

Appendix S2: Growth Analysis for selected tree species

The following material summarizes the graphical and spatial analyses of tree growth mapped over the niche of the tree species. This analysis was performed in order to understand better the likely consequences of climate change and associated projected range shifts. The following species are currently being presented here:

Species List:

Abies alba..... 2

Fagus sylvatica..... 3

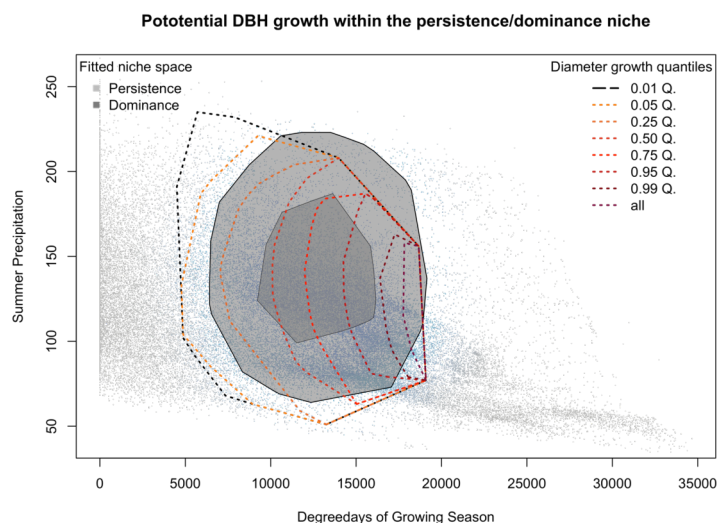
Picea abies..... 4

Abies alba

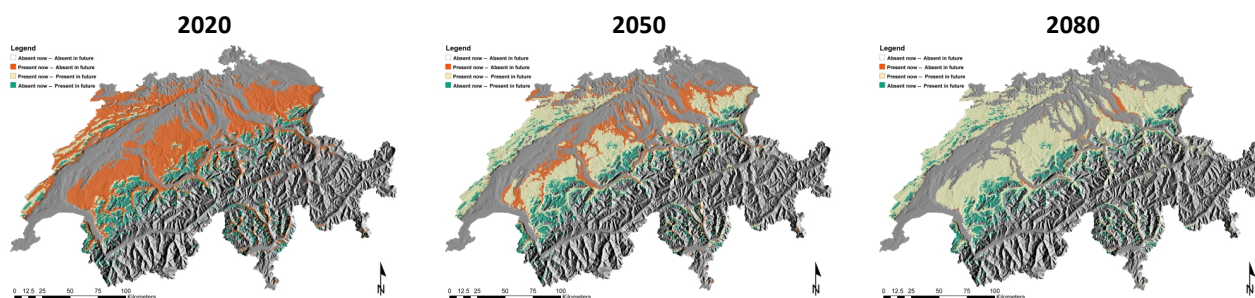
Description of growth model and ensemble projections

The highest growth rates in *Abies alba* all occur towards the warm (wet) end of the realized (persistence) niche of the species. This means that under warm/wet climates as can be found at the edge of the realized distribution of *Abies*, the growth is not limiting, and therefore, no immediate threat from a warming climate is visible. However, if climate is not only warming, but also drying up, then growth finally becomes limited, where summer precipitation falls below certain thresholds.

We interpret this result such that the warm (wet) range limit is primarily caused by competition, rather than by physiological constraints. If it were physiological constraints that limit the niche of *Abies* under these environmental conditions, then growth would have to be more severely constrained. Such constraints can be seen at the cold/dry and cold/wet edge of the distribution/niche.



Synthesis and Conclusions



Abies alba seems well capable of exceeding the currently realized niche at the warm end, as long as it is not getting too dry. These environmental domains just adjacent to the niche of *Abies* seem to be positioned well within the fundamental niche. The main reason for the niche limit under these conditions thus comes from competition by other species. Forest management can thus deal with such constraints and manage the competition of individual spruce trees in a forest. However, one may not want to manage *Abies alba* too far away from its high growth potential at the warm/wet edge of its niche, since we do not have a clear proof that growth will continue to stay high under even warmer climates. Given that respiration is increasing much more rapidly with higher temperatures than photosynthetic carbon uptake, it is well known that net primary productivity faces sudden drops after passing certain temperature thresholds.

In order to visualize the meaning of a relaxed view of what might happen under climate change, we have mapped two areas in close (low risk) and a bit more distant (high risk) proximity to the zone of high growth. Low risk means that the climate conditions are still very similar to those that the species encompasses within the realized niche where high growth occurs. It therefore can be interpreted as climatic conditions under which the species likely continues to thrive with high growth, given that competition by other species is managed. The high-risk zone is farther away from the realized niche edge in climatic terms, and thus it is not clear, whether *Abies* will be able to survive in the longer run.

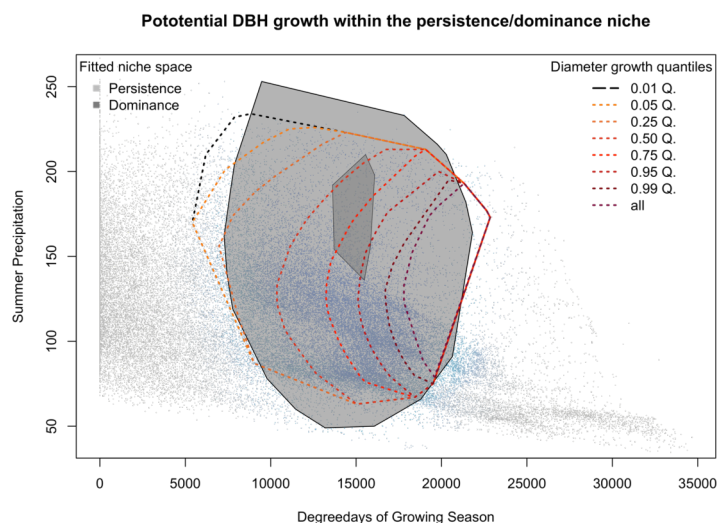
Here, we see that both low and high risk extensions of what can be considered suitable for *Abies* encompass almost all range area that is projected to go extinct. From a growth perspective, this area might still be suitable throughout the 21st century. However, this growth model does not consider threats from pests such as bark beetles, which might cause a more severe threat to *Abies* under a warming climate. Other threats not well included are increased climate variability with more severe and more frequent climate extremes. *Abies* might not be able to cope well with extreme climates

Fagus sylvatica

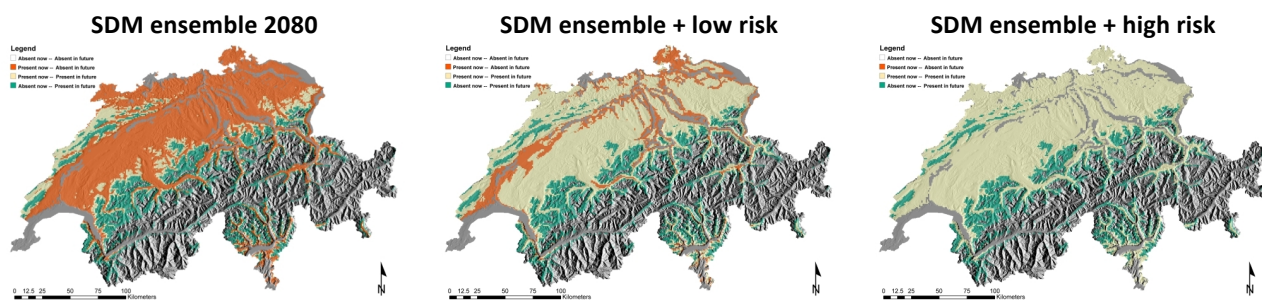
Description of growth model and ensemble projections

The highest growth rates in *Fagus sylvatica* all occur towards the warm (wet) end of the realized (persistence) niche of the species. This means that under warm/wet climates as can be found at the edge of the realized distribution of *Fagus*, the growth is not limiting, and therefore, no immediate threat from a warming climate is visible. However, if climate is not only warming, but also drying up, then growth finally becomes limited, where summer precipitation falls below certain thresholds.

We interpret this result such that the warm (wet) range limit is primarily caused by competition, rather than by physiological constraints. If it were physiological constraints that limit the niche of *Fagus* under these environmental conditions, then growth would have to be more severely constrained. Such constraints can be seen at the cold/dry and cold/wet edge of the distribution/niche.



Synthesis and Conclusions



Fagus sylvatica seems well capable of exceeding the currently realized niche at the warm end, as long as it is not getting too dry. These environmental domains just adjacent to the niche of *Fagus* seem to be positioned well within the fundamental niche. The main reason for the niche limit under these conditions thus comes from competition by other species. Forest management can thus deal with such constraints and manage the competition of individual spruce trees in a forest. However, one may not want to manage *Fagus sylvatica* too far away from its high growth potential at the warm/wet edge of its niche, since we do not have a clear proof that growth will continue to stay high under even warmer climates. Given that respiration is increasing much more rapidly with higher temperatures than photosynthetic carbon uptake, it is well known that net primary productivity faces sudden drops after passing certain temperature thresholds.

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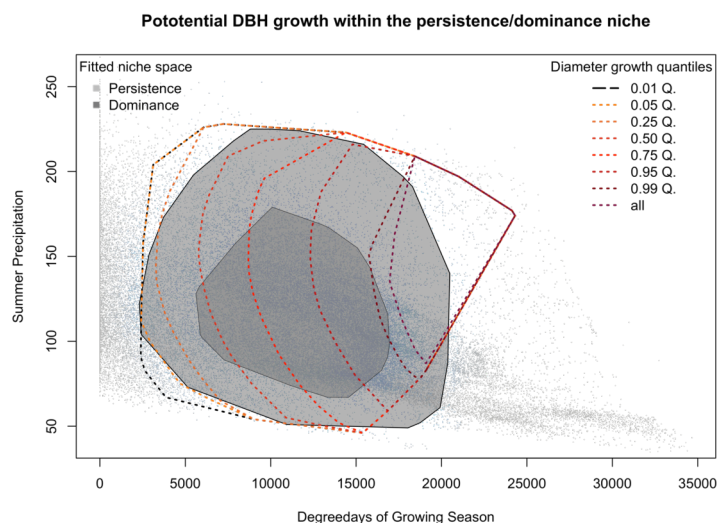
Here, we see that both low and high risk extensions of what can be considered suitable for *Fagus* encompass almost all range area that is projected to go extinct. From a growth perspective, this area might still be suitable throughout the 21st century. However, this growth model does not consider threats from pests such as bark beetles, which might cause a more severe threat to *Fagus* under a warming climate. Other threats not well included are increased climate variability with more severe and more frequent climate extremes. *Fagus* might not be able to cope well with extreme climates.

Picea abies

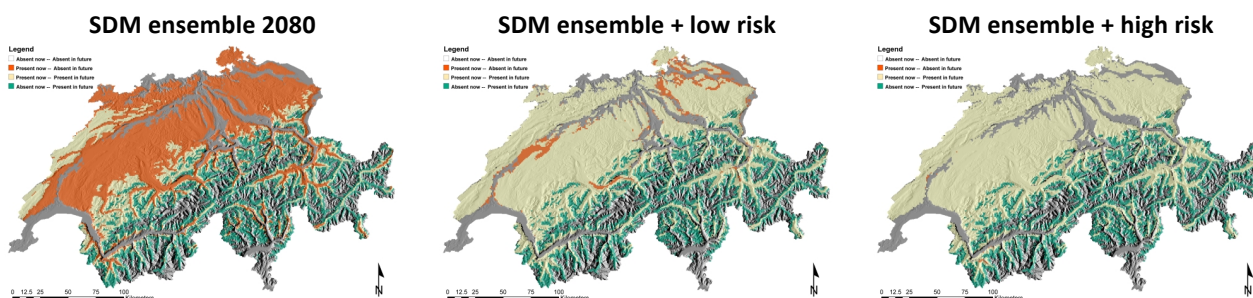
Description of growth model and ensemble projections

The highest growth rates in *Picea abies* all occur towards the warm (wet) end of the realized (persistence) niche of the species. This means that under warm/wet climates as can be found at the edge of the realized distribution of *Picea*, the growth is not limiting, and therefore, no immediate threat from a warming climate is visible. However, if climate is not only warming, but also drying up, then growth finally becomes limited, where summer precipitation falls below certain thresholds.

We interpret this result such that the warm (wet) range limit is primarily caused by competition, rather than by physiological constraints. If it were physiological constraints that limit the niche of *Picea* under these environmental conditions, then growth would have to be more severely constrained. Such constraints can be seen at the cold/dry and cold/wet edge of the distribution/niche.



Synthesis and Conclusions



Picea abies seems well capable of exceeding the currently realized niche at the warm end, as long as it is not getting too dry. These environmental domains just adjacent to the niche of *Picea* seem to be positioned well within the fundamental niche. The main reason for the niche limit under these conditions thus comes from competition by other species. Forest management can thus deal with such constraints and manage the competition of individual spruce trees in a forest. However, one may not want to manage *Picea abies* too far away from its high growth potential at the warm/wet edge of its niche, since we do not have a clear proof that growth will continue to stay high under even warmer climates. Given that respiration is increasing much more rapidly with higher temperatures than photosynthetic carbon uptake, it is well known that net primary productivity faces sudden drops after passing certain temperature thresholds.

In order to visualize the meaning of a relaxed view of what might happen under climate change, we have mapped two areas in close (low risk) and a bit more distant (high risk) proximity to the zone of high growth. Low risk means that the climate conditions are still very similar to those that the species encompasses within the realized niche where high growth occurs. It therefore can be interpreted as climatic conditions under which the species likely continues to strive with high growth, given that competition by other species is managed. The high-risk zone is farther away from the realized niche edge in climatic terms, and thus it is not clear, whether *Picea* will be able to survive in the longer run.

Here, we see that both low and high risk extensions of what can be considered suitable for *Picea* encompass almost all range area that is projected to go extinct. From a growth perspective, this area might still be suitable throughout the 21st century. However, this growth model does not consider threats from pests such as bark beetles, which might cause a more severe threat to *Picea* under a warming climate.