Resource-use description in physiology-based models

16.06.2011

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Addressing resource-related(?) problems with a physiology-based ecosystem model

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Definition: “physiology-based ecosystem model”
Definition: “problems”

(Cramer et al. 2001)

(Morales et al. 2005)
Definition: “problems”

Requirements:

1. Changes within the soil
   (microbes, storage changes)
2. Physiological adjustments
   (seasonal, inter-annual)
3. Interaction with other individuals
   (between species)
4. Response on disturbances
Modular Biosphere simulation Framework (MoBiLE)

2. Methods

Empirical Canopy Model (ECM)
(Grote 2007, Holst et al. 2010)

Dynamic Treegrowth Model (M-TREEDYN)
(Bossel et al. 1996, Grote et al. 2011)

Physiological Simulation Model (PSIM)
(Grote et al. 2009, 2010)

DeNitrification-DeComposition (DNDC)
(Li et al. 1992, 2000)

→ MoBiLE-PSIM
Modular Simulation Framework (MoBiLE)

DeNitrification-DeComposition (DNDC)

(Li et al. 1992, 2000)
Example: Interaction with soil → Höglwald/spruce
Example: Interaction with soil → Höglwald/spruce

Kreutzer et al. 2009 (slightly modified, all values in kg N ha⁻¹ resp. kg N ha⁻¹ a⁻¹)
Mycorrhiza

3. Results

**Mobilisation of N & P from organic polymers from microbial biomass, micro- & meso-fauna and plant litter intervention in microbial mobilisation-immobilisation cycles**

- Solubilisation of tri-calcium phosphate by ectomycorrhizal fungi and associated bacteria
- Enzyme activities: extracellular and secretion of compounds
- Interactions with other organisms

**Possible effects of mycorrhizal symbiosis**

- Increased drought tolerance
- Capture and restricted leach of base cations in acidified soil
- Chelation of toxic heavy metal and aluminium
- Mediation of stress

**Carbon cycling**

Flow of current assimilate drives soil respiration

Exudation of liquid drops at hyphal tips of *Suillus brevipes*. The drops are rich in oxalic acid.

Electronic autoradiography showing transfer of P from saprotrophic mycelium to a pine plant via an ectomycorrhizal fungus.

Synergistic, competitive or antagonistic interactions associative N fixation exudation of organic compounds at hyphal tips

Exudation of liquid drops at hyphal tips of *Suillus brevipes*. The drops are rich in oxalic acid.

**Finlay 2008**
3. Results

MYCOFON model

Meyer et al. 2010 (PS)
### MYCOFON model

<table>
<thead>
<tr>
<th>Year</th>
<th>Condition</th>
<th>Total N uptake*</th>
<th>Plant N supply*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>(normal)</td>
<td>231</td>
<td>158</td>
</tr>
<tr>
<td>1996</td>
<td>(dry)</td>
<td>237</td>
<td>155</td>
</tr>
<tr>
<td>1997</td>
<td>(wet)</td>
<td>271</td>
<td>182</td>
</tr>
</tbody>
</table>

*kg ha⁻¹ a⁻¹

→ N turnover increased app. 1.5 fold (results are preliminary)

Meyer et al. subm (EJFR)
3. Results

→ Belowground allocation decreases with N supply
   (results are preliminary)

Meyer et al. subm (EJFR)
Example: Physiological adjustments: Hesse/Beech
Example: Physiological adjustments: Hesse/Beech

- Parameter adjusted to meet average annual NEE exchange
- Model constrained with forest inventory data
- Model evaluated with soil water and transpiration (1997-2002)

2. Results

Grote et al. 2011 (AGRFORMET)

exceptional drought
Example: Physiological adjustments: Hesse/Beech

2. Results

Grote et al. 2011 (AGRFORMET)

- Missing tissue destruction by weather extremes?
- Missing resource depletion related to soil processes?
- Both?
Example: Physiological adjustments: Hyytiälä/Pine
Example: Physiological adjustments: Hyytiälä

• Parameter adjusted to meet average annual NEE flux
  Note: Model includes evaluated phenology (litterfall)
  Note: Model considers empirical seasonality term (Mäkelä et al. 2004)

Grote et al. subm. (FORSYS)
3. Results

Example: Physiological adjustments: Hyytiälä

- Seasonality of enzyme activity site specific?
- Missing influence of other plants?
- Both?

Grote et al. subm. (FORSYS)
Example: Interaction between species: Hyytiälä

Several Species at different places

Overstory/Understory

Forest inventory includes significant amounts of spruces and birches!
Example: Interaction between species: Hyytiälä

Several Species of the same size (WEIGHTED)  Overstory/Understory (MIXED)

3. Results
Example: Interaction between species: Hyytiälä

3. Results

→ Best statistical results for WEIGHTED and MIXED simulations

Grote et al. subm. (FORSYS)
Example: Interaction between species: Hyytiälä

Best dynamical results for WEIGHTED simulations

- Stand structure matters!
- ... and open questions still remain

Grote et al. subm. (FORSYS)
Major deficits considering long-term/one-generation modeling:

• Soil processes (mycorrhiza, phosphorus)  
  (LeRoux et al. 2001, Landsberg 2003, Hobbie 2006,  
  Fontes et al. 2010, McGuire & Treseder 2010)

• Acclimation, incl. Downregulation and long-term Damages  
  Hanson et al. 2004, Atkin et al. 2007, Leuzinger et al. 2011)

• Disturbances (i.e. fire, insects, management)  

➢ (Short-term) Interaction between species/species groups  
  (Moorcroft et al. 2003)
Physiologically-based models are not (yet) suitable for applications on long-term environmental changes.

Major progress can be expected with new model approaches that consider an ecosystem as multi-organismic and describe species interaction.
The End