Applying new tools in CLIMEX to explore parameter sensitivity, model uncertainty and inter-annual variation in climate suitability

The potential distribution of *Chilo partellus*, including the effects of irrigation

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Chilo partellus

- Major crop pest
- Originally from Asia and Africa
- Recently spread to the Mediterranean region
Considering irrigation for crop pest niche modelling

• Many (perhaps most) agricultural crops are irrigated somewhere in their range

• The cardinal assumption in correlative species distribution modelling is that the species is at equilibrium with its environment

• The fine print...
  • The environment is represented by bioclim variables
  • The bioclim variables are built using *natural rainfall* climate variables

• What is the effect of building a model with distribution points collected from a mixture of irrigated and non-irrigated sites?
  • Model parameters are distorted, losing meaning and interpretability
  • Model skill is reduced, with *specificity* sacrificed in order to maintain *sensitivity*
    – All arid regions become suitable, even if they are not irrigated.
The digital global map of irrigation areas
February, 2007

The map depicts the area equipped for irrigation in percentage of cell area. For the majority of countries the base year of statistics is in the period 1997 - 2002.


Stefan Siebert, Petra Döll, Sebastian Feick (Institute of Physical Geography, University of Frankfurt/M., Germany) and Jippe Hoogeveen, Karen Frenken (Land and Water Development Division, Food and Agriculture Organization of the United Nations, Rome, Italy)
Including Irrigation in CLIMEX Niche Models

• Collate distribution data
• Fit initial soil moisture and temperature parameters using biologically reasonable values
• Assess fit
• Identify outlying points
• Explore using Google Earth or similar, identify evidence of irrigation
• Apply an irrigation scenario (2.5 mm day-1 of top-up irrigation is usually satisfactory)
• Combine results of irrigated and natural models using the GMIA dataset
Composite niche maps

- Use spatial intersection to create a composite risk
- \( \text{Risk}(Y) = \text{Max}(Y_I, Y_N | \text{irrigation}) \)
- If irrigation is present, then the risk is the highest value of the two scenarios, otherwise it is the natural rainfall value.
Chilo partellus potential persistence in Asia
Global threat of *Chilo partellus*
Results compared

Overholt et al. 2000  
Bespoke method

Khadioli et al. 2000  
ILCYM

Hutchison et al. 2008  
CLIMEX

Yonow et al. 2016  
CLIMEX
Sensitivity and Uncertainty

• More frequent calls in the literature to undertake some form of uncertainty analysis
  • Venette et al. 2010 Roadmap paper
• CLIMEX Version 4 provides tools to automate the analyses
Sensitivity vs Uncertainty

- Parameter sensitivity is the strength of the effect of each parameter on state variables
  - Adjust each parameter and assess change in state variables
  - Produces a table of sensitivity results
  - Identifies which variables we need to consider carefully
  - Sensitive variables that we are poorly confident about = high concern

- Uncertainty is an estimate of incertitude in the results of the model
  - Apply parametric uncertainty
  - Latin hyper-cube sampling
  - Produces an agreement map
# Sensitivity analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mnemonic</th>
<th>Parameter Values</th>
<th>Range Change (%)</th>
<th>EI Change</th>
<th>Core Distribution Change (%)</th>
<th>Growth Variables</th>
<th>Stress Variables</th>
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<tbody>
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<td></td>
<td></td>
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<td>Default</td>
<td>High</td>
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<td>Degree-days per Generation</td>
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Uncertainty analysis
Cautions with Sensitivity and Uncertainty Analyses

- Both analyses depend on the regions in which the analyses are conducted
- Neither addresses other forms of uncertainty
  - Is the model appropriate?
- A model with low sensitivity and low uncertainty could be highly erroneous!
Interannual variation in climate

• PLAY Movie Here
Conclusions

• All distribution points do not mean the same thing
  • Ephemeral
  • Reliant upon artificial conditions

• Considering irrigation explicitly has a substantial (positive) impact on the modelling process and the results
  • Better model “skill”
  • Parameters retain their meaning, increasing confidence in the model

• Sensitivity analyses direct attention to important considerations

• Uncertainty analyses of more use to decision-maker
  • Needs more research attention to better convey messages

• Static maps hide the degree of variability in species range boundaries
Grazie mille!
Chilo partellus potential persistence in Africa