Modelling Water, Nitrogen and Carbon Fluxes during Decomposition of Crop Residues, Incorporated or left at the Soil Surface

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Introduction

• Global change:
  – carbon sequestration in agricultural land

• Reduced / no-tillage
  – change in crop residue localisation

  soil water dynamics
  nutrient distribution
  microbial activity

  Residue decomposition
  Fate of C, N in soil

• Soil column experiment
• Modelling
Experimental setup

- **Soil columns:**
  - Silt loam soil
    - sieved at 2 mm
    - compacted in columns (1.3 g/cm³; 25 cm, Ø 15 cm)
  - Oilseed rape residue
    - labelled $^{13}$C and $^{15}$N
    - particle size of 1 cm
    - incorporated (0-10 cm) or mulch
    - 14 g DM/column (equivalent 7.4 t/ha)

- **Incubation during 9 weeks at 20°C**
  - 3 dry-wet cycles
  - Rain applied with rain simulator: 2.5 h at 12 mm/h
Experimental setup

- Rain simulator
- Soil solution samplers
- Tensiometers
- TDR
- CO₂

Recous et al., this conference (n° 389)
Modelling

• **Why modelling?**
  – Interaction water dynamics ~ residue decomposition
  – Gross fluxes N-mineralization/immobilization
  – Scenario analysis
    • different rain applications
    • other crop residue quality

• **Which model?**
  – Link soil physical - biological processes
  – surface residue decomposition
  – simulation of $^{13}\text{C}$, $^{15}\text{N}$
Modelling: PASTIS model

- **PASTIS**: 1-dimensional, mechanistic model

- **module biotransformations C + N**
  - residue-C decomposition
    \[
    \frac{dC}{dt} = -K_i C_i f_T f_W f_N f_B
    \]
  (Garnier et al., 2003)

- **module transport**
  - water transfer
    \[
    \theta(t,z) \Rightarrow f_\theta(t,z)
    \]
  (Lafolie, 1991)
  - heat transfer
    \[
    T(t,z) \Rightarrow f_T(t,z)
    \]
  - solute transport
    \[
    [NO_3](t,z) \Rightarrow f_{[NO_3]}(t,z)
    \]
Modelling: C + N

Fresh Organic Matter (FOM)
- Rapidly decomposable material (RDM)
- Hemicellulose (HCE)
- Cellulose (CEL)
- Lignin (LIG)

Soluble Organic Matter (SOL)
- $K_1$
- $K_2$
- $K_3$
- $K_4$
- $H_1$
- $K_s$

Zymogenous Biomass (ZYB)
- $V_{max}$
- $N/C$

Humified Organic Matter (HOM)
- $K_h$

Autochtonous Biomass (AUB)
- $K_a$
Modelling: mulch decomposition

(Findeling et al., 2004)

Physical parameters
- initial mass of mulch
- max. mass in contact with soil
- min./max. water content
- max. rain interception
.....

Biological parameters
- quality = incorporation
- specific functions for
- Temperature
- Water content
- N availability

Soil

protected

decomposable

N_{inorganic}

Qc

Qnc

T_M, \theta_M
Modelling: concept

**Input**
- Constant temperature
- Hydrodynamic parameters
  - column control soil
- Biological parameters
  - incubation experiment

**Model**
- Initial conditions
- Boundary conditions

**Output**
- Water potential
- CO$_2$-flux
- NO$_3^-$-N
- residual $^{13}$C


Observation vs. Simulation

Soil water potential

Calibration: control columns
Same parameters for all treatments

- **Control**
  - Observation (-6 cm)
  - Simulation (-6 cm)
  - Observation (-14 cm)
  - Simulation (-14 cm)

- **Mulch**
  - Observation (-6 cm)
  - Simulation (-6 cm)
  - Observation (-14 cm)
  - Simulation (-14 cm)
Observation vs. Simulation

- **Control**
- **Water content mulch**
- **Incorporation**
- **Mulch**
Observation vs. Simulation

Residual oilseed rape-C

Incorp.: 55% C mineralized
Mulch: 18% C mineralized
**Observation vs. Simulation**

**NO$_3^-$-N (0-5 cm soil layer)**

- **Incorp.**: net N immobilization
- **Mulch**: net N mineralization

Measured NO$_3^-$-N:
- mineralization-immobilization, leaching + upward transport
Conclusion / Perspectives

• **Model**
  – interaction water / N-dynamics

• **Improvements for**
  – initial rate of C-mineralization
  – mulch decomposition
    • transport of nitrate, soluble C from mulch

• **Perspectives**
  – effect of residue quality
  – scenario analysis