Green Infrastructures:
a sustainable management approach

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COST
FP1204
GreenInUrbs

GREEN INFRASTRUCTURE

Nature based solutions for sustainable and resilient cities

ORVIETO, ITALY 4-7 April 2017

Presentation layout:

- General introduction
-
- Some research results

The sustainable approach to manage "the green" in green infrastructures

- **Design:** focused on plant needs and on site potentiality
- **Contract:** All details must be specified in order to meet plant requirements
- **Site preparation:** To ensure that site conditions are appropriate for the plants
- **Tree supply:** Plant material must be of the highest quality possible (morphological, physiological and phytosanitary) and to have the right fitness (in biology "The extent to which an organism is adapted to or able to produce offspring in a particular environment")
- **Planting:** to ensure that all the necessary interventions are provided before, during and after planting
- **Establishment:** to anticipate the typical problems of the urban environment like water scarcity, weed competition and man damages
- **Maintenance:** keep on caring trees for the time need according to plant material type and "don't think that once planted trees can live on their own"
- **Monitoring:** monitoring trees for an early detection of stress and diseases

Green Infrastructures

To allow trees to be long-living

To provide benefits

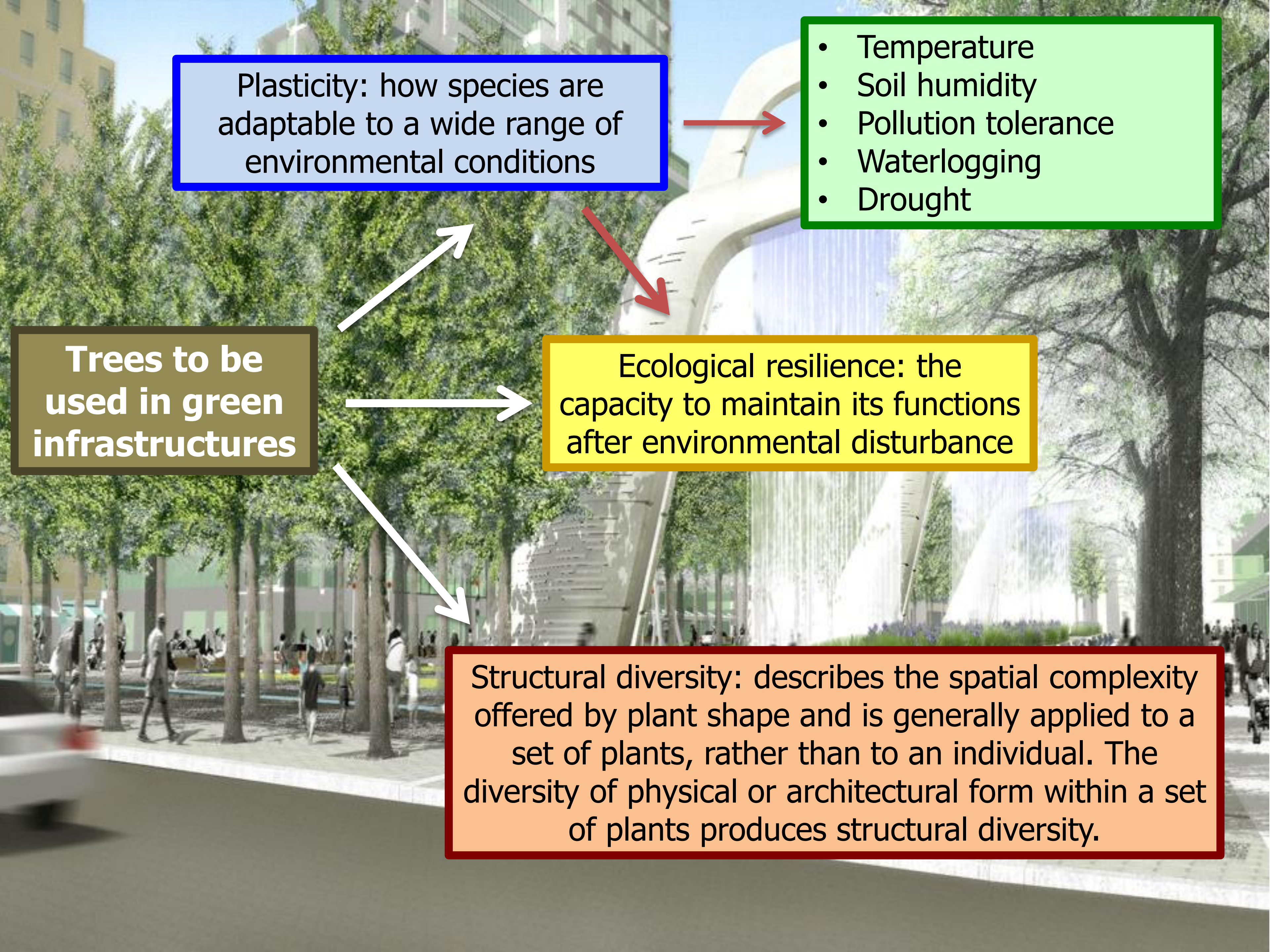
Sustainable management

1) Choice of planting material

2) Best management Pratices

3) Planning the renewal

1) Choice of planting material



Trees to be used in green infrastructures

Plasticity: how species are adaptable to a wide range of environmental conditions

- Temperature
- Soil humidity
- Pollution tolerance
- Waterlogging
- Drought

Ecological resilience: the capacity to maintain its functions after environmental disturbance

Structural diversity: describes the spatial complexity offered by plant shape and is generally applied to a set of plants, rather than to an individual. The diversity of physical or architectural form within a set of plants produces structural diversity.

Strategies to reduce infrastructures damage potential by plants

Infrastructures

Plants

https://it.pinterest.com/pin/277745501992095823/

Are the strategies preventive, remedial or both? (readapted from Costello and Jones, 2003)

Strategy	Preventive	Remedial
Tree based		
Species selection	☑	
Root pruning		☑
Infrastructure-based, Design		
Bigger planting space	☑	☑
Curving sidewalk	☑	☑
Pop-outs	☑	☑
Nonstandard slab size		☑
Monolithic sidewalks	☑	☑
Increase right-of-way	☑	☑
Eliminate sidewalk	☑	☑
Tree islands	☑	
Narrower street	☑	☑
Bridging	☑	☑
Lowered sites	☑	
Modified grave layer	☑	☑

Are the strategies preventive, remedial or both? (readapted from Costello and Jones, 2003)

Strategy	Preventive	Remedial
Infrastructure-based, Materials		
Reinforced slab	☑	☑
Thicker slab	☑	
Expansion joints	☑	☑
Pervious concrete	☑	☑
Asphalt	☑	☑
Decomposed granite	☑	☑
Compacted gravel	☑	☑
Pavers	☑	☑
Recycled rubber	☑	☑
Grind edge		☑
Ramps or wedges		☑
Mudjacking		☑

Are the strategies preventive, remedial or both? (readapted from Costello and Jones, 2003)

Strategy	Preventive	Remedial
Root zone based		
Root barriers	☑	☑
Continuous trenches	☑	
Root paths	☑	
Steel plates		☑
Foam underlay		☑
Structural soils	☑	
Soil Modifications	☑	
Water management	☑	☑

Conflicts bewteen trees and infrastucture: species selection can be a really important factor

Species reported to form surface roots or cause damage to infrastructures. Source information are listed, but methods used to evaluate species for rooting characteristics are not consistent among sources (readapted from Costello and Jones, 2003)

Species	Common name	Source
Acer platanoides	Norway maple	Gilman, 1997
Acer rubrum	Red Maple	Gilman, 1997; Rindels, 1995; Fraedrich, 1995
Acer saccharinum	Silver Maple	Rindels, 1995; Reimer and Mark, 2001; Lesser, 2001; Kopinga, 1994
Aesculus hippocastanum	Horsechestnut	Reimer and Mark, 2001
Ailanthus altissima	Tree of heaven	Gilman, 1997
Betula pendula	European white birch	Koping, 1994
Celtis australis	European hackberry	Coate, 1990
Cinnamomum camphora	Camphor tree	Gilman, 1997; Reimer and Mark, 2001; Lesser, 2001; Sealana, 1994; Fraedrich, 1995
Fagus sylvatica	European Beech	Reimer and Mark, 2001
Ficus spp	Fig species	Gilman, 1997; McPherson et al., 2000
Fraxinus spp	Ash	Gilman, 1997; Rindels, 1995; Fraedrich, 1995
Gleditsia triachanthos	Honeylocust	Gilman, 1997
Juglans spp.	Walnut species	Gilman, 1997
Liquidambar styraciflua	Sweetgum	Rindels, 1995; Wagar and Barker, 1983; Lesser, 2001; Sealana, 1994; McPherson et al., 2000; Fraedrich, 1995
Liriodendron tulipifera	Tulip tree	Rindels, 1995; Fraedrich, 1995
Magnolia grandiflora	Southern magnolia	Wagar and Barker, 1983; Reimer and Mark, 2001; Lesser, 2001; McPherson et l. 2000
Morus alba	White Mulberry	Wagar and Barker, 1983;
……		

Species reported to form surface roots or cause damage to infrastructures. Source information are listed, but methods used to evaluate species for rooting characteristics are not consistent among sources (readapted from Costello and Jones, 2003)

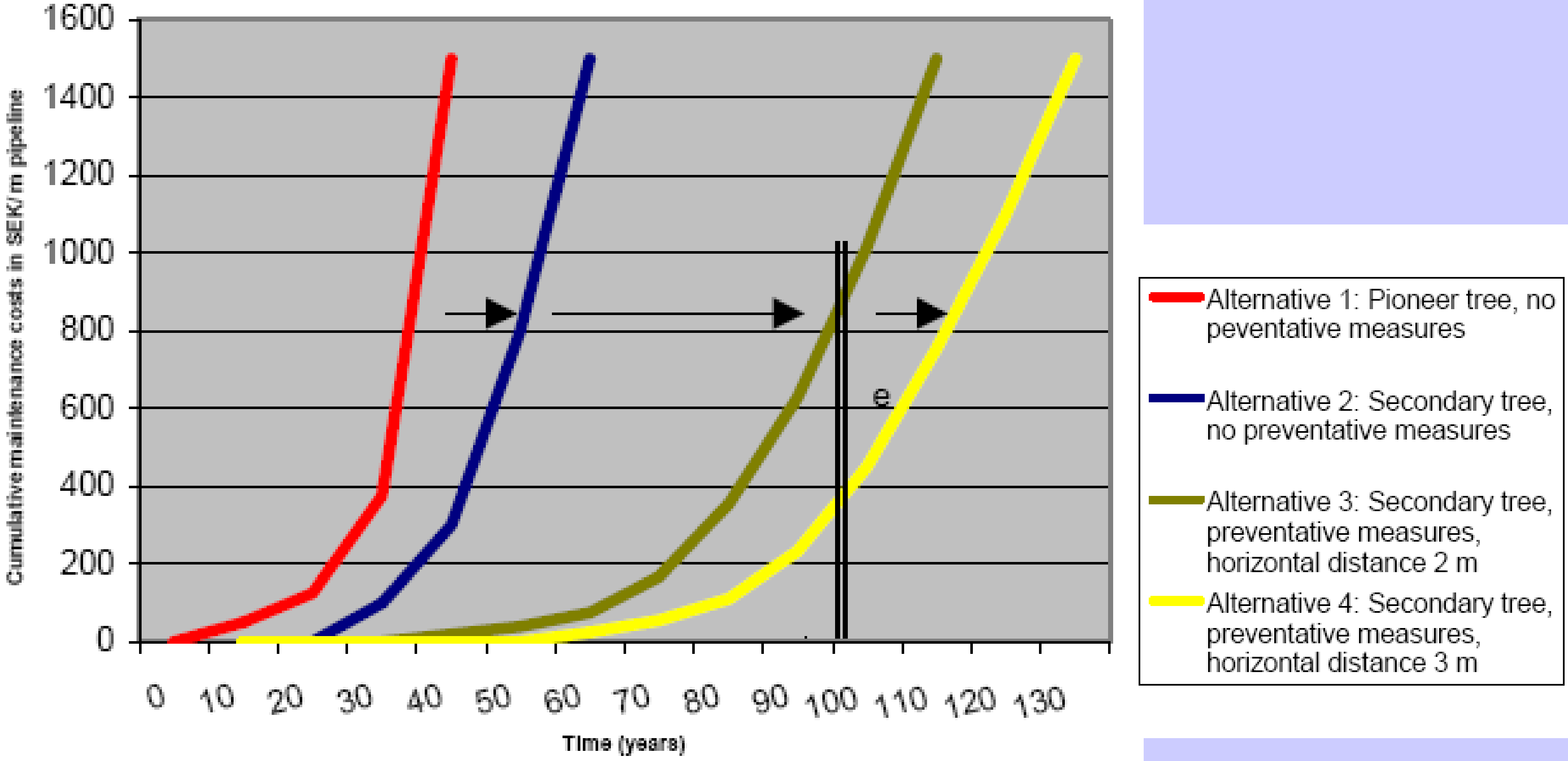
Species	Common name	Source
……..		
Pawlonia tomentosa	Princess tree	Gilman, 1997
Pinus pinea	Italian stone pine	McPherson et l. 2000
Pinus sylvestris	Scots pine	Kopinga, 1994
Platanus x acerifolia	London plane	Wagar and Barker, 1983; Reimer and Mark, 2001
Pterocarya spp.	Wingnut	Gilman, 1997; Ferrini, 2008.
Quercus spp	Oak	Gilman, 1997;
Quercus ilex	Holly oak	Lesser, 2001
Robinia pseudoacacia	Black locust	Gilman, 1997; Reimer and Mark, 2001; Kopinga, 1994
Salix spp.	Willow	Gilman 1997; Rindels, 1995; Reimer and Mark, 2001; Lesser, 2001; Kopinga, 1994; Fraedrich, 1995
Schinus molle	California pepper	Reimer and Mark, 2001;
Ulmus spp.	Elm	Gilman 1997; Rindels, 1995; Reimer and Mark, 2001; Lesser, 2001; Kopinga, 1994; Fraedrich, 1995
Zelkova serrata	Sawleaf zelkova	Coate, 1990; Sealana, 1994

Indicative list of some common street trees in Europe of first size (height > 12 m) and the frequency in which damage to pavements is observed in the Netherlands (indications between brackets are based on statistically low level of observations and must be regarded as provisional) (from Kopinga, 2007, in AAVV, 2007, modified)

Species	Frequent	Occasional	Rare	Species	Frequent	Occasional	Rare
Acer platanoides			x	*Pinus pinea and P. sylvestris*	x		
Acer pseudoplatanus		x		*Platanus acerifolia*		x	
Acer saccharinum	x			*Populus alba*	x		
Aesculus hippocastanum			x	*Populus nigra*	x		
Ailanthus altissima		(x)		*Populus simonii*		(x)	
Betula spp.	x			*Populus spp.*	x		
Carpinus betulus			x	*Quercus robur*			x
Catalpa spp.		(x)		*Quercus rubra*		x	
Celtis spp.		(x)		*Quercus palustris*		x	
Corylus colurna			x	*Robinia pseudoacacia*	x		
Fagus sylvatica			x	*Salix alba*	x		
Fraxinus excelsior		x		*Sophora japonica*		(x)	
Gledisia triacanthos		x		*Sorbus spp.*			x
Juglans nigra			x	*Tilia spp.*			x
Pauwlonia tomentosa		(x)		*Ulmus spp.*		x *	

*Also depending on the type of rootstocks

Cost consequences of placing trees close to sewage pipes (choice of placement, root barrier, etc.)(After Orvesten and Stal, 2003)



Arrow illustrates postponement of costs in time.
Pipe lifetime shown with a vertical double line

Stormwater Tree

Stormwater Tree Trench

Corner Bump-out

City of Philadelphia Green Street Design Manual (2014)

2) Best management practices
Research on trees and green infrastructures

Effects of root severance by excavation on growth, physiology and stability of two urban tree species: results from a long-term experiment

- Construction activities and trenching near trees commonly cause extensive root damage (Hauer, 1994; Matheny and Clark, 1998; Jim, 2003)
- A single trench can remove 18% to about 50% of a tree root system, (Watson, 1998; Wajja-Musukwe et al., 2008)
- Root damage increased mortality over the next 8 years by 18-22% (Hauer et al., 1994)
- Visible symptoms may not occur until years after the damage (Watson, 1998; Despot and Gerhold, 2003; Wajja-Musuke et al., 2008)
- However, little attention has been given to the physiological reasons of tree decline

G. Watson

Cutting roots can lead to tree failure

Species tolerance to root loss (readapted from Costello and Jones, 2003)

Species	Common name	Tolerant	Intermediate	Intolerant
Acer negundo	Box Elder	Matheny and Clark, 1998		
Acer platanoides	Norway Maple	Carlson, 1999	Matheny and Clark, 1998; Phillips, 1999	
Acer saccharinum	Silver maple	Carlson, 1999; ; Phillips, 1999	Matheny and Clark, 1998	
Ailanthus altissima	Trees of heaven	Matheny and Clark, 1998		
Betula ssp	Birch			Matheny and Clark, 1998
Catalpa spp	Catalpa		Matheny and Clark, 1998	
Cedrus spp	Cedar	Matheny and Clark, 1998 **?**		Ferrini, pract. Obs.
Cinnamomum camphora	Camphor			Carlson, 1999; Warriner, 2000
Eucalyptus spp	Eucalyptus		Matheny and Clark, 1998	Bernhardt and Swiecki, 1991
Fagus spp.	Beech			Matheny and Clark, 1998; Carlson, 1999
Ficus spp	Fig	Warriner, 2000		
Fraxinus spp	Ash	Matheny and Clark, 1998	Carlson, 1999	
Ginkgo biloba	Ginkgo	Matheny and Clark, 1998; Carlson, 1999; Phillips,1999		
Gymnocladus diiocus	Kentucky coffee tree		Matheny and Clark, 1998	

Species tolerance to root loss…continue (readapted from Costello and Jones, 2003)

Species	Common name	Tolerant	Intermediate	Intolerant
Juglans spp	Walnut spp			Matheny and Clark, 1998
Liquidambar styraciflua	Sweetgum		Matheny and Clark, 1998	Warriner, 2000
Liriodendron tulipifera	Tulip tree			Matheny and Clark, 1998; Phillips, 1999
Magnolia spp	Magnolia			Carlson, 1999
Pinus spp.	Italian stone pine			Bernhardt and Swiecki, 1991
Platanus spp	Sycamore	Carlson, 1999; Phillips,1999		
Populus spp.	Poplar	Matheny and Clark, 1998		
Pyrus calleryana	Callery Pear			Matheny and Clark, 1998; Carlson, 1999; Phillips, 1999
Quercus spp	Oak		Phillips,1999	Carlson, 1999; Phillips, 1999
Robinia pseudoacacia	Black locust	Matheny and Clark, 1998		
Salix spp.	Willow		Matheny and Clark, 1998; Phillips, 1999	
Tilia spp.			Matheny and Clark, 1998; Phillips, 1999	Carlson, 1999
Ulmus spp.	Elm	Matheny and Clark, 1998; Carlson, 1999		

The aims of this work were:

1. to evaluate the long-term effects of two different levels of root severance on growth and physiology of two tree species supposed to differ in tolerance to root manipulation

2. to evaluate the consequences of root severance on both theoretical (calculated) and measured (by pulling test) resistance to uprooting.

Methods: plant material

48 uniform European limes (*Tilia x europaea*) and 48 horsechestnuts (*Aesculus hippocastanum*) were planted in 2004 in a loam sandy soil and allowed to establish undisturbed for five years.

Tilia is supposed to better tolerate root manipulation than *Aesculus* (Matheny, 2005)

2004

2009

Methods: treatments

Control - **C**

Trenching on 1 side of the tree - **MD**

Trenching on 2 sides of the tree - **SD**

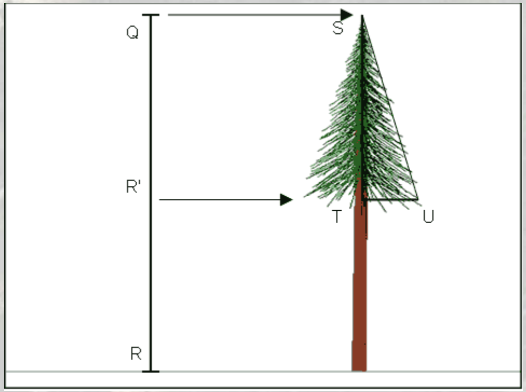
Trenches (70 cm deep) were excavated 40 cm from the root flare in June 2009.

The experimental design was a randomized complete block with 4 blocks

Methods: measurements

GROWTH:

- **Shoot growth**
- **Stem diameter growth**:
- **Tree height and canopy size**:



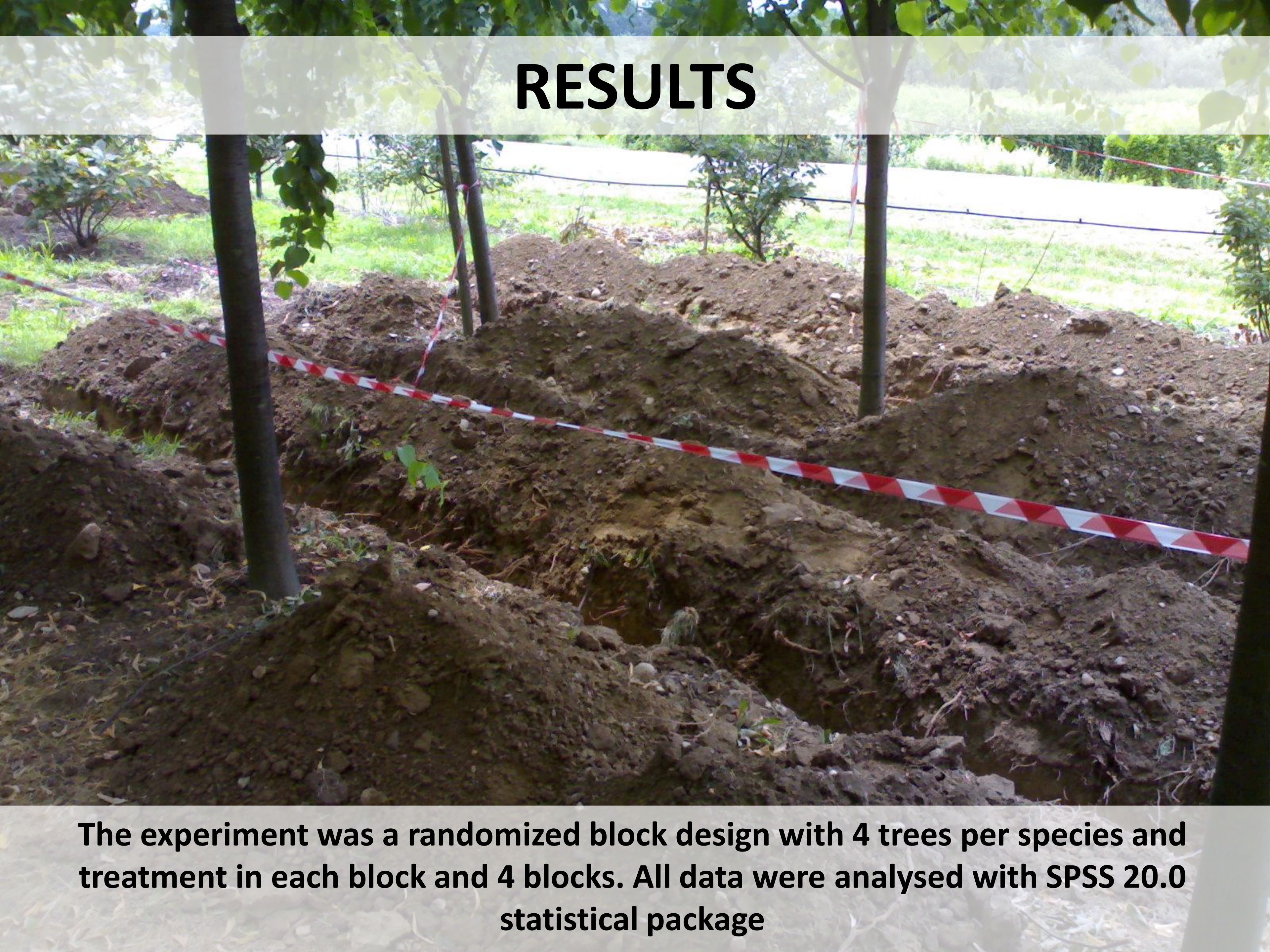
PHYSIOLOGY:

- **Leaf gas exchange:**
- **Maximal quantum yield of PSII photochemistry (Fv/Fm):**
- **Pre-dawn water potential (Ψ_w, MPa):**

Methods: the pulling test

Pulling test was performed 3 weeks and 4 years after root severance as described in Sani et al. (2012). Two inclinometers were used to evaluate tree response to pulling in both tension and compression

RESULTS



The experiment was a randomized block design with 4 trees per species and treatment in each block and 4 blocks. All data were analysed with SPSS 20.0 statistical package

STEM DIAMETER

	$Ø_{\text{stem}}$ before trenching (cm)	ΔØ year 1 (cm)	ΔØ year 2 (cm)	ΔØ year 3 (cm)	ΔØ year 4 (cm)
Effect of root severance					
Control	9.7 a	1.4 a	1.3 a	1.1 a	1.8 a
MD	10.0 a	1.5 a	1.0 b	0.8 b	1.3 b
SD	8.9 a	0.9 b	0.9 b	0.8 b	1.3 b
P	n.s.	**	**	*	*
Effect of species					
Tilia	10.0 a	1.5 a	1.1 a	0.9	1.5
Aesculus	9.0 b	1.0 b	1.2 a	1.0	1.4
P	**	**	n.s.	n.s.	n.s.
Root severance x Species					
P	n.s.	n.s.	n.s.	*	n.s.

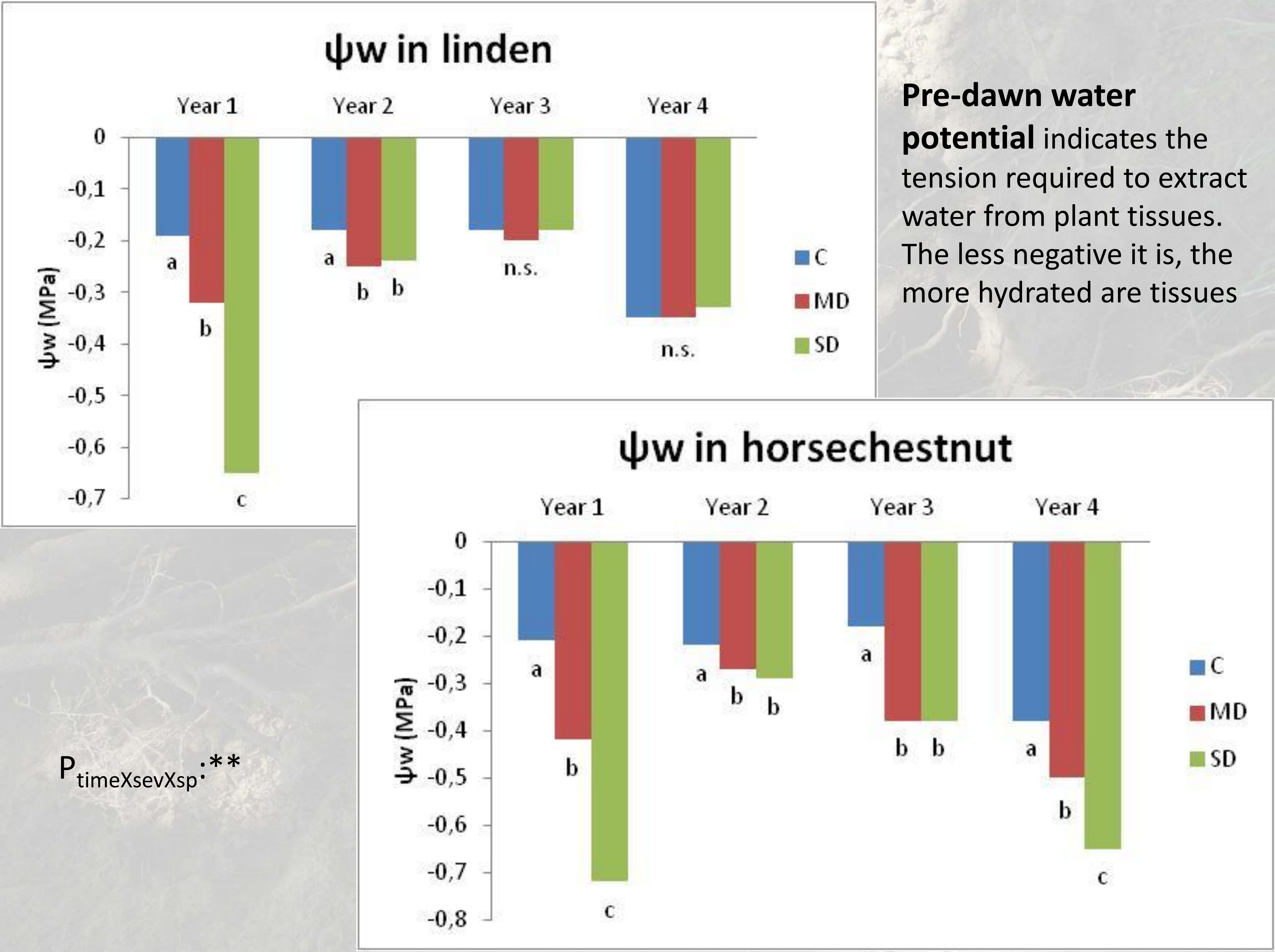
Control - **C**

Trenching on 1 side of the tree - **MD**

Trenching on 2 sides of the tree - **SD**

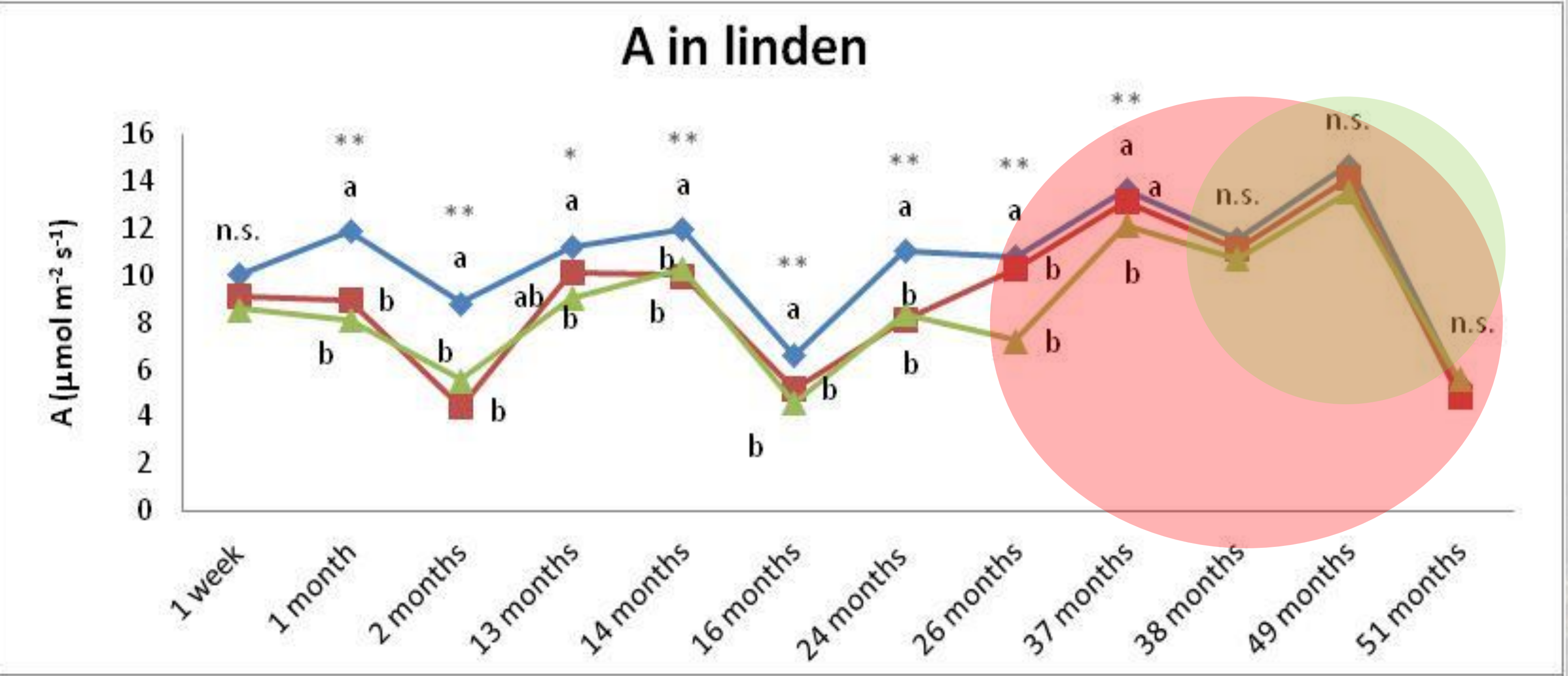
SHOOT GROWTH

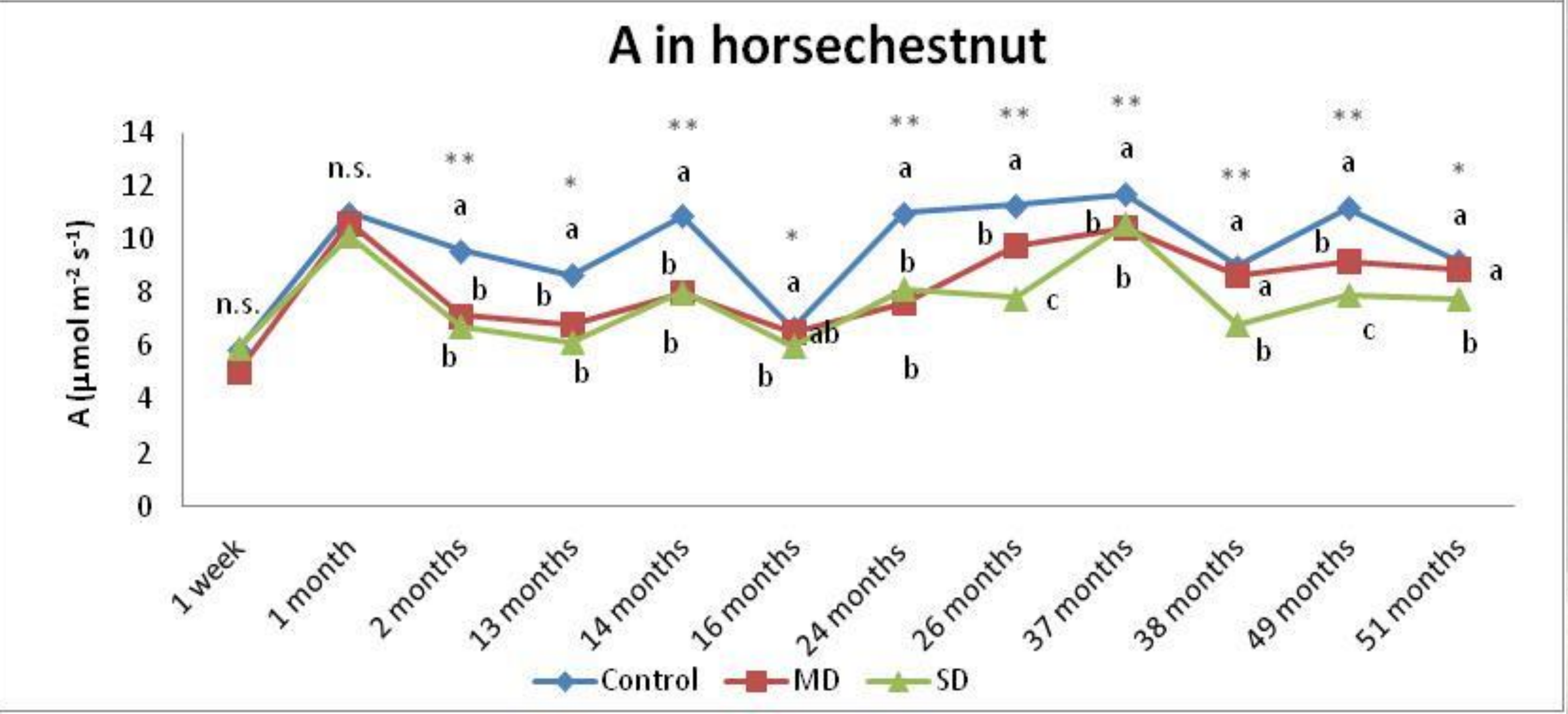
	Shoot growth year 1 (cm)	Shoot growth year 2 (cm)	Shoot growth year 3 (cm)	Shoot growth year 4 (cm)
Effect of root severance				
Control	40,1 a	24,49 a	38,02 a	30.0 a
MD	29,43 b	18,82 b	27,49 b	17.3 b
SD	27,91 b	15,22 b	21,01 c	14.8 b
P	**	**	**	**
Effect of species				
Tilia	42,39 a	19,85	20,1 b	17.2 b
Aesculus	22,56 b	19,16	37,58 a	24.2 a
P	**	n.s.	**	**
Root severance x Species				
P	n.s.	*	*	*



Pre-dawn water potential indicates the tension required to extract water from plant tissues. The less negative it is, the more hydrated are tissues

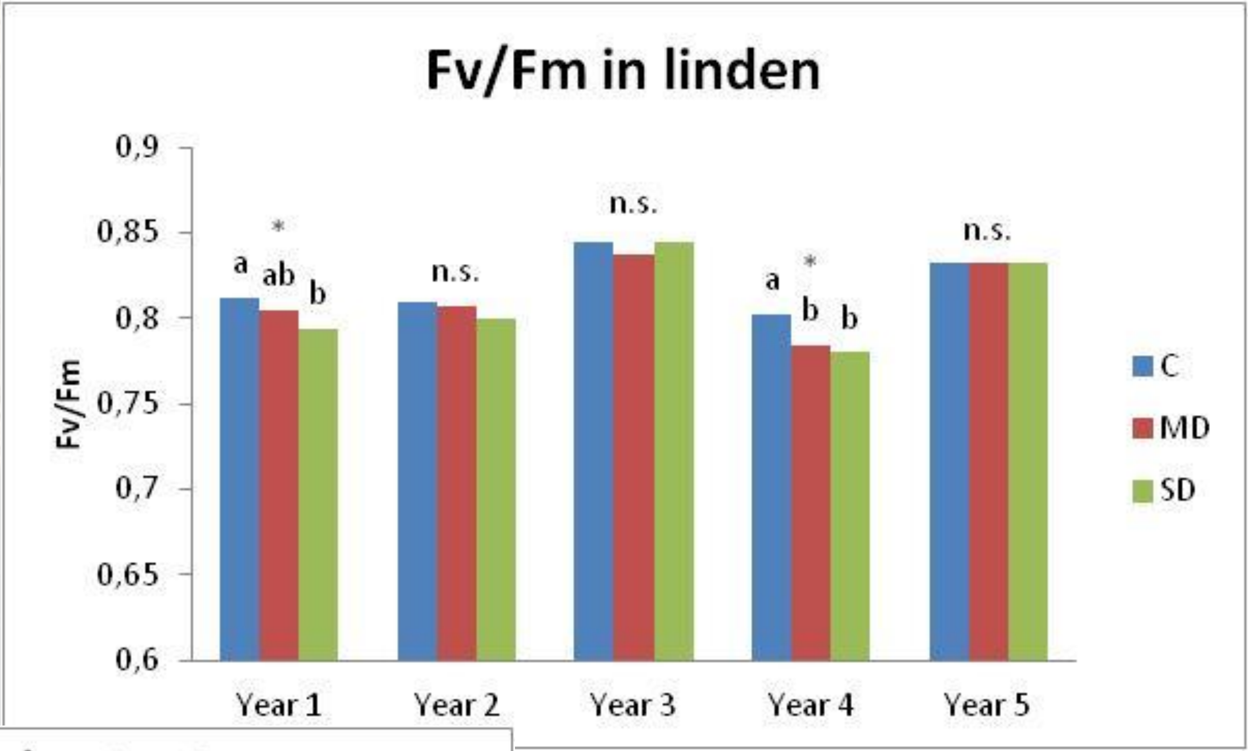
$P_{timeXsevXsp}$:**

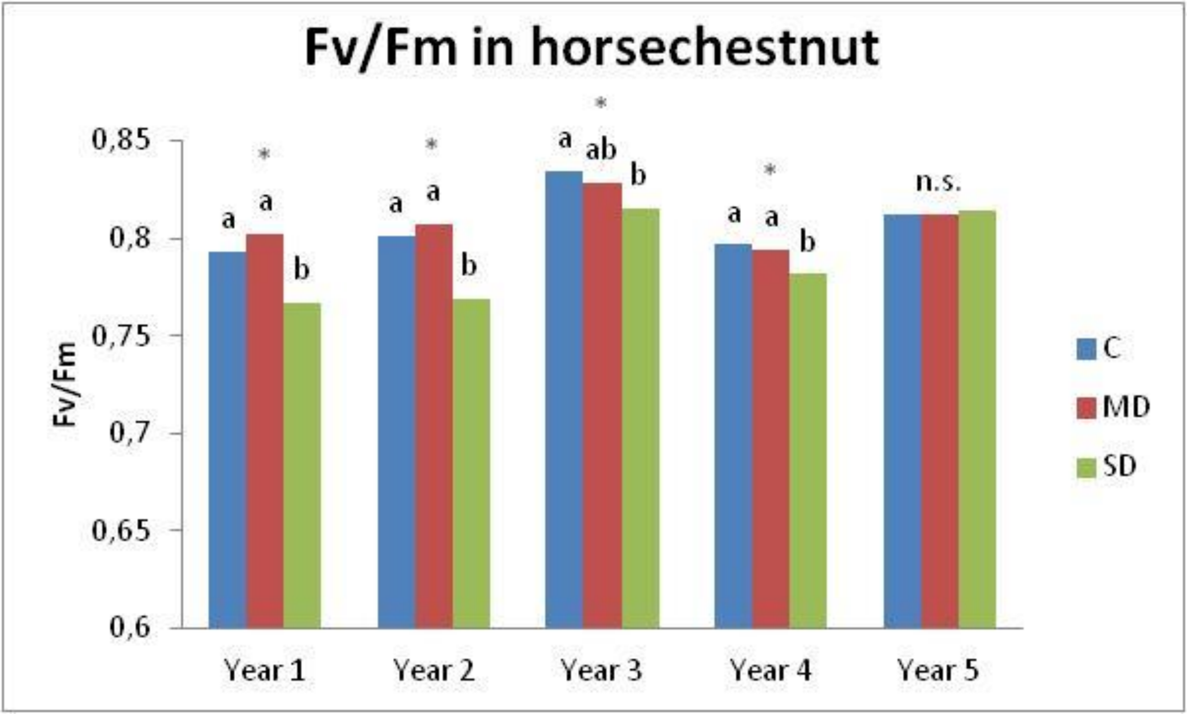




CO$_2$ assimilation is the amount of CO$_2$ assimilated from 1 m^2 of leaf area per unit time

MAXIMUM QUANTUM YIELD OF PSII





Healthy leaves usually display values greater than 0.8. Photoinhibition occurs at values lower than 0.75

Physiological effects of root damage on young trees: take home message

- From a physiological point of view, root severance on young trees induced similar effects as a mild water stress, characterized by diffusive limitation to photosynthesis (metabolic limitation, typical of more severe stress, rarely occurred) and a moderate change in pre-dawn water relation (data not shown).

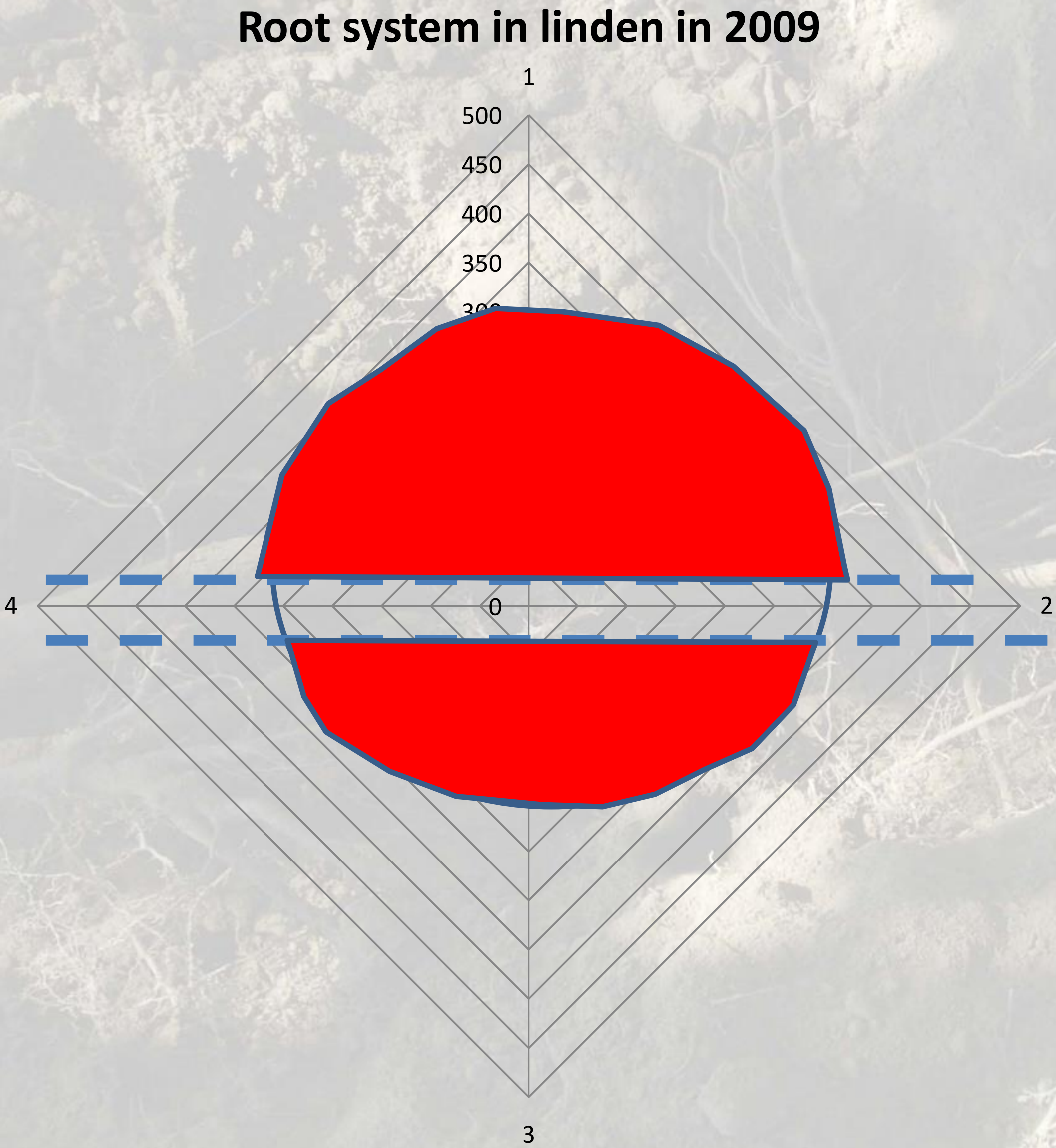
- However, recovery is slower than most abiotic (mild) stresses, particularly in sensitive species such as horsechestnut

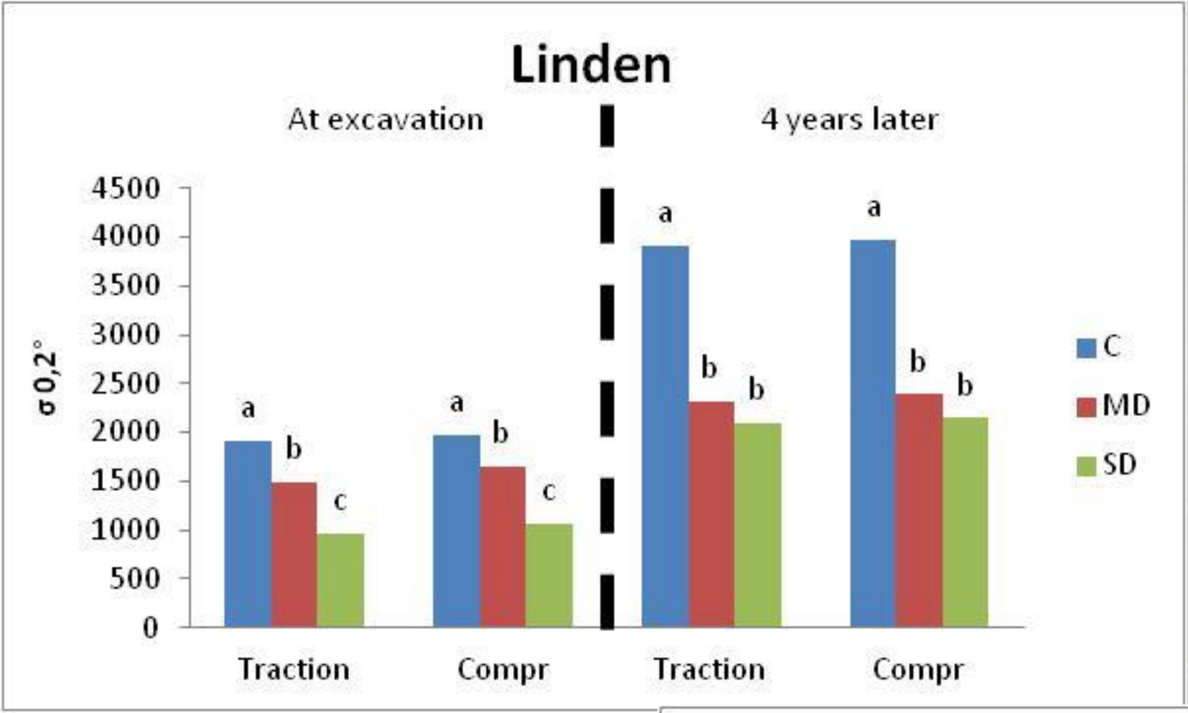
- Linden displayed greater physiological tolerance to root loss than horsechestnut

- It must be considered that experiment was performed during quite rainy years

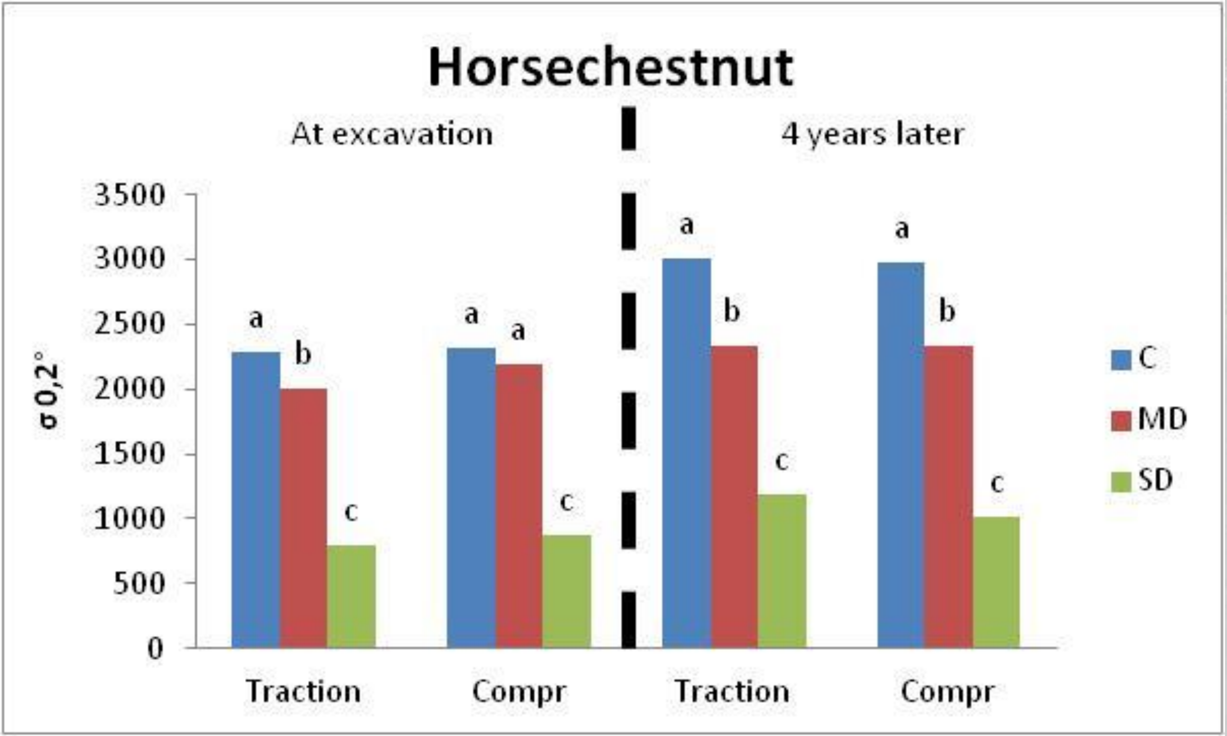
Will severed trees stand up?

What about roots?





Bending moment (both traction and compression) to reach 0.2° change in inclination of the root plate, determined by pulling test



CONCLUSIONS

- The change in absorbing root surface caused by root loss induced a chronic mild water stress to trees, even in very rainy years, when water stress is very unlikely to happen on undamaged trees

- Recovery from this stress is extremely slow, because it depends on root regeneration, rather than on resource (water) supply

- Thus, root damage may act as a predisposing factor, which may lead to tree decline as secondary stressors occurs

- The uprooting resistance, both measured and calculated, was reduced by excavation, and recovery was very slow and incomplete in both species

LIMITATION TO THIS STUDY

Results of this study show the response of linden and horsechestnut to root damage. However, when extrapolating these findings to urban conditions, it must be considered that **trees were young (25-30 cm circumference at the beginning of the experiment)**. Older trees may show a different response and further research should be aimed at investigating the effects of trenching on mature and senescent trees.

A 3-year-study evaluating the effects of soil sealing on newly planted trees

From Elkin, 2011

Methods – Building the plots

- 24 plots (50 m^2 area) were built in November 2011
- Each plot was separated from the surrounding ones by polypropylene barriers, buried in the soil down to 70 cm.
- Two planting pits (1 m^2 area) were left unpaved in each plot
- Plastic cylinder were put through the pavements, to allow direct soil measurements. Some cylinders are near the planting pit, some other are buried 5 m away
- Pavement thickness was about 15 cm, including sub-grade, in all treatments

Methods - treatments

Impervious design: asphalt on a concrete sub-grade

Permeable desing: curb on a crushed rock sub-grade

POROUS PAVEMENTS:
The pavements itself is permeable to water across its entire structure

PERMEABLE PAVEMENTS:
Pavements made by impervious modular elements, but voids between elements allow water infiltration

Porous desing: epoxy resin + even-graded inert on a crushed rock sub-grade

Control: unpaved soil (chemical weeding used for weed control)

Methods - species

Celtis australis L. - hackberry
Fraxinus ornus L. – manna ash

- 24 plants per species (14-16 cm circumference; 2’’ caliper) were planted in March 2012, according to a randomized block design with 6 blocks

- Each tree was planted in a 1 m^2 planting hole, surrounded by 25 m^2 paved soil

Measurements: soil traits

- Soil moisture (v/v), measured weekly **at 20 cm** (5 cm below sub-grade) and **45 cm** (30 cm below sub-grade) depth, measured with FDR soil moisture probes
- Soil temperature, measured monthly at 25 cm depth using a temperature probe
- Soil oxygen content and soil CO_2 efflux, measured monthly using a soil respiration chamber

These parameters were measured both in the paved soil next to the planting pits and in the paved soil in the middle of the paved plot, not colonized by roots yet.

Measurements: plant traits

GROWTH:

- **Shoot growth** (10 shoots per plant), measured at the end of the growing season in 2012, 2013, and 2014
- **DBH**, measured at the end of the growing season in 2012, 2013, and 2014

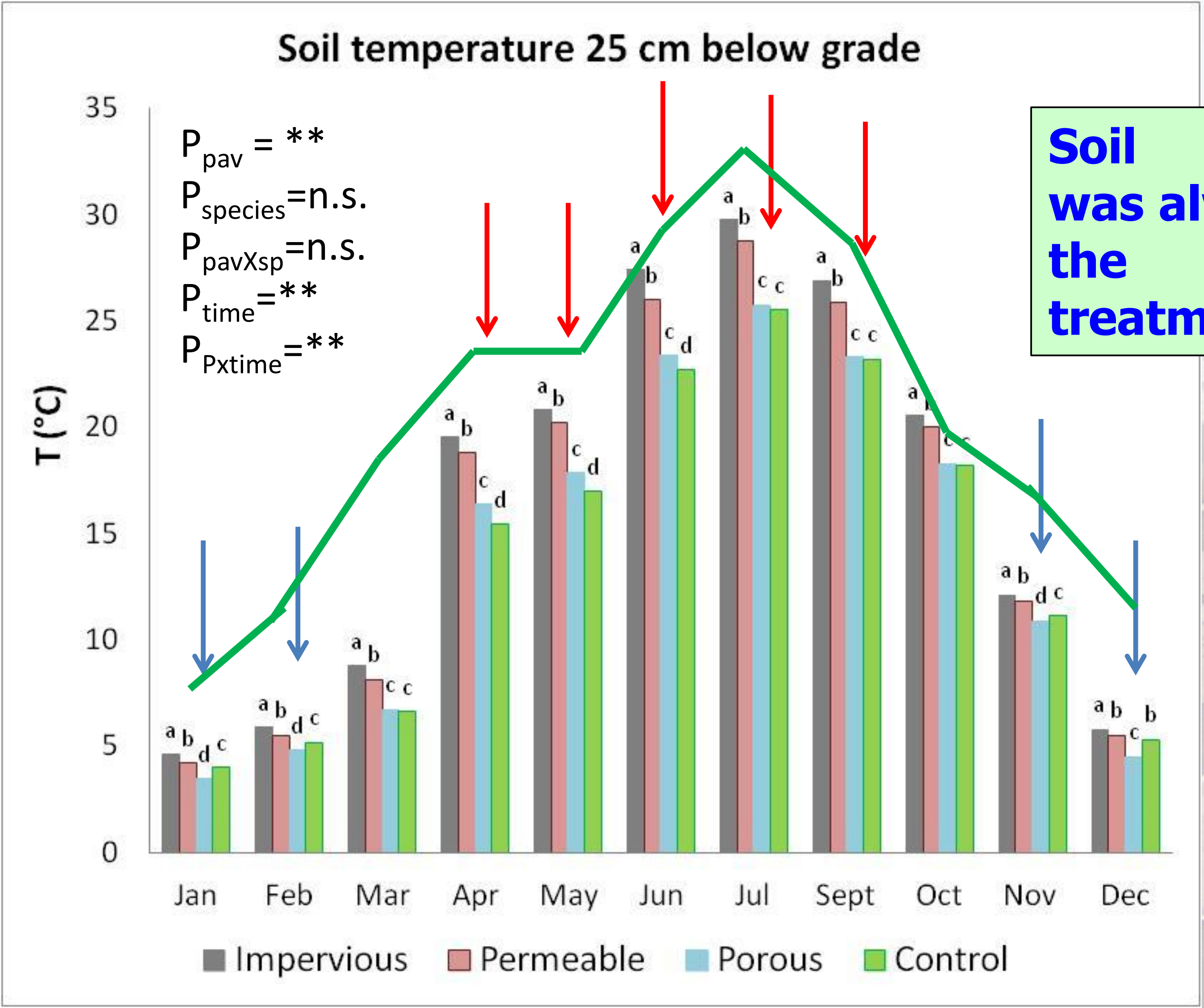
PHYSIOLOGY:

- **Leaf gas exchange** (photosynthesis and transpiration) **measured monthly** during the growing season on 12 leaves per treatment and species using a IRGA
- **Fv/Fm**, **measured on the same leaves** as gas exchange using a portable fluorometer
- **Pre-dawn and midday water potentials,** measured using a Scholander-type pressure bomb

Results

Data were analysed using two-way ANOVA with SPSS statistical package (IBM)

Effects on soil - Temperature



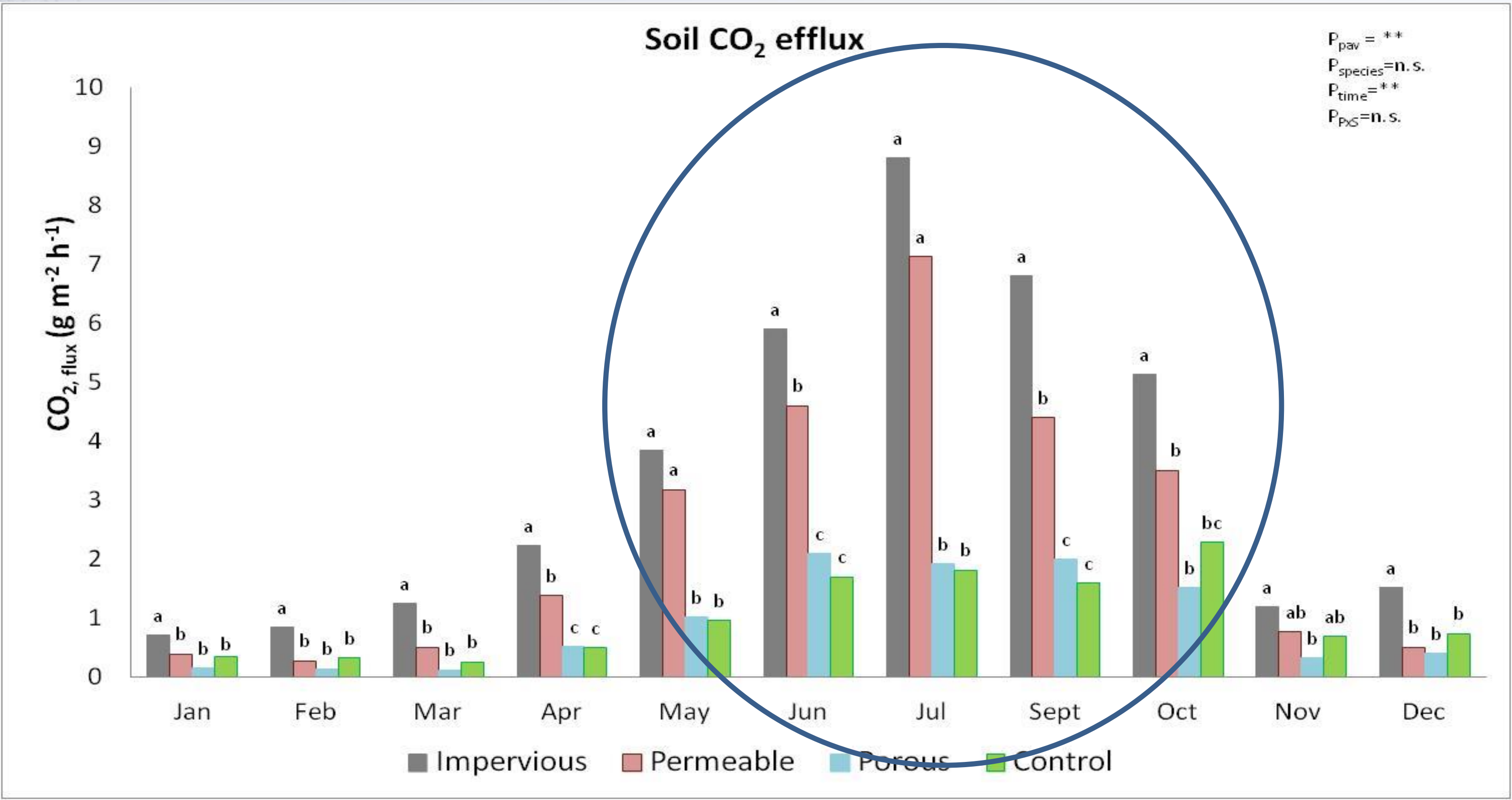
Soil temperature was always higher in the impermeable treatment

Data are the average of monthly measurements conducted from June 2012 to May 2015.

Line indicates air temperature

During a snowfall, plots paved with asphalt are probably warmer

Effects on soil – soil CO_2 efflux



- According to Fick's Law, higher CO_2 efflux reflects a higher accumulation of inorganic C (CO_2) in the soil below impervious pavements
- Permeable pavements are less permeable to CO_2 than porous ones
- **DO NOT CONFOND INORGANIC CARBON WITH SOIL ORGANIC CARBON**, which has been found to decrease in sealed soils (Wei et al., 2014)

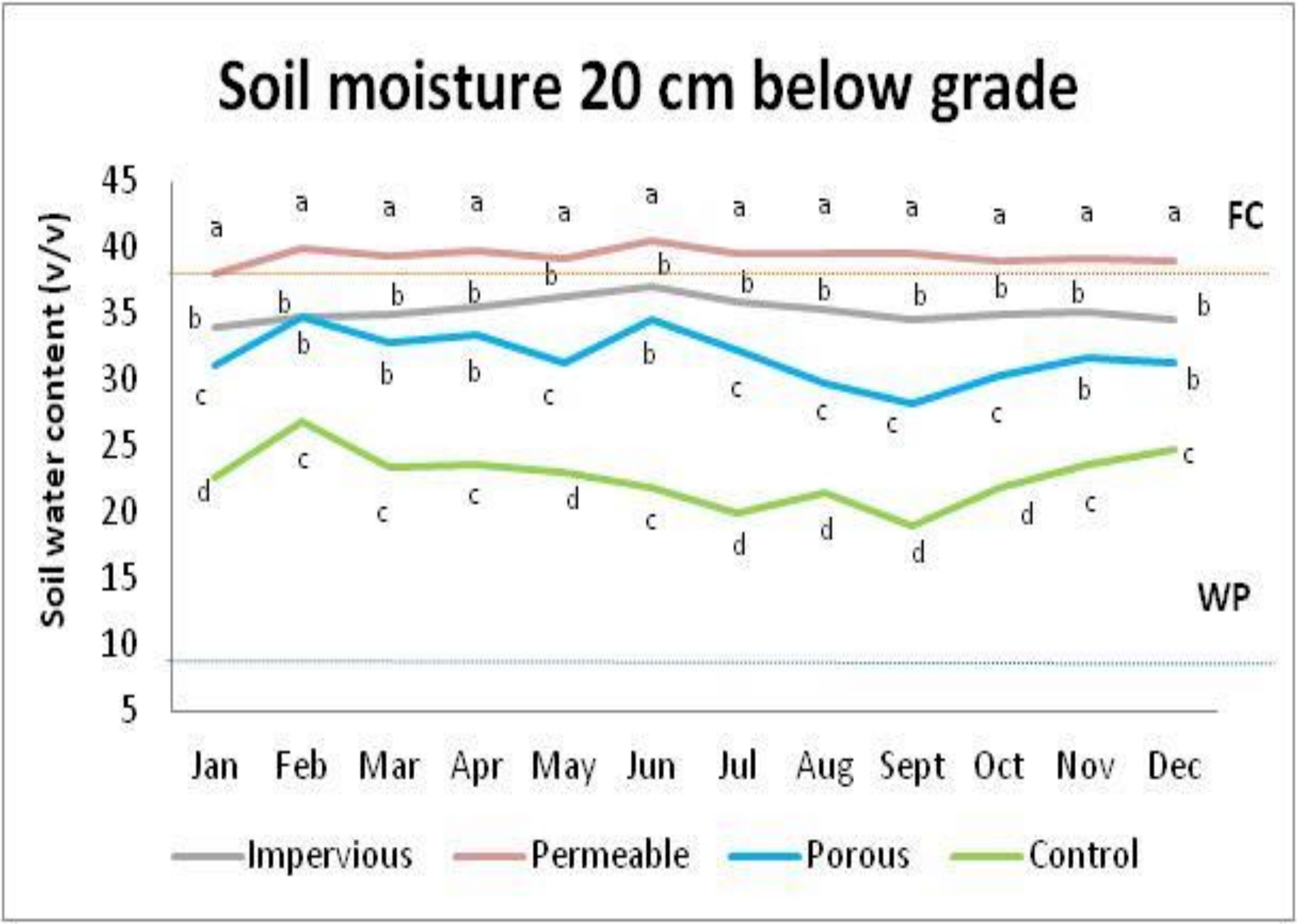
Effects on soil - moisture

Frequency domain reflectometry (FDR) moisture probes

20 cm deep

45 cm deep

Effects on soil - Moisture in paved soils with no tree roots

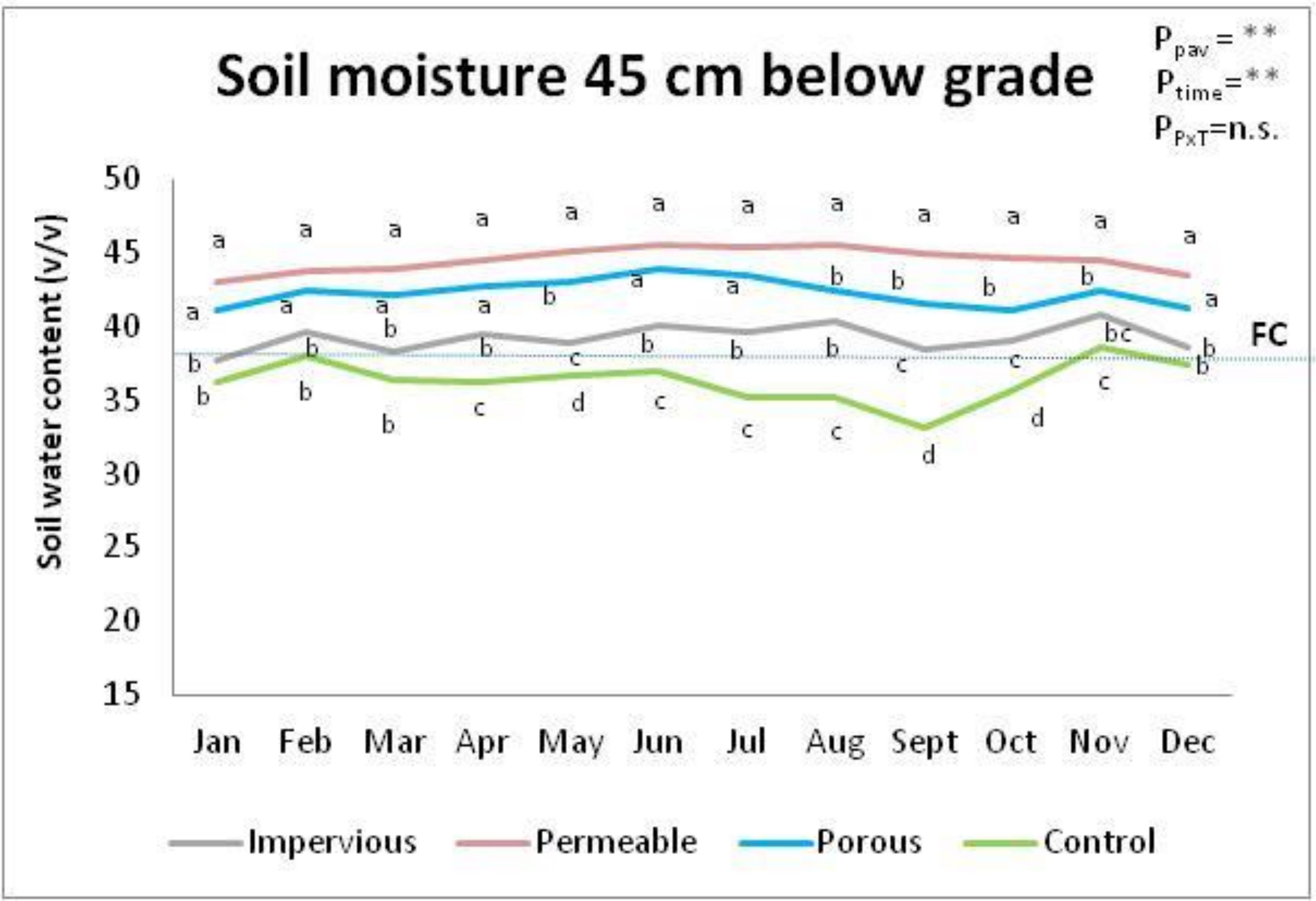


WP and FC denote wilting point and field capacity

Variation in moisture through the year:

Asphalt: 8%
Permeable: 7%
Porous: 18%
Control: 29%

Soil moisture a little deeper – soil without tree roots



Conclusions – Effects on soil

- Soil sealing induces 3-5 °C warming in the soil. The effect is likely due to impaired evaporation and can be mitigated using porous pavements.

- Because evaporation is reduced, soil moisture increases with soil sealing, being often above field capacity in soils not planted with trees. This was found in all paved soils. Trees can “bridge” the pavement and transpiration restores water cycle in urban areas.

- CO_2 accumulates below impervious pavements, potentially reducing root activity and growth. Porous and, to a lesser extent, permeable pavements can mitigate this effect

- Oxygen slightly declines below impervious pavements. Both porous and permeable pavements can be used to avoid such decline.

Impervious

Permeable

Porous

Control

TAKE HOME MESSAGE:

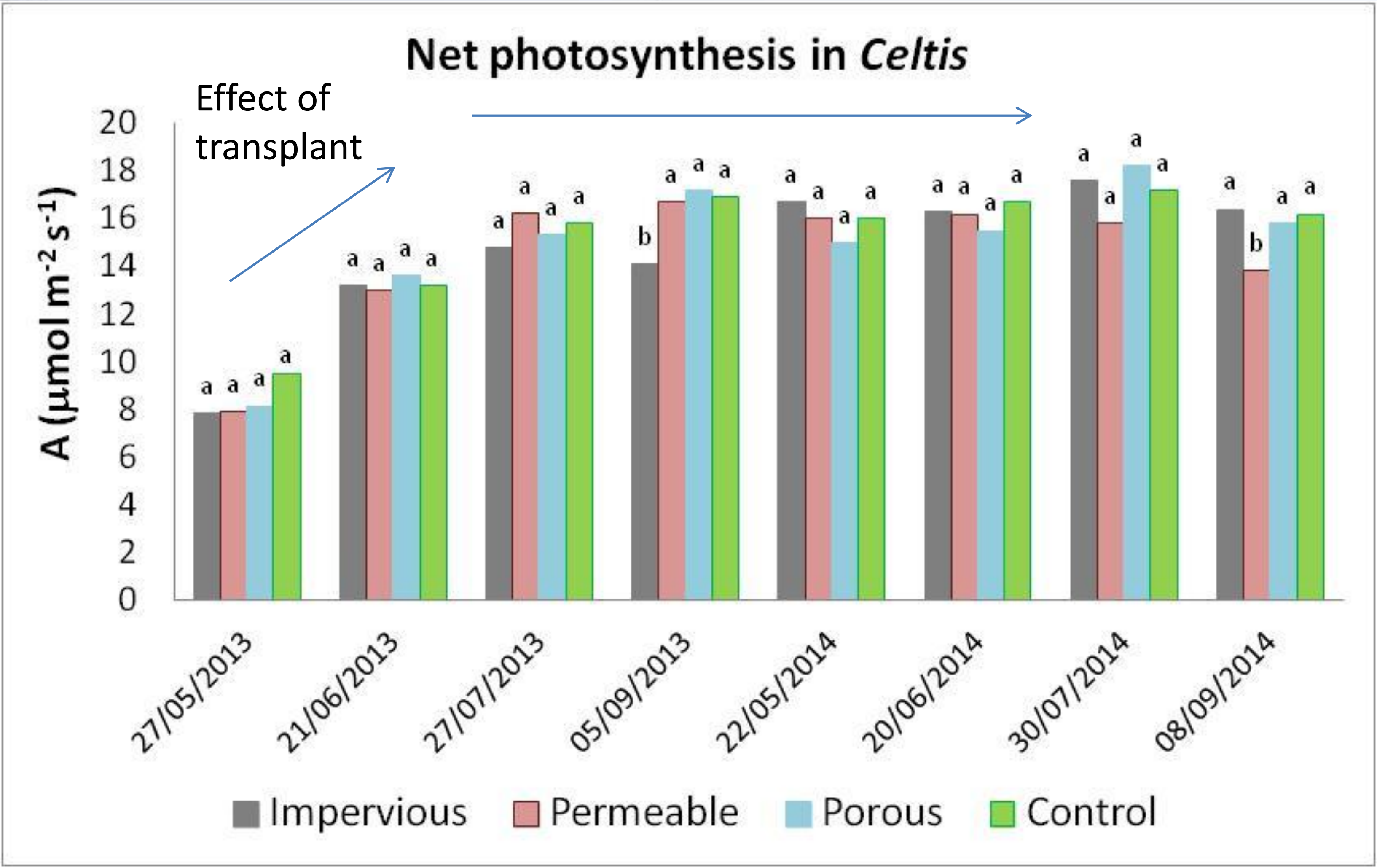
differences among pavement types, no trees

PAVEMENT	INFILTRATION	EVAPORATION	WATER CONTENT at 20 cm	WATER CONTENT at 45 cm
Impervious	Low	Very Low	Slightly below FC	Slightly above FC
Permeable	Medium*	Low	Saturated	Saturated
Porous	High	Medium	75% available water	Saturated
Control	High	High	40% available water	At or slightly below FC

* May become clogged in about 3 years, decreasing infiltration rate by up to 83%

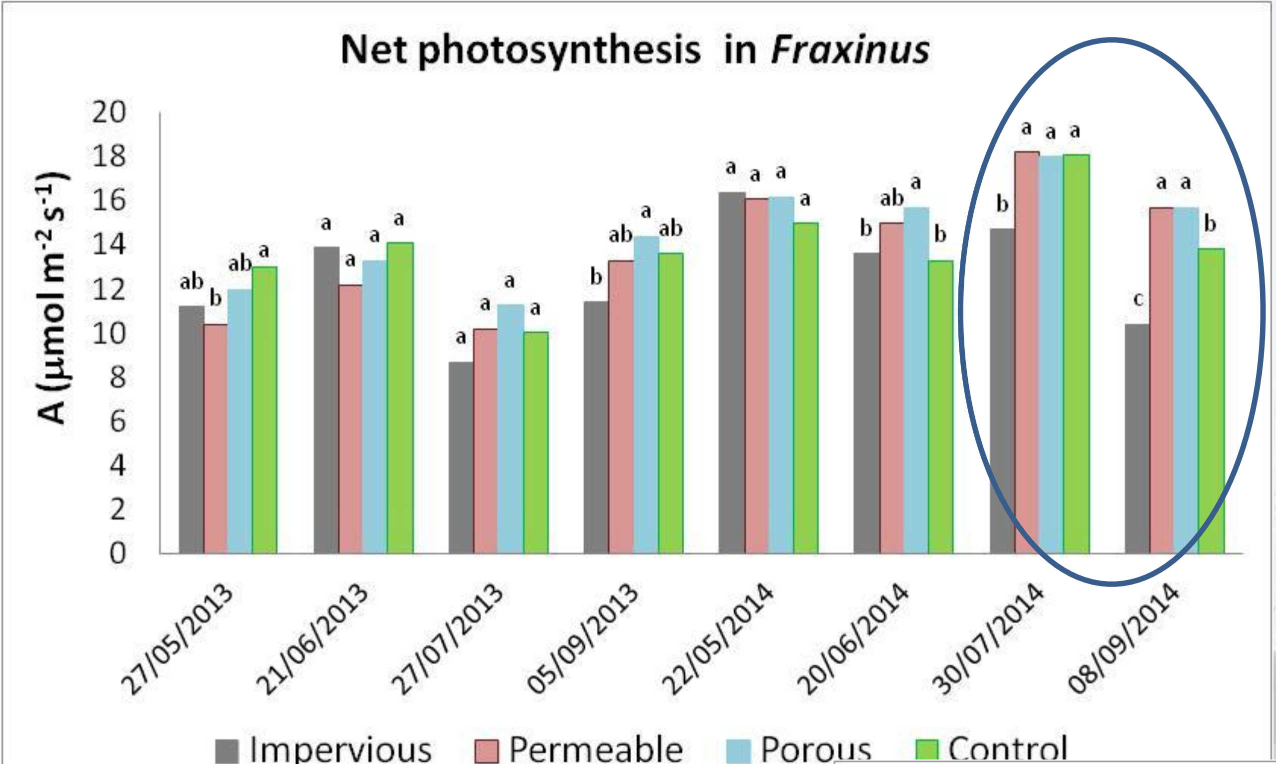
(Asaeda and Ka, 2000; Abbott et al., 2003; Collins et al., 2008; Morgenroth et al., 2013)

Effects on trees – photosynthesis



Different letters within the same sampling date indicate significant differences among treatments at $P<0.05$ using Duncan's MRT

PHOTOSYNTHESIS VS. TRANSPIRATION in manna ash

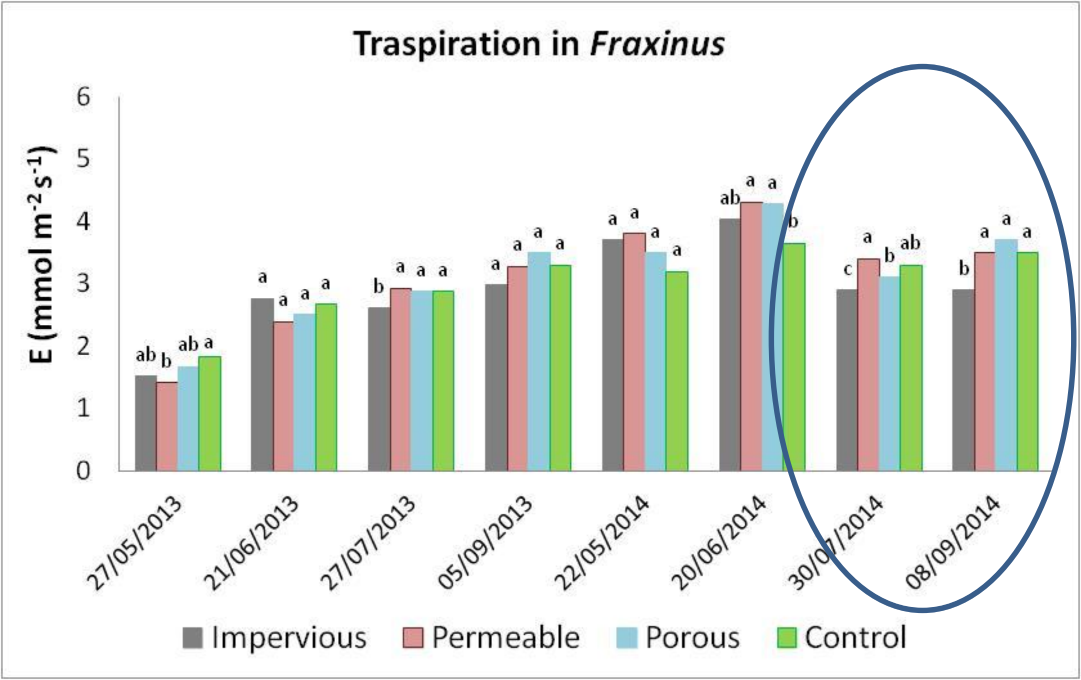


Net photosynthesis in *Fraxinus*

Greater decline in A than E (lower water use efficiency) in “impervious ashes”.

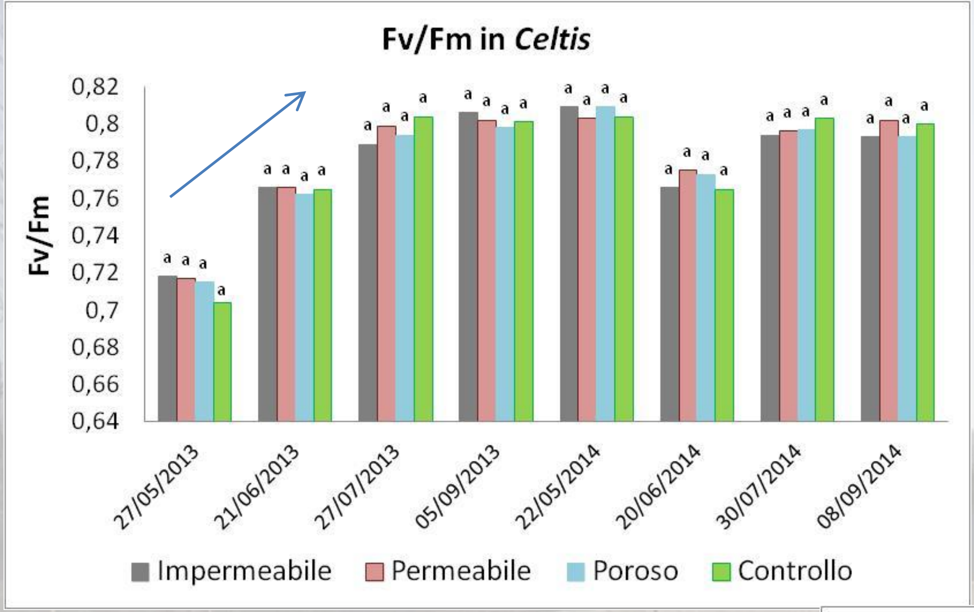
Uncommon when photosynthesis is limited by stomatal closure

Evidence for biochemical limitations?



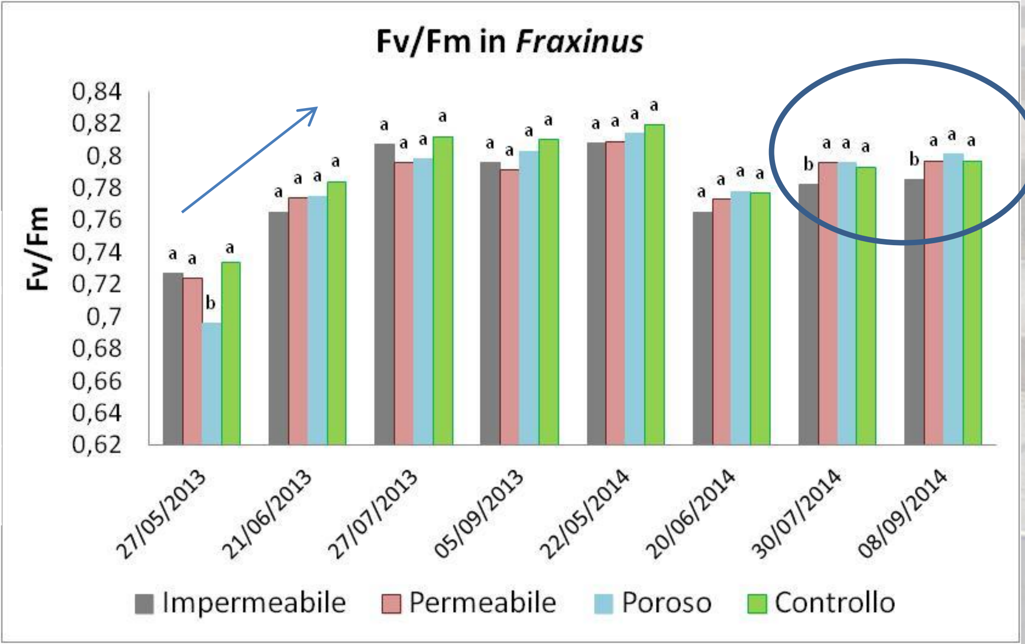
Traspiration in *Fraxinus*

Evidence for metabolic stress on PSII?

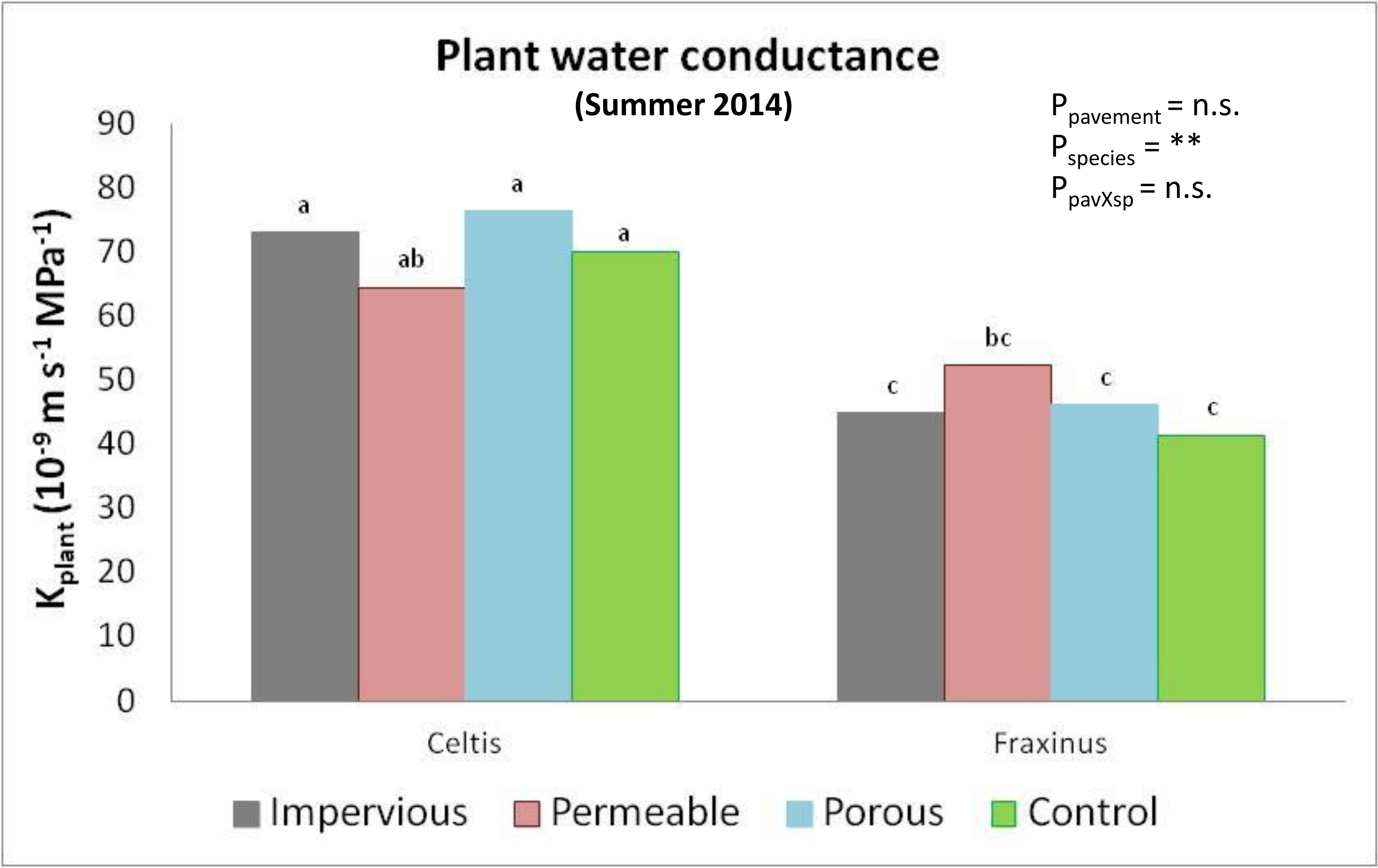

Fv/Fm in *Celtis*

- No evidence of photoinhibition in hackberry
- Some in ashes growing in the impervious treatment, but only very mild stress and in the last two samplings

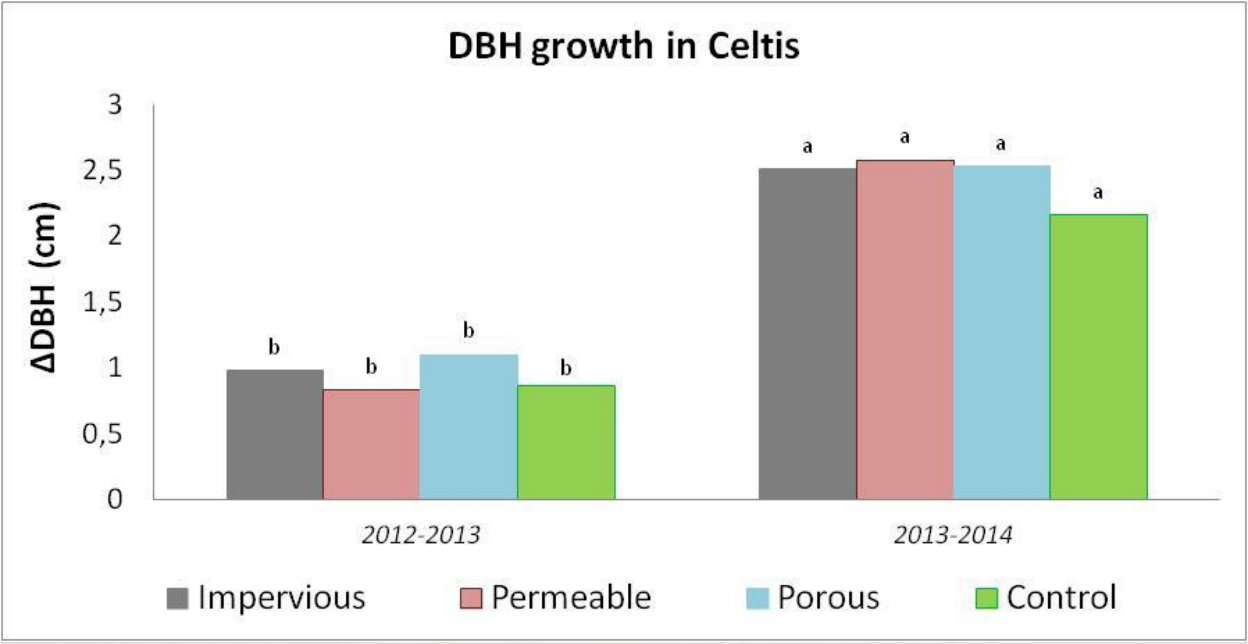
Fv/Fm	Plant health
> 0,80	Healthy
0,70 – 0,80	Slightly stressed
< 0,7	Severely stressed

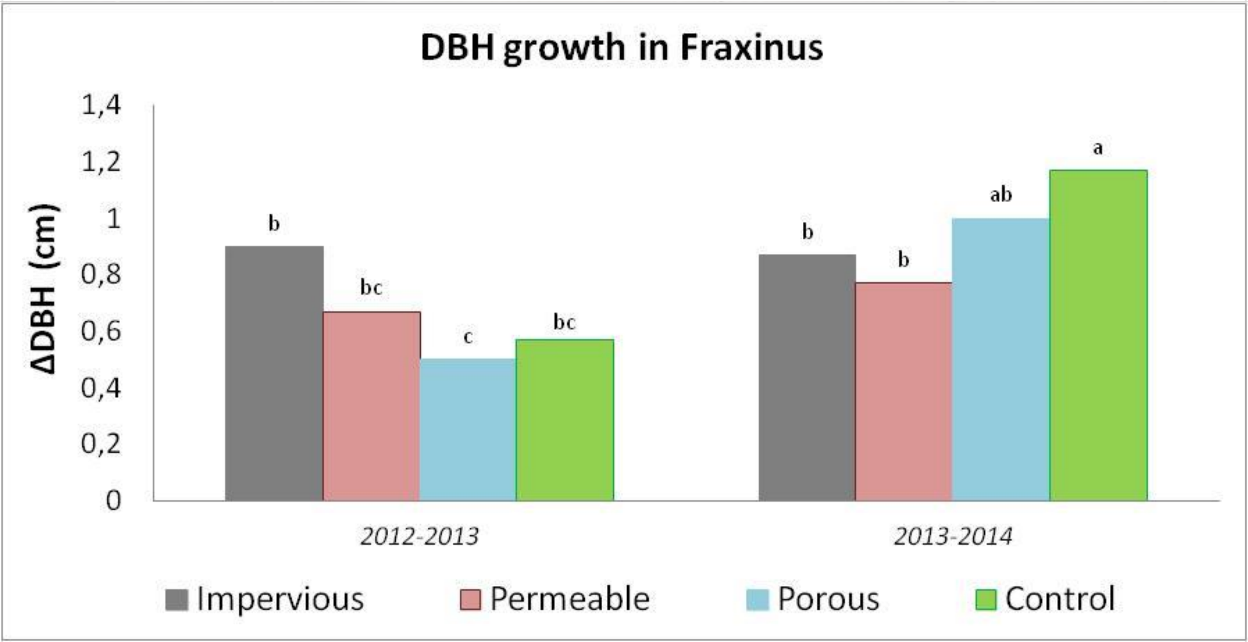

Fv/Fm in *Fraxinus*

$K_{plant} = E/(\Psi_{predawn} - \Psi_{midday})$



Effects on trees - DBH


DBH growth in Celtis


DBH growth in Fraxinus

$P_{pavement}$: n.s.
$P_{species}$: **
P_{pavXsp}: *
P_{time}: **
using repeated measures ANOVA

Conclusions – Effects on establishing trees

- Planting trees in paved soils is essential to maintain evapotranspiration in urban areas

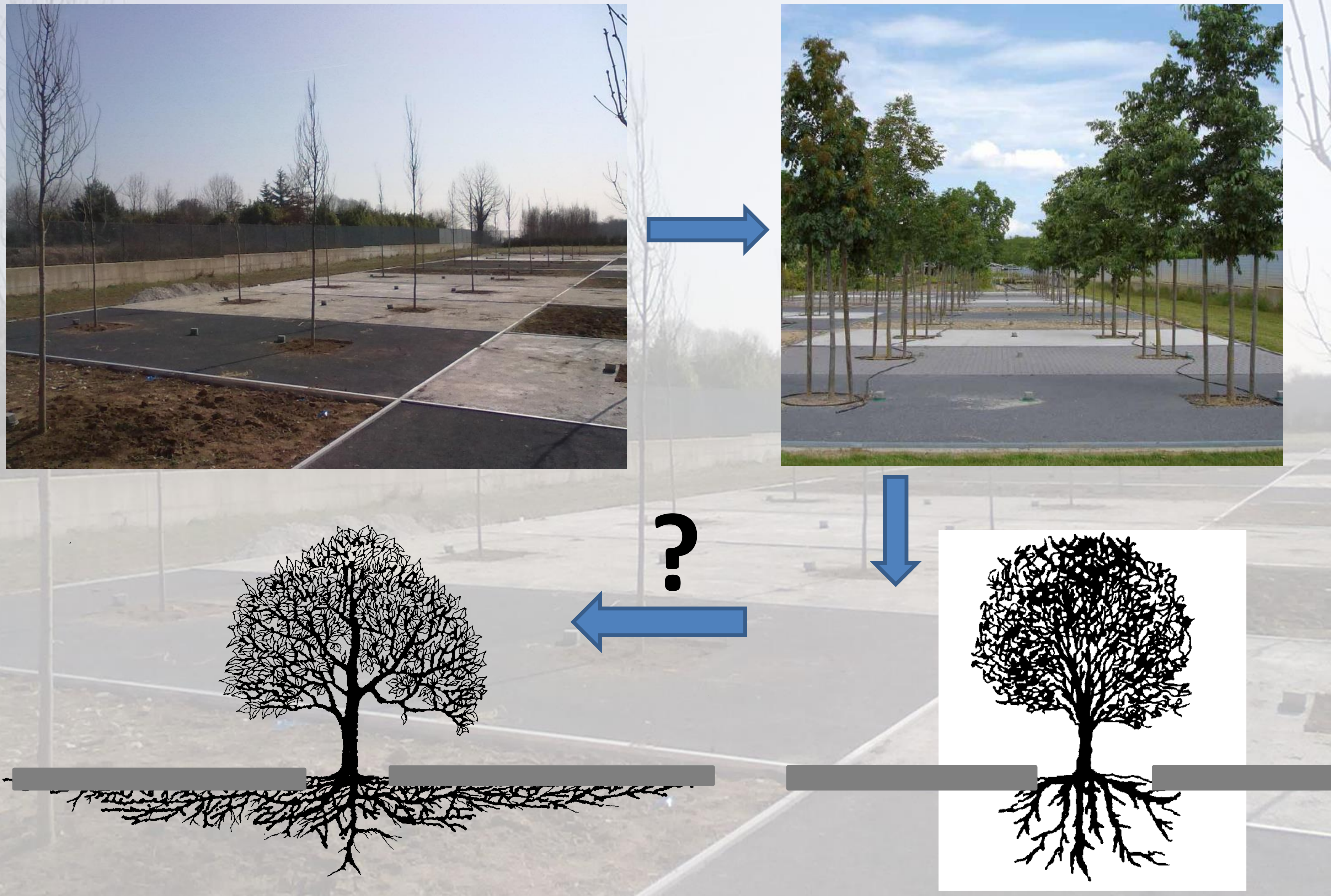
- Pavements had limited effects on growth and physiology of newly planted trees

- *Celtis* is very tolerant to all types of soil cover, during establishment

- *Fraxinus* in impervious pavements displayed some signs of (very mild) stress since the third year from planting

environmental research

Limitations



Future perspectives

TREE FUND
Cultivating Innovation

Jack Kimmel Award: 10000 $
Research Fellowship Grant: 100000 $

The Research Project will continue until 2021 to evaluate the plant – soil – pavement interaction once trees are established:

- Root growth by multiple means (GPR, geoelectric, sismic waves, airspade)

- VOC emission as affected by soil sealing

- Plant physiology and biochemistry, with particular emphasis on root signaling (i.e. ABA) affecting photosynthetic yield

- Long term effects of pavements on soil physical, chemical and biological characteristics

3) Trees and senescence (managing renewal)

People must know the difference between senescent trees and veteran trees

Sustainable management also means, sometimes, renewal

Sometimes it’s hard and painful to take the decision to remove old trees and planting young and healthy ones. If you decide to do so, you are not necessarily….

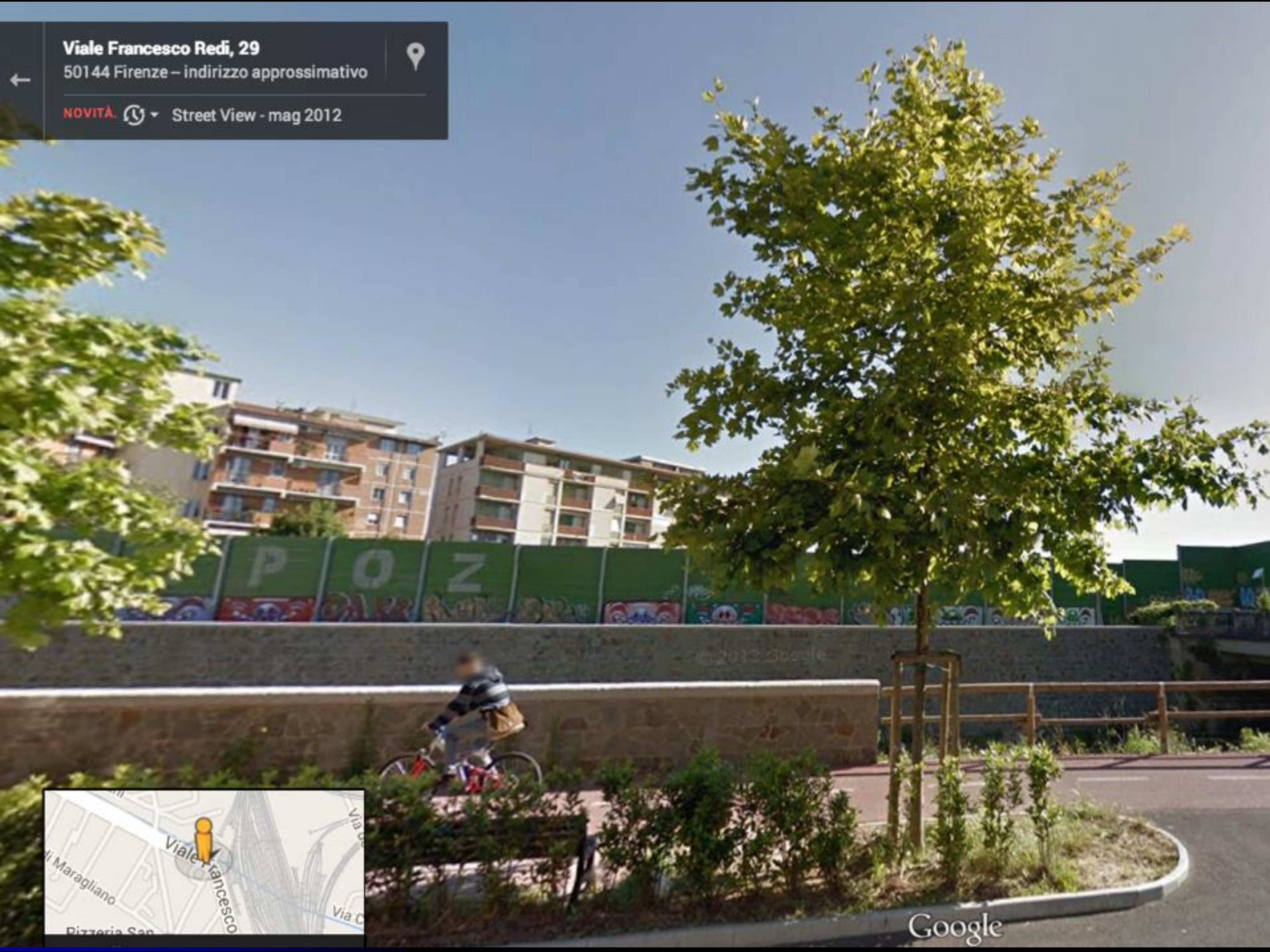
Threk the “Tree Ogre”

But you are doing it for the future generations

FALL 2009

WINTER 2010

SPRING 2010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NOVITÀ.
Street View - mag 2012
POZ
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Viale Francesco
Maragliano
Via C
Pizzeria San
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May 2013

May 2014

May 2015


HOTEL ADA
HOTEL
RISTORANTE
PIZZERIA
HOTEL ADA
HOTEL
RISTORANTE
PIZZERIA

April 2012

April 2017

Green Infrastructures management

Conclusions

Green infrastructures management MUST BE planned in the long term and be very accurate because the "green parts" in the network are not made by spontaneous populations but cultivated plants and, as such, they MUST BE PROPERLY MANAGED

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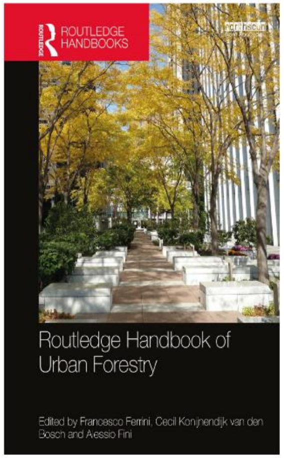
Routledge Handbook of Urban Forestry

Edited by **Francesco Ferrini, Cecil C. Konijnendijk van den Bosch, Alessio Fini**



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eBook: 9781315627106
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More than half the world's population now lives in cities. Creating sustainable, healthy and aesthetic urban environments is therefore a major policy goal and research agenda. This comprehensive handbook provides a global overview of the state of the art and science of urban forestry.

It describes the multiple roles and benefits of urban green areas in general and the specific role of trees, including for issues such as air quality, human well-being and stormwater management. It reviews the various stresses experienced by trees in cities and tolerance mechanisms, as well as cultural techniques for either pre-conditioning or alleviating stress after planting. It sets out sound planning, design, species selection, establishment and management of urban trees. It shows that close interactions with the local urban communities who benefit from trees are key to success.

By drawing upon international state-of-art knowledge on arboriculture and urban forestry, the book provides a definitive overview of the field and is an essential reference text for students, researchers and practitioners.

Editors

Francesco Ferrini is Dean of the School of Agriculture and Professor of Arboriculture at the University of Florence, Italy.

Cecil C. Konijnendijk van den Bosch is Professor of Urban Forestry at the University of British Columbia, Canada.

Alessio Fini is a researcher in the Department of Production and Agri-Environment at the University of Florence, Italy.

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Save the date:

ADVANCED COURSE ON BIOMECHANICS OF THE TREES
Pistoia (ITALY), 5-9 June 2017

Speakers (English with simaltenuous translation in Italian=
All details within mid-february

BARRY GARDINER Emeritus Silviculturist (Research Fellow)
BRUNO MOULIA - Ressearch Director at INRA, 20 years experience in research on Plant Bio-Mechanics and Plant Developmental Biology
DUNCAN SLATER - Lecturer in Arboriculture, Myerscough College, Lancashire and a Chartered Forester.
BRIAN KANE Associate Professor of Commercial Arboriculture at the University of Amherst Massachusetts
FRANK TELEWSKI – Michigan State University
GILMAN, EDWARD F., University of Florida, Gainesville, United States

Topics

The dynamics of wind-tree interactions, mechanosensing, thigmomorphogenesis and wind acclimation, posture control vs gravity and growth (gravisensing, proprioception, mechanics and control of the bending movement, reaction woods.
Anatomy of branch junctions (to include bark-included junctions), Natural bracing in trees, UK arboriculture's assessment and treatment of branch junctions in trees, Thigmomorphogenesis in relation to branch junction and tree form
Basic tree biology- types of wood (juvenile vs mature; normal vs reaction (tension, compression, flexure); early vs latewood; non-porous vs porous; diffuse porous vs ring porous).
Introduction to tree biomechanics and hazard trees. Thigmomorphogenesis: Wind loading in trees, perception and acclimation.
Measuring young tree stability and lodging. Growing high quality root systems.
Can pruning reduce tree damage in storms. Pruning strategies leading to enhanced stability.

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SOI Italian Society of Horticulture
SIA – Società Italiana di Arboricoltura


THAT'S ALL
FOLKS !