Likely effects of climate change on growth of Fagus sylvatica: study along altitudinal gradients and comparison with the co-occurring species Abies alba

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LIKELY EFFECTS OF CLIMATE CHANGE ON GROWTH OF *FAGUS SYLVATICA*: STUDY ALONG ALTITUDINAL GRADIENTS AND COMPARISON WITH THE CO-OCCURRING SPECIES *ABIES ALBA*

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Introduction

Forest growth in Mediterranean mountains is limited by two major factors: summer drought at low elevation and low temperatures at high altitude (Korner 2007). As a consequence of climate change, observed trends would be the consequence of the contradictory effects of reduced frost and increased drought (IPCC 2007). On the one hand, an increase of tree growth is expected at higher elevations resulting of warming temperatures, lengthening of growing season (Badeck et al. 2004), and rising atmospheric CO_2 concentrations. On the other hand, late frost damages might not decrease (Hanninen et al. 2006). At the same time, tree growth should be reduced as a consequence of summer drought increase in sites at lower elevations (Jump et al. 2006).

The aim of this study was to analyze the effects of altitude and climate change on the growth of European beech (*Fagus sylvatica* L.) in a Mediterranean mountain. A comparative dendroclimatological study of climate-growth relationships was done. Then, the difference of growth between the North and the South faces and along elevational gradients was assessed. Effects on radial growth of recent climate change since the beginning of the twenty first century were further studied by analyzing global trends and shifts of growth optima.

Finally, a comparison with a co-occurring species was done and according to these results, a prediction of their future potential growth and distribution range in the study site was made.

Materials and Methods

The study was conducted on Mont Ventoux, a calcareous mountain in south-eastern France, where beech is located in the mountain vegetation area on the north and south face. On the North face, beech is generally associated with fir.

On the north face, 73 firs and 77 beeches were sampled along a continuous elevational transect with the same slope orientation for both species from 970 to 1530 m and were cored in autumn 2006 and 2007. On the south face, 80 beeches in 4 different plots (890m, 1115m, 1410m, and 1525m) were cored in autumn 2007. Dendrochronological analyses were made using the software CooRecorder & CDendro v5.3 (Larsson L.A. et al. 2006, Cybis Elektronik & Data AB. Sweden).

To get free from age and date effect, and to compare growth of both species, a polynomial curve was fitted against regional age mean curve of cumulative basal area. Using this function, we projected the cumulative ring area (RA) for all trees at a same age (90 years), which gave theoretical mean of annual area increase at 90 years (RA90). The same methodology was applied to study mean annual growth for the period 2000-2006.

Results and Discussion

Only results on the North face and dealing with the comparison with silver fir were presented here.

Comparison of Beech Ecology with silver fir: two co-occurring species

Climate-growth relationships: Even if these late-successional species are associated on the North face, radial growth-climate relationships were divergent.

A positive correlation was found between April temperatures and fir growth. Indeed, it causes earlier budburst and cambium activation that lengthen the growing season and increase the carbon assimilation. Inversely, a significant negative effect of maximal temperatures in April was observed for beech. An earlier budburst increases the risk of late frost damages on open buds and leaves, which can provoke a decrease of radial growth (Dittmar et al. 2006).

Drought during the first half of summer (May-July) influenced negatively ring-width of fir. In contrast, beech growth index were not related to summer rainfalls, and a positive role of May temperatures was found.

Altitude: Until the end of the 20th century, fir growth optimum was at intermediate altitude (figure 1b; S3: 1140 to 1240 m) whereas for beech it was at lower elevation (figure 1a; B1 and B2: 950 to 1230 m). Its weak presence below 950 m should probably be due to low recolonization rates from upper sites. Possible presence from about 800 to 1600 m was expected (figure 2a). This concept of optimum of growth potentialities is connected with the existence of two major limiting factors depending on altitude whose impact growth intensity : i) late frost damage and the time of growing period at high elevation and ii) summer drought in the bottom of the gradient.

Climate change effects

Global trend: In South-eastern France, temperatures increase (0.6°C to 0.7°C by decade since 1960) was not matched by rainfalls increase. Our results show that it has provoked a shift of growth optimum to higher altitudes. Since beginning of twenty-first century, most of firs showed a growth decline (52%), with mortality, whereas for beech no significant trend was shown up. In the study area, rising temperatures and decreasing rainfalls (4-27%) are predicted (IPCC 2007). These growth trends would logically go on.

Effects on climate events: An earlier budburst results in an increase of damage probabilities due to late frosts (Hanninen et al. 2006). As a consequence, growth of beech at high altitude might be not as much favored as it could be by the temperature increase.

2003 summer was exceptional for the intensity and the length of the heat-wave but it occurred at the end of growing season (most in August). No significant growth decrease was observed during this year because most of the growth rings were produced earlier (Bouriaud 2004). A significant growth decrease took place in 2004 due to the reduction of carbohydrate storage and to the reduced rainfalls during June and July 2004. We found a higher negative response for beech than for fir.

The higher sensitivity of beech growth to climate events may be due to the non persistence of its leaves.

Likely modification of species' range

The elevational gradient can be schematized as a curve where the two majors limiting factors progress exponentially with the altitude (figure 2a, 2b). The number of frost days and their intensity increase exponentially with the upward shift in altitude. Toward lower altitudes, the frequency, intensity and duration of summer drought increase exponentially owing to the mix of rising of temperatures and decline of rainfalls.

In lowest altitudes fir would disappear (figure 2b), but the expected increase of heat-waves (Meehl and Tebaldi 2004) will affect also beech vitality. At high elevation, the upward shift of beech may probably be limited by late frost damages. Silver fir will completely take advantage of the temperature rising and the lengthening of growing season. Distribution range would be reduced since their upward progression thanks to dispersion which will be probably lower than the rising of temperatures.

If extreme events were not taken in account, *Abies alba* is predicted to face higher risk of extinction than *Fagus sylvatica* (Ohlemüller et al. 2006). But the probably increase of late frosts, heat-waves frequency and intensity would put beech in a disadvantageous situation.

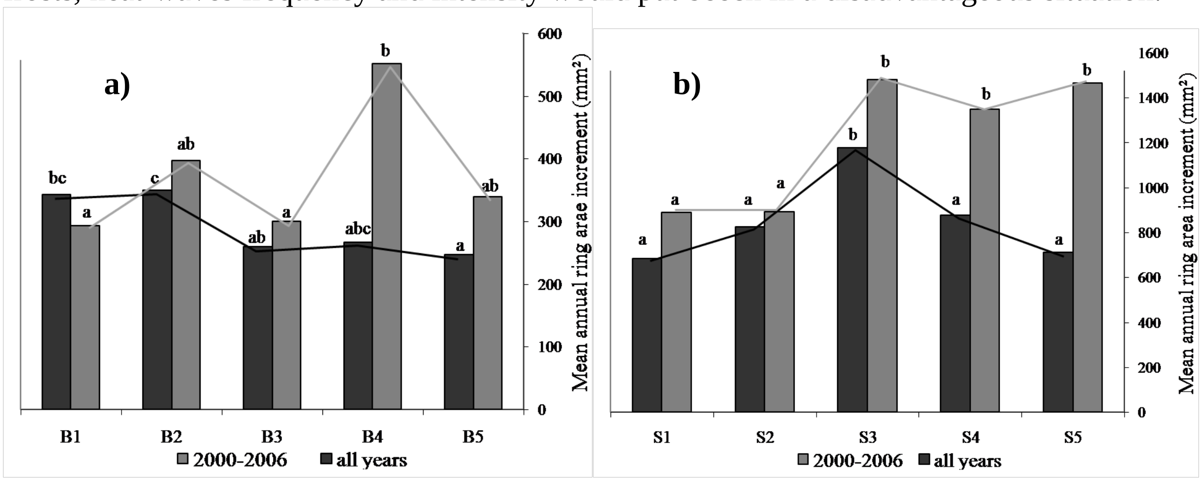

Figure 1: Altitude effect on mean annual ring-area increment (mm²) of *Fagus sylvatica* (a) and *Abies alba* (b) for all the period studied (black histogram) and for the period 2000-2006 (grey histogram). Elevational levels are the altitudinal classes (B1 and S1: low altitude to B5 and S5: high altitude). Different letters indicate significant differences between means for the same period (P<0.1, t.test).

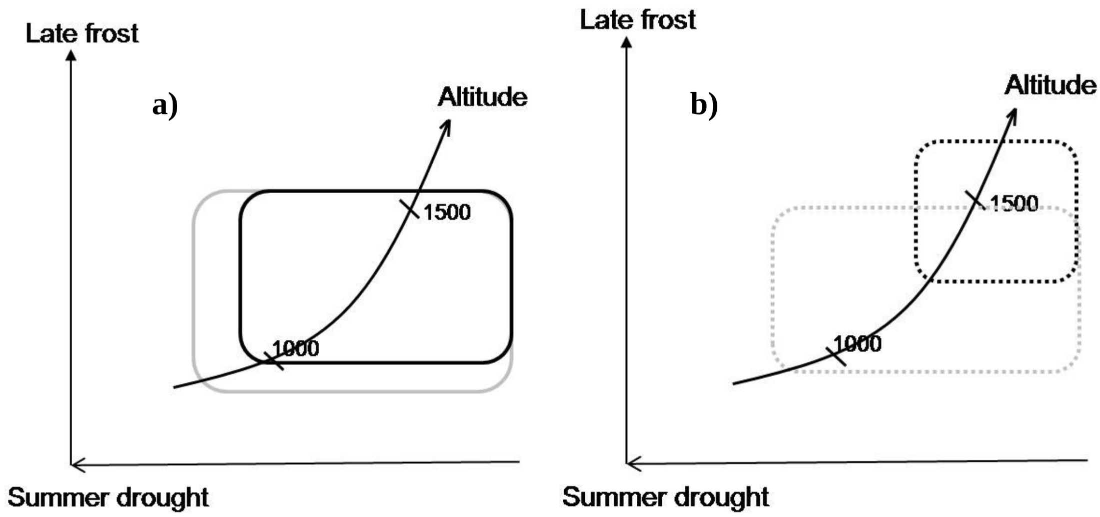

Figure 2: Actual (a) and likely future (b) distribution range of silver fir (black) and common beech (grey). The two major limiting factors are late frost (number and/or intensity), and summer drought (frequency, intensity and/or duration). The curve is the elevational gradient of the North face of the Mont Ventoux.

References

Badeck, F.W., et al. 2004. New Phytol. 162: 295-309.
Bouriaud, O., et al. 2003. Trees 18: 264-276.
Dittmar, C., et al. 2006. Eur. J. For. Res. 125: 249-259.
Hanninen, H. 2006. Tree Physiology 26: 889-898.
Jump, A.S., et al. 2006. Global Change Biology 12: 2163-2174.
Körner, C. 2007. Trends Ecol. Evol. 22: 569-574.
Meehl, G.A., Tebaldi, C. 2004. Science, 305: 994-997.
Ohlemüller, R., et al. 2006. Global Change Biology 12: 1788-179