Climate change: Which parameters are most important?

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Dias 1
Climate Change

• IPCC climate projections for 2100: 1.8-4°C temperature increase

• Climate projections for Denmark:
  • 3-5 °C temperature increase
  • More frequent heavy precipitation
  • Increased frequency of intense storms

• Climate important component in geographic distribution of plants

• Climate change is already affecting animal and plant population distributions
Climate change will affect the composition of forests

- Three possible outcomes:
  - Natural migration to suitable niches
  - Adapt to new conditions
  - Cease to exist

- Trees will need to move at a rate of 1000 meters per year

- US study (Iversen et al. 2004) shows that trees are able to spread 100-200 meters per year
Assisted Migration

• Hewitt et al. (2009): “the intentional translocation or movement of species outside their historic ranges in order to mitigate actual or anticipated biodiversity losses caused by anthropogenic climatic change”

• Many examples of human mediated movement of species
  • Agriculture
  • Medicine
  • Ornamental
  • Silviculture

• Identification of new species already able to grow outside their natural habitat
Species Distribution Modeling (SDM)

- SDMs important tool for predicting successful introduction of species
- Used to identify contemporary and future homologous niches
- SDMs project distributions based on statistical associations between species occurrence/absence and environment variables
- Problems with SDMs:
  - Model limited to known distribution
  - Failure to find correct explaining variables (covariation between parameters)
Species Distribution Modeling

National and European perspectives on climate change sensitivity of the habitats directive characteristic plant species

Signe Normand\textsuperscript{a, c}, Jens-Christian Svenning\textsuperscript{a}, Flemming Skov\textsuperscript{b}

- Bioclimatic variables based on monthly mean temperature and precipitation:
  - Growing degree days
  - Absolute minimum temperature
  - Water balance

- SDMs used to evaluate sensitivity of 84 plant species under two climate change scenarios
  - 69-99\% negatively affected
  - 4-7 \% lost from Denmark
Species Distribution Modeling

- Review of 163 SDM articles

- Three common approaches to variable selection:
  - All available bioclimatic variables
  - Reduction of bioclimatic and –physical variables to account for collinearity
  - Selection of variables based on ecological knowledge

- 119 distinct variables:
  - Mean annual precipitation
  - Mean annual temperature

- Greater focus must be given on each predictor entering the SDM
Aim of this project

• The intention was to investigate what we could achieve by a meta-type analysis of the Arboretum

• Is it possible to deduct anything *general* about performance of species at the Arboretum

  • Can we identify homologous climates for the Arboretum?
  • Are homologous climates the same for different genera?

• Improve knowledge of climatic requirements for future selection of variables, and thereby improve the accuracy of model predictions
The Hørsholm Arboretum

- Established in 1936
- More than 2000 species of trees and bushes
- The largest collection in Denmark

Current use of the Arboretum:
- Ressource for botany teaching
- Live genebank, used for a range of studies on trees and shrubs
- Studies of associated fauna and flora (fungi)
- Inspiration and leisure for ca. 20,000 annual visitors
- (Testing and identifying promising species)

- Has recognized the importance of data collection, storage and sharing from early on
- Registration books, Index cards, Database
Study Genera

- *Quercus* distributed throughout the Northern Hemisphere
  - 531 accepted species
  - 50 species in Europe and Mediterranean region
  - Only 2 naturally occurring *Quercus* species in Denmark (*Q. robur* and *Q. petraea*)
  - 118 trees in the Arboretum with representatives of 27 species mainly collected in North America, Europe and Asia
Study Genera

- *Abies* distributed throughout the Northern Hemisphere
- 52 species
- 8 species naturally occur in Europe and Asia minor
- No naturally occurring *Abies* species in Denmark
- The Arboretum holds 398 trees with representatives of 33 species collected in North America, Europe, Asia and North Africa
Study Genera

- *Rhododendron* has wide distribution but largest number of species are found in Asia
  - 1025 species
  - Small number of species occur in Europe
  - Only 1 naturally occurring *Rhododendron* species in Denmark (*R. tomentosum*)
  - 1380 plants in the Arboretum with representatives of 124 species collected from North America, Europe and Asia
Data collection

- Index cards and old versions of the Database were reviewed
- Source of collection coordinates (GPS coordinates, Latitude and Longitude, Location Name, Arboretum, Unknown)
- Collection site identified for each accession number (Atlases, Google Maps, Travel descriptions)
- Accuracy of identified collection site (30 seconds, 2.5 arc-minutes, 5 arc-minutes, 10 arc-minutes resolution)
Data collection

- Fieldwork:
  - Presence/absence of each accession number
  - Height and Diameter for *Quercus* and *Abies*

- Mean height and diameter for each accession number calculated

- Two measures for Growth calculated: mean height/age, mean diameter/age

- Exclusion of samples originating from botanical gardens, arboretums and unknown locations

- Exclusion of data with specificity of collection site of 10 arc-minutes resolution
Climate data

• Climate data downloaded from Worldclim
• Current conditions 1950-2000
• Downloaded using 5 arc-minute resolution
• 19 bioclimatic variables + altitude
• Altitude manually corrected when information available in registration books
• Quadratic covariate for each variable created in order to accommodate non-linear tendencies in the data

\[
\begin{align*}
\text{BIO1} &= \text{Annual Mean Temperature} \\
\text{BIO2} &= \text{Mean Diurnal Range (Mean of monthly (max temp - min temp))} \\
\text{BIO3} &= \text{Isothermality (BIO2/BIO7) } \ast 100 \\
\text{BIO4} &= \text{Temperature Seasonality (standard deviation *100)} \\
\text{BIO5} &= \text{Max Temperature of Warmest Month} \\
\text{BIO6} &= \text{Min Temperature of Coldest Month} \\
\text{BIO7} &= \text{Temperature Annual Range (BIO5-BIO6)} \\
\text{BIO8} &= \text{Mean Temperature of Wettest Quarter} \\
\text{BIO9} &= \text{Mean Temperature of Driest Quarter} \\
\text{BIO10} &= \text{Mean Temperature of Warmest Quarter} \\
\text{BIO11} &= \text{Mean Temperature of Coldest Quarter} \\
\text{BIO12} &= \text{Annual Precipitation} \\
\text{BIO13} &= \text{Precipitation of Wettest Month} \\
\text{BIO14} &= \text{Precipitation of Driest Month} \\
\text{BIO15} &= \text{Precipitation Seasonality (Coefficient of Variation)} \\
\text{BIO16} &= \text{Precipitation of Wettest Quarter} \\
\text{BIO17} &= \text{Precipitation of Driest Quarter} \\
\text{BIO18} &= \text{Precipitation of Warmest Quarter} \\
\text{BIO19} &= \text{Precipitation of Coldest Quarter}
\end{align*}
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Statistical Analysis

• 2 main components:

  • Linear regression to determine factors important to growth for *Quercus* and *Abies*

  • Logistic regression to determine factors affecting survival for *Quercus*, *Abies* and *Rhododendron*
## Linear and Logistic Regression

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<thead>
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<th></th>
<th>Abies Diameter/Age^{1/2}</th>
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<th>Abies Survival</th>
<th>Quercus Diameter/Age^{1/2}</th>
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<th>Quercus Survival</th>
<th>Rhododendron Survival</th>
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Significance levels: 0.001 ‘***’, 0.01 ‘**’, 0.05 ‘*’, Brown = Quadratic variable included
Linear and Logistic Regression

BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
Linear and Logistic Regression

**BIO3 = Isothermality (BIO2/BIO7) (* 100)**
- BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
- BIO7 = Temperature Annual Range (BIO5-BIO6)
- BIO5 = Max Temperature of Warmest Month
- BIO6 = Min Temperature of Coldest Month

![Graphs of Isothermality vs. Species](image)

- **Quercus**
- **Abies**
- **Rhododendron**

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The most successful species in the Arboretum

<table>
<thead>
<tr>
<th>Genus</th>
<th>Diameter</th>
<th>Height</th>
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<tbody>
<tr>
<td>Quercus</td>
<td>Q. coccinea</td>
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<td>Q. velutina</td>
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<td>Q. palustris</td>
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<td>Q. rubra</td>
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<td></td>
<td>Q. petraea (DK)</td>
<td>Q. petraea (DK)</td>
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<tr>
<td>Abies</td>
<td>A. grandis</td>
<td>A. grandis</td>
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<td>A. borisii-regis (EU)</td>
<td>A. alba (EU)</td>
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<td>A. cephalonica (EU)</td>
<td>A. sachalinensis</td>
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<td>A. homolepis</td>
<td>A. amabilis</td>
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<td>A. alba (EU)</td>
<td>A. veitchii</td>
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</tbody>
</table>

- Non-survivors:
  - 13 species of *Quercus*
  - 4 species of *Abies*
  - ~40 species of *Rhododendron*
What can we learn from the Hørsholm Arboretum

- No shared significant predictor variables for both growth measurements between *Quercus* and *Abies*

- Shared predictor variables significant for either Height/Age or Diameter/Age between *Quercus* and *Abies*:
  - Mean Diurnal Range
  - Precipitation of Wettest Month
  - Precipitation of Wettest Quarter
  - Precipitation of Warmest Quarter
  - Altitude

- Only one common predictor variable (Isothermality – Bio3) for Survival between *Quercus*, *Abies* and *Rhododendron*

- Both linear and logistic regression showed a clear difference in significant predictor variables for each genera
Problems related to use of data from the Arboreum

- We can only measure what has survived
- Small dataset
- Skewed (biased?) distribution introductions
- Unequal numbers of plants tested from different accessions
- Origins may not be precisely described
- Plants established at different times have been exposed to different climatic conditions
- Heterogeneity of the Arboretum, lack of replications
- Arboretum highly managed / what about real life competition?
Can data from the Arboretum be used?

A generic method for climate change impact analysis of tree species planting domains

Trevor H. Booth • Tom Jovanovic • Chris E. Harwood

• Can data from the Arboretum can be used to identify species that will thrive under future climate conditions?

• Species survive and some even thrive in Hørsholm despite biovariables being warmer/colder/higher/lower than the areas from which they have been sampled

• Requirements based solely on expert opinion of conditions within the natural distribution

• Results in main plantation areas described as climatically unsuitable
Can data from the Arboretum be used?

- Knowledge of climatic requirements from trials, plantations and arboretums can improve description of a species climatic requirements

- By using identified significant climatic parameters we can avoid over-fitting models

- SDM predictions may be more accurate with the application of a “customized” set of predictor parameters
Thank you for listening