Technische Universität Braunschweig

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Modeling Phytoremediation by Mangroves

Otto Richter[1], Hoang Anh Nguyen[1,2] and Van Phuoc Nguyen[2]

[1]Institute of Geoecology, University of Technology Braunschweig, Germany,
[2]Institute for Environment & Resources, HCM-City, Vietnam
[1]o.richter@tu-bs.de

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Subproject 5 “The role of mangrove ecosystems for pollutant reduction”

Institut für Geoökologie
Abteilung für Umweltsystemanalyse

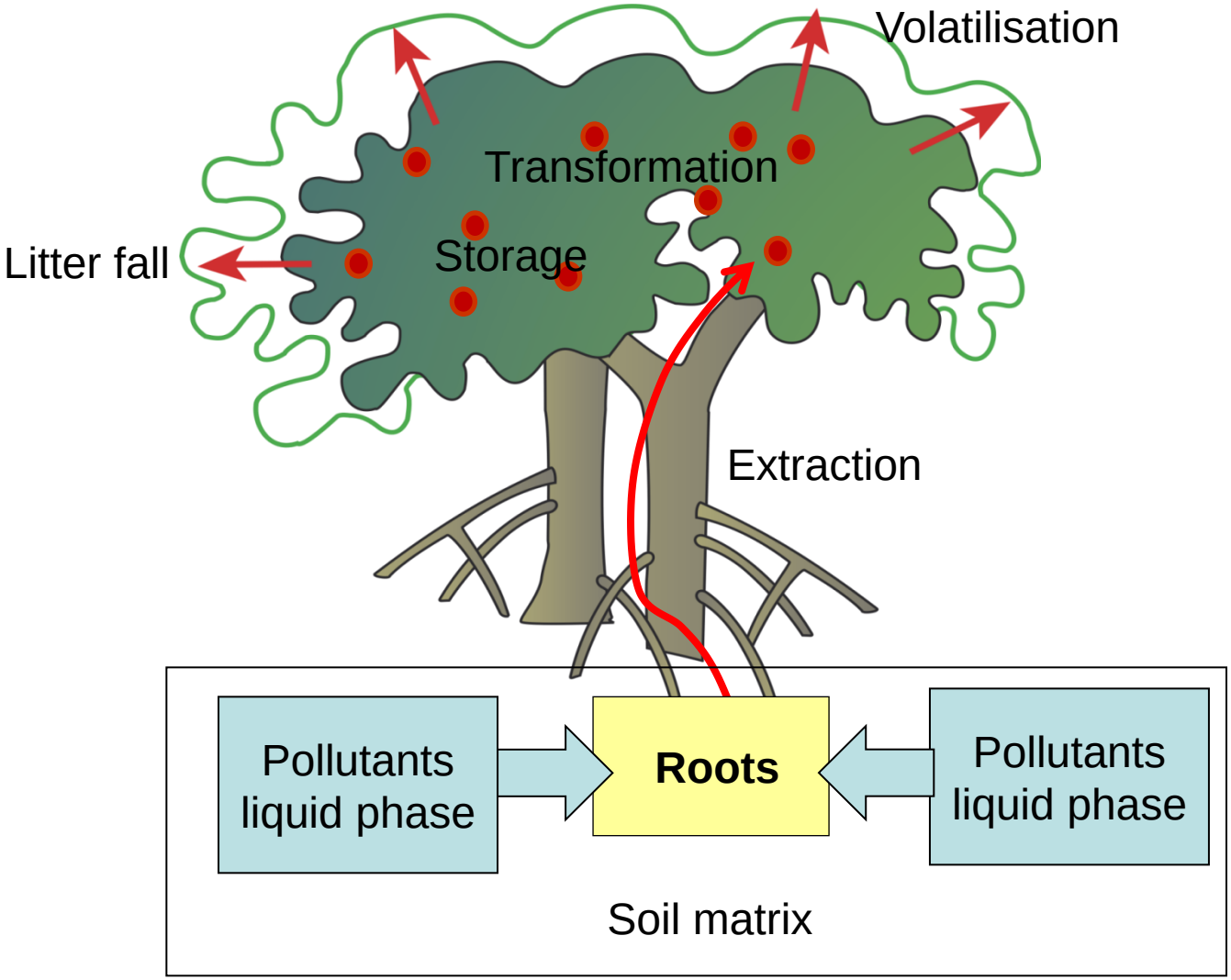
Introduction

- Mangrove forests provide means for immobilization and removal of pollutants in tidal zones of river estuaries.
- Objective of the model is the quantification of this remediation potential.
- The numerical study is part of a large experimental effort for estimating model parameters.

This is a typical multiphysics problem comprising

- Porous media flow of water and pollutants in soil
- Ascendent flow of water and pollutants based on cohesion tension theory
- Stomatal controlled evaporation in the canopy as driving force

Conceptual model

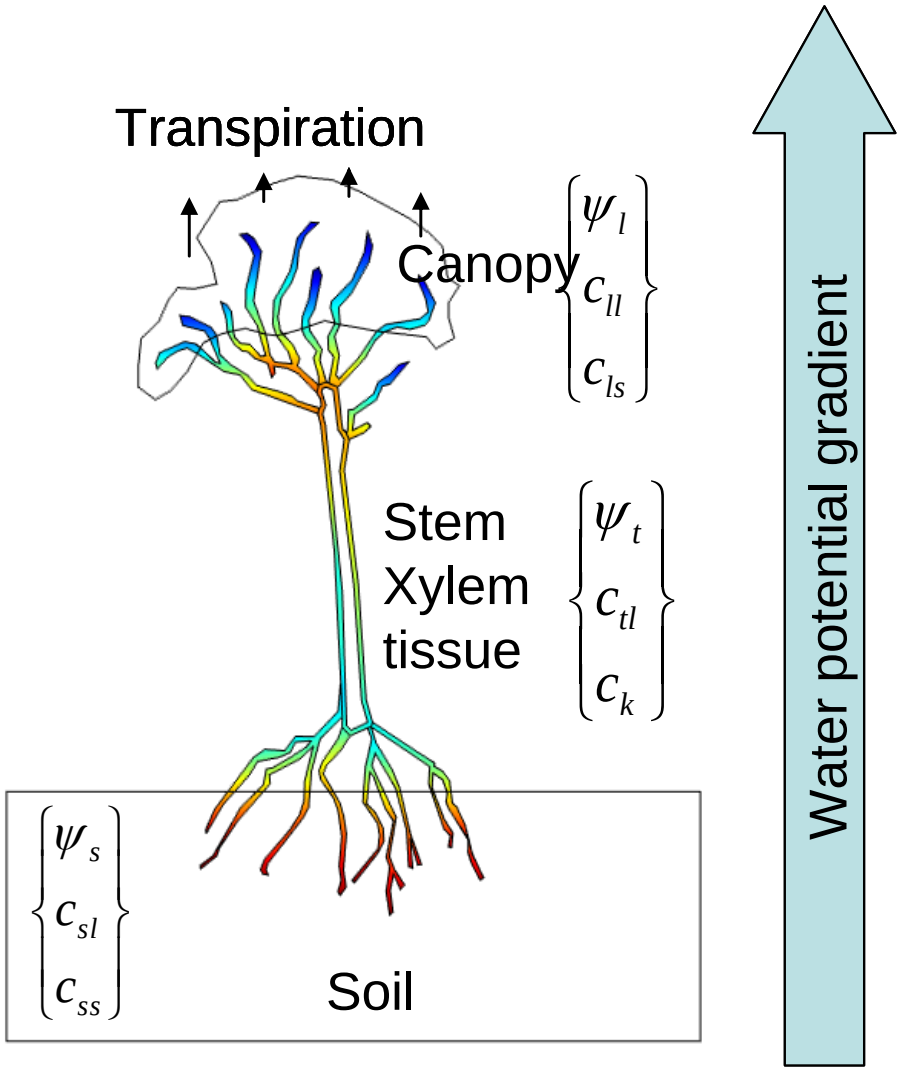


Cohesion tension concept

ψ_i water potential in compartment „i“

C_{il}: concentration liquid phase

C_{is}:concentration solid phase



General form of equations

$$C_i(\psi_i)\frac{\partial \psi_i}{\partial t} = \nabla \cdot K_i(\psi_i)\nabla(\psi_i - z)$$

Water potential

capacity

Hydraulic conductivity

Gravitation potential

$$\frac{\partial(\theta c_{li})}{\partial t} = \nabla \cdot (\overline{\overline{D}}\nabla c_{li} - \vec{q}_i c_{li}) - k_{des}(K_i c_{li} - c_{si})$$

Concentration in liquid phase

Water content

Dispersion tensor

Convection

Sorption and desorption

$$\frac{\partial}{\partial t} c_{si} = k_{des}(K_i c_{li} - c_{si})$$

Concentration in solid phase

Sorption and desorption

$$\nabla = (\partial_x, \partial_y, \partial_z)$$

Canopy

Canopy is conceived as continuum characterized by its leaf area density function

$$C_l(\psi_l)\frac{\partial \psi_l}{\partial t} = \nabla \cdot K_l(\psi_l)\nabla(\psi_l - z)$$

$$- E(v, T, PAR, VPD, \psi_l, \psi_{air})$$

Transpiration losses as function of wind speeed v, temperature T, photosynthetic active radiation PAR, vapor pressure deficit VPD, leaf water potential ψ_l and air water potential ψ_{air}

Transpiration submodel

leaf area density

saturation specific humidity at temperature T_l

$$E = \frac{\rho_{air}}{\rho_w} \alpha(\vec{x}) b(z) u(z) (q_s(T_l(z)) - q_a(z))$$

transpiration rate

wind speed

$$b(z) = \frac{ch}{1 + ch \frac{\rho_{air}}{g_s} u(z)}$$

bulk transfer coefficient for latent heat

$$g_s = g_{\max} f_1(PAR) f_2(T) f_3(VPD) f_4(\psi_l)$$

stomatal conductance

$$f_1(PAR) = \frac{PAR}{PAR + \frac{g_{\max}}{a_s}}$$

$$f_2(T) = \left(\frac{T - T_n}{T_0 - T_n}\right)\left(\frac{T_x - T}{T_x - T_0}\right)^{(T_x - T_0)/(T_0 - T_x)}$$

$$f_3(VPD) = \frac{1}{1 + \beta VPD}$$

$$f_4(\psi_l) = \frac{1}{1 + \left(\frac{\psi_l}{\psi_c}\right)^2}$$

Boundary conditions

Flow between adjacent compartments (internal boundary conditions)

$$F_{ij} = K_{ij}(\psi_i - \psi_j)$$ water flow

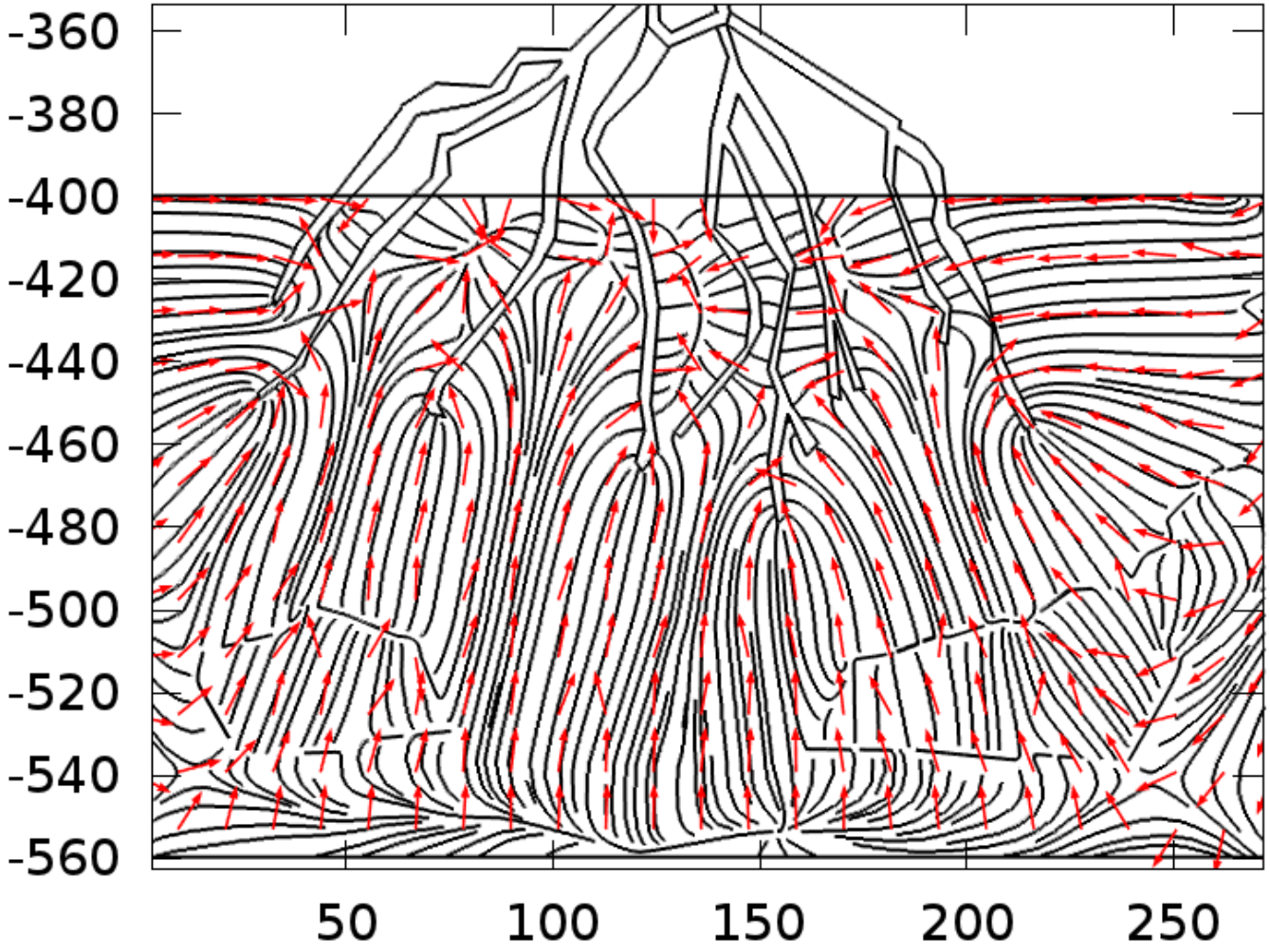
$$J_{ij} = \kappa_{ij}(c_i - c_j)$$ matter flow

Exchange with the environment (external boundary conditions)

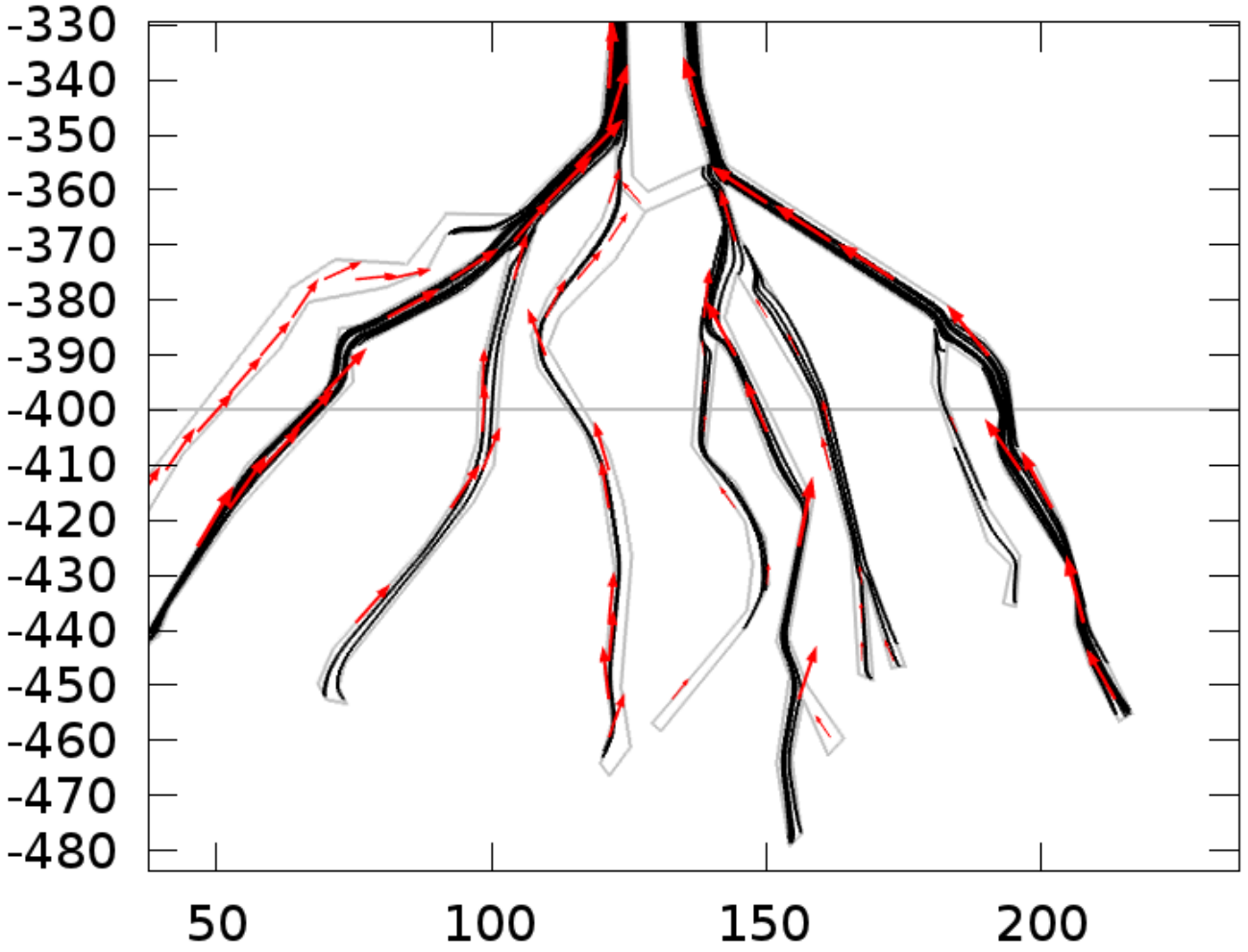
$$K_s(\psi_s)\nabla(\psi_s - z)\Big|_{soil\ surface} = v(t)$$ Infiltration of water

$$D\nabla c_{sl} - \vec{q}c_{sl}\Big|_{soil\ surface} = v(t)\,c_0$$ Infiltration of substance

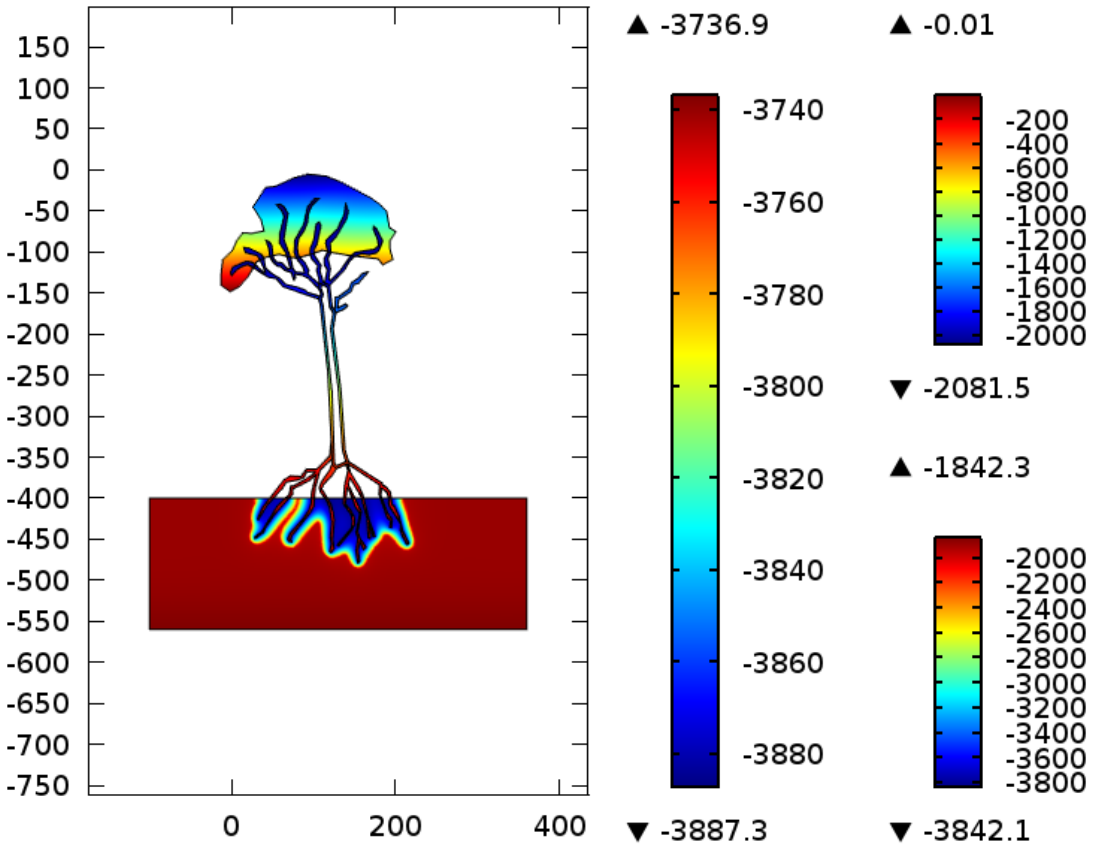
Streamlines in the root zone



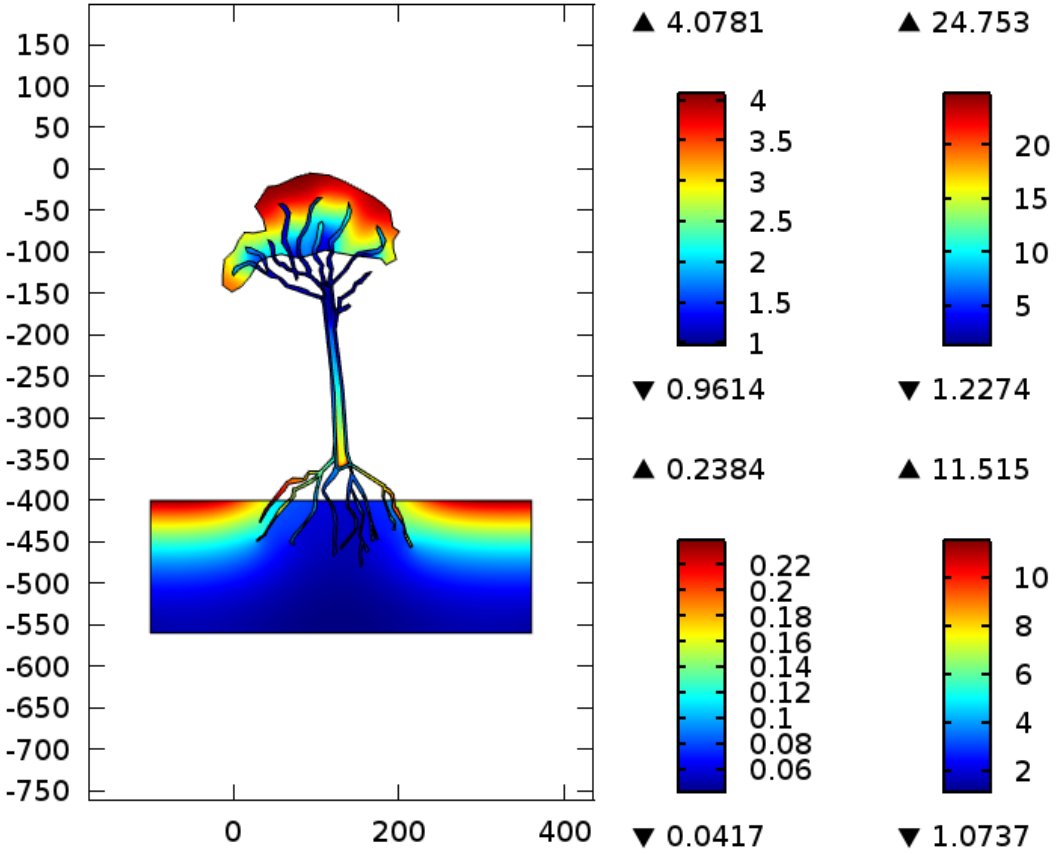
Streamlines in xylem



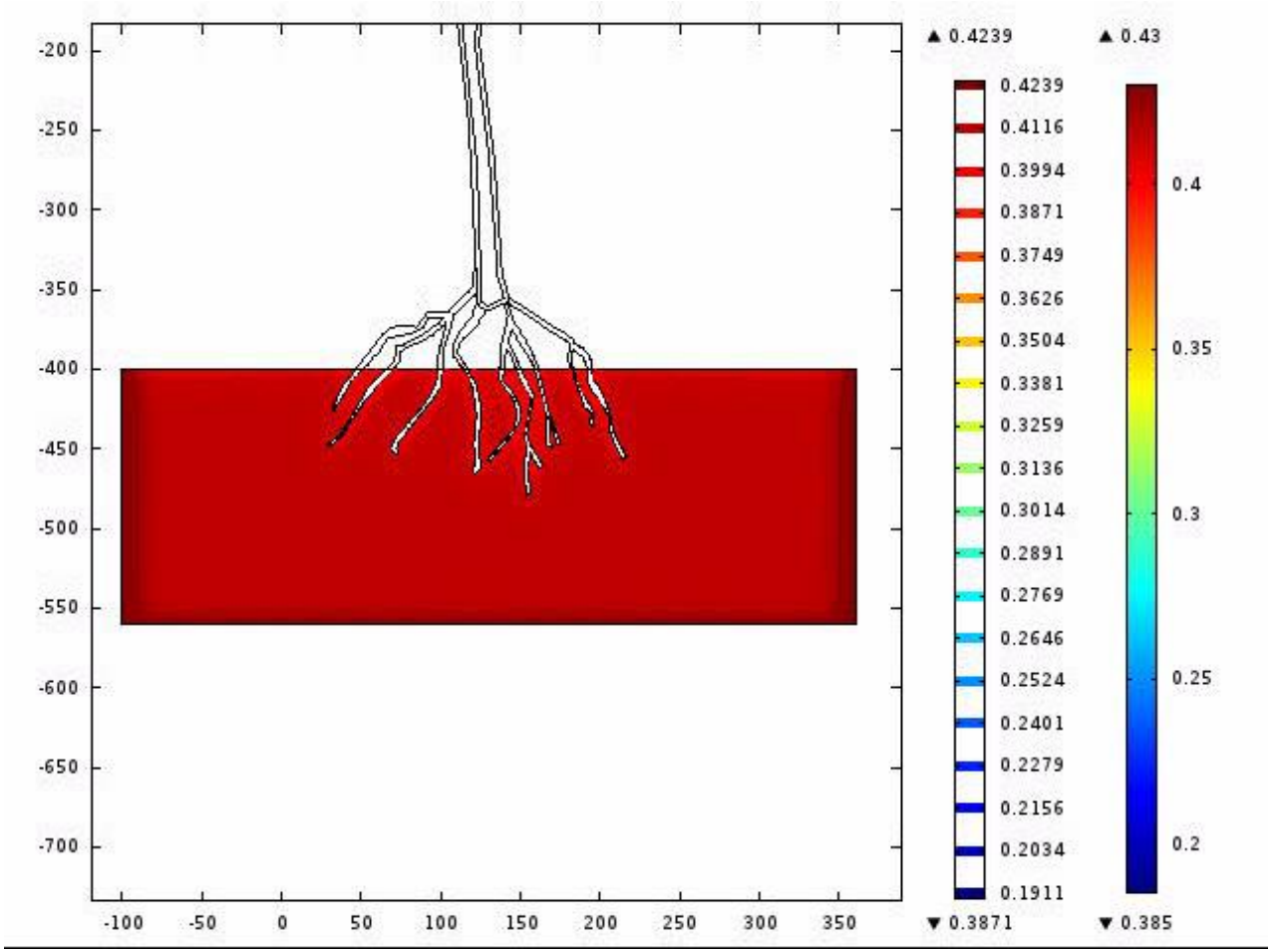
Water potential



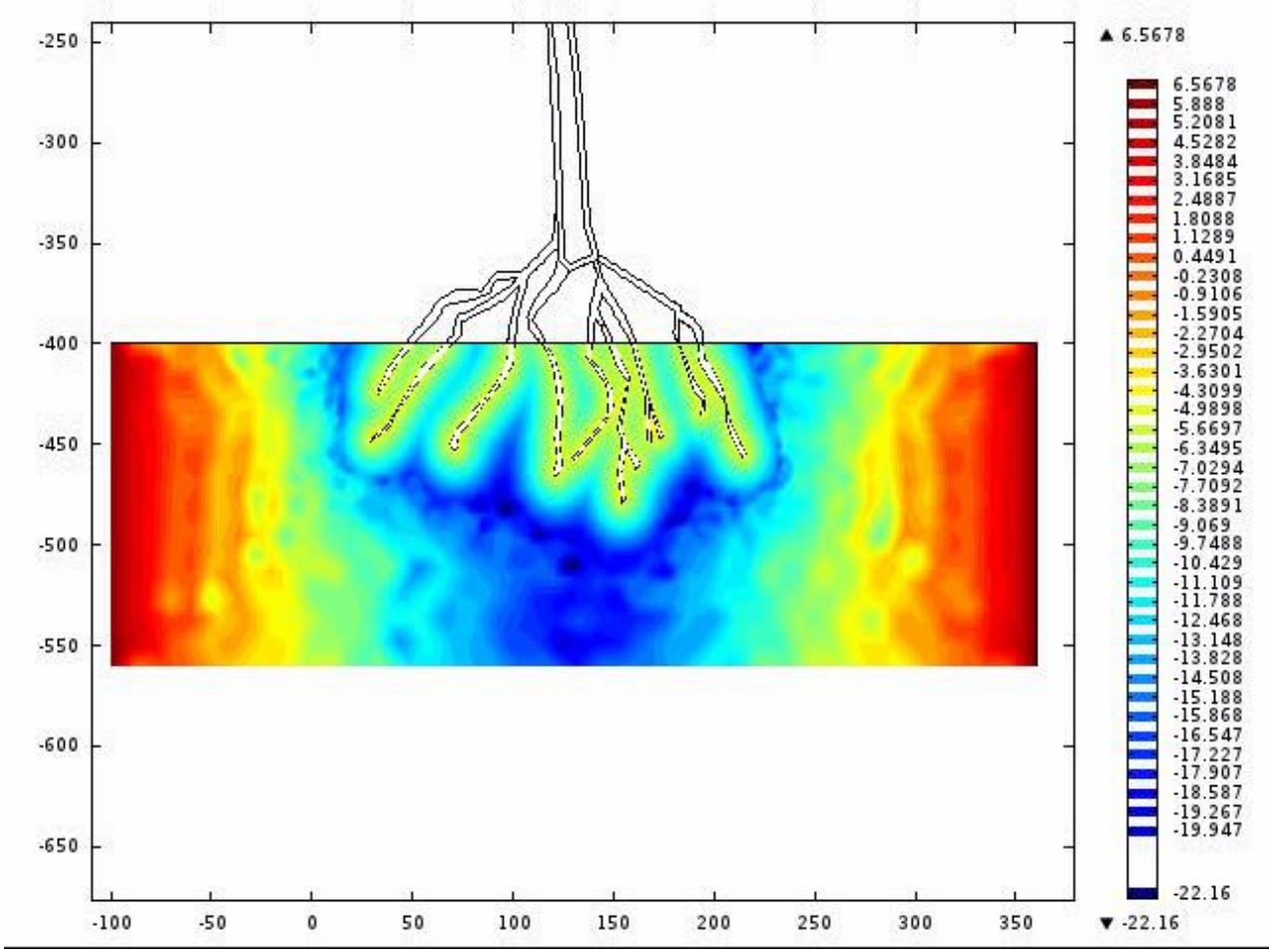
Concentration of pollutant



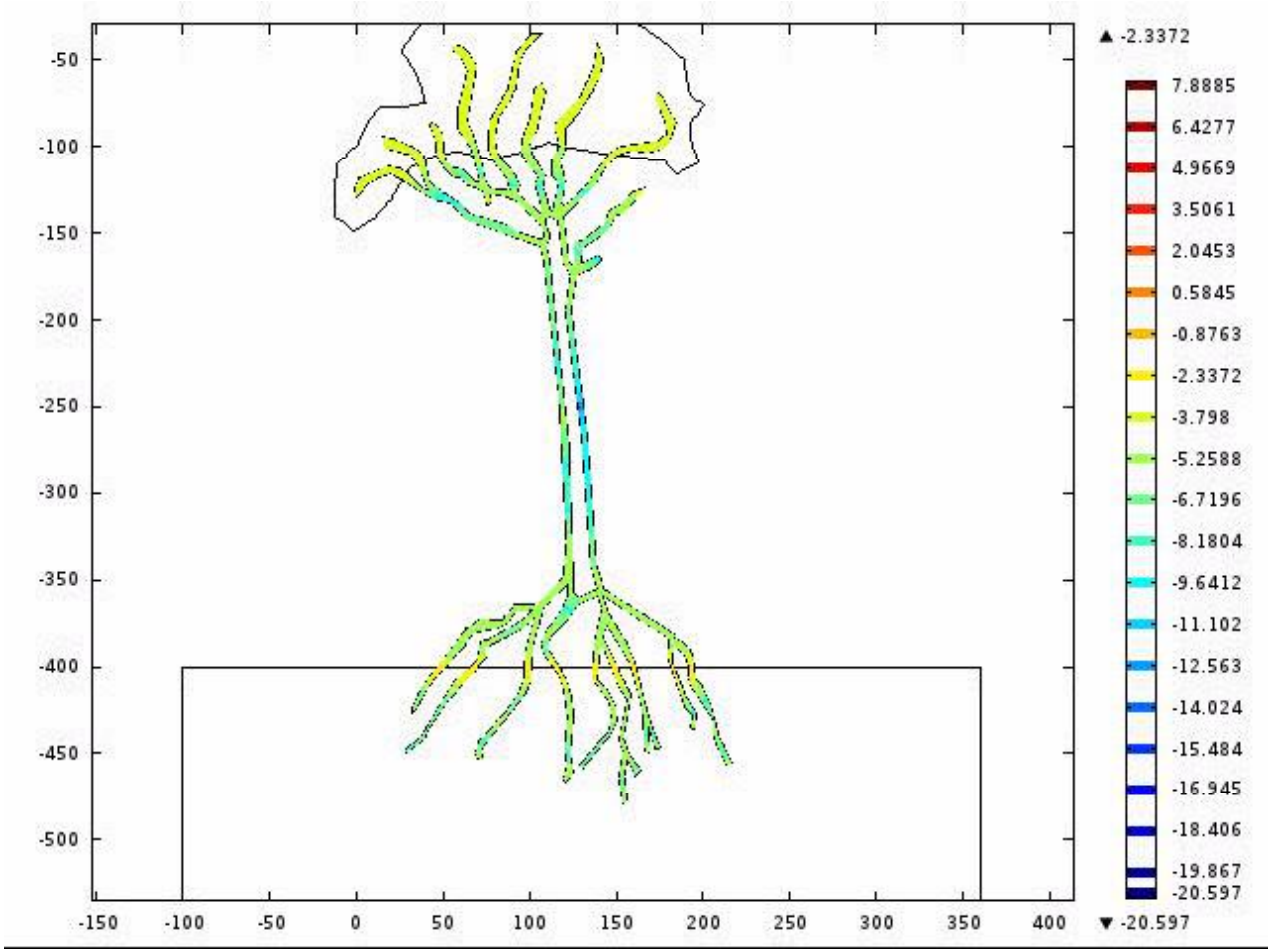
Water content in soil



Pollutant in soil

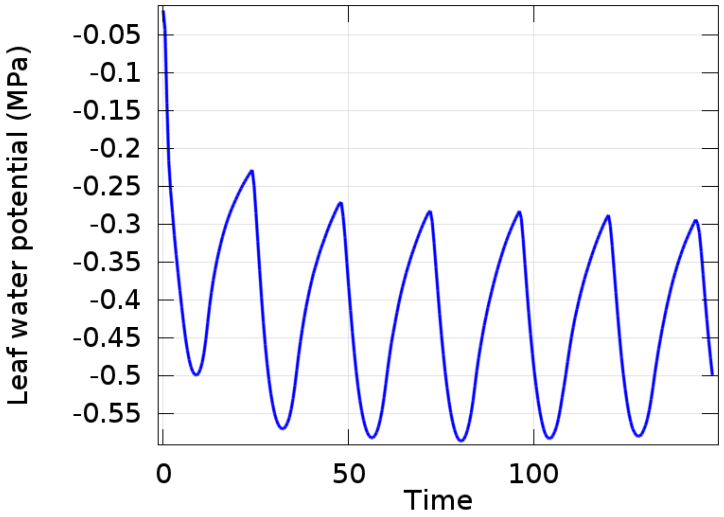


Pollutant in xylem

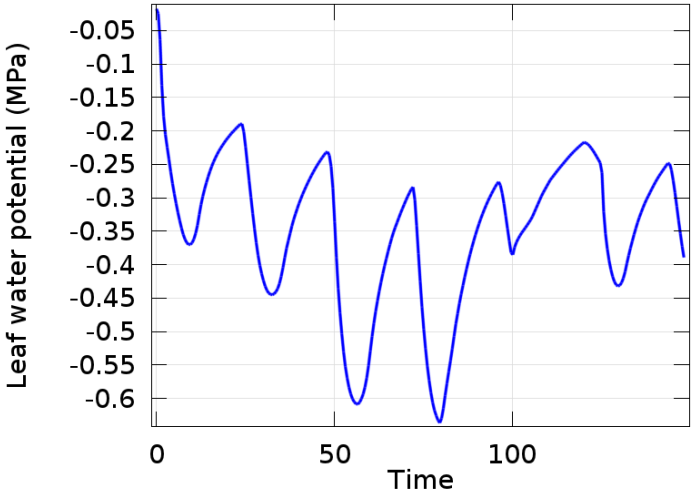


Variation of leaf water potential

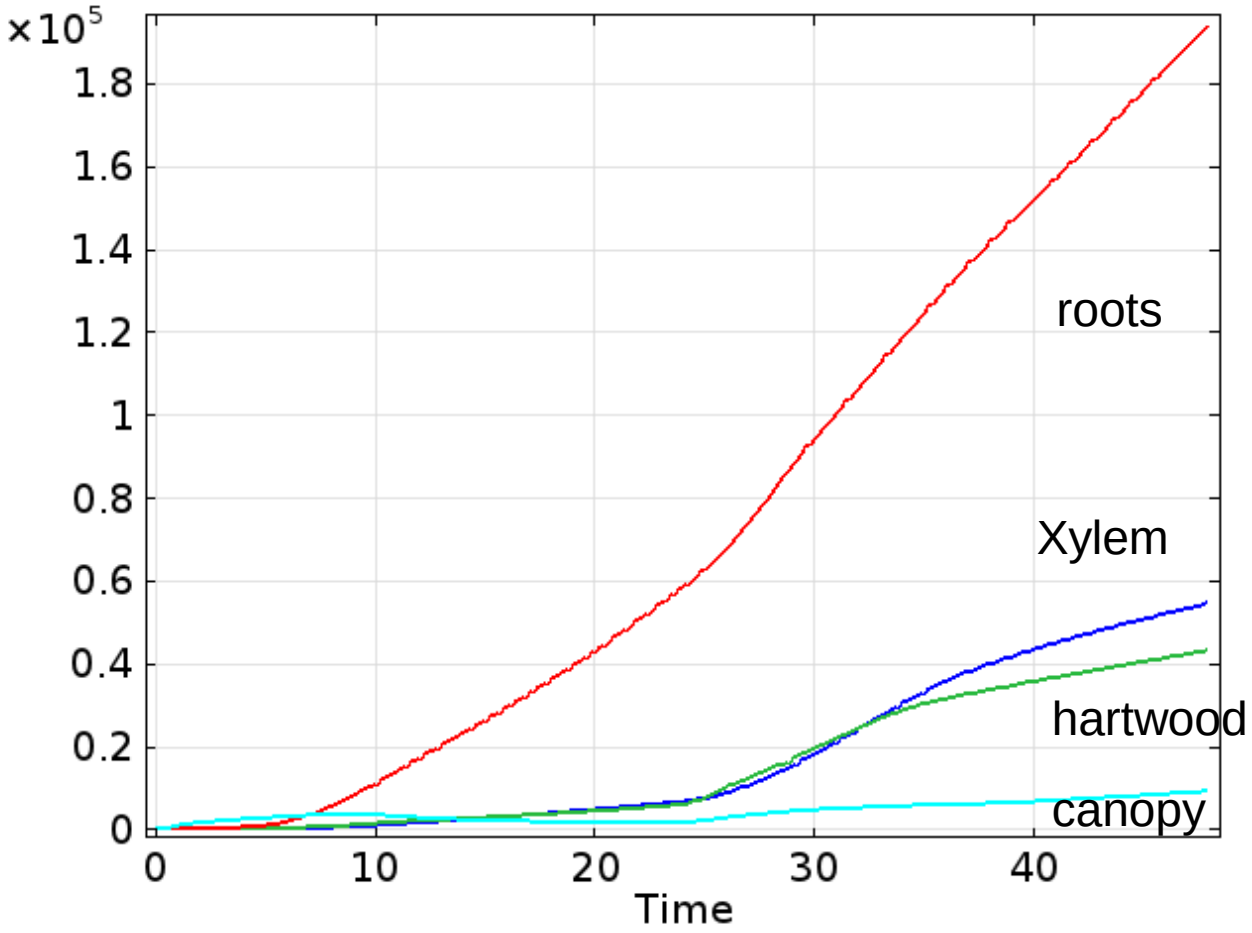
Uniform wind velocity



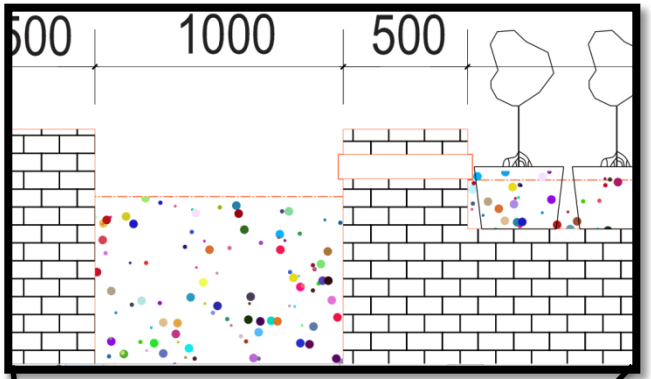
Varying wind velocity

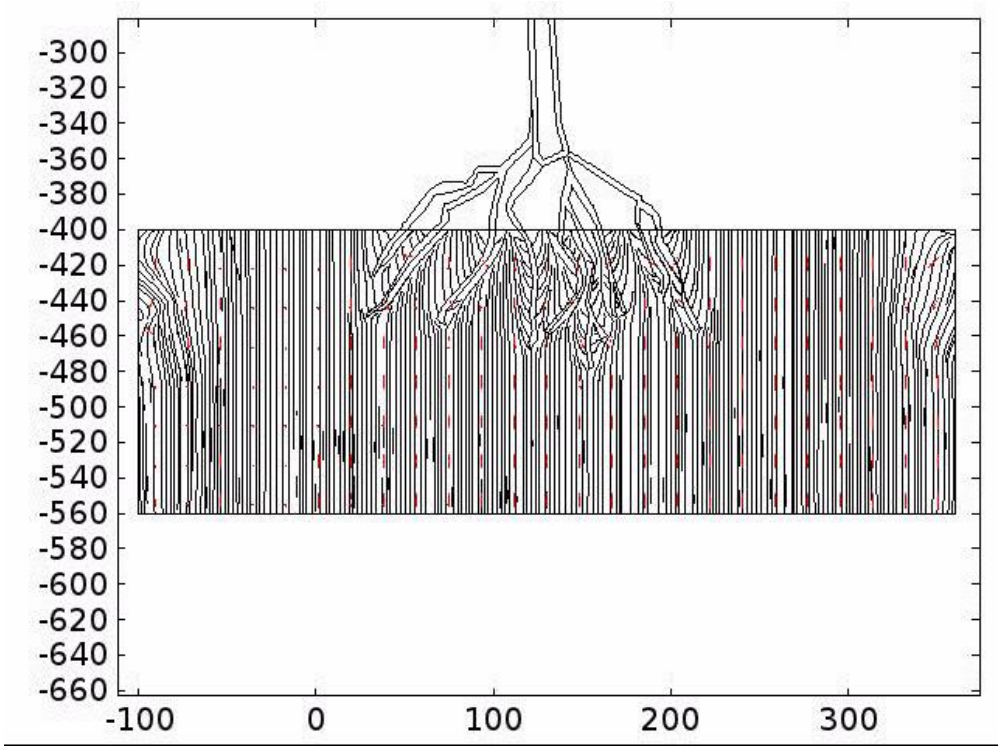


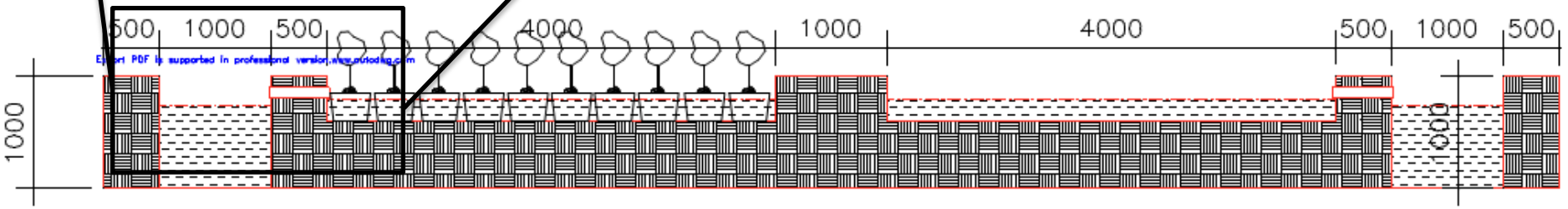
Surface Integrals of concentrations



Experimental Desidn








Thank you for your attention!

Conceptual Model