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MODELLING ROOT DISTRIBUTION AND ROOTING DEPTH TO ANALYSE CROP N EXPLORATION FROM DIFFERENT SOIL DEPTHS

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Abstract

Background
Plant soil and atmosphere models are commonly used to predict crop yield and environmental consequence. Such models often include complex modelling modules for water movement, soil organic matter turnover and, above ground plant growth. However, the root modelling in these models are often very simple, partly due to a limited access to experimental data. We present a two-dimensional model for root growth and proliferation. The model focuses on annual crops, and attempt to model root growth of the crops and its significance for N uptake from different parts of the soil volume.

Methods
Root parameters in the model are based on field trials where root depth, root distribution, above ground dry matter and N content has been monitored. In many models it is assumed that distribution of roots can be described by an exponential function. A way to modify this function to make more realistic root simulations is to include a form parameter, which makes it possible to changes the distribution of root length density in soil profile.

Results
It is possible to model variable root distribution and estimate N uptake from different soil depths. The proposed model can simulate a rage of crop species as cereals and vegetables and even crops growing in rows will be modelled.

Conclusion
By modifying the function of root distribution together with root development in width and depth it is possible to estimate crop N uptake, also for row crops. The model is a tool to increase nitrogen use efficiency in crop rotations. The model predicts the depth of N left in the soil, and indicates whether N is available at larger soil depths, which may be taken up by deep-rooted crops or catch crops.

Modelling root distribution and nitrogen uptake

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Background / New challenges

Plant soil and atmosphere models are commonly used to predict crop yield and environmental consequence. Such models often include complex modelling of water movement, soil organic matter turnover and, above ground plant growth. However, the root modelling in these models is often very simple, partly due to a limited access to experimental data. We present a two-dimensional model for root growth and proliferation in row crops. The model focuses on annual crops, and attempt to model root growth of the crops and its significance for N uptake from different parts of the soil volume.

Generally depth distribution of root density have been simulated by logarithmic functions. This seem to simulate the root systems of grasses and cereals reasonably well. However, many dicotyledoneous crops show very different root distribution patterns, with higher root density at deeper soil layers than can be simulated by logarithmic equations (figure 1). The depth distribution of these root systems seem to vary strongly with crop age and other factors, and we have too little basis for introducing new functions which can simulate these distributions. Therefore, we have adjusted the logarithmic function, to allow it to simulate a larger fraction of the root system is found in the deeper soil layers (figure 2).

Field study

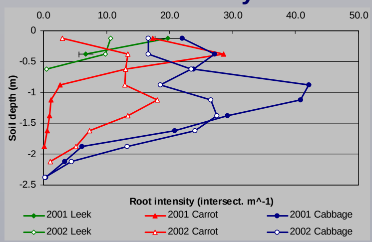


Figure 1: Example of vegetable root distribution from two years of field study at DIAS Aarslev, Denmark. Leek, beetroot and cabbage root proliferation were studied by minirhizotrons. Root intensity are measured by counting root intersections with lines on minirhizotron surface.

Model study

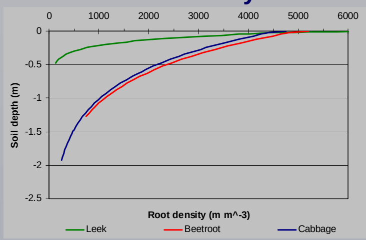


Figure 2: Predicted root density for Leek, beetroot and cabbage. In this simulation all crops have the same root biomass but different root penetration rate, maximum depth and form parameter. Beetroot and cabbage have been simulated with the same form parameter into depth, whereas a higher value was used for leek to simulate the observed distribution (Figure 1). Leek has a higher specific root length.

Tools

Root parameters in the model are based on field trials where root depth, root distribution, above ground dry matter and N content has been monitored. Preliminary simulation in two dimension has been worked out in Microsoft Excel and using the soil crop simulation model Daisy. Soil processes are simulated in 5 X 5 cm grids. Equations used to simulate vertical and horizontal root development are shown in eq. 1. The same equation is used for both directions, but with separate values for z_{max}. Root density is calculated by eq. 2, here the formfactor "a" determining the distribution of the root density in the soil profil. Eq. 3 shows potential nitrogen uptake and eq. 4 the actual uptake in even soil unit.

$$eq.1\ R_z = \begin{cases} 0 & ;\ \sum T \le T_{lag} \\ \sum T - T_{lag} * k_r + z_{\min} & ;\ \sum T > T_{lag} \\ z_{\max} & ;\ \sum T - T_{lag} * k_r + z_{\min} > z_{\max} \end{cases}$$

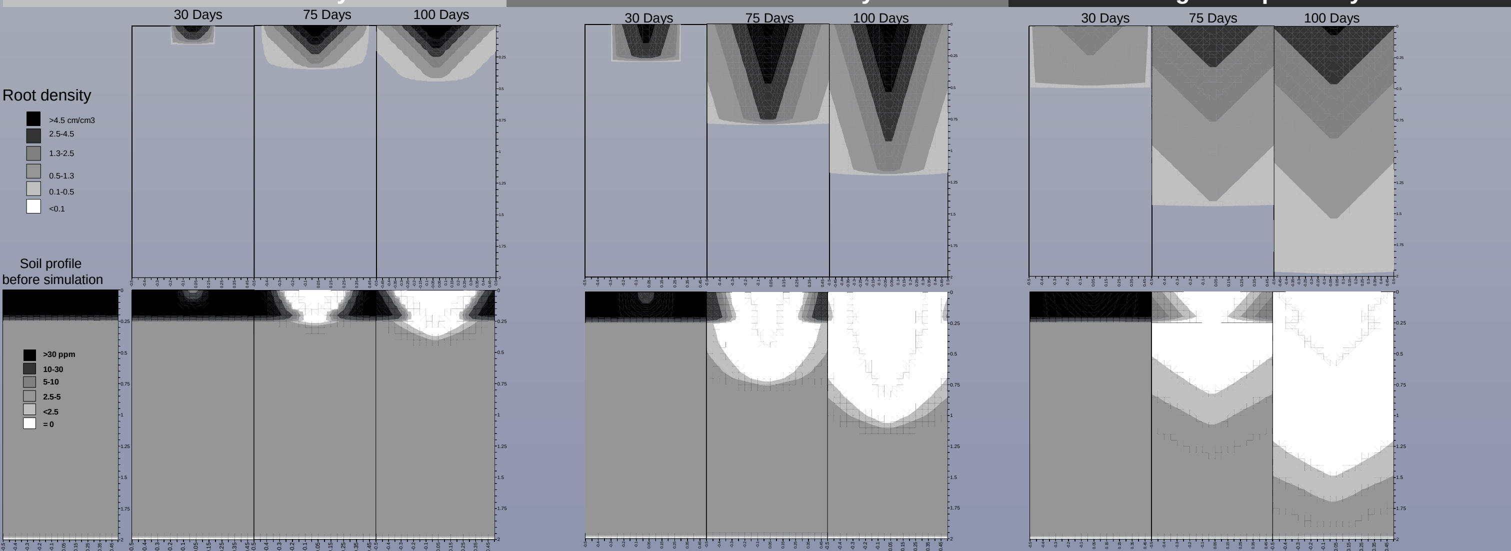
$$eq.2\ L_z = \begin{cases} L_0 e^{(-a*z)} & ;\ z < R_z \\ 0 & ;\ z > R_z \end{cases}$$

$$eq.3\quad \text{potential nitrogen uptake} = L * r_N * [N\min]$$

$$eq.4\quad \text{actual nitrogen uptake} = \frac{pot.uptake * demand}{\sum pot.uptake}$$

R_z: root depth/width, T: Temperature, T_{lag}: lagfase, k_r: Root pentration rate into depth/width, z_{min}: start depth, Z_{max}: Maximum root depth / width, L_z: Root density at soil depth z, L_0: Root density at soil surface, a: formfactor, Z: current root depth, r_N N uptake rate, L root length, [Nmin] soil mineral N concentration.

Leek: Shallow root system	Beetroot: Medium root system	Cabbage: Deep root system



Leek
Slow and shallow root growth compared to beetroot and cabbage. Root depth is normally 0.5 m. Slow horizontal root growth, and much lower root intensity between crop rows than under the crop rows. Low N uptake between rows and below 0.5 m.

Beetroot
Rooting depth development is intermediate compared to cabbage and leek, and limited horizontal root growth. Root depth is normally 1.5 m. Beetroot deplete for N more efficiently under the crop row then between the rows.

Cabbage
Rapid root development and proliferation of roots vertically as well as horizontally. Strong N depletion of the whole soil profile. Root depth can be 2.5 m or more. Cabbage had a higher N-uptake capacity then carrot and leek.

Conclusions / End gaols

By improving the equation for root density distribution we will try to comply with field data for other crop species than cereals such as vegetable crops. By a improved simulation of root development and distribution in deeper soil layer the models will be better to predict nitrogen uptake and residual nitrogen left for succeed crops or leaching. The work on this model will be used as part of the crop model development in EU project "EU-Rotate_N" and in a project under the Danish Research Centre for Organic Farming (DARCOF).

EU-Rotate_N

EU-Rotate_N
European Community network to develop a model based decision support system to optimise nitrogen use in horticultural crop rotations across Europe
http://www.hri.ac.uk/eurotate/index.htm

Danish Research Centre for Organic Farming
Interactions between nitrogen dynamics, crop production and biodiversity in organic crop rotations analysed by dynamic simulation models (BIOMOD) http://www.darcof.dk