Crop diseases and climate change in the AgMIP framework

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Outline of presentation

• **Climate change and crop disease:**
  – Problems and importance

• **Plant disease epidemics as affected by climate:**
  – Stages in infection cycle, effects of climate and microclimate
  – Constant versus oscillating temperatures

• **Pathogen and plant disease models:**
  – Overview
  – Example: potato late blight

• **Coupling crop models and disease models**
  – Effects of disease on crop physiology – yield loss
  – Example: groundnut late leaf spot

• **Gaps in crop-disease-economic models**
  – Assess climate change impacts and adaptation
Global variation in climate

- Change in surface temperature over 1901-2012
- Warming in N. regions, Brazil, West Africa
- Projected changes in the hydrological cycle:
  - Precipitation (mm/day): more in temperate climates and less in the tropics
  - Relative humidity (%): increasing in central Africa and India, decreasing in South Africa and Amazon region
- Daily, seasonal and inter-annual variations in climate less well known than averages
Crop diseases and climate change: problems and importance

- Global crop productivity increased over past 50 years; **production per acre stabilized**, mainly due to pests and diseases
- **Pests and diseases** reduce crop yield **30-40%**, including post-harvest
- **Pests and diseases not included in crop models** predicting effects of climate change
- Crop models run **at daily time steps**, pathogens operate at various scales from hourly to daily and multi-annual scales: problems linking crop – disease models
- Crops produced **at field scale**, pathogens operate at plant tissue, field, farm and landscape scales: problems integrating scales
- **Linking of crop and disease models to economic models** is essential, but currently little attention for crop loss by disease
<table>
<thead>
<tr>
<th>Stage</th>
<th>Duration</th>
<th>Temperature</th>
<th>Leaf wetness</th>
<th>Relative humidity</th>
<th>Wind speed, dir.</th>
<th>Solar radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spore germination</td>
<td>2-24 hrs</td>
<td>Optim. curve</td>
<td>Positive, duration</td>
<td>positive</td>
<td>No effect</td>
<td>negative</td>
</tr>
<tr>
<td>Colonization (latent period)</td>
<td>Several days</td>
<td>Inverse optimum curve</td>
<td>No effect</td>
<td>No effect</td>
<td>No effect</td>
<td>No or indirect effect</td>
</tr>
<tr>
<td>Sporulation</td>
<td>At night, days</td>
<td>Optim. curve</td>
<td>Positive effect</td>
<td>Positive effect</td>
<td>Negative at high wind</td>
<td>negative</td>
</tr>
<tr>
<td>Spore release</td>
<td>Morning hours</td>
<td>No effect</td>
<td>negative</td>
<td>at drop in RH</td>
<td>positive</td>
<td>Positive, trigger</td>
</tr>
<tr>
<td>Spore dispersal</td>
<td>Morning days</td>
<td>Negative at high T</td>
<td>Rain positive</td>
<td>wind</td>
<td>Negative (UV)</td>
<td></td>
</tr>
<tr>
<td>Spore deposition</td>
<td>seconds</td>
<td>No effect</td>
<td>Rain +/-</td>
<td>neutral</td>
<td>wind</td>
<td>No effect</td>
</tr>
</tbody>
</table>
Theoretical relations between disease development rate and temperature

• A: constant temp growth curve (BETE function)
• B: simulations with oscillating temps with 0, 5 and 10C amplitudes
• Conclusions:
  – substantial differences between development at constant and fluctuating temperatures with the same means
  – mean temperatures without information about the amplitudes of the fluctuations may not be sufficient to predict growth or development

Scherm and van Bruggen, 1994
Pathogen and disease models

<table>
<thead>
<tr>
<th>Modeling methods</th>
<th>Effects of climate (daily averages)</th>
<th>Effects on yield/economics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empirical models</td>
<td>sometimes</td>
<td>sometimes</td>
</tr>
<tr>
<td>Temporal analytical models</td>
<td>usually not</td>
<td>no</td>
</tr>
<tr>
<td>Spatio-temporal analytical models</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>GIS-based models</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Numerical simulation, deterministic</td>
<td>yes</td>
<td>usually not</td>
</tr>
<tr>
<td>Numerical simulation, stochastic</td>
<td>yes</td>
<td>usually not</td>
</tr>
<tr>
<td>Functional-structural models (3D architectural</td>
<td>sometimes, microclimate</td>
<td>not yet</td>
</tr>
<tr>
<td>models)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Network models</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Forecasting/management models</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>
Example: potato late blight

- Pathogen: *Phytophthora infestans* (a water mold)
- Center of origin: Toluca Valley, Mexico (or Andes?)
- 1845: late blight epidemics in Europe -> Irish potato famine
- Latent period as low as 3 days!!
Example: potato late blight
CIP- UF collaborative project on effect of climate change on potato production in the high Andes
Example: potato late blight
Rate of development to sporulation

- At fluctuating temps. the optimum curve is flatter than at constant temps.
- Temperature effects differ under oscillating compared to constant temperatures with the same mean!
- Models with daily averages overestimate climate change effects in the high range, but underestimate effects in the low range
Example: potato late blight
Potato models and late blight models

- **Potato models**
  - LINTUL-POTATO, temp. daylength (Kooman, Haerkort, 1995)
  - POTATOS, a simple potato crop growth model used to assess climate change impacts (Wolf, Wageningen, 2002)
  - CROPSYSTVB-CSPOTATO: a crop simulation model for potato-based cropping systems (Marcos, 2012)
  - Many others

- **Late blight models**
  - Simulation model LATEBLIGHT (Bruhn and Fry, 1981), disease, weather, fungicides, host resistance, coarse economic
  - Forecast model Blitecast, accumulated severity values (Krause, 1975)
Coupling crop and disease models: Effects of disease on crop growth processes
Example: groundnut late leaf spot
Coupling peanut model and leaf spot damage using the DSSAT approach

- Decision support system for agrotechnology transfer: DSSAT-CSM (soil, weather, crop models)
- Effects of late leaf spot on photosynthesis (‘virtual lesion effect’) and senescence (necrosis and leaf drop)

Singh et al., 2013: Using the CSM-CROPGRO-Peanut model to simulate late leaf spot effects on peanut cultivars of differing resistance. Agron. J. 105: 1307-1316.

Cultivar Carver more leaf spot than York, But York more reduced photosynthesis
Effects of climate change on crop growth, development and disease (educated guesses so far)

- In temperate zones more crops and different crops can grow; different kinds of diseases and pests, including disease vectors
- Crop development (and flowering) will be faster and several pests and diseases may be promoted
- Survival in the off-season may be longer
- Effects of temperature are less pronounced if daily amplitudes become smaller
- Probably more effect of weather extremes (rainfall, drought, extreme heat) than of average climatic conditions
- Better forecasting models are needed to take management decisions in view of changes in climate.
Gaps in ability to predict effects of climate change on crop yield and economic impact

• Coupling of crop and disease models needed: physiological effects
• What kind of crop models? Numerical simulation models like DSSAT-CSM
• What kind of disease models? Generic simulation models like the SEIR model EPIRICE (Savary et al., 2012) or soybean rust model with CSM-CROPGRO-Soybean (Fernandes et al., 2009)
• Problems:
  – Climate effects at different scales
  – Spatial distribution, movement of inoculum not included
  – Interaction effects among diseases and pests unknown
  – Effects on yield mostly unknown
  – Economics affected by policy decisions, not just yield and price
• Challenges and opportunities:
  – Collaboration in interdisciplinary teams
  – Mitigation possibilities: crop diversity, stress resistance and resilience
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