Introduced or native tree species to maintain forest ecosystem services in a hotter and drier future?

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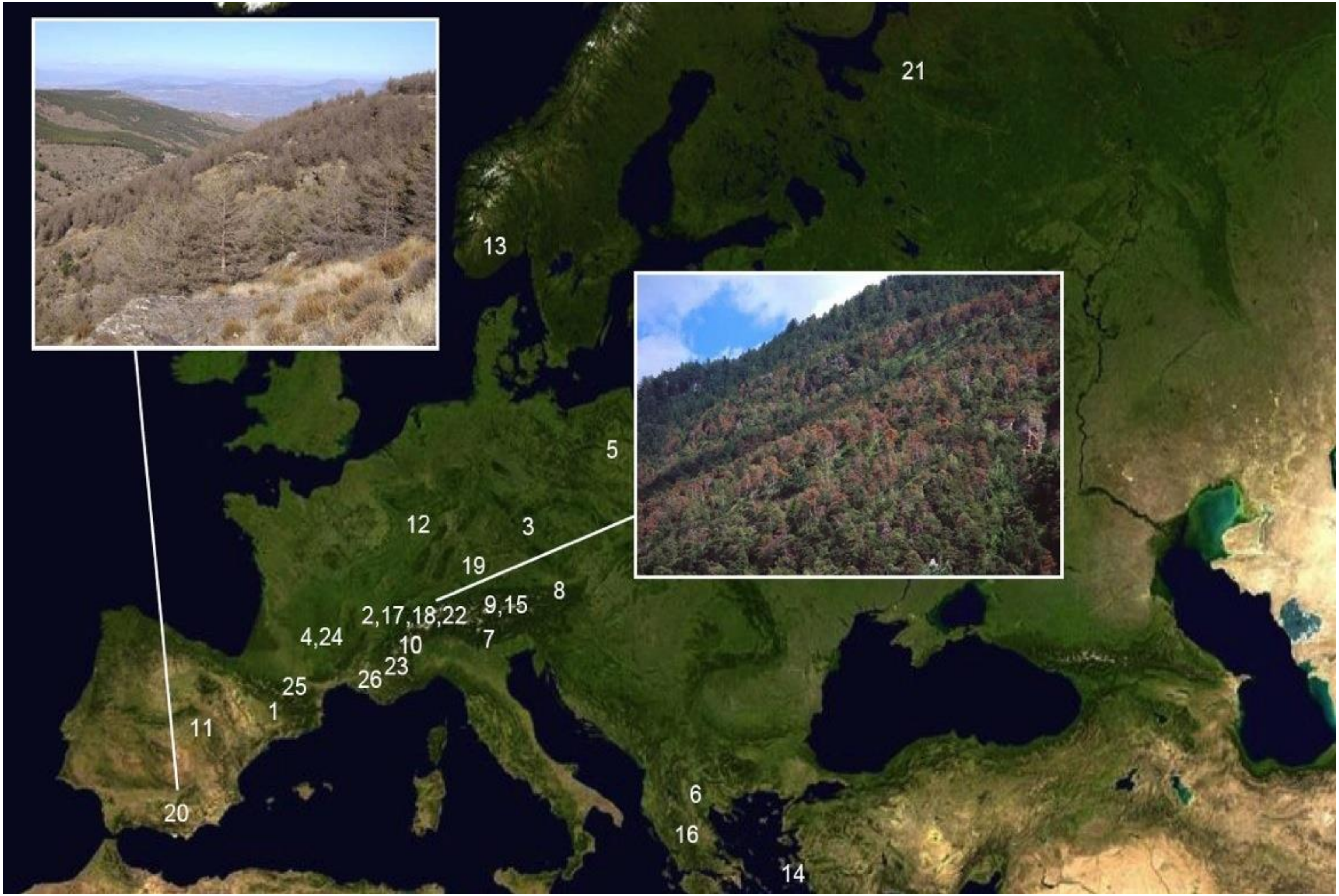
WSL

Drought and tree mortality



Global overview on drought-induced tree mortality

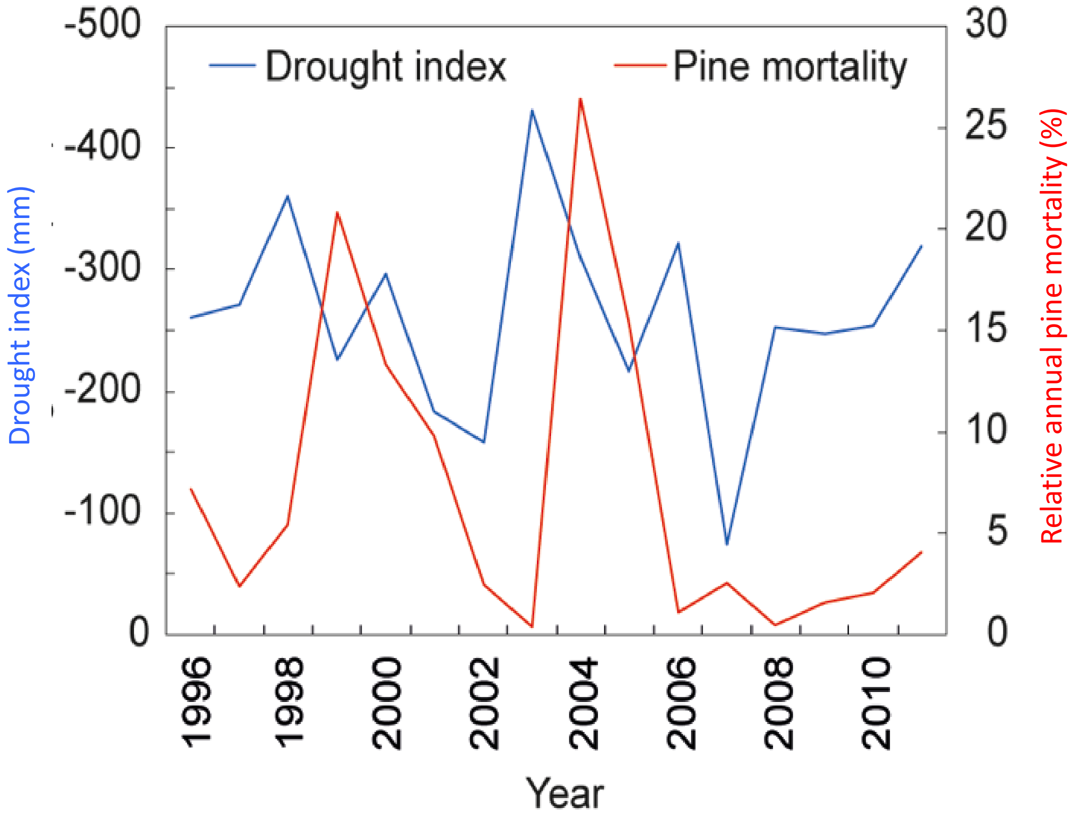
(Allen et al. 2010 Forest Ecology and Management)

Waves of Scots pine mortality in Valais, Switzerland

Swiss Alps, Valais, near Visp: Telwald 1996 (Foto B. Wermelinger)

Drought and tree mortality, pests & diseases

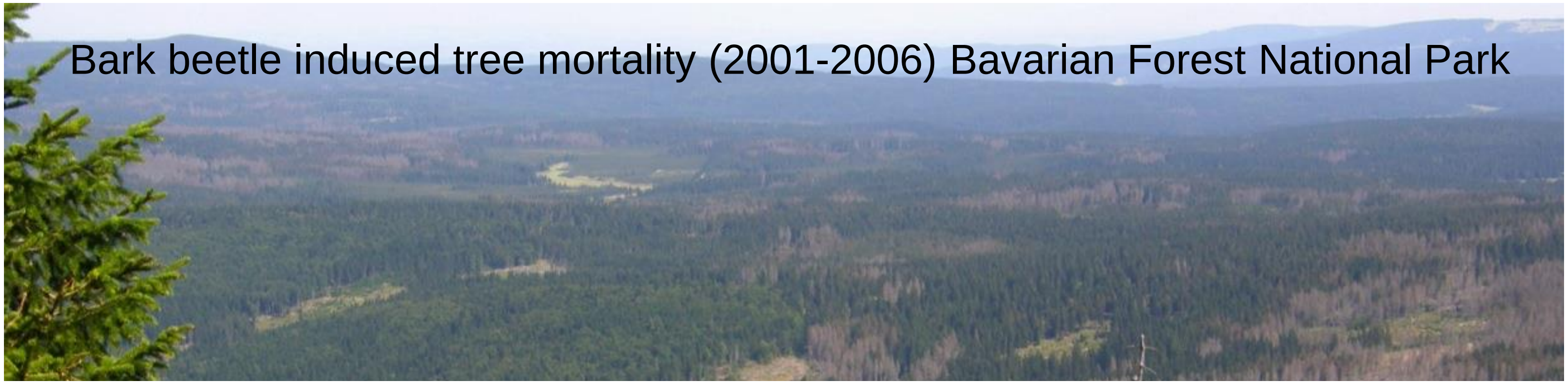
Mortality, monitoring plot Visp - 1995-2005: 60% of the pine, but only15% broadleaves died

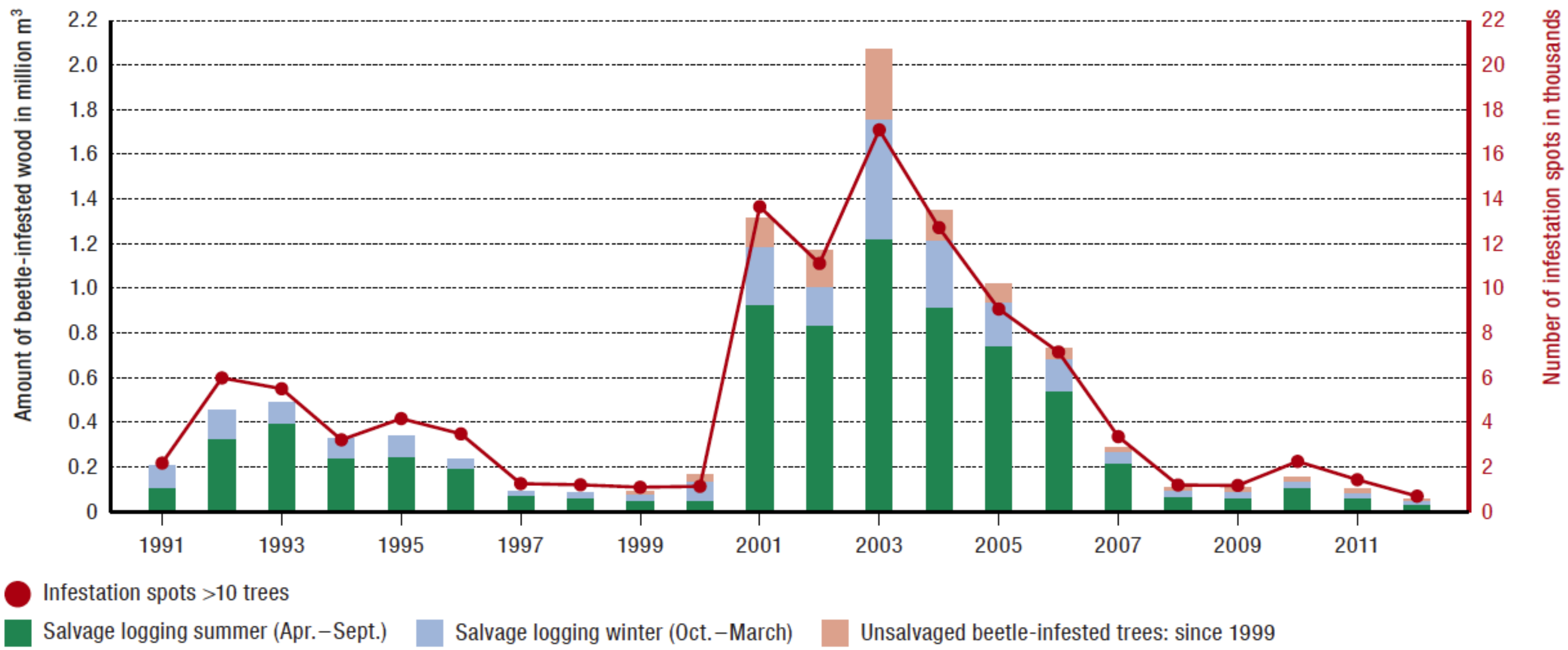


- Pine mortality highest after hot/dry summers
- Multiple drought years increase mortality risk

(Bigler et al. 2006 Ecosystems; Rigling et al. 2013 Global Change Biology)

Bark beetle and large-scale spruce mortality





- Bark beetle calamities incited by heavy storms and stimulated by heat and drought

(Rigling & Schaffer, Swiss Forest Report 2015)

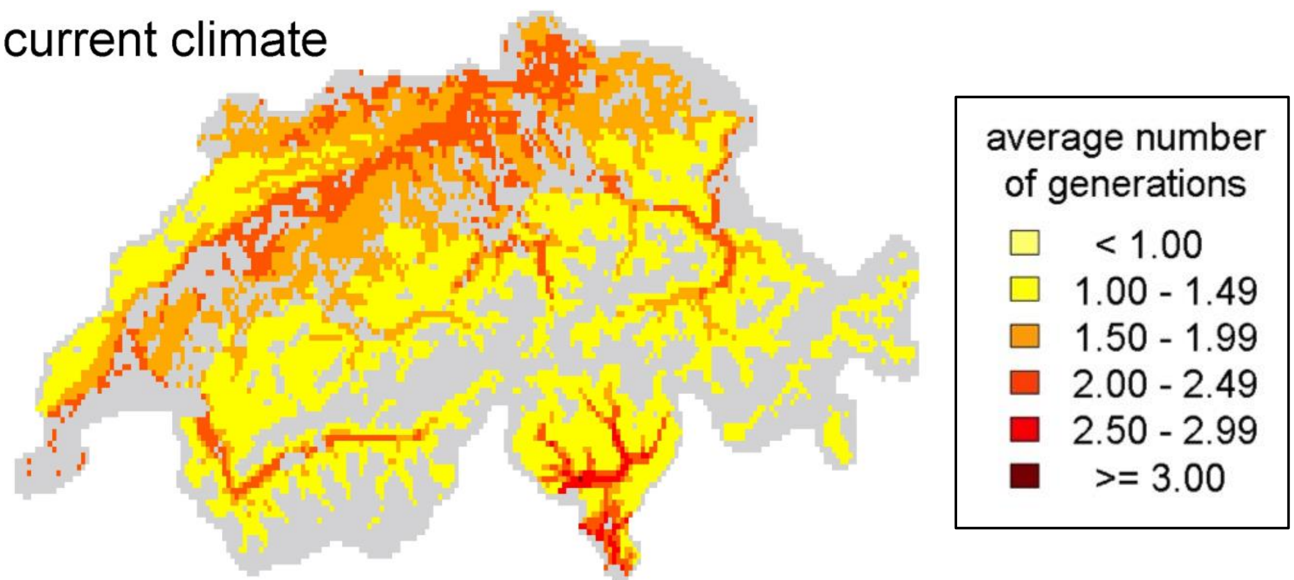
Outbreak risk spruce bark beetle

Swiss Climate Change Scenarios CH2011

- Changes in the phenology of the spruce bark beetle

→ Increase in potential number of generations

→ Shift in flight period to earlier dates



(Jacoby et al. in review)

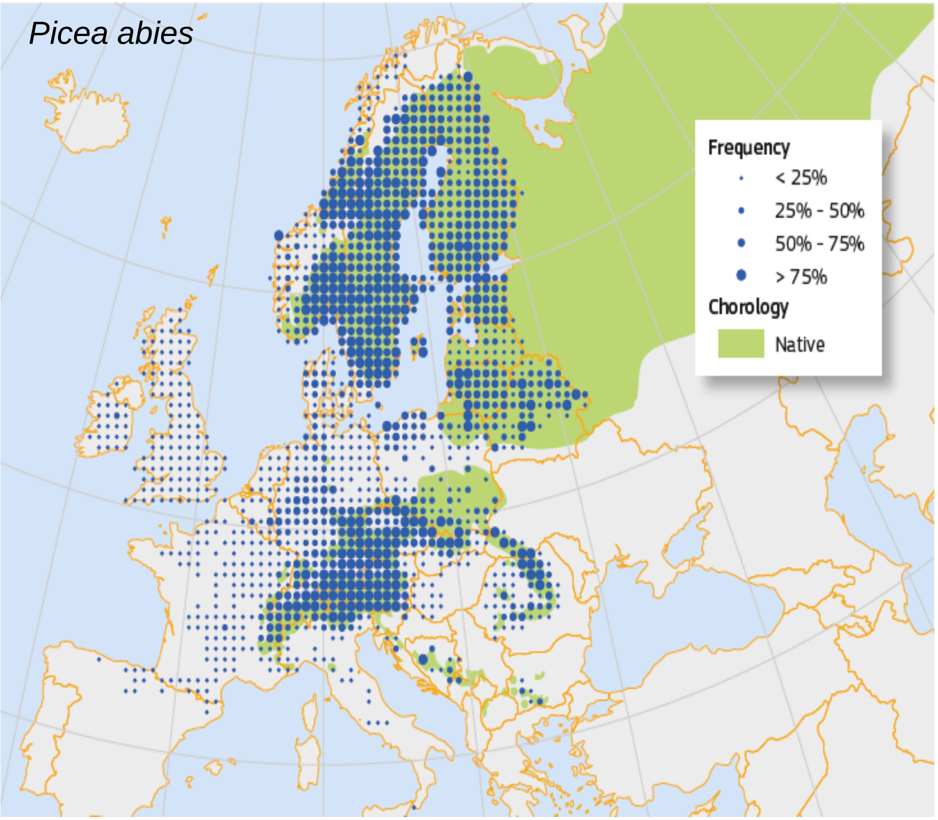
Rationale

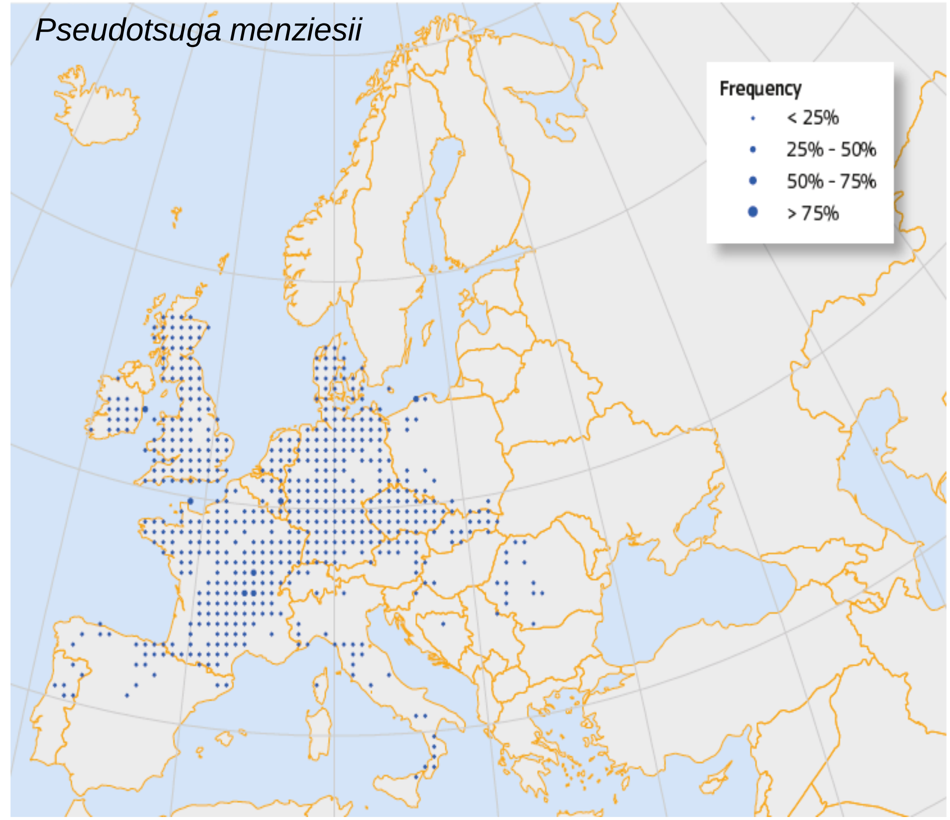
- Why non-native tree species? Because native tree-species portfolio might come to its limits in a hotter and dryer future
- What might be potential alternatives? Specifically for spruce and Scots pine?
- How can we test these alternatives?
- What are the boundary conditions considered when introducing non-native tree species?

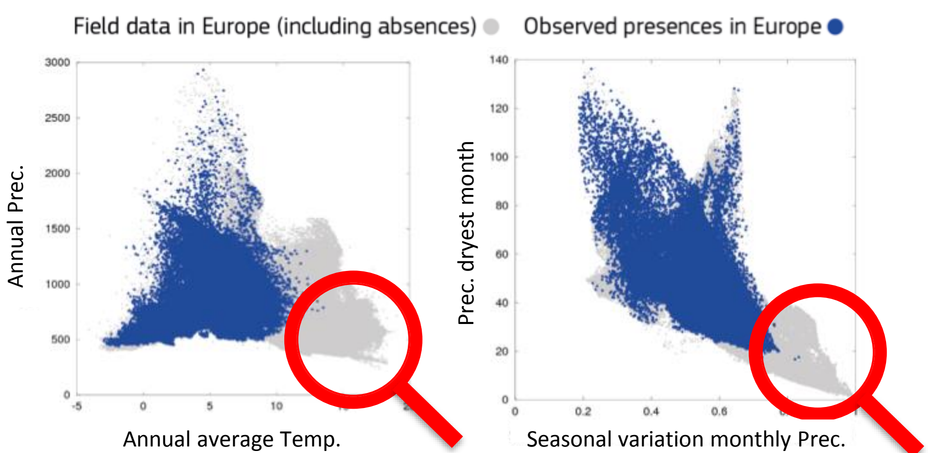
What are the alternatives?

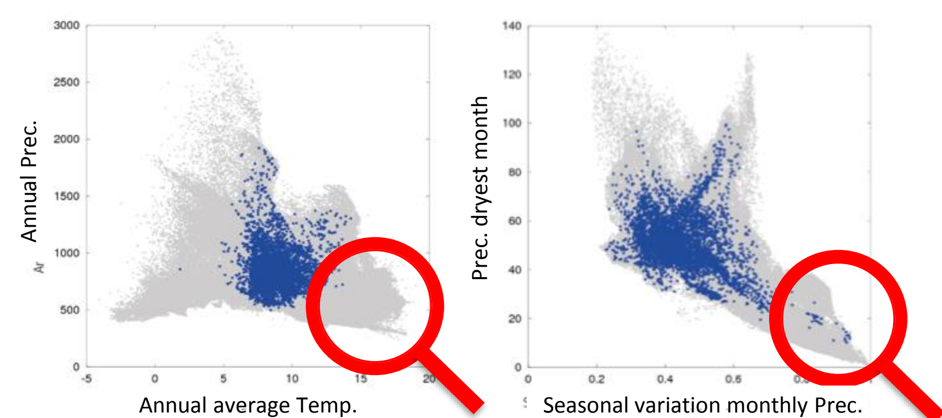
Distribution maps

San-Miguel-Ayanz J, de Rigo D. Caudullo G, Houston Durrant T, Mauri A (eds) 2016 European atlas of forest tree species. European Commission. DOI 10.2788/038466









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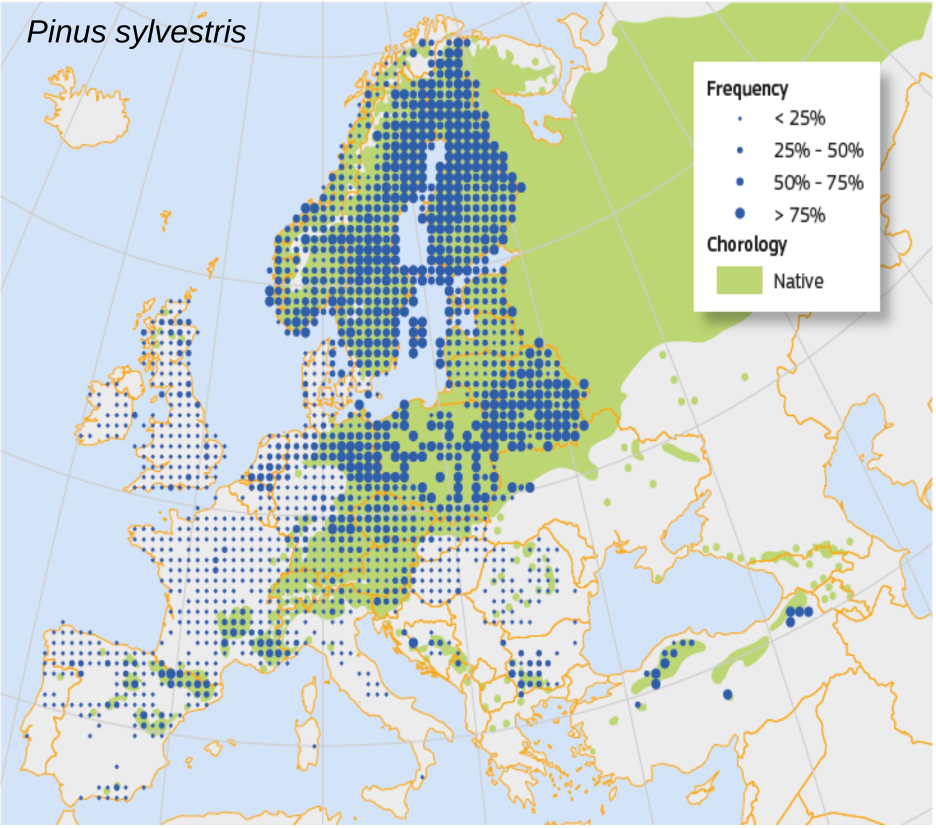
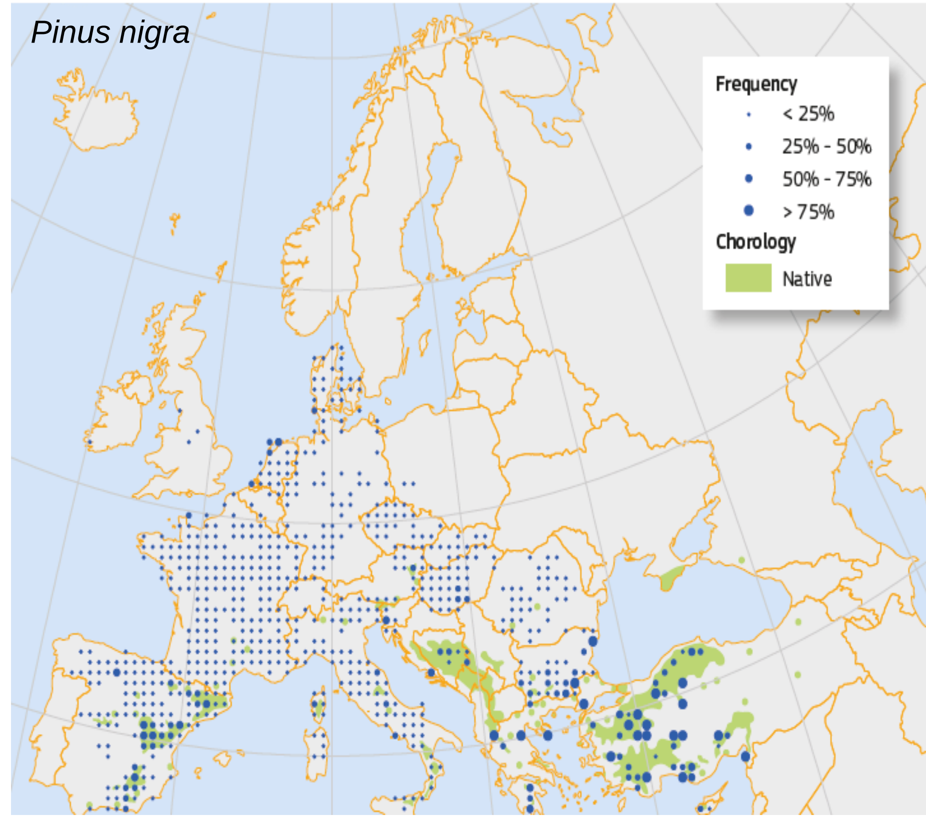
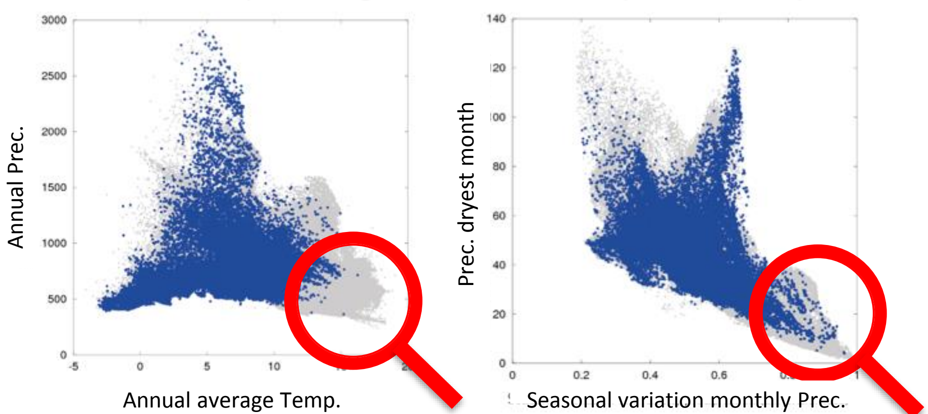
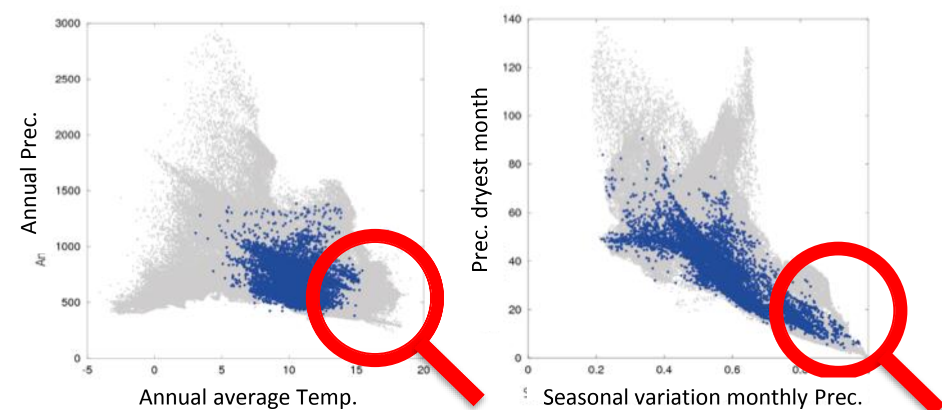




Field data in Europe (including absences) Observed presences in Europe

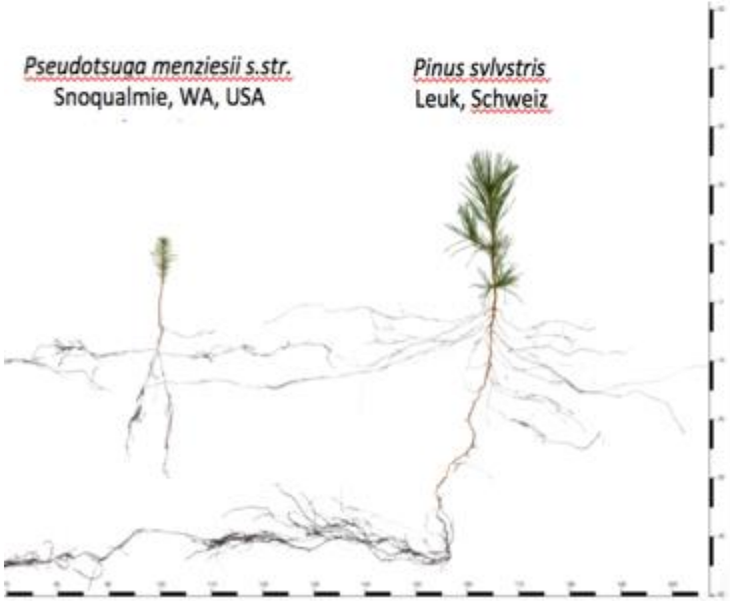




Testing alternatives

Specific limitations along tree's life

Regeneration / regrowth

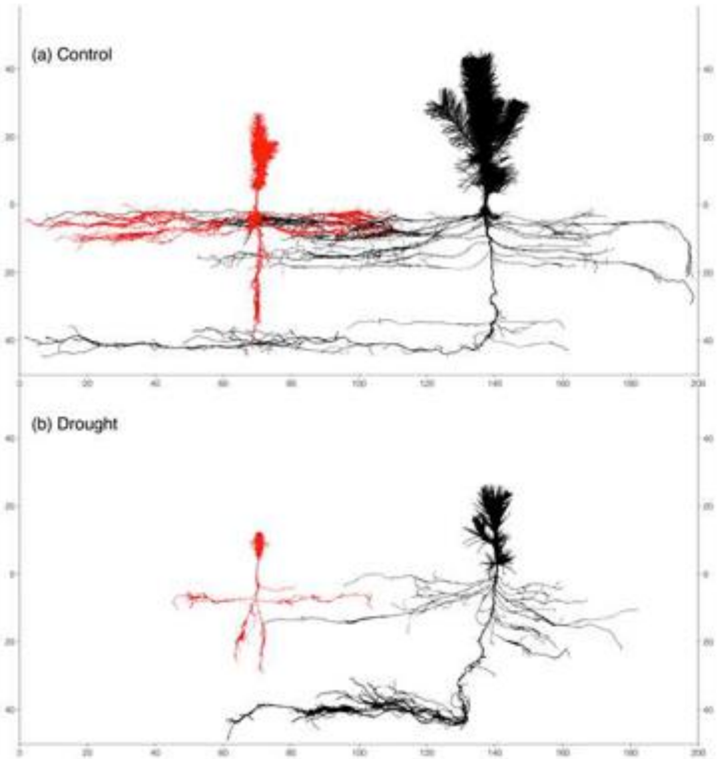


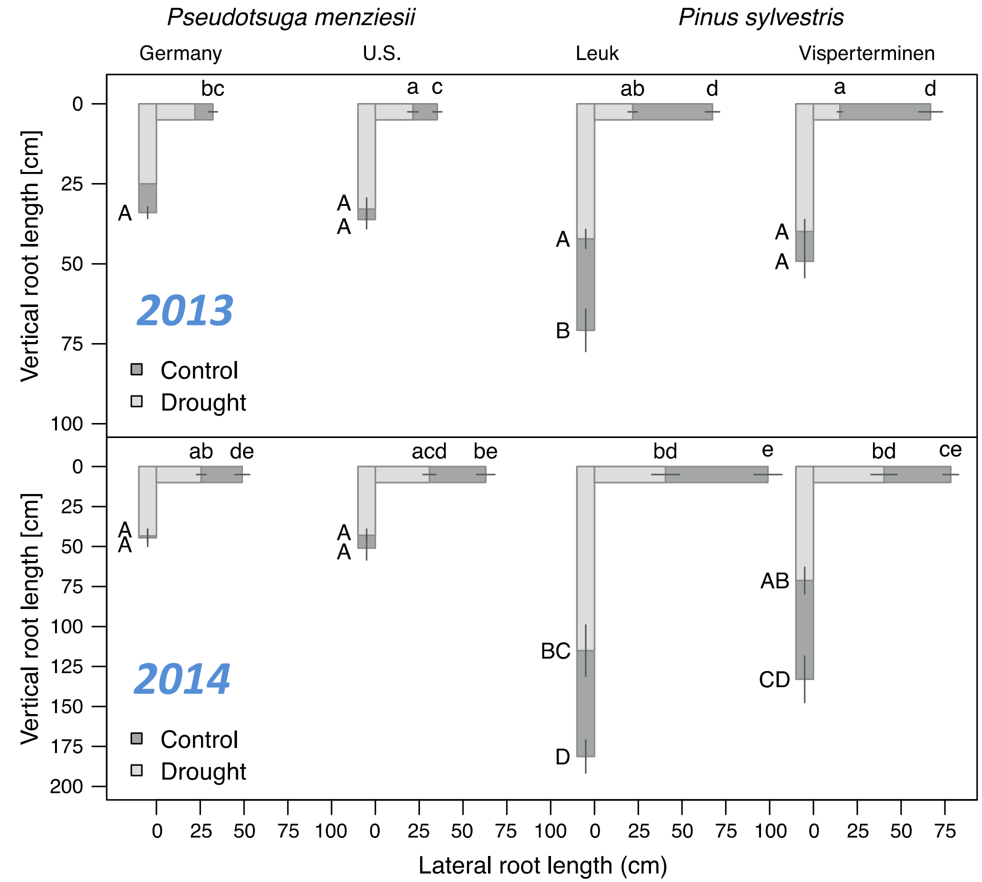
Germination / installation

Adult / old growth

Germination / installation

Pseudotsuga menziesii – Pinus silvestris



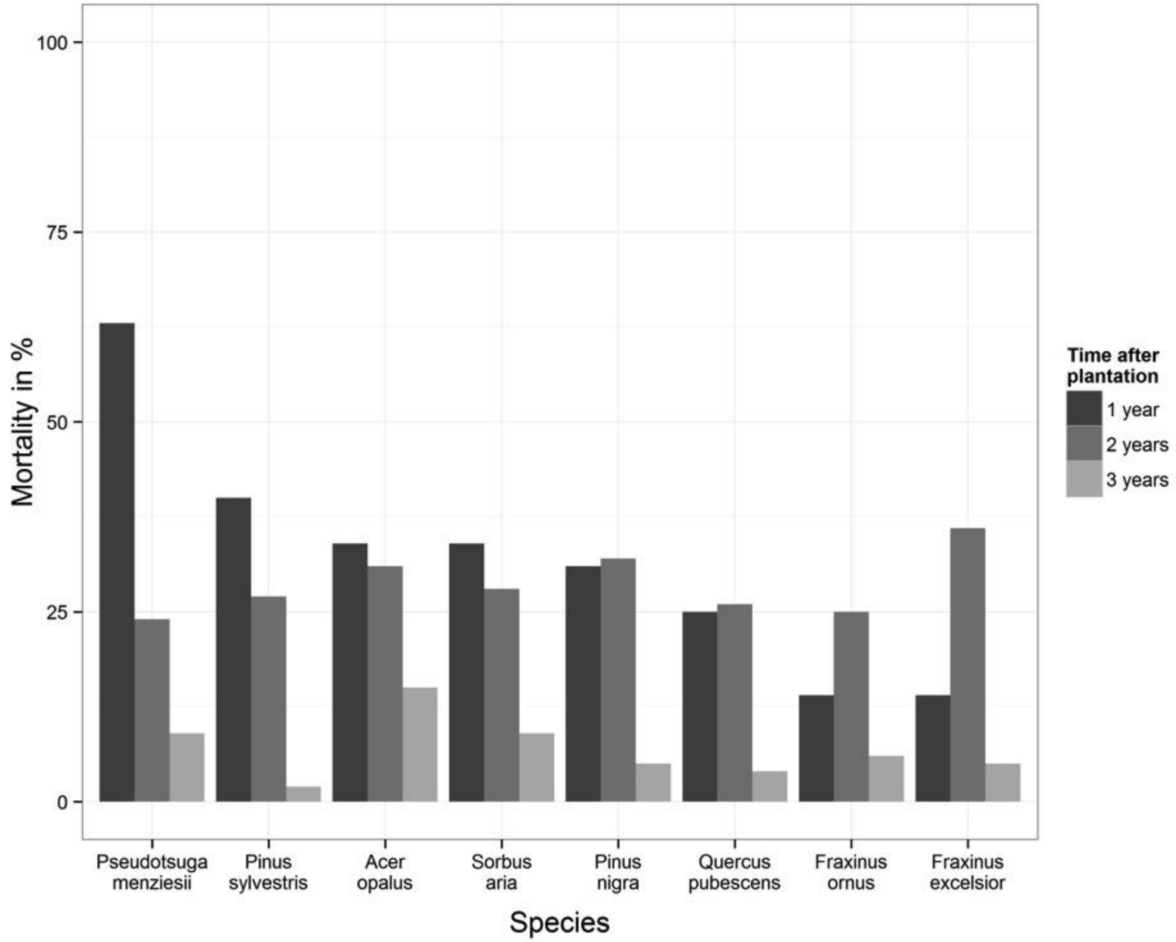


- *Pseudotsuga m*. larger proportion of biomass to roots than *Pinus sylvestris*
- Soil exploitation strategies: *P.m.* vertical root length <*50%* P.s. after 3 years
- *P.m*. seedling mortality 5x higher after two consecutive summer droughts
- → Root architecture limits the establishment of Pseudotsuga menziesii under dry conditions (-50% P)

(Moser et al. 2016 Annals of forest science)

Regeneration / regrowth

Afforestation experiment in a dry environment, Lötschberg-Südrampe



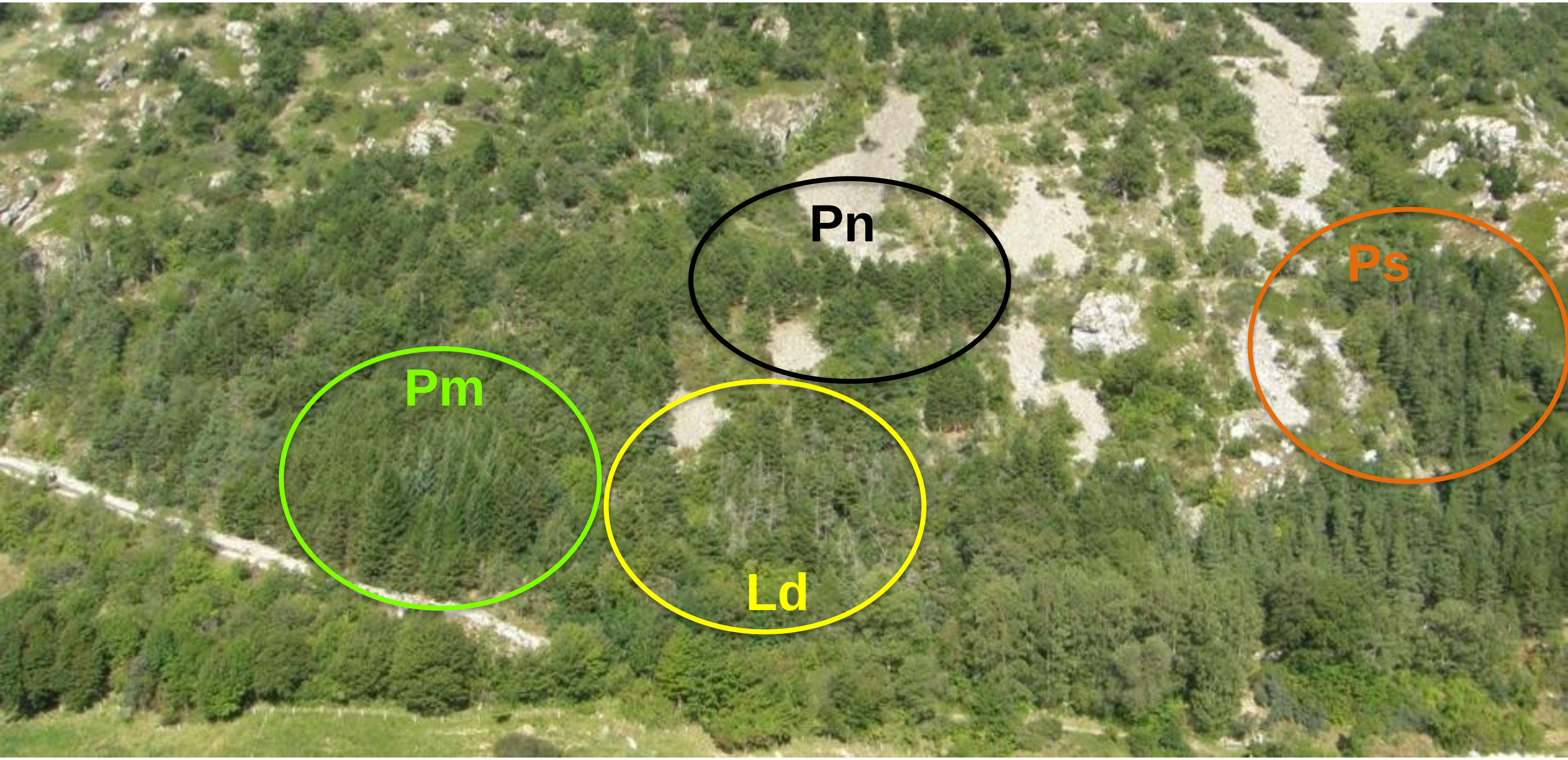
- Irrigation sign. reduced mortality
- Control trees: High mortality after 3 years 58-98%
- Dgl. most sensitive in the first year, complete failure after 3 years

(Feichtinger et al. in prep)

Adult trees: Growth reaction to drought

Afforestation Gampel (central Valais), planted 1970 (irrigation until 1992)

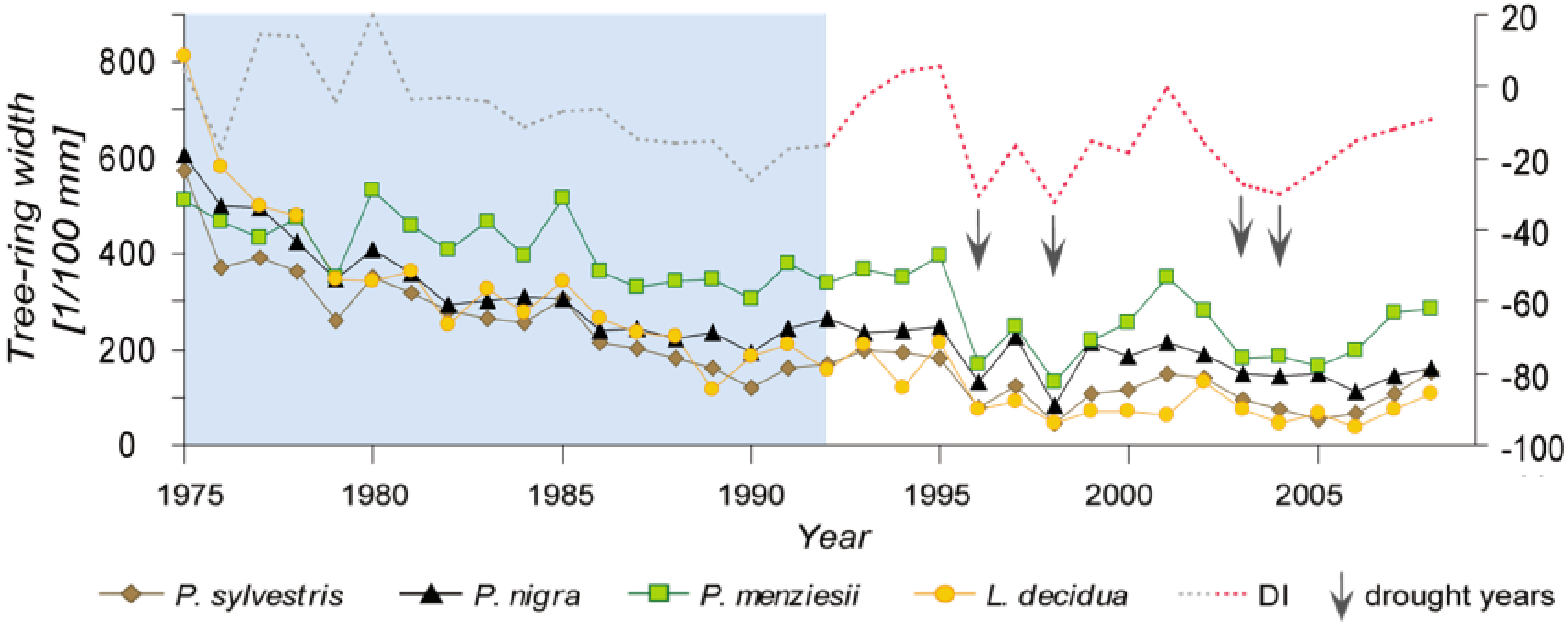
- *Pinus sylvestris*, *Larix decidua*, *Pseudotsuga menziesii*, *Pinus nigra*



- Impact of irrigation stop and 4 extreme drought years 1996, 1998, 2003, 2004

(Eilmann & Rigling 2012 Tree Physiology)

Adult trees: Growth reaction to drought



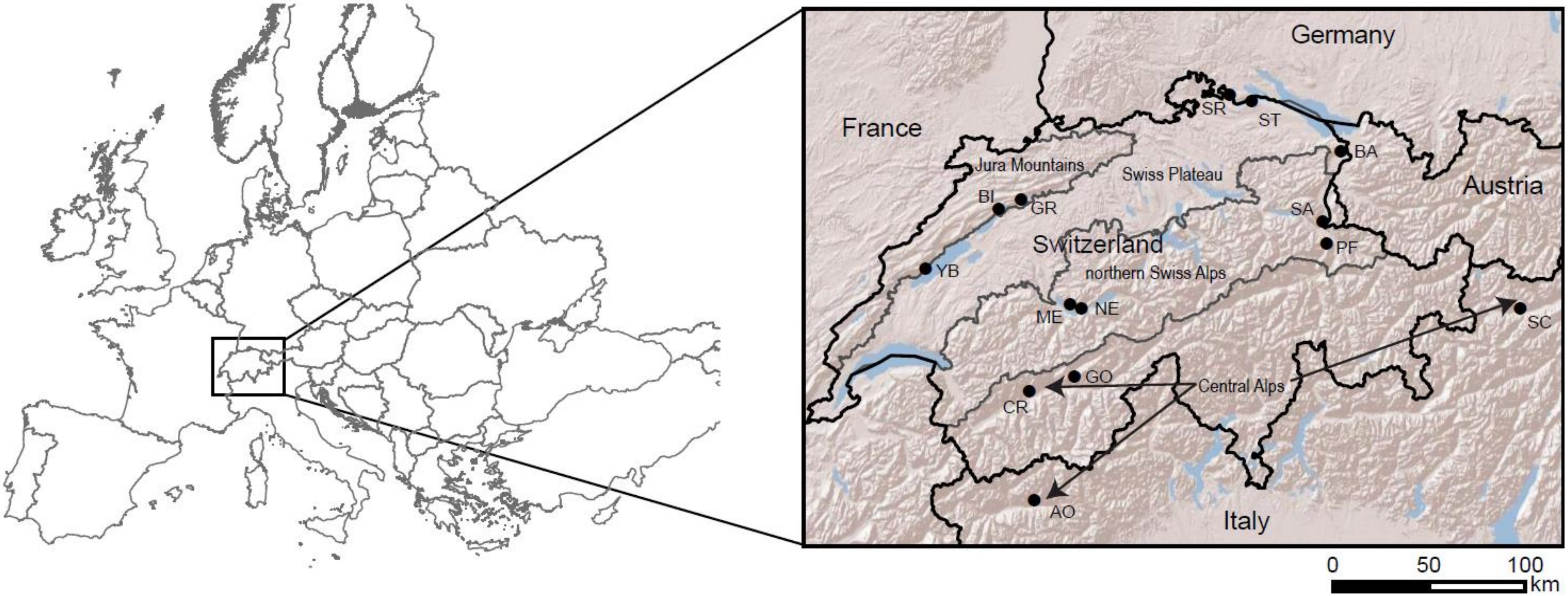
Analysis of a) growth **level**, b) abrupt **changes** of the growth level, c) growth **reductions** in drought years, d) growth **recovery** after drought

- ***P. sylvestris, L. decidua:*** mortality and crown dieback, growth decline, many break points, low growth rates, slow recovery after drought, clear impact of irrigation stop
- ***Pseudotsuga m, P. nigra****: no mortality, vital crowns, relatively high growth rates, high variability in growth, fast recovery after drought, less sensitive to irrigation-stop*

(Eilmann & Rigling 2012 Tree Physiology)

Adult trees: Growth response of 5 conifers

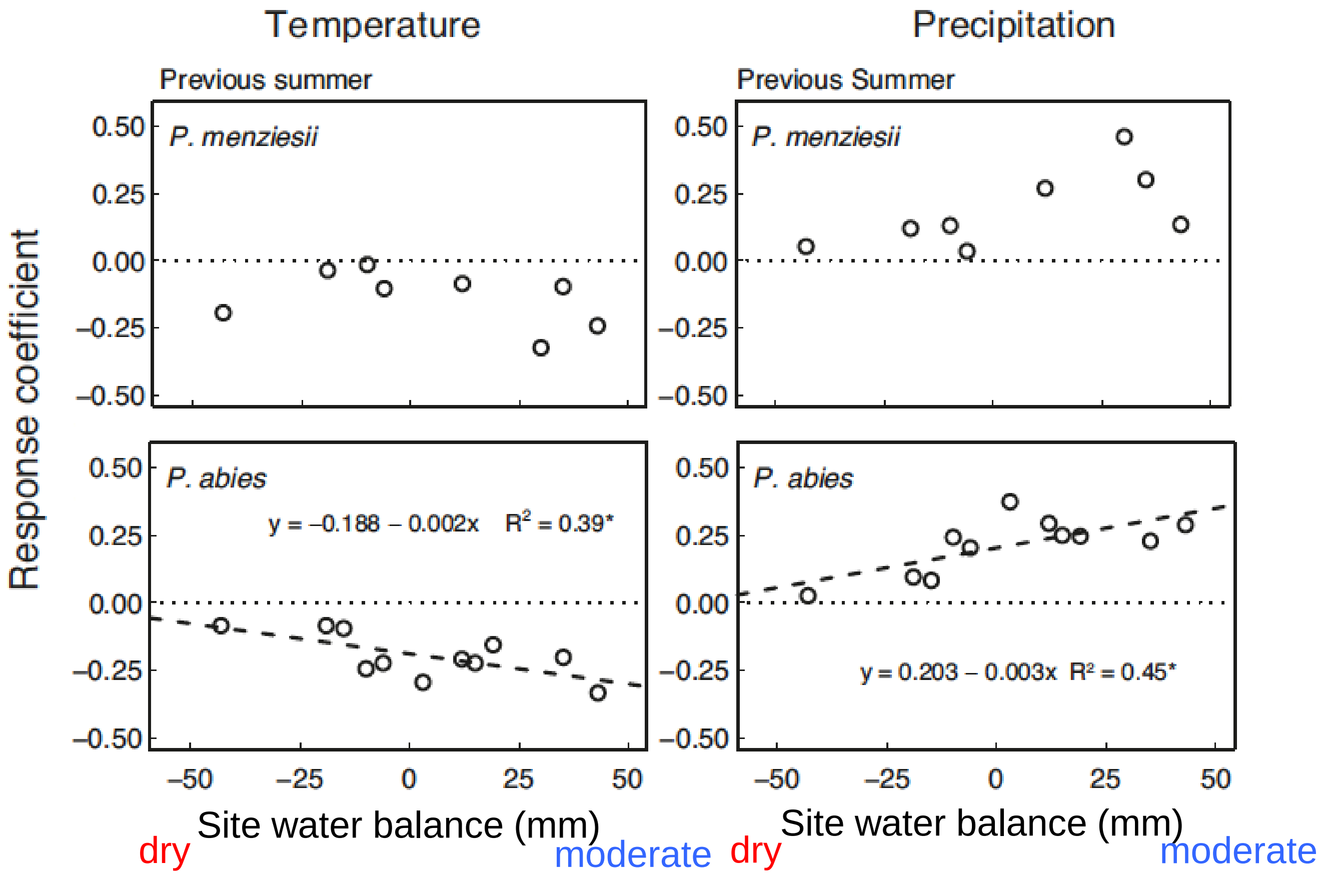
Growth response of 5 co-occurring conifers to drought across a wide climatic gradient



- 14 sites, 770 trees, *Picea a., Pseudotsuga m., Pinus sylvestris, P. nigra, Larix d.*
- Species-specific growth sensitivity to climate and severe drought along the gradient
- Tree-ring width, Response-function analysis, Principal Component Analysis (PCA), linear regressions and Superposed Epoch Analysis

(Lévesque, Rigling, Bugman, Weber, Brang 2014 Agr For Meteorol)

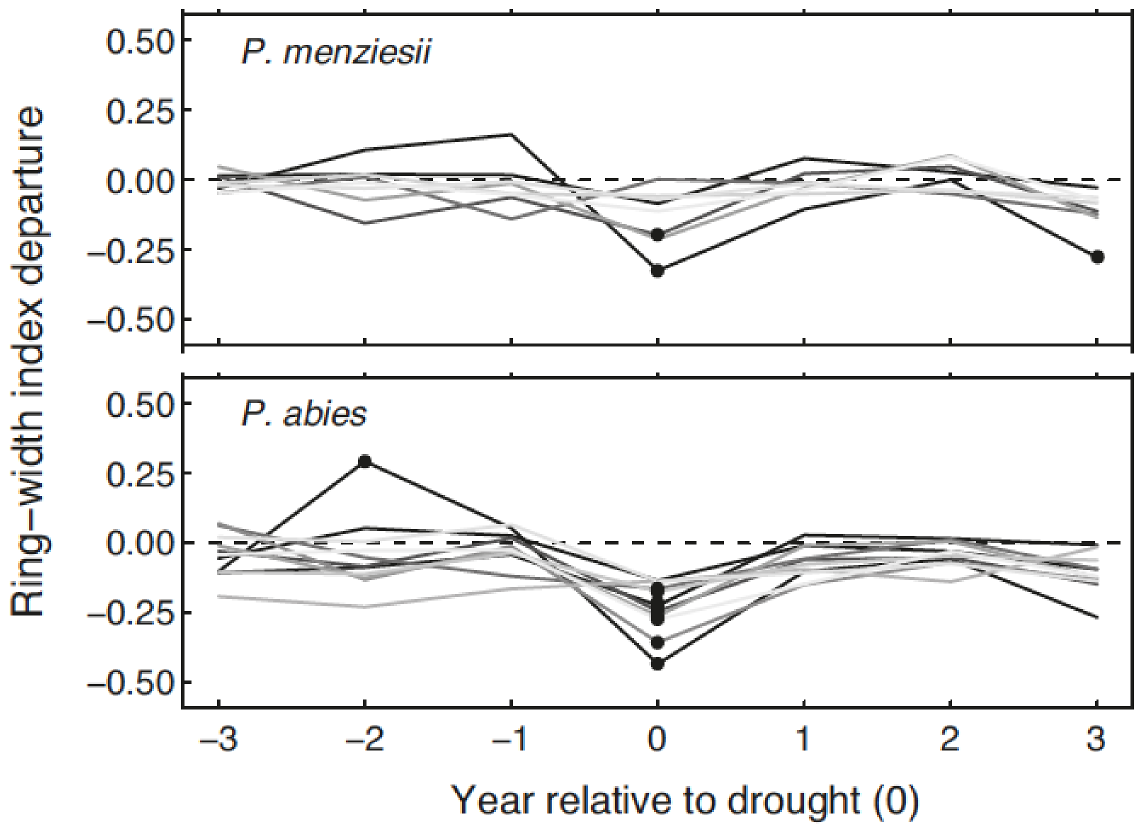
Drought response of 5 conifers – long-term response



- Response coefficients between standardized TRW-chronologies of the species and seasonal temperatures and precipitation sums
- *P.m.* showed NO relationship between growth sensitivity to past climatic conditions and site moisture conditions – In contrast, *P.a.* showed an increased susceptibility to drought and heat on more **moderate** sites.

(Lévesque, Rigling, Bugman, Weber, Brang 2014 Agr For Meteorol)

Drought response of 5 conifers - short-term response



- Superposed Epoch Analysis revealed sign. lower impacts of extreme drought years on growth of *P.m.* than *P.a.*
- The native *Picea a., Pinus sylvestris, Larix d.* most sensitive to drought, *Pseudotsuga m.* and *P. nigra* clearly more robust.

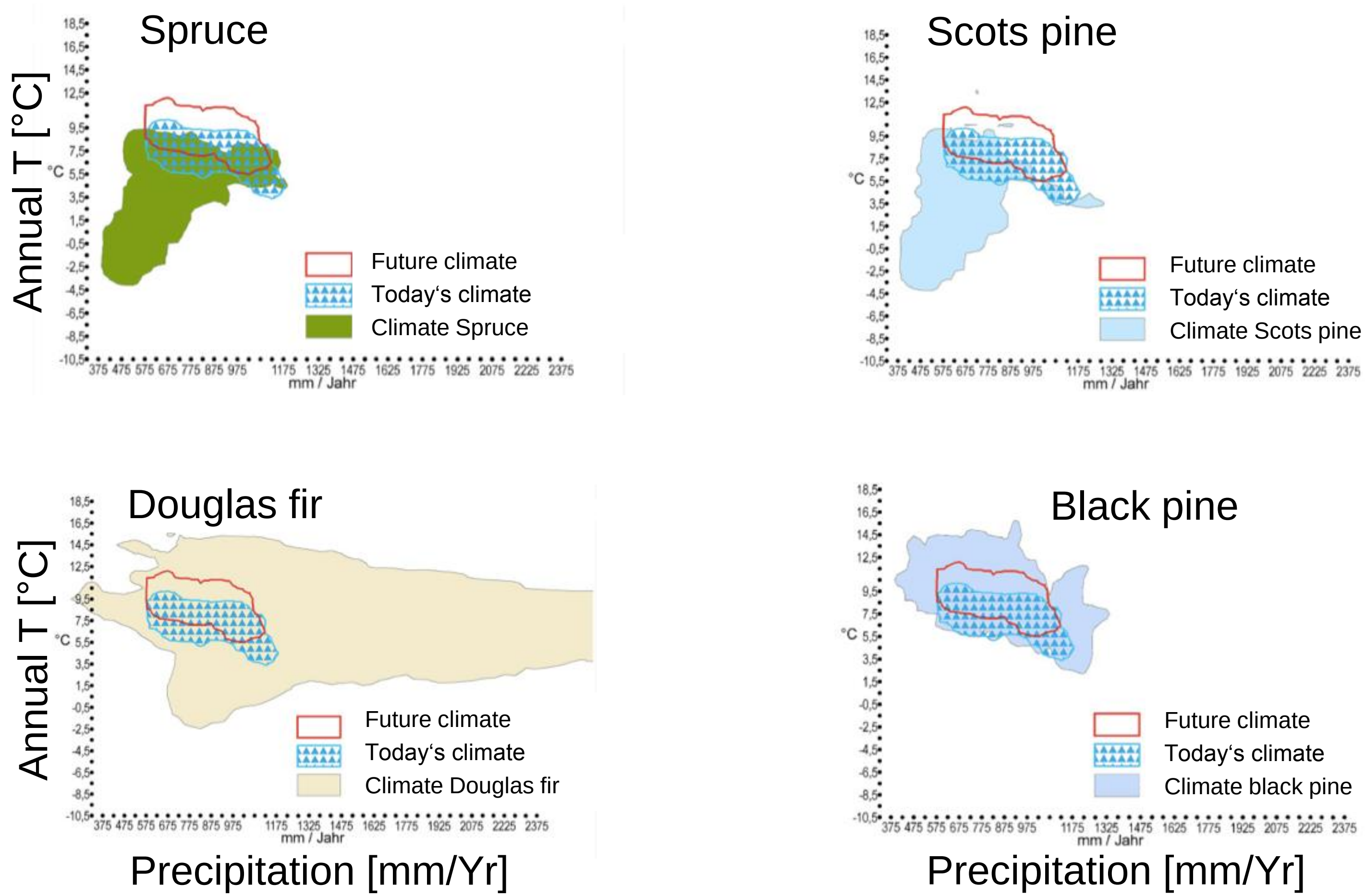
(Lévesque, Rigling, Bugman, Weber, Brang 2014 Agr For Meteorol)

What brings the future?

Forest soil and ground vegetation, summer 2015 near Zuerich, Switzerland

Climate envelopes for Bavaria (DE)

Future climate: Scenario B1 (+1.8°C)



- Spruce and Scots pine might move out of the climate envelope at many sites in Bavaria, whereas Douglas fir and black pine seem to stay inside the envelope *(Newest results for Switzerland are in prep. in the research program Forest & Climate)*

(Kölling 2007 AFZ)

Conclusions

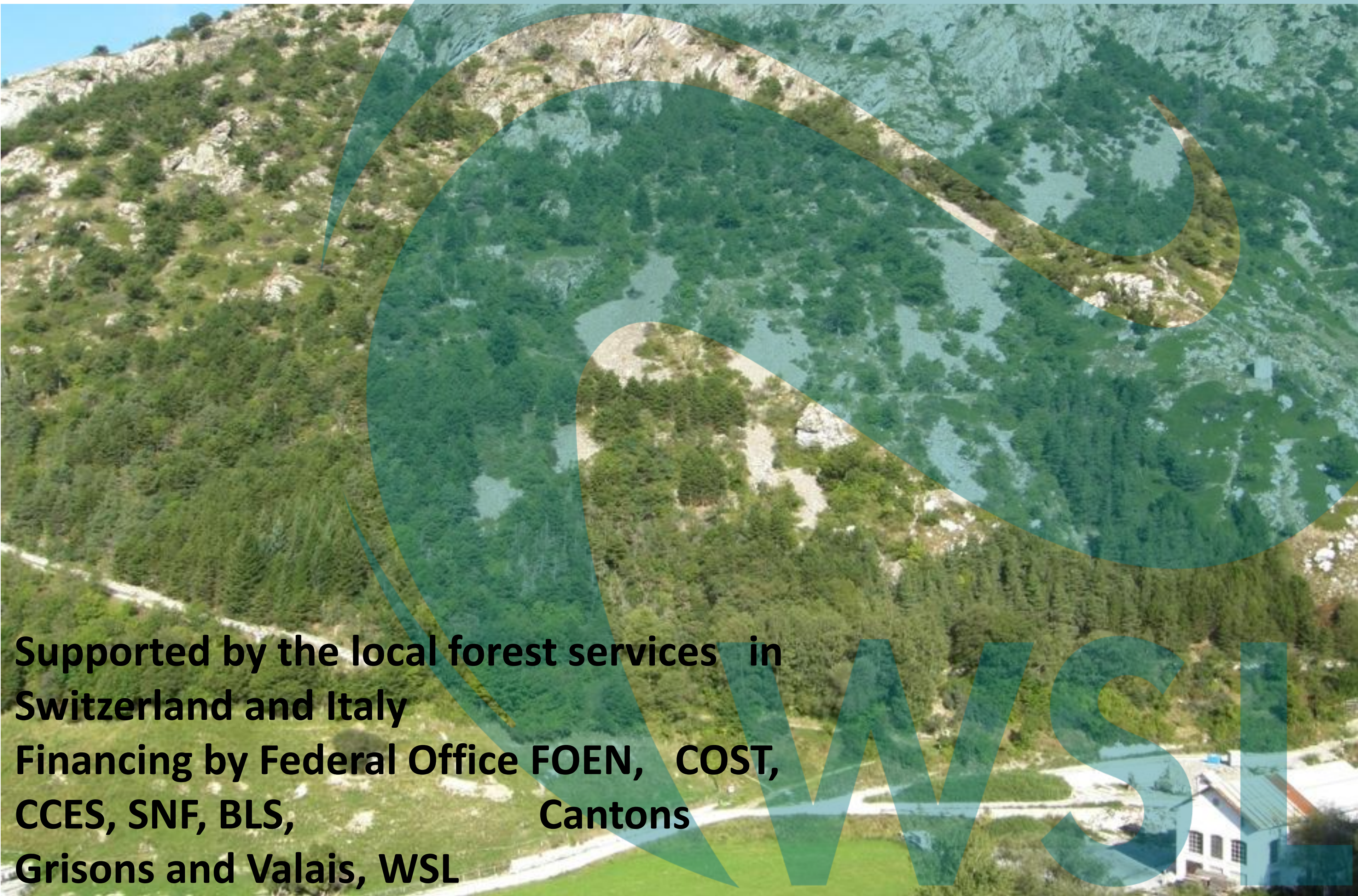
- The vulnerability of trees to drought varies amongst species due to intrinsic traits and it shifts between life stages → the establishment versus the old growth phase
- Douglas fir is highly sensitive to drought in the germination and the establishment phase but once installed this species is able to adjust to extreme drought events
- Black pine is a potential substitute for Scots pine but its high susceptibility to diseases needs to be considered

- Hence substitute species need to fulfil different aspects:
  - Being able to live today and to adapt to future climate (drought, frost, fire, …)
  - Being resistant against upcoming biotic risks
  - Guarantee all relevant ES (not only wood production)

- In order to prepare current forests to future hotter and drier conditions, trade-offs between lowered productivity but increased drought resistance need to be considered

- When substituting native with introduced tree species, large-scale monocultures should be avoided and mixed as well as uneven-aged stands that are less sensitive to pests and diseases should be promoted

Thank you for your attention



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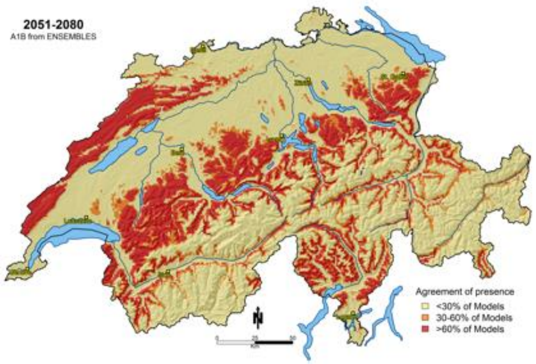
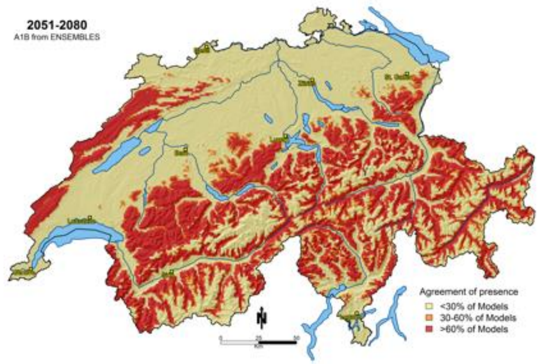
SDM and climate projections CH (A1B scenario 1.4-6.4°C)

2051-2080

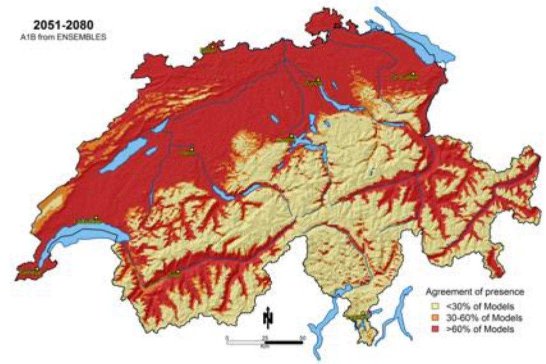
Beech (*Fagus sylvatica)*

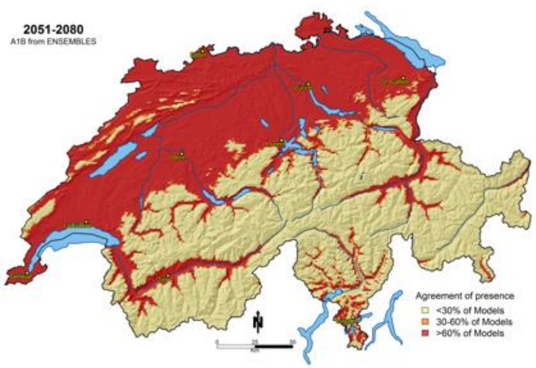


Spruce (*Picea abies*)

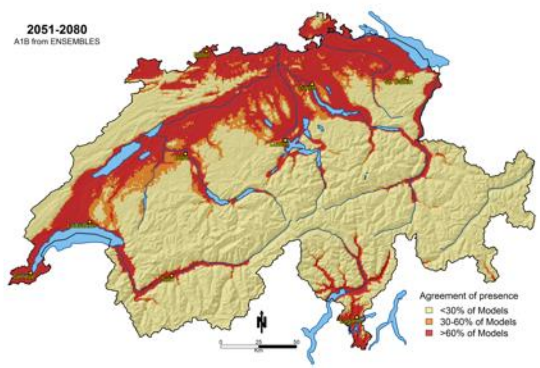


Scots pine (*Pinus silvestris*)

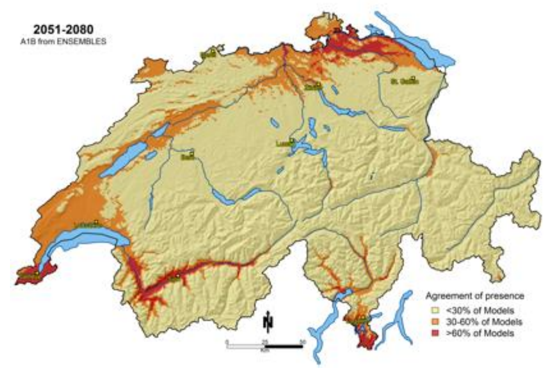




Oak (*Quercus robur, petraea, pubescens)*



Black locust (*Robinia pseudoaccacea*)



Black pine (*Pinus nigra*)

(Niklaus Zimmermann, http://www.wsl.ch/lud/portree/method.ehtml)