessment, each class of Ib-g is split in several classes according to topography and soil, giving a fractally complex mosaic. The span of Ib classes (Ib-g + Ib-l) can reach the equivalent of up to 6 Ib-g classes within the compass of few hectares of hilly landscape.

The potential distribution area of species is highly fragmented in the landscape: drought tolerant species are already scattered in rocky and south-facing sites within the hinterland, ready to spread from these bases. Numerous favorable sites allow mesophilous species to survive in dry or hot areas, although such sites may become rarer and smaller in time.
Our model, including variables describing precisely landscape structure, allows the assessment of climate change impact on flora diversity at a biologically realistic scale, our basic pixel corresponding to the average dispersal distance of a majority of species.

4 - Validating with field data

Figure 7

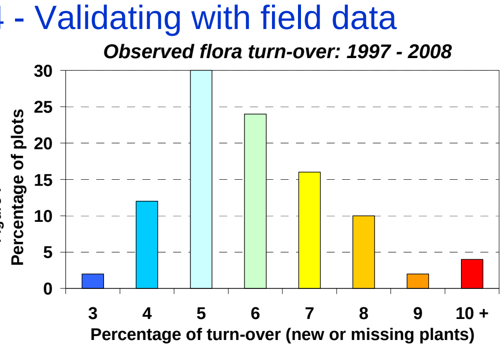


Figure 8

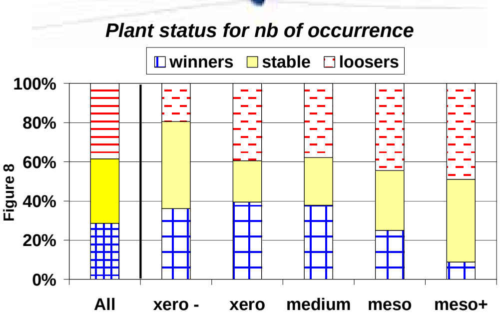
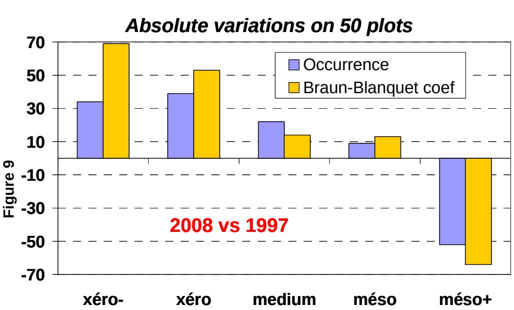


Figure 9



We performed a new census in 2008 for 50 of 1997 plots, representative of the study area. If flora turn-over was not exceptional by its proportion for a 10 years time span (fig. 7), it was highly selective, biased towards a sharp increase of water-stress resistant and thermophilous plants and decrease of water demanding species (fig.8), as well for occurrence as for cover - Braun-Blanquet coefficients (fig.9). This turn-over did not rich the model-simulated level, probably thanks to the ecosystem short-term resistance and inertia. But it validated the simulation options, proving that the two ends of the plant distribution in the water balance gradient are first concerned by present climate changes.

IUFRO Conference on Biodiversity in Forest Ecosystems and Landscapes, Kamloops, August 5-8th 2008

(a) Ecosystèmes Méditerranéens et Risques - Mediterranean Ecosystems and Associated Risks Research Unit
Cemagref, Aix en Provence (France)
www.cemagref.fr

Research funded by
MINISTERE DE L'AGRICULTURE ET DE LA PÊCHE
Région Provence-Alpes-Côte d'Azur