Ecosystem services of urban trees: how can planning and management enhance benefits?

Alessio Fini*, Irene Vigevani, Sebastien Comin, Francesco Ferrini, Marco Gibin, Alice Pasquinelli, Piotr Wezyk, Pierangelo Botteghi, Edoardo Cagnolati, Łukasz Mielczarek, Przemysław Szwałko, Osvaldo Failla, Piero Frangi, Paolo Viskanic

*DiSAA – University of Milan, alessio.fini@unimi.it

CICES theme	*CICES class*	*TEEB categories*
Provisioning	• Nutrition	• Food, water
	• Materials	• Raw materials, genetic resources, medicinal resources, ornamental resources
	• Energy	
Regulating and maintenance	• Regulation of waste	• Air purification, waste treatment
	• Flow regulation	• Disturbance prevention, regulation of water flows, erosion prevention
	• Regulation of physical environment	• Climate regulation, maintaining soil fertility
	• Regulation of biotic environment	• Gene pool protection, lifecycle maintenance, pollination, biological control
Cultural	• Symbolic	• Information of cognitive development
	• Intellectual and experiential	• Aesthetic, inspiration for culture, art and design, spiritual experience, recreation and tourism

YOU'RE ONE IN A MILLION

We did it! One million trees for New York City!

The Nature Conservancy's Plant a Billion Trees campaign is a major forest restoration effort with a goal of planting a billion trees across the planet. Trees provide so many benefits to our everyday lives. They filter clean air, provide fresh drinking water, help curb climate change, and create homes for thousands of species of plants and animals. Planting a Billion Trees can help save the Earth from deforestation. It's a big number, but we know we can do it with your help.

3 milioni di alberi entro il 2030.

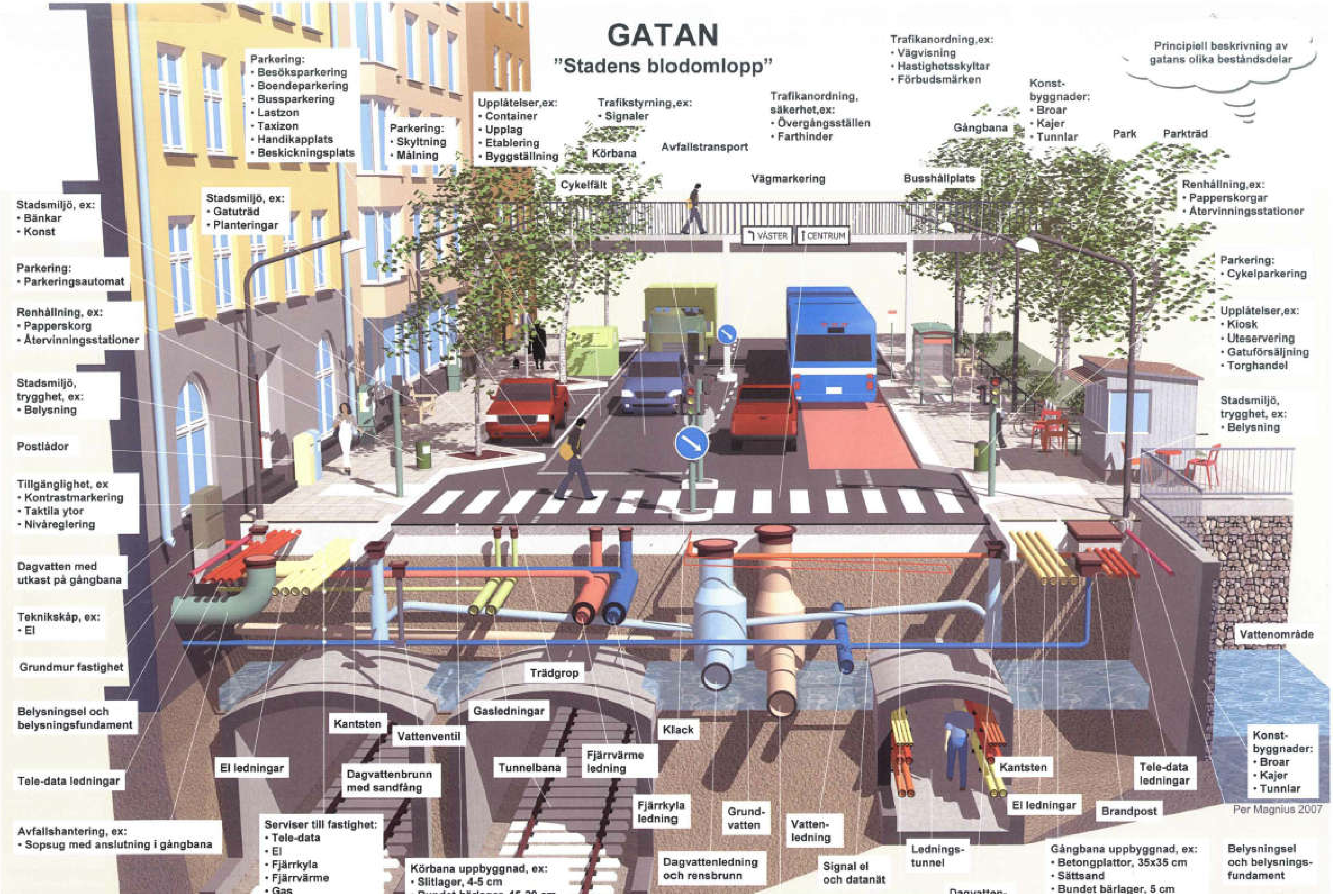
Ad oggi 281.160 piantati

PLANT A BILLION TREES

Forestami è un progetto promosso da Città … di Milano, Comune di Milano, Regione Lombardia … co Nord Milano, Parco Agricolo Sud Milano, ERSAF e Fondazione di Comunità Milano. Nato da una ricerca del Politecnico di Milano grazie al sostegno di Fondazione Falck e FS Sistemi Urbani.

TRILLION TREE CAMPAIGN

PLANT FOR THE PLANET


GATAN
"Stadens blodomlopp"
Principiell beskrivning av gatans olika beståndsdelar
Parkering:
• Besöksparkering
• Boendeparkering
• Bussparkering
• Lastzon
• Taxizon
• Handikapplats
• Beskickningsplats
Parkering:
• Skyltning
• Målning
Upplåtelser,ex:
• Container
• Upplag
• Etablering
• Byggställning
Trafikstyrning,ex:
• Signaler
Körbana
Avfallstransport
Trafikanordning, säkerhet,ex:
• Övergångsställen
• Farthinder
Trafikanordning,ex:
• Vägvisning
• Hastighetsskyltar
• Förbudsmärken
Konst-byggnader:
• Broar
• Kajer
• Tunnlar
Gångbana
Park
Parkträd
Cykelfält
Vägmarkering
Busshållplats
VÄSTER
CENTRUM
Stadsmiljö, ex:
• Bänkar
• Konst
Stadsmiljö, ex:
• Gatuträd
• Planteringar
Parkering:
• Parkeringsautomat
Renhållning, ex:
• Papperskorg
• Återvinningsstationer
Stadsmiljö, trygghet, ex:
• Belysning
Postlådor
Tillgänglighet, ex
• Kontrastmarkering
• Taktila ytor
• Nivåreglering
Dagvatten med utkast på gångbana
Teknikskåp, ex:
• El
Grundmur fastighet
Belysningsel och belysningsfundament
Tele-data ledningar
Avfallshantering, ex:
• Sopsug med anslutning i gångbana
Renhållning,ex:
• Papperskorgar
• Återvinningsstationer
Parkering:
• Cykelparkering
Upplåtelser,ex:
• Kiosk
• Uteservering
• Gatuförsäljning
• Torghandel
Stadsmiljö, trygghet, ex:
• Belysning
Vattenområde
Trädgrop
Gasledningar
Kantsten
Vattenventil
Klack
El ledningar
Dagvattenbrunn med sandfång
Tunnelbana
Fjärrvärme ledning
Fjärrkyla ledning
Grund-vatten
Vatten-ledning
Kantsten
El ledningar
Tele-data ledningar
Brandpost
Konst-byggnader:
• Broar
• Kajer
• Tunnlar
Per Magnius 2007
Serviser till fastighet:
• Tele-data
• El
• Fjärrkyla
• Fjärrvärme
• Gas
Körbana uppbyggnad, ex:
• Slitlager, 4-5 cm
Dagvattenledning och rensbrunn
Signal el och datanät
Lednings-tunnel
Gångbana uppbyggnad, ex:
• Betongplattor, 35x35 cm
• Sättsand
• Bundet bärlager, 5 cm
Belysningsel och belysnings-fundament

Tolerant to what?

ABIOTIC stress factors

Soil Compaction
<u>Drought</u>
Salinity
Waterlogging
Low soil quality
High/low light
Temperature

BIOTIC stress factors

Insects
Fungi
Phytoplasms
Virus
Bacteria

Stress due to HUMAN ACTIVITIES

Transplant
Improper pruning
Construction activities
Soil sealing

It is known that the ability to withstand drought differs among genera

Quercus, a genus whose species native from Europe are extremely tolerant to drought

Liquidambar, a genus known to poorly tolerate drought

Differences exist within species of the same genus or cv of the same species

Arboriculture & Urban Forestry 35(5): September 2009 241

ISA

Arboriculture & Urban Forestry 2009. 35(5): 241–251

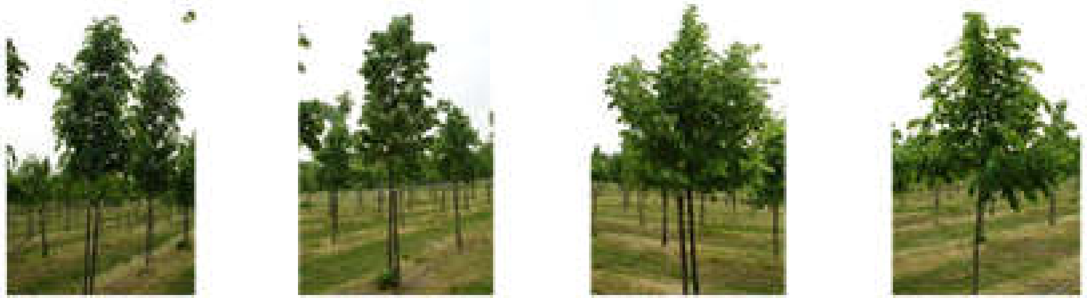
ARBORICULTURE & URBAN FORESTRY

Withholding Irrigation During the Establishment Phase Affected Growth and Physiology of Norway Maple (*Acer platanoides*) and Linden (*Tilia* spp.)

Alessio Fini, Francesco Ferrini, Piero Frangi, Gabriele Amoroso, and Riccardo Piatti

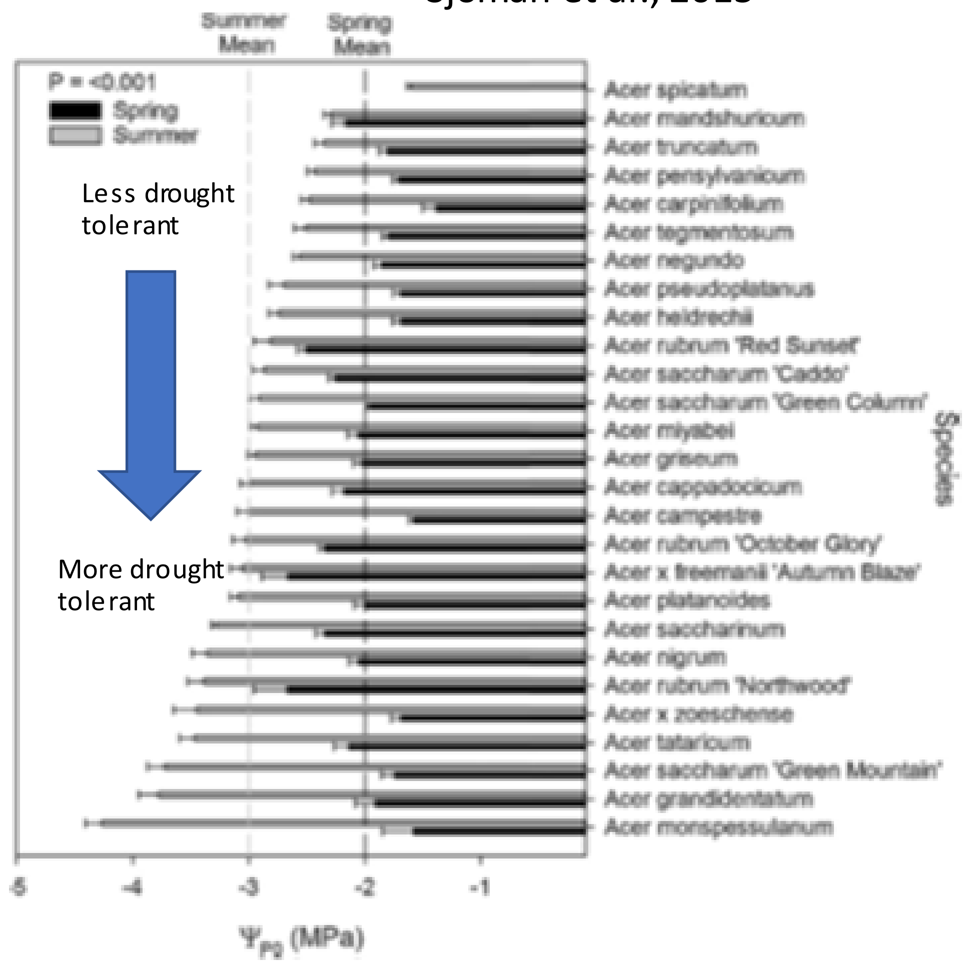
A. platanoides 'Emerald Queen' ≥ A. 'Deborah' > A. 'Summershade'

More drought tolerant ← Less drought tolerant

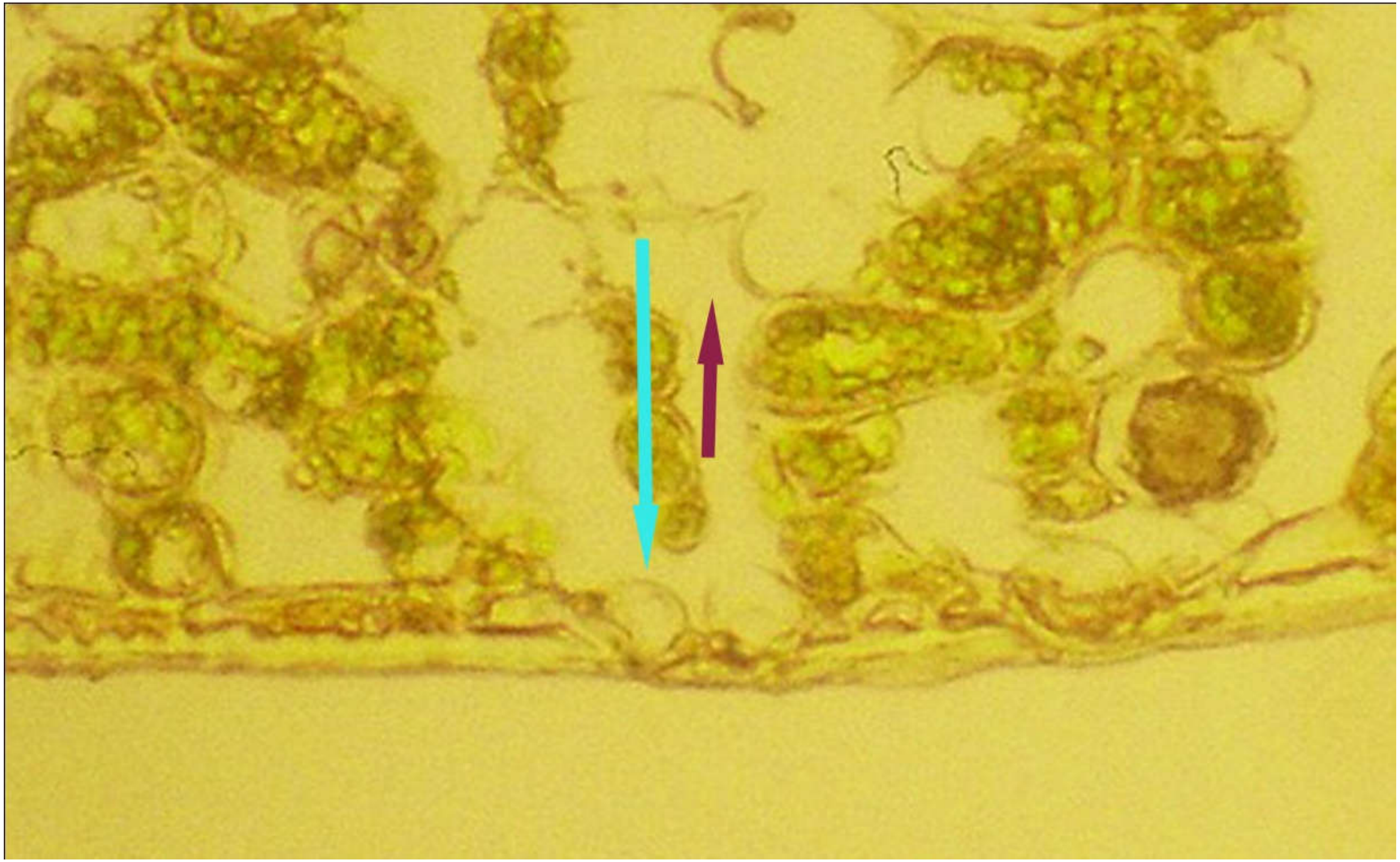


Tilia cordata = *T. tomentosa* > *T. x europaea* > *T. platyphyllos*

Sjoman et al., 2015



Stomata are the pressure regulators in plants.
Changes in stomatal opening allow to save water, but restrict CO_2 influx




Thirst or starvation?
gettyimages
Stephen D Harper
171294245

Anisohydric species

Case study:
Fraxinus ornus L.

...and several Oleaceae species..

Journal of Plant Physiology 169 (2012) 929–939

Contents lists available at SciVerse ScienceDirect

Journal of Plant Physiology

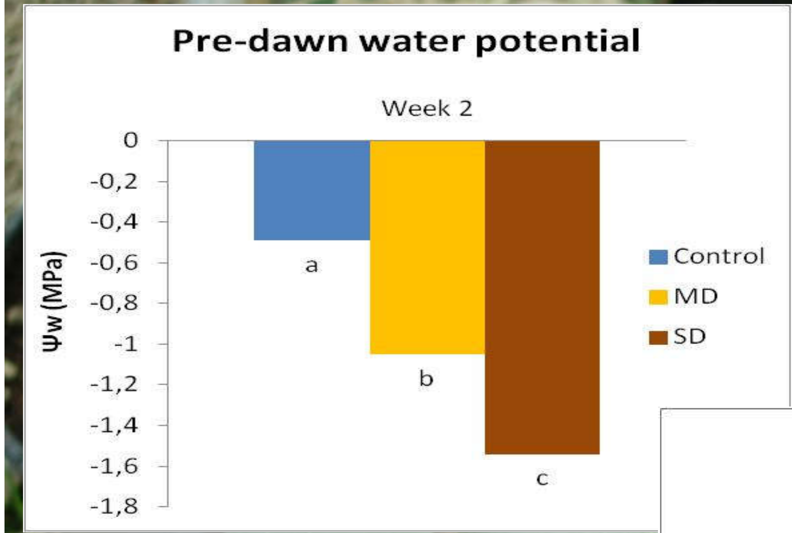
journal homepage: www.elsevier.de/jplph

Drought stress has contrasting effects on antioxidant enzymes activity and phenylpropanoid biosynthesis in *Fraxinus ornus* leaves: An excess light stress affair?

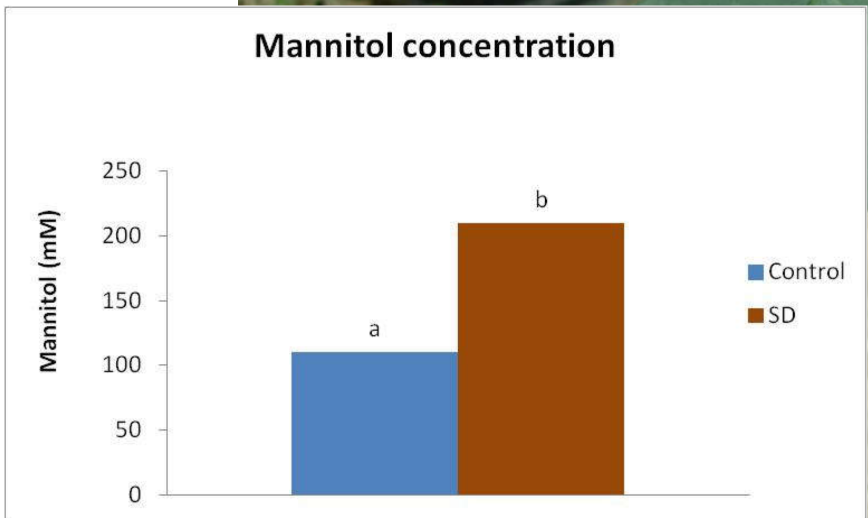
Alessio Fini[a], Lucia Guidi[b], Francesco Ferrini[a], Cecilia Brunetti[a], Martina Di Ferdinando[a], Stefano Biricolti[a], Susanna Pollastri[a], Luca Calamai[a], Massimiliano Tattini[c,*]

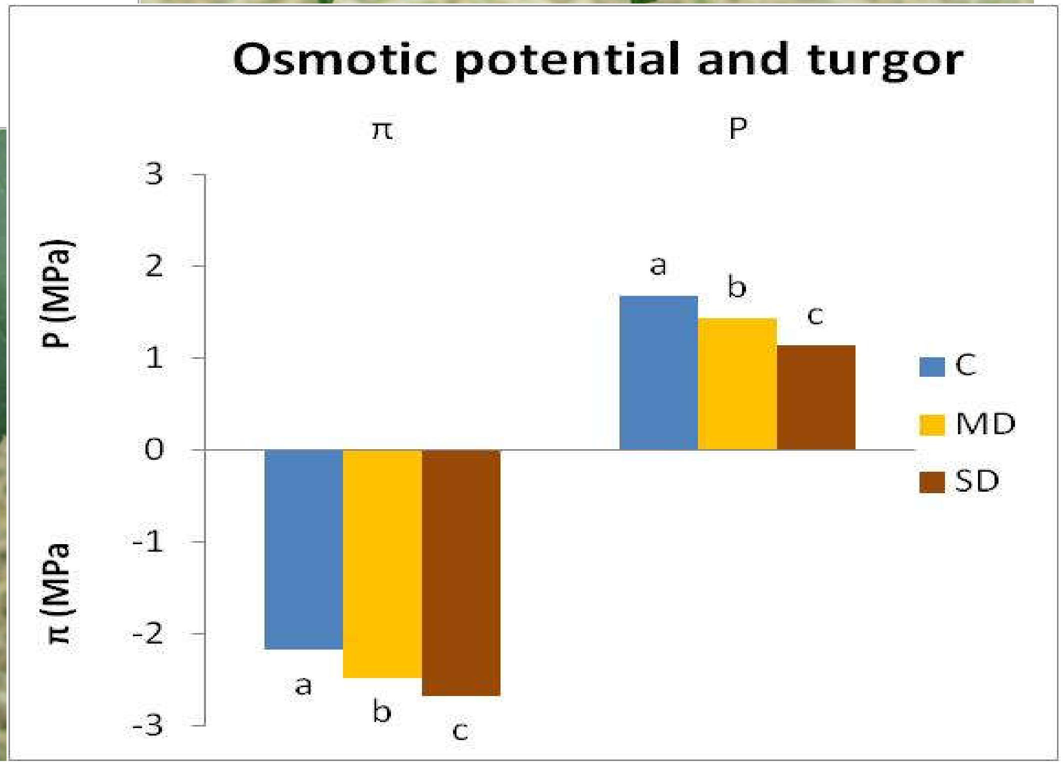
[a] Dipartimento di Scienze delle Produzioni Vegetali, del Suolo e dell'Ambiente Agroforestale, Università di Firenze, Viale delle Idee 30, I-50019, Sesto Fiorentino, Firenze, Italy
[b] Dipartimento di Biologia delle Piante Agrarie, Università di Pisa, Via del Borghetto 80, I-56124 Pisa, Italy

Water relations after 2 weeks of drought

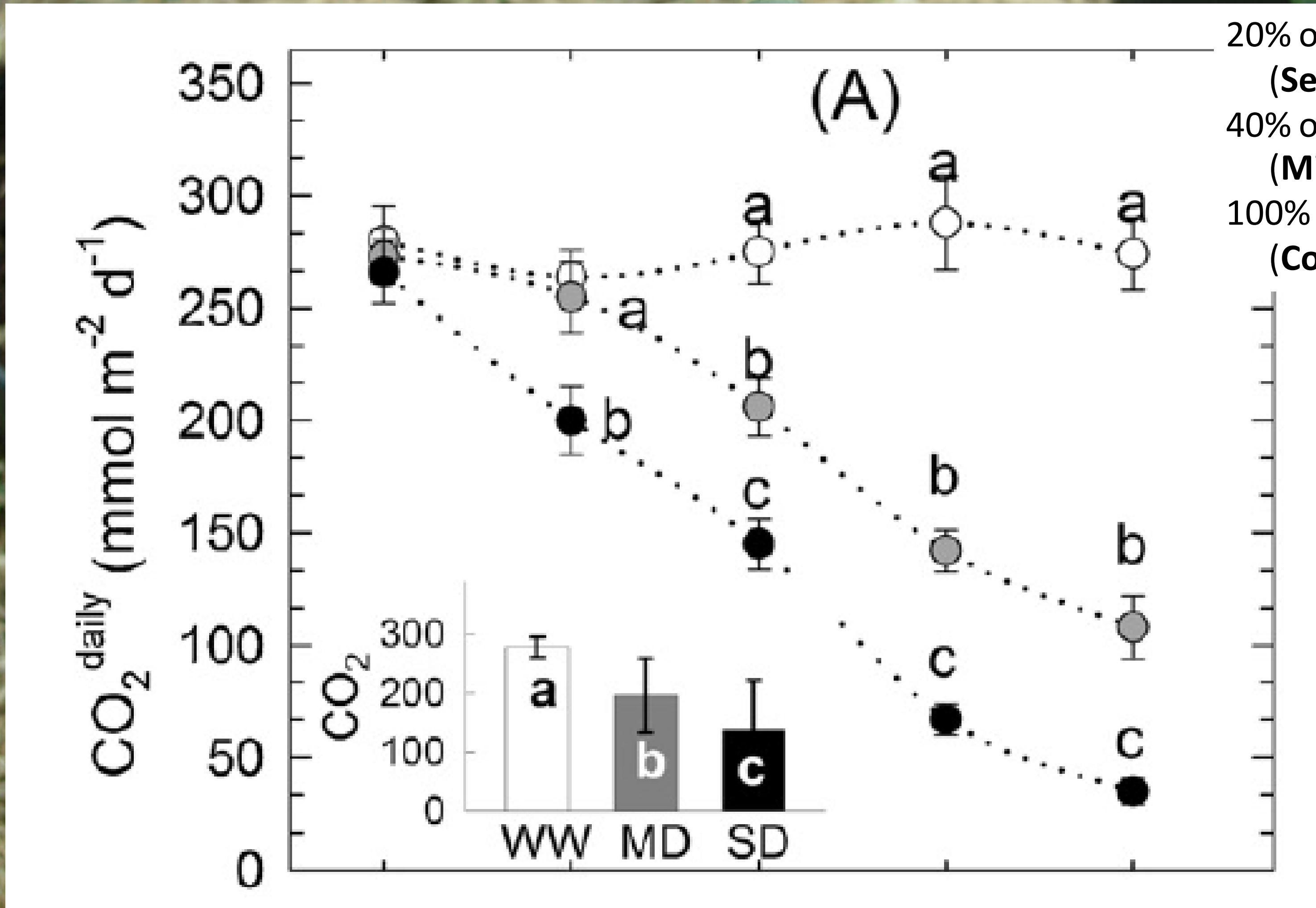


20% of daily ETP
(**Severe drought - SD**)
40% of daily ETP
(**Mild drought - MD**)
100% of daily ETP
(**Control - C**)





Photosynthesis after 2 weeks of drought



20% of daily ETP
(**Severe drought - SD**)
40% of daily ETP
(**Mild drought - MD**)
100% of daily ETP
(**Control - C**)

Fini et al., 2012, J. Plant Physiol.

Isohydric species

Case study
Platanus x acerifolia

New Phytologist

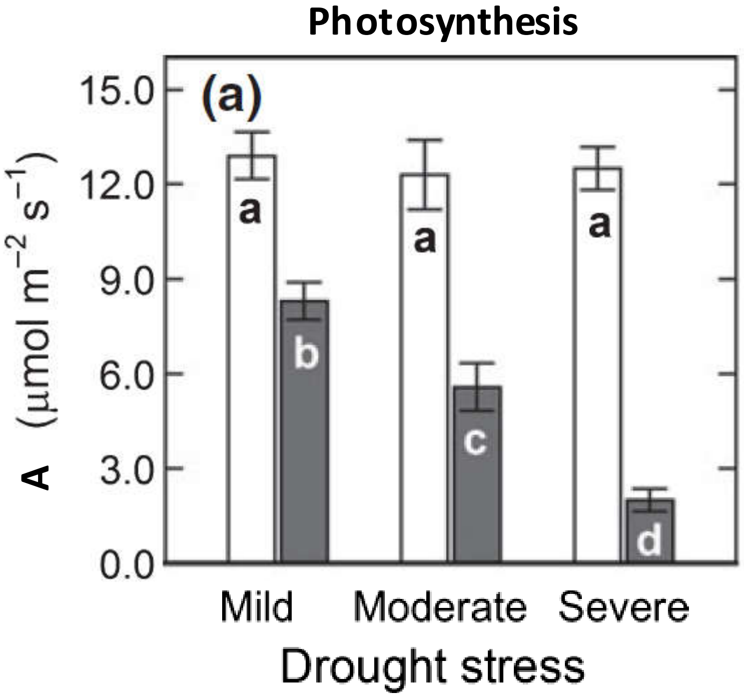
Research

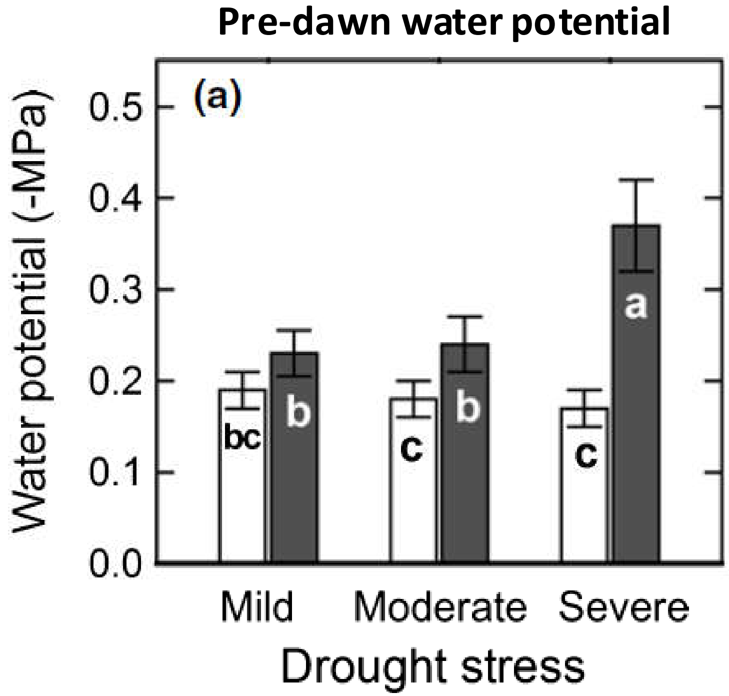
Isoprenoids and phenylpropanoids are part of the antioxidant defense orchestrated daily by drought-stressed *Platanus × acerifolia* plants during Mediterranean summers

Massimiliano Tattini[1], Francesco Loreto[2], Alessio Fini[3], Lucia Guidi[4], Cecilia Brunetti[1,5], Violeta Velikova[6], Antonella Gori[1,5] and Francesco Ferrini[3]

[1]Department of Biology, Agriculture and Food Sciences, The National Research Council of Italy (CNR), Institute for Sustainable Plant Protection, I-50019 Sesto Fiorentino (Florence), Italy; [2]Department of Biology, Agriculture and Food Sciences, The National Research Council of Italy (CNR), I-00185, Rome, Italy; [3]Department of Plant, Soil and Environmental Sciences, University of Florence, I-50019 Sesto Fiorentino (Florence), Italy; [4]Department of Agriculture, Food and Environment, University of Pisa, I-56124 Pisa, Italy; [5]Department of Biology, Agriculture and Food Sciences, The National Research Council of Italy (CNR), Trees and Timber Institute, I-50019 Sesto Fiorentino (Florence), Italy; [6]Department of Biodiversity and Molecular Ecology, Research and Innovation Centre, Fondazione Edmund Mach, S. Michele all'Adige (Trento), Italy

Platanus x acerifolia: A and ψw





Empty bars = Control
Filled bars = WS

Tattini et al., 2015, New Phytol.

Conclusion: practical implications

Knowing the strategy gives planners the opportunity to design a planting site to boost plant performance and benefits

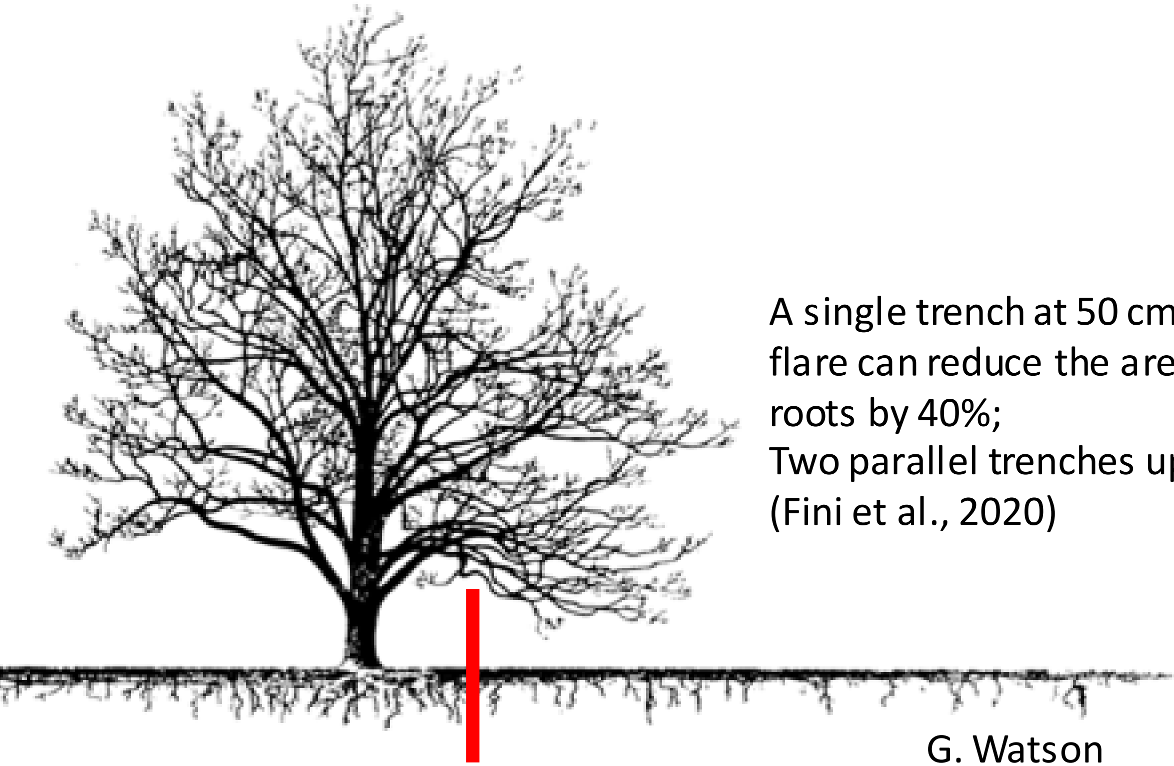
Anisohydric	Isohydric water saving
Better tolerate drought in the sun	Better tolerate drought in shady environments
Nursery hardening	Nursery hardening doesn't work well
Use where drought is short but frequent	Use where drought is prolonged and infrequent
Use in mildly but chronically drought stressed sites	Rely on shallow water: leave large planting pits unpaved

Stress related to human activities:

1- root severance

Root severance and construction damage

- If allowed to grow unrestricted, root can spread 1.4 - 4.4 times (average 2.9) beyond the dripline, depending on tree species (Gilman, 1988)
- Roots are shallow: up to 90% of the root system usually grows in the upper 70 cm of soil (Watson, 2003; Gerhold and Johnson, 2003)
- Root system characteristics are rarely considered during trenching or construction activities



A single trench at 50 cm from the flare can reduce the area of the roots by 40%;
Two parallel trenches up to 70% (Fini et al., 2020)

G. Watson

Root severance experiment

Control - **C**

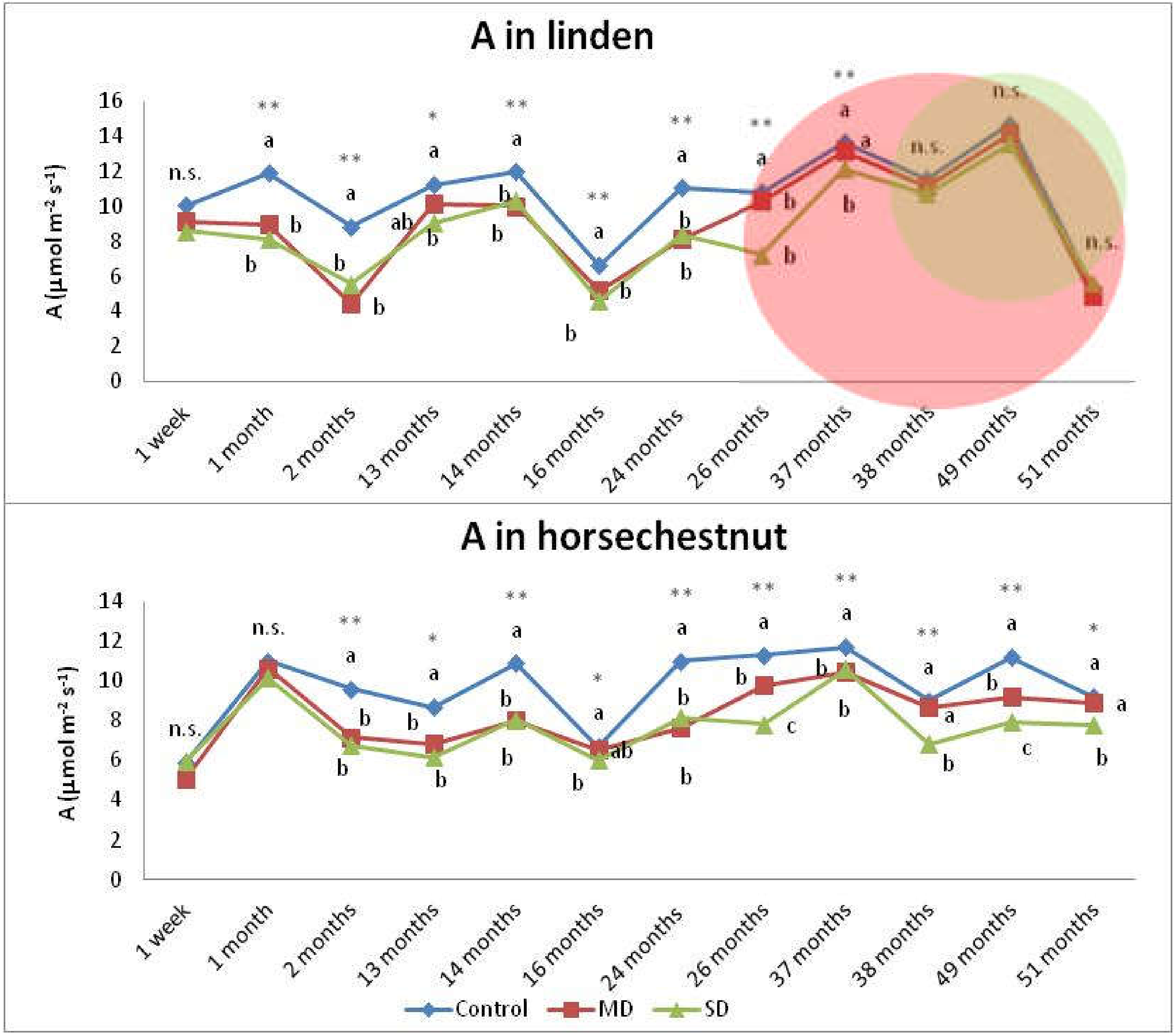
Trenching on 1 side of the tree - **MD**

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

Species: *Aesculus* and *Tilia*, planted in 2004; excavated in 2009

Site: Vertemate con Minoprio (CO, Italy)

Aim: assess the effects of root severance on physiology and uprooting resistance over 51 months



CO_2 assimilation (A) is the amount of CO_2 assimilated from 1 m^2 of leaf area per unit time

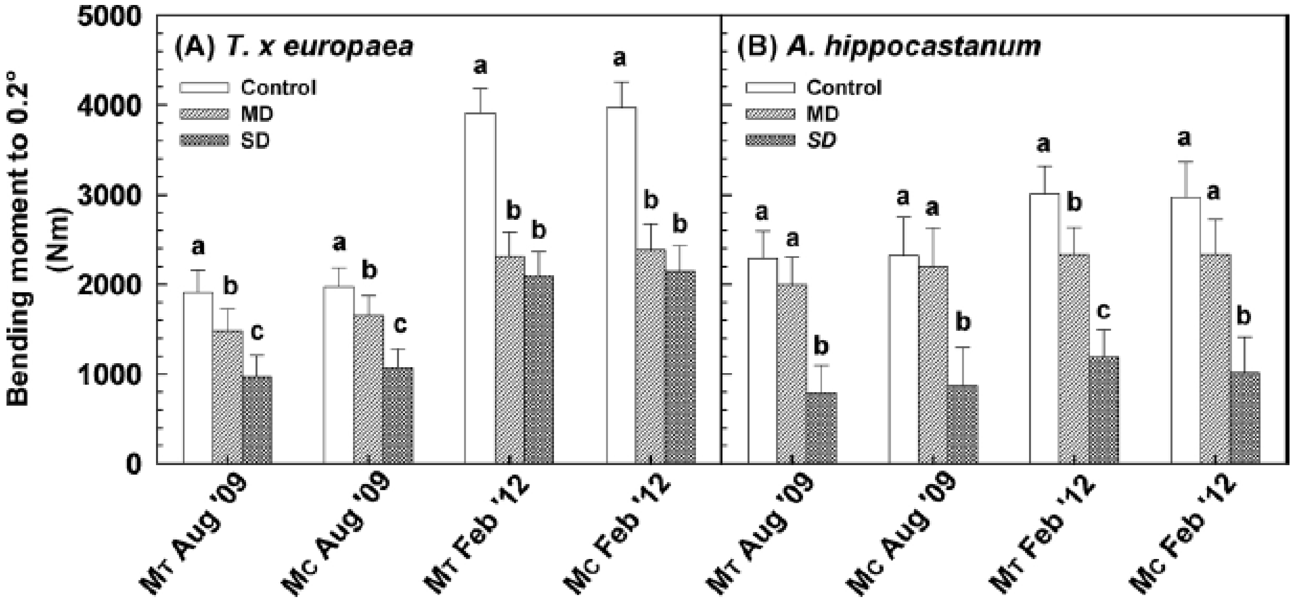
A recovered after 26 and 38 months in MD and SD Tilia, respectively

A did not recove in Aesculus

Leaf predawn water potential displayed a similar pattern (data not shown)

None of severed treatments could recover the root system area and the root system to stem cross sectional area ratio (Fini et al., 2020)

Trees were pulled 2 and 44 months after the excavation and the moment required to bend the root flare by 0,20° was calculated using Orebla



Resistance to uprooting declined after severance and did not recover by the end of the project

Conclusions

- Root damage acts as a predisposing, rather than inciting, stress factor.

- It may not cause visible consequences to trees for years, while chronically affecting plant physiology, as well as capacity of the tree itself to stand.

- Little resilience by urban trees to root severance may explain why after several years of
lack of visible symptoms, trees may suddenly decline, as soon as environmental conditions turn unfavorable.

- Species with larger root area supplying the unit of stem cross sectional area, such as Tilia, showed a faster recovery than species with small root area per unit stem cross sectional area, such as Aesculus,
which was not able to recover by the end of the experiment.

Urban Forestry & Urban Greening 53 (2020) 126734

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

ELSEVIER

Evaluating the effects of trenching on growth, physiology and uprooting resistance of two urban tree species over 51-months

Alessio Fini[a,*], Piero Frangi[b], Jacopo Mori[c], Luigi Sani[d], Irene Vigevani[a], Francesco Ferrini[c]

How to avoid damage to trees: the protected root zone

Species tolerance	Age	Distance from trunk (m cm⁻¹ stem diameter)
Good	Young	0.06
	Mature	0.09
	Senescent	0.12
Moderate	Young	0.09
	Mature	0.12
	Senescent	0.15
Low	Young	0.12
	Mature	0.15
	Senescent	0.18

Matheny, 2005

Stress related to human activities: 2- soil sealing

In 2011, an experimental field with 24 plots was built

$50\ m^2$ plot (5x10 m)

Barriers buried down to 70 cm to separate plots

Cilinders for soil respiration measurement

1 m2 unpaved planting pit

Gravel sub-grade in the "permeable" and "porous" treatments

Concrete sub-grade in the "impermeable" treatment

Four soil treatments were imposed, with 6 replicates each arranged according to a randomized complete block design. Pavement thickness was about 15 cm in all pavements

Impermeable design: asphalt on a concrete sub-grade

Permeable desing: curb on a crushed rock sub-grade

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

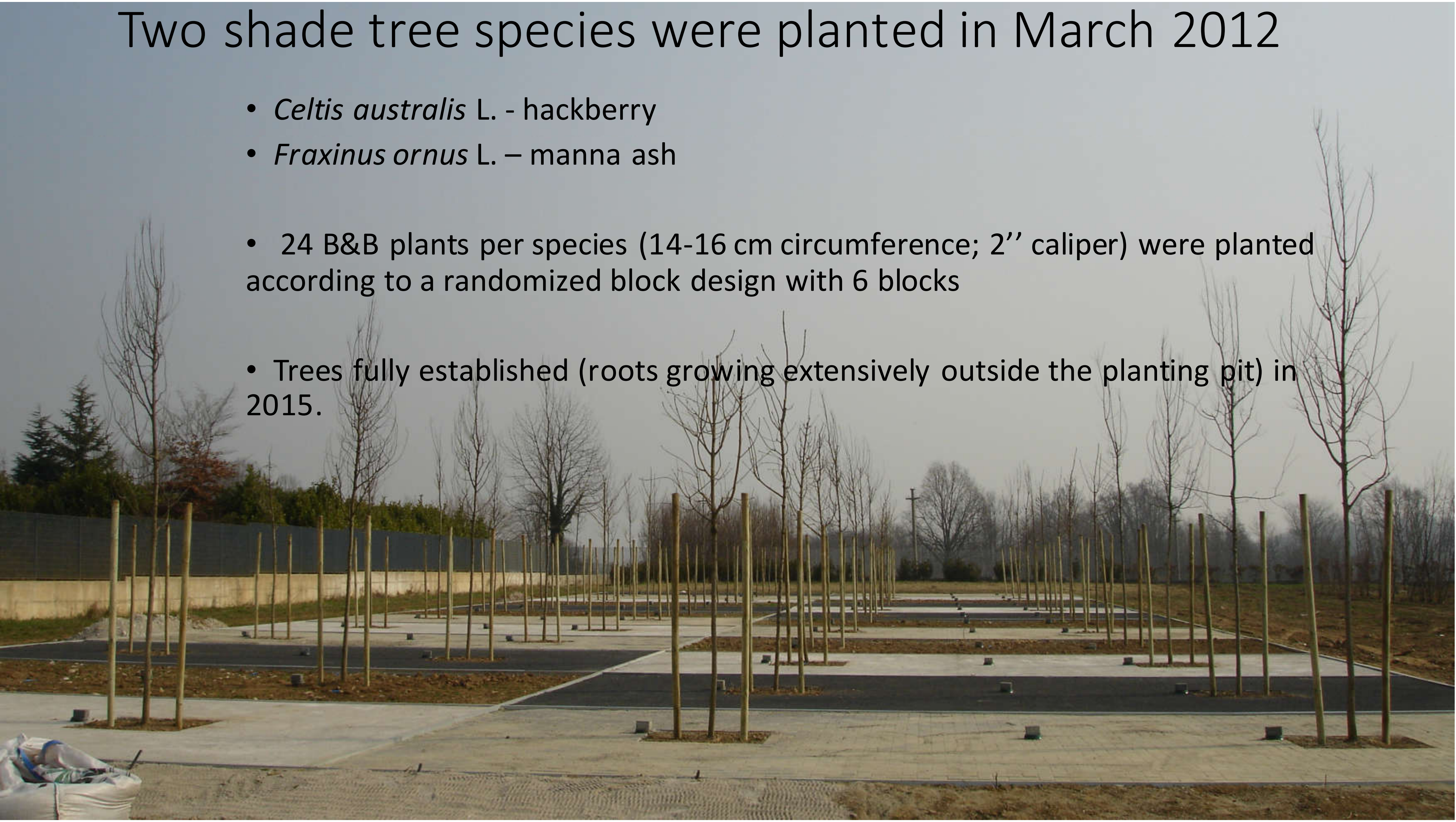
Control: unpaved soil (chemical weeding used for weed control)

Two shade tree species were planted in March 2012

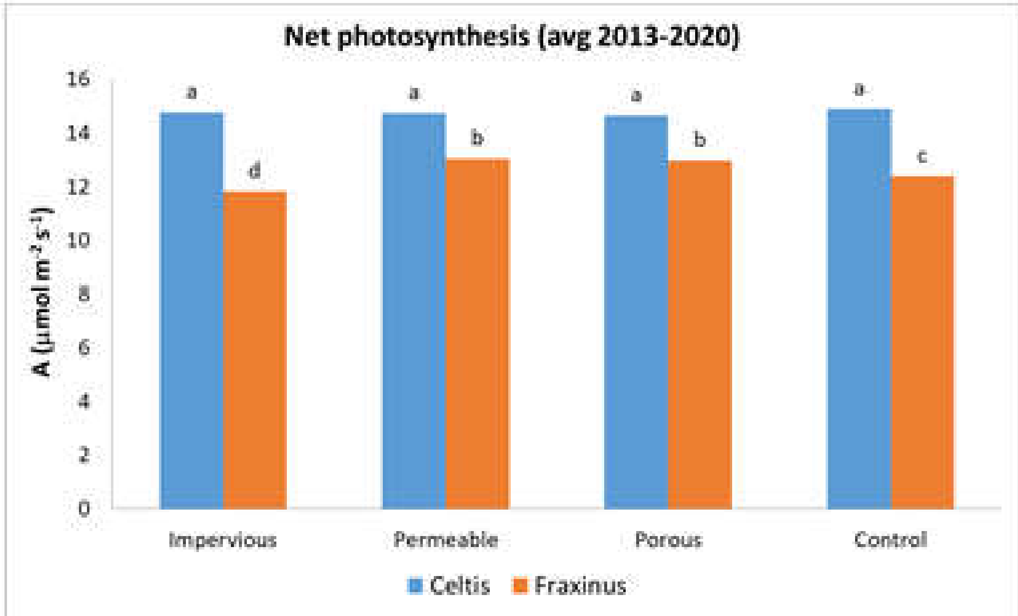
- *Celtis australis* L. - hackberry
- *Fraxinus ornus* L. – manna ash

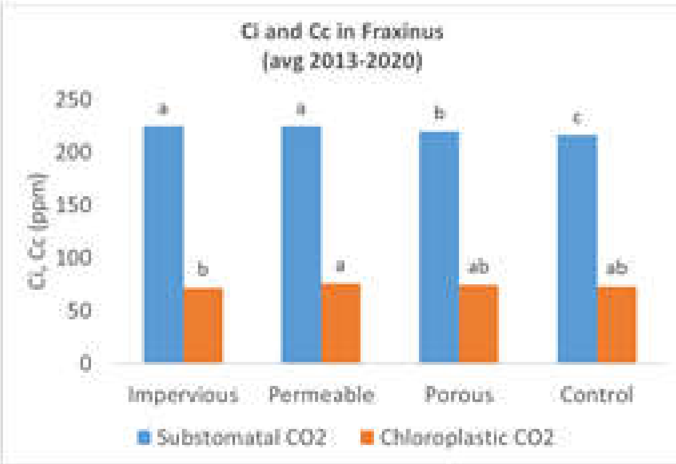
- 24 B&B plants per species (14-16 cm circumference; 2’’ caliper) were planted according to a randomized block design with 6 blocks

- Trees fully established (roots growing extensively outside the planting pit) in 2015.

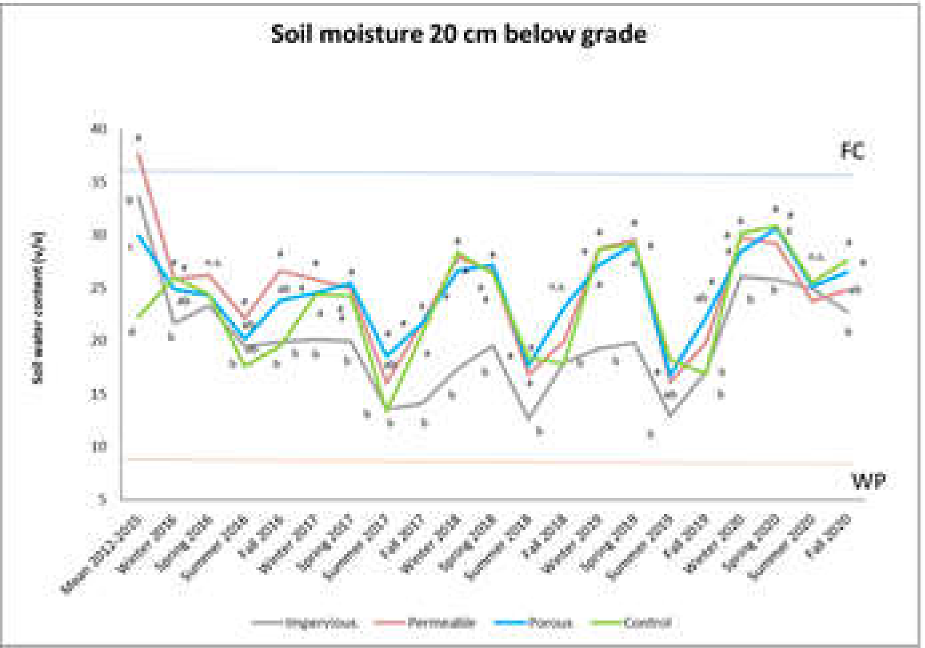


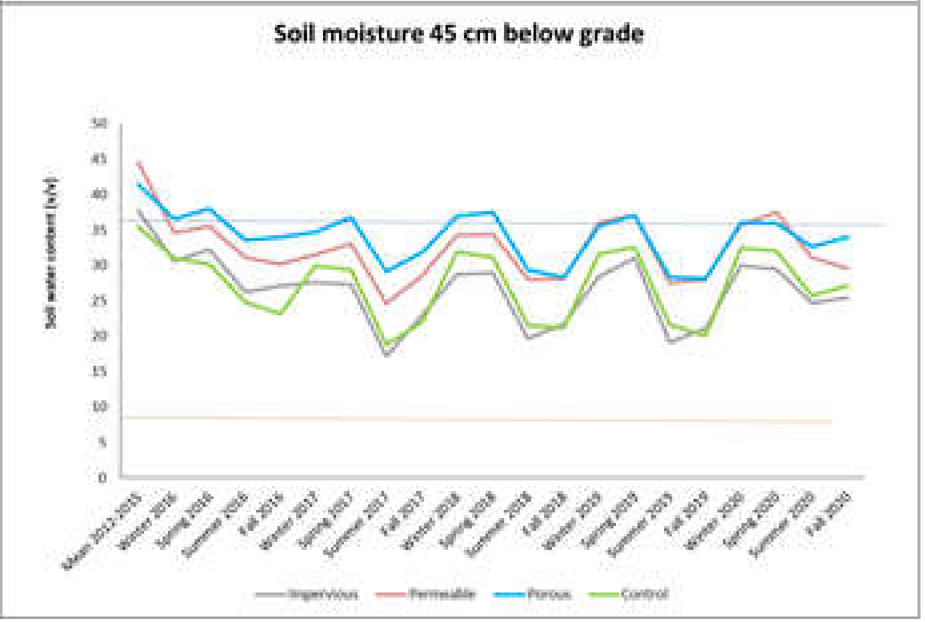
Leaf gas exchange and plant conductivities – 2013 to 2020



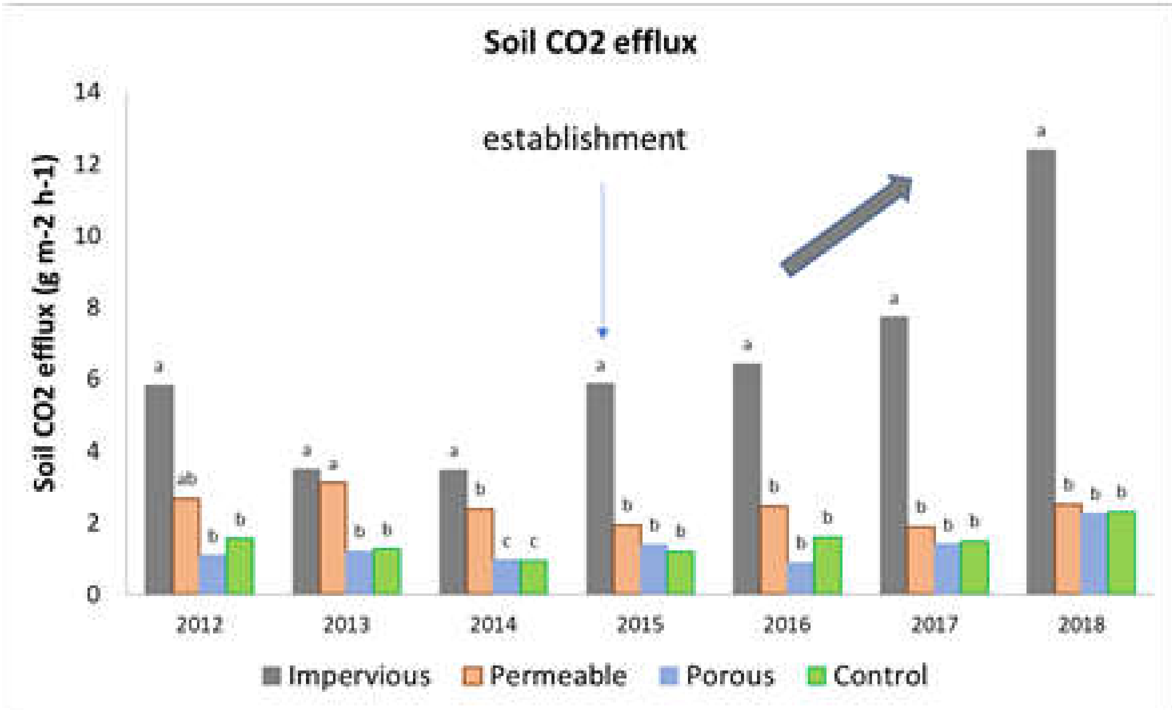


- Average of about 3000 leaves measured since 2013 and 2020
- Pavement treatments did not affect above-ground growth and leaf gas exchange in *Celtis.*
- Impermeable pavements did not affect growth, but slightly reduced A in *Fraxinus*, compared to control, whereas permeable and porous ashes had higher A than control.
- Changes in mesophyll conductance to CO2 diffusion were responsible of the reduction in A.





2012-2015: before establishment
2016-2019: after establishment



Elevated soil CO2, rather than low O2 or moisture availability, was found below asphalt, compared to other treatments

Pavement	DWfine/DWcoarse
Impermeable	0,03 c
Permeable	0,05 bc
Porous	0,12 a
Control	0,08 b

Conclusions

- Nine years of measurement revealed that, despite large changes in soil physical trait which induced changes in root morphology, the effects on tree physiology were small and species-specific
- From the tree's perspective, a high-quality soil matters much more than a pavement, but..
- Above ground tree growth is little affected by pavements

Some tree species, such Celtis, are extremely plastic, the urban environment is much less..


Environmental Research 156 (2017) 443–454

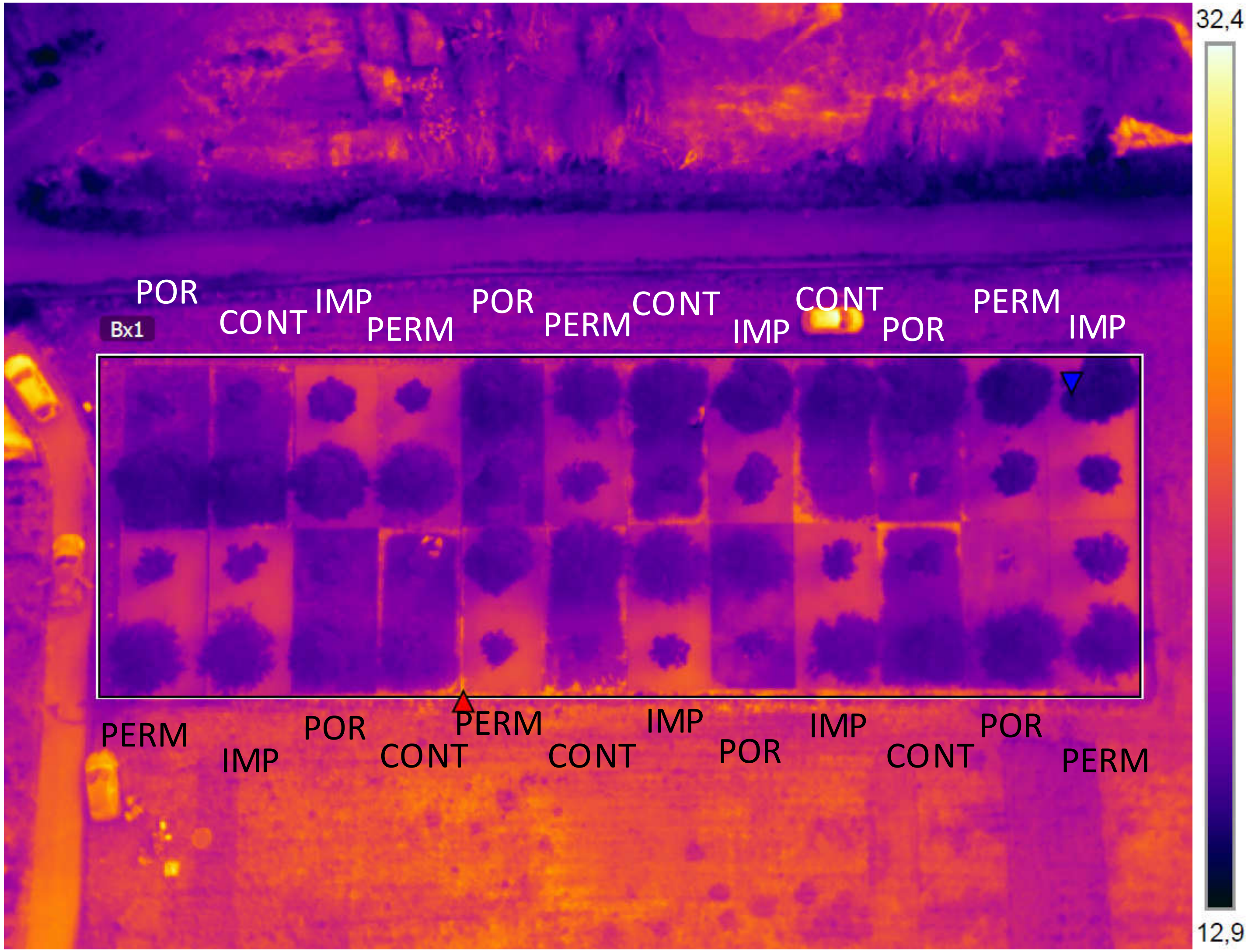
Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Nature based solutions to mitigate soil sealing in urban areas: Results from a 4-year study comparing permeable, porous, and impermeable pavements

A. Fini[a,e,*], P. Frangi[b], J. Mori[a], D. Donzelli[c], F. Ferrini[a,d]



False color thermal picture of the field, done using a drone in summer 2018

Impermeable and permeable pavements can trigger the UHI

This is due to lower evaporation from soil covered with asphalt or interlocking curb compared to control and porous pavements.

Porous pavements are effective in mitigating the UHI

Trees are even more effective

↓

ECOSYSTEM SERVICES

LIFE URBANGREEN

LIFE URBANGREEN (2018-2022)

2 municipalities: Rimini (Cfa) and Krakow (Dfb)

10 woody species

Goals: 1- measure some ecosystem services by urban trees;
2- investigate the effects of maintenance on ecosystem services (ongoing)

Methods

10 species per city (9 broadleaves, 1 evergreen)

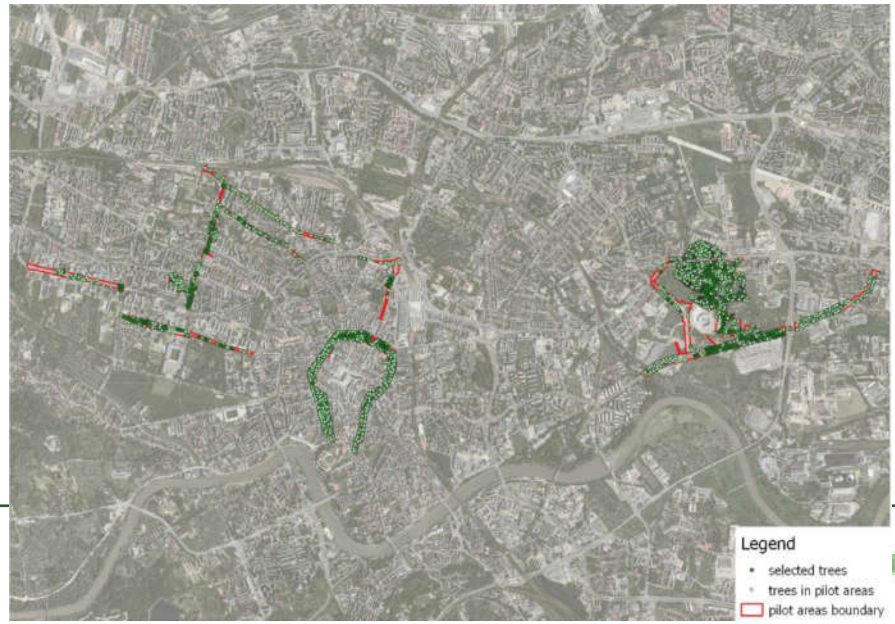
2 strata (paved and unpaved sites)

12 replicates

Rimini	Krakow
Quercus robur	***Quercus robur***
Platanus x acerifolia	*Fraxinus excelsior*
Populus nigra	***Populus nigra***
Quercus ilex	*Ulmus laevis*
Pinus pinea	*Pinus nigra*
Tilia x europaea	*Tilia cordata*
Aesculus hippocastanum	***Aesculus hippocastanum***
Acer negundo	*Acer platanoides*
Ligustrum lucidum	*Sorbus aucuparia*
Prunus laurocerasus	*Cornus alba*

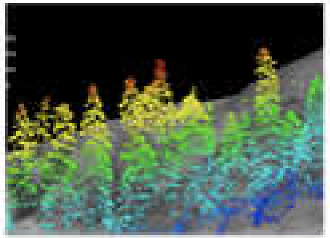
Rimini
250 ha

Krakow
480 ha



Integration of physiological and dendrometric data for the measurement of ES

- Lidar scanning and field measurements are ongoing for determining dendrometric traits and leaf area.
- Two-week measurement campaigns have been conducted in the two cities in spring, summer, and fall.
- Physiological traits directly inducing a benefit were measured on over 2000 leaves from 2018 to 2020:

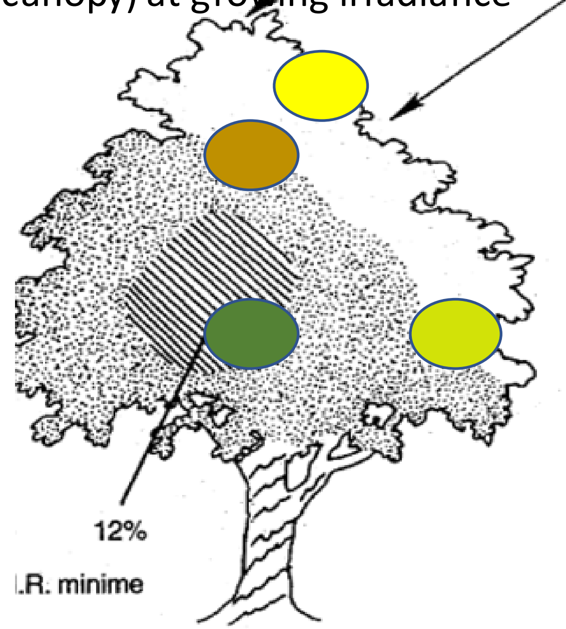


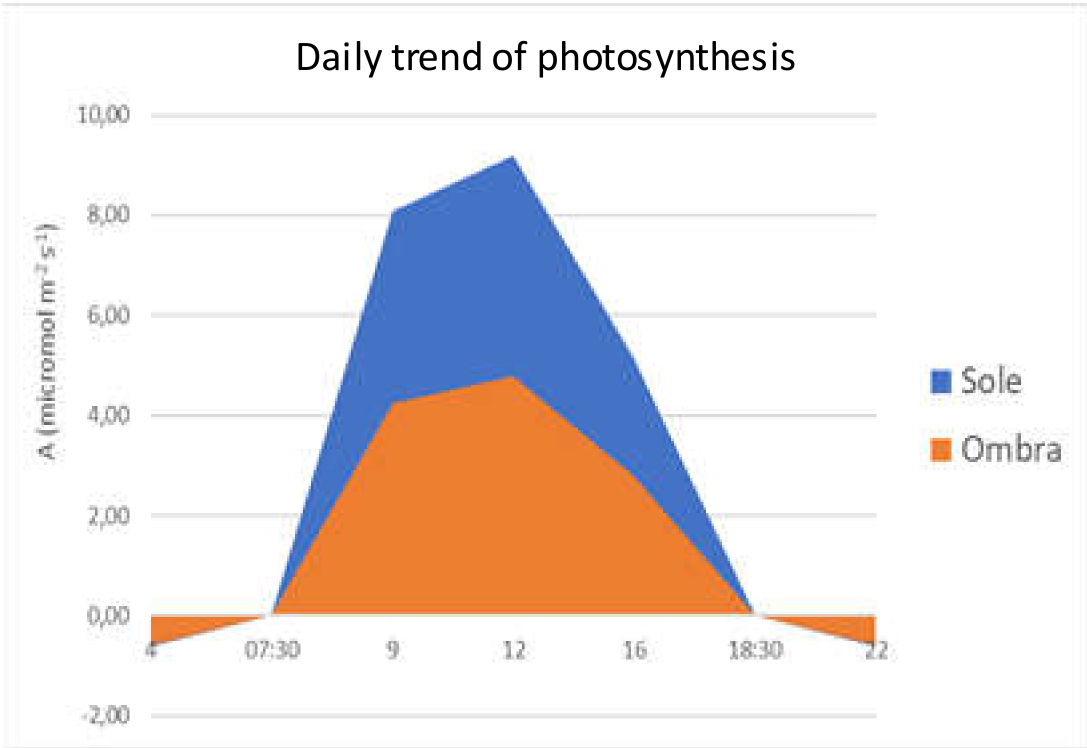
- Assimilation CO_2
- Adsorption of PM
- Microclimate improvement by transpiration

CO2 assimilation and transpiration

A real canopy model: representative plants, selected after assessing instantaneous rates of CO2 assimilation and transpiration, were used for daily measurements of leaf gas exchange.

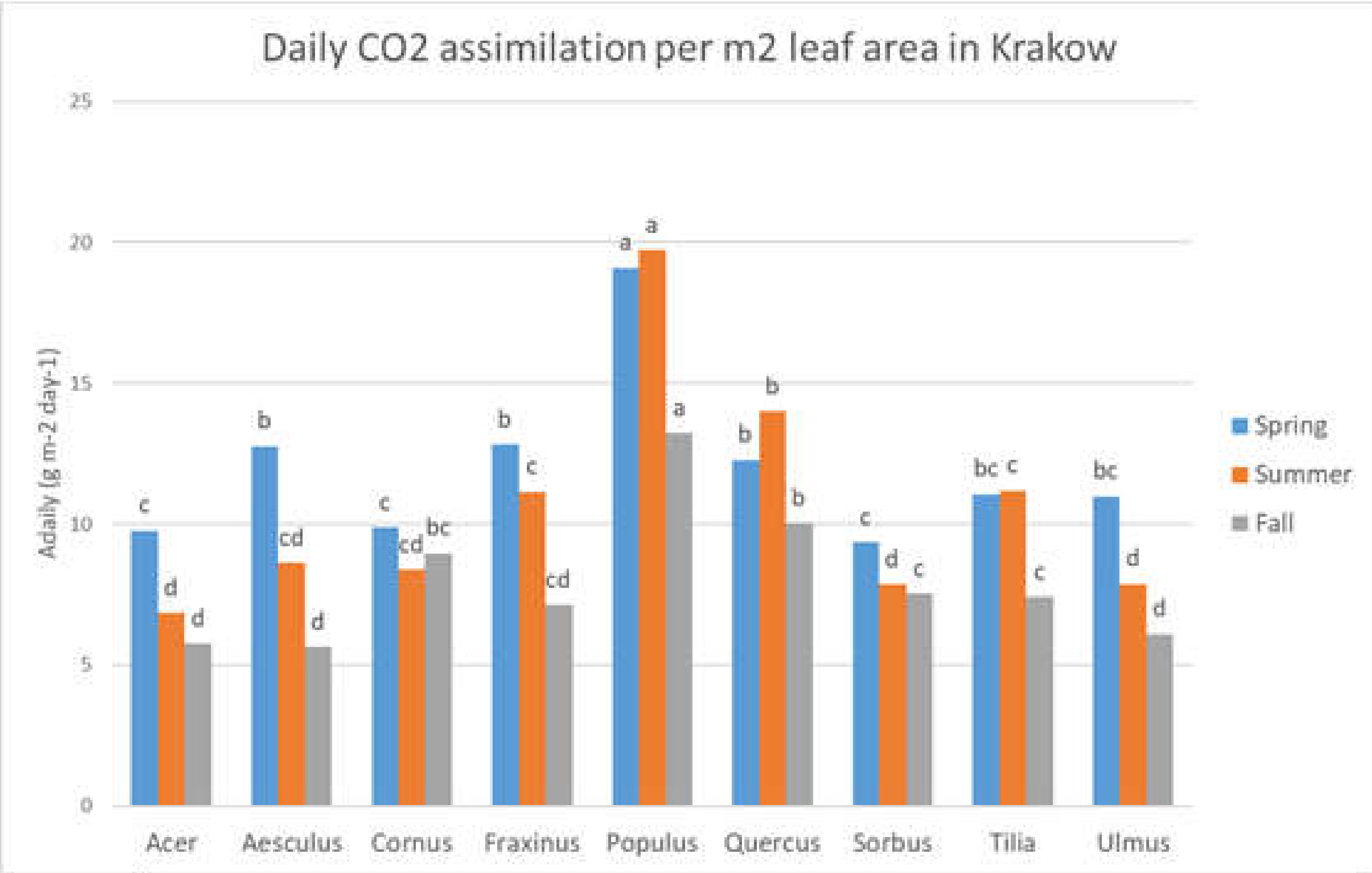
Measurements were conducted 9-11; 13-15; 16-18 on four leaf classes (full sun and shaded leaves, in the upper and lower canopy) at growing irradiance





Time of the day

Same leaf area, different carbon yield



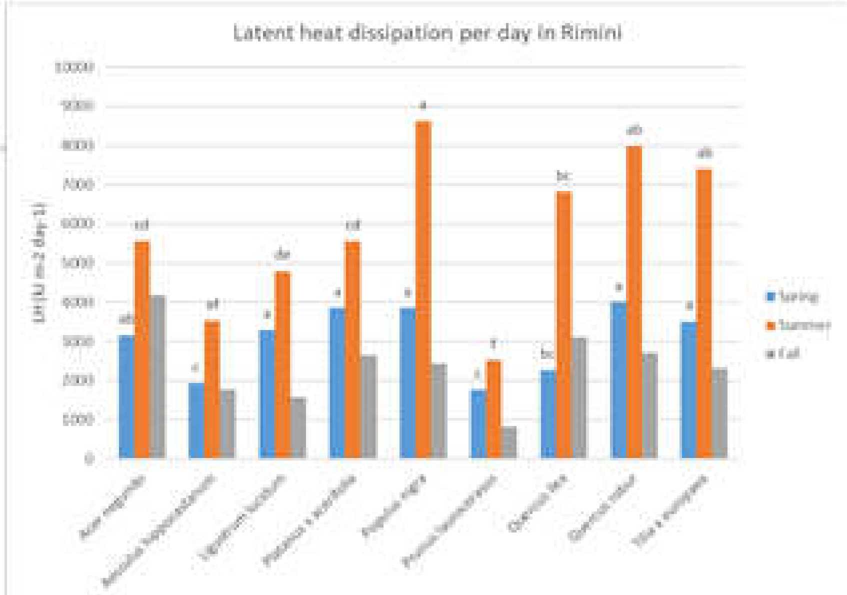
Populus nigra and Quercus robur had the higher CO2 assimilation per unit leaf area in both cities

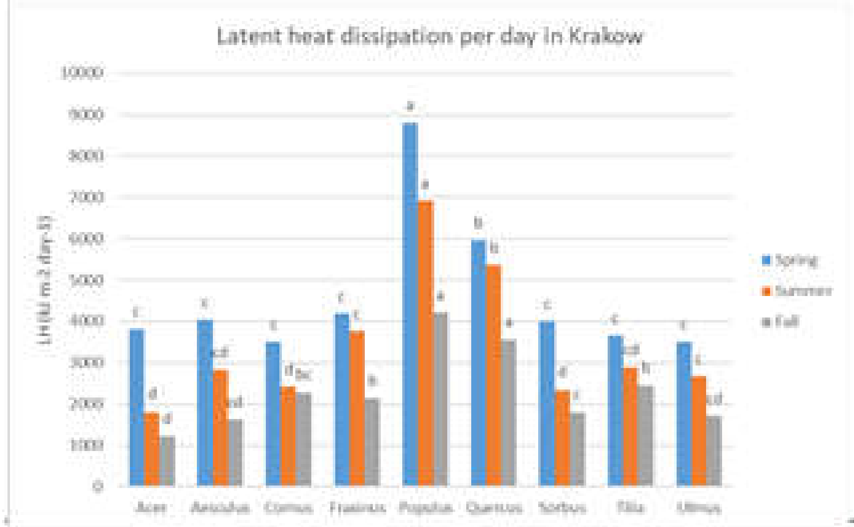
Acer and the Rosaceae species (Prunus, Sorbus) had the lower CO2 assimilation per unit leaf area in both cities

Different trend between isohydric and anisohydric species was found in Rimini more than in Krakow.

In Rimini, isohydric species are effective in spring, but their benefit decreases as environment turns harsher

Different letters within the same season indicate significant differences among species at P<0,01





Same leaf area, different cooling

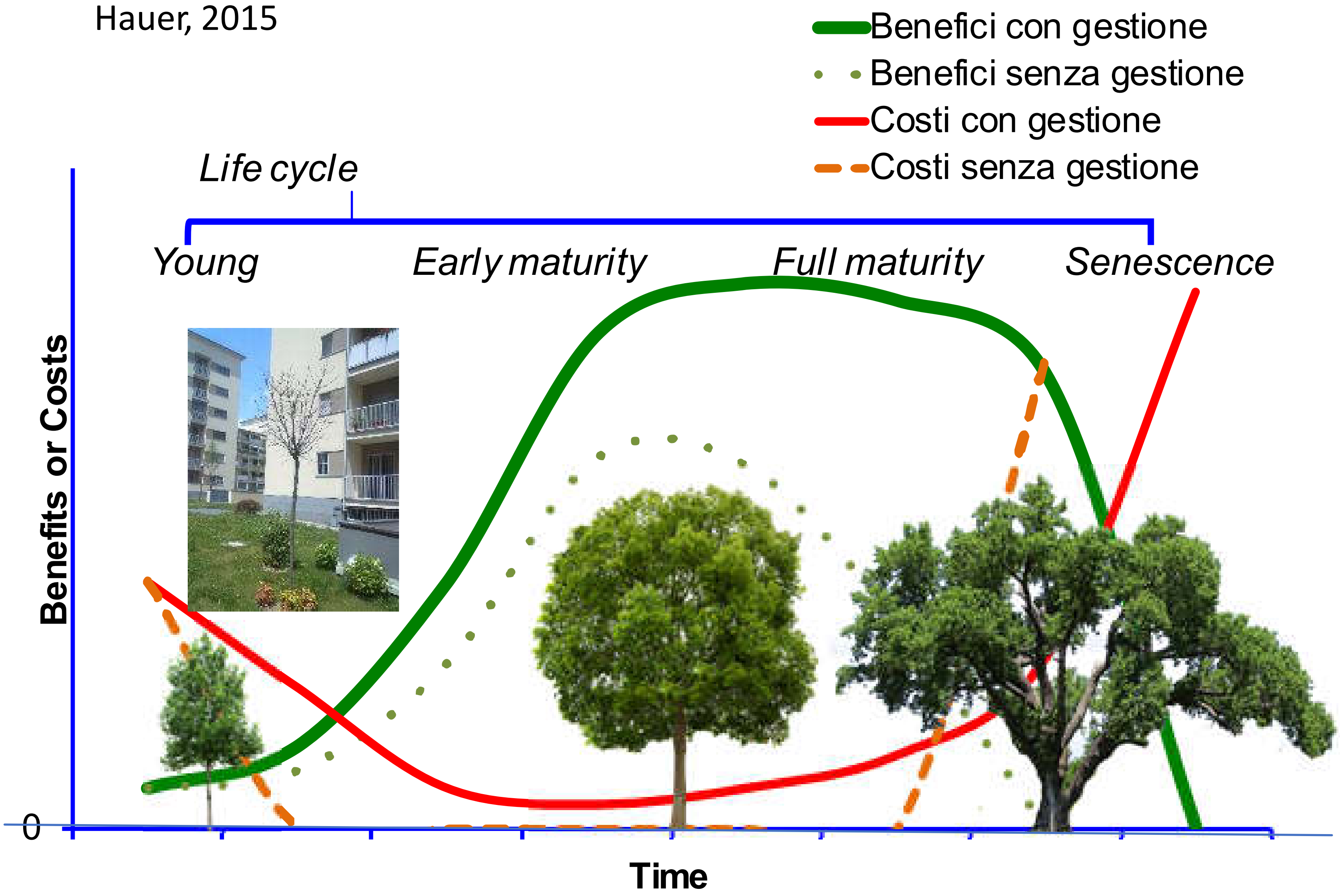
Each gram of water transpired dissipates 2,45 kJ as latent heat

Species exhibited a different capacity of latent heat dissipation

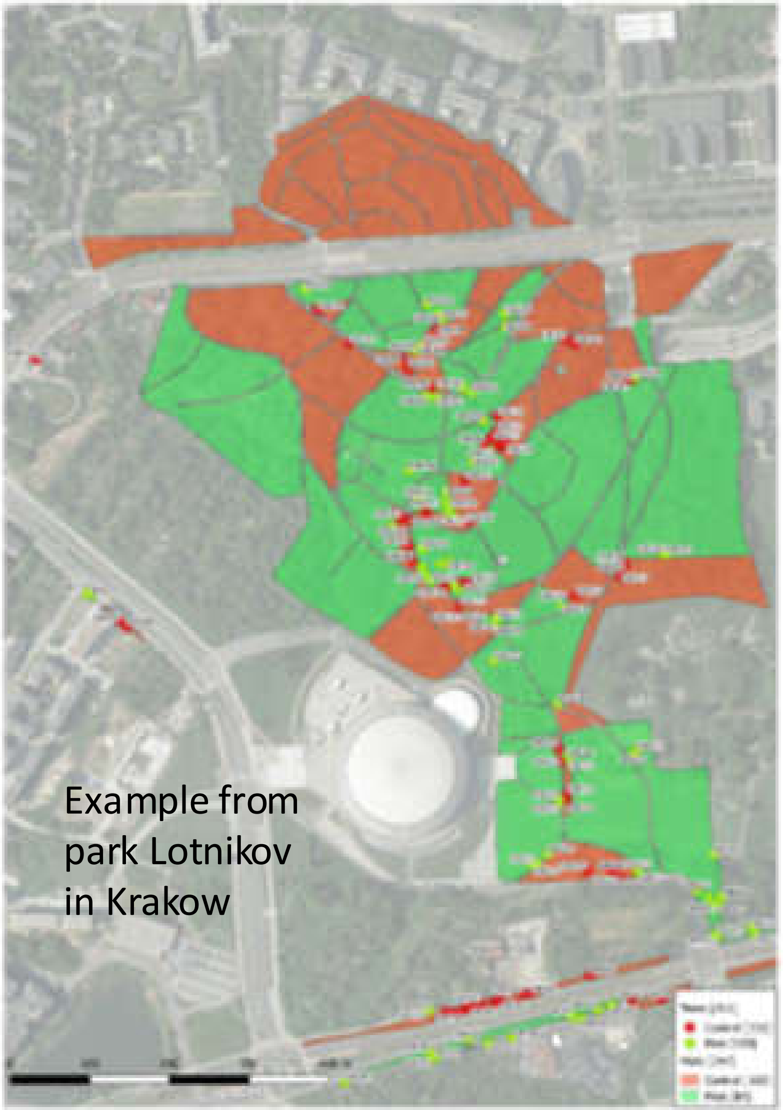
Populus and Quercus robur were more effective to cool air during summer than Acer, Aesculus, Cornus, Ligustrum, Fraxinus, Prunus, and Ulmus

The yearly pattern of transpiration differed between sites, due do different climatic conditions at the sites (hot summer in Rimini; hot spring and rainy summer in Krakow)

Hauer, 2015

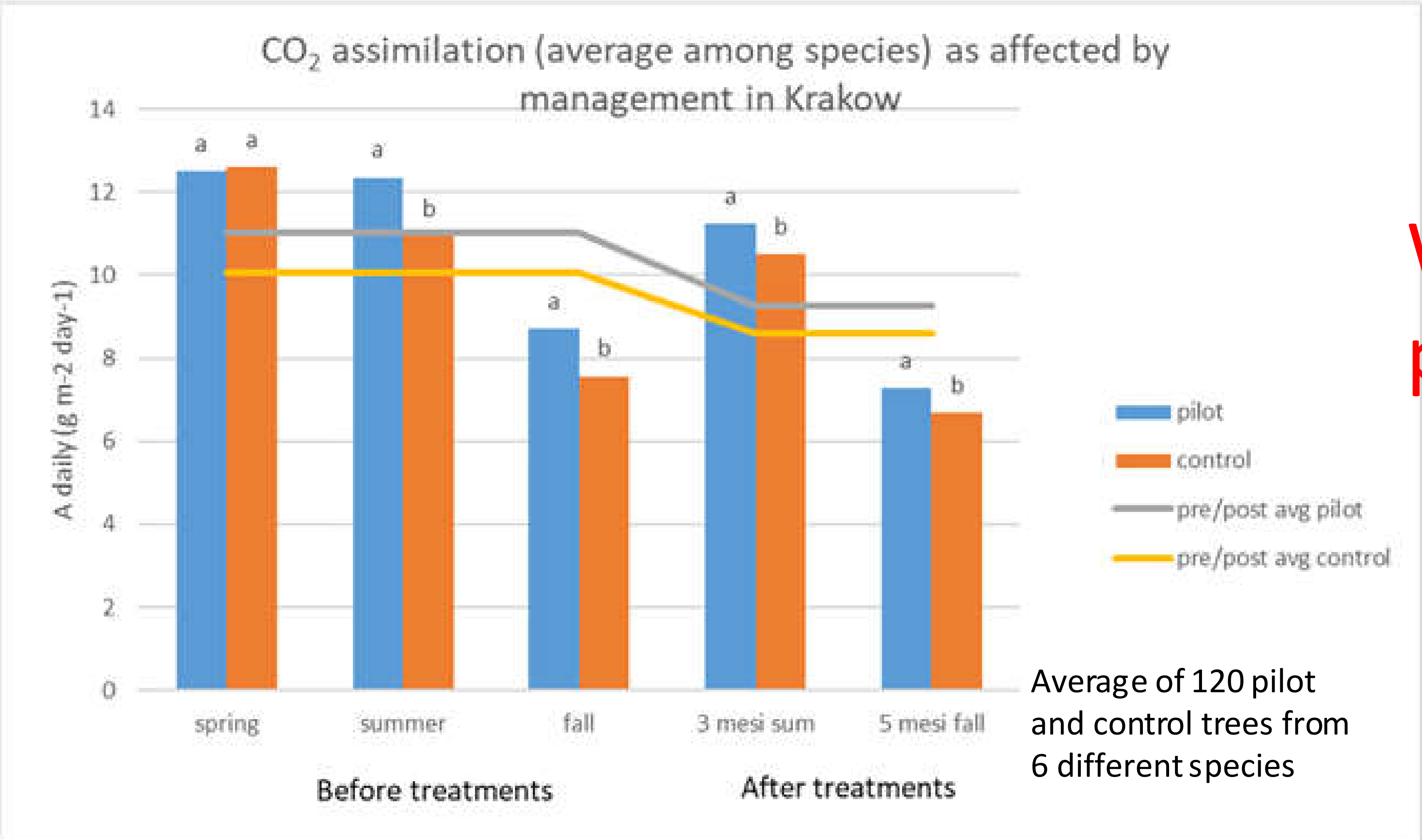

Benefici con gestione
Benefici senza gestione
Costi con gestione
Costi senza gestione
Life cycle
Young
Early maturity
Full maturity
Senescence
Benefits or Costs
0
Time

Right species with the right management



The experimental areas have been randomly assigned to pilot and control treatments, that consist in different management:

Management	Pilot	Control
Mulching	Organic mulching	No mulching
Pruning	Target pruning or no pruning (BMP)	Pruning according to city standards
Soil decompaction	Deep jetting	No action
Irrigation	Smart irrigation	No irrigation
Lawn maintenance	Grass mulching	Grass bagging



Work in progress

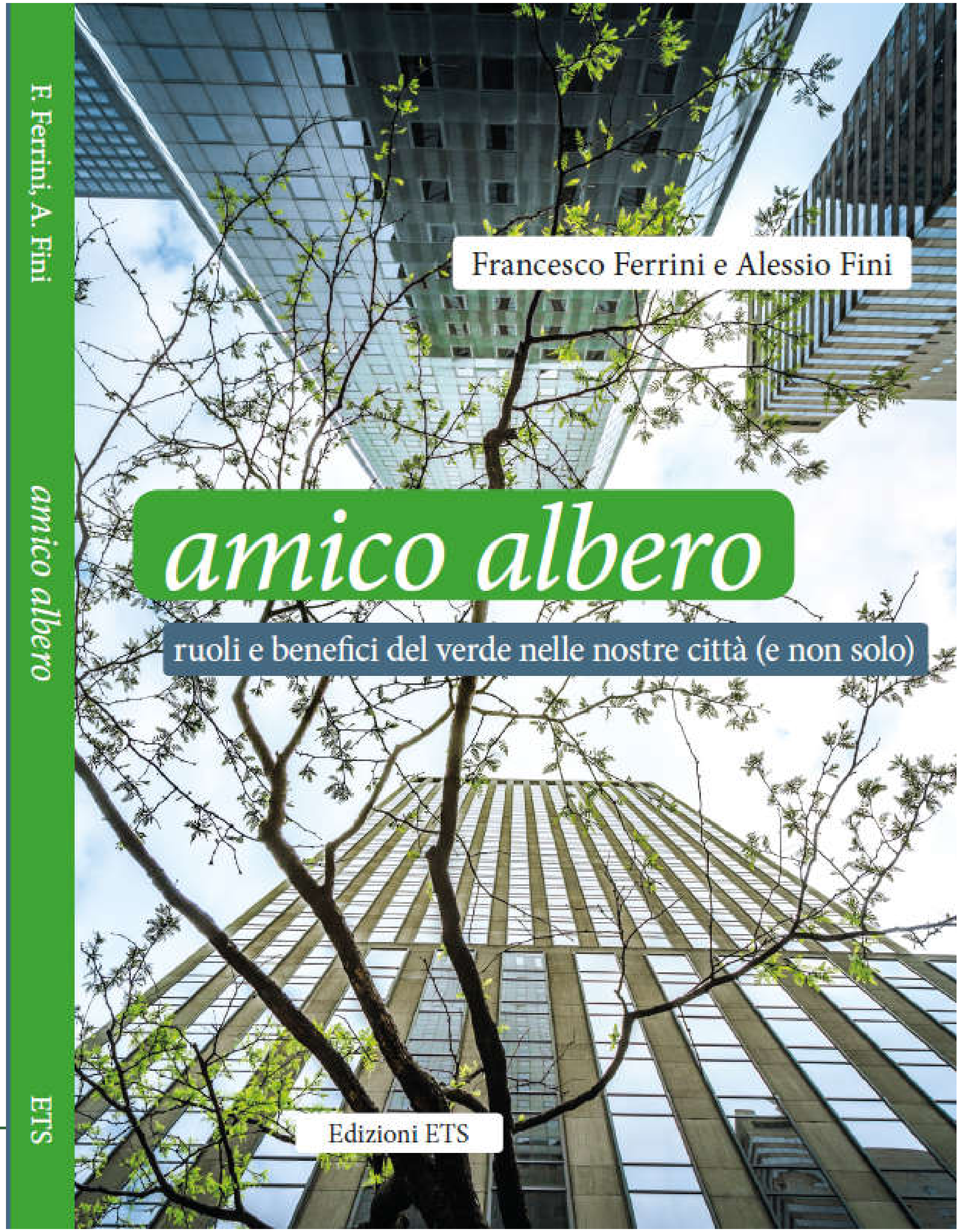
Conclusion

Urban trees are more than a mere ornament

Both ecosystem services and disservices come with urban trees

The selection of horticultural-tolerant species can increase B/C ratio

More knowledge is needed about the ecophysiological performance of individual species in cities



Diversify!

The excessive use of few specie and genera can lead to catastrophic tree losses due to pest or diseases

30-20-10 rule: keep the frequency of each Family below 30%, each genus below 20%, each species below 10% (Santamour, 1991)

5% rule: keep the frequency of each genus below 5% at the city level (Ball, 2016)

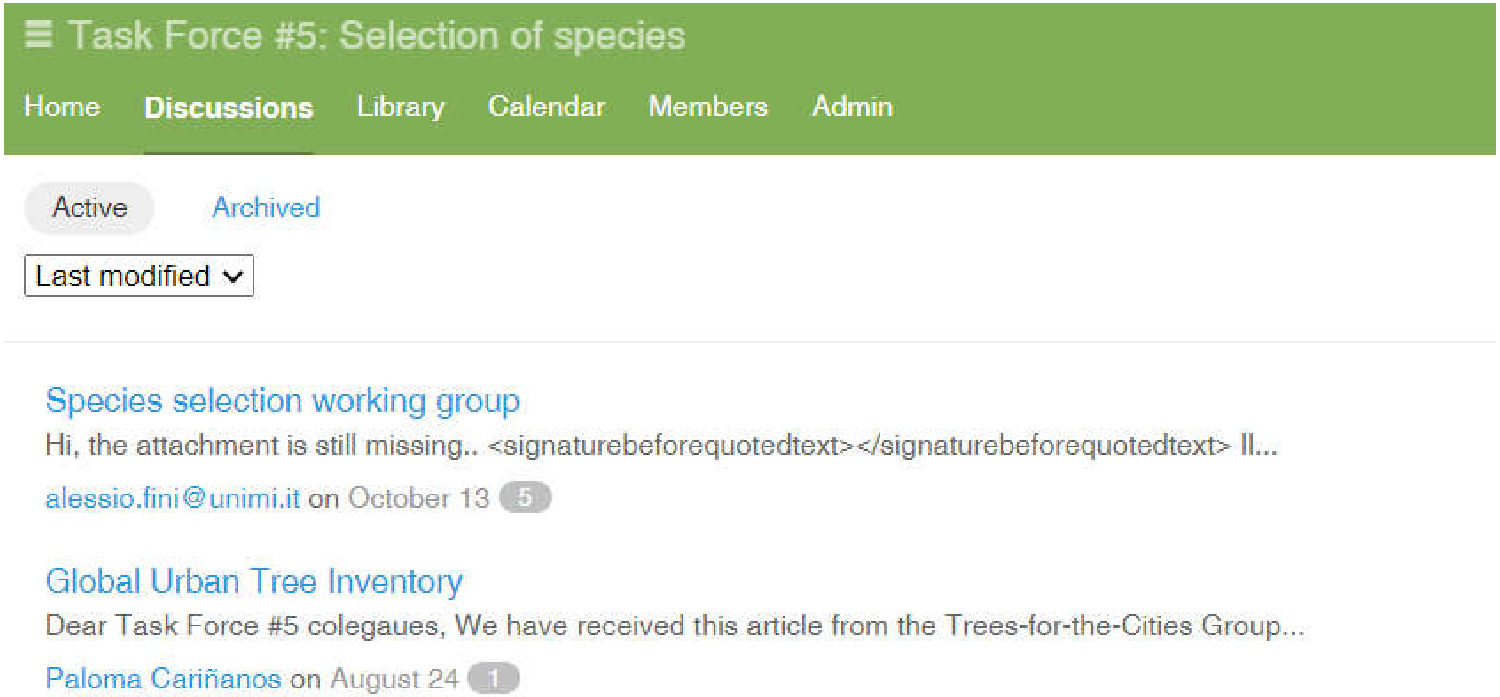
FAO Silva Mediterranea WG on Urban and Peri-Urban forests
Task force 5 – Species selection

- **Coordinator**: Alessio Fini
- **Members:** Nehza Acil, Simone Borelli, Pedro Calaza-Martinez, Thomas Campagnaro, Paloma Carinanos, Michela Conigliaro, Fabio Salbitano, Andrew Speak, Dimitris Tsiplinas, Giorgio Vacchiano
- **Countries:** Italy, Spain, Greece, Morocco

Main goal: retrieve and share science-based information about Mediterranean woody species suitable for the urban environment

Task force 5 – Specie selection

If you are interested in the topic and willing to contribute, please join us at Dgroups (https://dgroups.org/fao/silvamed-wg7/task-force-5_selection-species)



Thank you all for your attention

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