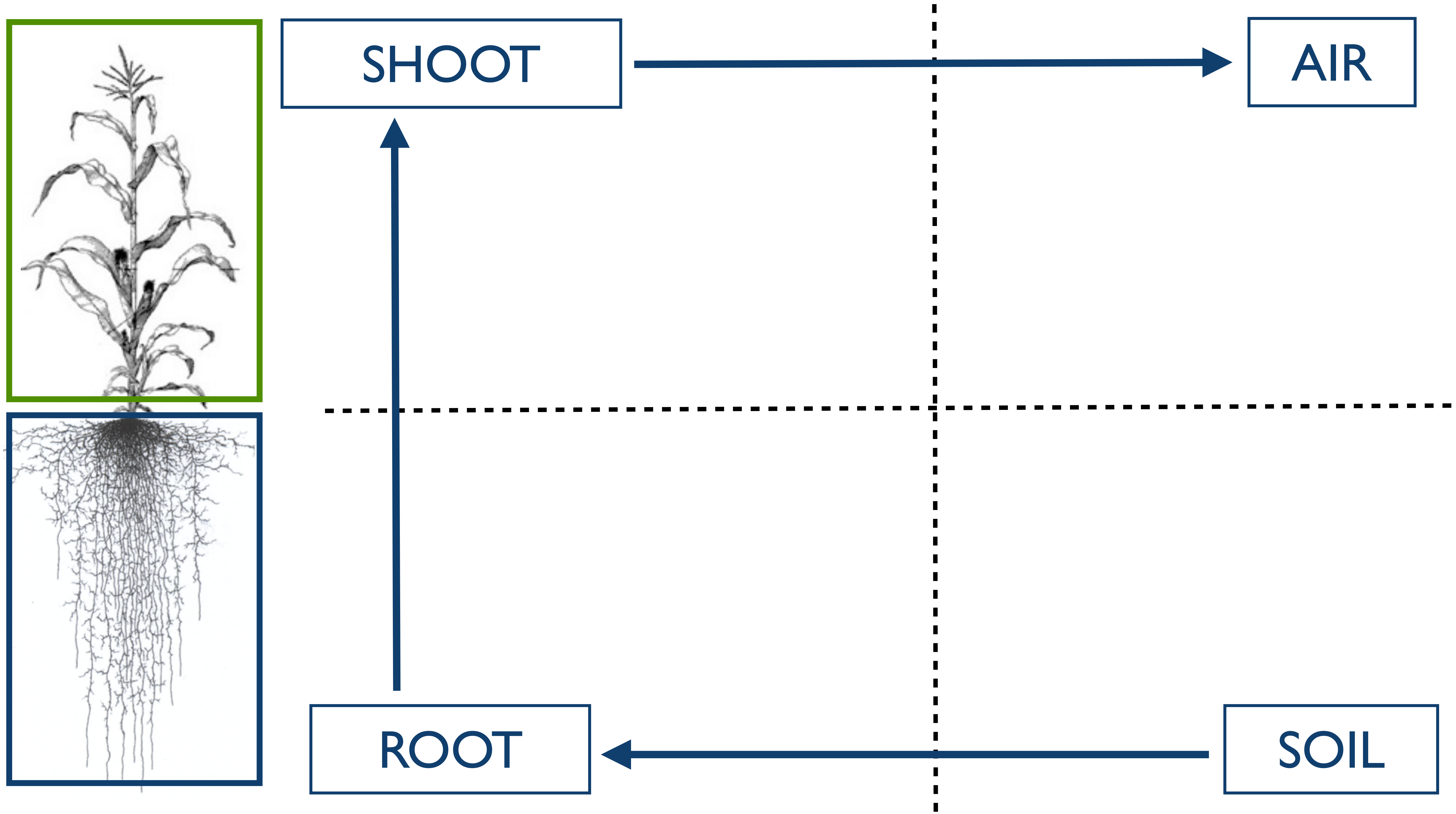
# New insights on the role of radial root conductivity on the overall water uptake dynamics

Guillaume Lobet, Valentin Couvreur,
Mathieu Javaux and Xavier Draye

Mini-Symposium on Roots for Improving Resource Acquisition in Crops
13th April 2011

# Water fluxes in the plant




Root image from Kutschera et al., 1997

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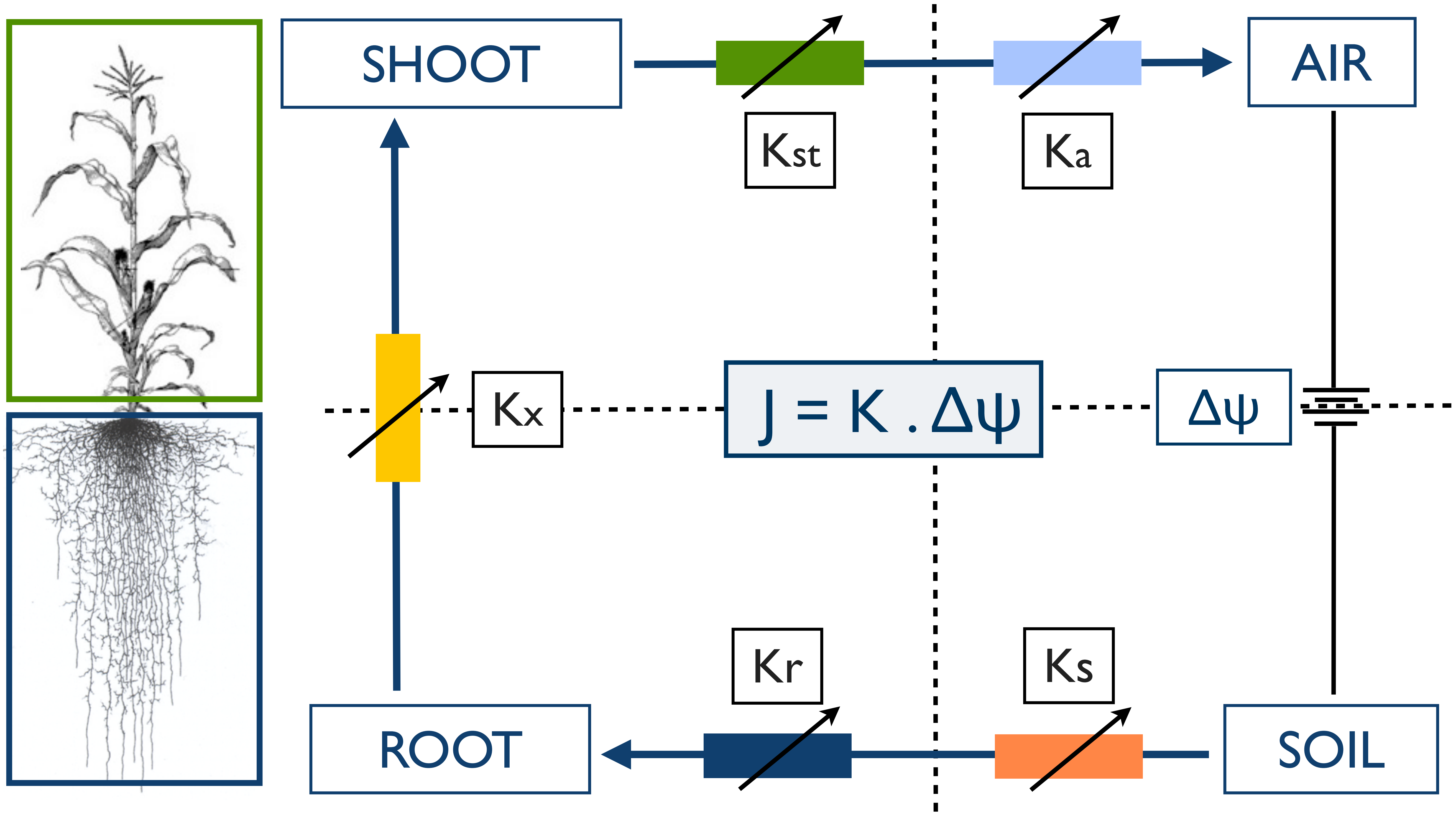
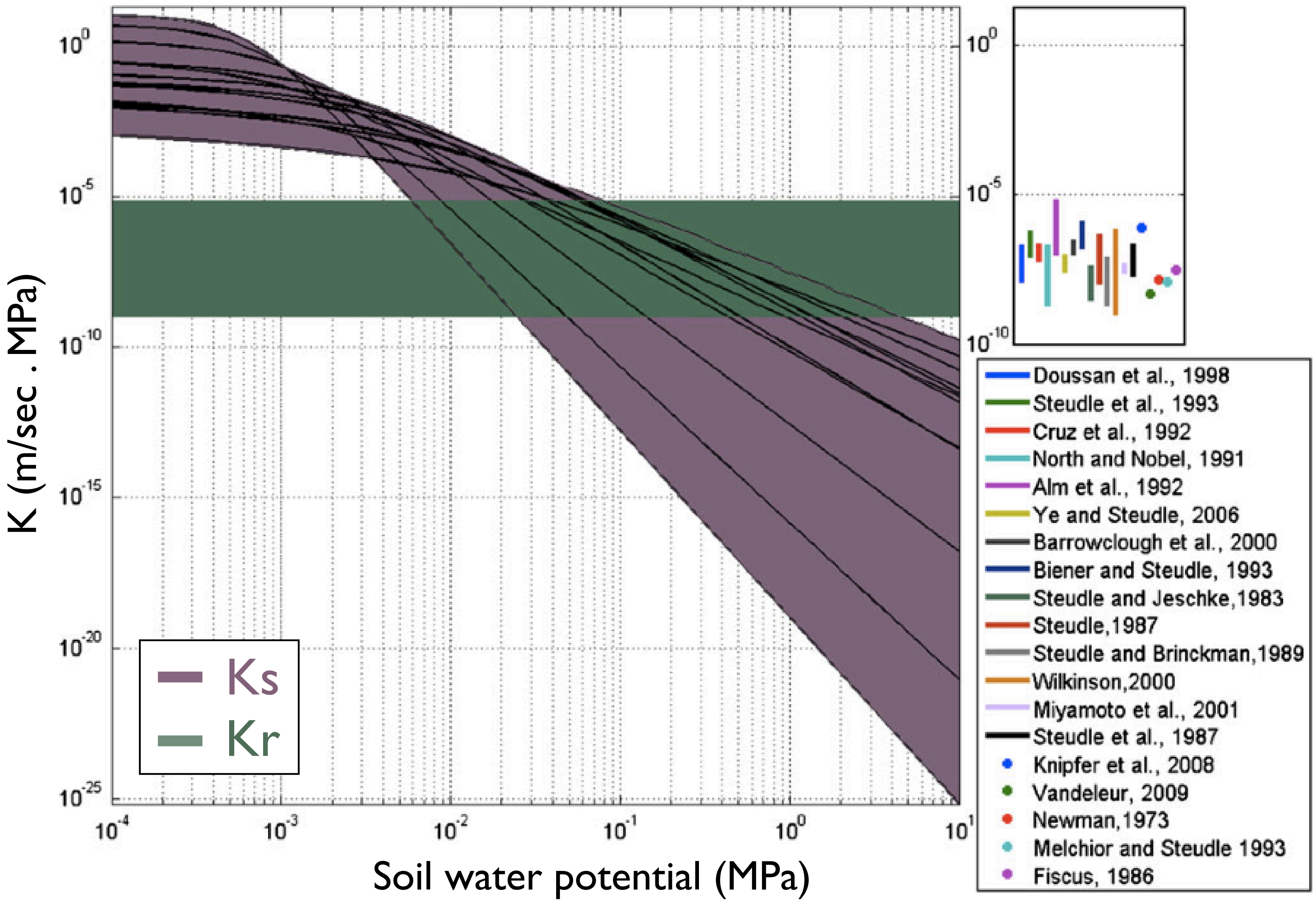



Root image from Kutschera et al., 1997

# Relative ranges of conductivities




Draye et al. 2010, J Exp Bot 61 (8)

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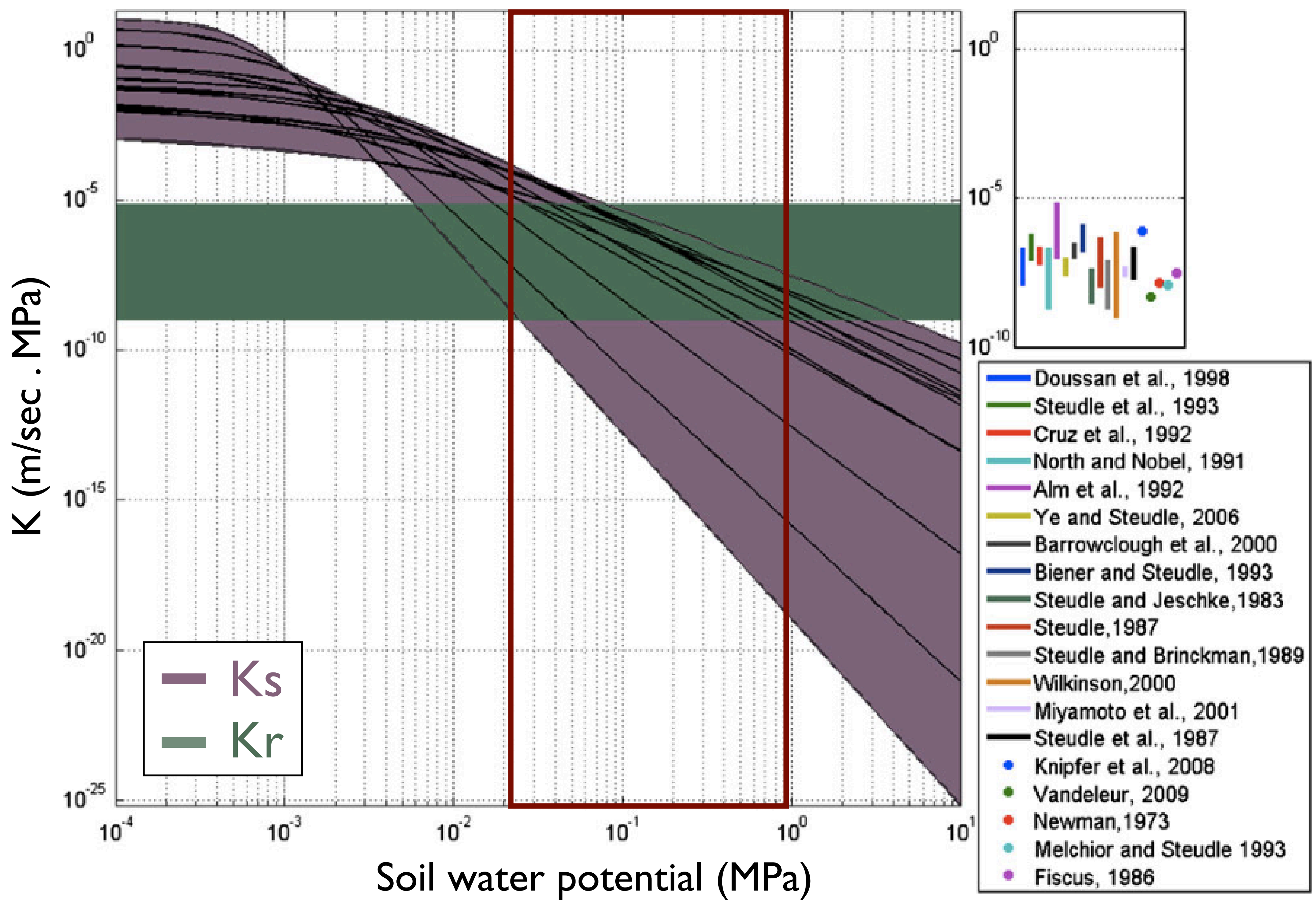


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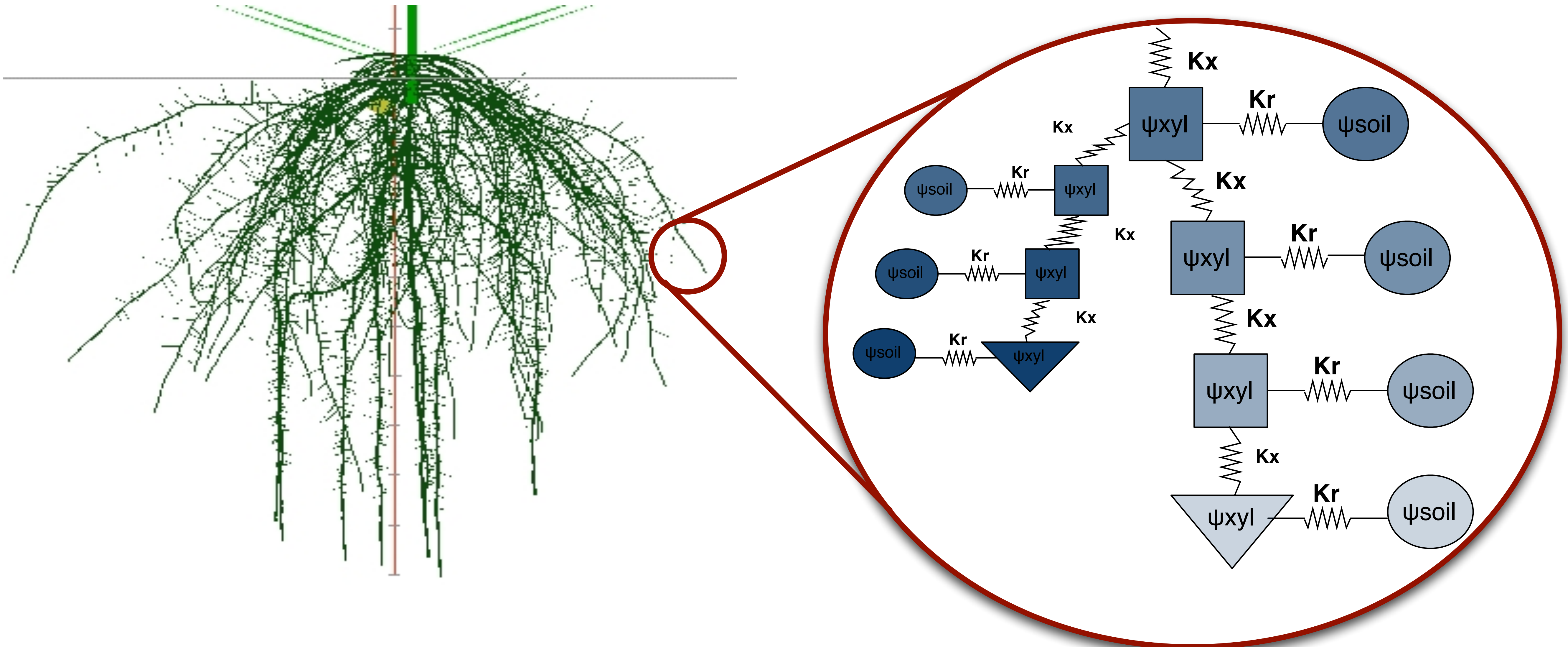
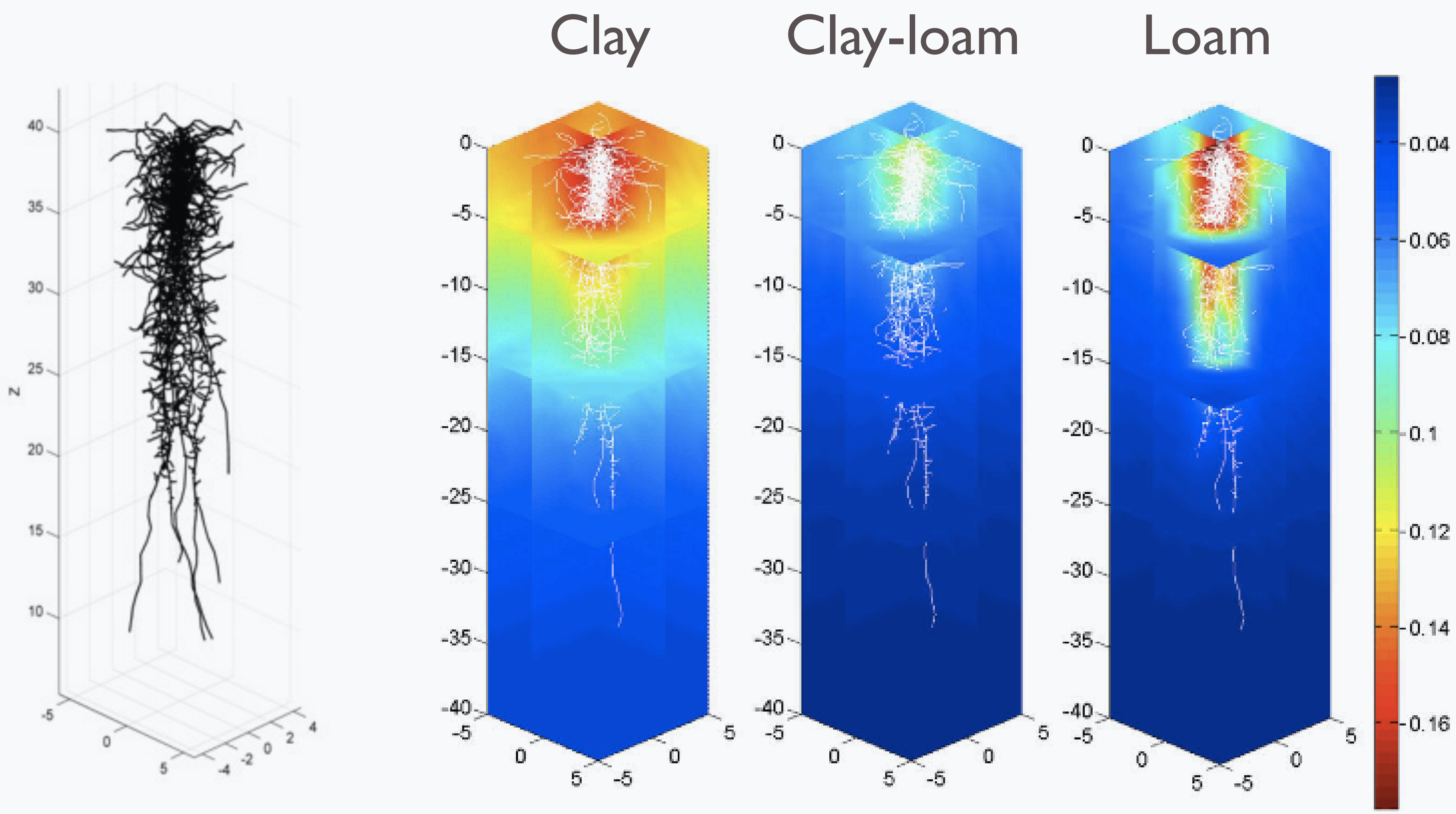
# Hydraulics and architecture



# Influence of the soil conductivity

## Simulation with R-SWMS




Javaux et al. 2008, Vadoze Zone J 7

# Objectives

Can we extend these concepts to study the plant behaviour ?

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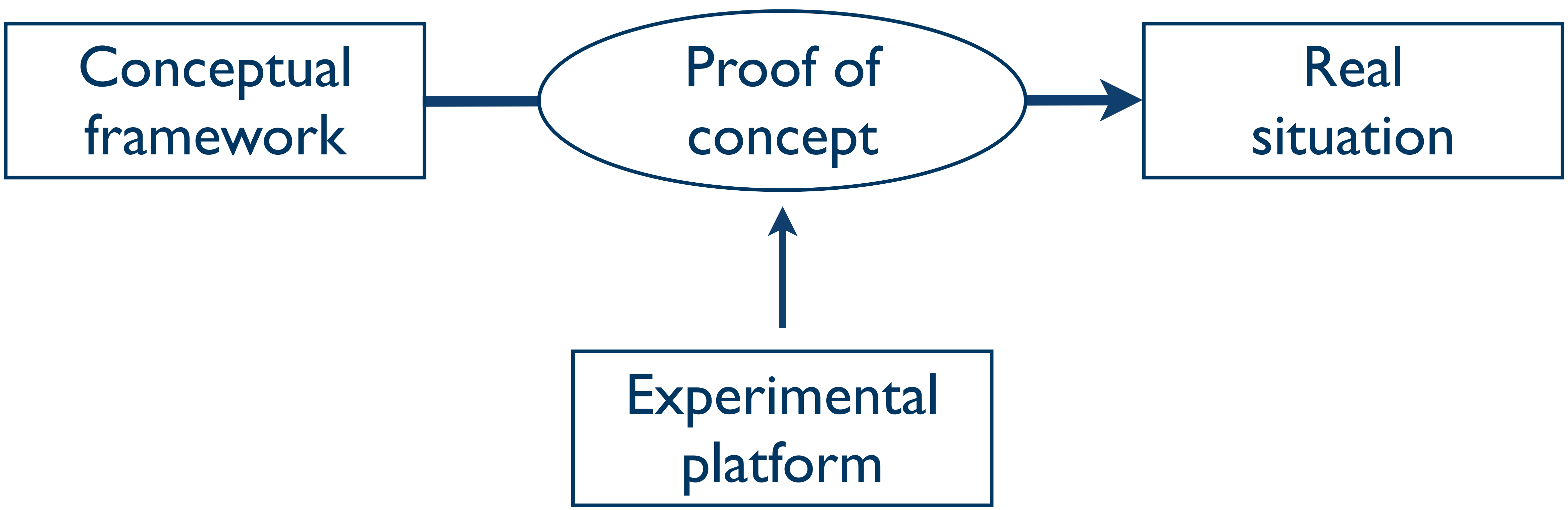
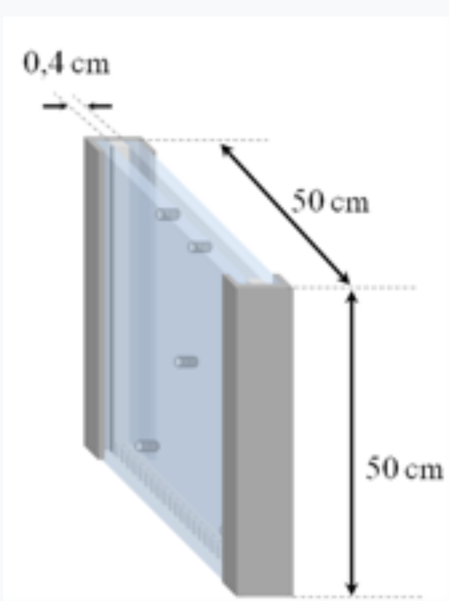


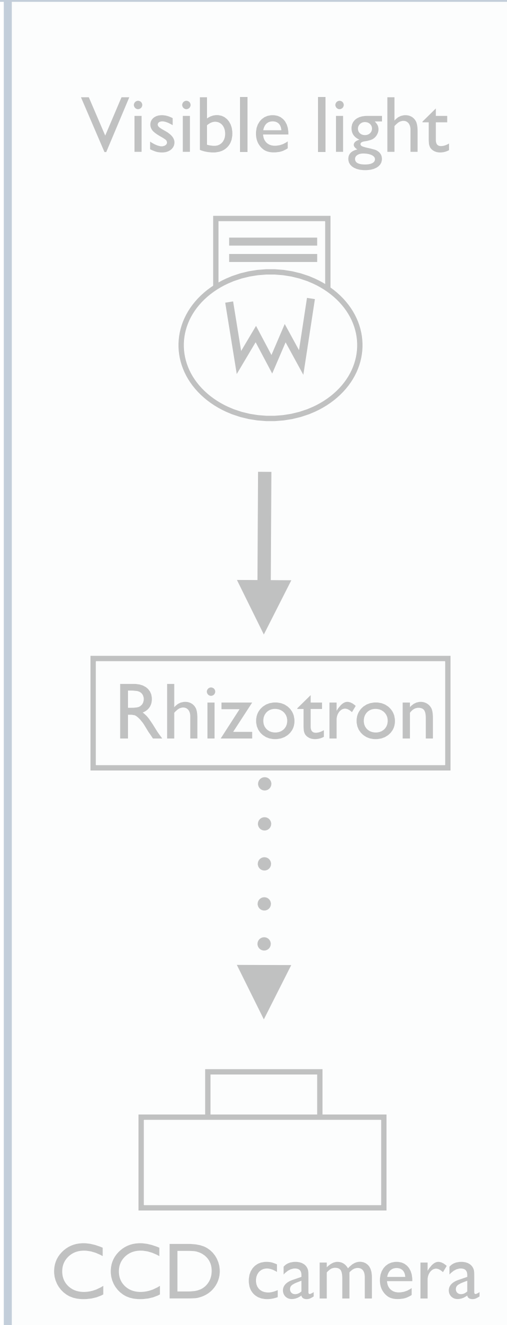
# Experimental platform

*Zea mays*




Rhizotrons

Light Transmission




Soil θ

# Experimental platform

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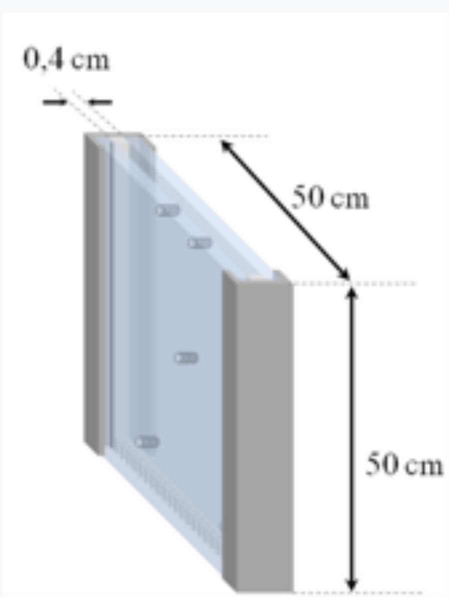


## Rhizotrons

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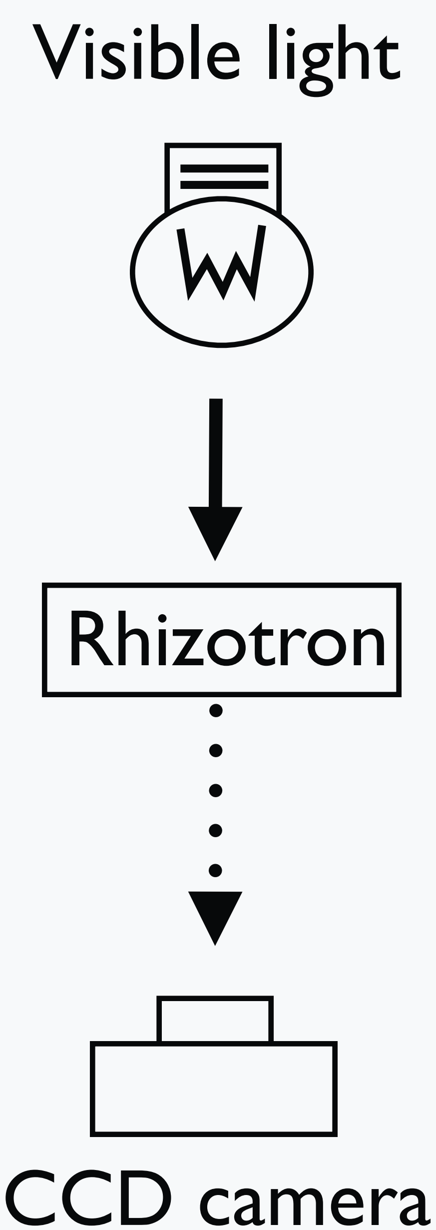


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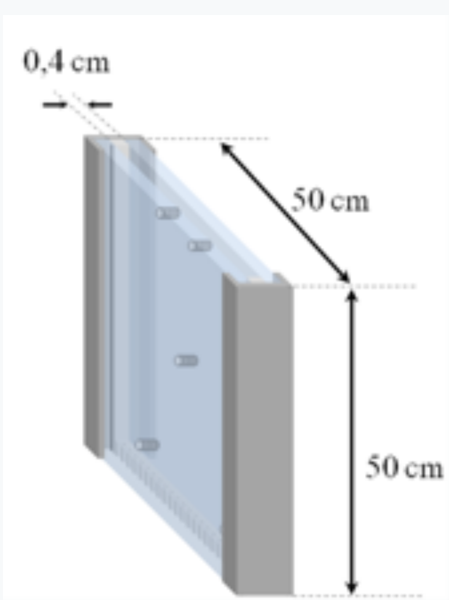


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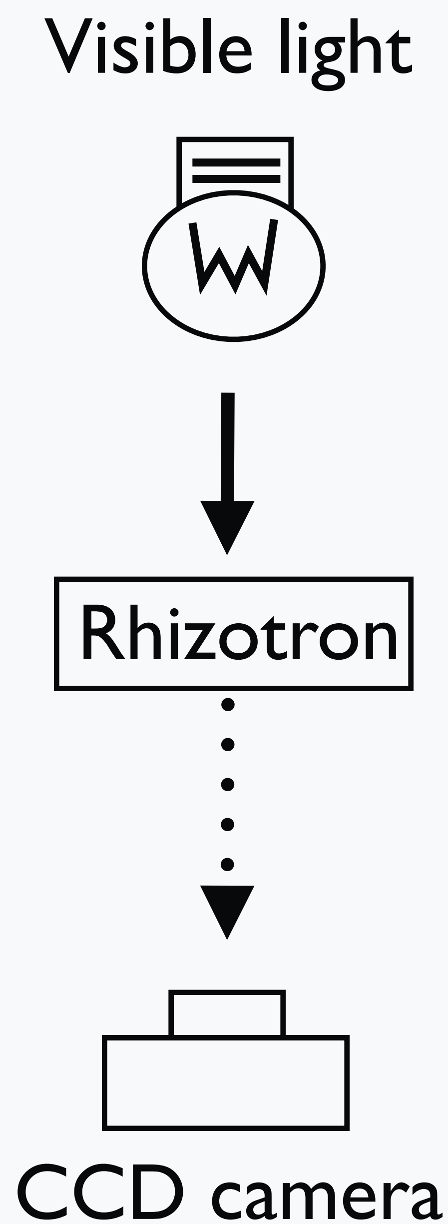


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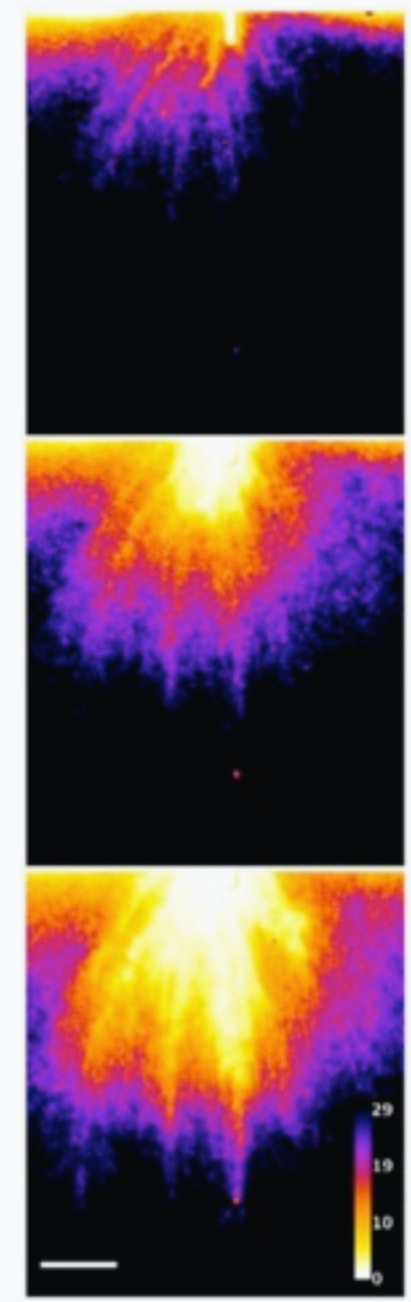
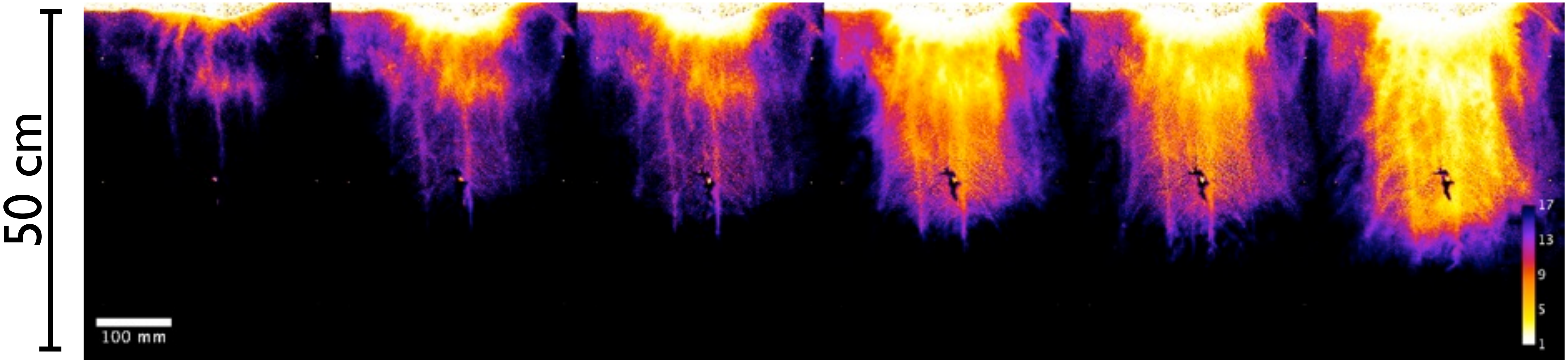
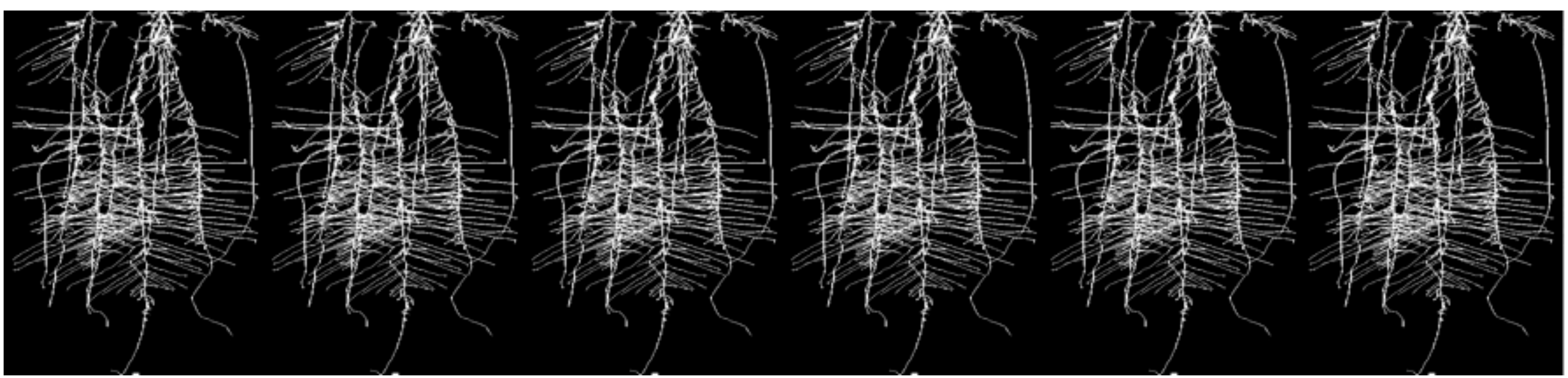


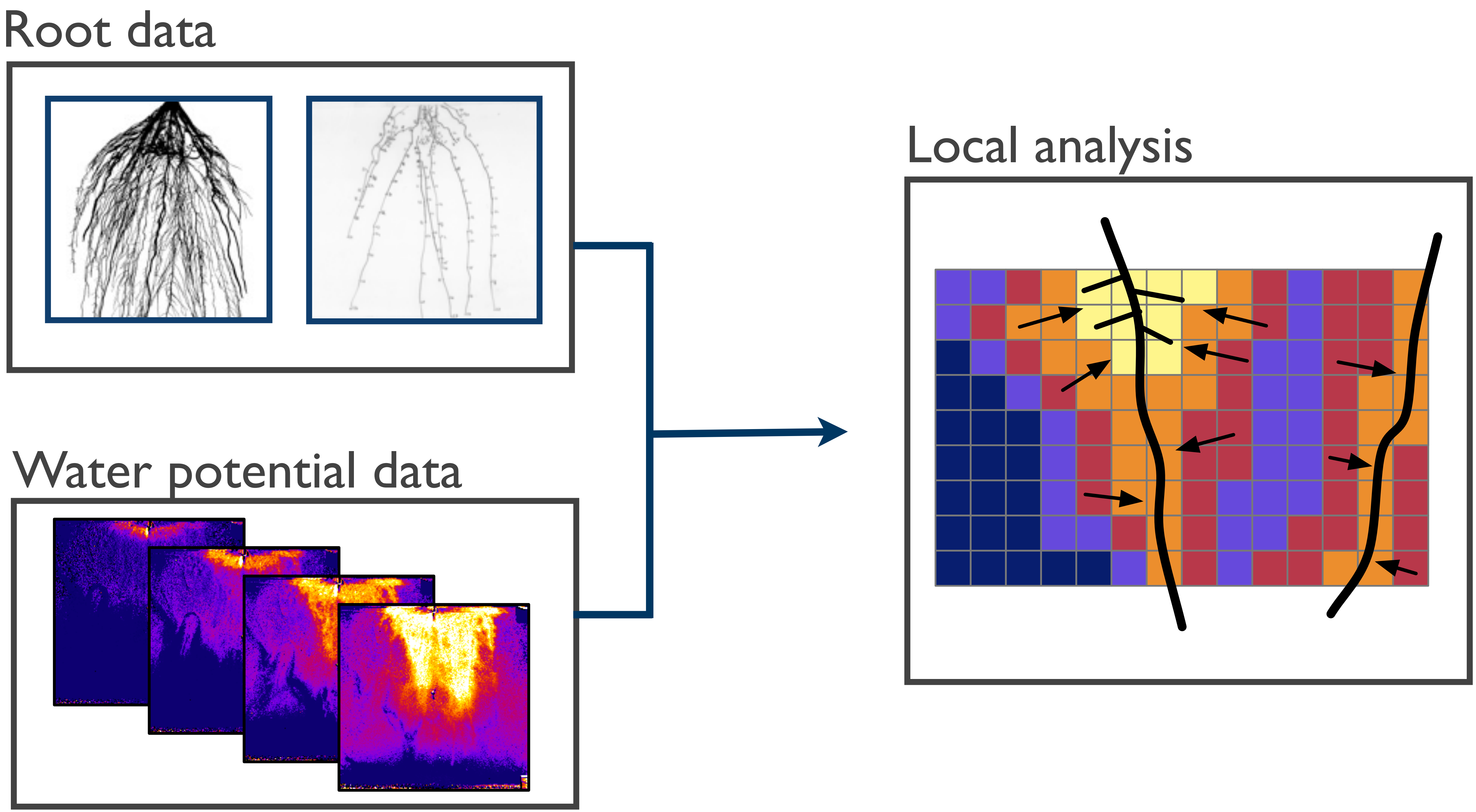
# Uptake overview

## Water uptake follows a downward dynamics during a water deficit episode

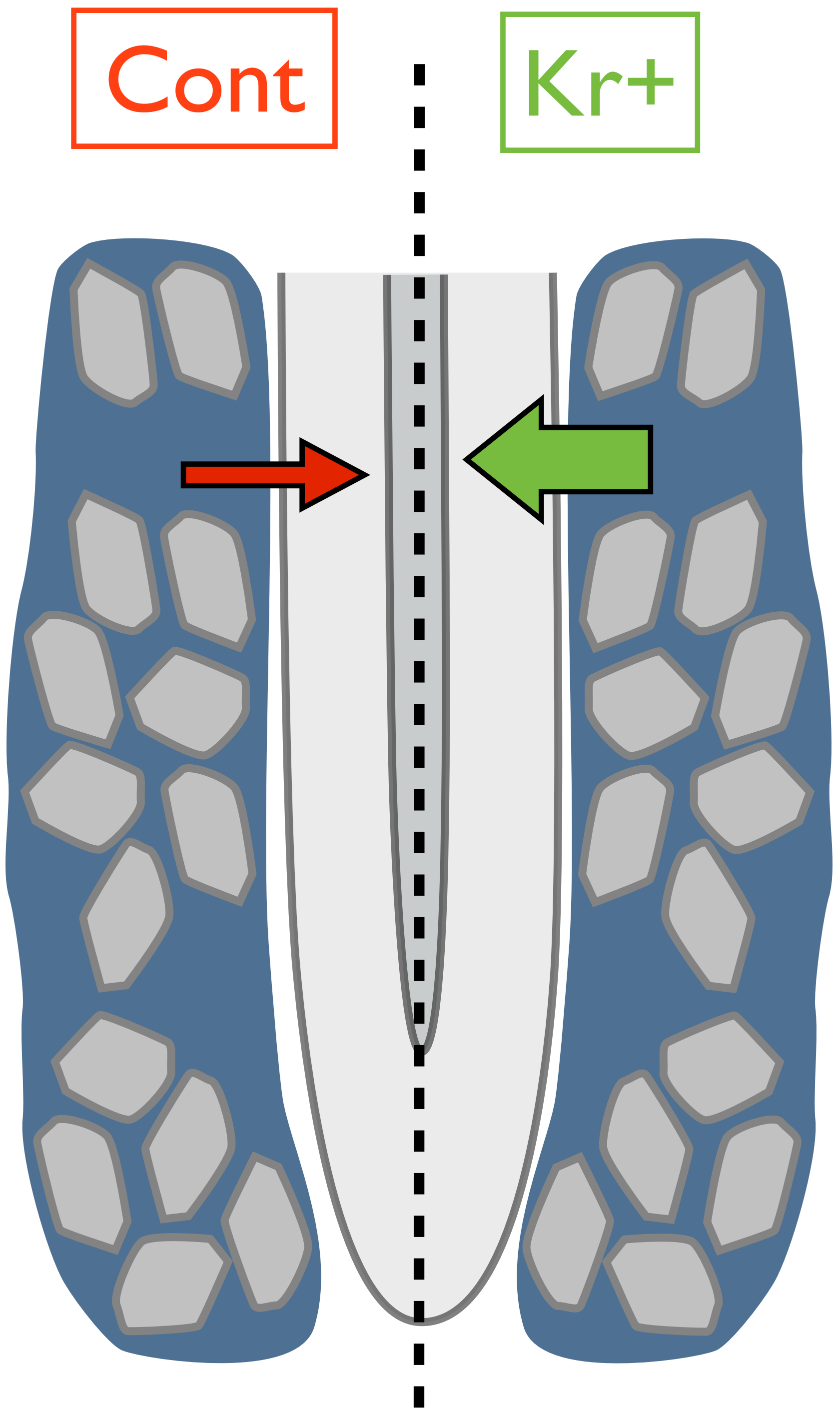


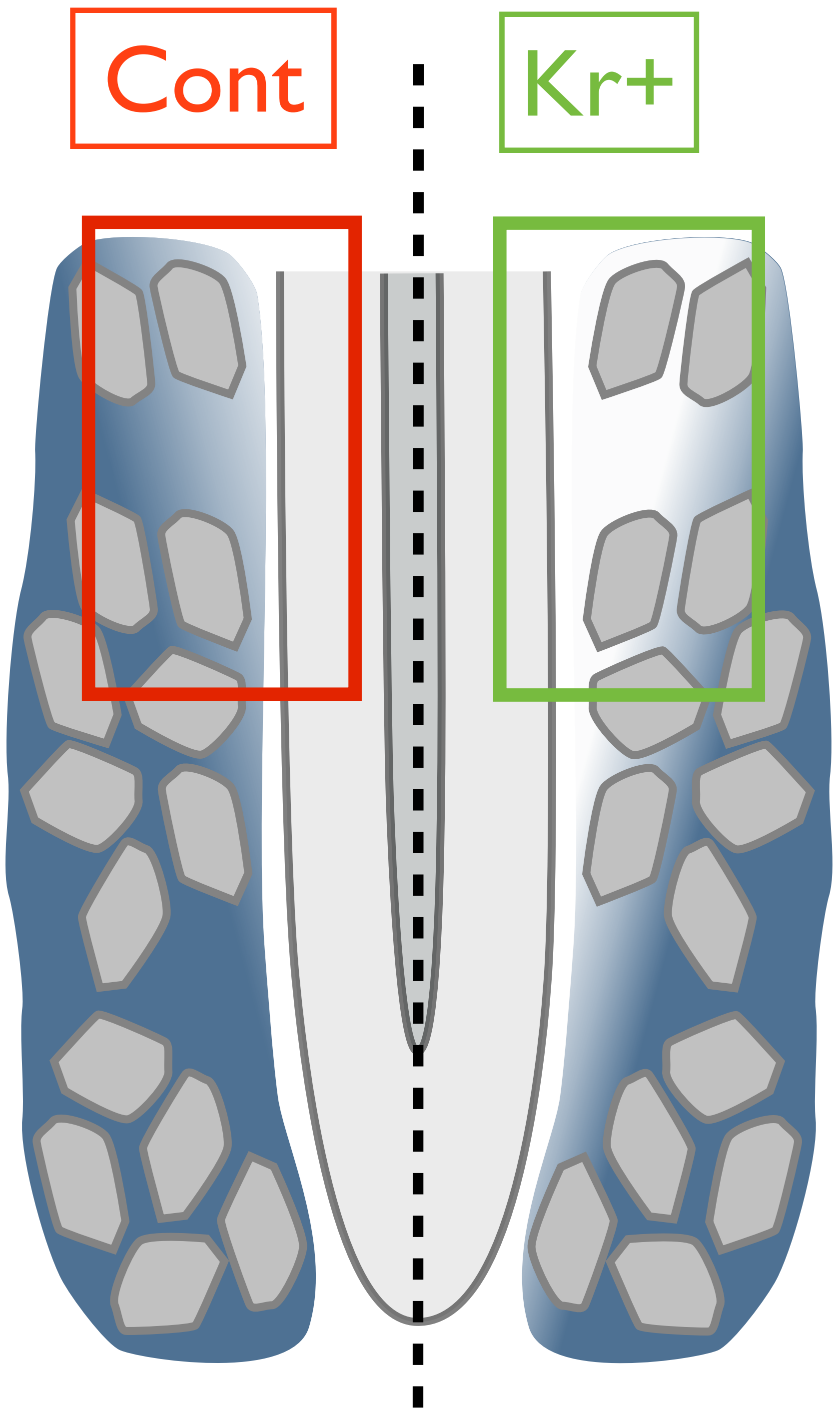
# Local uptake analysis

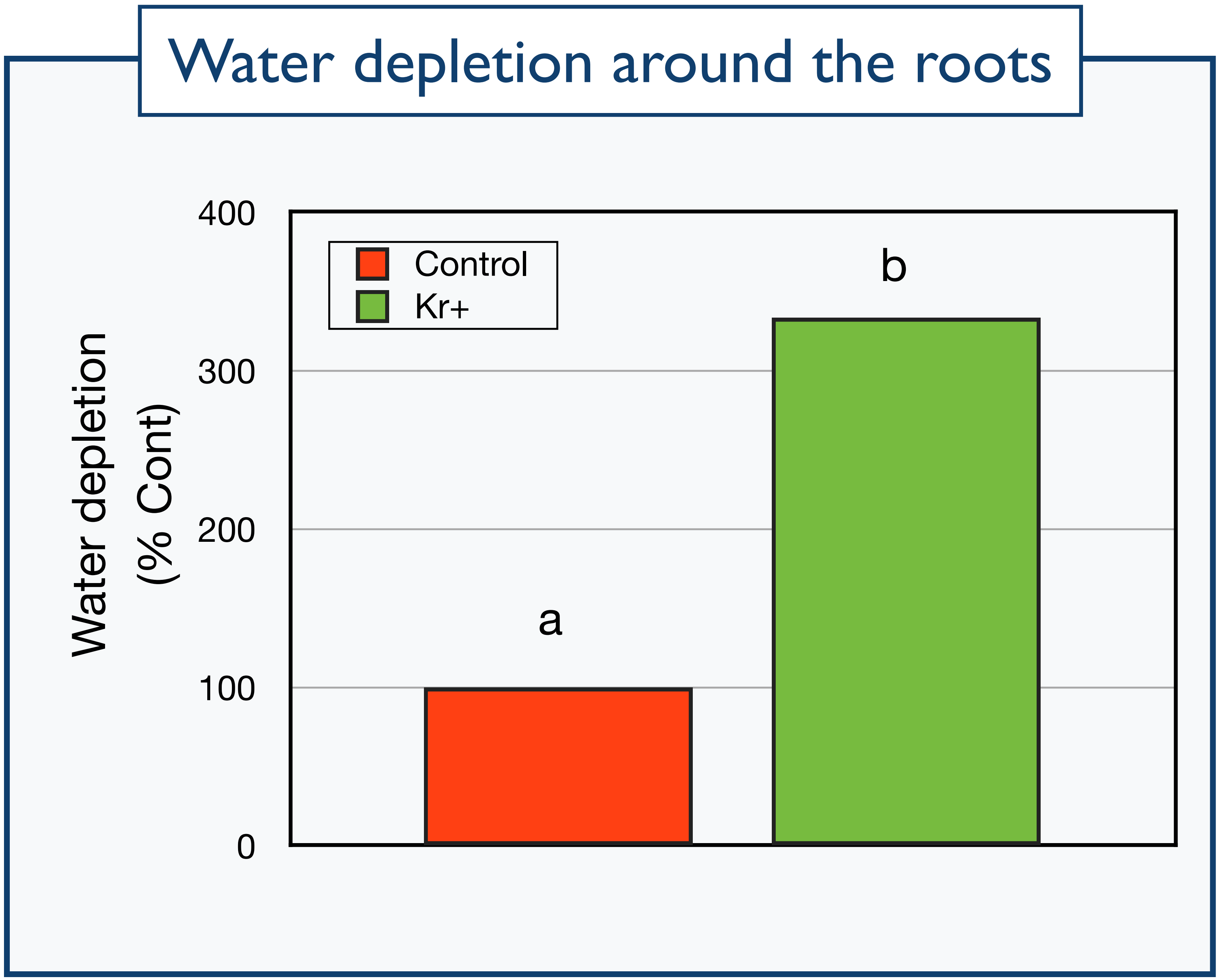


# Kr influences local uptake rates

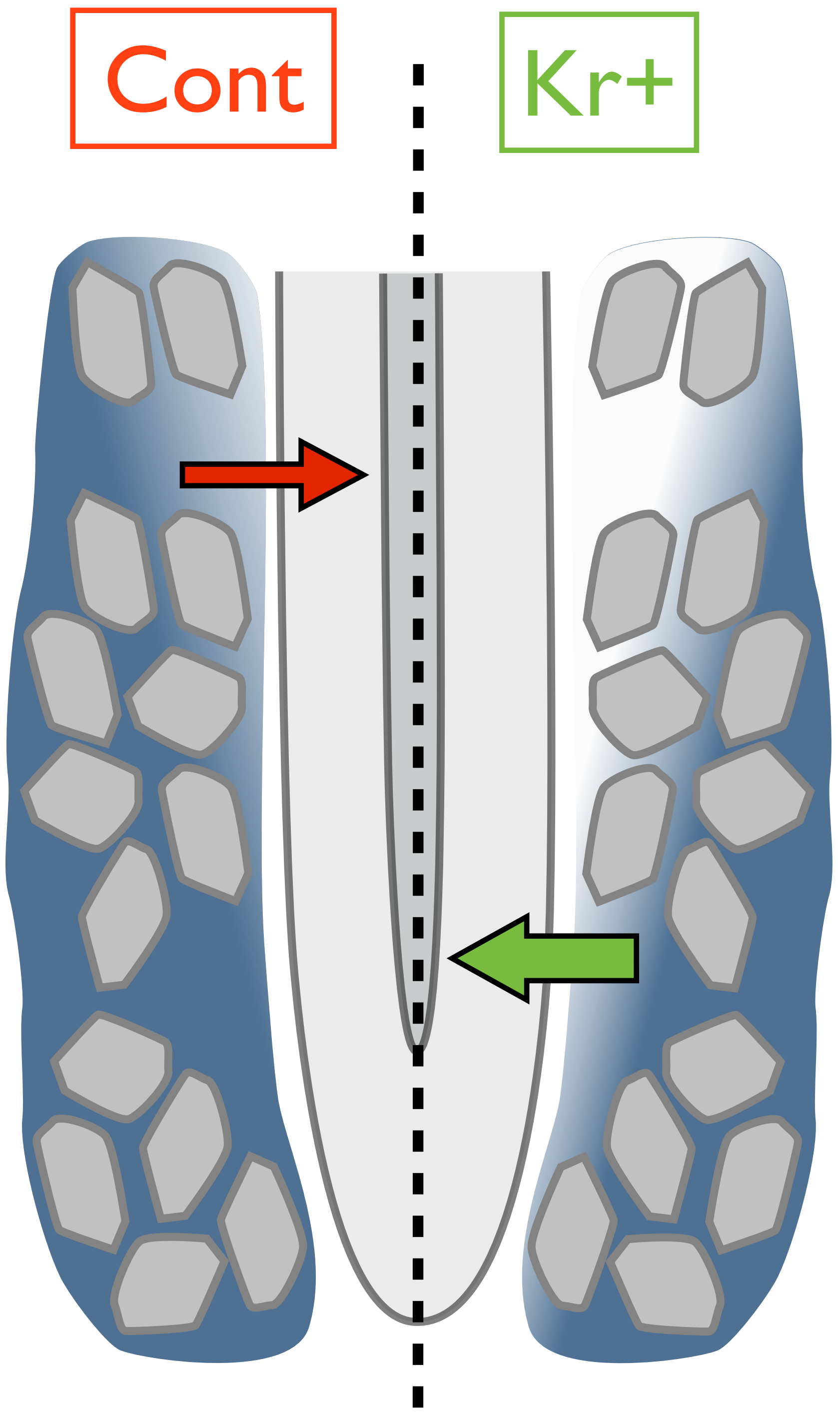


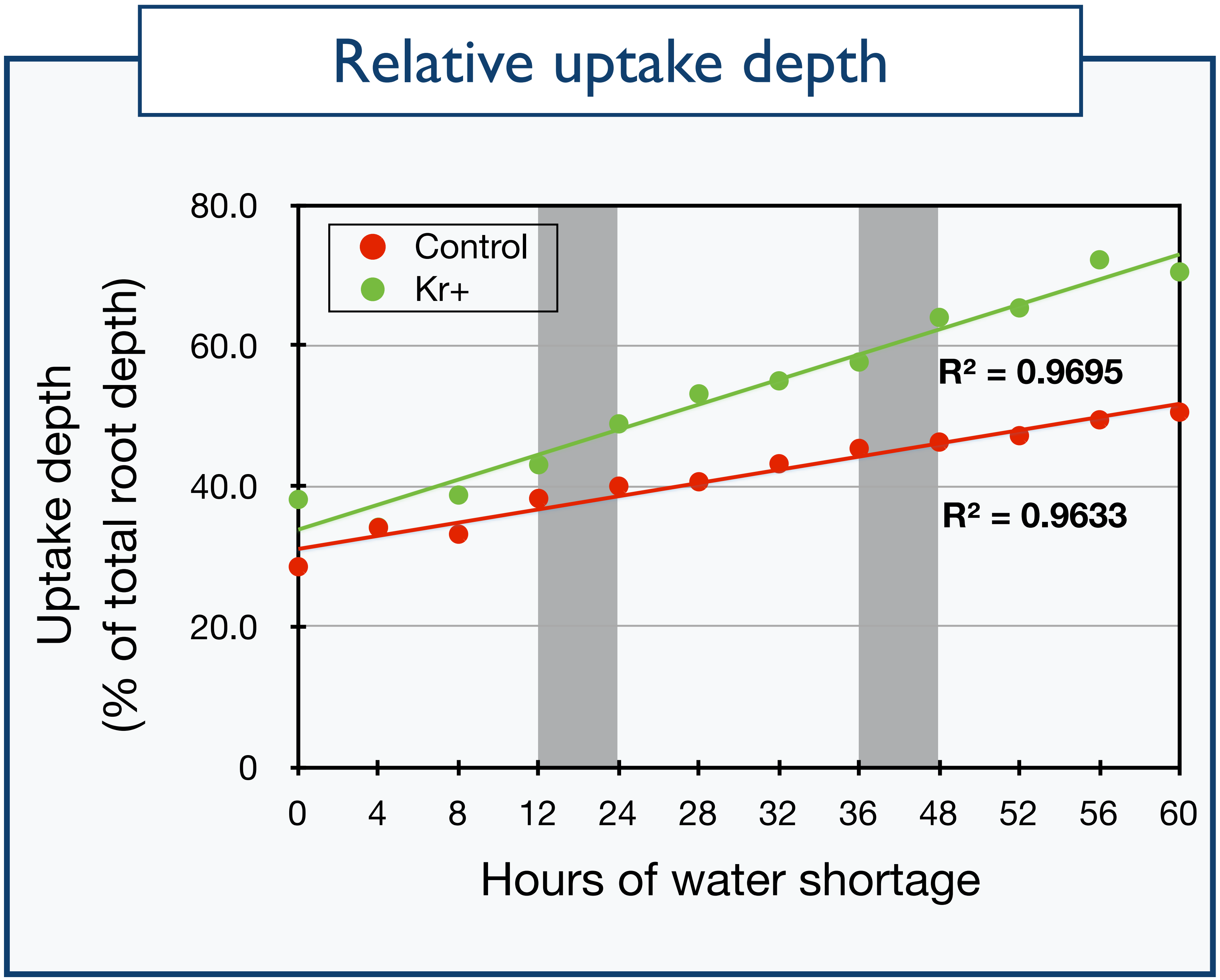

# Uptake rate influences water depletion



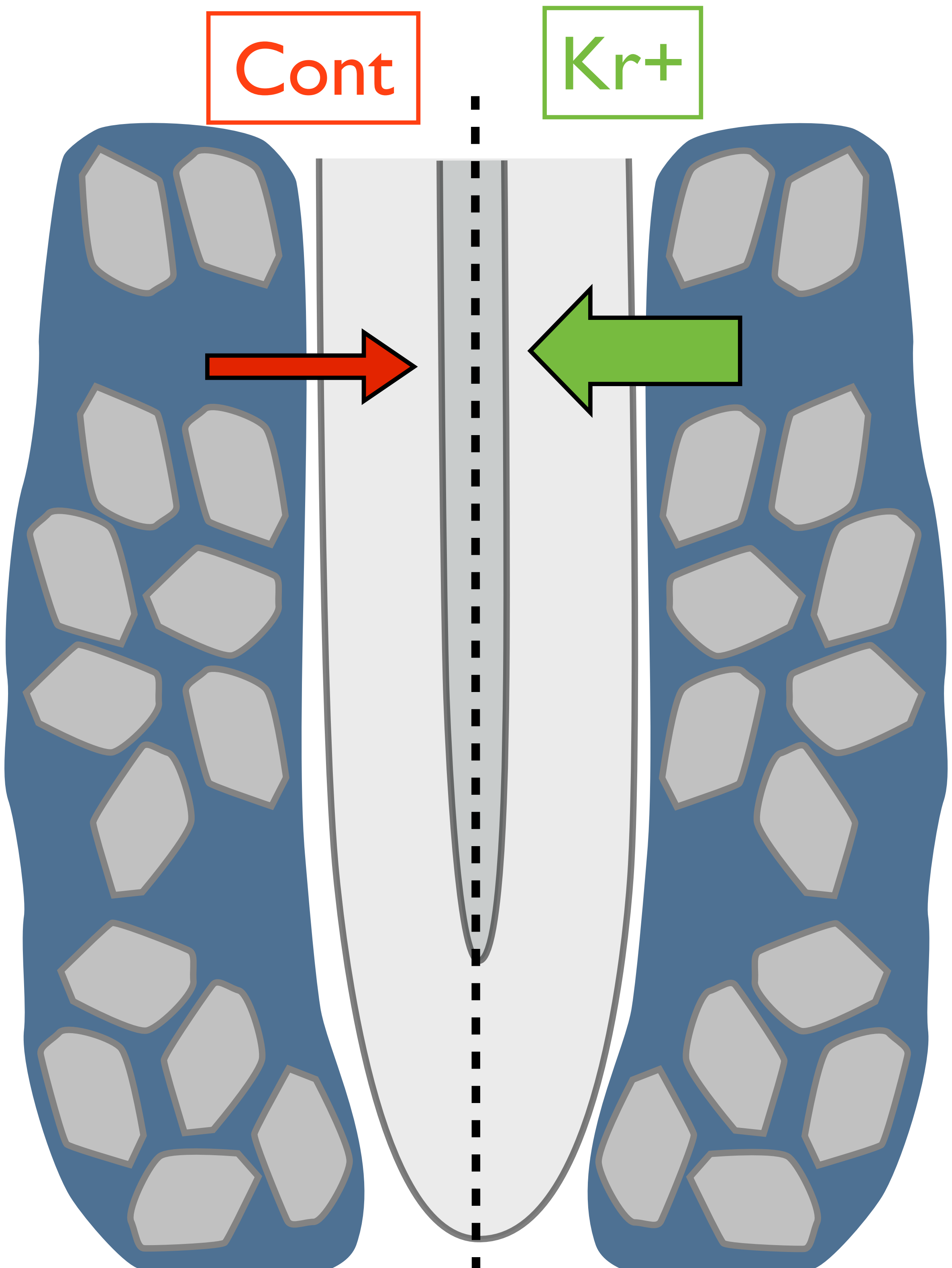



# Water depletion influences dynamics



# Integration of root and soil parameters




↑ Kr ↑ Flux ↑ RLD

High uptake rate

Soil water depletion

Local conductivity drop

Uptake moves downward

"Drought" in a wet soil

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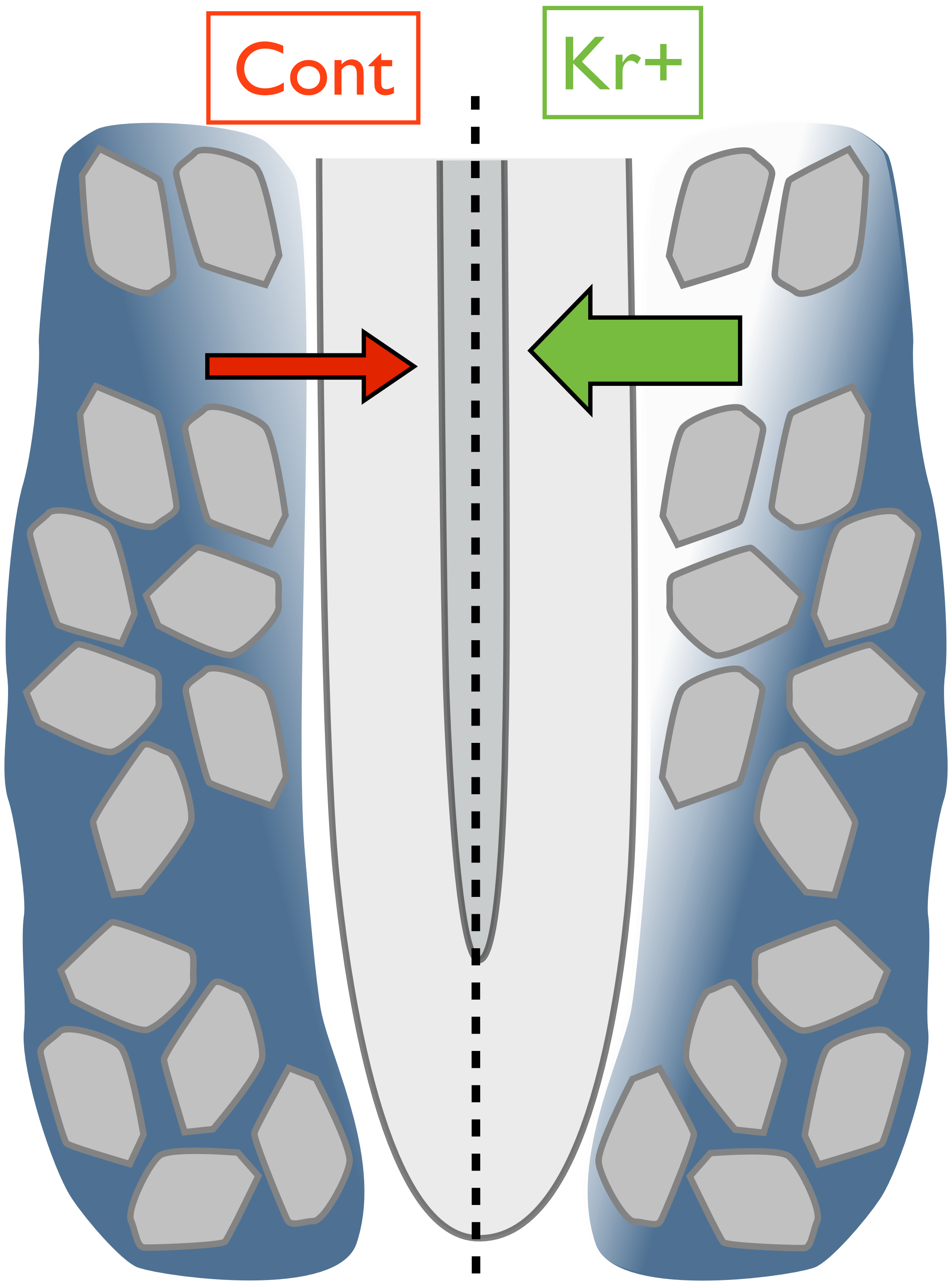


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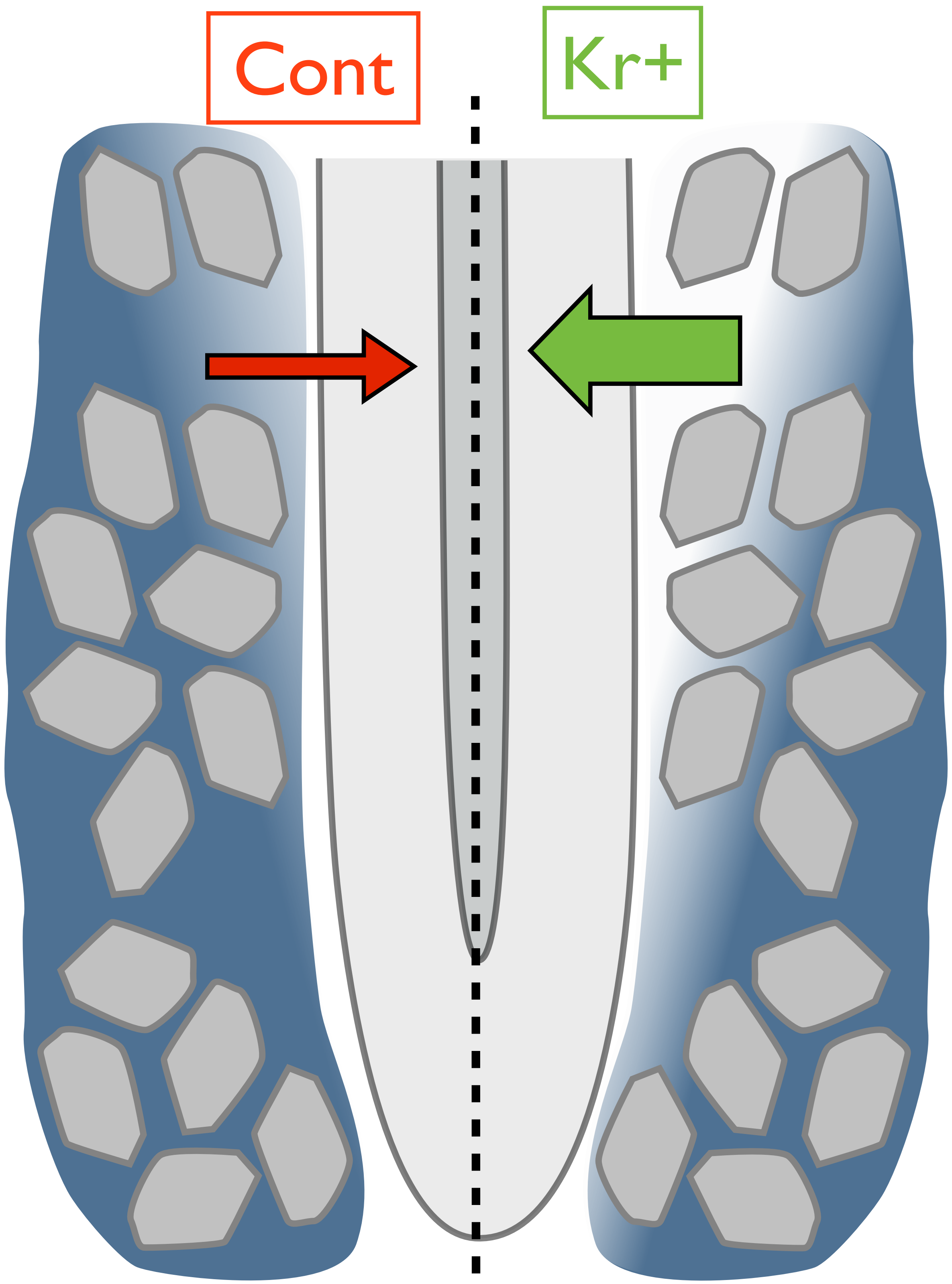


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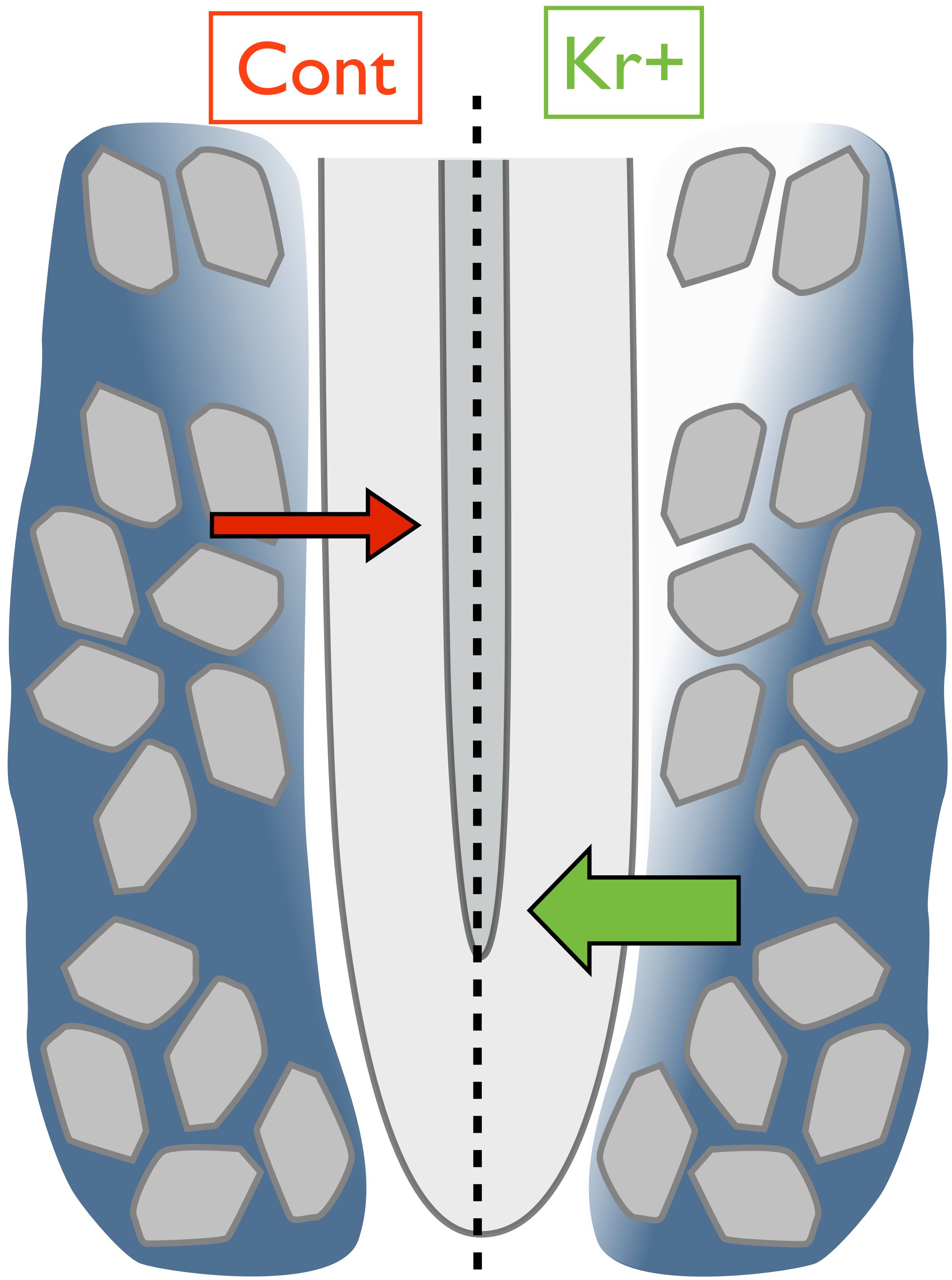


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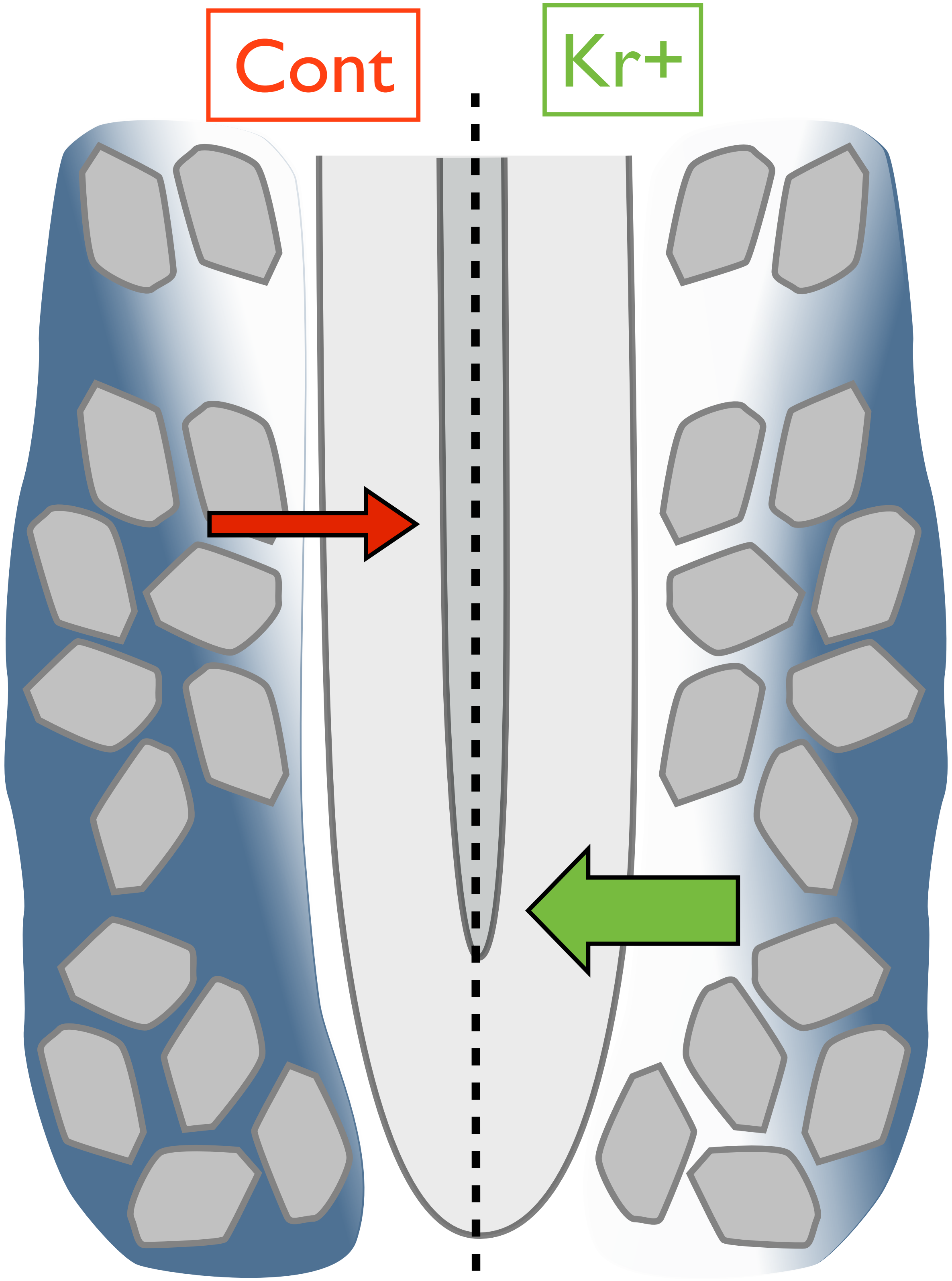


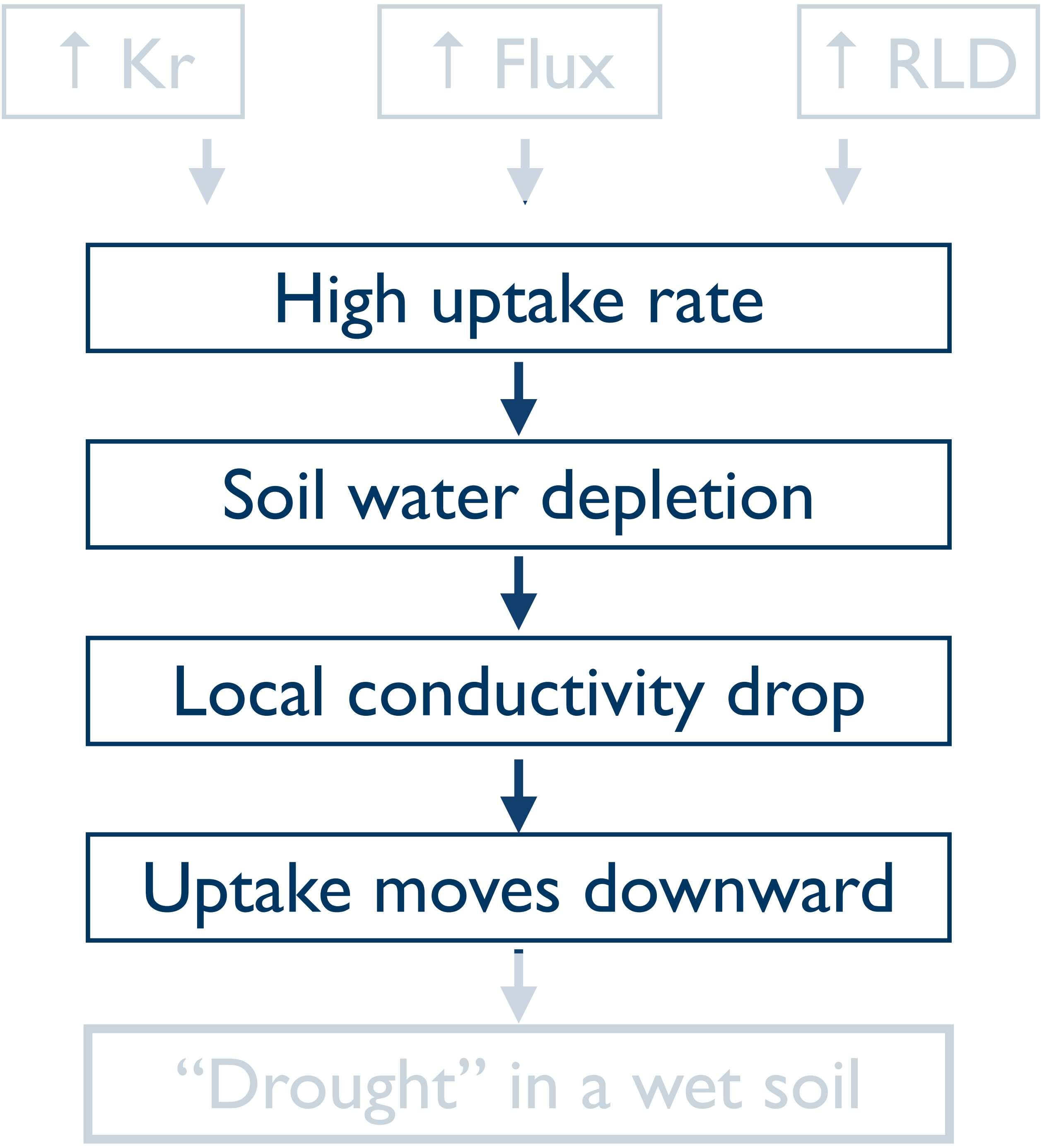

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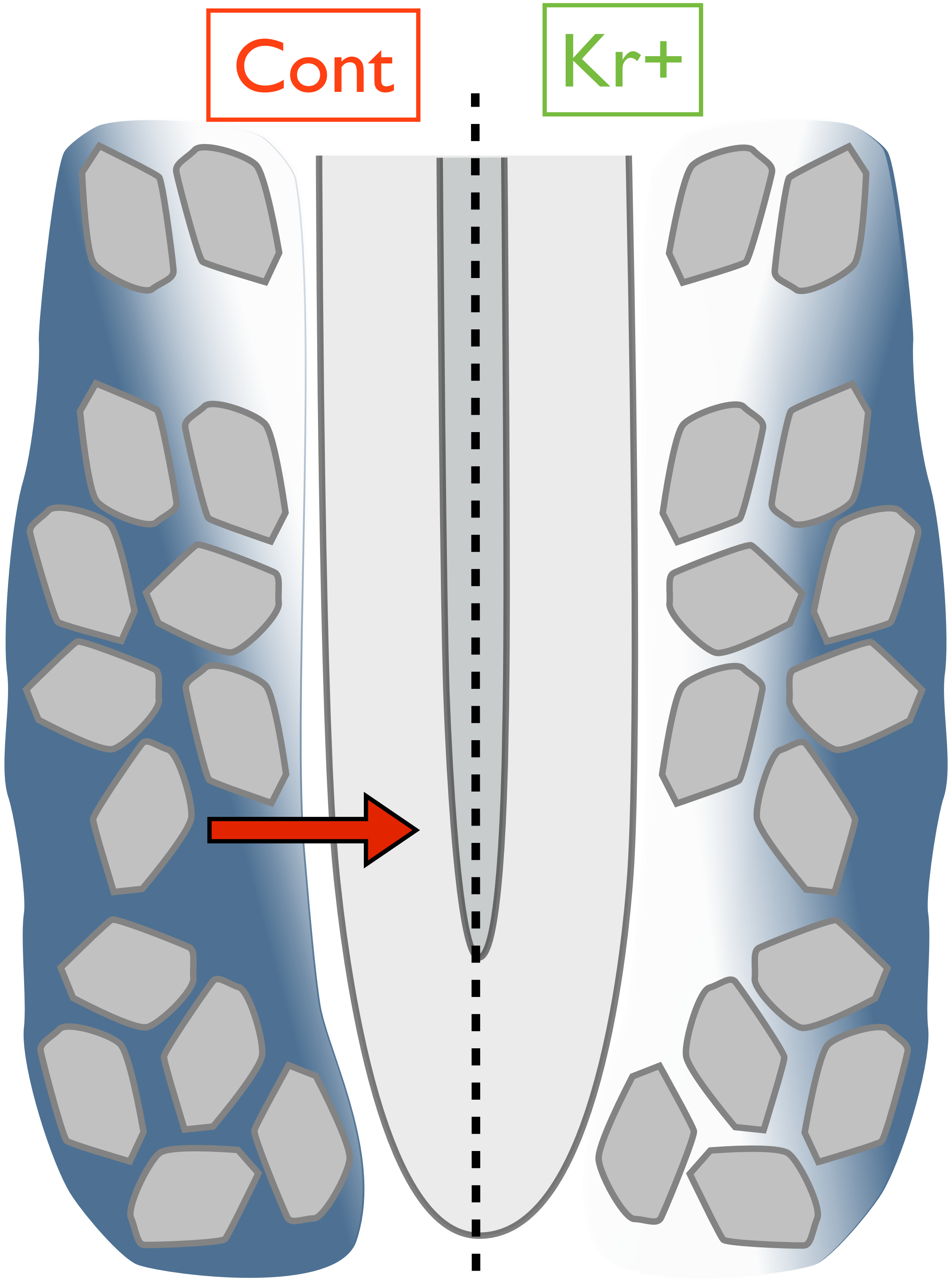


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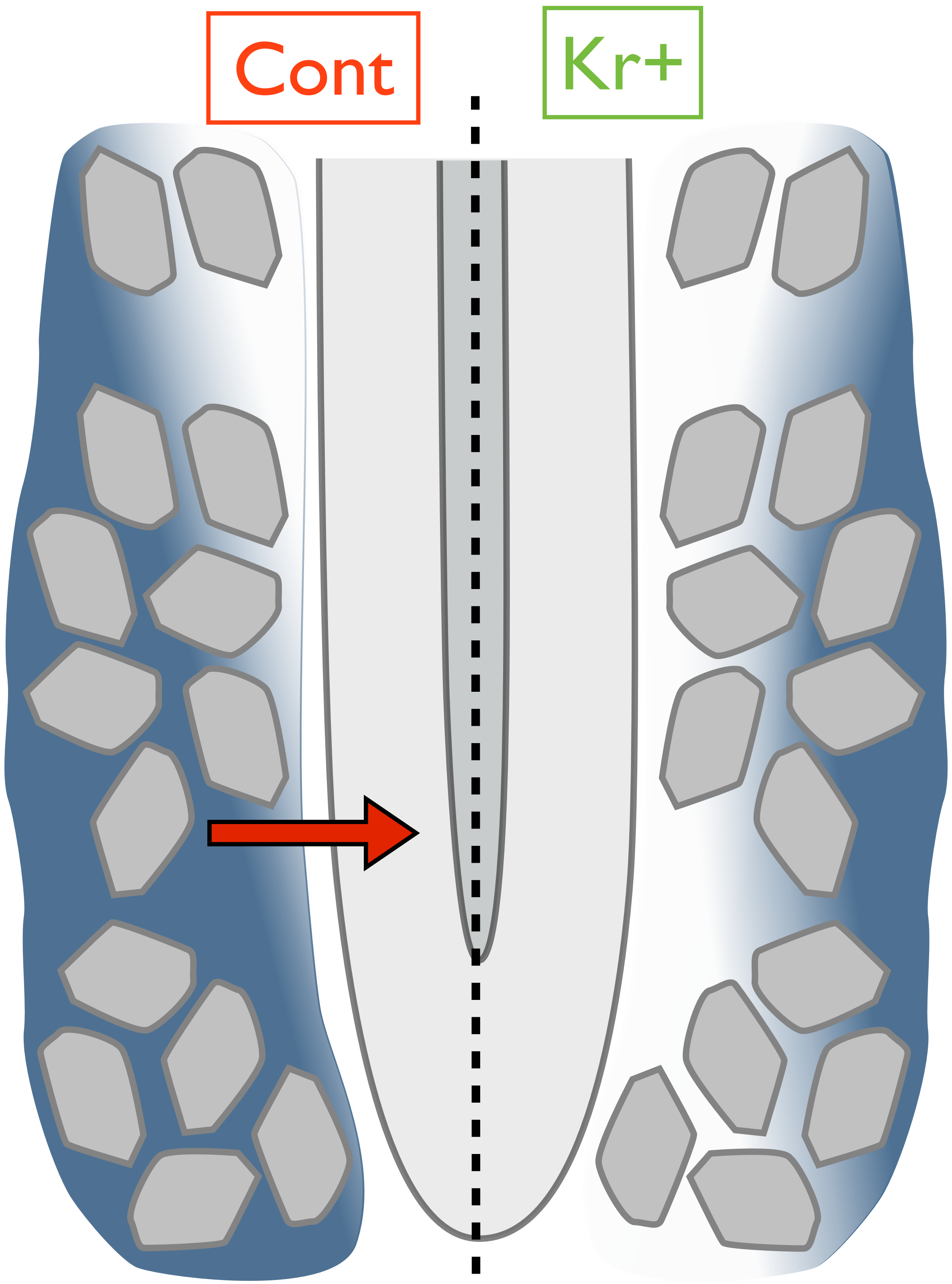


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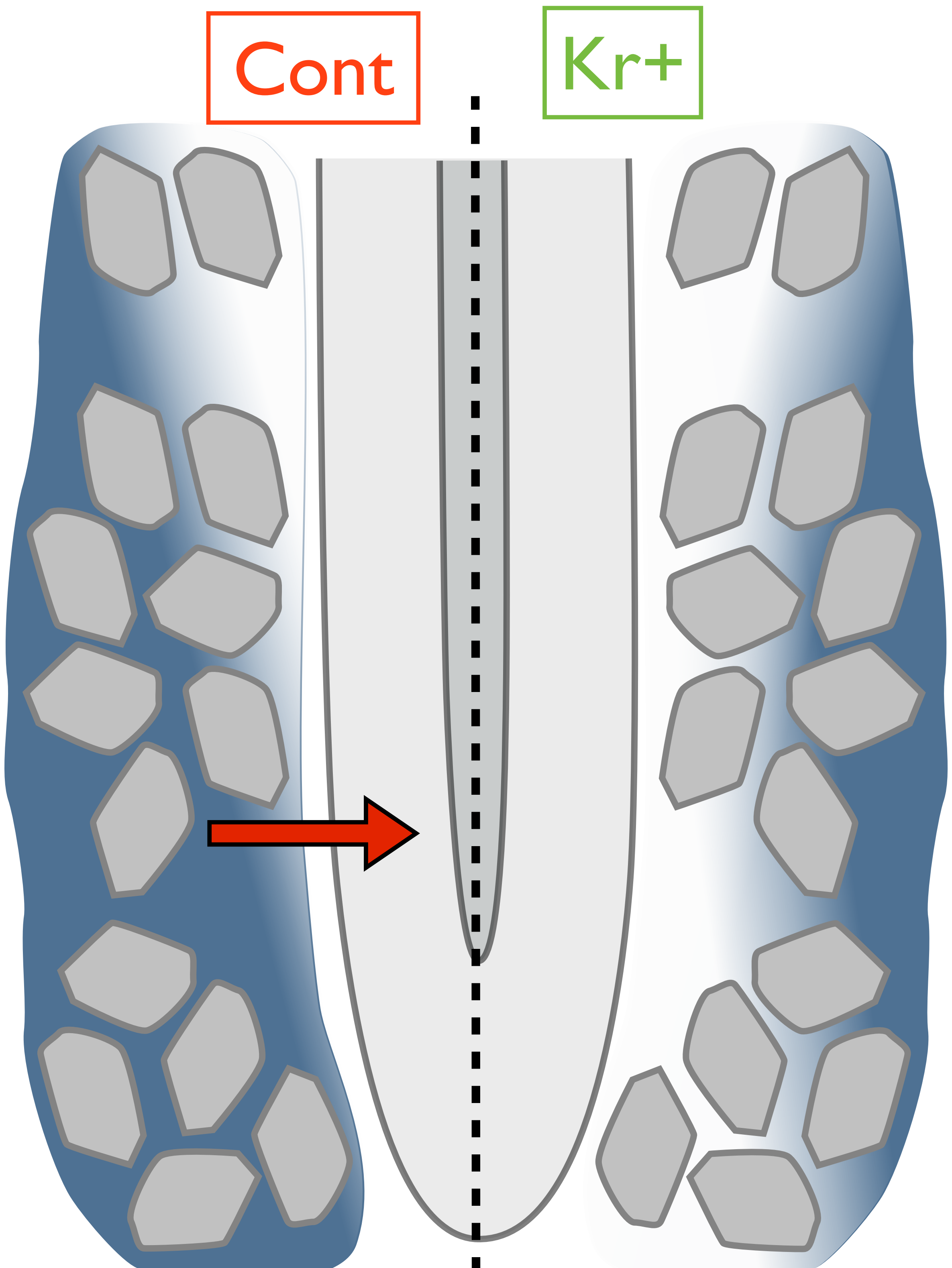


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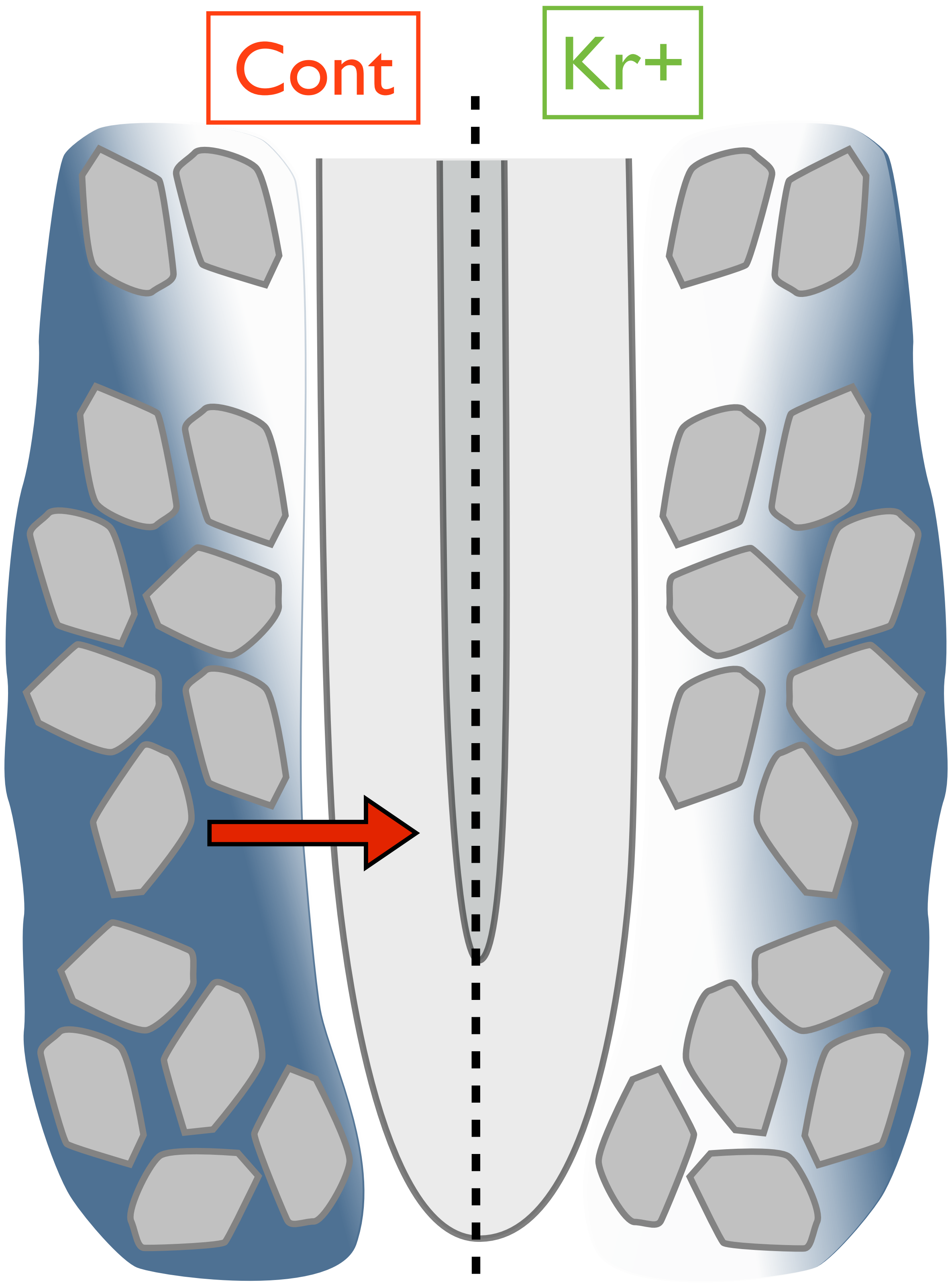


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**"Drought" in a wet soil**

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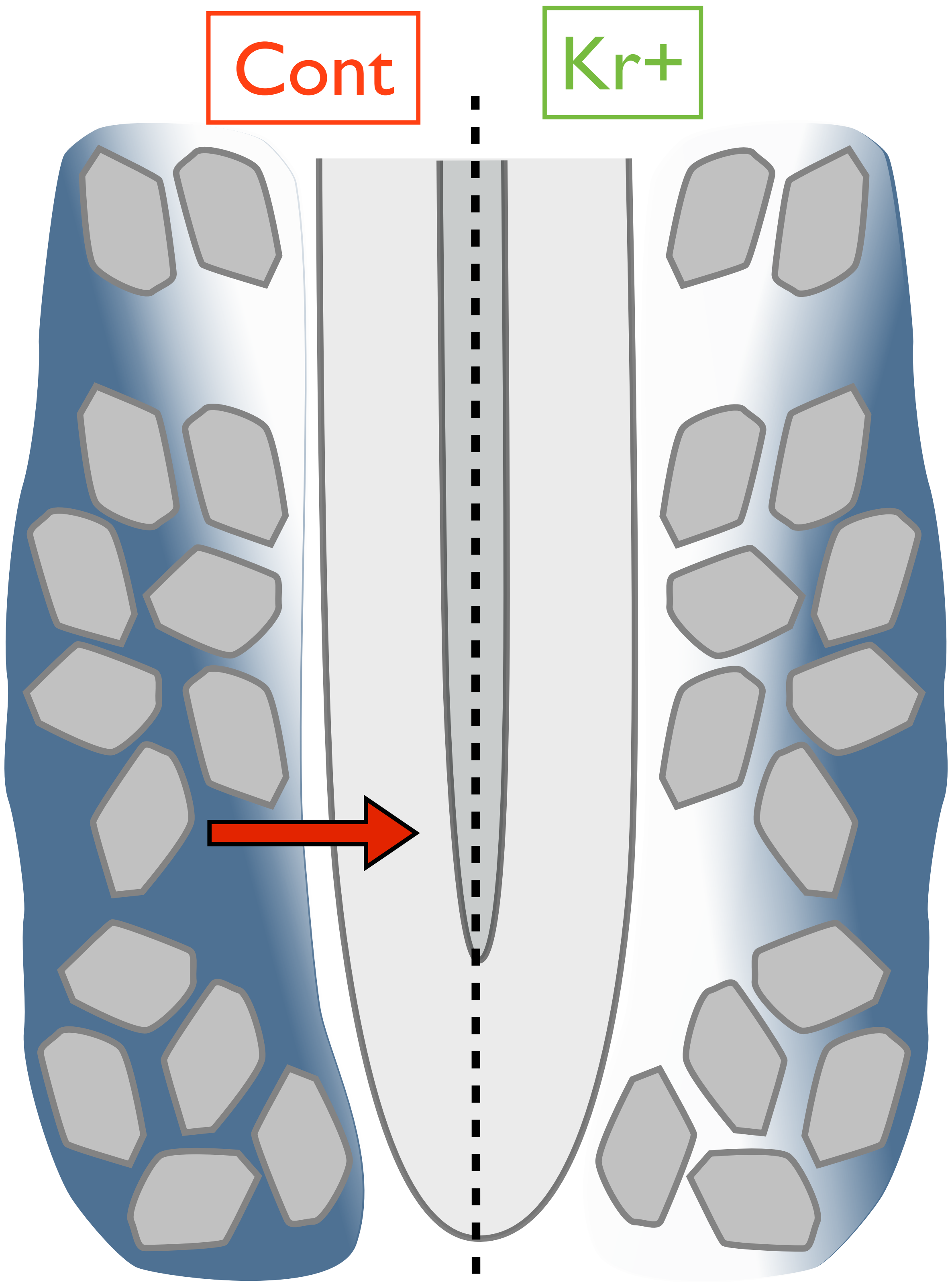


PLANT

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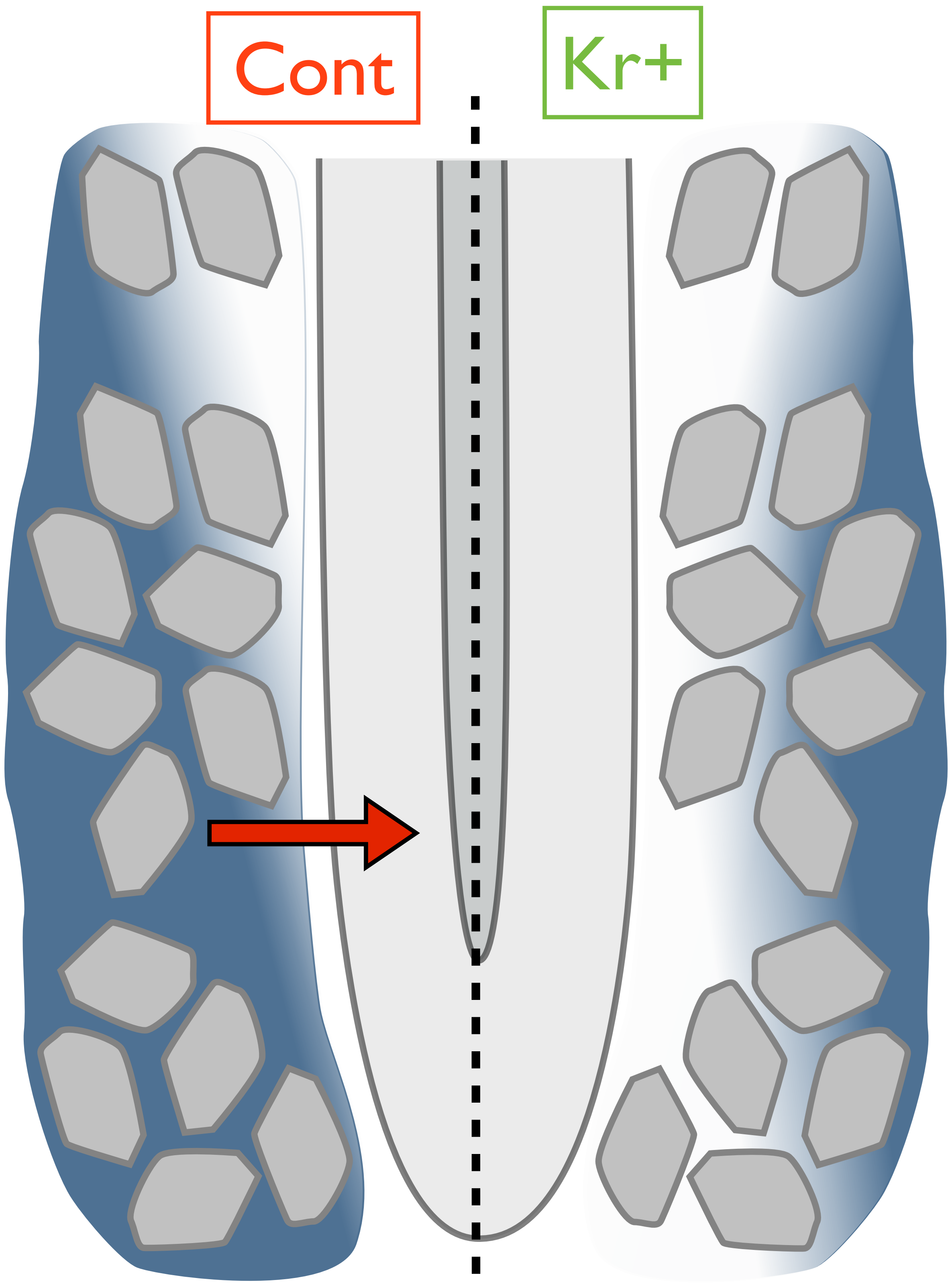


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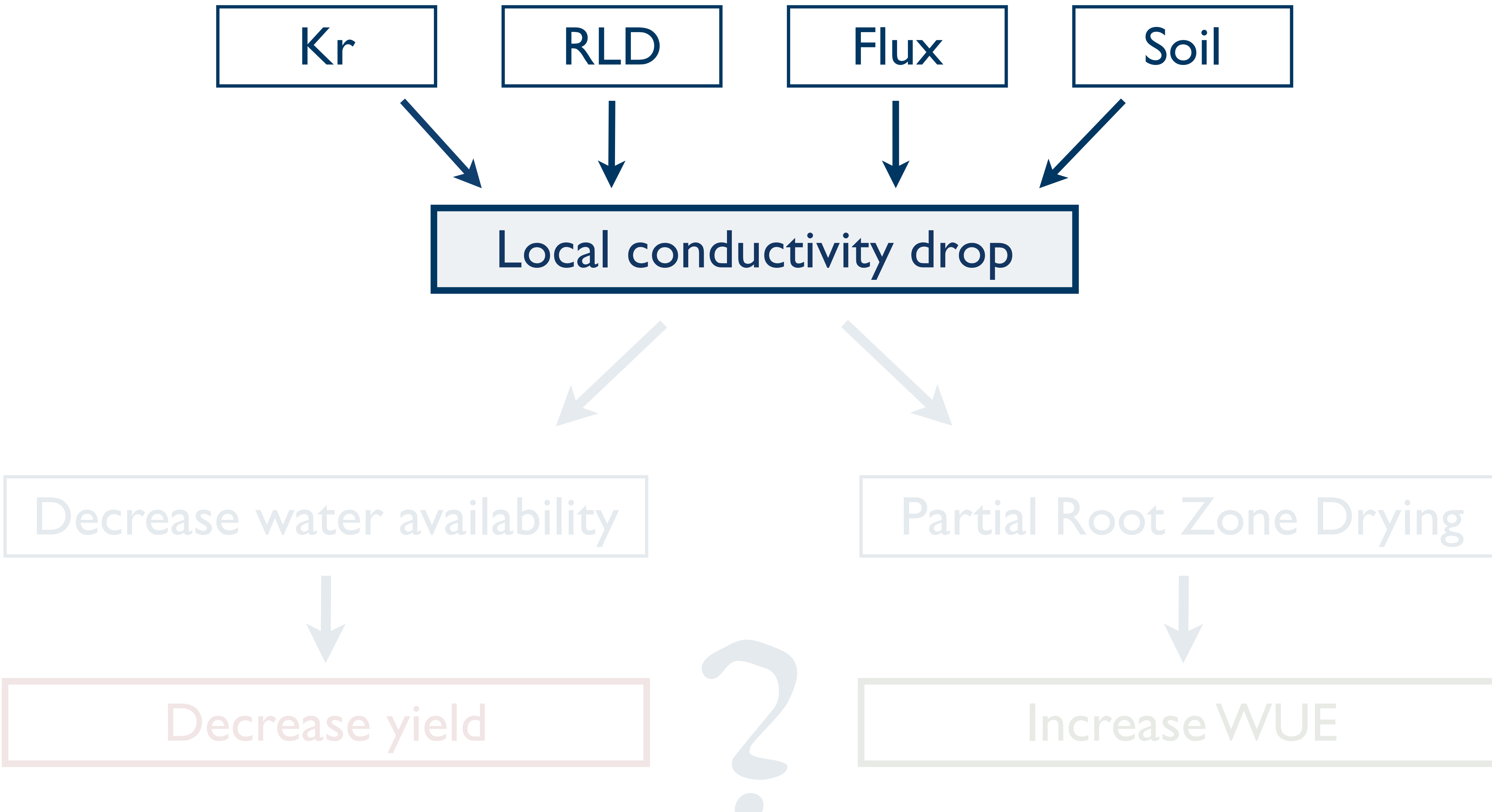
# New insights



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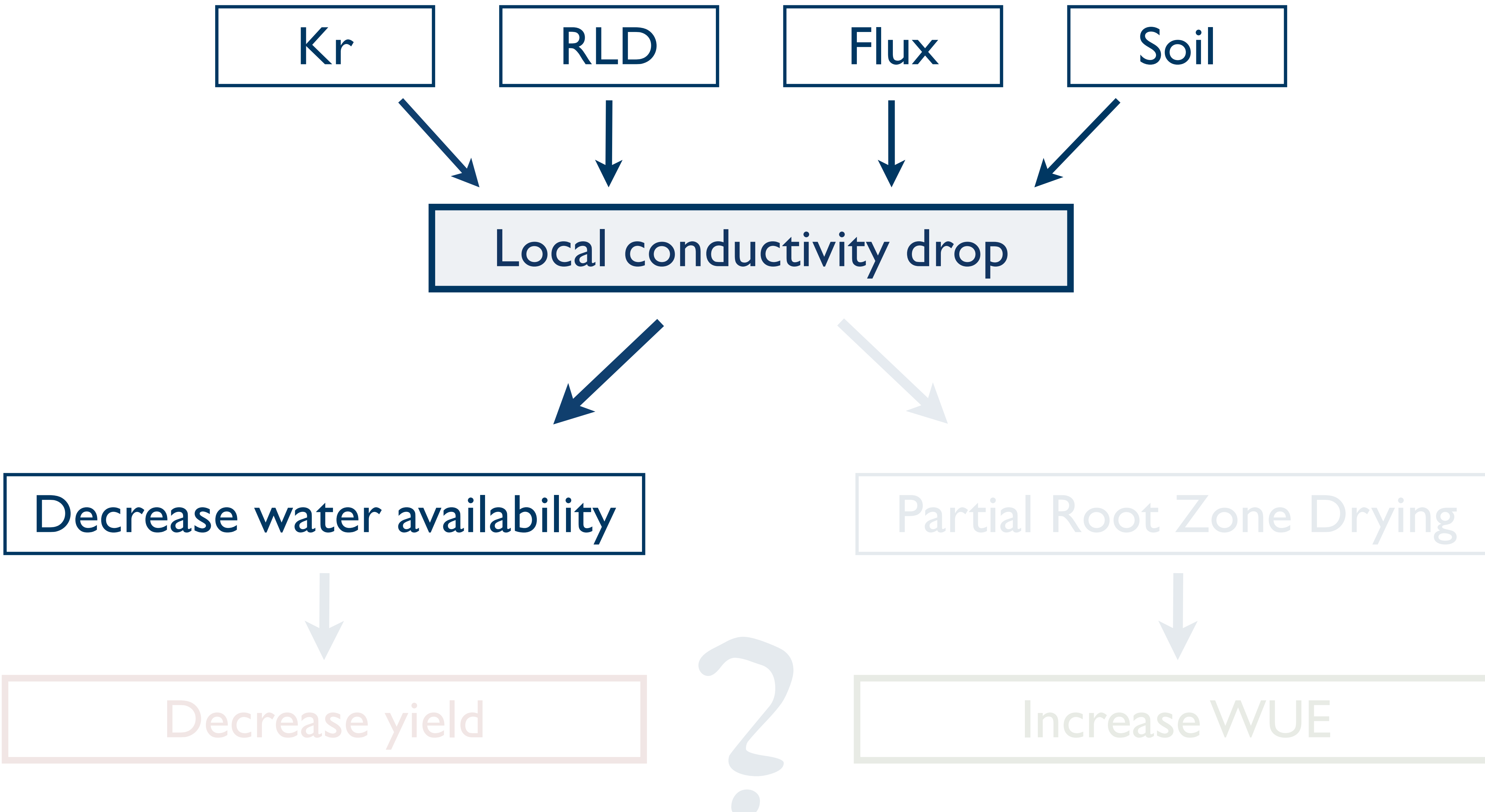

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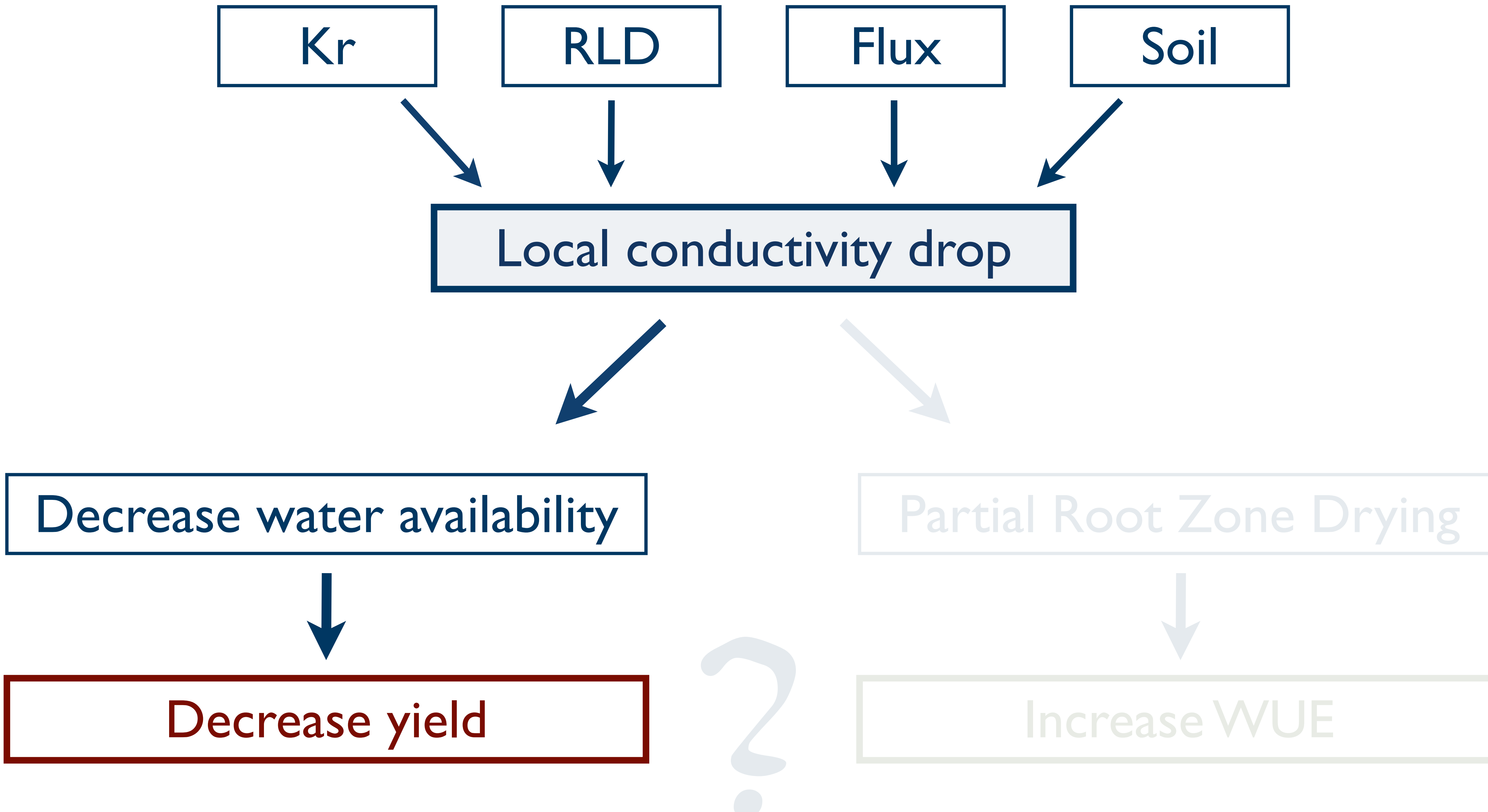

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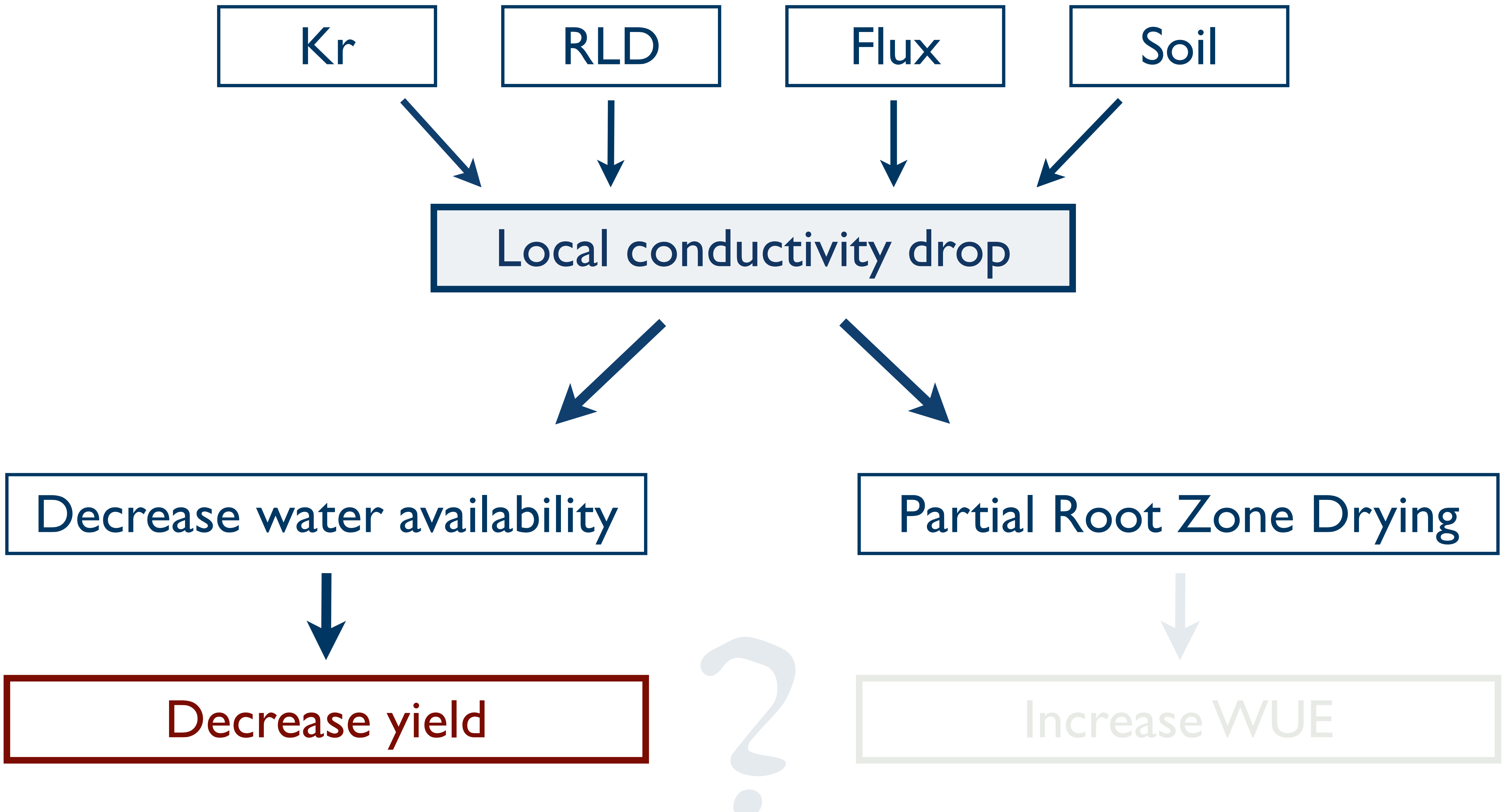

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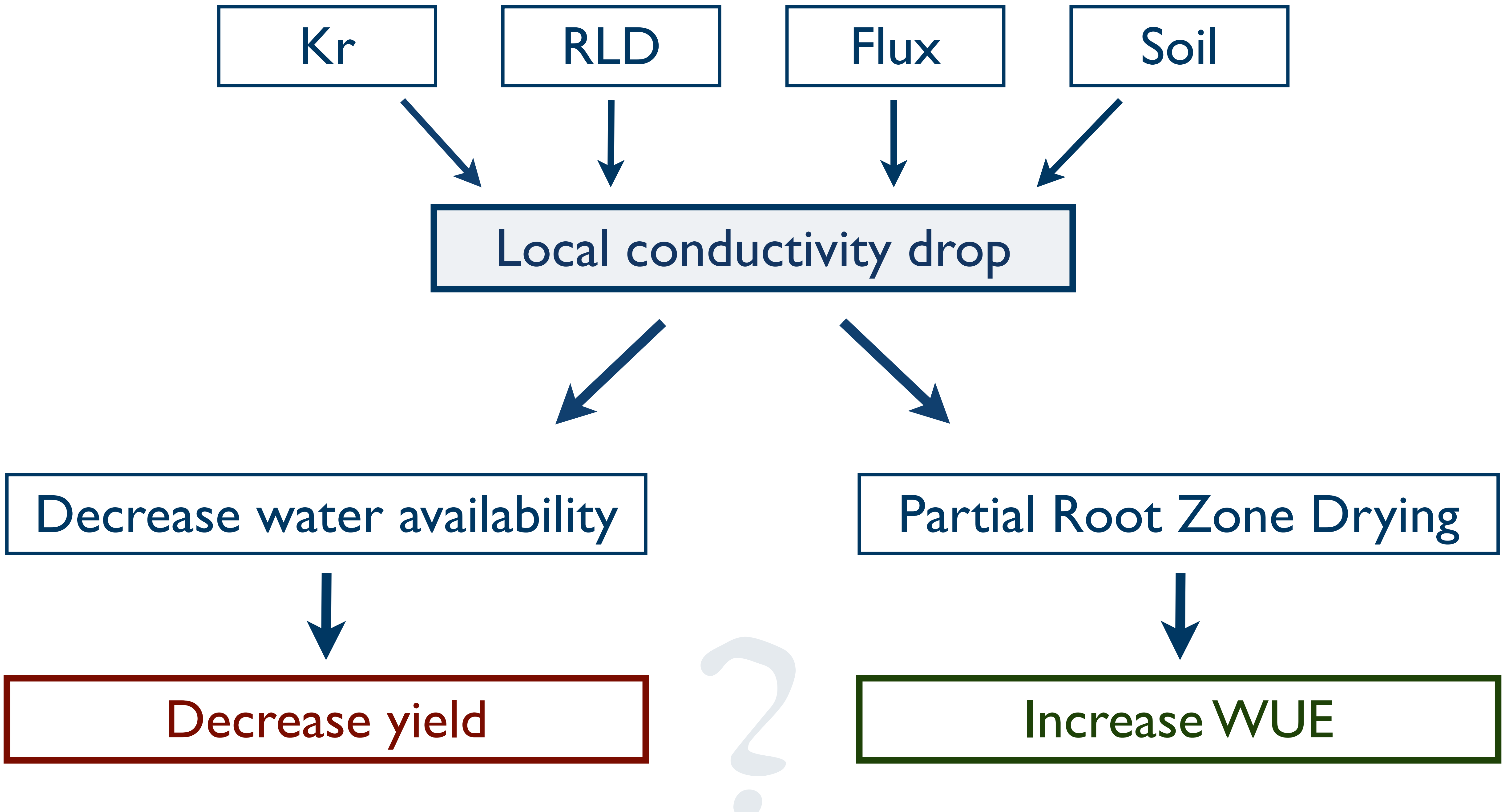

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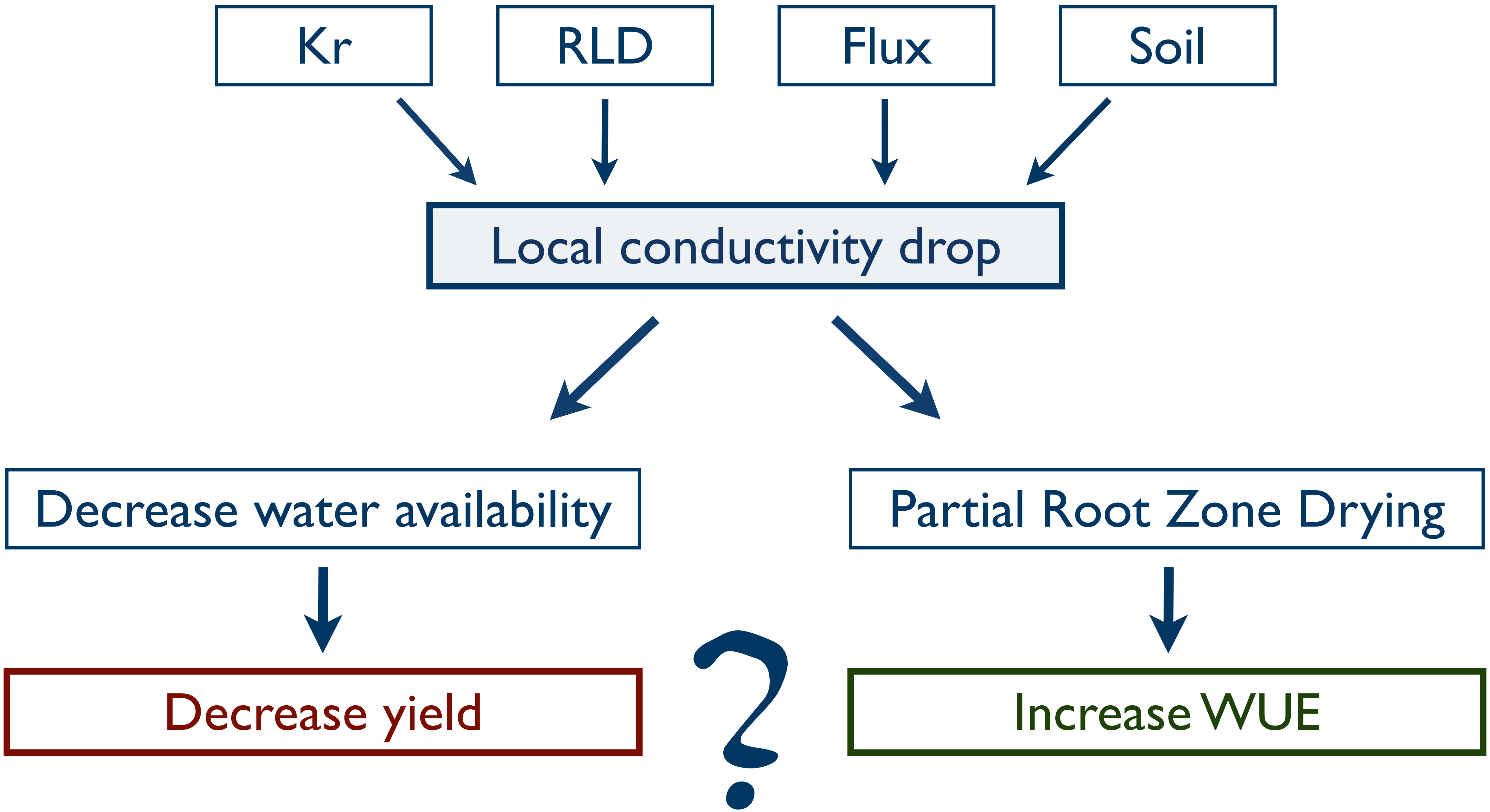

# Practical implications at the plant scale

Influence uptake dynamics → Change soil properties

↓

Change root characteristics

Change root architecture
King et al. 2003, Ann Bot 91 (3)
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Change Kr and Kx
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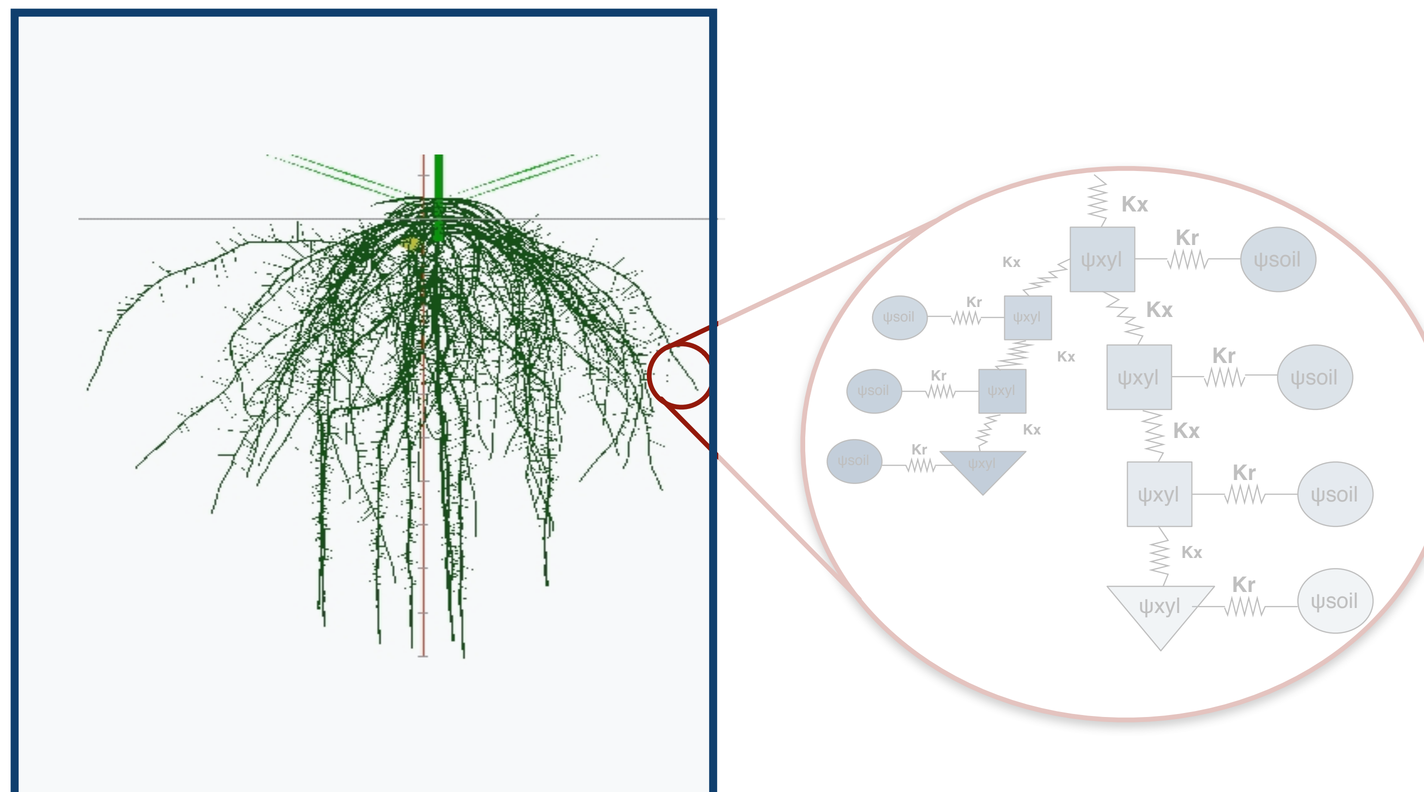

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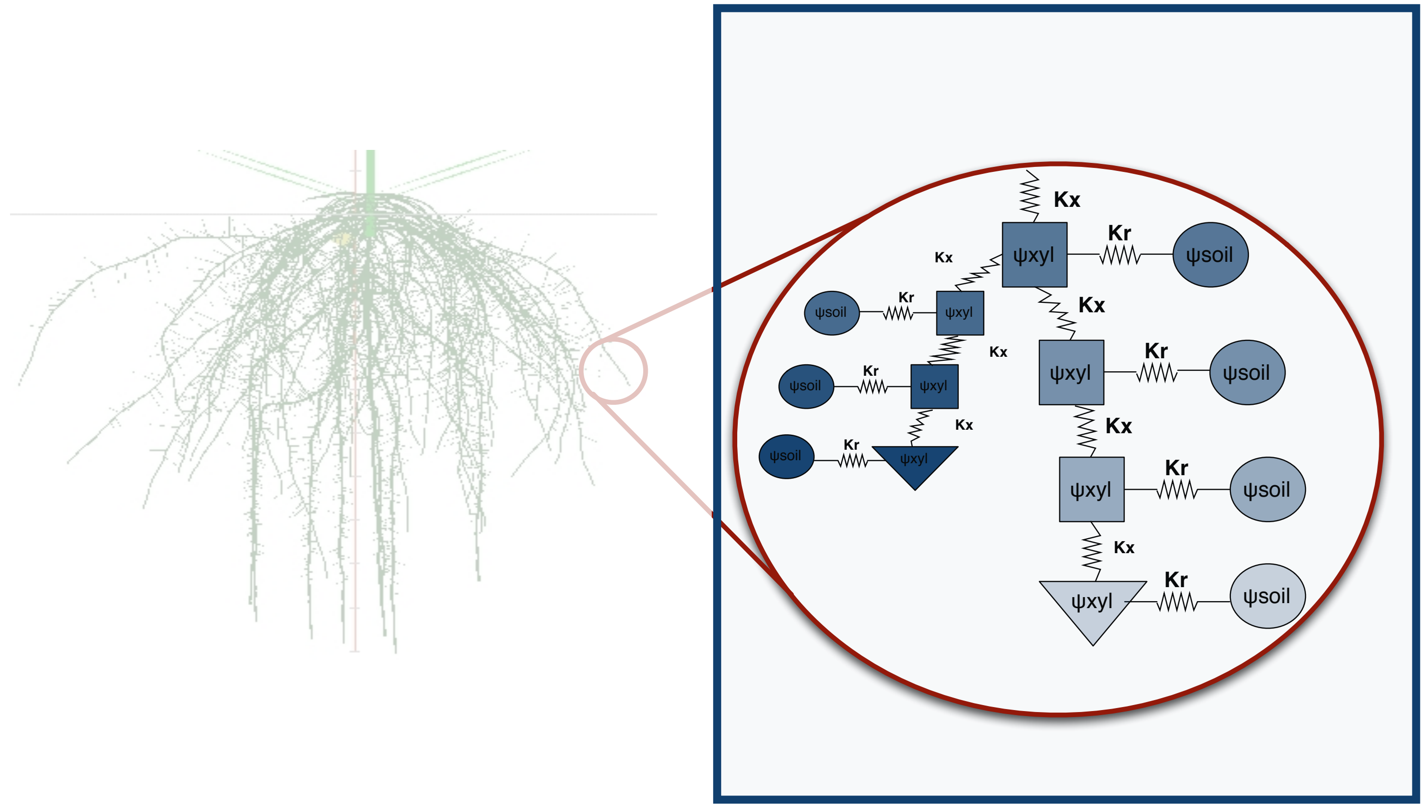

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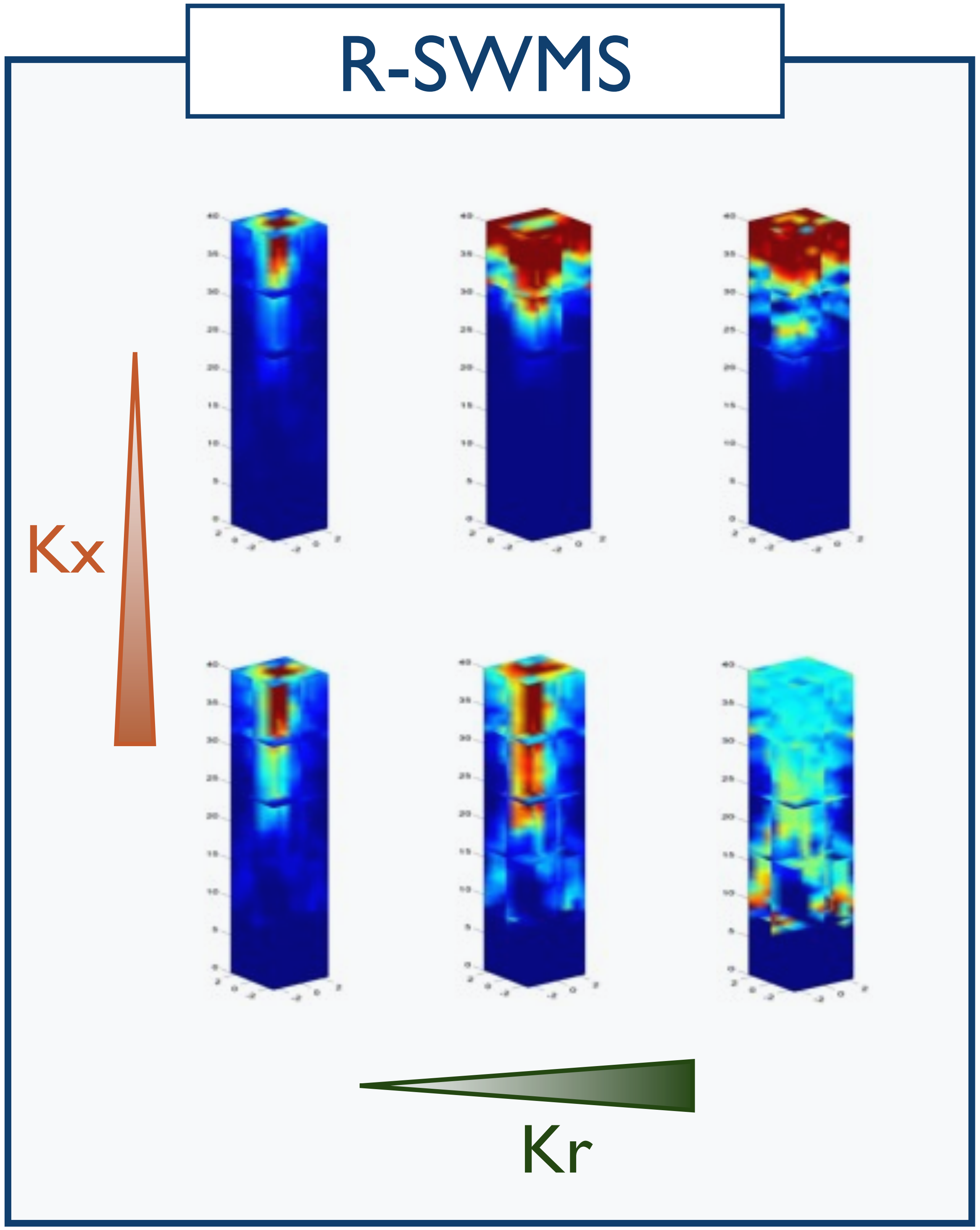
→ Computer modeling can be used to design water extraction strategies and ideotypes

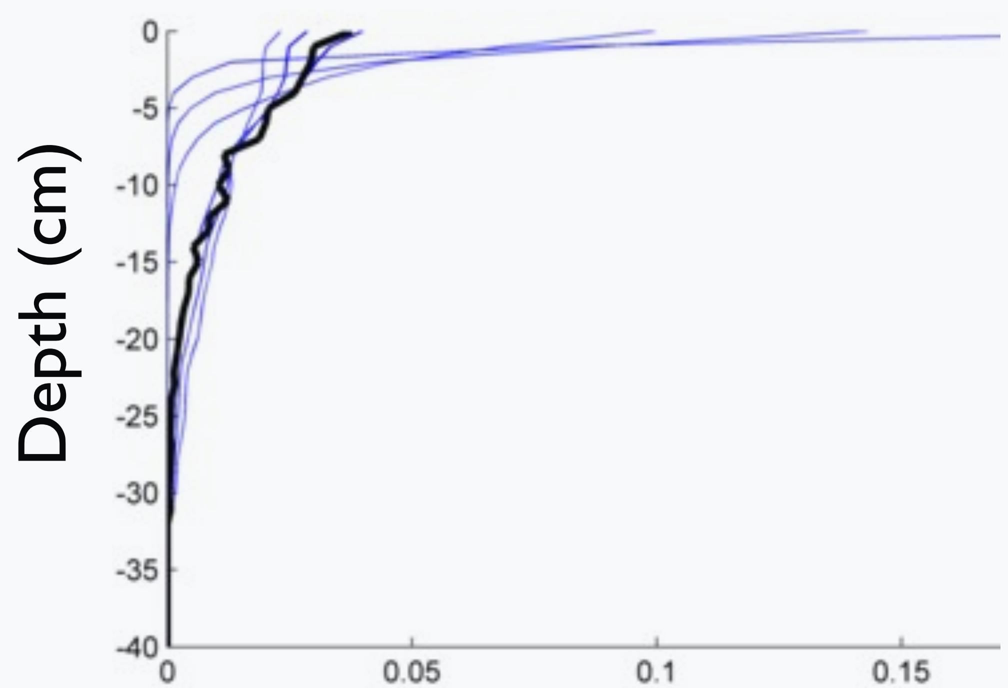
# Modelling as an ideotype design tool



# Modelling as an ideotype design tool

## SSD

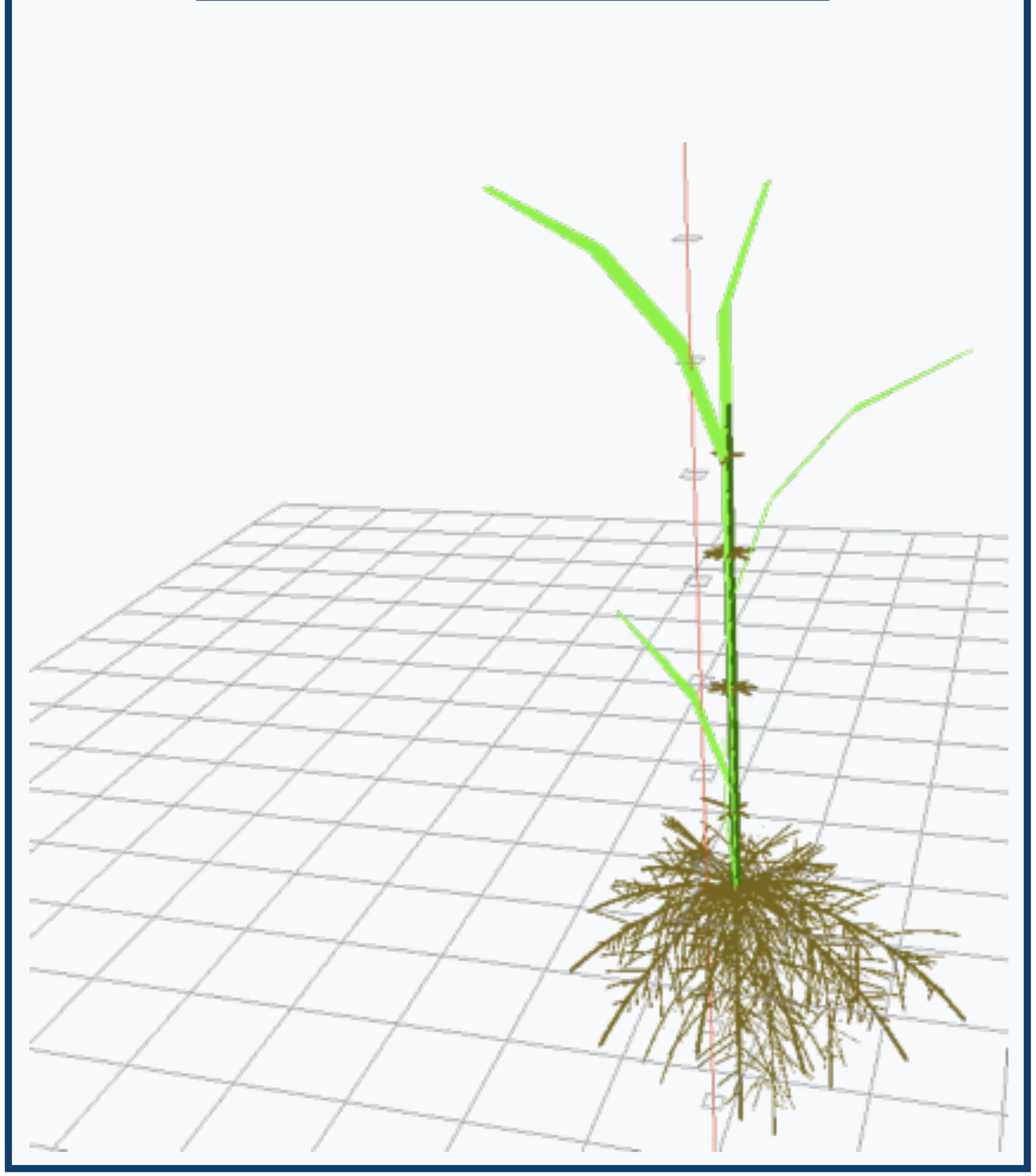
Standard Sink Distribution




RLD vs SSD

# Modelling as an ideotype design tool

PlaNet - Maize



# Take home message

Uptake pattern matters

Need to integrate root system architecture and hydraulic properties (root and soil)

Importance of multi-scale and space-time dynamics

Experimental and modeling tools are available

# Acknowledgments


## Collaborations

Université catholique de Louvain

Prof. François Chaumont
Vincent Larondelle
Nicolas Lieutenant

INRA Avignon

Loïc Pagès

University of Lancaster

Ian Dodd

## Funding

Rank Price Fund

F.N.R.S. - F.R.I.A.

Université catholique de Louvain

Walloon region

P.A.I.

# Influence of the soil conductivity

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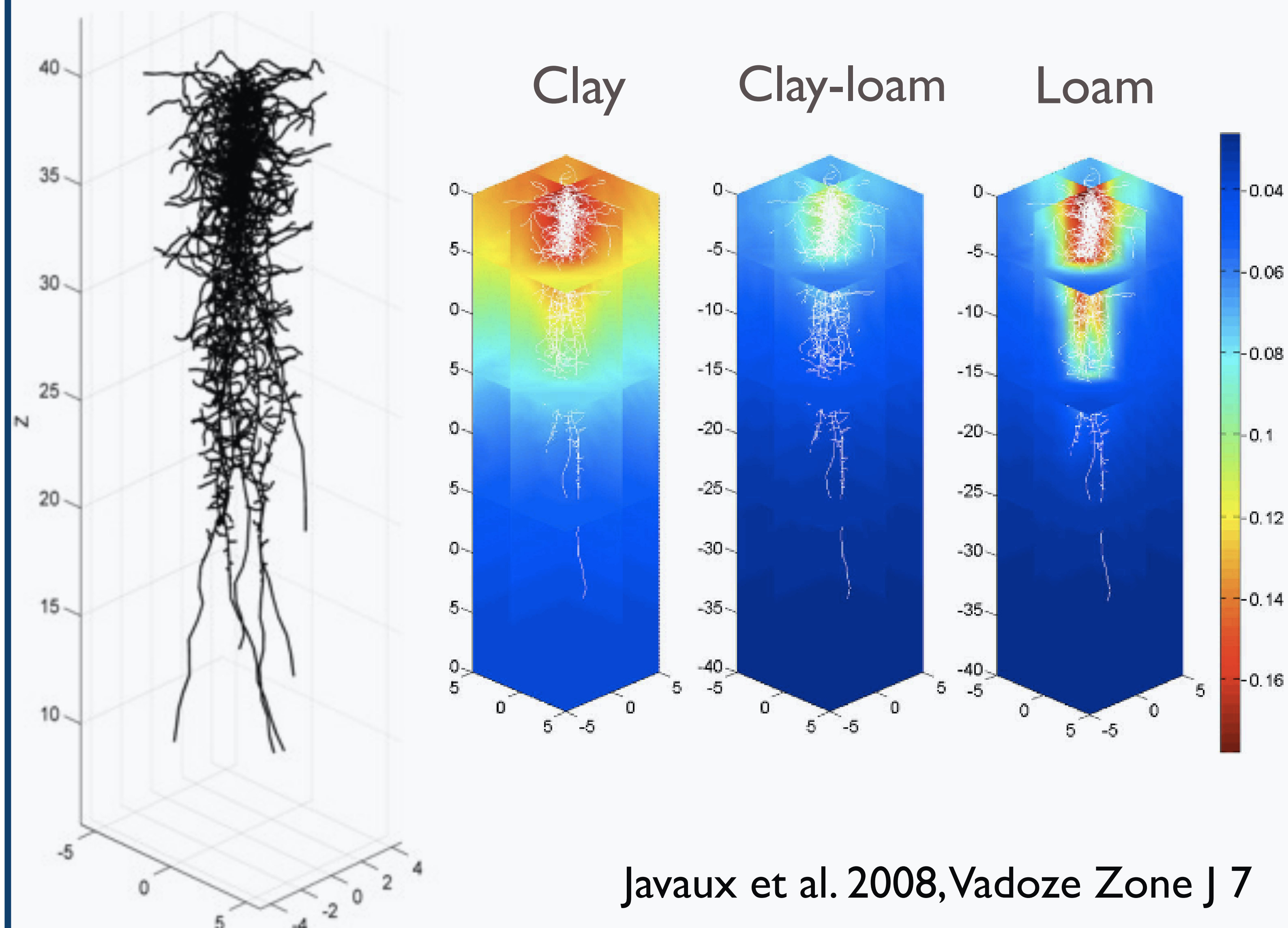



Javaux et al. 2008, Vadoze Zone J 7

**SAME:**
Root architecture
Root hydraulic properties
Transpiration

**DIFFERENT:**
Soil type

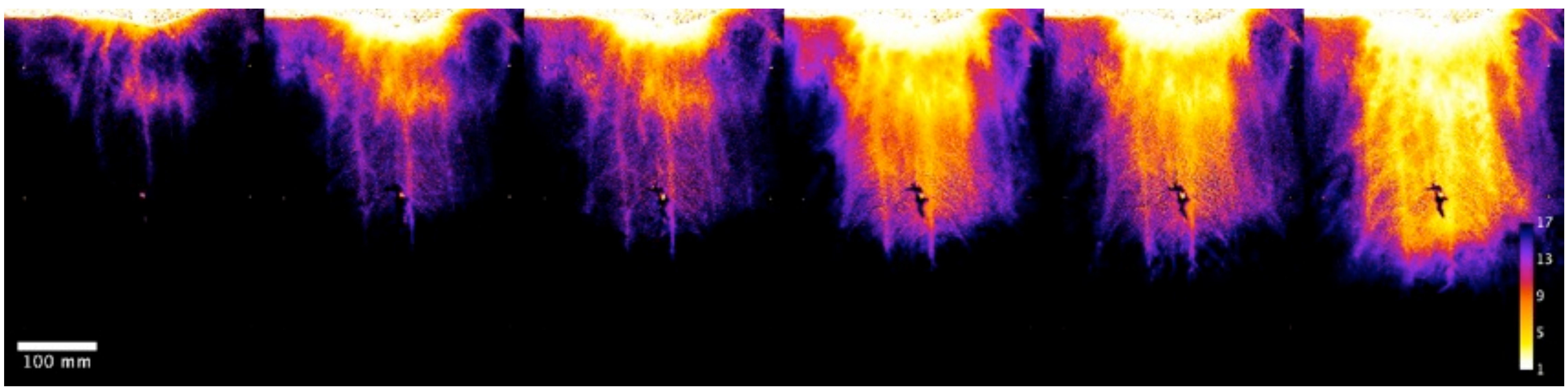
↓

**Uptake distribution**

# Uptake overview

Water uptake follows a downward dynamics

% of roots in depleted areas increases with time



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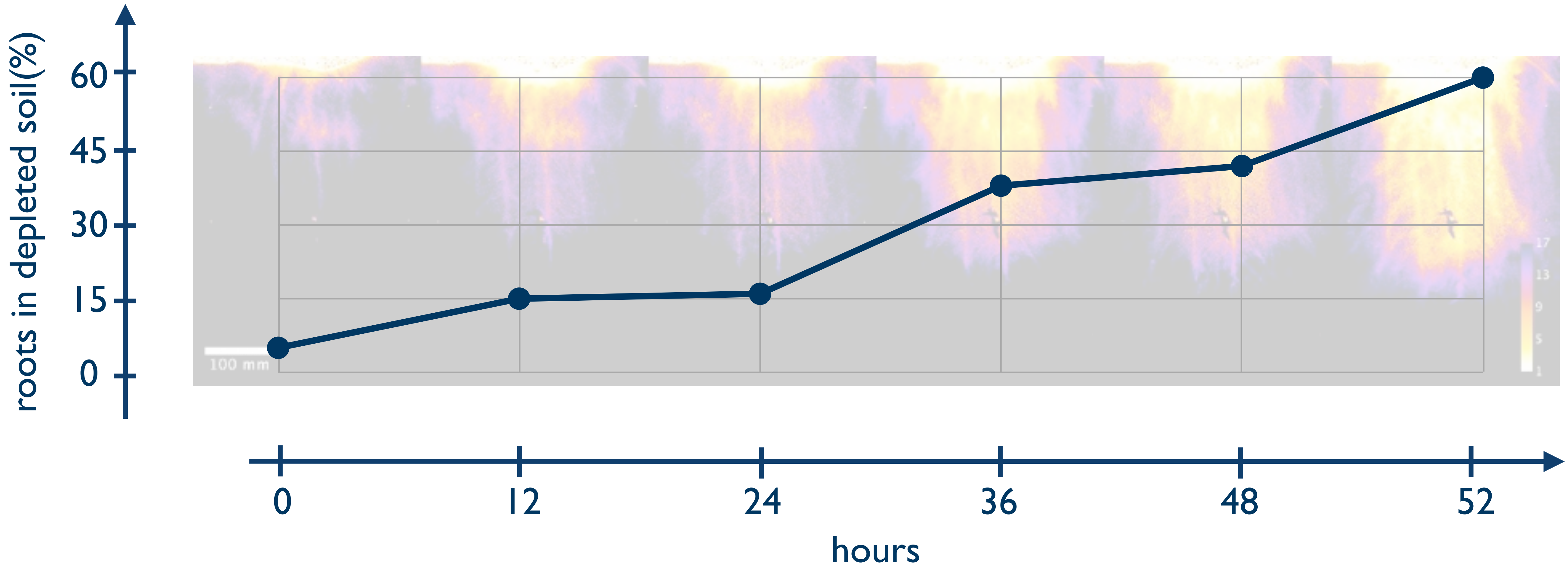
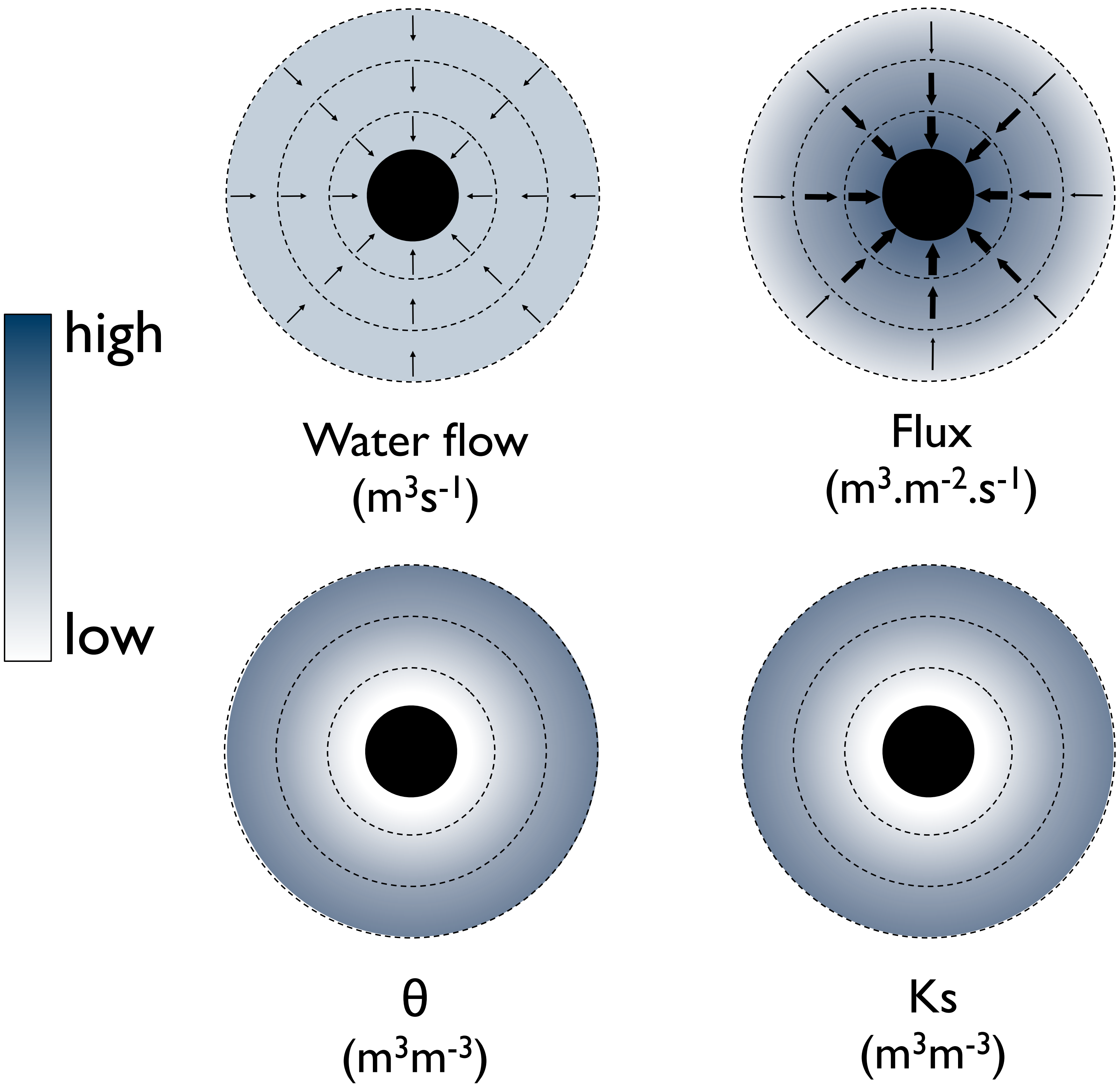
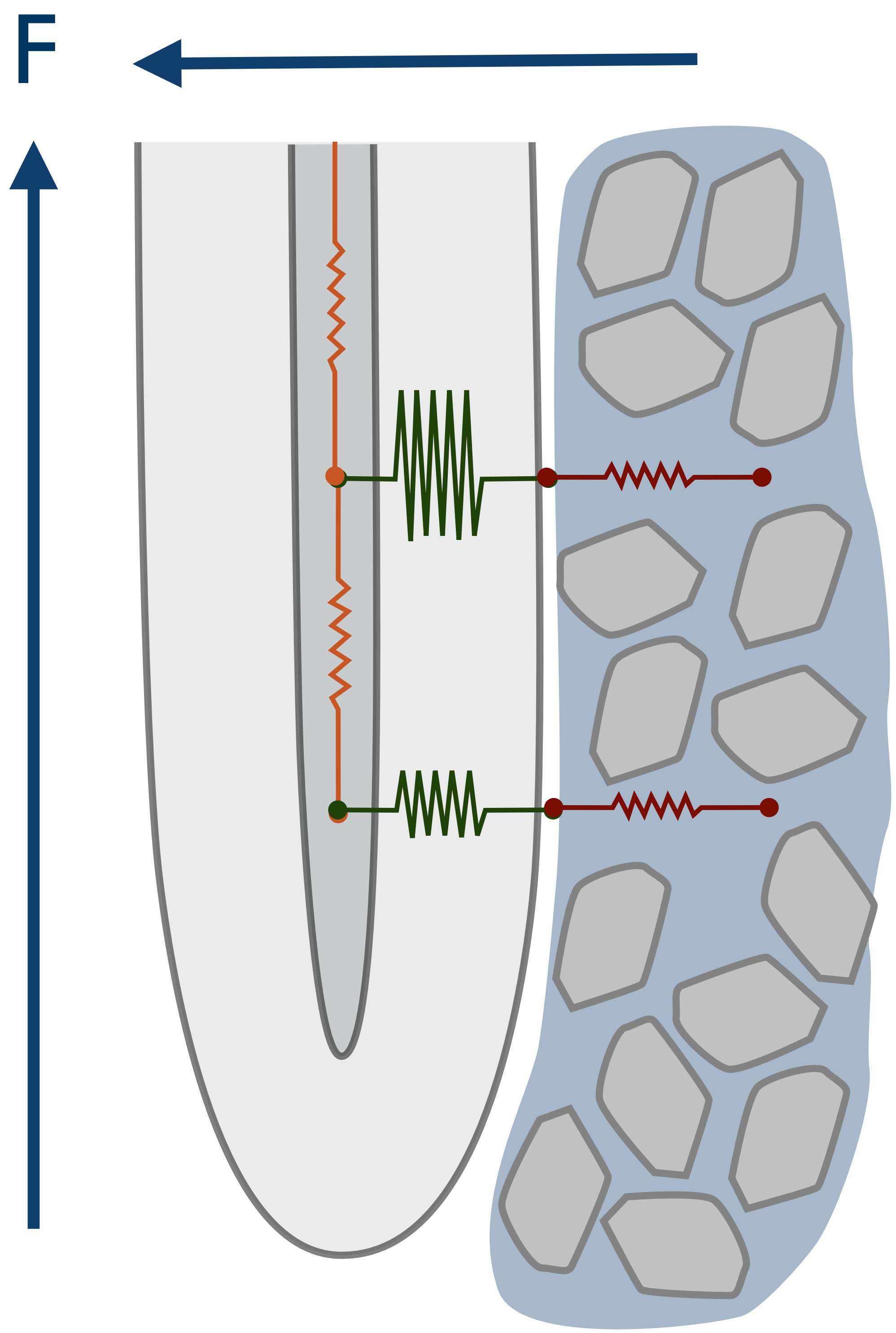


# Why does "radialness" matters?




High influence of the uptake rate

# Conductivities along a root




Soil conductivity (Ks)

Soil type
Water content (θ)

Root radial conductivity (Kr)

Root type
Root segment age
Environment

Root axial conductivity (Kx)

Root type
Root segment age
Environment

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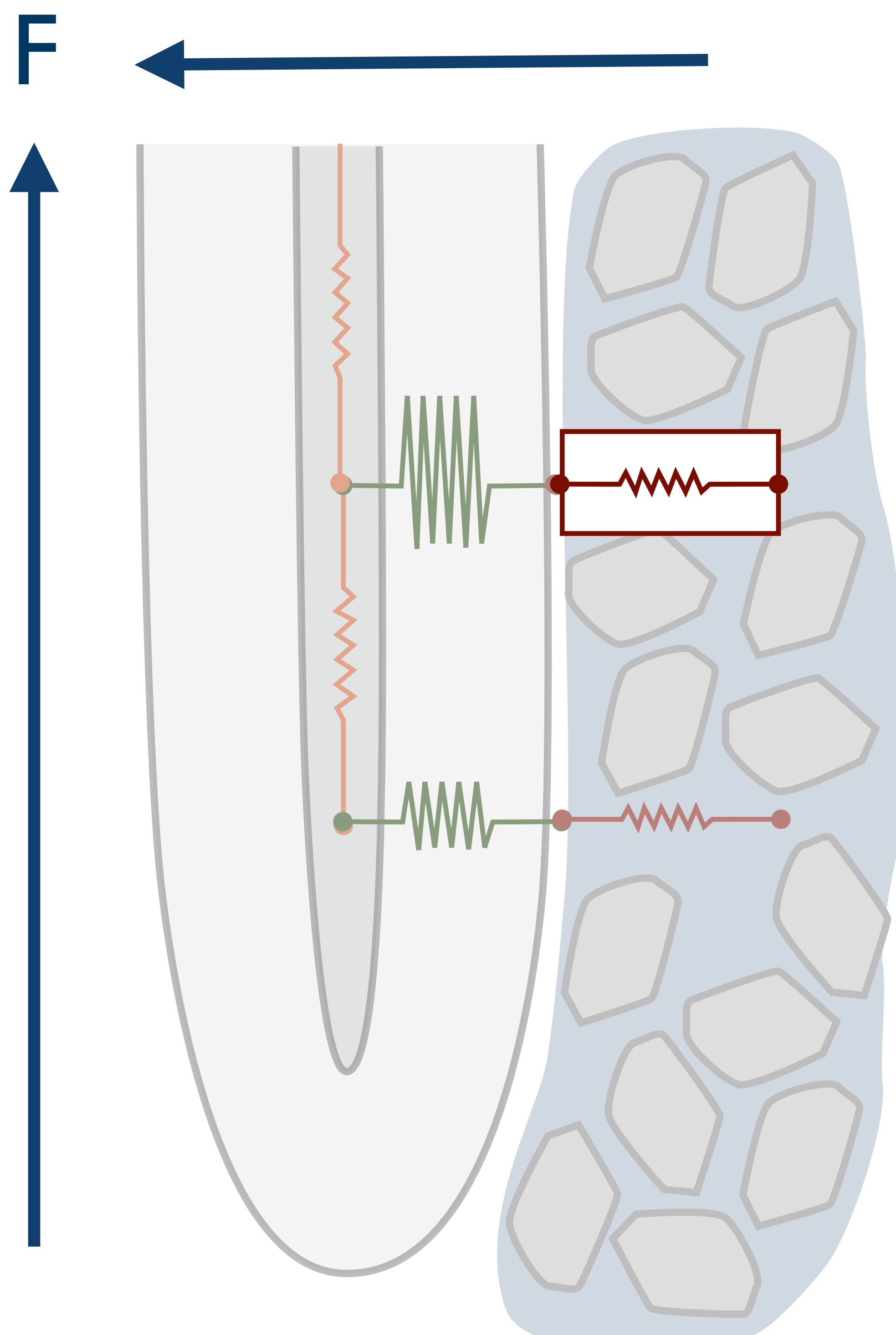


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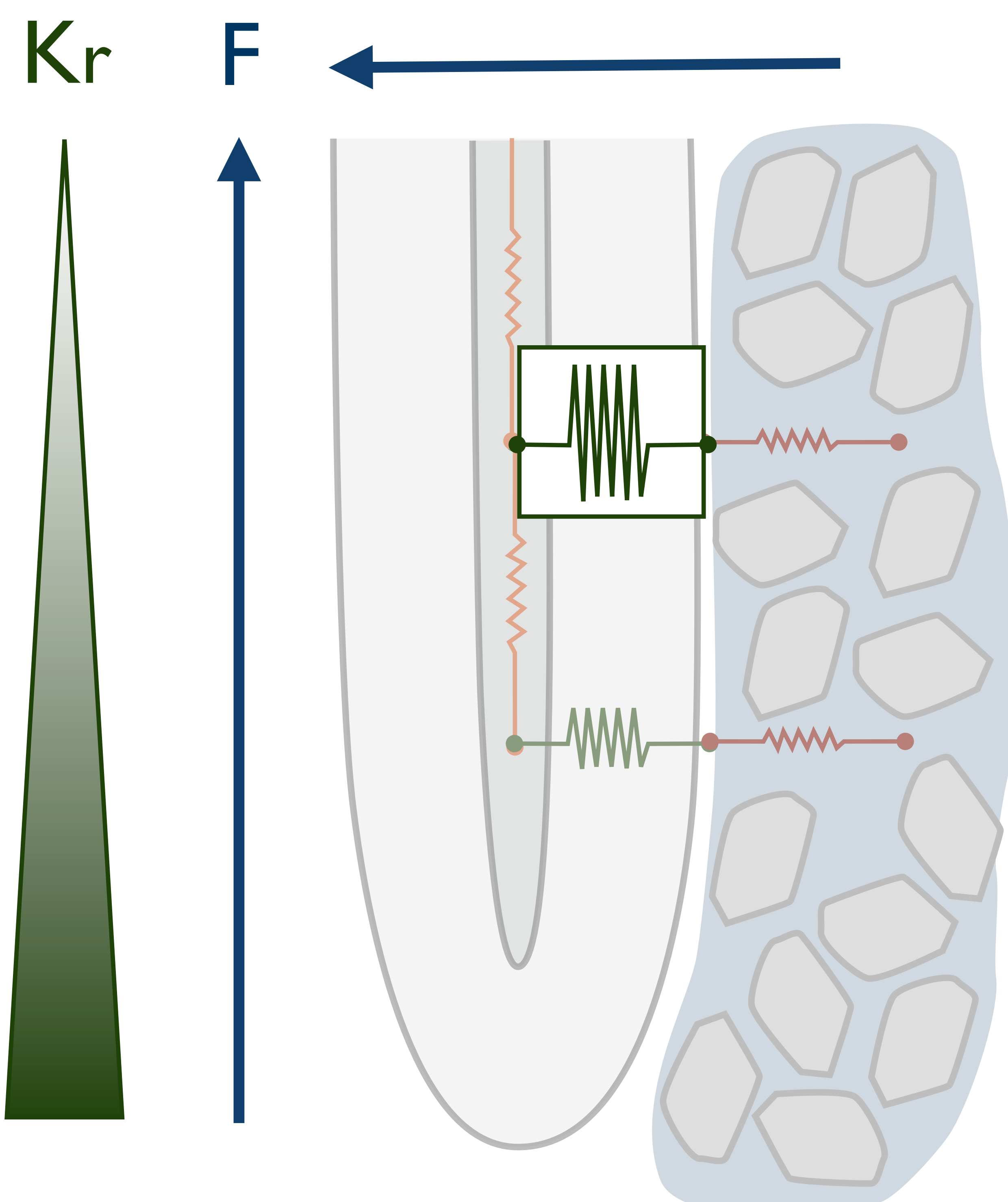


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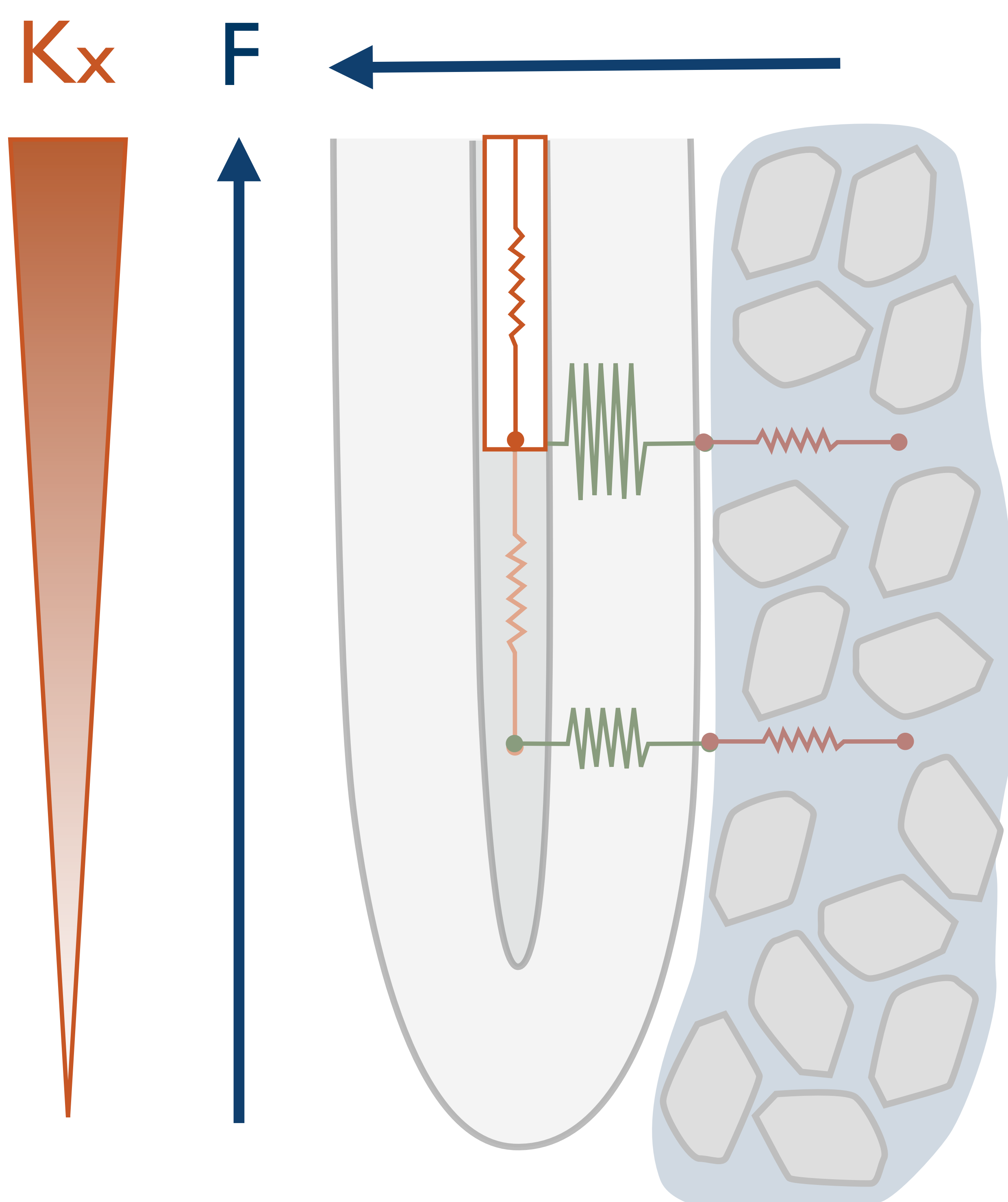


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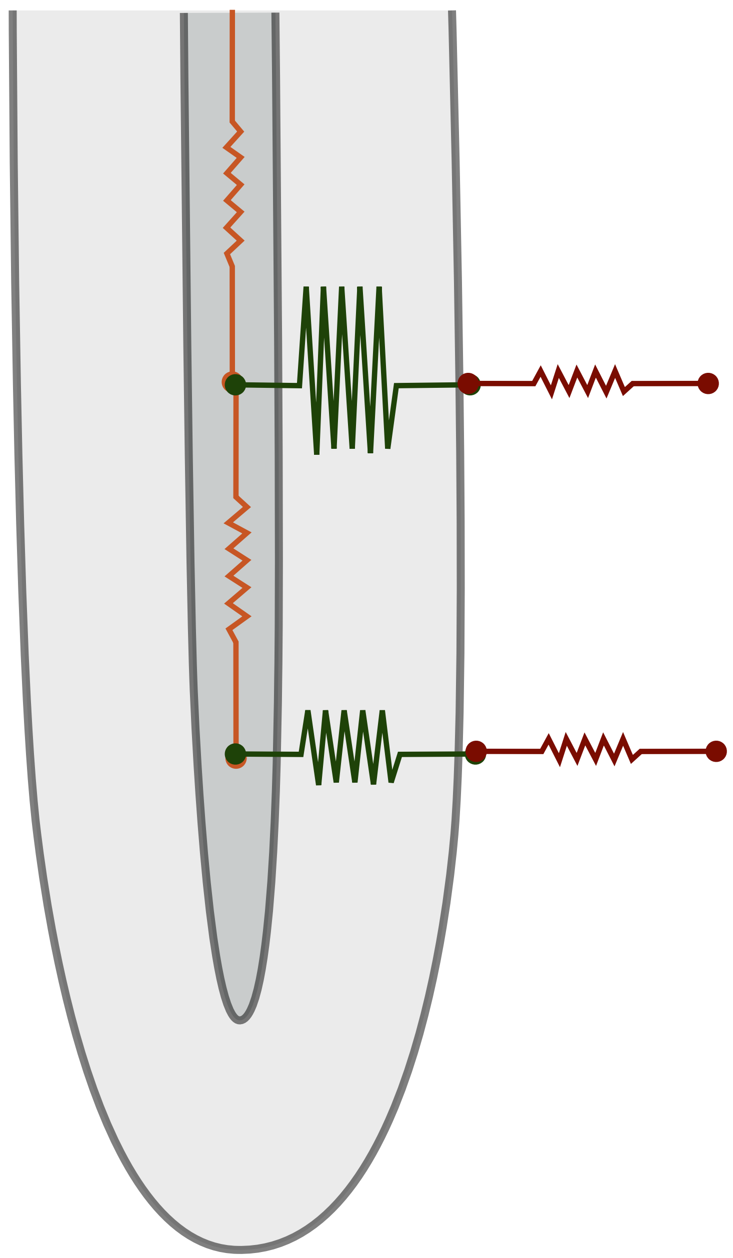
# Integration at the root system level

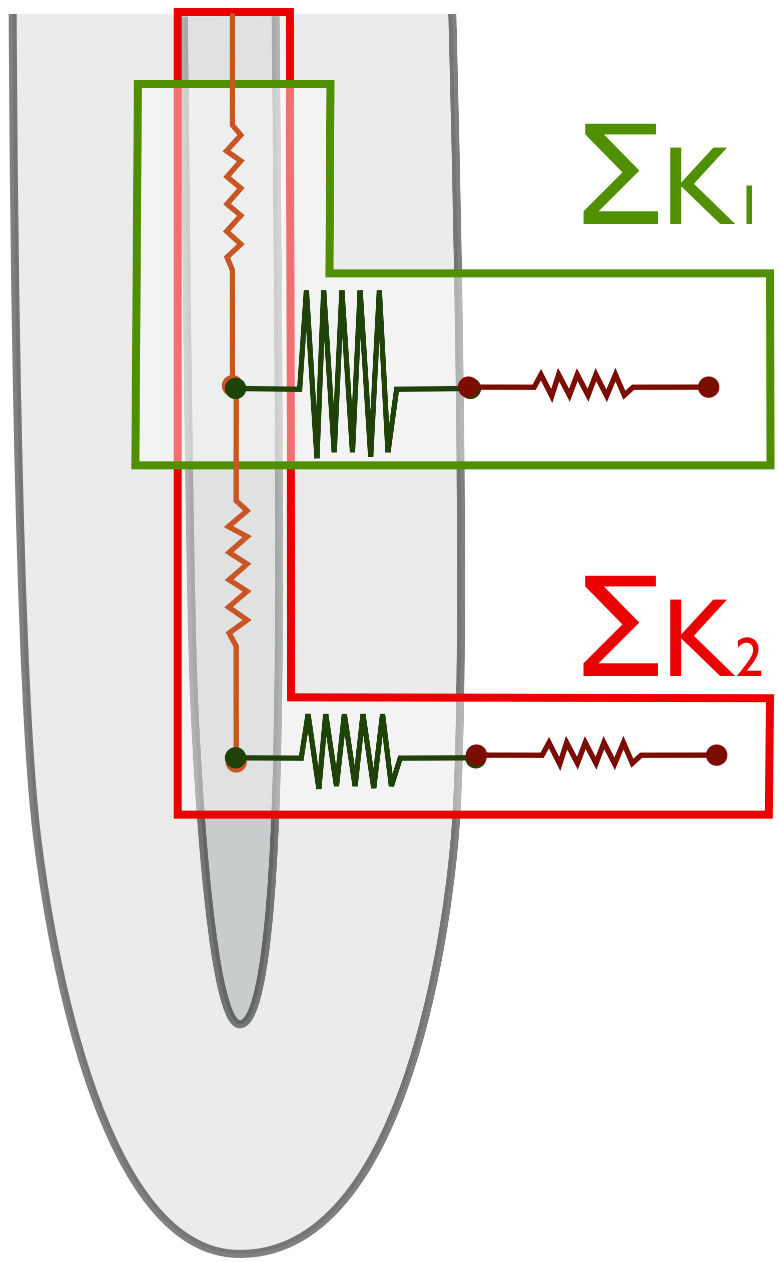


$$\Sigma K = \Sigma 1/K_x + \Sigma 1/K_r + \Sigma 1/K_s$$

Water preferably takes the path of maximum conductance (for a given $\Delta\psi$)

The **lowest** conductance will be the limiting factor

# Integration at the root system level

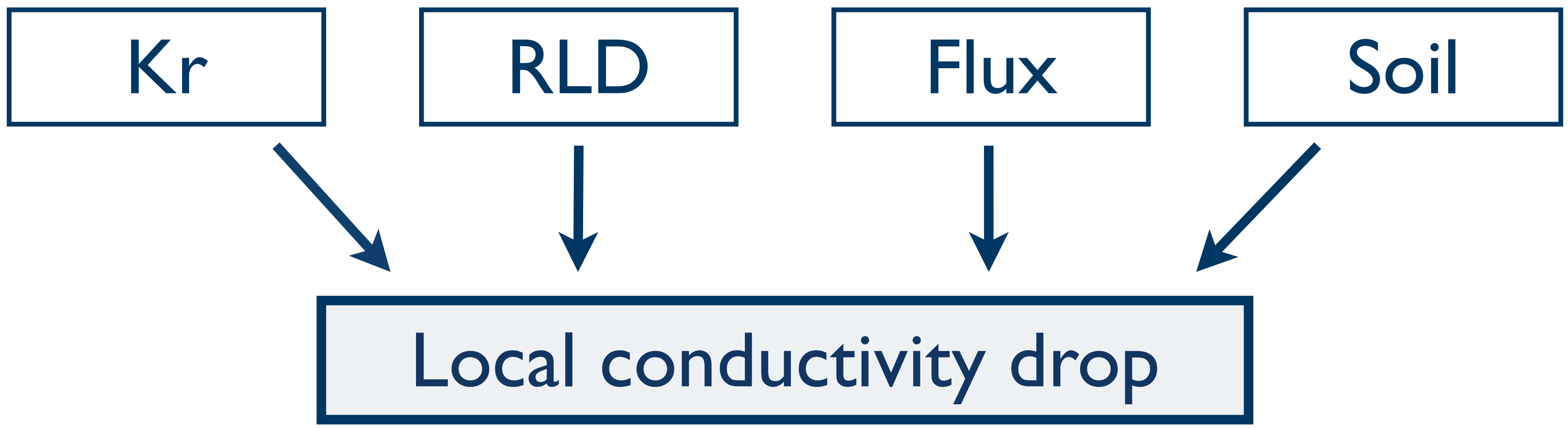



$$\Sigma K = \Sigma 1/K_x + \Sigma 1/K_r + \Sigma 1/K_s$$

Water preferably takes the path of maximum conductance (for a given $\Delta\psi$)

The **lowest** conductance will be the limiting factor

# New insights



# New insights

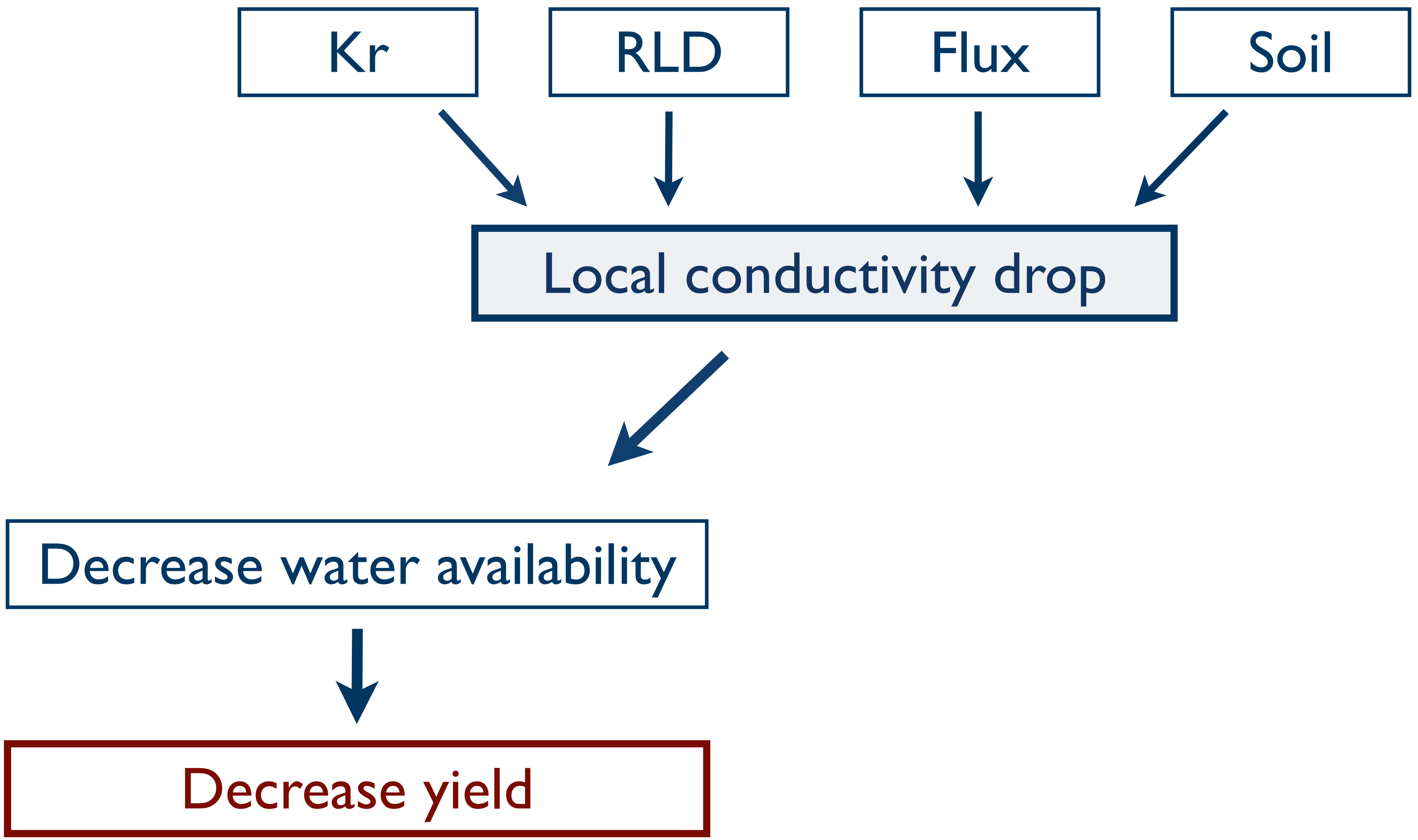
Kr → RLD → Flux → Soil →

**Local conductivity drop**

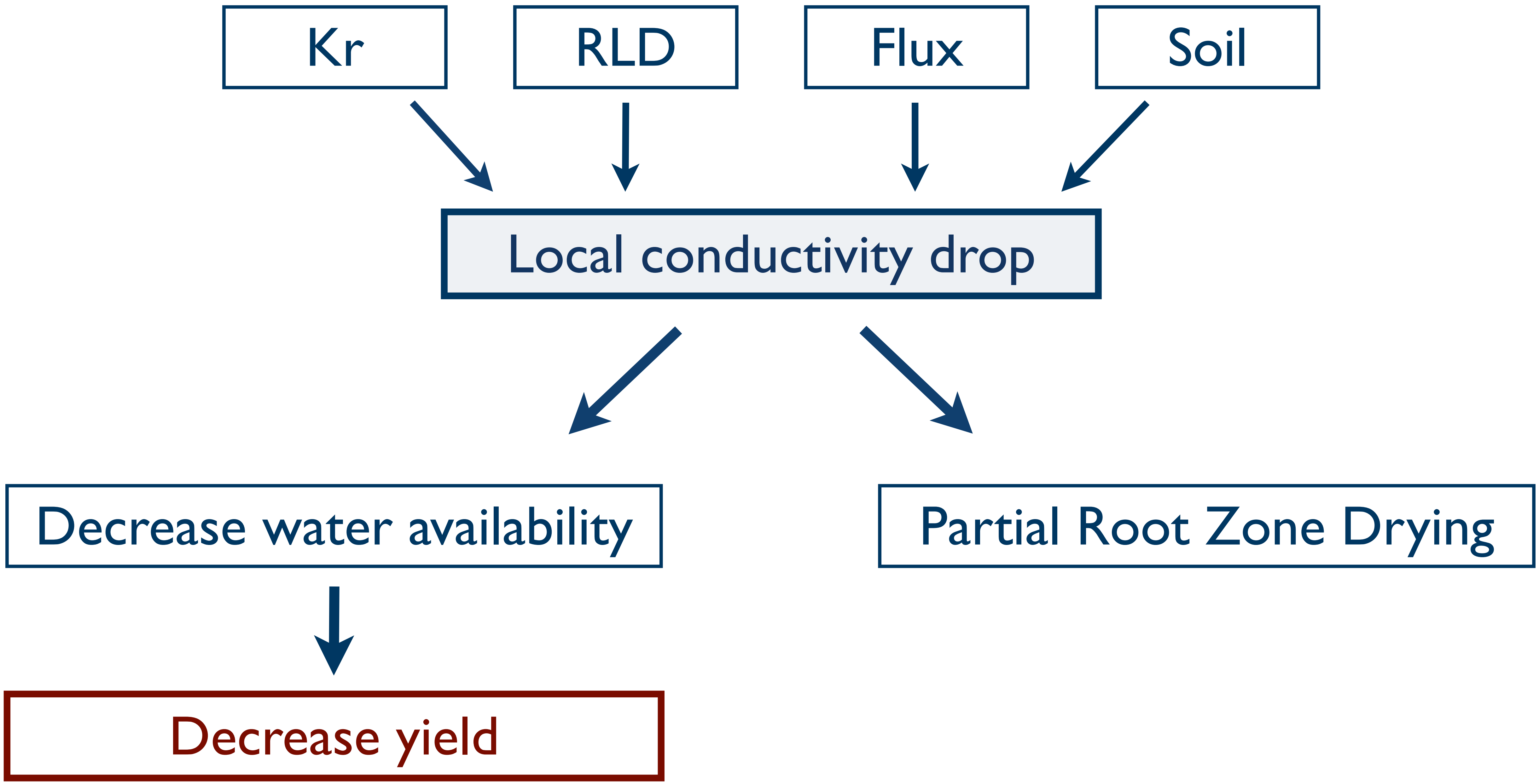
↓

Decrease water availability

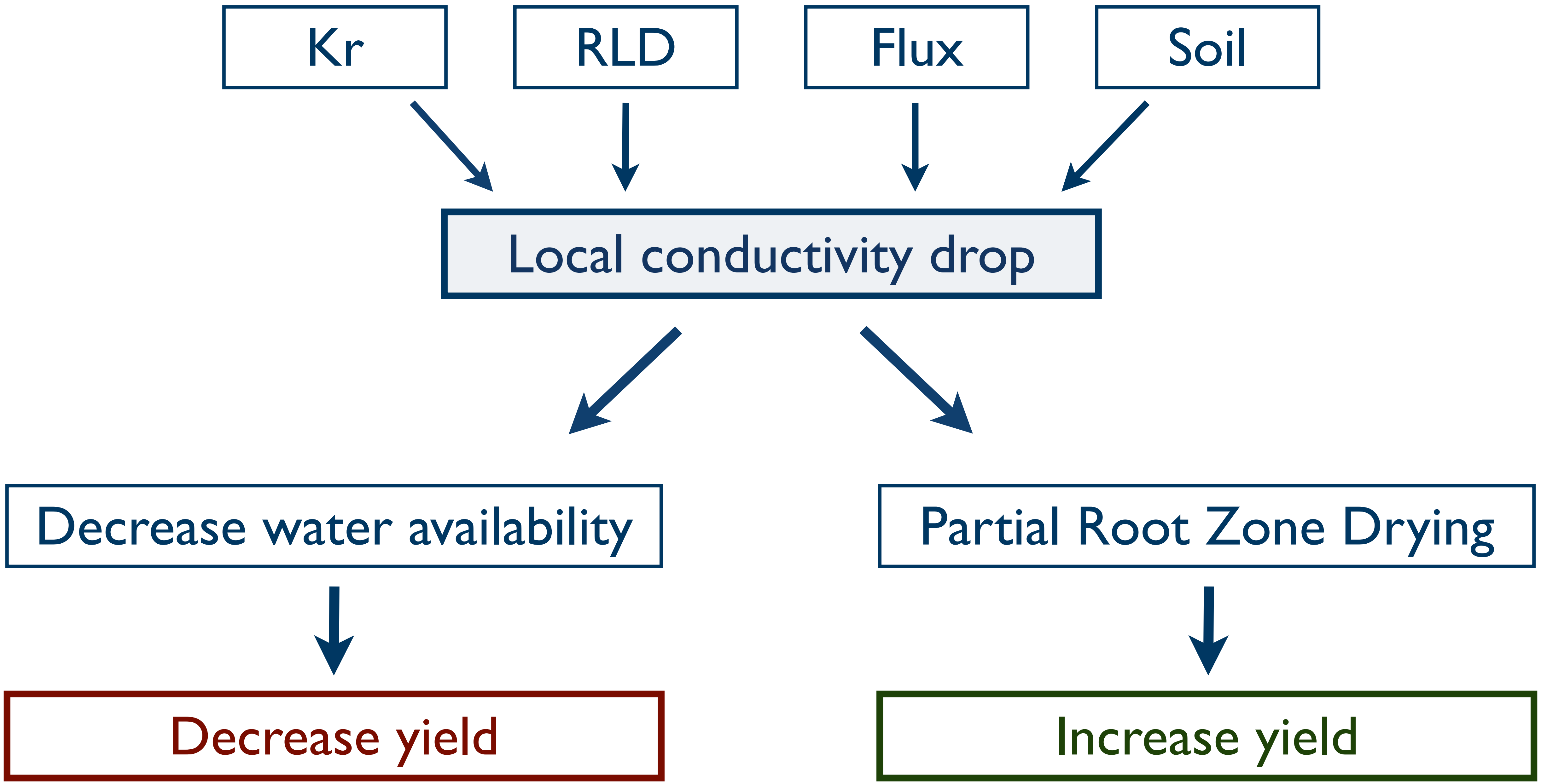
# New insights



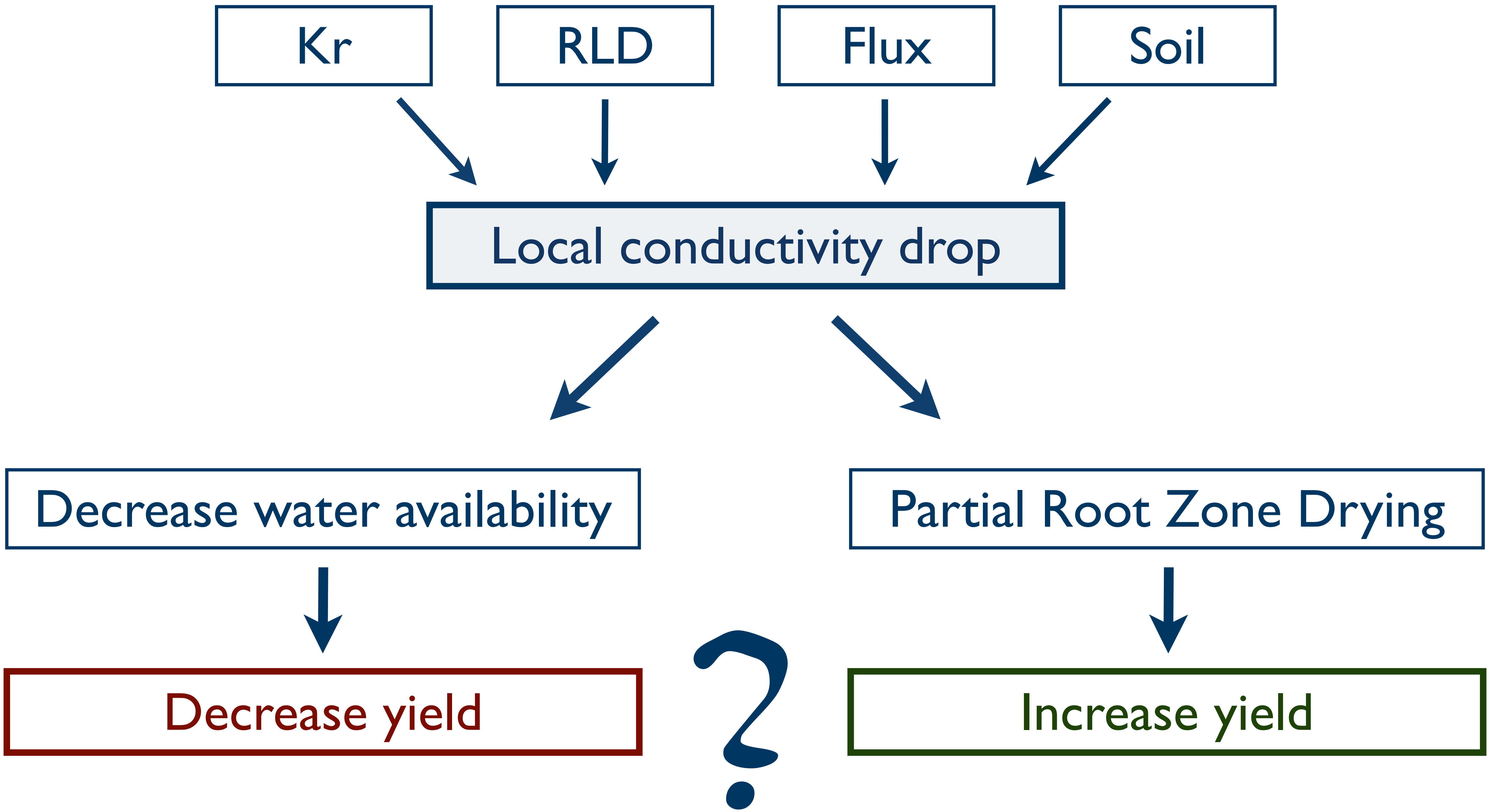
# New insights



# New insights



# New insights



# Practical implications

Influence uptake dynamics

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Influence uptake dynamics → Change soil properties

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↓

Change root characteristics

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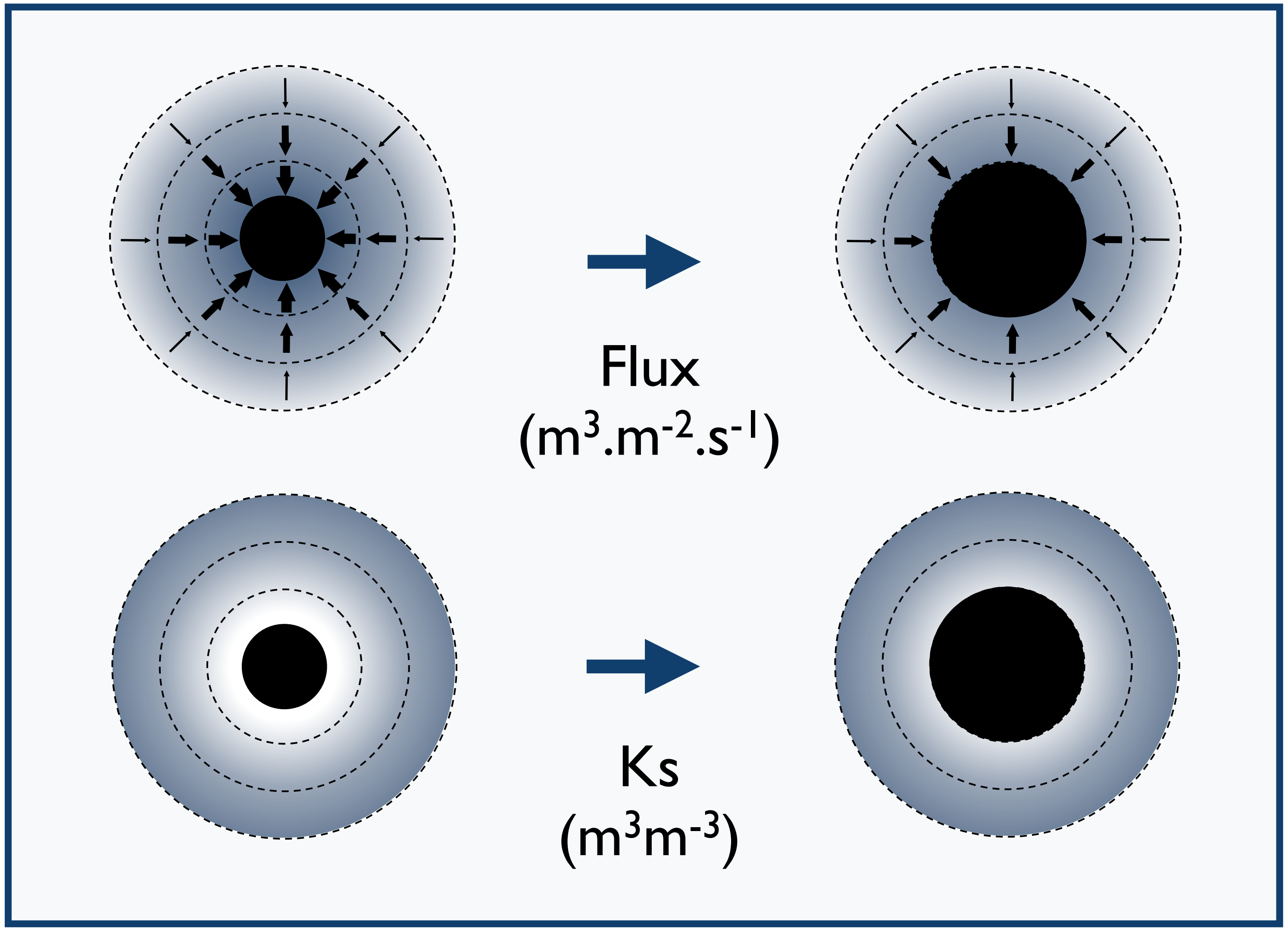
Influence uptake dynamics → ~~Change soil properties~~

↓

Change root characteristics

Change the root diameter
de Jong v. L. et al. 2006, Vadoze Zone J 5 (4)



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↓

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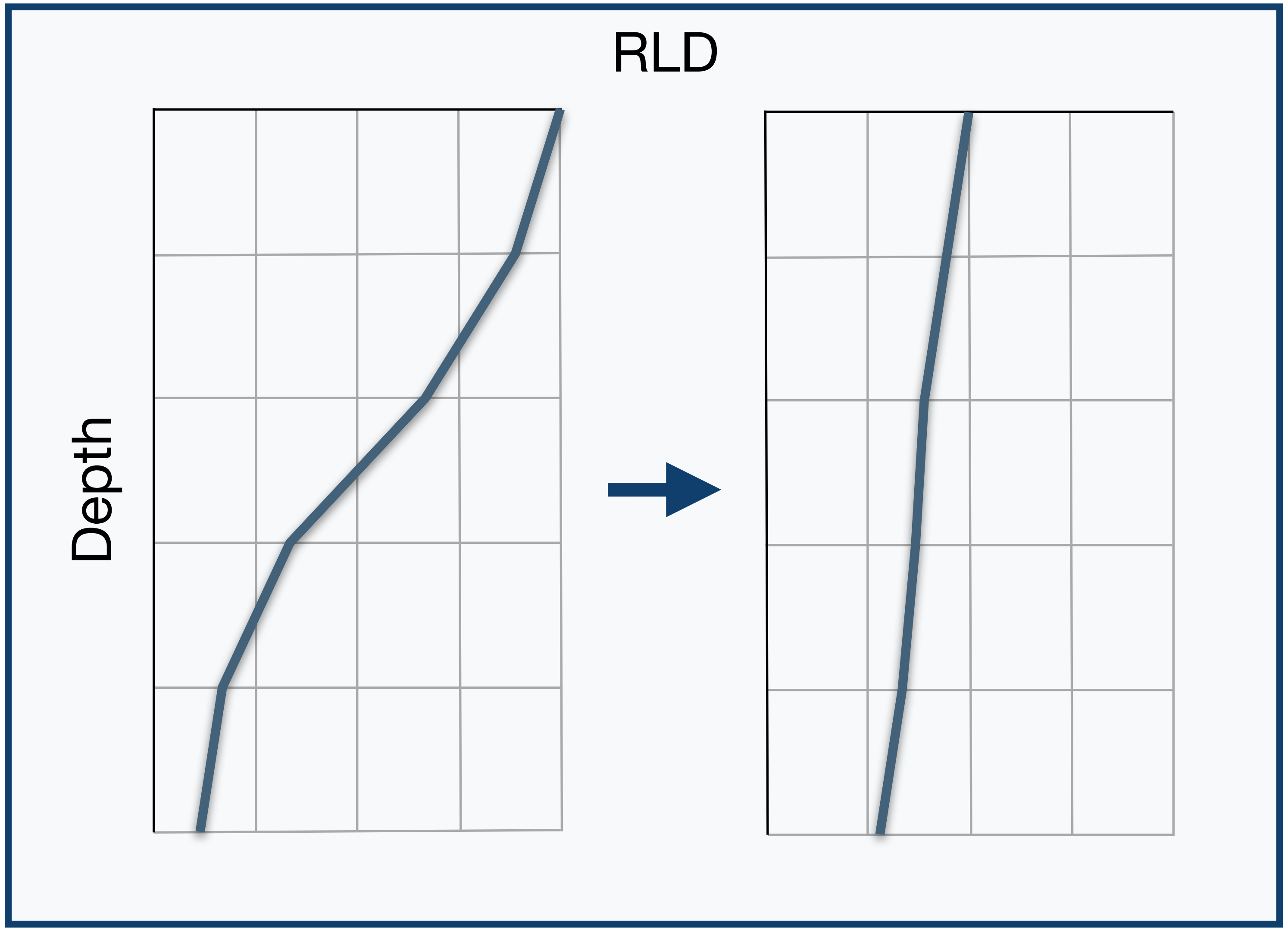


**Change the root diameter**
de Jong v. L. et al. 2006, Vadoze Zone J 5 (4)

**Change root architecture**
King et al. 2003, Ann Bot 91 (3)
Bernier et al. 2009, Field Crops Res 110

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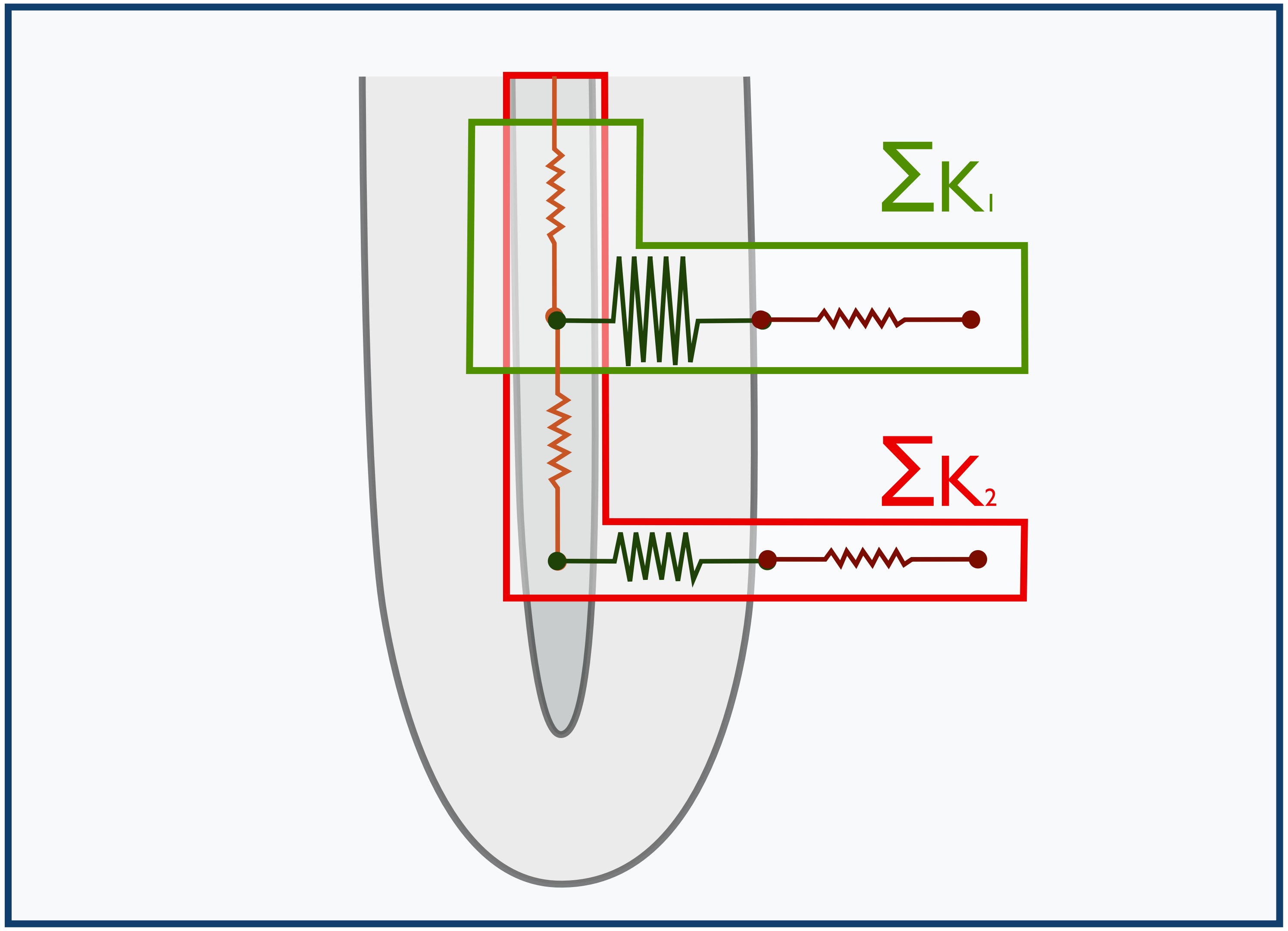
Richards et al., 1989, Aust J Agr Res 40



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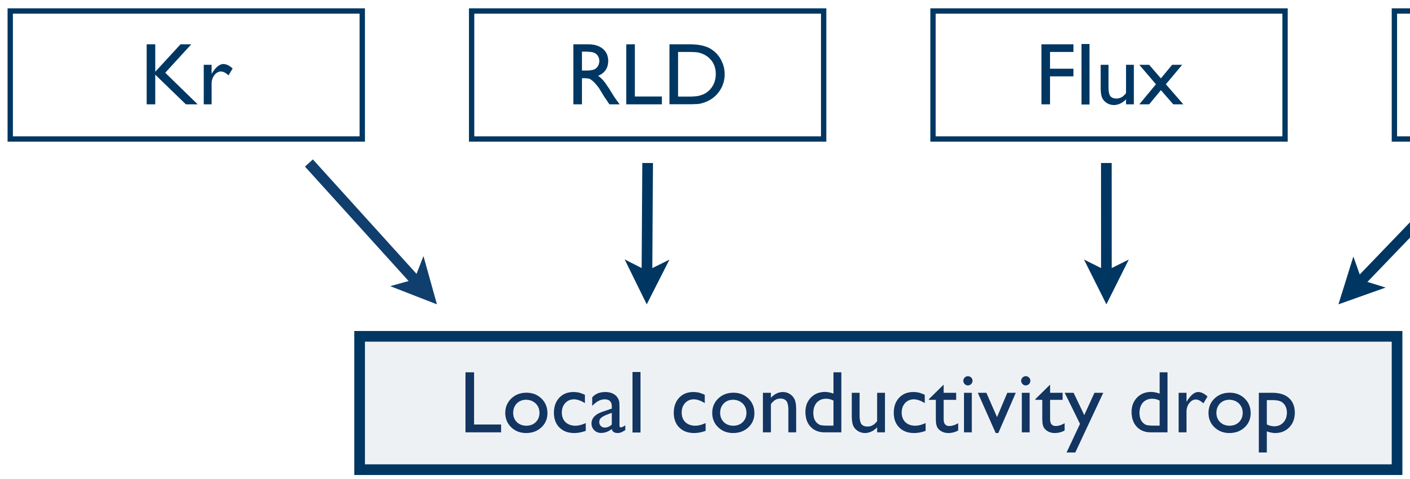
→ Computer modeling can be used to define an ideotype

# New insights



# New insights