DNDC and Its Applications

Changsheng Li
Institute for the Study of Earth, Oceans and Space
University of New Hampshire

DNDC stands for Denitrification and Decomposition, two processes dominating loss of N and C from soil into the atmosphere, respectively.

The DNDC model is a result of more than 10-year international efforts with researchers from the U.S., China, Germany, the U.K., Canada, Australia, New Zealand, the Netherlands, and Japan.

Input Parameters

1. Climate: - Daily air temperature and precipitation; - Solar radiation; - Atmospheric N deposition;
2. Soil: - Bulk density; - Texture (clay fraction); - Total organic C content; - pH;
3. Management: - Crop type and rotation; - Tillage; - Irrigation; - Fertilization; - Manure amendment; - Grazing.
Output

1. Crop: - Photosynthesis;
   - Respiration;
   - Water and N demands/uptake;
   - Biomass allocation;
   - Yield and litter production;
2. Soil: - Temperature, moisture, pH and Eh profiles;
   - SOC dynamics;
   - N leaching;
   - Emissions of N₂O, NO, N₂, NH₃, CH₄ and CO₂

Biogeochemical Model Predicts Impacts of Alternative Management on Crop Yield and Environmental Safety

INPUT

- Climate
  - Temperature
  - Precipitation
  - N deposition

- Soil properties
  - Texture
  - Organic matter
  - Bulk density
  - pH

- Management
  - Crop rotation
  - Tillage
  - Fertilization
  - Manure use
  - Irrigation
  - Grazing

PROCESSES

- Model:
  - Dynamics of soil water
  - N₂O, N₂, CH₄, CO₂ emissions
  - Growth of crop biomass
  - Competition
  - N leaching

OUTPUT

- Used by soil microbes
- Used by plants
- Growth of crop biomass
- Emissions of N₂O, NO, N₂, CH₄ and CO₂

Model Validation

Comparison on CO₂ emissions from a silty loam soil in a tilled and fertilized winter wheat field in Columbia, Missouri

100-year soil organic carbon dynamics at a winter wheat field with different treatments in a 1994-1999

80-year SOC dynamics at 3 plots with different crop rotations in the Morrow Plots, Urbana, IL, 1984-96
DNDC captured long-term SOC dynamics observed at four crop fields in China:
- Lianshui, Jiangsu
- Yucheng, Shandong
- Pingliang, Gansu
- Yueyang, Hunan

Two N2O peaks were caused by fertilization and rainfall at a grassland in England:
(FIELD data from Ryden 1983)
Low N₂O fluxes were measured at a grassland in Colorado. Both nitrate and DOC were limiting factors. (Field data from Mosier et al., 1996)

Two high peaks of N₂O flux were caused by fertilization at a corn field in Costa Rica, 1994. (Field data from Crill et al., 1999)

Low N₂O fluxes were measured at a grassland in Colorado. Both nitrate and DOC were limiting factors. (Field data from Mosier et al., 1996)

Two high peaks of N₂O flux were caused by fertilization at a corn field in Costa Rica, 1994. (Field data from Crill et al., 1999)

Comparison of Measured and Modeled N₂O Fluxes from 8 Agricultural Sites In the U.S., China, Germany, and Costa Rica

Low N₂O fluxes were measured at a grassland in Colorado. Both nitrate and DOC were limiting factors. (Field data from Mosier et al., 1996)

Two high peaks of N₂O flux were caused by fertilization at a corn field in Costa Rica, 1994. (Field data from Crill et al., 1999)

Comparison of Measured and Modeled N₂O Fluxes from 8 Agricultural Sites In the U.S., China, Germany, and Costa Rica

Low N₂O fluxes were measured at a grassland in Colorado. Both nitrate and DOC were limiting factors. (Field data from Mosier et al., 1996)

Two high peaks of N₂O flux were caused by fertilization at a corn field in Costa Rica, 1994. (Field data from Crill et al., 1999)

Comparison of Measured and Modeled N₂O Fluxes from 8 Agricultural Sites In the U.S., China, Germany, and Costa Rica

Low N₂O fluxes were measured at a grassland in Colorado. Both nitrate and DOC were limiting factors. (Field data from Mosier et al., 1996)

Two high peaks of N₂O flux were caused by fertilization at a corn field in Costa Rica, 1994. (Field data from Crill et al., 1999)

Comparison of Measured and Modeled N₂O Fluxes from 8 Agricultural Sites In the U.S., China, Germany, and Costa Rica

Low N₂O fluxes were measured at a grassland in Colorado. Both nitrate and DOC were limiting factors. (Field data from Mosier et al., 1996)

Two high peaks of N₂O flux were caused by fertilization at a corn field in Costa Rica, 1994. (Field data from Crill et al., 1999)

Comparison of Measured and Modeled N₂O Fluxes from 8 Agricultural Sites In the U.S., China, Germany, and Costa Rica

Low N₂O fluxes were measured at a grassland in Colorado. Both nitrate and DOC were limiting factors. (Field data from Mosier et al., 1996)

Two high peaks of N₂O flux were caused by fertilization at a corn field in Costa Rica, 1994. (Field data from Crill et al., 1999)
Application 1: Predicting mitigation options
Application 2: Regional Inventory

U.S. agricultural land emitted 876 Tg CO₂-C in 1990

U.S. agricultural land received 1153 Tg residue-C in 1990

U.S. Agricultural Land gained 460 Tg SOC in 1990

DNDC-Modeled C Storage in and Fluxes from Agricultural Land in the U.S. in 1990

<table>
<thead>
<tr>
<th></th>
<th>Cropland</th>
<th>Grassland and pasture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acreage (million ha)</td>
<td>141.2</td>
<td>204.5</td>
</tr>
<tr>
<td>C storage in 0-30 cm (Tg C)</td>
<td>7880.8</td>
<td>4135.7</td>
</tr>
<tr>
<td>Incorporated plant residue (Tg C)</td>
<td>331.7</td>
<td>821.4</td>
</tr>
<tr>
<td>Manure amendment (Tg C)</td>
<td>81.0</td>
<td>78.5</td>
</tr>
<tr>
<td>CO₂ emission (Tg C)</td>
<td>446.8</td>
<td>424.7</td>
</tr>
<tr>
<td>CH₄ emission (Tg C)</td>
<td>0.05</td>
<td>-0.83</td>
</tr>
<tr>
<td>DOC leaching (Tg C)</td>
<td>7.8</td>
<td>2.4</td>
</tr>
<tr>
<td>SOC change (Tg C)</td>
<td>-7.4</td>
<td>466.8</td>
</tr>
</tbody>
</table>