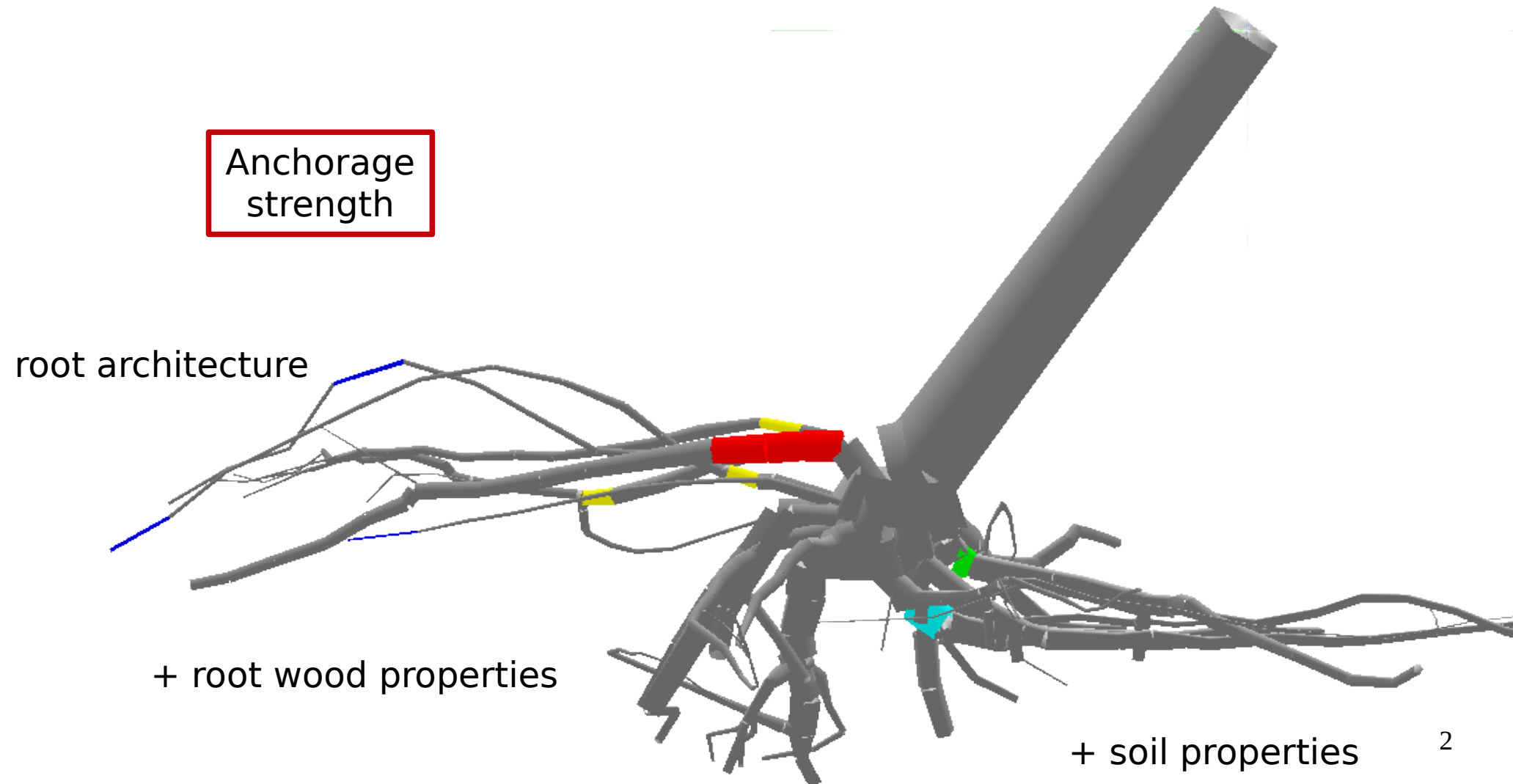


Root architecture and anchorage: what we learned from maritime pine on sandy soils in the Landes forest

Frédéric Danjon¹, Pauline Défossez², Ming Yang², Clément Saint Cast^{1,2}, Antoine Danquechin Dorval¹, Céline Meredieu¹ ¹INRA & Université de Bordeaux UMR1202 BIOGECO, Cestas ² ISPA, Villenave d'Ornon, France

Anchorage is a key factor
in wind damage by stem leaning/toppling/uprooting



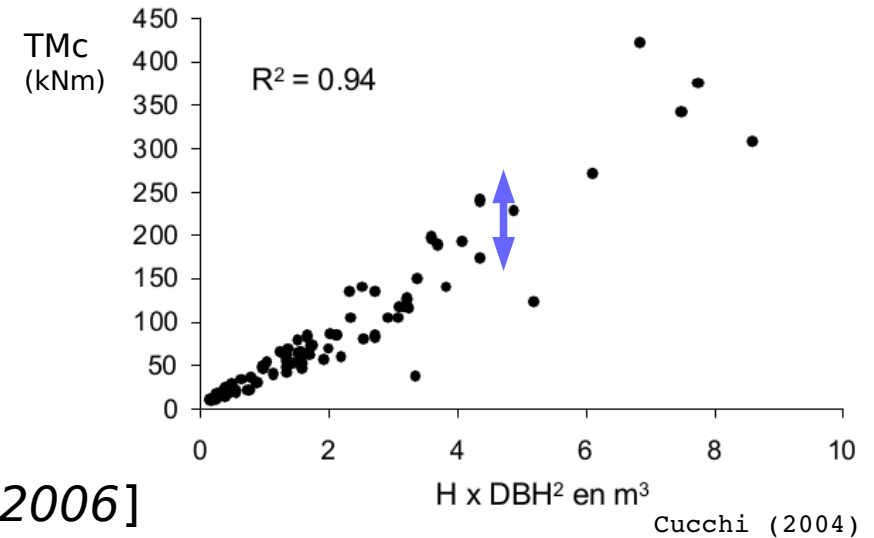
Experiments to determine anchorage parameters

-> Winching = maximum turning moment

Anchorage strength is related to the size of the tree ($H \text{ DBH}^2$)

variation for a same size:

e.g. root depth x soil type x species [*database of British tree-pulling experiments Nicoll et al. 2006*]



-> inventory of storm damage

-> **Empirical relationships**

But winching a large amount of trees can be tedious and winching is not predictive

Potential contribution of explanatory approaches

What we would need is quality of anchorage **as a function of factors** like species, genotype, nursery conditions (cutting/seed), installation techniques (planting/sowing), soil profile, soil water content, soil preparation

-> **explanatory approach:**

Root architecture & material properties assessment

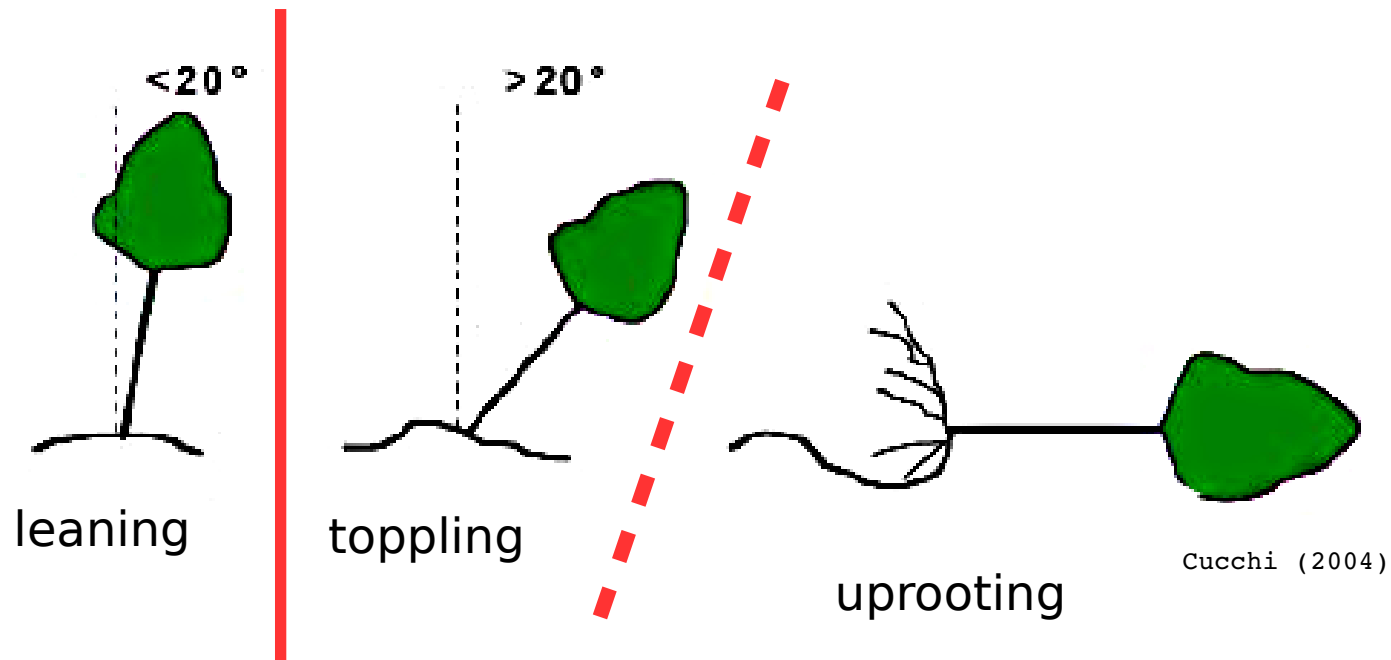
Anchorage strength is given by:

Winching / storm damage / stem straightness / biomechanical models

Thanks to explanatory approaches, we may provide anchorage parameters for a range of factors with **extrapolations** at a given age and from age to age

Particularities of anchorage


- soil can be a highly heterogeneous medium + variable water content -> **high variability in root systems**
- all is **hidden in the soil**, entangled in roots from other plants.
- tree anchorage failure is a **discrete** phenomenon:

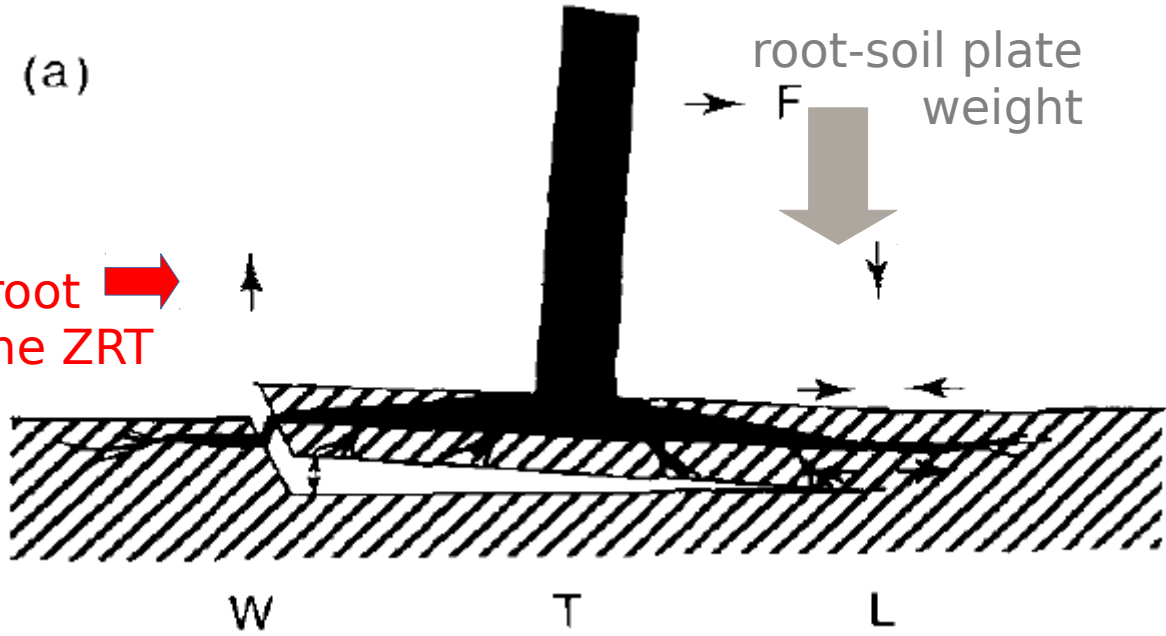


Root architecture and anchorage in trees: what's known ?

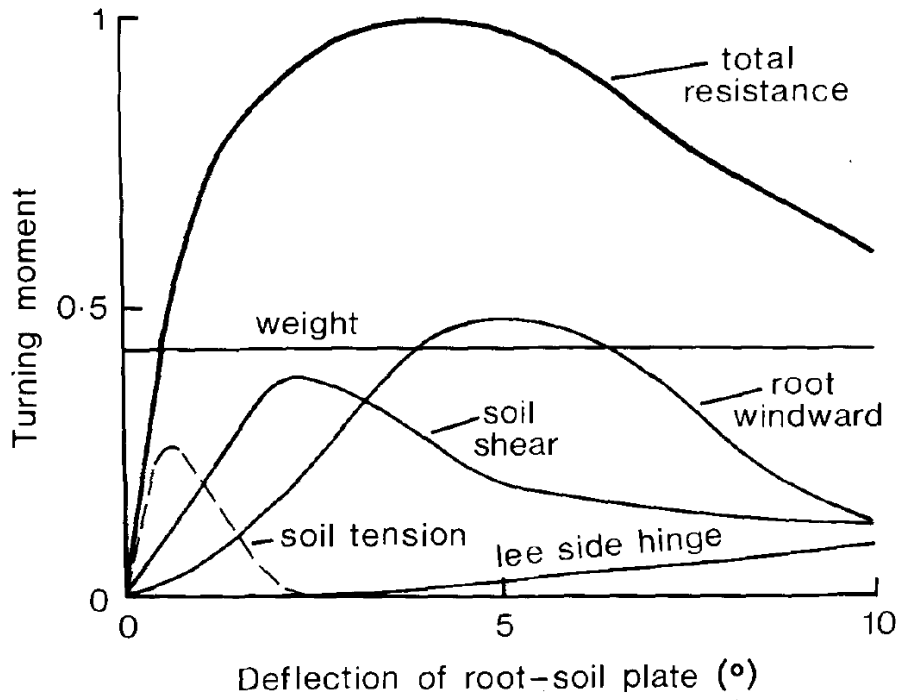
Coutts, Nicoll, Gardiner et al.:
 very shallow soil (< 40 cm),
 larger trees, ditches

Uprooting

shallow root  guying the ZRT



Coutts (1983)



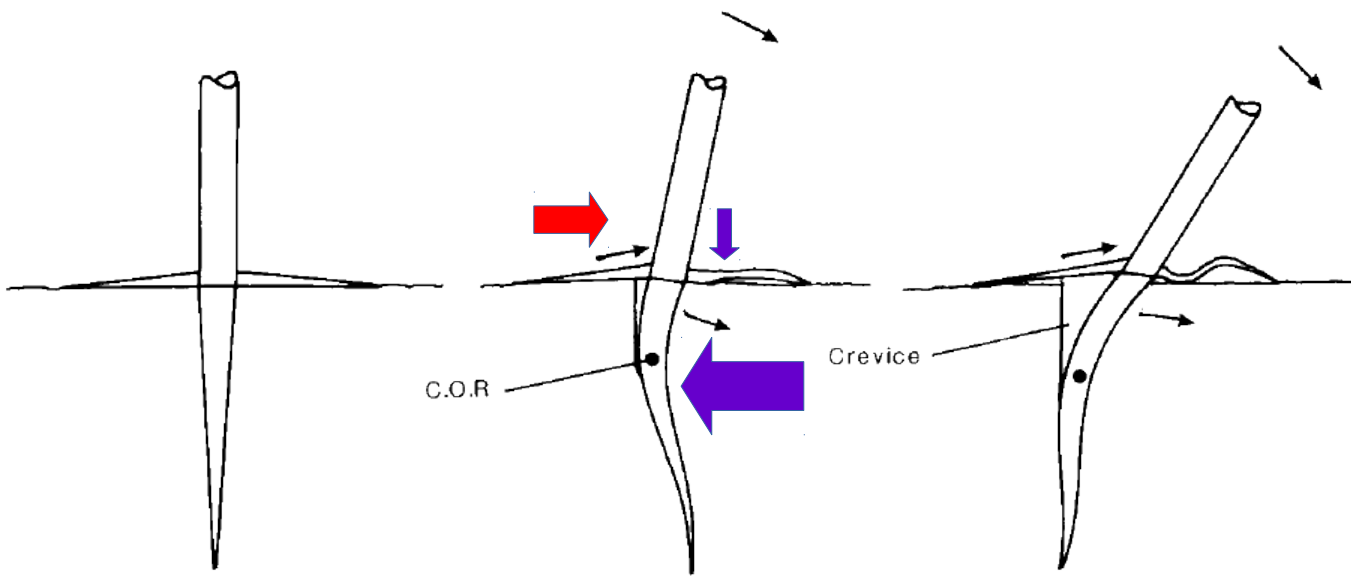
Root architecture and anchorage in trees: toppling

Crook, Ennos, Goodman, Mickovski et al.:
deeper tap-rooted species (*Mallotus*, *Larix*, *Pinus*)

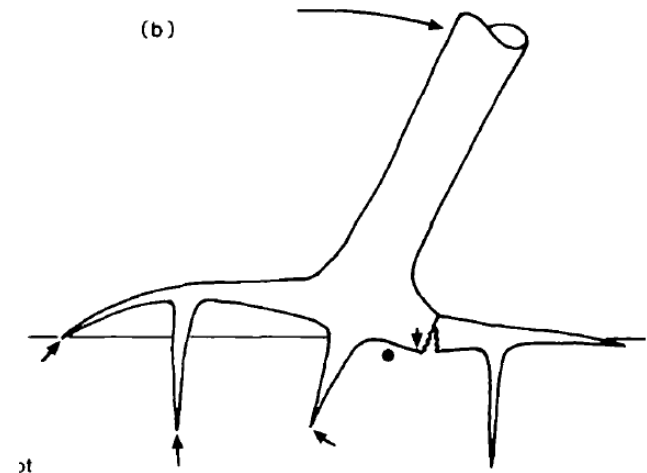
Toppling

taproot: 80% anchorage

sinkers predominant



Mallotus, Crook et al. 1997



Larix, Crook Ennos (1996)

3-9 laterals, 3.2 cm diameter

very simple root system or simplified description of root architecture

The way we choose to study relationship between architecture and anchorage

media

woody plants
full deployment of RSA

in the field

in pots

in agar

hydroponics



Mechanical uprooting

In-depth phenotyping of complex root architectures

media

in the field

in pots

in agar

hydroponics

measurement

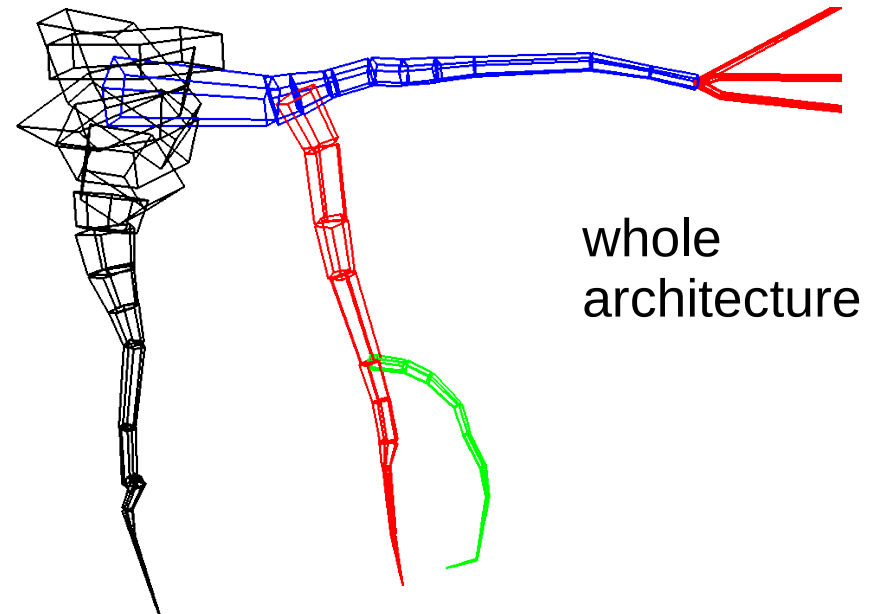
manual

3D
magnetic
digitizer

CTscan

Laser scan

GPR



whole
architecture

In-depth phenotyping of complex root architecture

media

in the field

in pots

in agar

hydroponics

measurement

3D magnetic digitizer

manual

CTscan

Laser scan

coding

MTG format

In-depth phenotyping of complex root architecture

media

in the field

in pots

in agar

hydroponics

measurement

3D magnetic digitizer

manual

CTscan

Laser scan

coding

MTG format

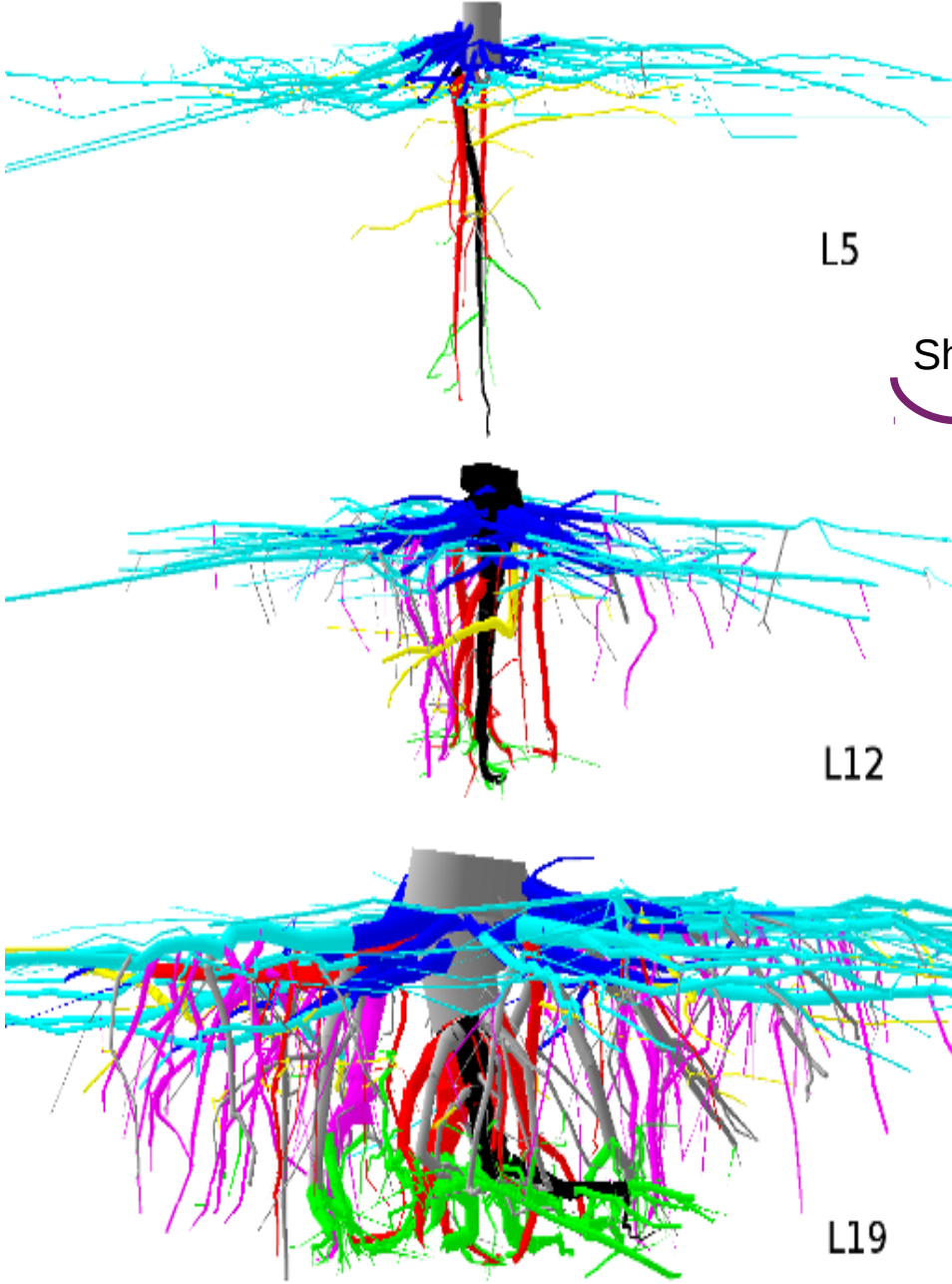
analysis

Architectural analysis

Architectural analysis

= classifying roots in 9 root types

root segment



laterals

1st order root

stump

taproot

Shallow

Intermediate

Deep

horizontal

Oblique

Vertical

Sinkers

Shallow

Intermediate horizontal

Sinkers beyond

ZRT

Shallow beyond ZRT

Deep Phenotyping of Coarse Root Architecture in *R. pseudoacacia* Reveals That Tree Root System Plasticity Is Confined within Its Architectural Model

Frédéric Danjon^{1,2*}, Hayfa Khuder³, Alexia Stokes⁴

1 INRA, UMR1202 BIOGECO, Cestas, France, **2** Université de Bordeaux, UMR1202 BIOGECO, Cestas, France, **3** Université de Bordeaux, UMR 5295, Institut de Mécanique et d'Ingénierie - Bordeaux (I2M), Département Génie Civil et Environnemental (GCE), Bordeaux, France, **4** INRA, UMR AMAP (Botanique et bioinformatique de l'architecture des plantes), Montpellier, France

Abstract

This study aims at assessing the influence of slope angle and multi-directional flexing and their interaction on the root architecture of *Robinia pseudoacacia* seedlings, with a particular focus on architectural model and trait plasticity. 36 trees

Pinus Pinaster, podzols: large trees failing by uprooting

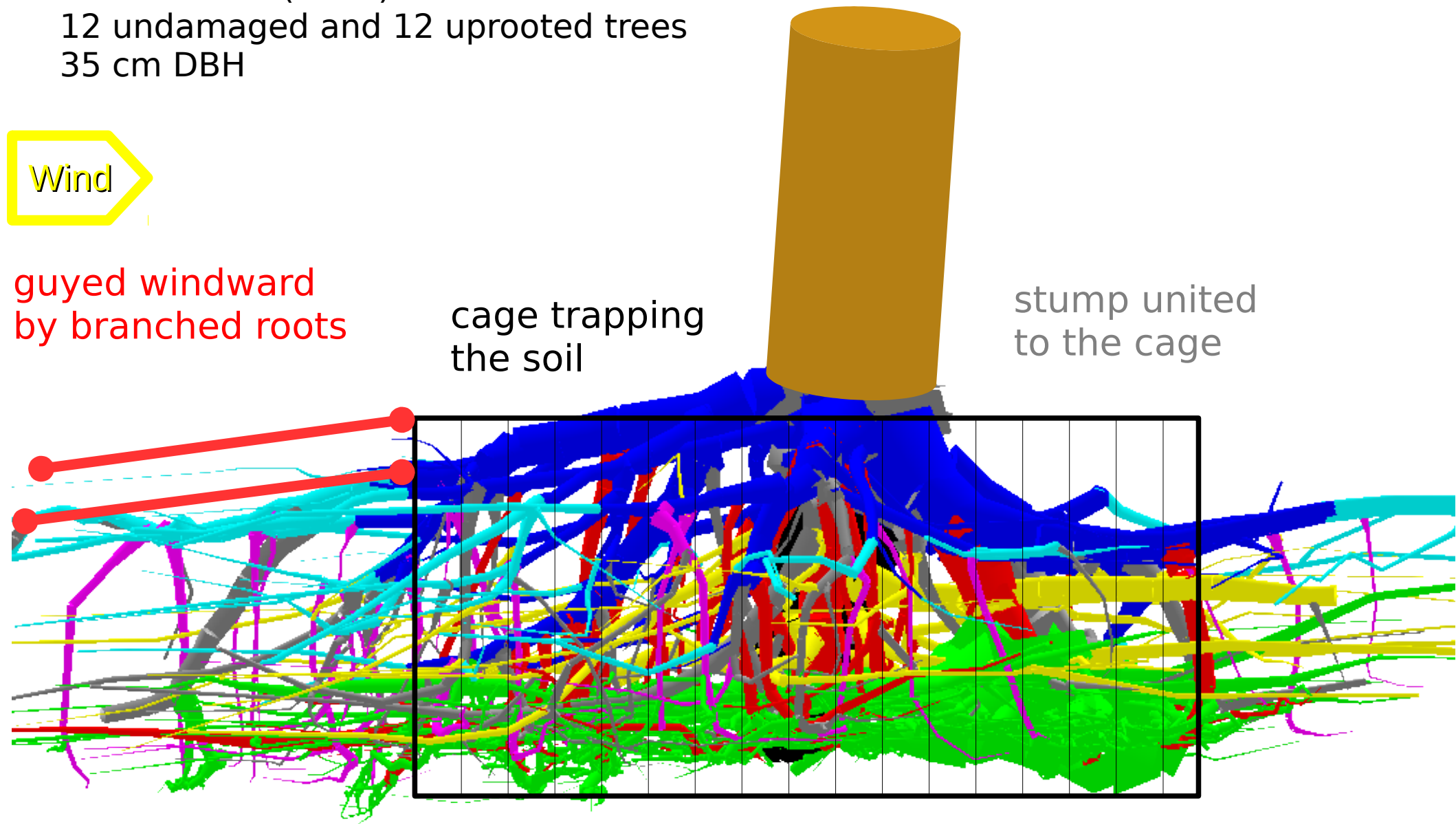
Martin storm (1999)
12 undamaged and 12 uprooted trees
35 cm DBH

Wind

guyed windward
by branched roots

cage trapping
the soil

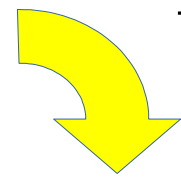
stump united
to the cage





Wind

Resulting force



root-soil plate weight
(requires a rigid cage)



flexion



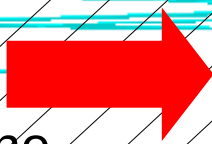
flexion =
hinge



windward

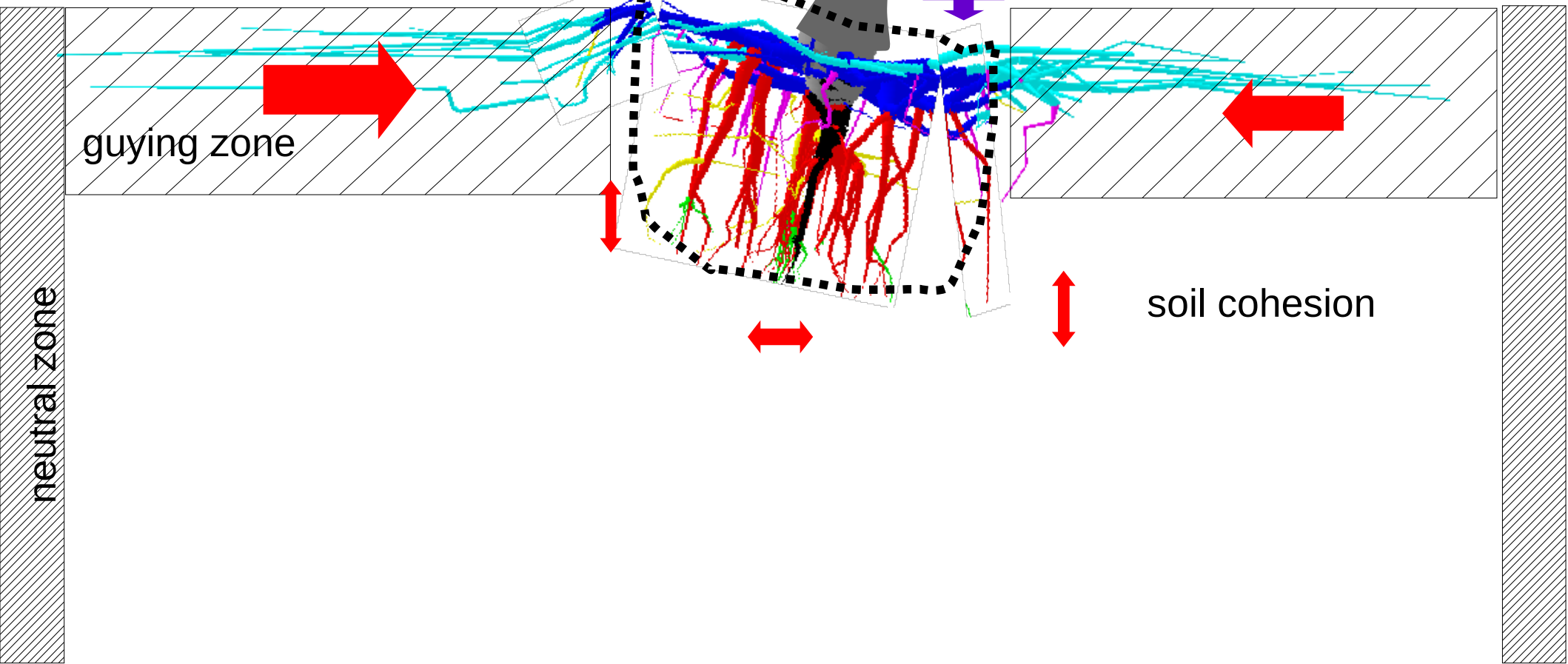
leeward

guying zone



neutral zone

soil cohesion

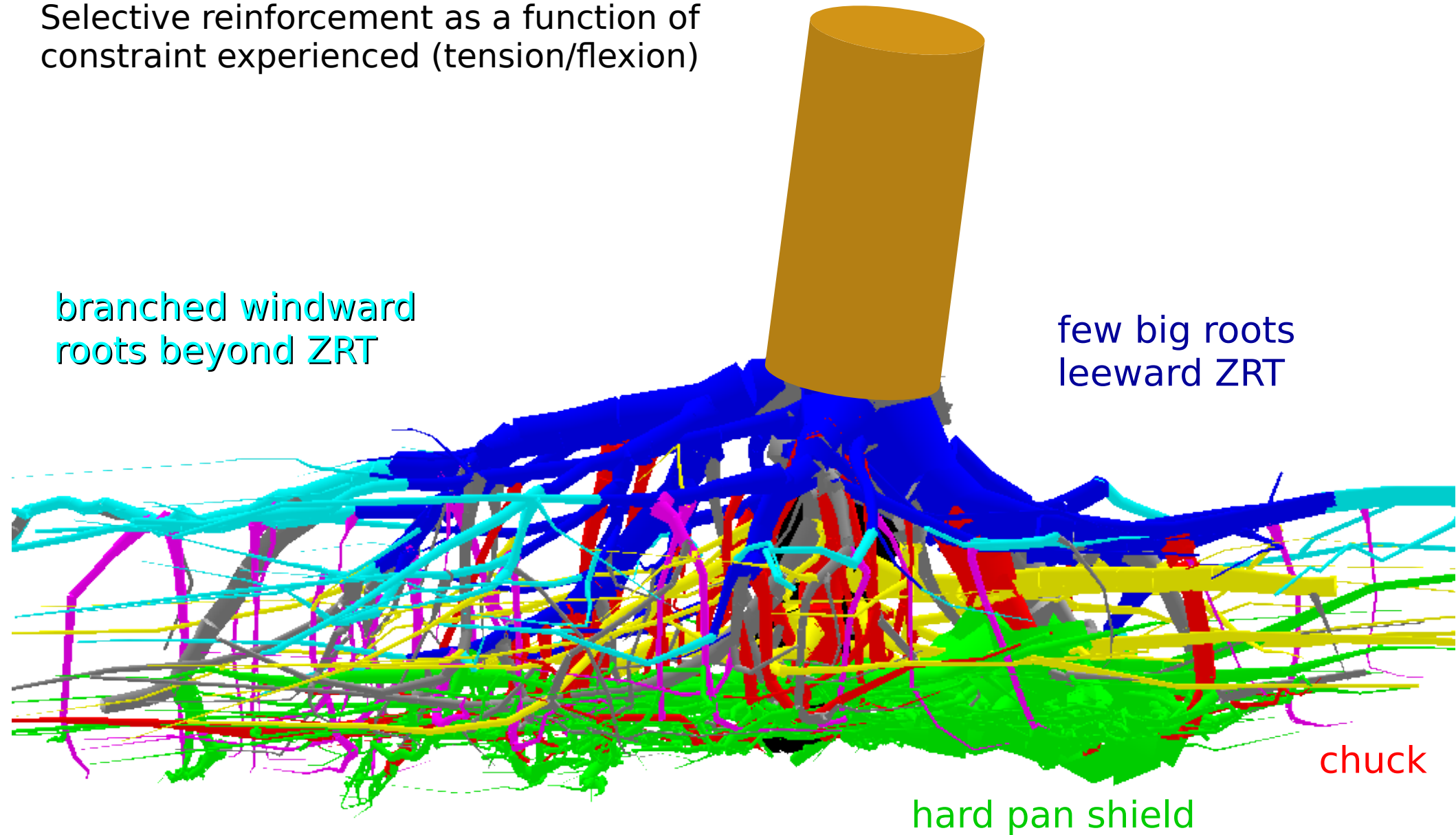


Large selective acclimation to prevailing wind

Very large acclimation:
Selective reinforcement as a function of
constraint experienced (tension/flexion)

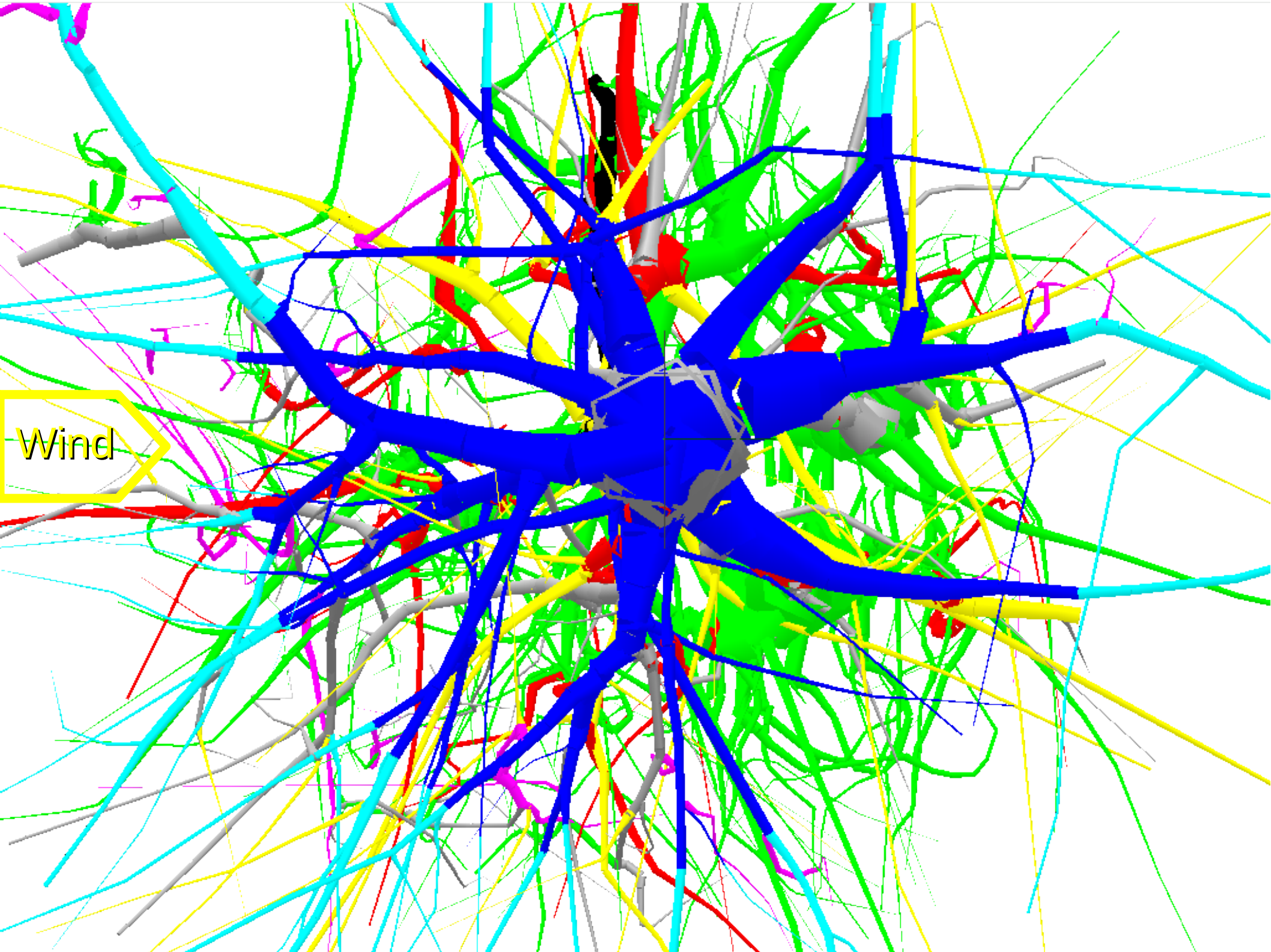
branched windward
roots beyond ZRT

few big roots
leeward ZRT



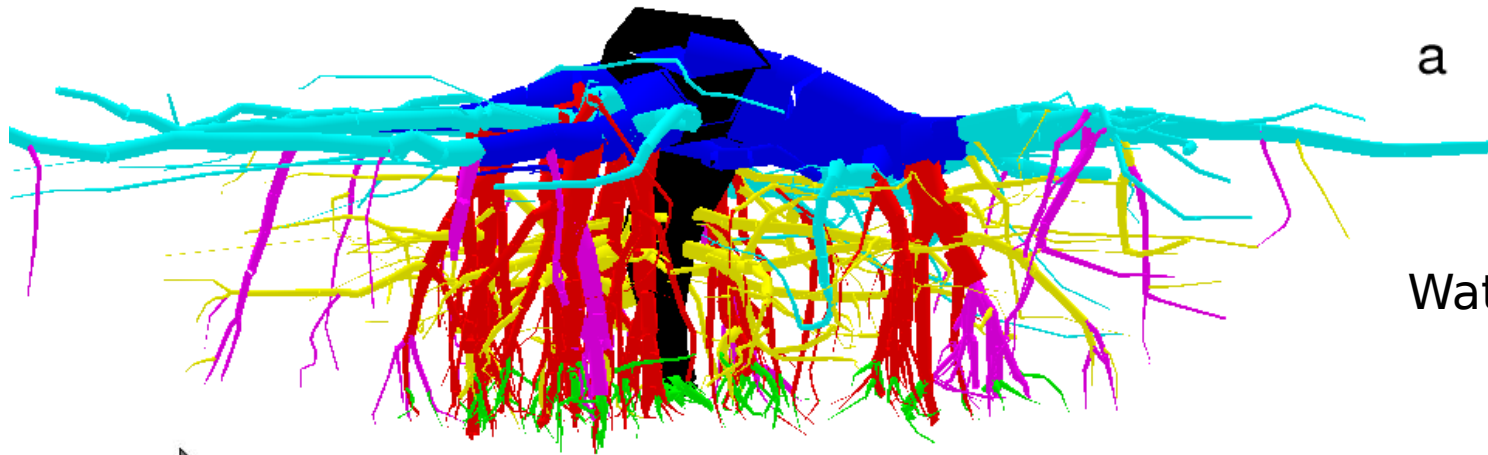
hard pan shield

chuck



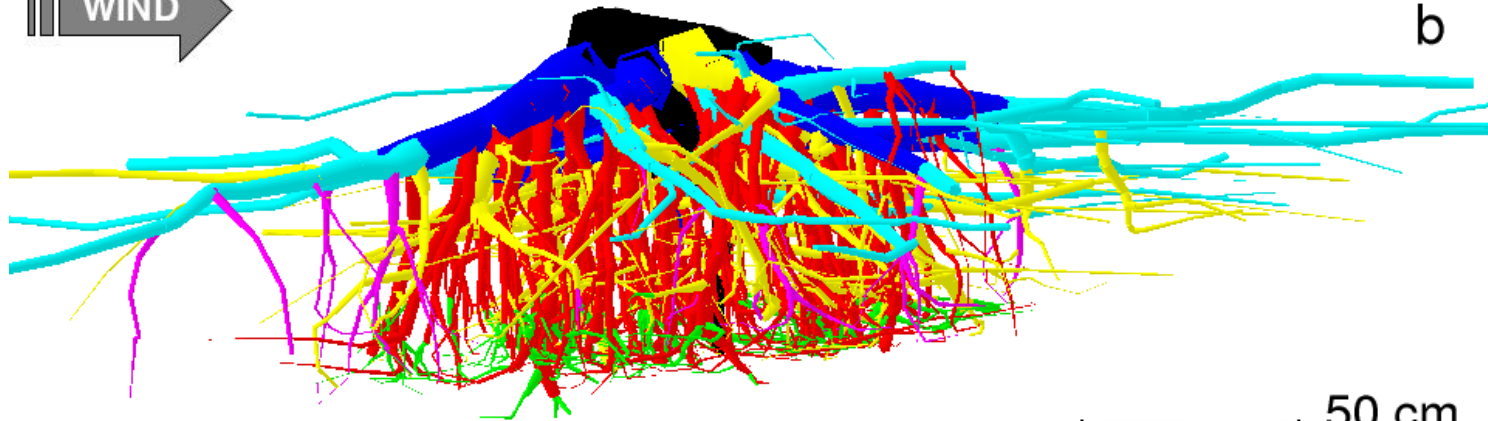
Wind

Large acclimation to soil depth/soil profile



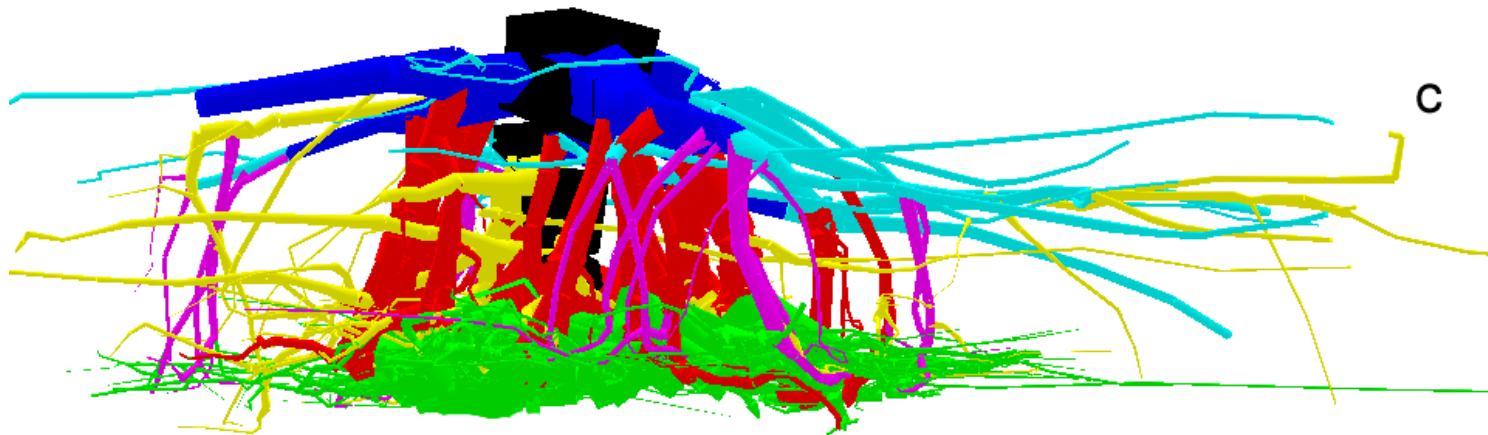
a

Water table: brushes



b

50 cm



c

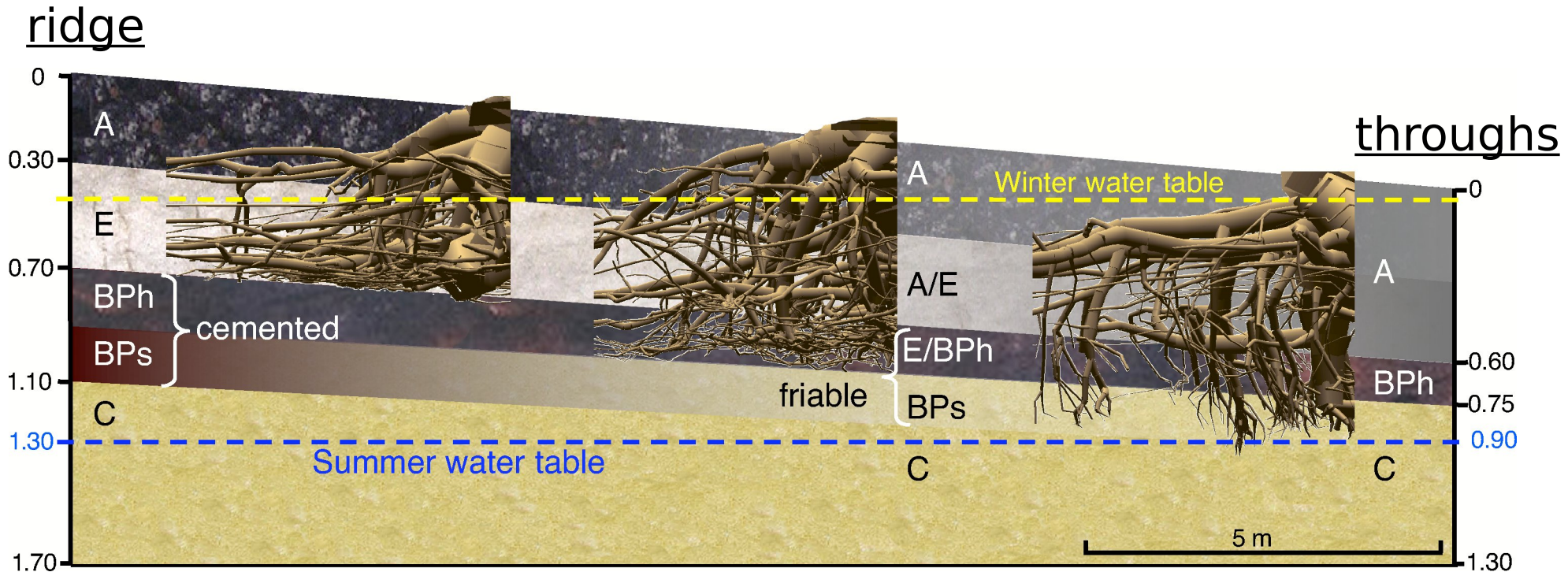
Hard pan: shields

18

18

Large intra-stand soil variability

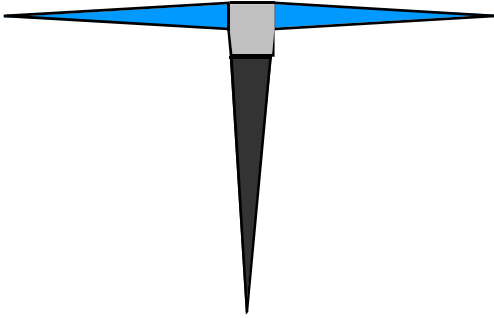
-> soil profile is determined by the micro-topography



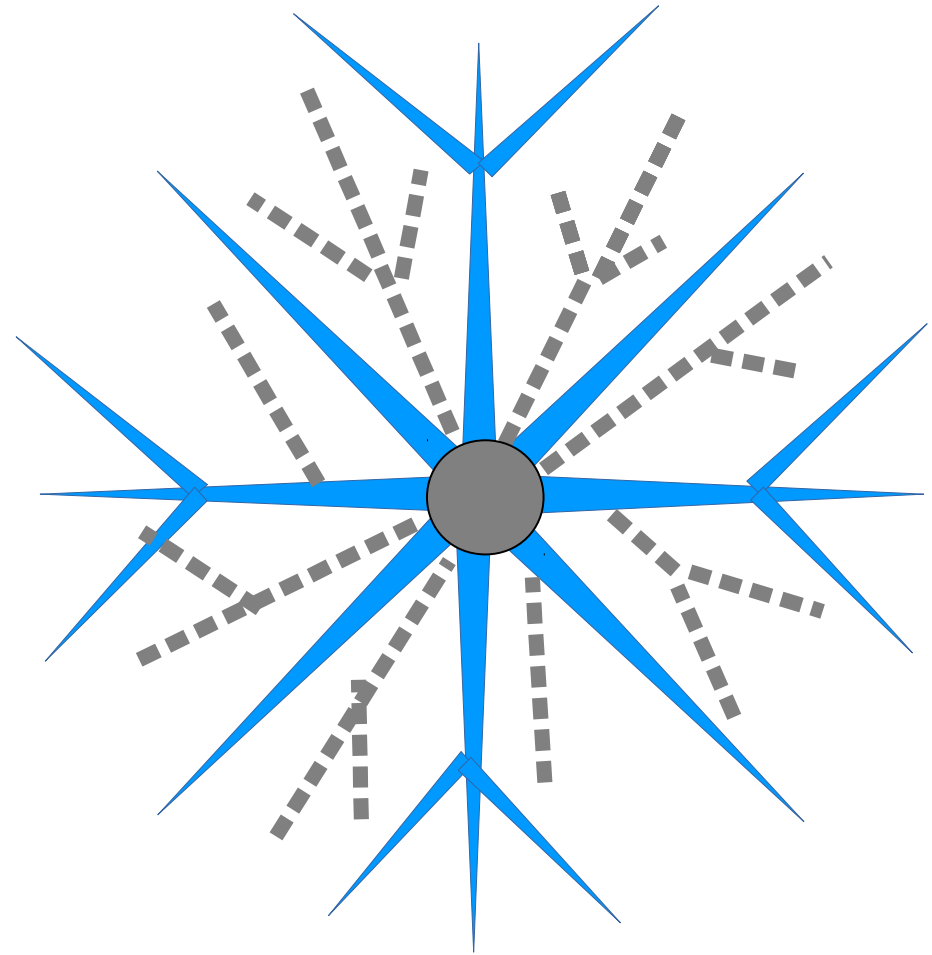
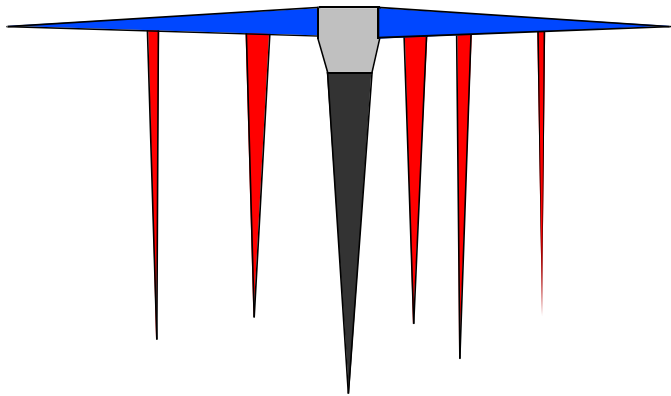
-> large plasticity of root system as a response to available soil depth

Pinus Pinaster, architectural scheme

tap-rooted

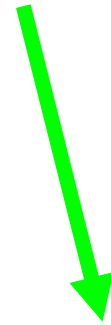
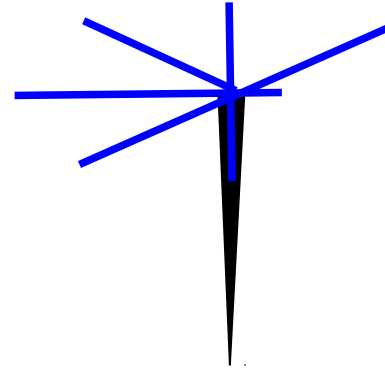
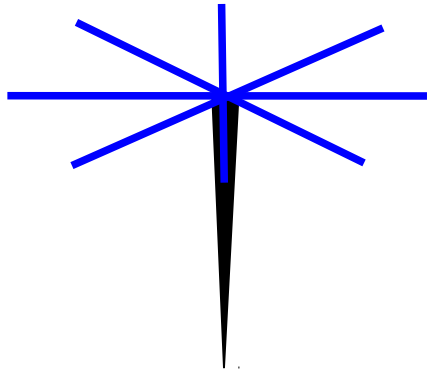


secondary sinkers

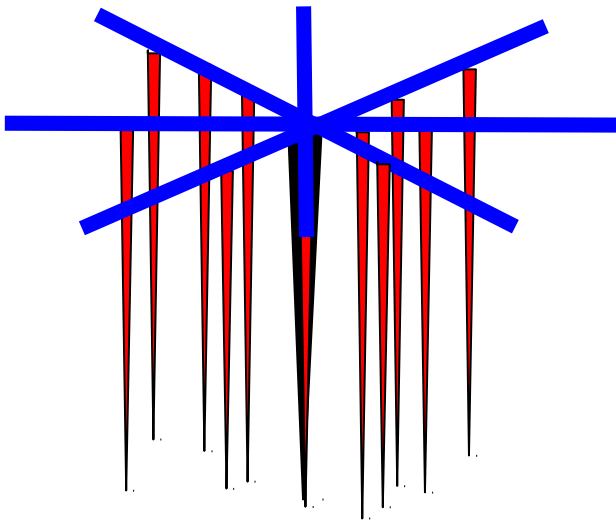


No retarded branching

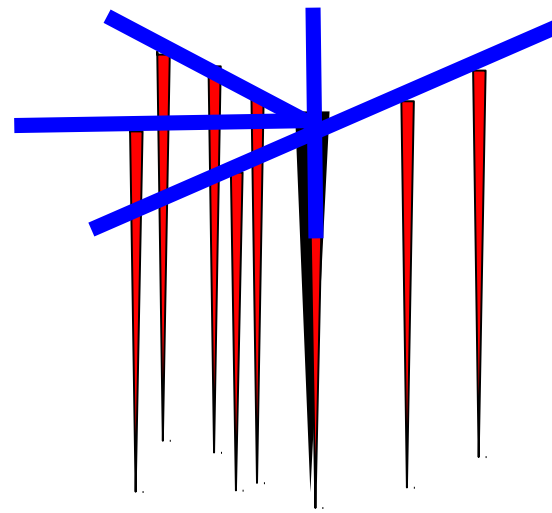
Atger & Edelin (1994)



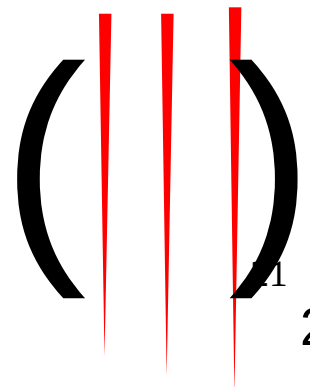
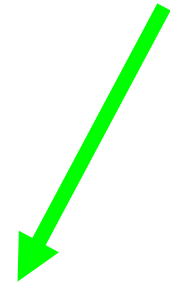
no retarded branching



Stable



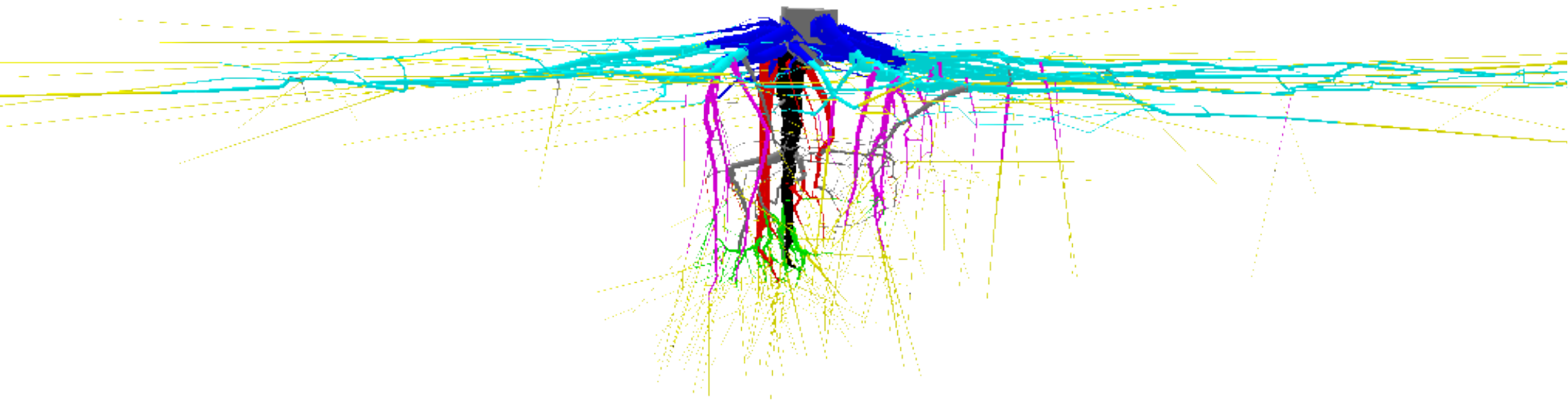
Instable

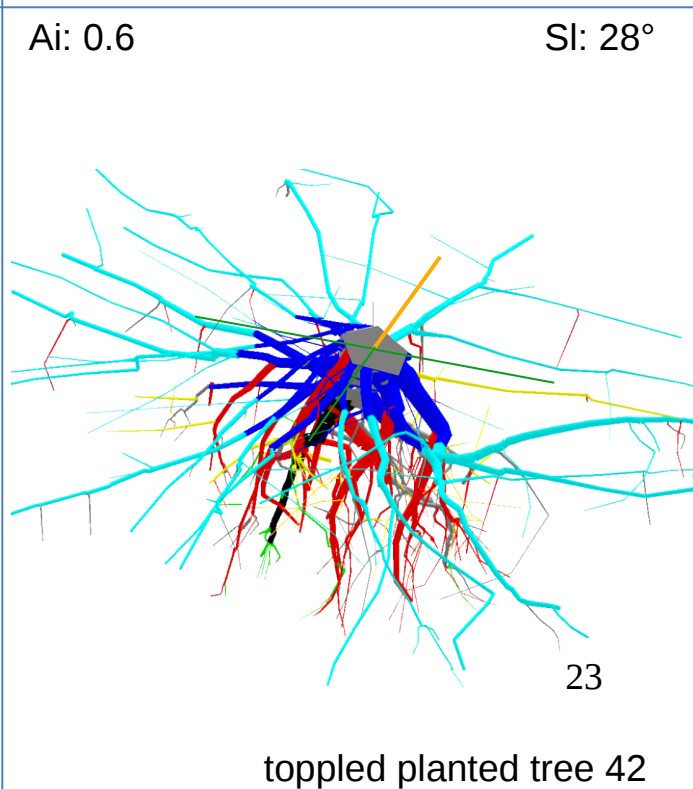
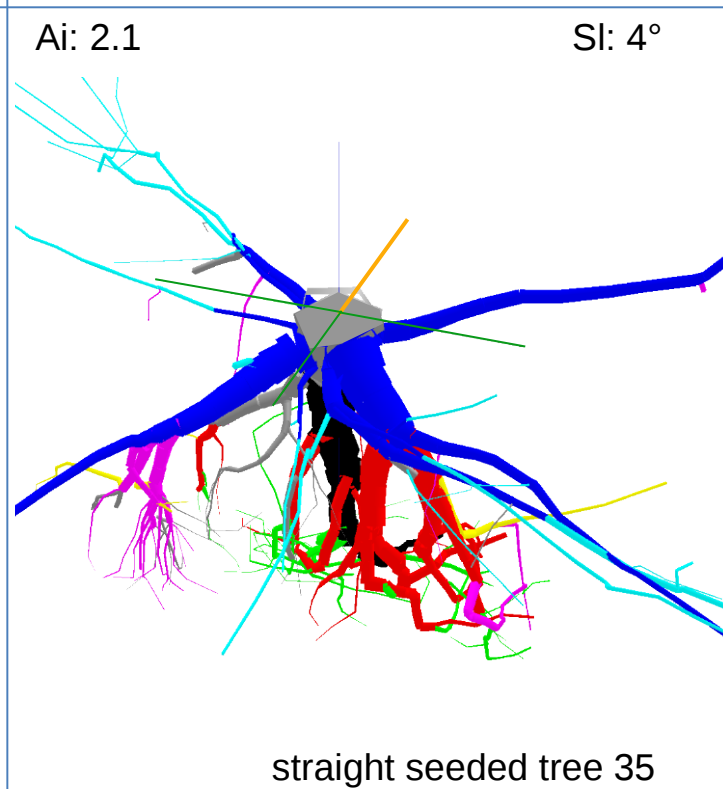
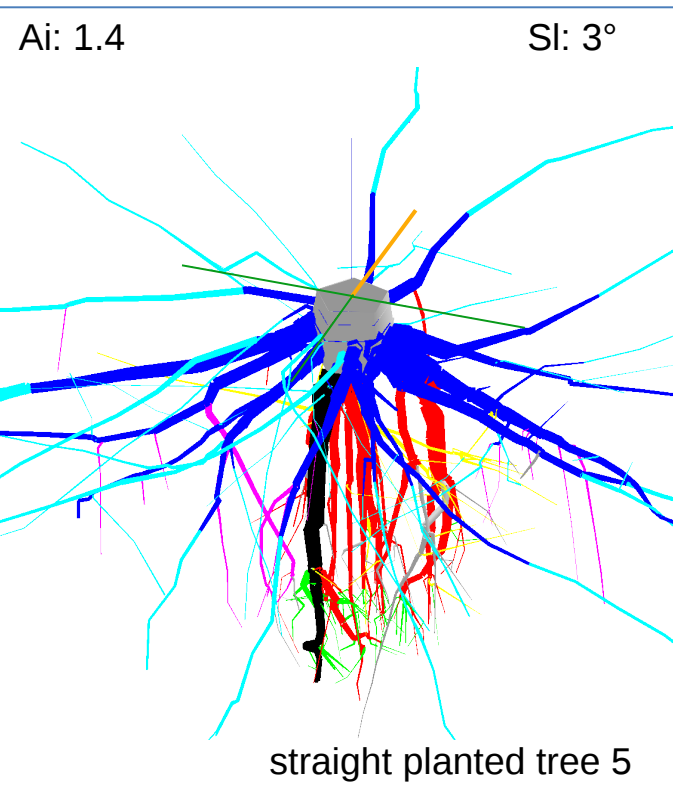
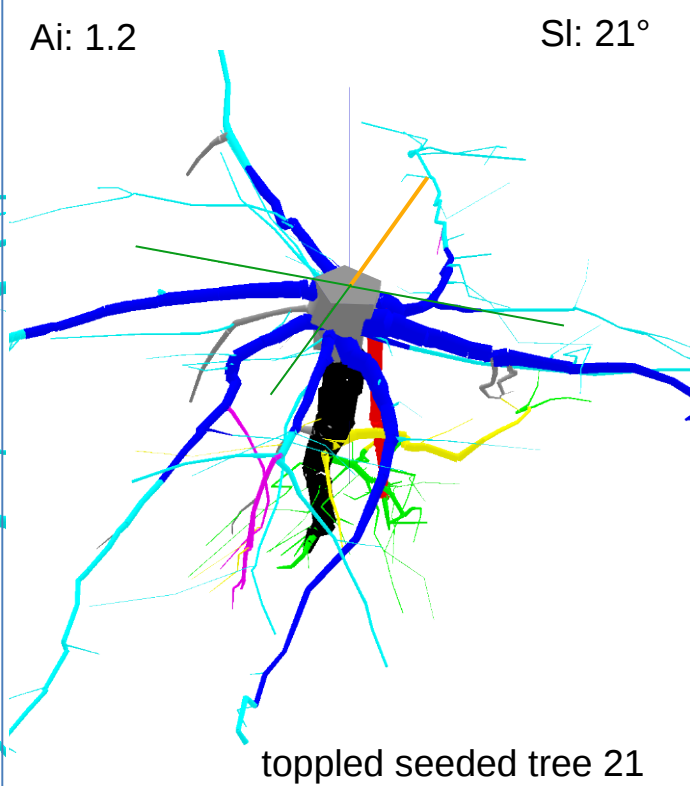
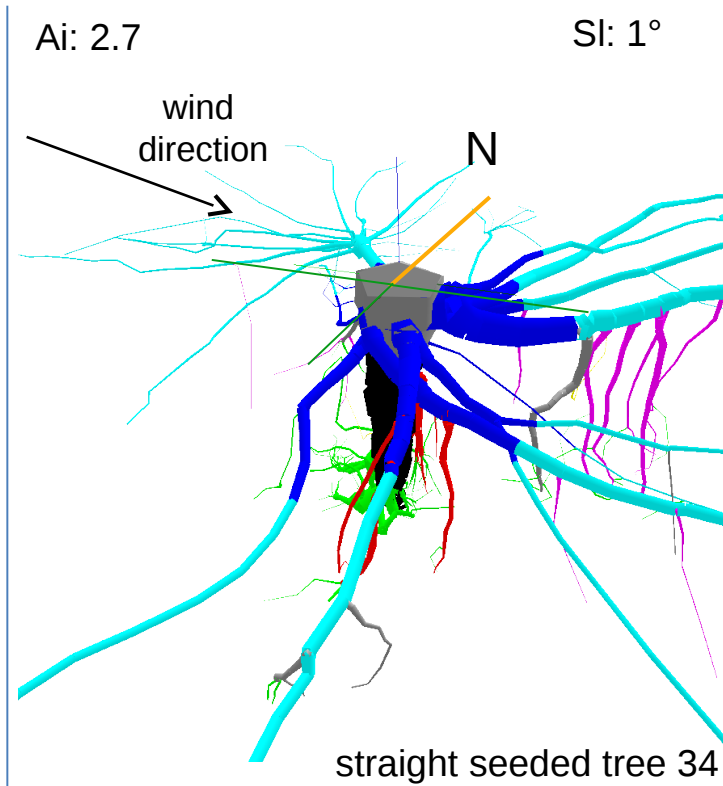
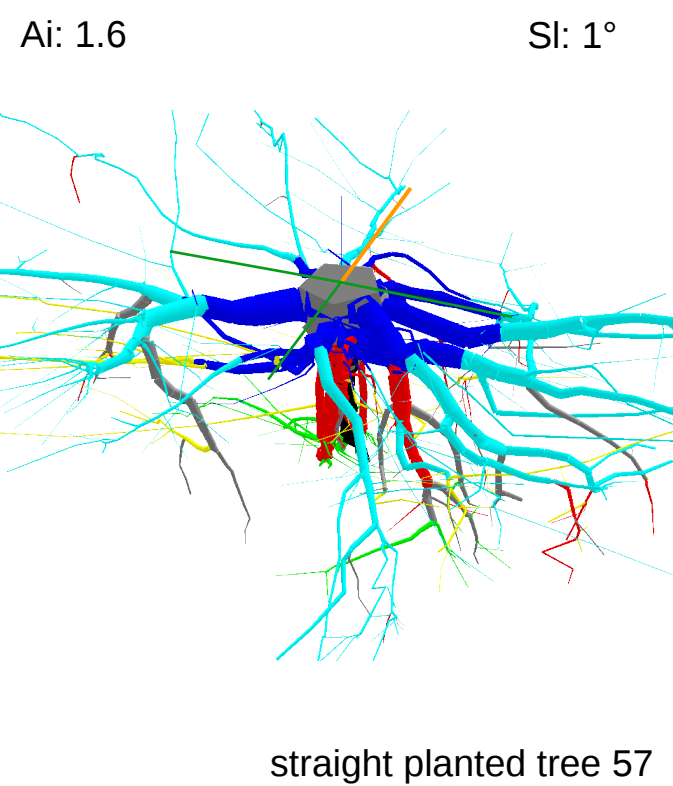


Pinus Pinaster, podzols: smaller trees failing by toppling

Klaus storm (2009)
48 trees, including 12 toppled
17 cm DBH

Estimation of roots lost during uprooting = yellow - (Danjon et al. 2013)



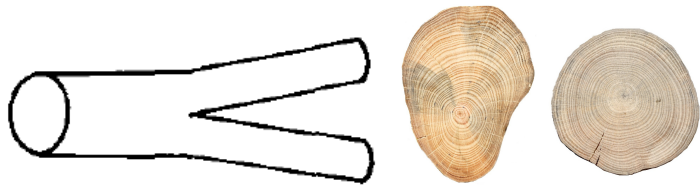


Computing mechanical characteristics from morphological data

maximal tensile load ———

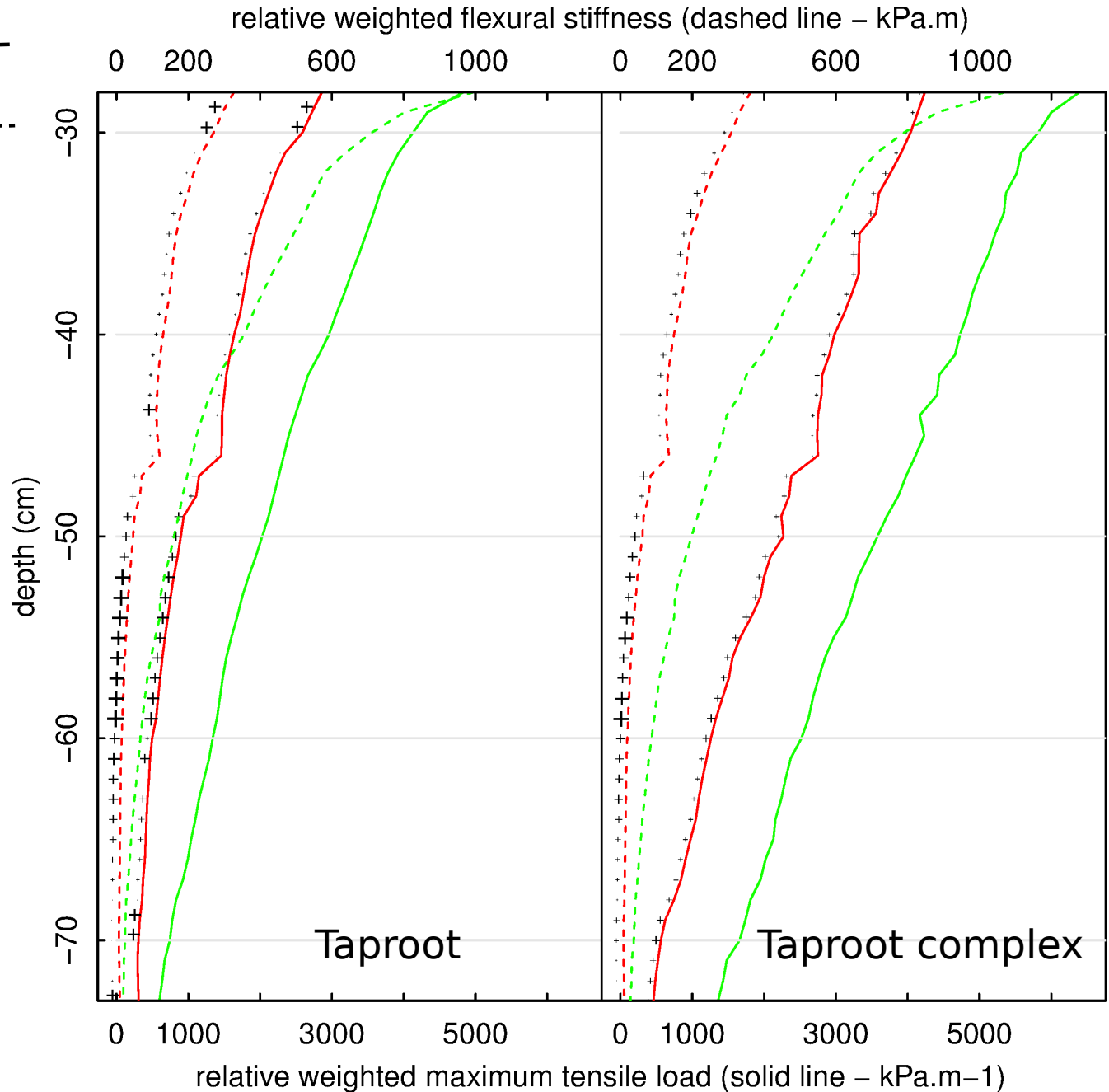
flexural stiffness - - - - -

straight
toppled



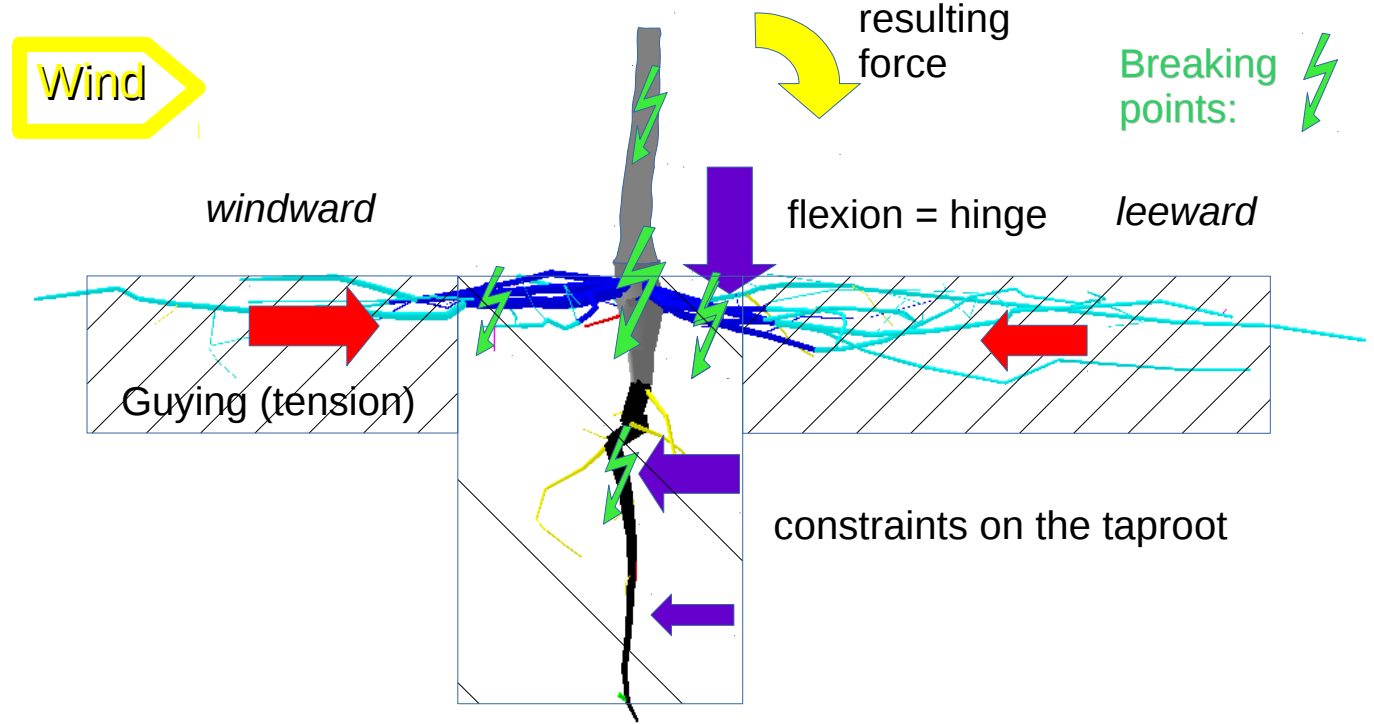
Central root system has to be rigid to prevent a small displacement of the stump.

A large taproot guyed by deep roots is still the main component of anchorage + soil depth

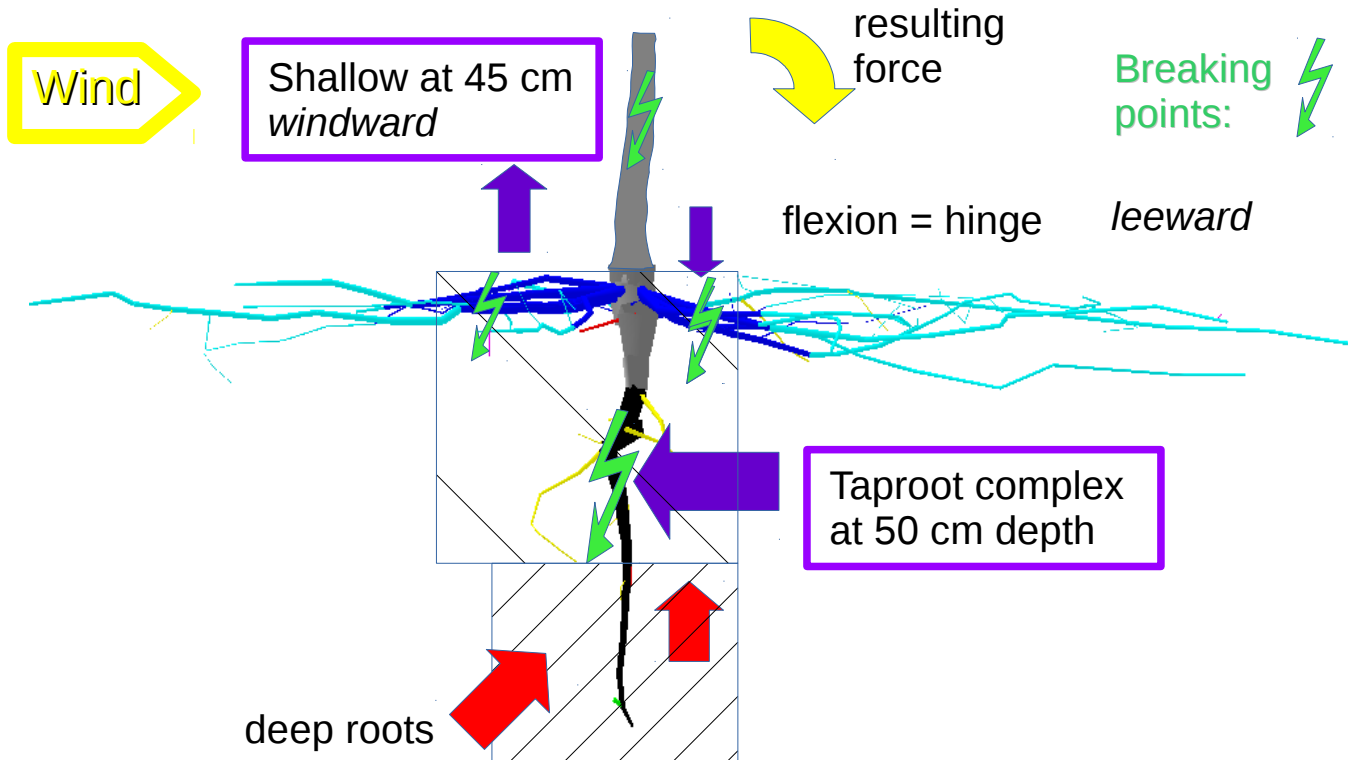


From literature

« guyed stake »



Danjon et al. 2013



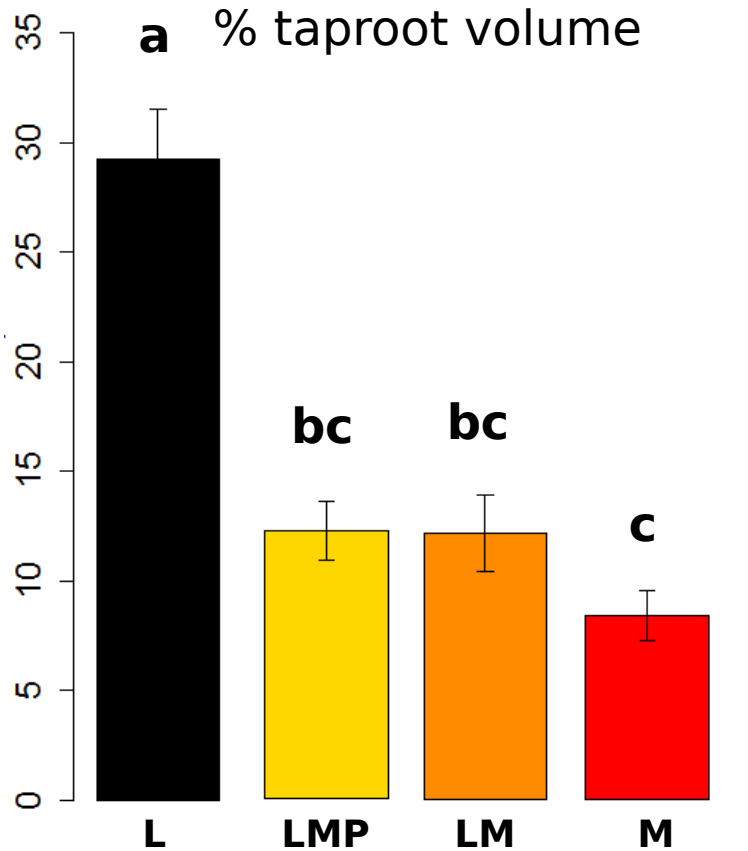
From experiment

a rigid central part guyed by the bottom

Genetic variability of root architecture: natural selection

4-years-old trees / 10 trees per genetic unit

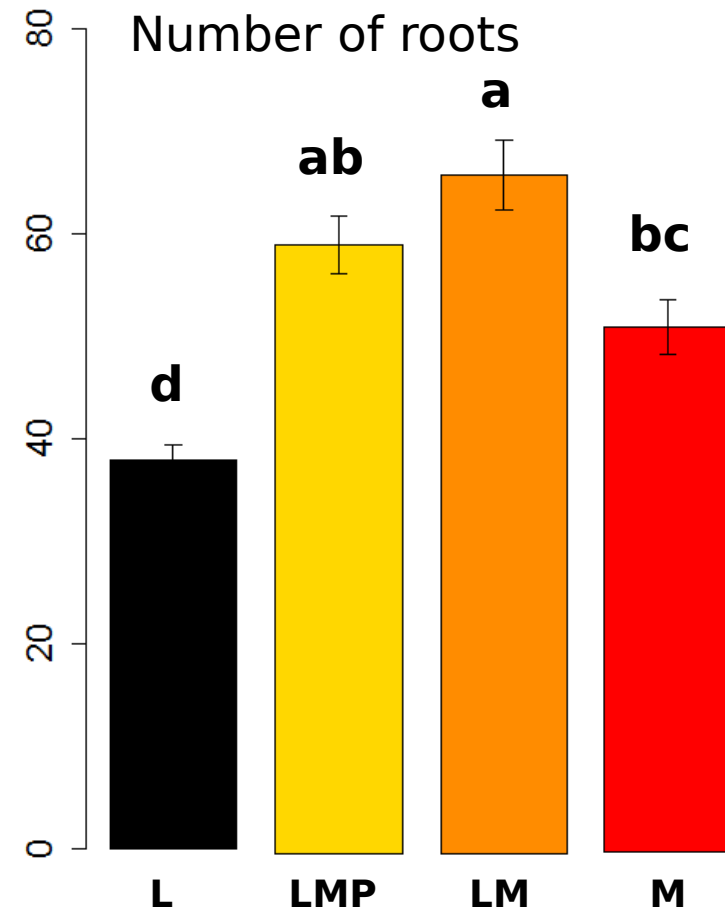
a % taproot volume



Local

Moroccan

Number of roots



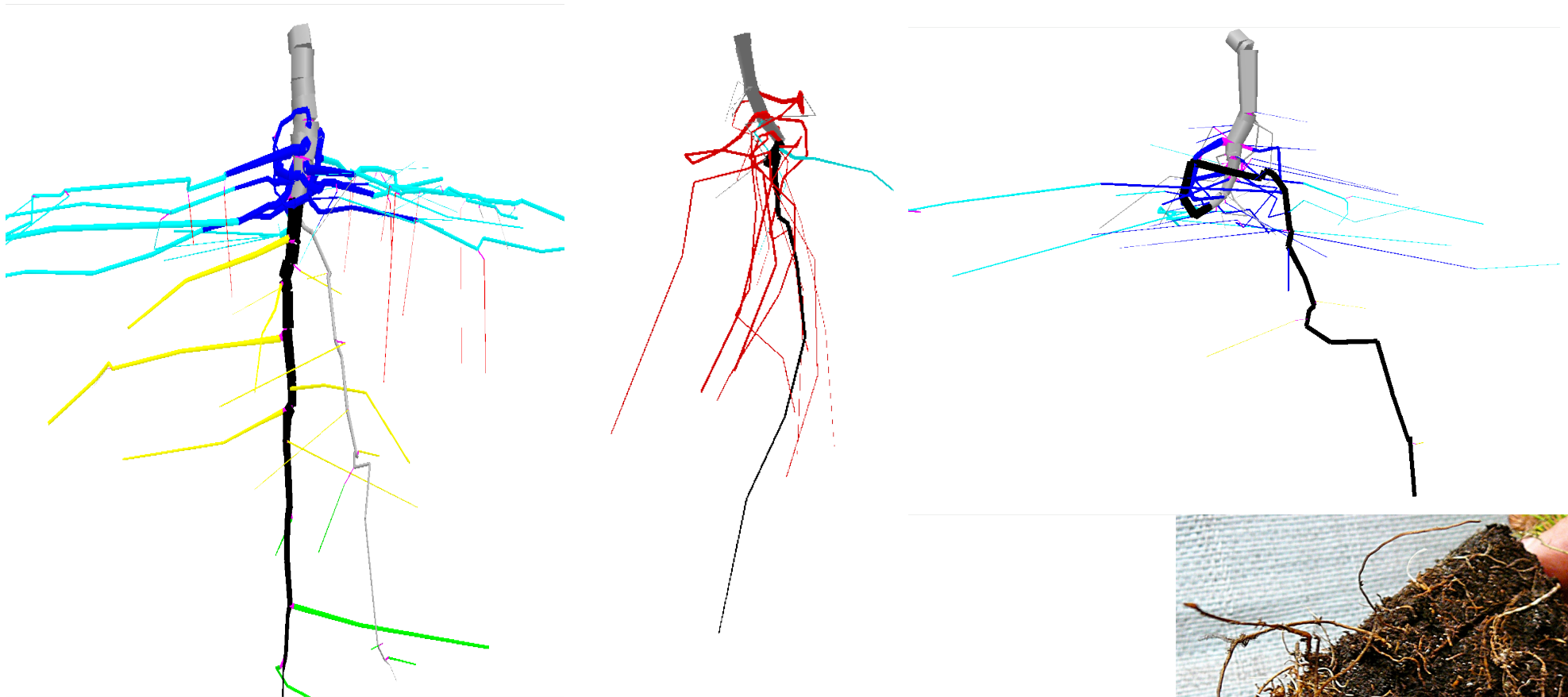
Dominance of drought avoidance characteristics

Unclear results for artificial selection

Perturbation of architectural scheme by planting

Turf plug planting: 300 three-years-old trees.

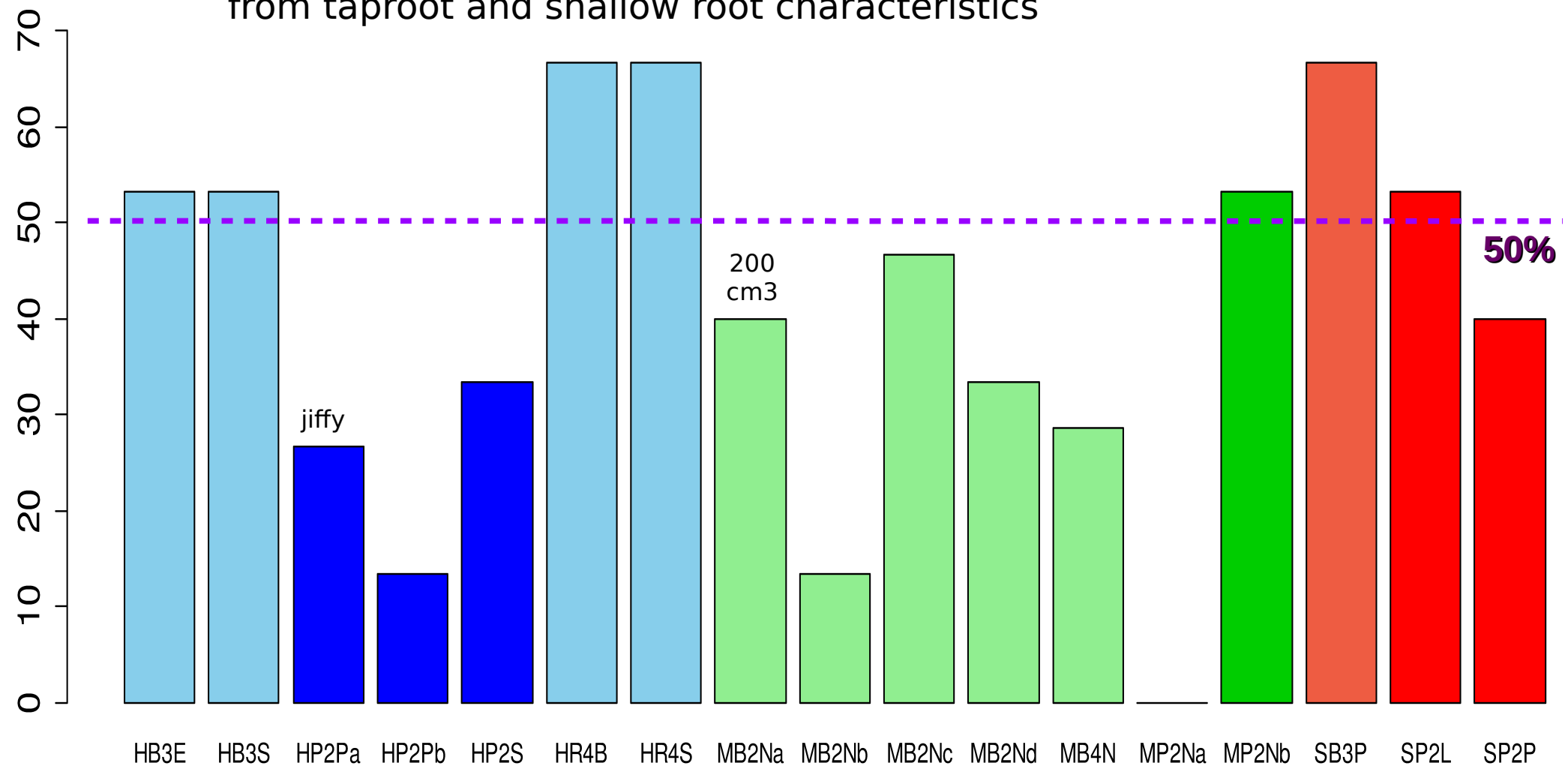
no clustering, clumping of shallow roots, generally good regeneration of taproot.



retrospective approach : what happened at plantation ?

Prospective approach: portion of crop trees in stands

from taproot and shallow root characteristics

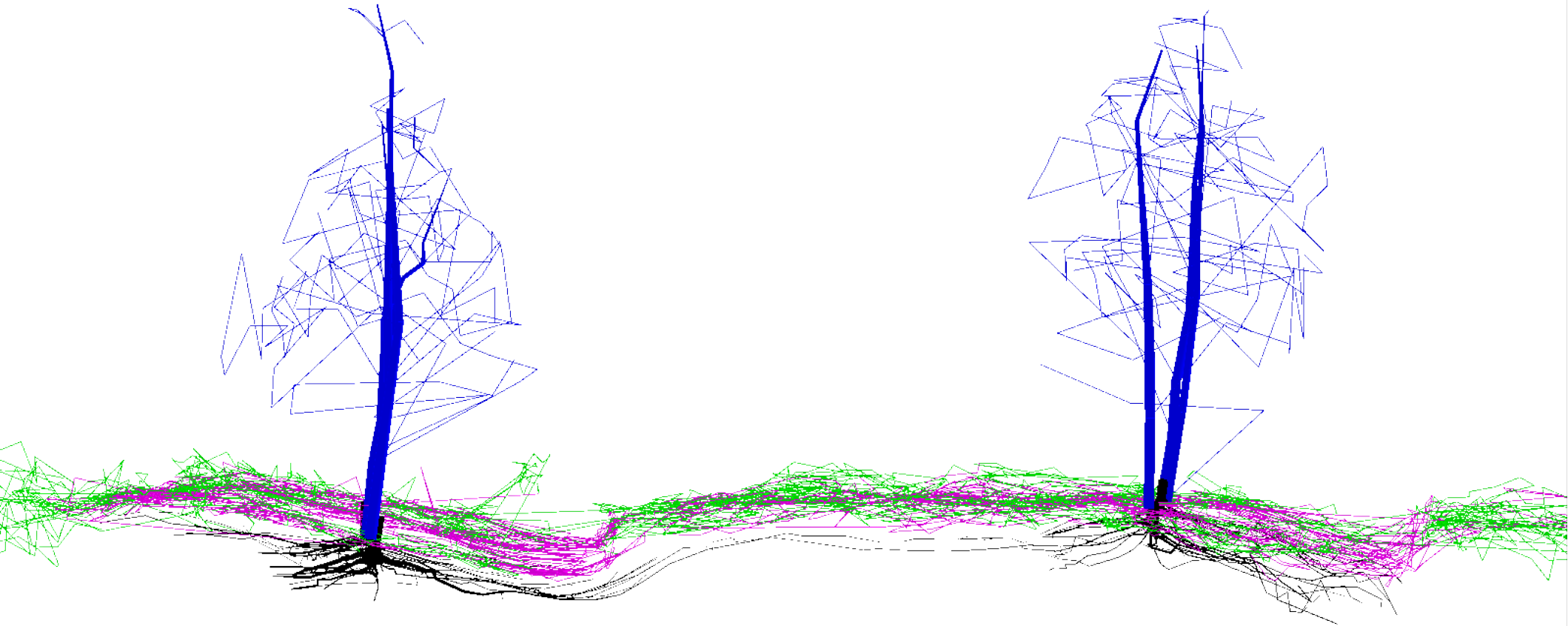


half the plots had less than 50% crop trees

large variation in perturbations of architectural model:
could not be attributed to silvicultural practices.

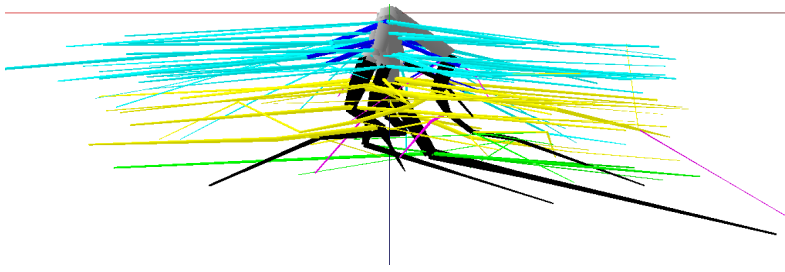
In a sandy soil: influence of soil preparation on root architecture

Strip ploughing leaving a ditch + mapping shallow roots/sinker branching point in situ: roots follow soil surface

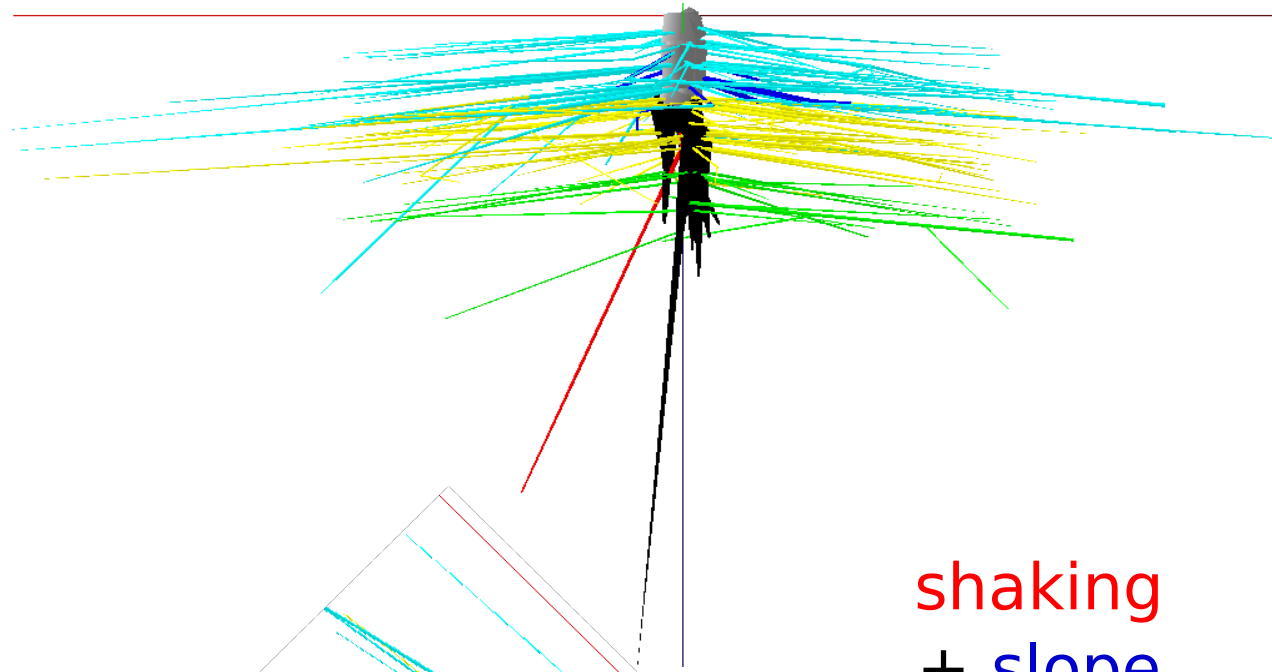




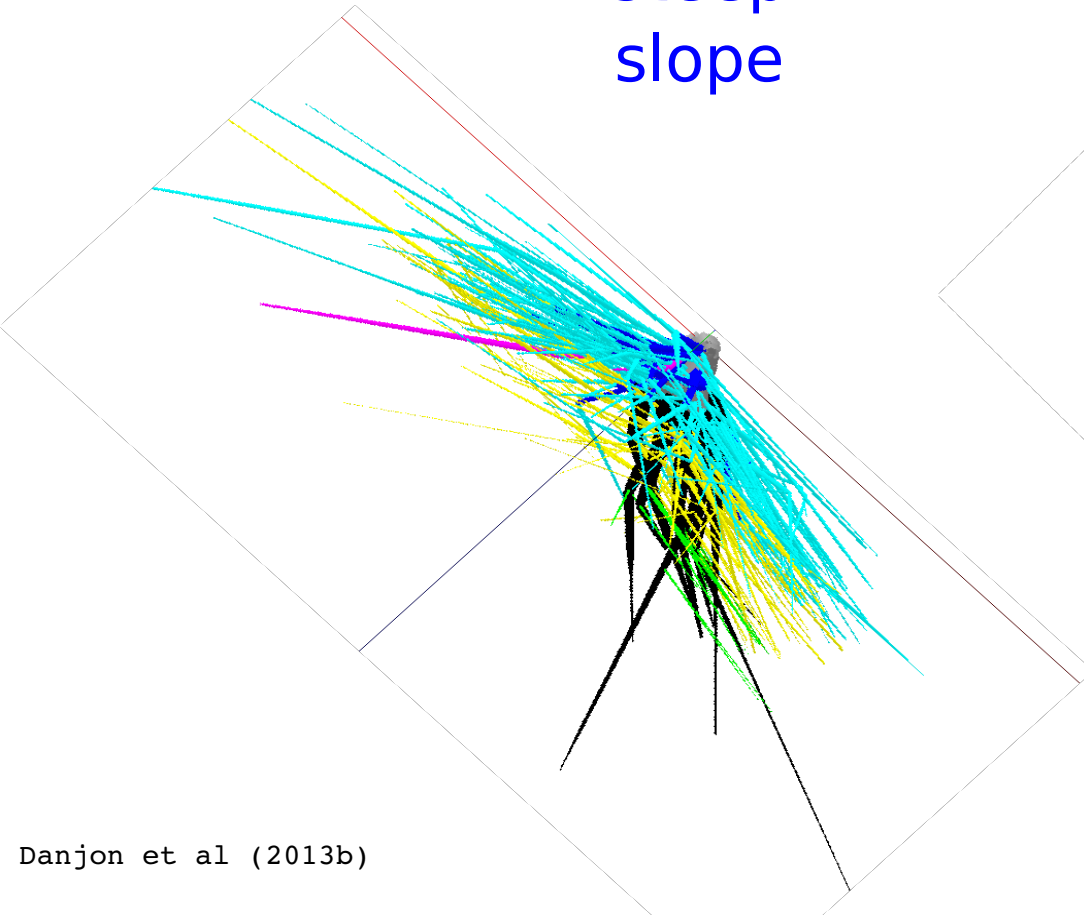
control



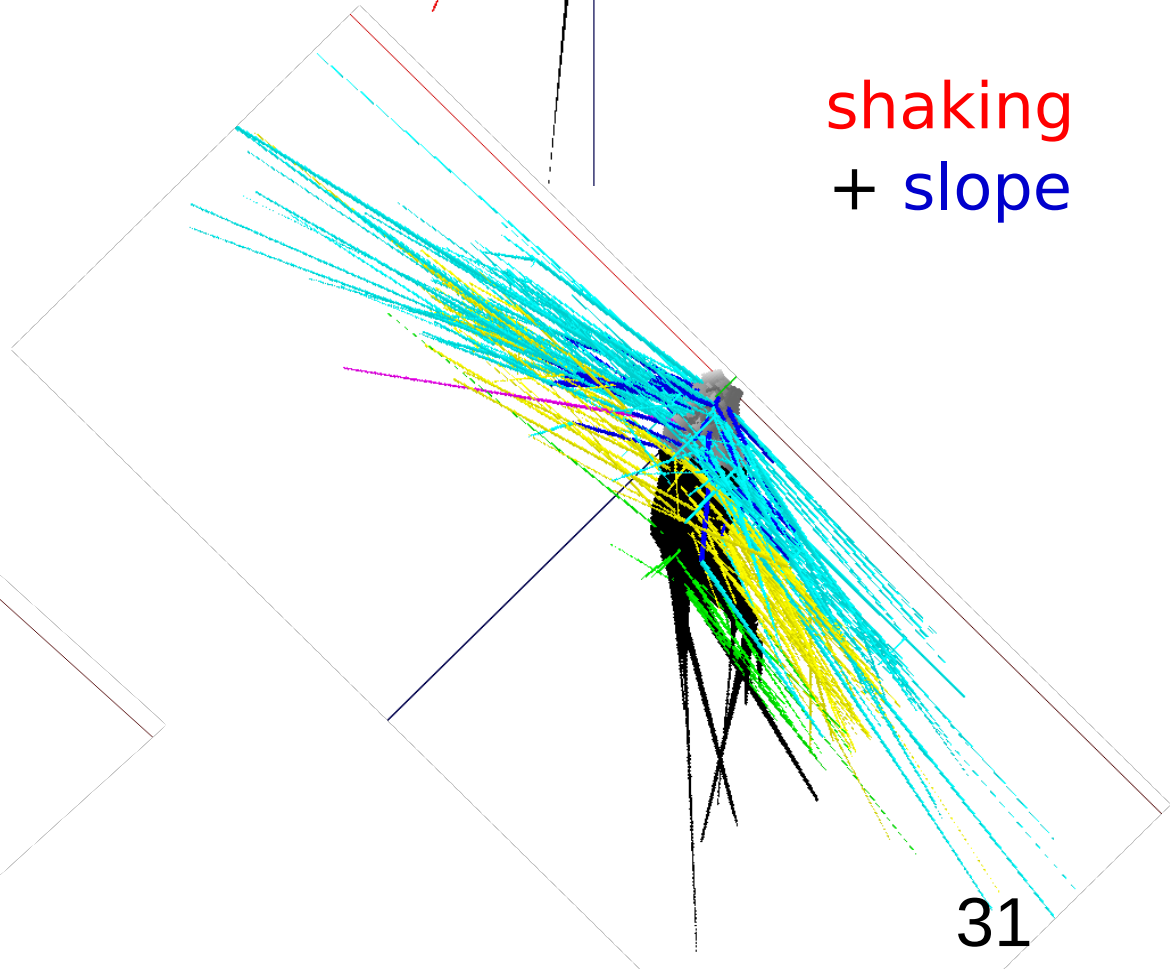
shaking



steep
slope



shaking
+ slope



Conclusion: potential contribution of explanatory approaches

We have static data, we could quantify factors effect on root architecture

Growth model for interpolation/extrapolation/summarizing knowledge

Anchorage assessed with the biomechanical model (Yang et al. 2014)

Input in wind risk models:

e.g. planting technique: could not be linked to anchorage strength

low stem straightness: higher probability of anchorage failure

End

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support

