Introduction

- Numerical simulations of water flow and urea-ammonium-nitrate reactions and transport can improve our understanding of the processes in the vadose zone.

- HYDRUS codes have been successfully used to simulate fertigation and transport of nitrogen.

- Lysimeters are also used as a tool for evaluating solute transport models, and to monitor the fate and mobility of contaminants.

Materials and methods

- One zero tension lysimeter was installed at each location at depth of 50 cm (L1, L2, L3, L4).
- Soil hydraulic properties were assessed (particle size distribution, water retention, bulk densities, water content).
- Water outflows (samples) were collected from lysimeters.
- Nitrate concentration was determined with a continuous flow analyzer San+ (Skalar).
- Groundwater level was measured on a daily basis (Orphimedes lymnigraphs).
- Crop production was monitor (date of sowing and harvest, amounts and type of fertilizer application, date of application).

Main focus

I. Four zero-tension plate lysimeters were tested experimentally in heavier types of soils (silty clay) during the 4 year period (2007 – 2010).

II. Efficiency of zero-tension plate lysimeters to collect soil water samples and to assess soil water regime and nitrate leakage in soils influenced by high groundwater table were evaluated.

III. The ability of HYDRUS-2D to reproduce observed water and nitrate outflows (collected by lysimeters) was assessed.

Note: Results were published by Filipović et al. (2013). Here the data for 2010 is presented.
Scheme and installation of zero tension lysimeter

- Soil types were silty clay (influenced by high groundwater table)

Soil hydraulic functions were described using the van Genuchten–Mualem model (van Genuchten 1980)

\[
\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{\left(1 + \left|h / \theta_s\right|^n \right)^m} \quad \text{for } h < 0
\]

\[
\theta(h) = \theta_s \quad \text{for } h \geq 0
\]

\[
K(h) = K_s S_h^2 \left(1 - \left(1 - S_h^2 \right)^m \right)^2
\]

\[
S_h = \frac{\theta - \theta_r}{\theta_s - \theta_r}
\]

\[
m = 1 - \frac{1}{n}; \quad n>1
\]

Measured Soil hydraulic parameters

<table>
<thead>
<tr>
<th>Location</th>
<th>Depth (cm)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
<th>Bulk density (g cm(^{-3}))</th>
<th>(\Theta_s) (cm(^3) cm(^{-3}))</th>
<th>(K_s) (cm day(^{-1}))</th>
<th>(\alpha) (cm(^{-1}))</th>
<th>(n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>0-40</td>
<td>13</td>
<td>65</td>
<td>22</td>
<td>1.59</td>
<td>0.38</td>
<td>11</td>
<td>0.00261</td>
<td>1.17607</td>
</tr>
<tr>
<td></td>
<td>40-75</td>
<td>4</td>
<td>63</td>
<td>33</td>
<td>1.57</td>
<td>0.37</td>
<td>15</td>
<td>0.00263</td>
<td>1.17177</td>
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<tr>
<td>L2</td>
<td>0-30</td>
<td>9</td>
<td>67</td>
<td>24</td>
<td>1.56</td>
<td>0.36</td>
<td>17</td>
<td>0.0018</td>
<td>1.26197</td>
</tr>
<tr>
<td></td>
<td>30-75</td>
<td>2</td>
<td>61</td>
<td>37</td>
<td>1.55</td>
<td>0.37</td>
<td>12</td>
<td>0.00017</td>
<td>1.25264</td>
</tr>
<tr>
<td>L3</td>
<td>0-40</td>
<td>6</td>
<td>60</td>
<td>34</td>
<td>1.49</td>
<td>0.37</td>
<td>14</td>
<td>0.00158</td>
<td>1.20382</td>
</tr>
<tr>
<td></td>
<td>40-90</td>
<td>6</td>
<td>60</td>
<td>34</td>
<td>1.55</td>
<td>0.38</td>
<td>9</td>
<td>0.00285</td>
<td>1.18177</td>
</tr>
<tr>
<td>L4</td>
<td>0-30</td>
<td>5</td>
<td>54</td>
<td>41</td>
<td>1.37</td>
<td>0.42</td>
<td>12</td>
<td>0.00136</td>
<td>1.19612</td>
</tr>
<tr>
<td></td>
<td>30-70</td>
<td>3</td>
<td>54</td>
<td>43</td>
<td>1.55</td>
<td>0.41</td>
<td>14</td>
<td>0.00212</td>
<td>1.17585</td>
</tr>
</tbody>
</table>
Precipitation from 2007 till 2010 (30 years average 681 mm)

Groundwater level (PH) measurement on two Lymigraphe from 2007 till 2010

### Agricultural production monitoring

Crop, sowing, harvest and fertilizer application

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Crop</th>
<th>Sowing date</th>
<th>Harvest date</th>
<th>Application date</th>
<th>Fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L3</td>
<td>Corn</td>
<td>04.05.2010.</td>
<td>10.10.2010.</td>
<td>04.05.2010.</td>
<td>NPK 15:15:15 700 kg/ha, UREA 180 kg/ha</td>
</tr>
<tr>
<td></td>
<td>L4</td>
<td>Corn</td>
<td>01.05.2010.</td>
<td>03.10.2010.</td>
<td>01.05.2010.</td>
<td>NPK 15:15:15 600 kg/ha, UREA 180 kg/ha</td>
</tr>
</tbody>
</table>

### Boundary conditions

- **WF:** Calculated final pressure head distributions were used as initial conditions for following year in all simulated scenarios.
- **ST:** The initial ammonium and nitrate contents in soils were set as nitrogen concentrations in soil water (expressed in mmol cm\(^{-3}\)) for each specie.

### Mathematical description of water flow and solute transport

The Richards equation, which describes isothermal Darcian flow in a variably saturated rigid porous medium, was used in the model:

\[
\frac{\partial \theta(h)}{\partial t} = \frac{\partial}{\partial x_j} \left[ k(h) \left( \frac{\partial h}{\partial x_j} + k' \right) \right] - S(h)
\]

The partial differential equations governing nonequilibrium chemical transport of solutes involved in a sequential first-order decay chain were used for each solute specie:

**UREA:**

\[
\frac{\partial c_1}{\partial t} = \nabla (D \nabla c_1) - \nabla (qc_1) - \mu_a c_1 - S_w c_1
\]

**Ammonium:**

\[
\frac{\partial c_2}{\partial t} + \frac{\partial S_a}{\partial t} = \nabla (D \nabla c_2) - \nabla (qc_2) - \mu_v c_2 + \mu_0 c_2 + \mu_a c_1 - S_w c_2
\]

**Nitrate:**

\[
\frac{\partial c_3}{\partial t} = \nabla (D \nabla c_3) - \nabla (qc_3) + \mu_v c_2 - S_w c_3
\]
**Water flow modeling**

Observed cumulative outflows from lysimeters in 2010 and simulated ones using HYDRUS-2D.

**Solute (nitrate) transport**

Observed cumulative nitrate outflows from lysimeters in 2010 and simulated ones using HYDRUS-2D.

Simulated pressure heads within the two-dimensional transect—lysimeter 4, 2010, day 71 (a—left) and 152 (b—right).

Simulated nitrate concentration within the two-dimensional transect—lysimeter 4, 2010, day 200.
Conclusions

The efficiency of zero-tension plate lysimeters to collect soil water samples and to assess soil water regimes and nitrate leakage in soils influenced by the groundwater table was evaluated in this study.

- Low efficiency during the vegetation period was mostly caused by high plant water demand and possible water diversion into the sides when the groundwater table was low.
- The simulated water and nitrate outflows showed that water regime was dominantly influenced by groundwater table.
- The water diversion from the plate and no water discharge through the lysimeter were obtained when groundwater table was low.
- The outflows were simulated only when soil above the plate was saturated from below and/or during intensive rainfall.

- Nitrate outflows reflected simulated water outflow and actual nitrate concentrations above the lysimeter plate.
- The lysimeter plate acted as a barrier for water flow and also solute transport.
- The HYDRUS-2D was able in some degree to reproduce observed water and nitrate outflows.
- Our results indicate that HYDRUS can be very helpful for estimating water flow and nitrate dynamics under real field conditions.

Thank You for your attention!