Assessing water status of urban trees: Combining very high spatial resolution imagery and microdendrometer measures approaches for *Acer platanoides* and *Tilia euchlora* species in Dijon

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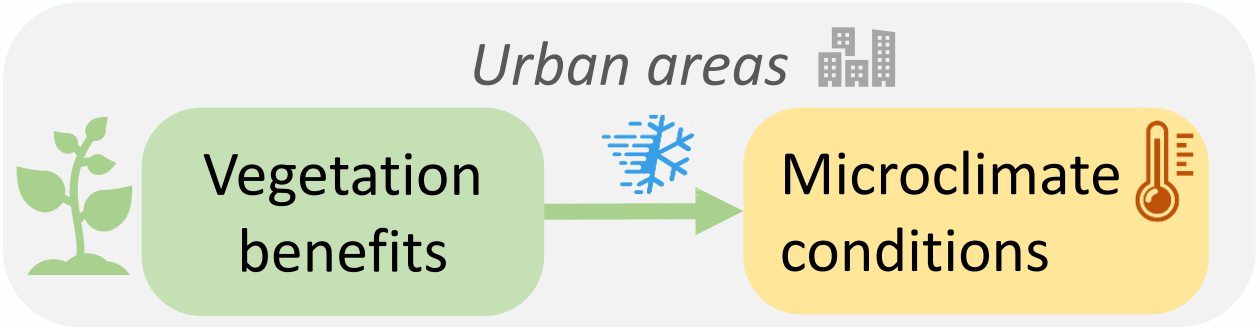
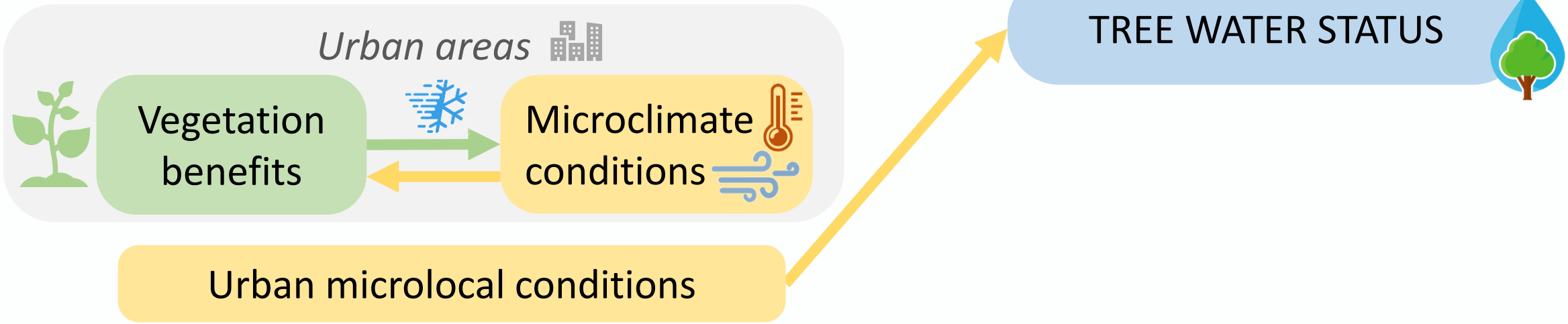
GENERAL CONTEXT



GENERAL CONTEXT



- Meteorological conditions (building morphology, …)
- Soil impermeabilisation
- Air quality
- …

GENERAL CONTEXT

Urban areas

Vegetation benefits

Microclimate conditions

Urban microlocal conditions

TREE WATER STATUS

→ TREE WATER STATUS SPATIALISATION

- Meteorological conditions (building morphology, …)
- Soil impermeabilisation
- Air quality
- …

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- …

TREE WATER STATUS

→ **TREE WATER STATUS SPATIALISATION**

Tree species

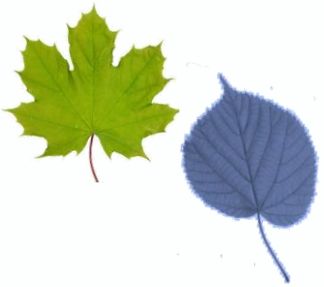
Leuschner et al. 2024

Acer platanoides*, *Tilia euchlora

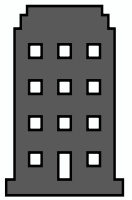
Table 3
Traits and plant responses relevant for drought resistance in the five studied species according to the results of this study and some published literature results. *Fagus sylvatica* as a relatively drought sensitive species is listed for comparison, based on the studies of Backes and Leuschner (2000), Zimmermann et al. (2015), Knutzen et al. (2017), Leuschner et al. (2019) and Weigel et al. (2023). The traits/responses are assessed in relative terms in their assumed positive effect on the fitness during drought (from clearly positive ++ to indifferent (±) and clearly negative −−; '?' no data or unclear). We judged more negative P_{TLP} and P_{50}, larger HSM, deeper rooting, P_{50} acclimation, osmotic adjustment, fine root biomass adjustment (increase upon reduced precipitation), higher growth resistance and resilience, higher stem water storage, and sensitive stomatal regulation (which prevents Ψ drops to P_{12} or P_{50}) as leading to higher drought resistance, while higher tree water consumption, negative growth trends, increasing growth synchrony and pointer year frequency, and higher crown damage are assessed as indicators of reduced resistance. While most data for the first five species are from this study, some morphological, physiological and dendrochronological data are taken from Pigott (1991), Bréda et al. (1992), **Tissier et al. (2004)**, Leuzinger et al. (2005), Hemery et al. (2009), Dietrich et al. (2018), Lobo et al. (2018), Kunz et al. (2018), and Latte et al. (2020). **The information for *Fagus sylvatica* is mostly derived from** Leuschner (2020).

	Acer	Carpinus	Fraxinus	Quercus	Tilia	Fagus
Sensitive stomatal regulation	+	+	−−	± ?	+ +	−
Turgor loss point P_{TLP}	−	+ +	+ +	+	±	+ +
…istance (P_{50}/P_{88})	+ +	+ +	− ?	+ + ?	±	±
…margin	+ +	+	+ ?	+ + ?	±	−
…o drought	−	−	?	?	+	±
…ent	−?	+ +	+ +	+ +	+ +	+ +
…umption	±	+	+ +	±	−	±
…age	+	+	−	−	+ +	+
…oting depth	+	+	+	+ +	+	+
…t drought sensitivity	+	±	+	+ +	−	−
…t biomass adjustment	+ +	+	−	−	+	+ +
…synchrony increase	+	?	+	+	+	−
			+	+ +	−	−
			+ +	+ +	+	±
			+	+	+	− −
			+ +	+ +	+ +	− −
Crown damage 2018/19	+	−	+	+ +	±	− −
Drought resistance ranking	**2**	**4**	**2**	**1**	**3**	**5**

SCIENTIFIC QUESTIONS



1) Are there differences in tree water status between *Acer platanoides* and *Tilia euchlora*?



2) How microlocal conditions impact tree water status?

3) Are remote sensing vegetation indices good proxies for tree water status?

GENERAL METHOD

Remote sensing 1

VHSR

++ spatial / -- temp. res.

Pléiades image

Vegetation Index

- MSAVI2

Site selection

Instrumented sites & trees

Field data

- spatial / ++ temp. res.

Microdendrometer measurements

Indicators

- Maximum Daily Shrinkage
- Tree Water Deficit

(+ Meteo measurements)

Remote sensing 2

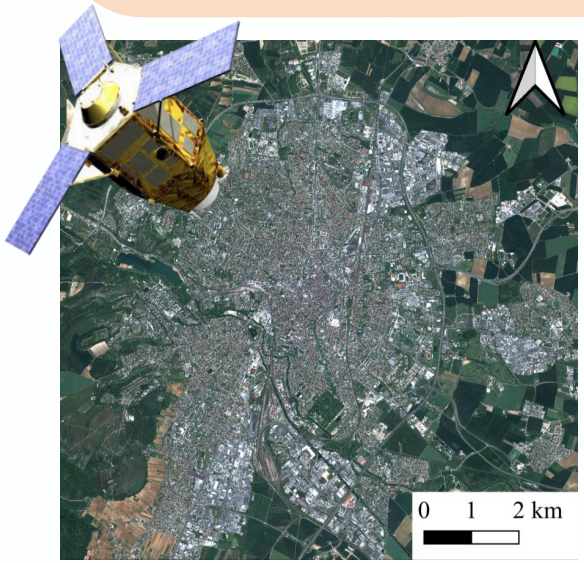
HSR

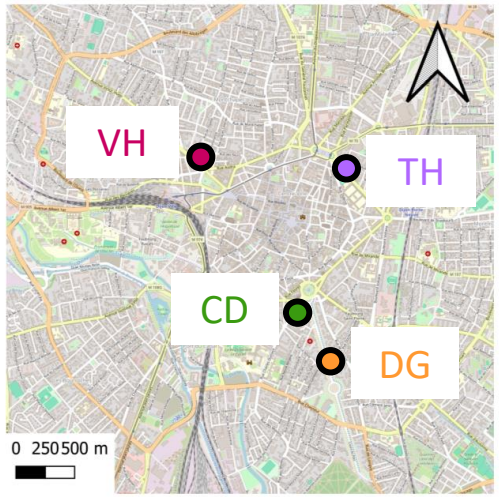
+ spatial / + temp. res.

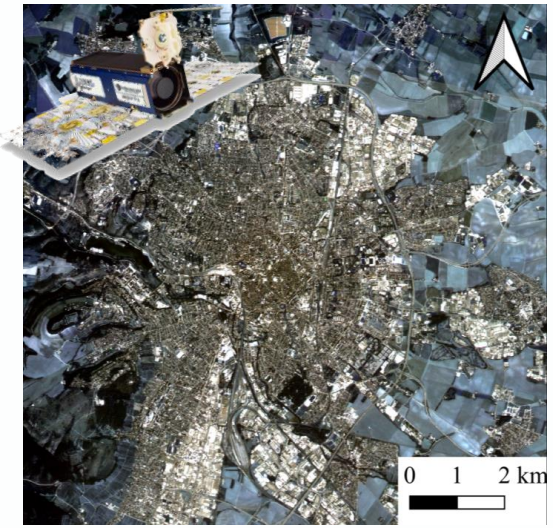
SuperDove images

Vegetation Indices

- NDVI - SIPI







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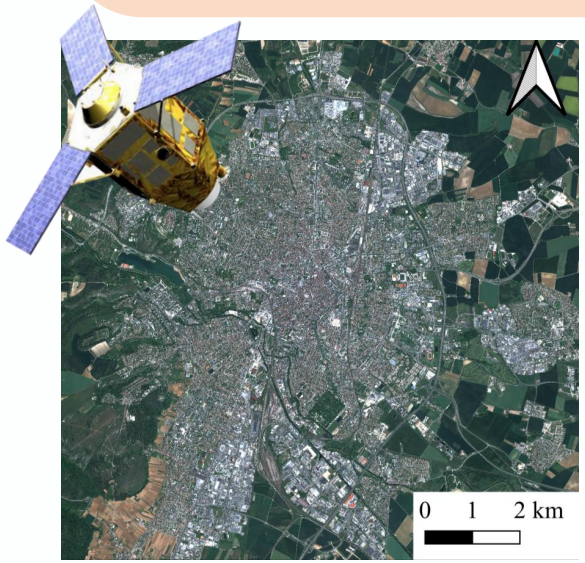
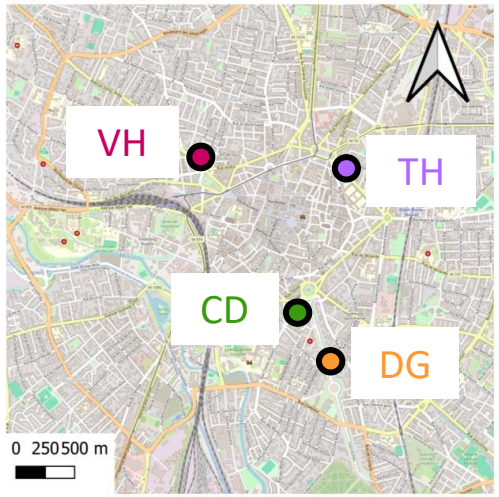
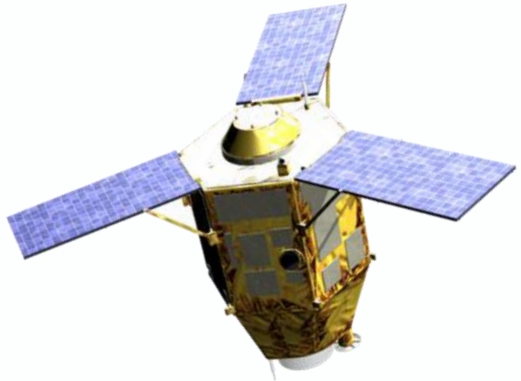




PLEIADES IMAGE



Bands	Wavelength
Blue	430 - 550 nm
Green	500 - 620 nm
Red	590 - 710 nm
NIR	740 – 940 nm

CNES

>2011

Very High Spatial Resolution
(PAN: 70cm & MS: 2.8m)

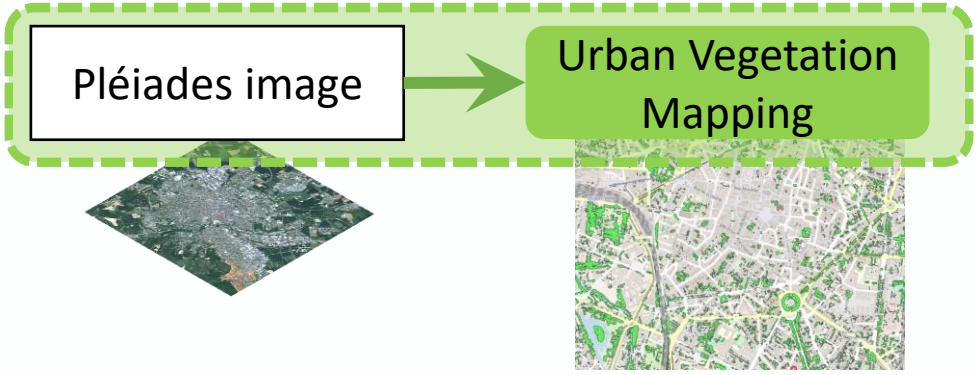
Daily revisit time

29 May 2021

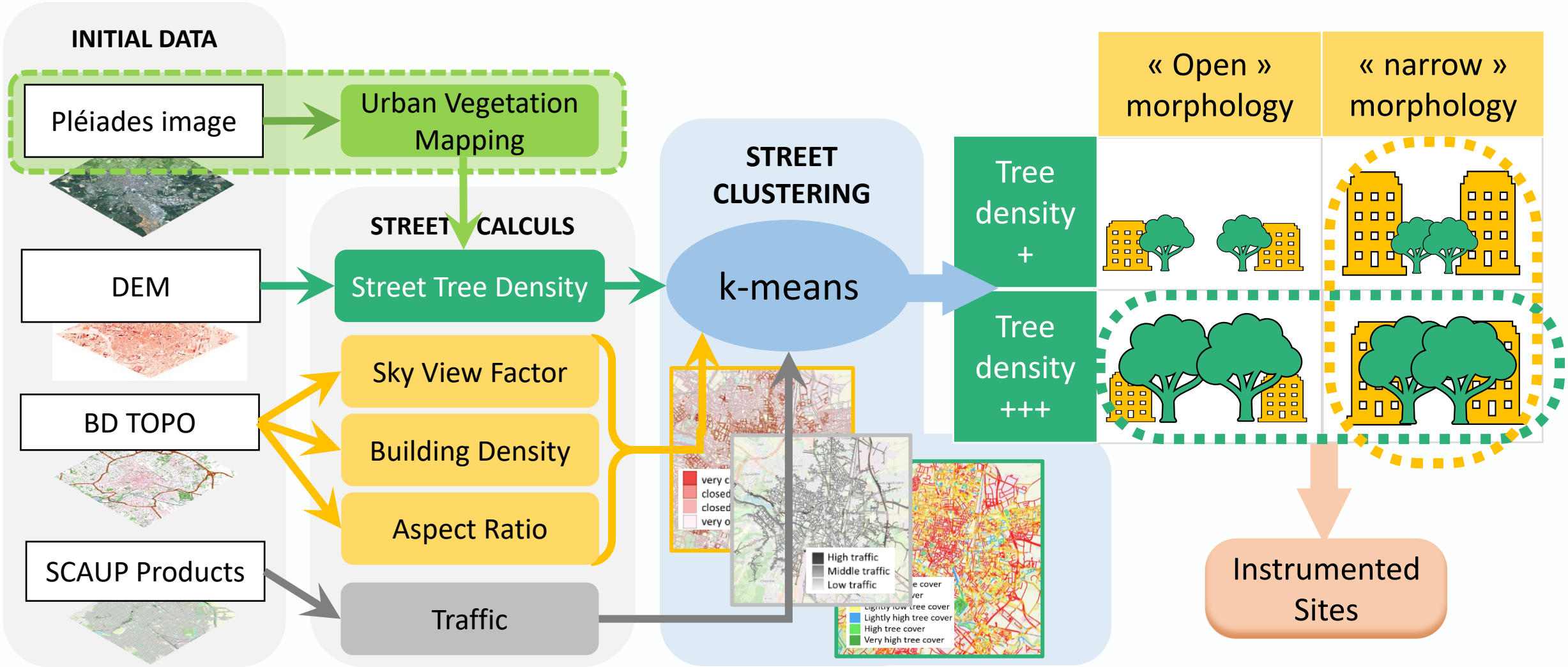
Pansharpened image
May,2021

Index	Vegetation index formula
MSAVI2	$(2 \times \rho_{NIR} + 1 - \sqrt{(2 \times \rho_{NIR} + 1)^2 - 8 \times (\rho_{NIR} - \rho_{red})}) / 2$

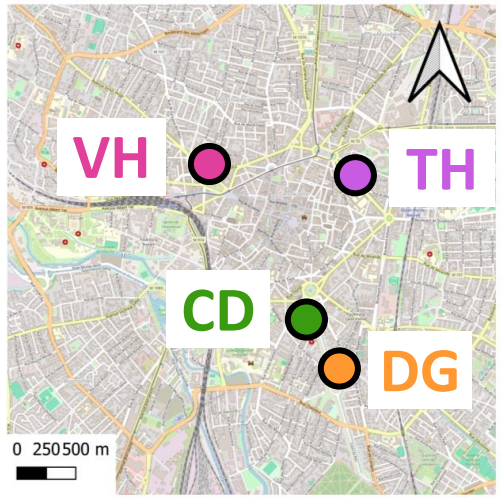
Supervised classification (MSAVI2 treshold by pixel counts)

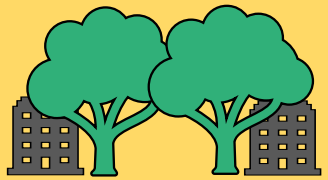


SITE SELECTION



INSTRUMENTED SITES



	« open » morphology	« narrow » morphology
Tree density +		
Tree density +++		

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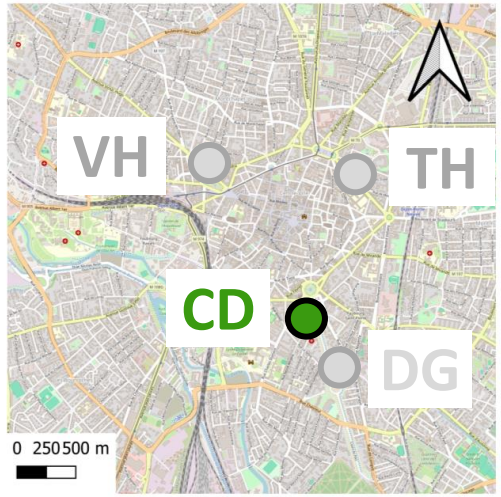

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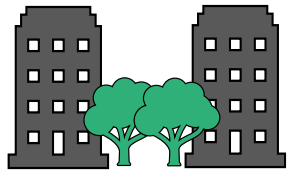
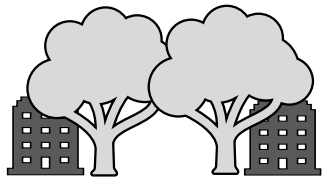
Tree density +		
Tree density +++		

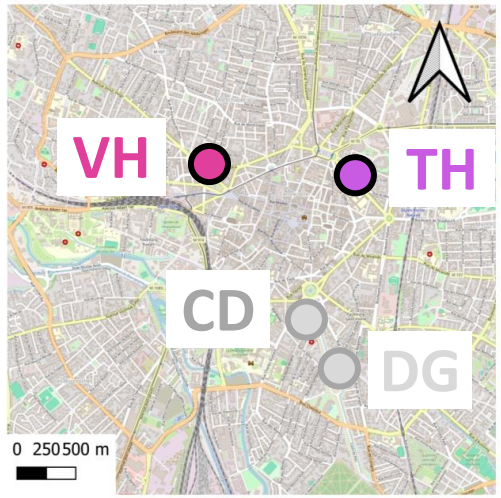
CD Charles Dumont

TH Thiers

DG De Gaulle

VH Victor Hugo

INSTRUMENTED SITES



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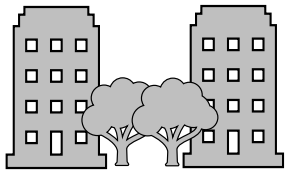
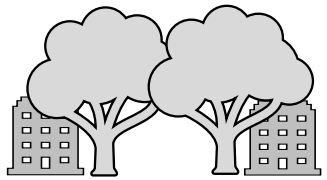
Tree density +		
Tree density +++		

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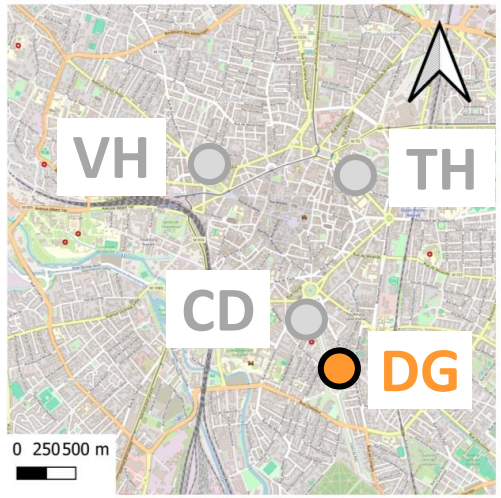

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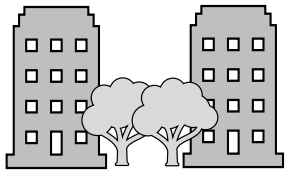
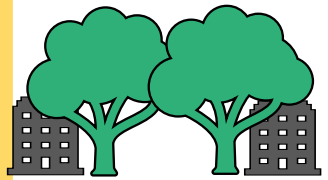
Tree density +		
Tree density +++		

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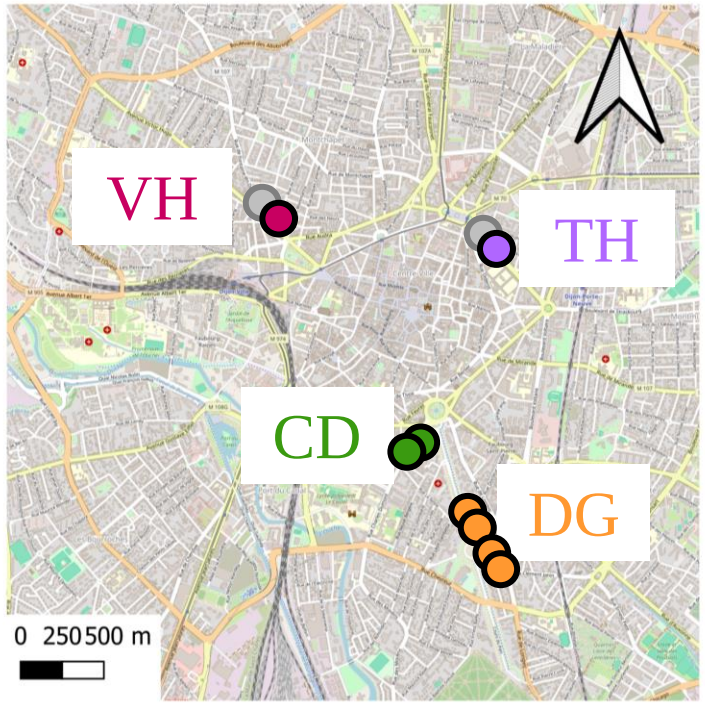

8 trees equipped with a µdendrometer
3 Acer platanoides + 5 Tilia euchlora

July 2023 → March 2024

µdendrometer

Tilia e. (CDn)

Tilia e. (THs)

Tilia e. (DGn)

Acer p.		
Site	DBH (cm)	Height (m)
VHn	27	12.9
DGn	27	14.0
DGs	24	13.9
Tilia e.		
Site	DBH (cm)	Height (m)
THs	23	13.9
CDn	24	8.9
CDs	23	8.3
DGn	34	13.0
DGs	29	12.8

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Pléiades image

Vegetation Index

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Microdendrometer measurements

Indicators

- Maximum Daily Shrinkage
- Tree Water Deficit

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SuperDove images

Vegetation Indices

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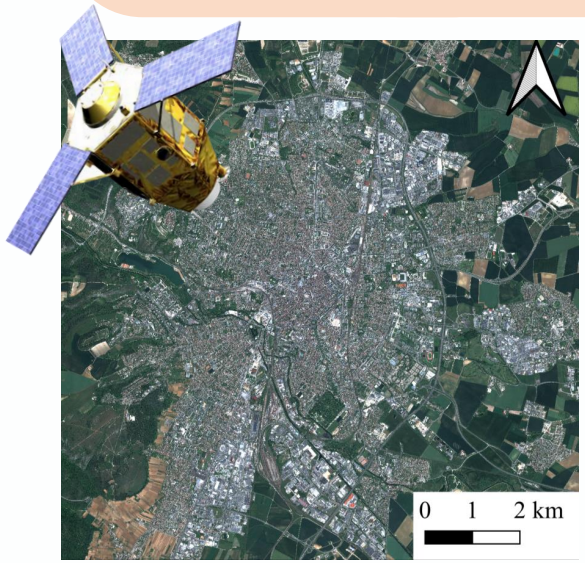
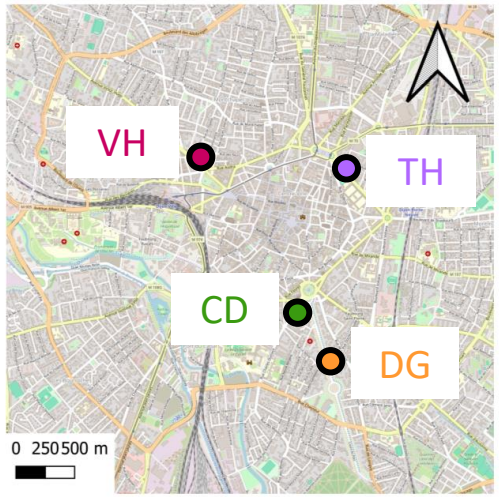
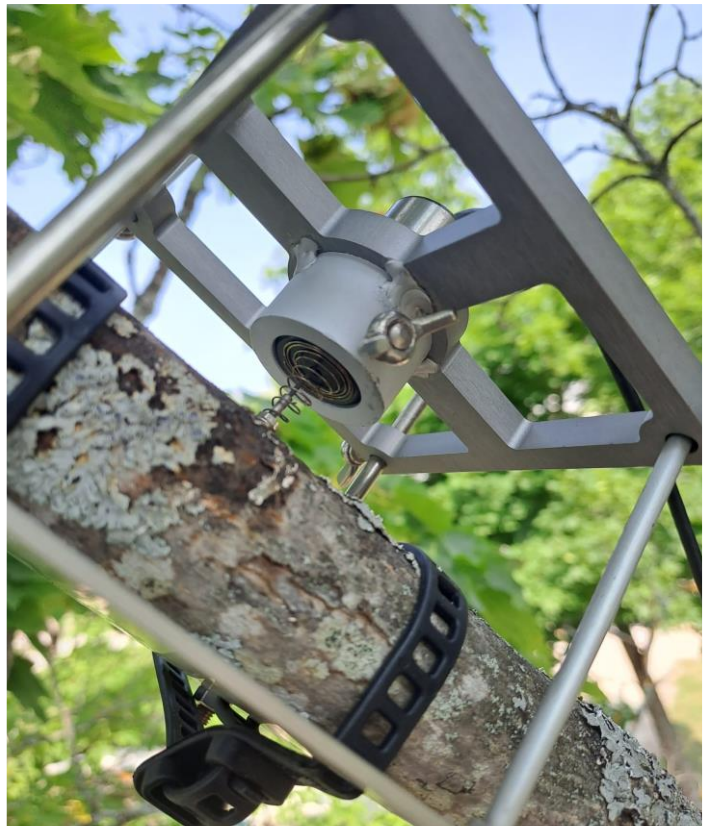




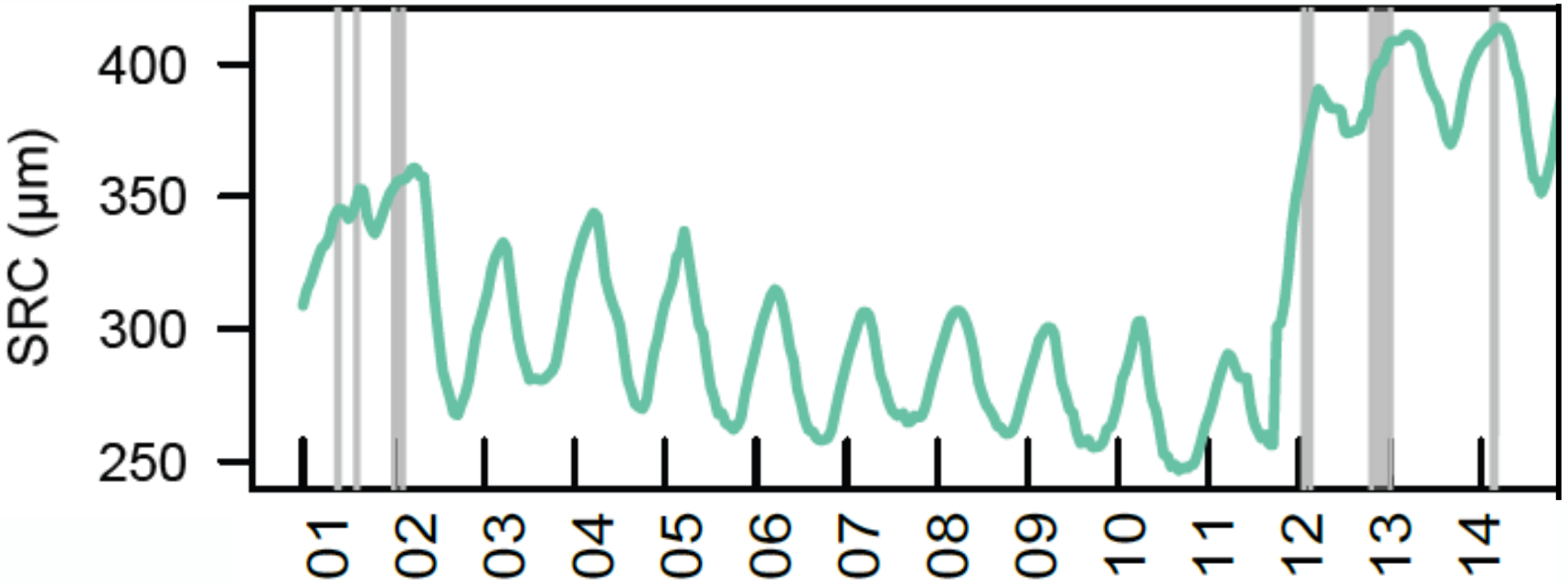
MICRODENDROMETERS

| MEASUREMENTS



PEPIPIAF system - hourly data

Ileo, 2023

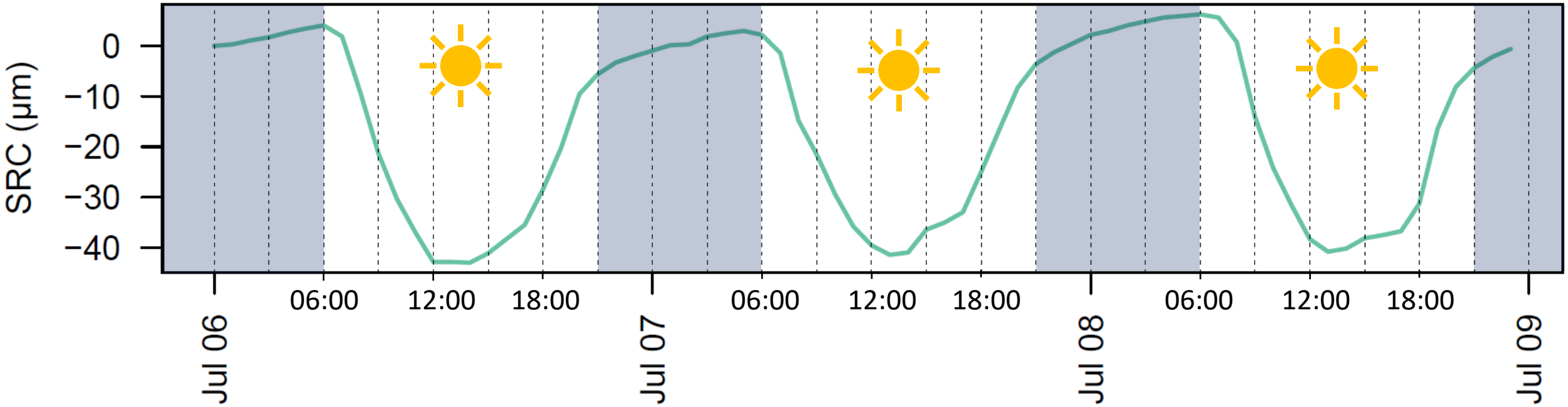


SRC (Stem Radius Changes):

Microvariations of the diameter of the tree branch

MICRODENDROMETERS

| MEASUREMENTS



MICRODENDROMETERS

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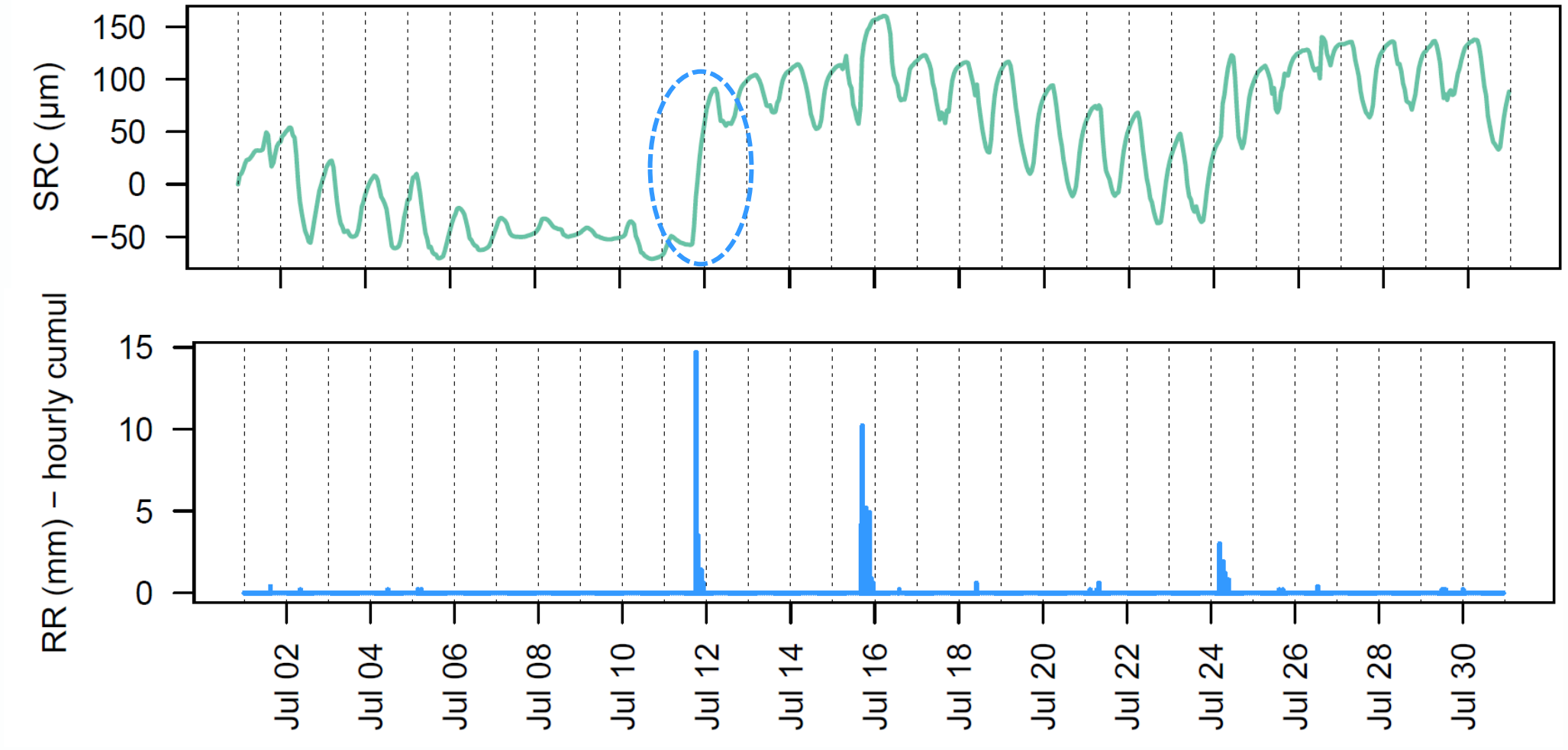

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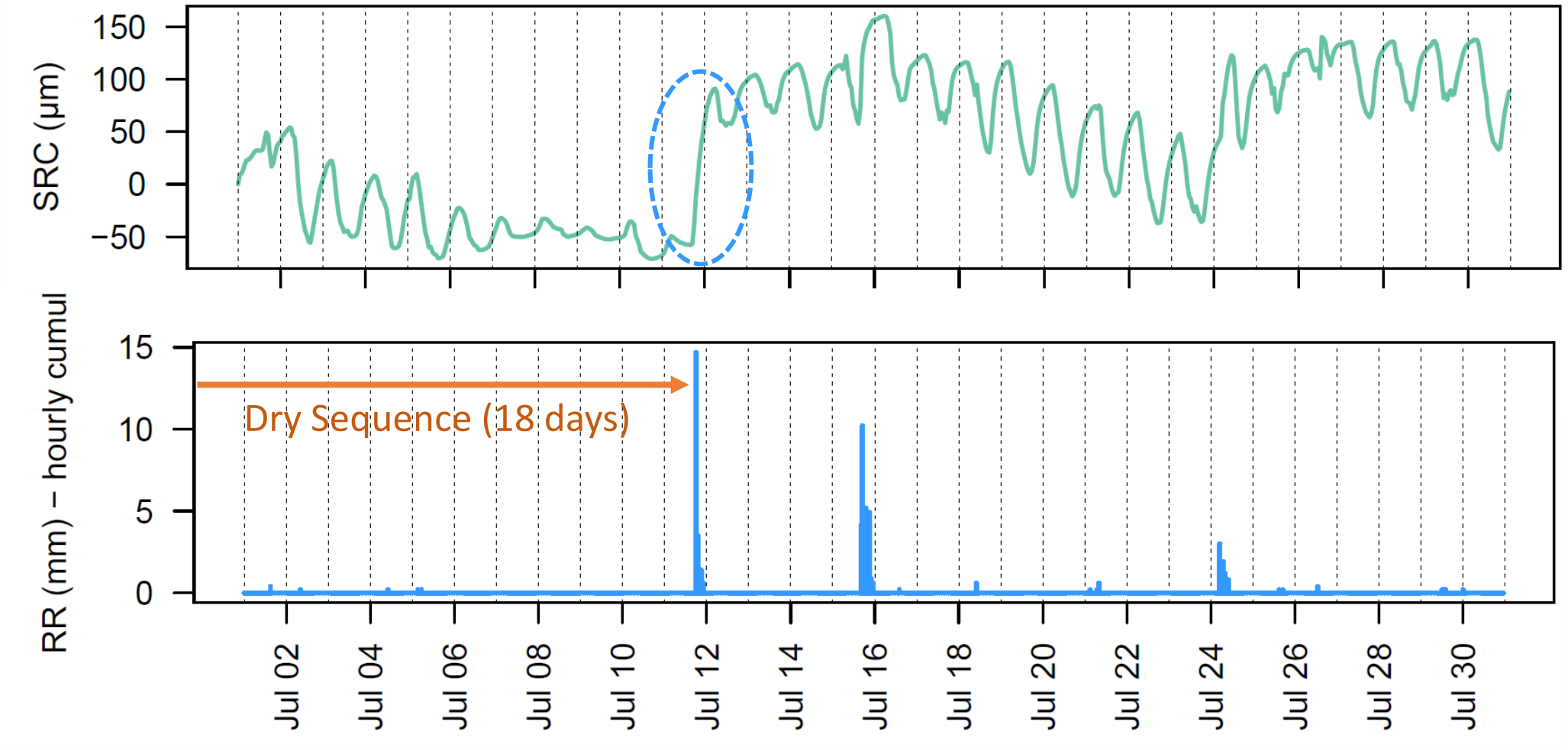

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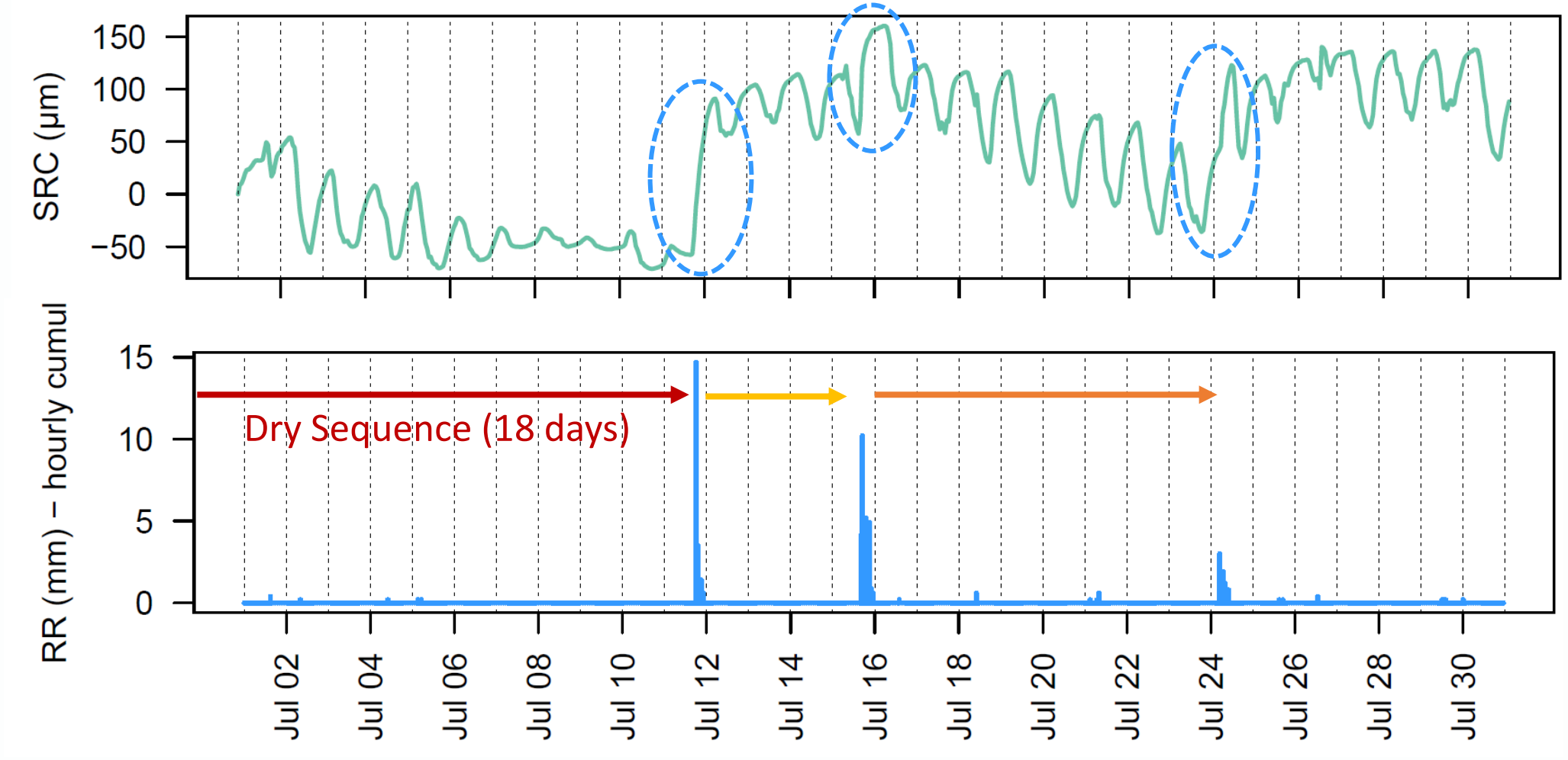

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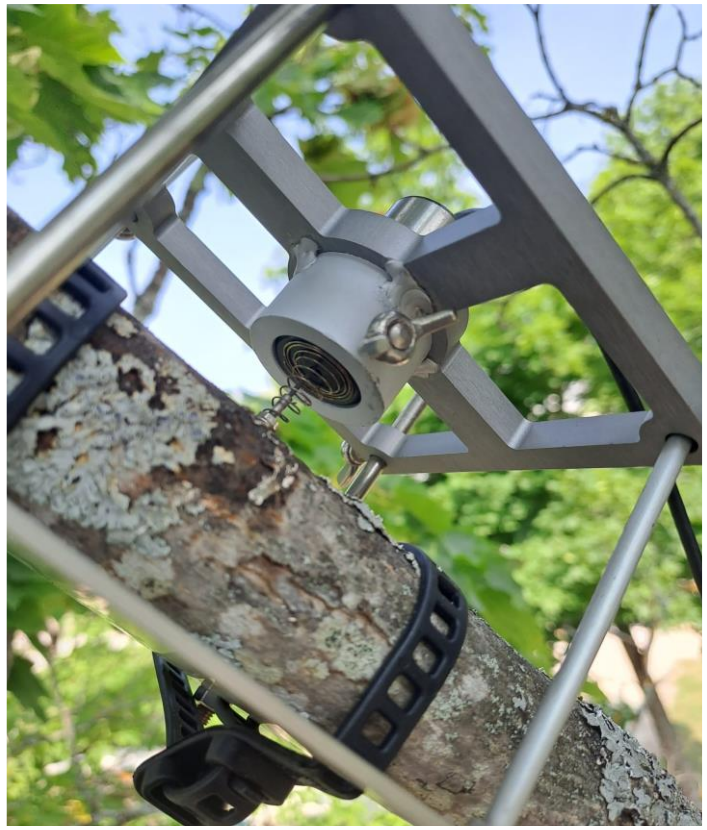

PEPIPIAF system - hourly data

Ileo, 2023

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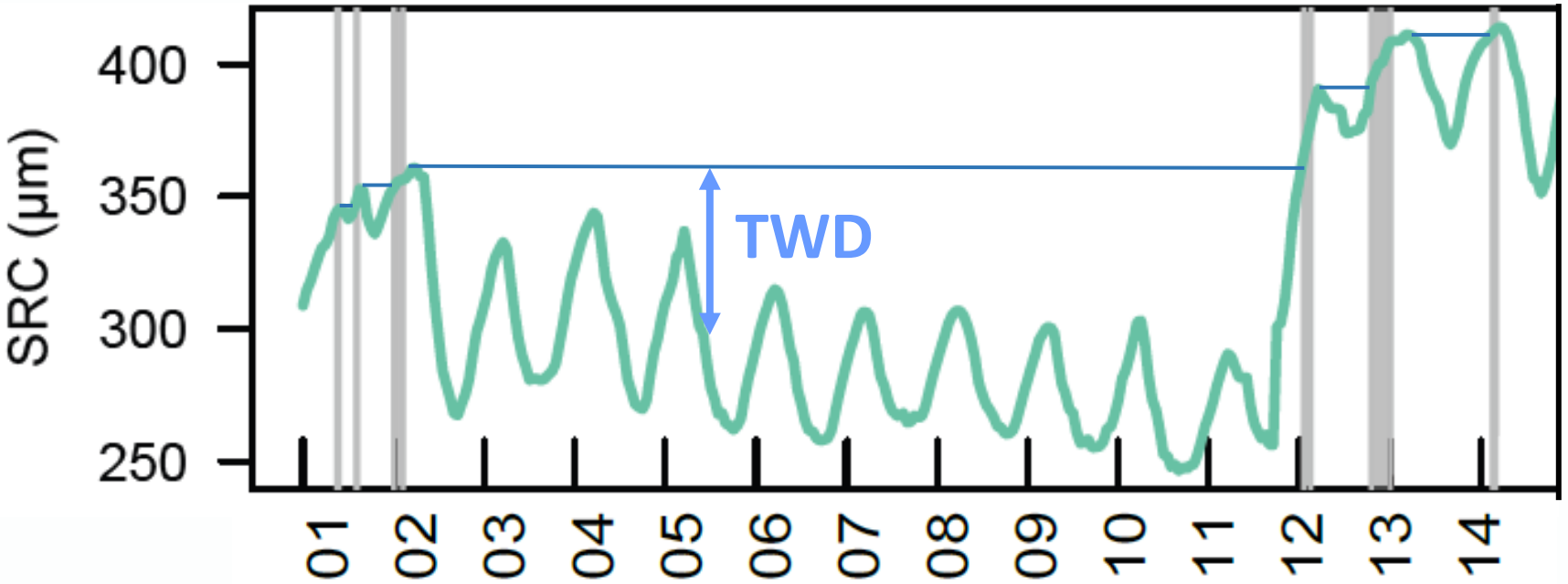
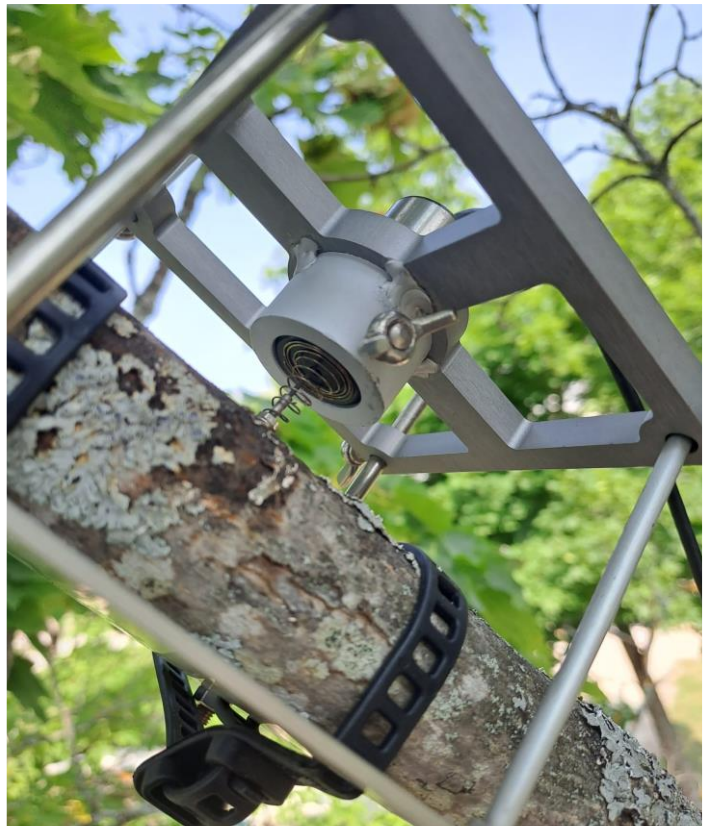


TWD (Tree Water Deficit) → Drought stress (cumul)

MICRODENDROMETERS

| MEASUREMENTS



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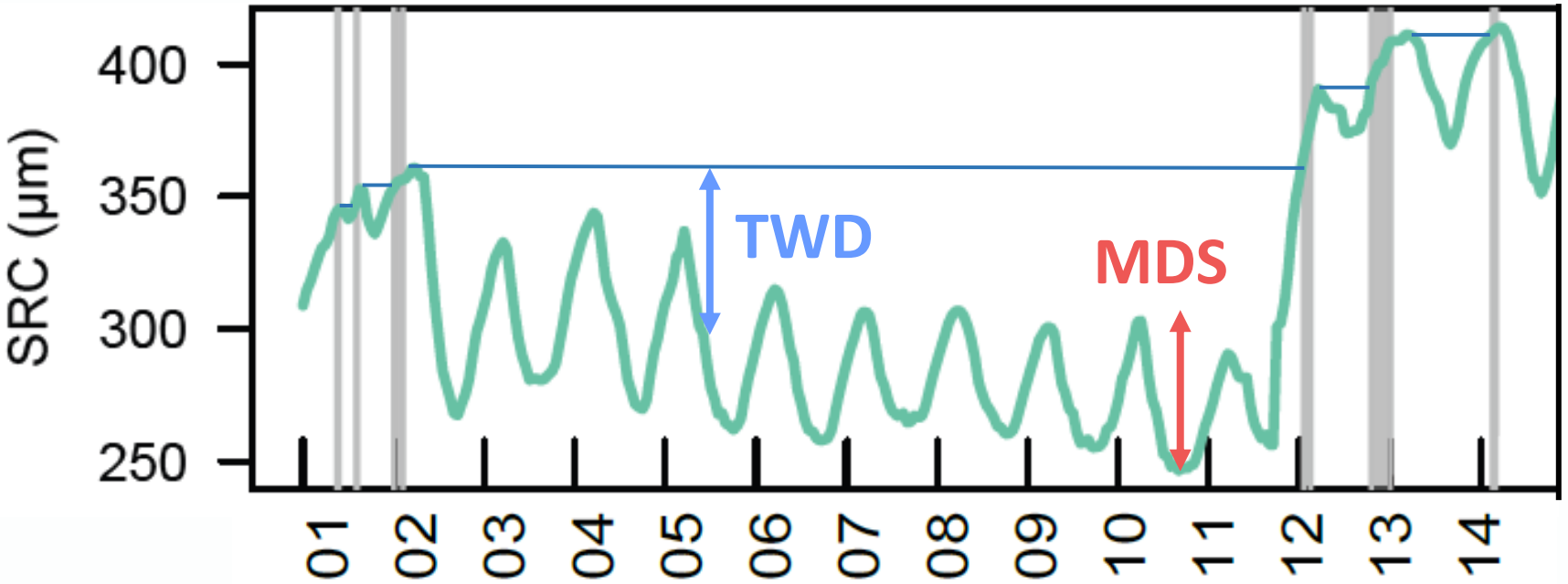

TWD (Tree Water Deficit) → Drought stress (cumul)

MDS (Maximum Daily Shrinkage)

Zero Growth Approach + Data cleaning (frost periods) + TWD & MDS Normalisation

(Zweifel et al, 2016)

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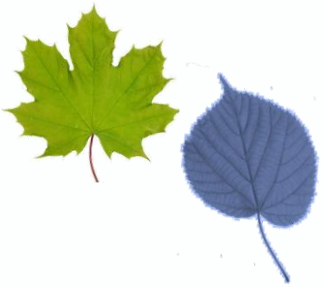
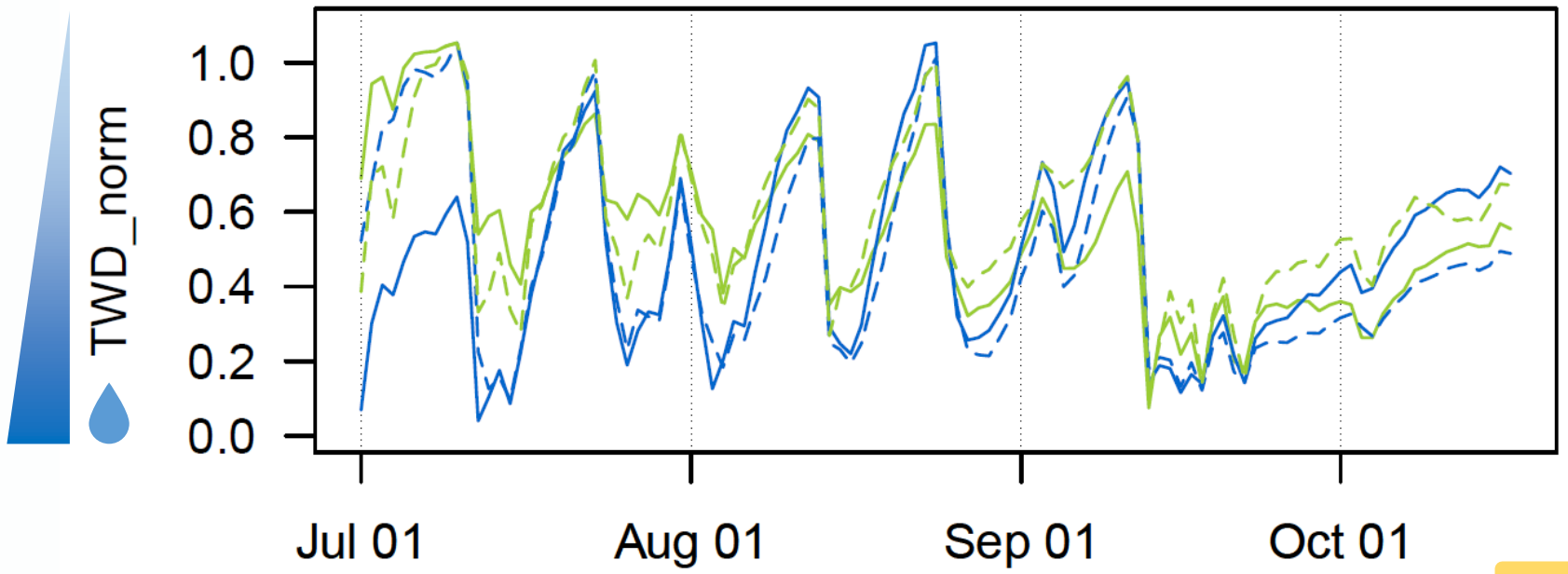
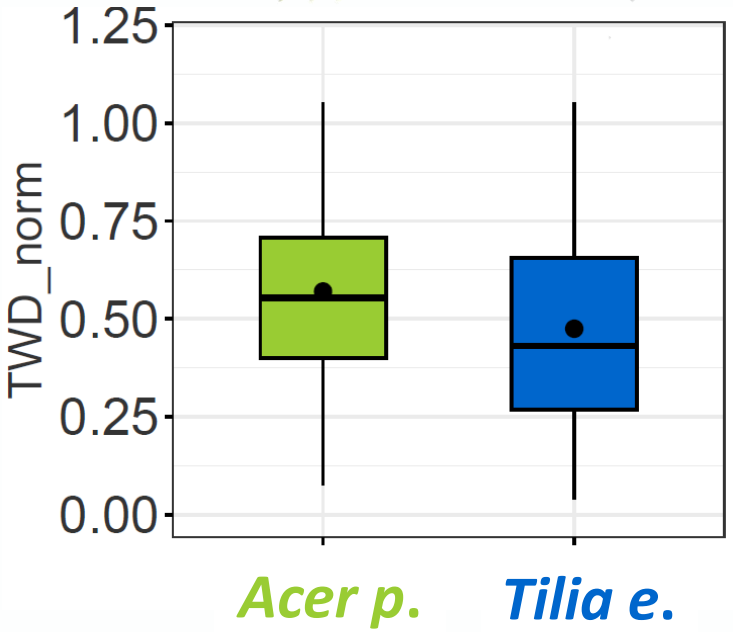


2) How microlocal conditions impact tree water status?

3) Are remote sensing vegetation indices good proxies for tree water status?

DENDRO. SPECIES DIFFERENCES





→ Water deficit: ***Tilia e.*** < ***Acer p.*** *(significant $p < 0.05$)*

→ Variability: ***Acer p.*** < ***Tilia e.***

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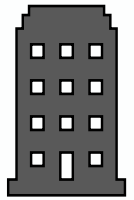

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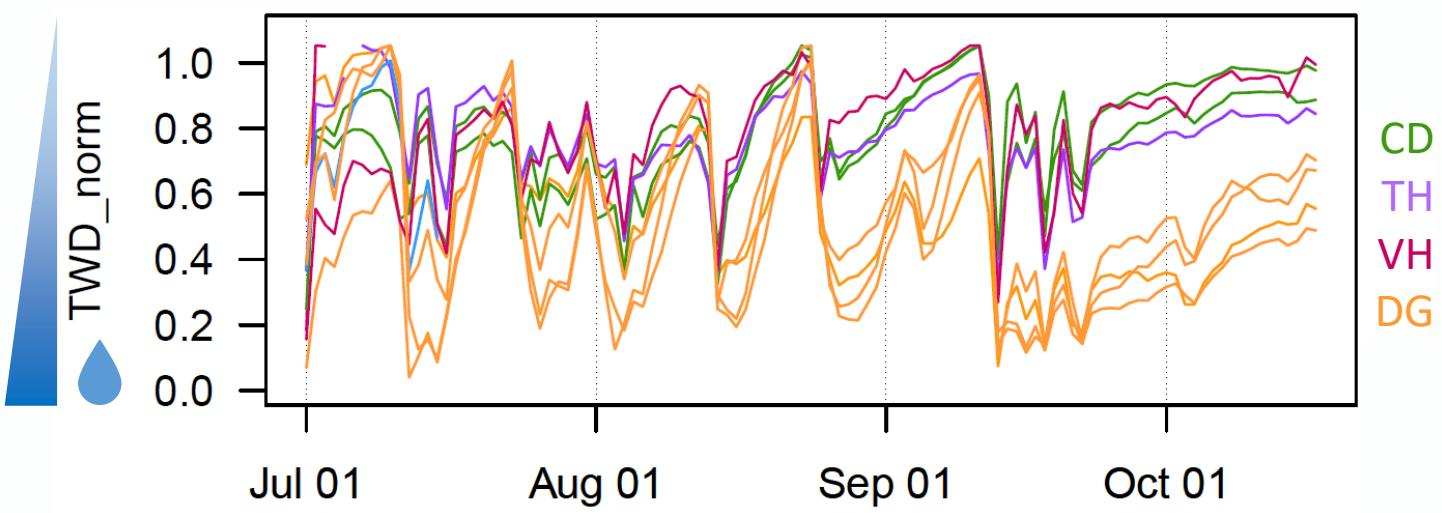
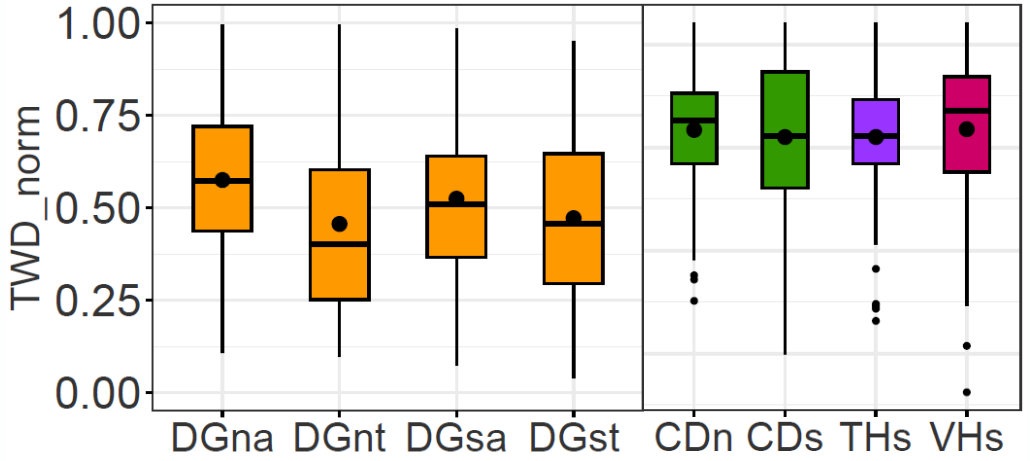
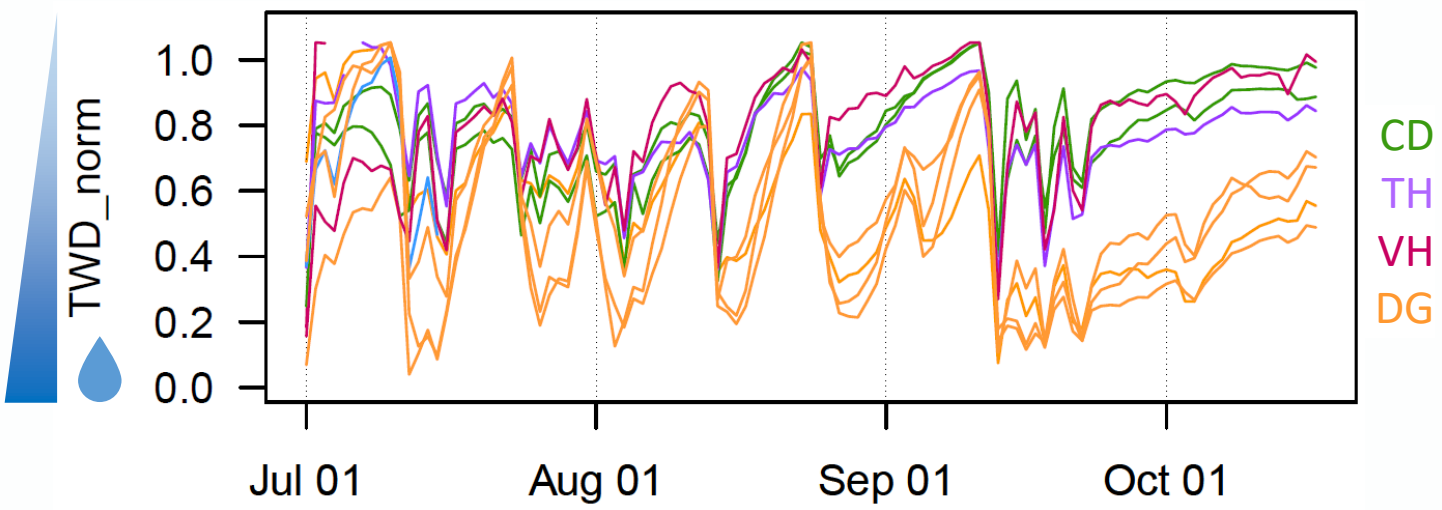


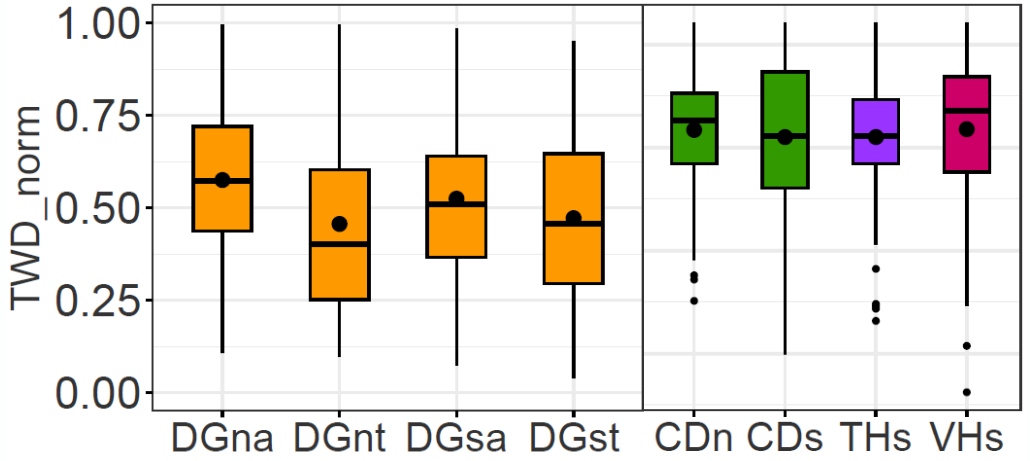


Intersite variability > interspecie variability

Water deficit: **DG** < CD, TH, VH

DENDRO. SITES DIFFERENCES





Intersite variability > interspecie variability

Water deficit: **DG** < CD, TH, VH

→ Soil impermeabilisation influence

GENERAL METHOD

Remote sensing 1

VHSR

++ spatial / -- temp. res.

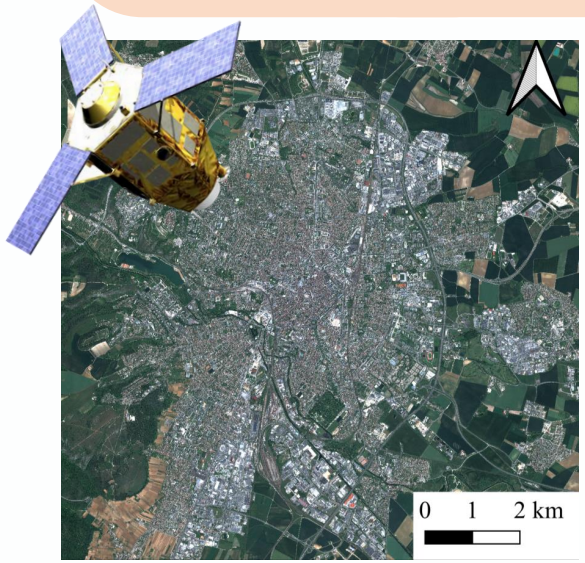
Pléiades image

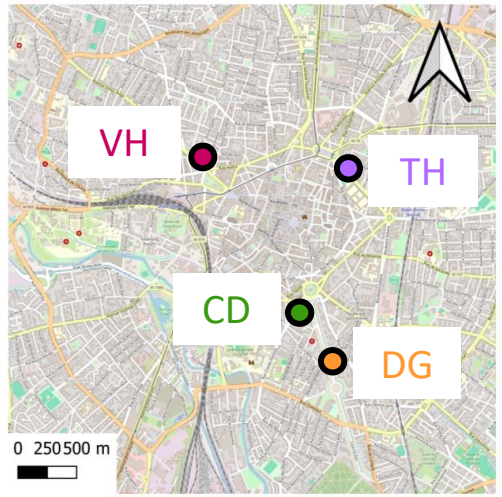
Vegetation Index

- MSAVI2

Site selection

Instrumented sites & trees





Field data

- spatial / ++ temp. res.

Microdendrometer measurements

Indicators

- Maximum Daily Shrinkage
- Tree Water Deficit

(+ Meteo measurements)

Remote sensing 2

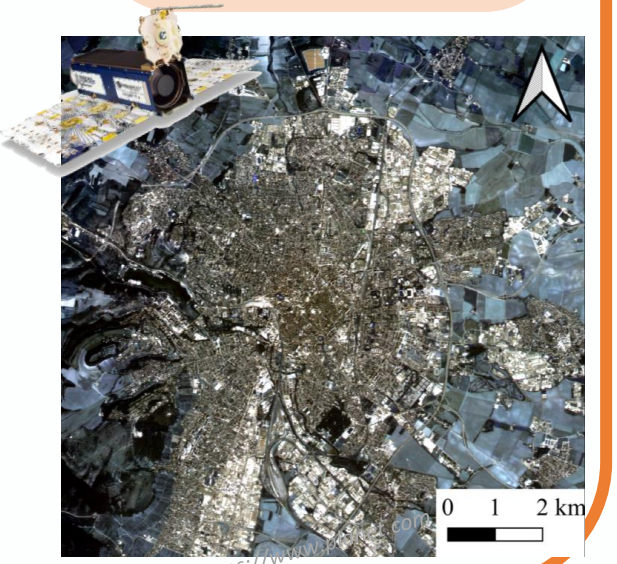
HSR

+ spatial / + temp. res.

SuperDove images

Vegetation Indices

- NDVI - SIPI



1) Are there differences in tree water status between *Acer platanoides* and *Tilia euchlora*?

2) Does the microlocal conditions impact tree water status?

3) Are remote sensing vegetation indices good proxies for tree water status?

SUPERDOVE IMAGES

| OBSERVATIONS

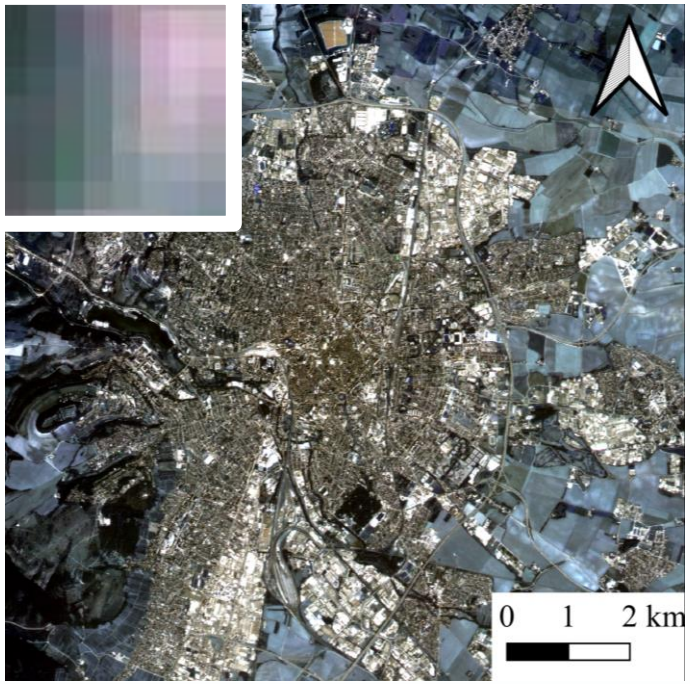
Next-generation satellite (>2018)

+ spatial (High spatial resolution (3m))
+ temp. (Daily revisit time)

Jul. 2023 → Dec. 2023 = 40 images

Tree crown manual delimitation

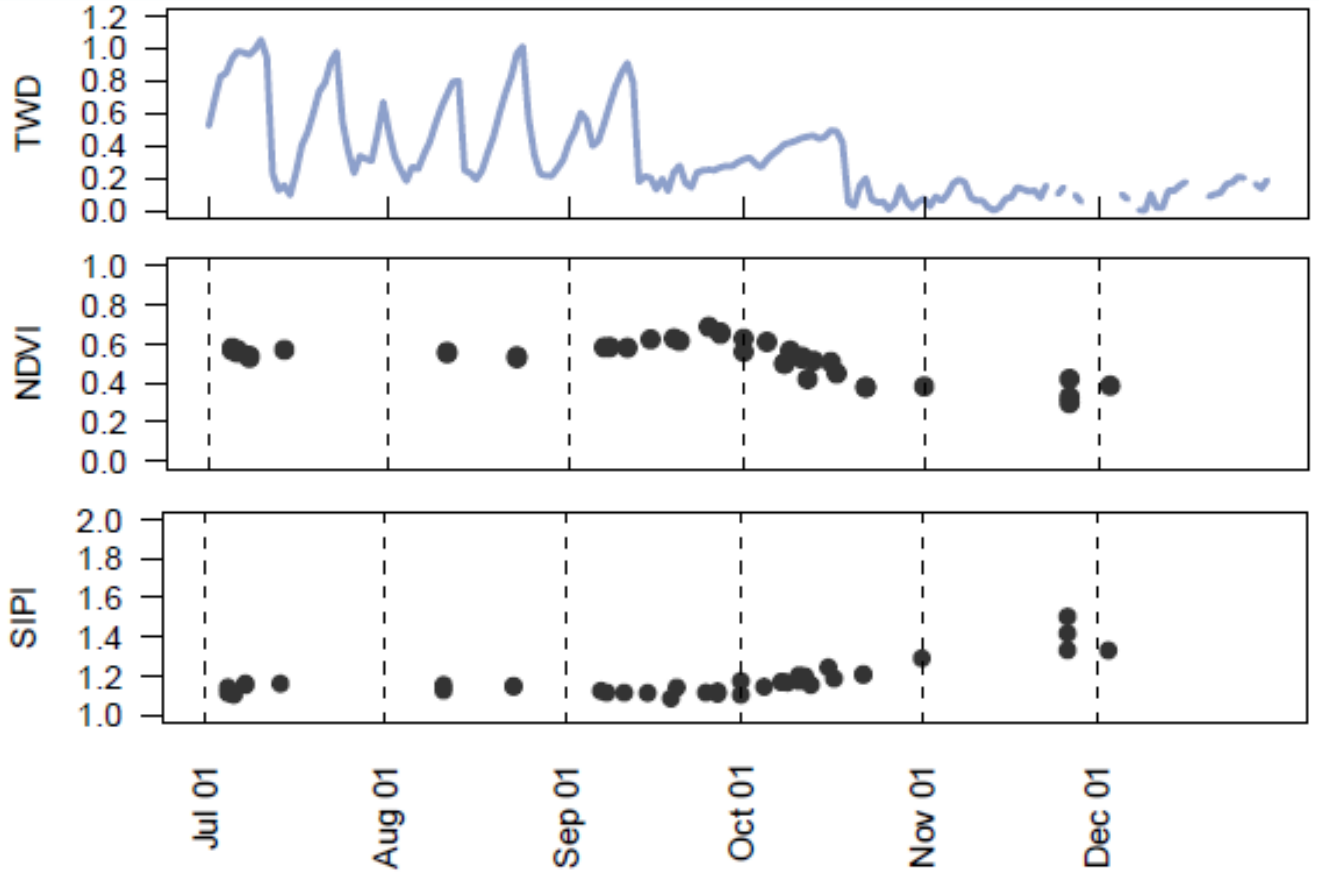
Mean of pixel vegetation indices per crown



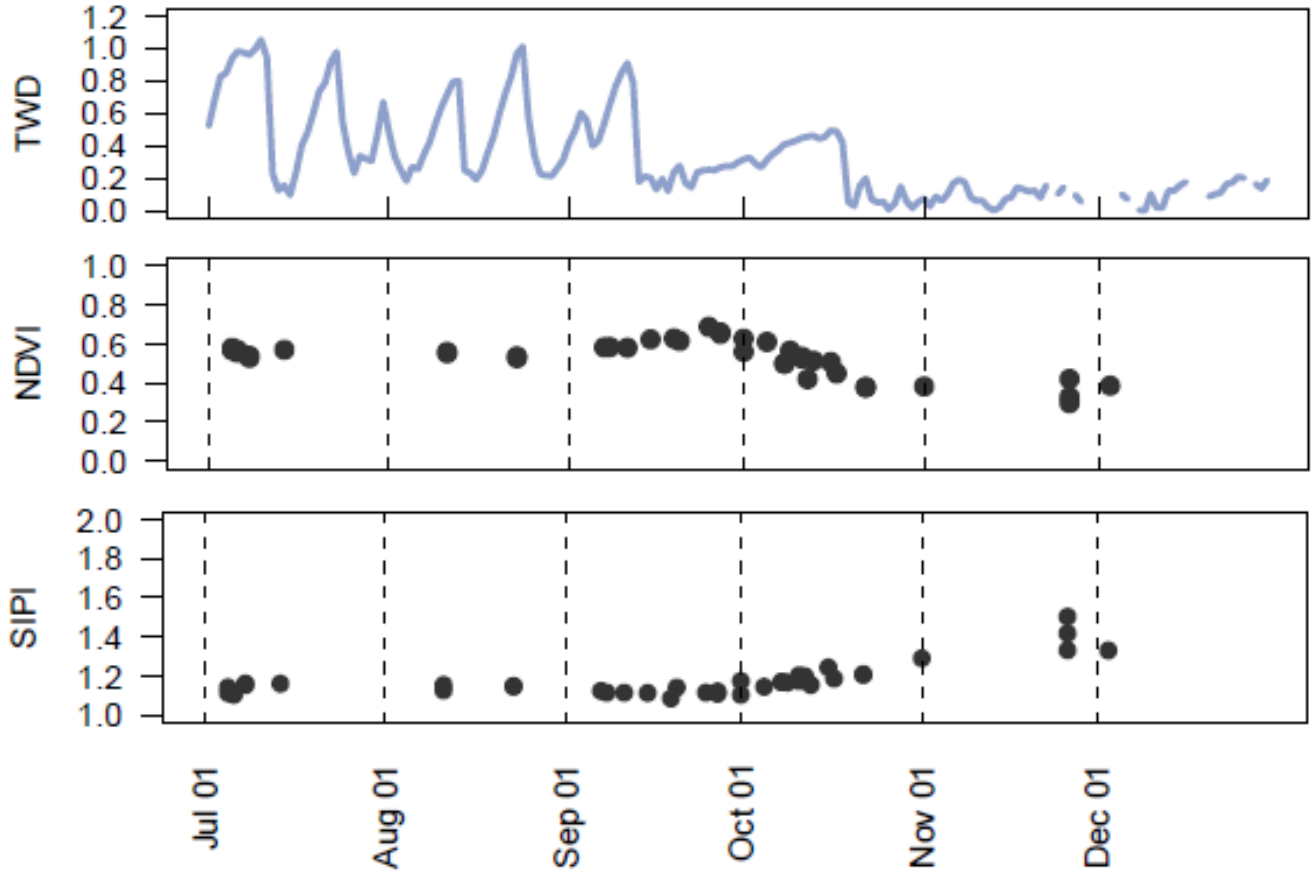
Bands	Wavelength
Coastal Blue	431 - 452 nm
Blue	465 - 515 nm
Green I	513 - 549 nm
Green II	547 - 583 nm
Yellow	600 - 620 nm
Red	650 - 680 nm
Red-Edge	697 - 713 nm
NIR	845 - 885 nm

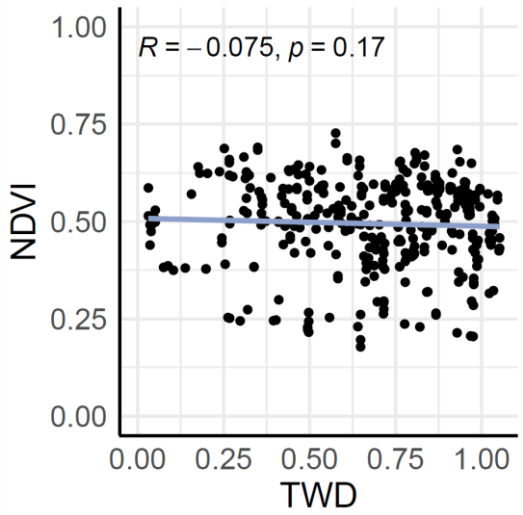
Index	Vegetation index formula
NDVI	$(\rho_{NIR} - \rho_{red}) / (\rho_{NIR} + \rho_{red})$
SIPI	$(\rho_{NIR} - \rho_{blue}) / (\rho_{NIR} - \rho_{red})$

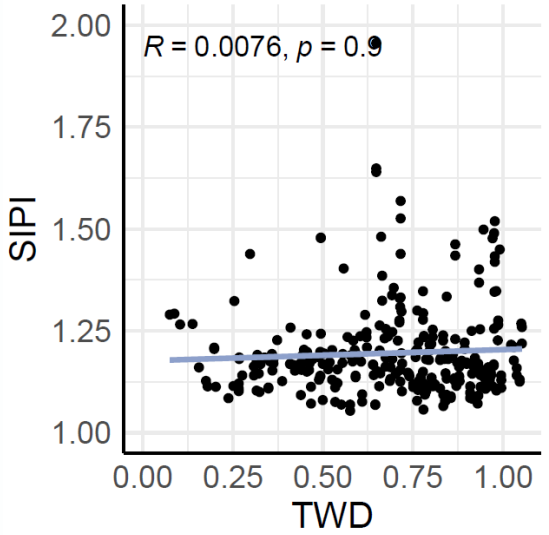
SUPERDOVE DATA NEW INSIGHTS



SUPERDOVE DATA NEW INSIGHTS

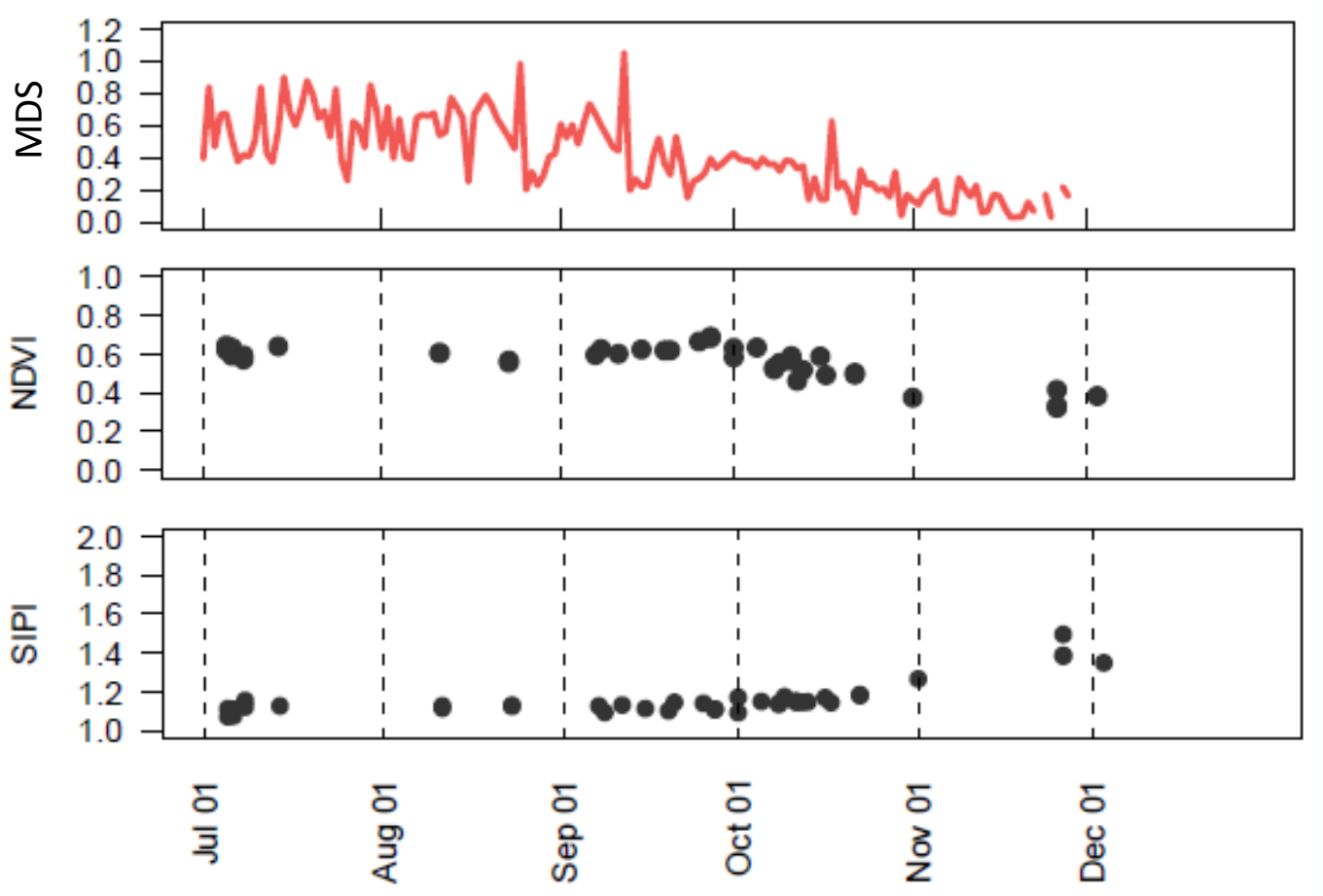


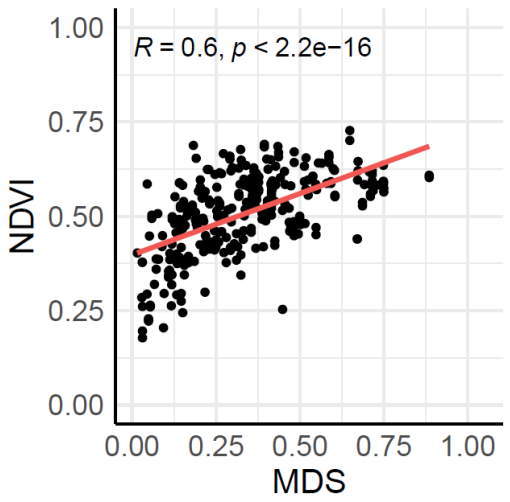


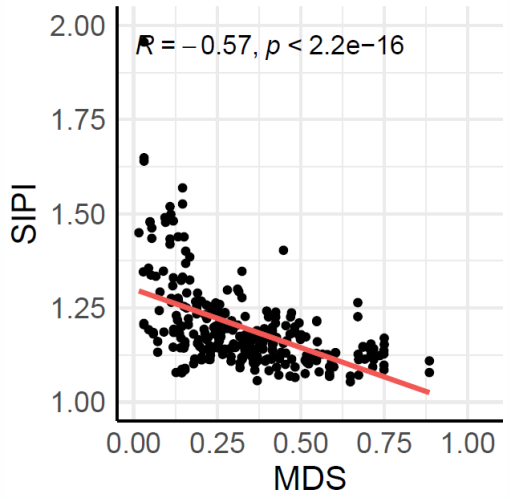


→ **No significant correlation**

SUPERDOVE DATA NEW INSIGHTS







→ **Significant correlation** ($p < 0.05$)

CONCLUSIONS

TWD ***Tilia*** < TWD ***Acer***
Acer variability < ***Tilia*** variability

Intersite variability > interspecie variability
Soil permeabilisation influence

PERSPECTIVES

Second campaign of measurements (parcs vs streets)

Tensiometric probes in soil to measure available water for trees.

CONCLUSIONS

TWD ***Tilia*** < TWD ***Acer***
Acer variability < ***Tilia*** variability

Intersite variability > interspecie variability
Soil permeabilisation influence

SuperDove vegetation indices and
microdendrometric indicators :
- no significant correlation with **TWD**
- significant correlation with **MDS**

→ Encouraging preliminary result to build the spatial model.

PERSPECTIVES

Second campaign of measurements (parcs vs streets)

Tensiometric probes in soil to measure available water for trees.

Estalish **relation rules** between **MDS** and **SuperDove vegetation indices** and meteorological and morphological conditions

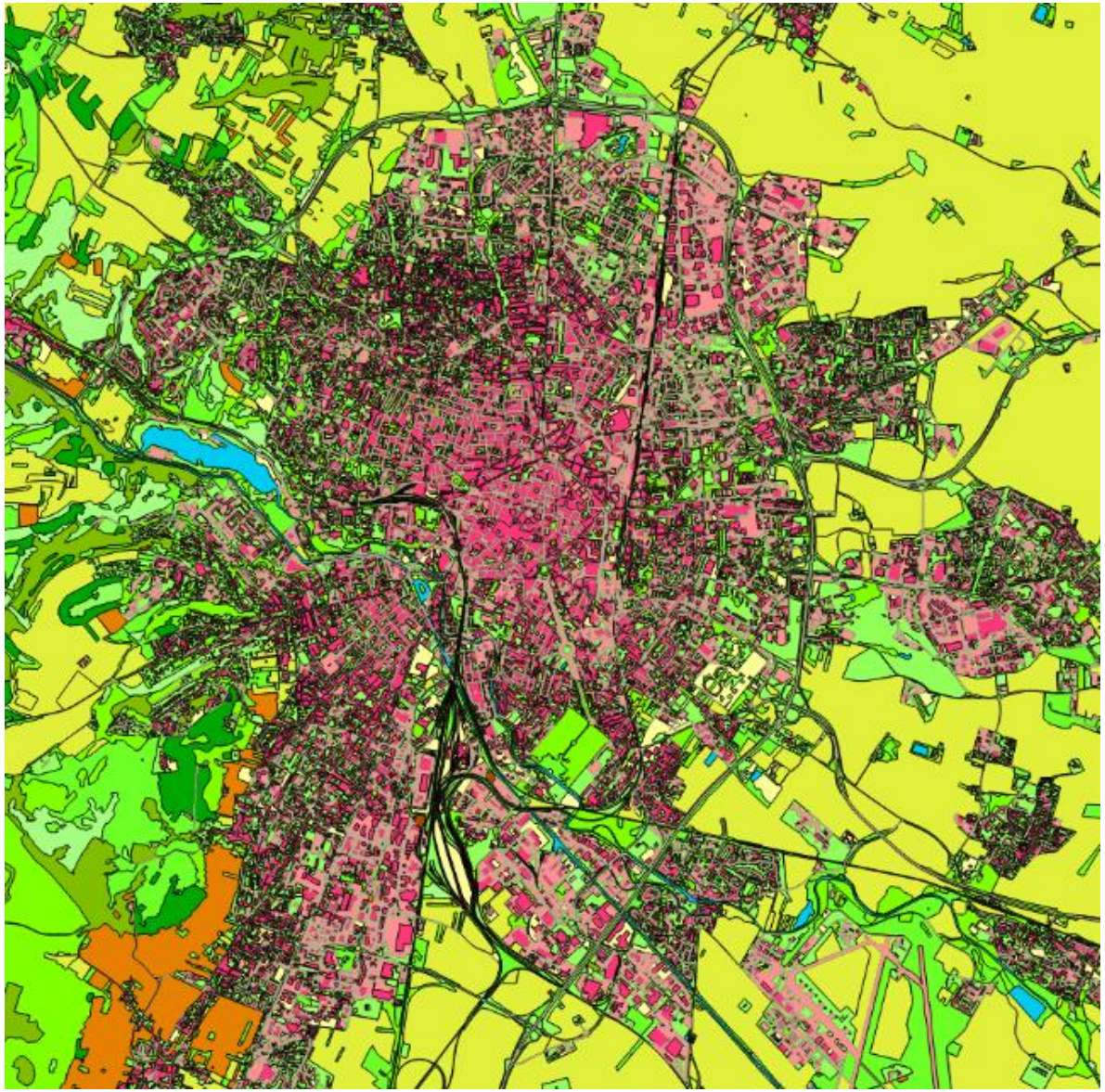
Thank you for your attention

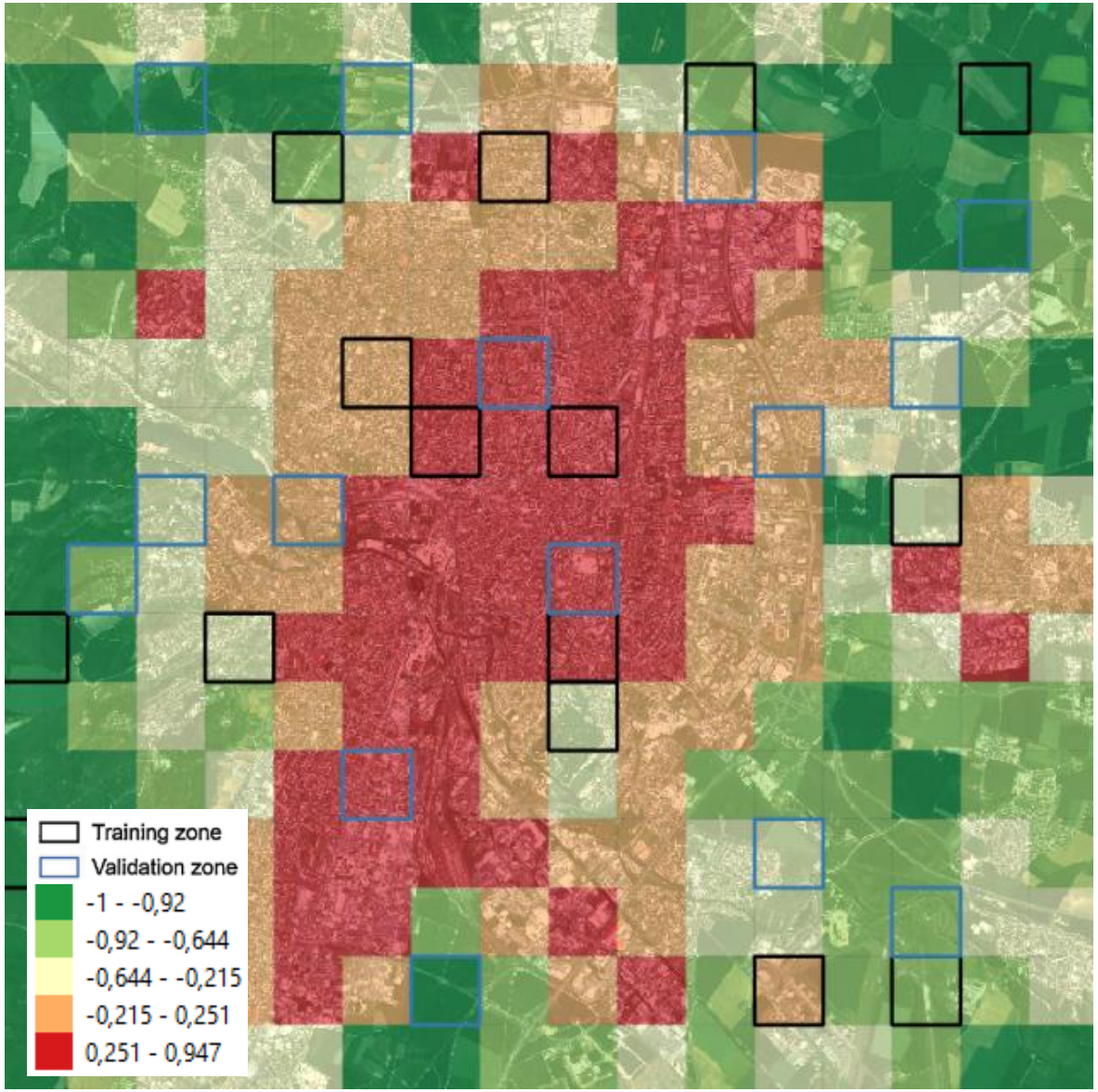
Lola CANOVAS
Lola.Canovas@u-bourgogne.fr

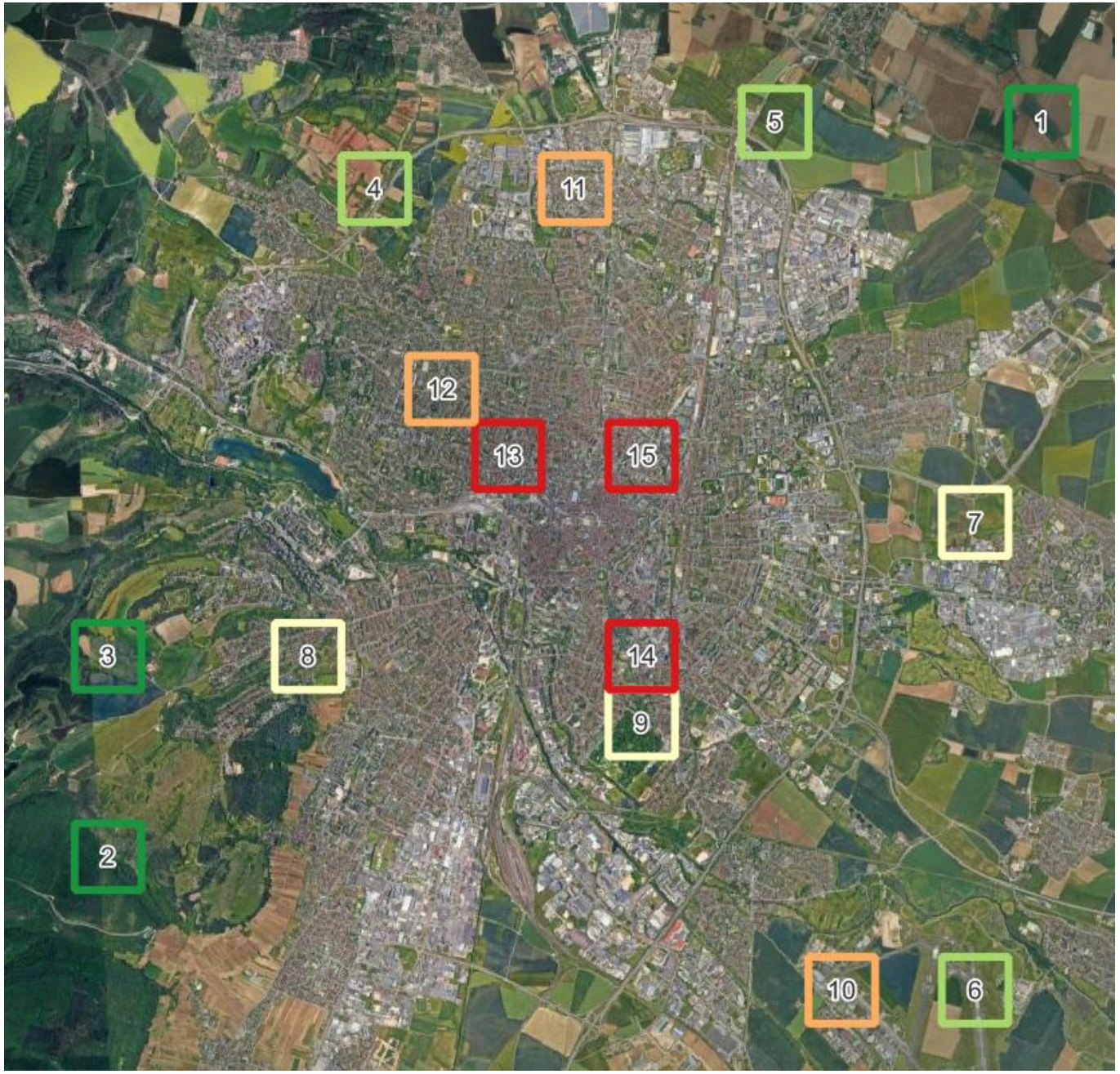
BIBLIOGRAPHY

- Brinkmann N, Eugster W, Zweifel R, Buchmann N, Kahmen A (2016) Temperate tree species show identical response in tree water deficitbut different sensitivities in sap flow to summer soil drying. Tree Physiol 36:1508–1519
- Zweifel R, Haeni M, Buchmann N, Eugster W (2016) Are trees able to grow in periods of stem shrinkage? New Phytol 211(3):839–849
- Puissant A, Rougier S, Stumpf A (2014) Object-oriented mapping of urban trees using Random Forest classifiers. International Journal of Applied Earth Observation and Geoinformation 26:235–245

$$Iu = \frac{A_{NV} - A_V}{A_T - A_W}$$



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2
10
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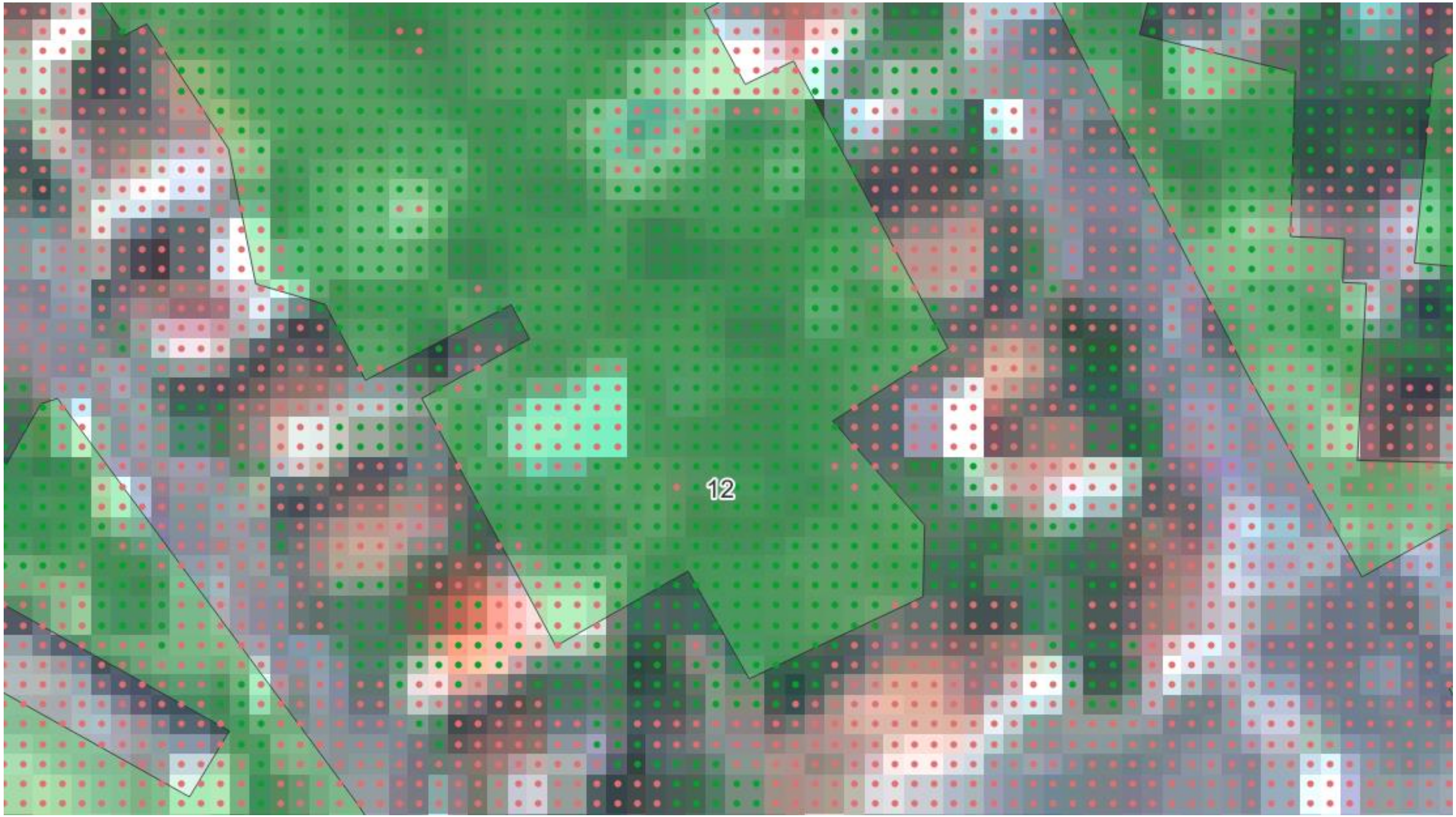
4
8
12
13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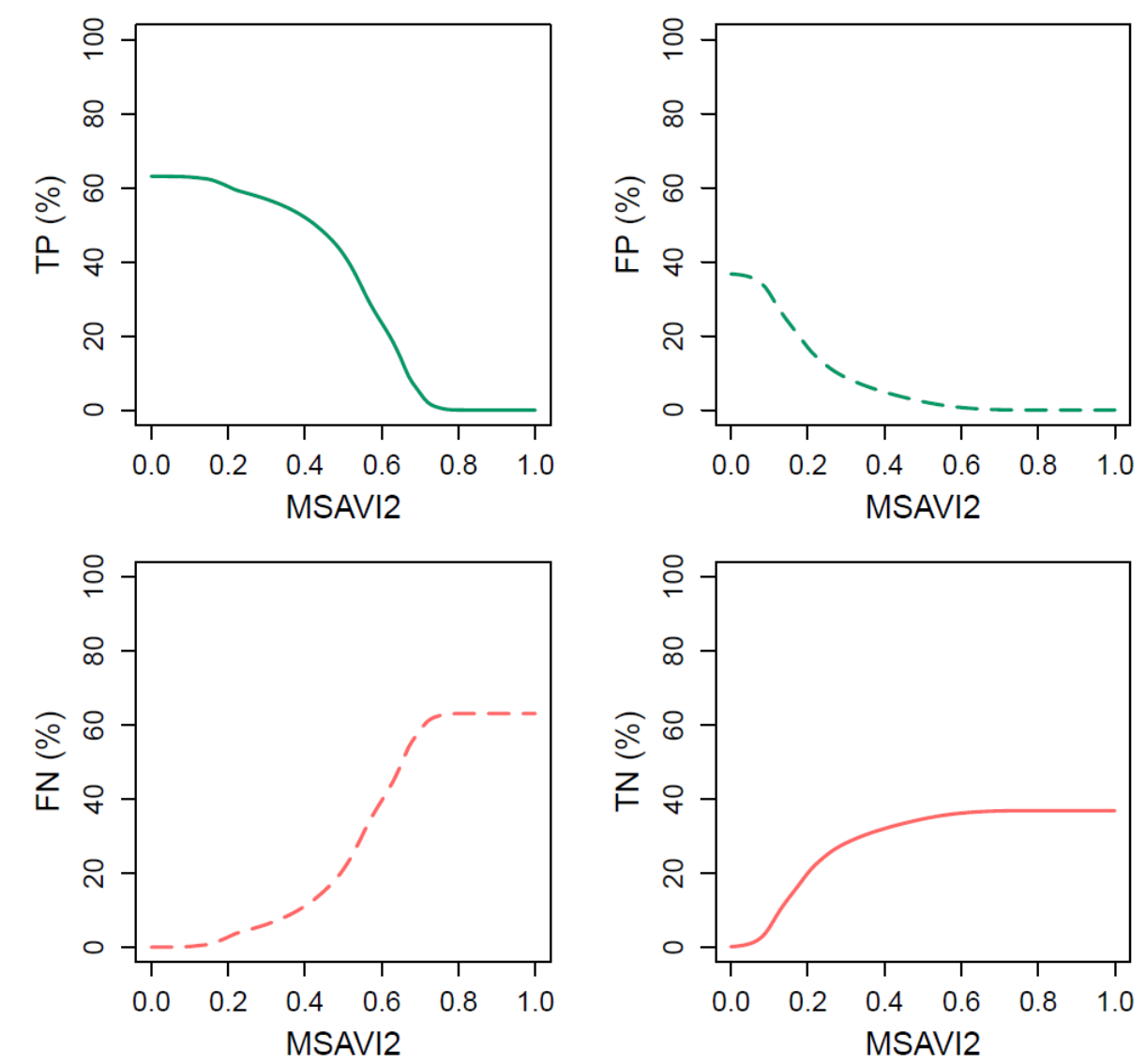
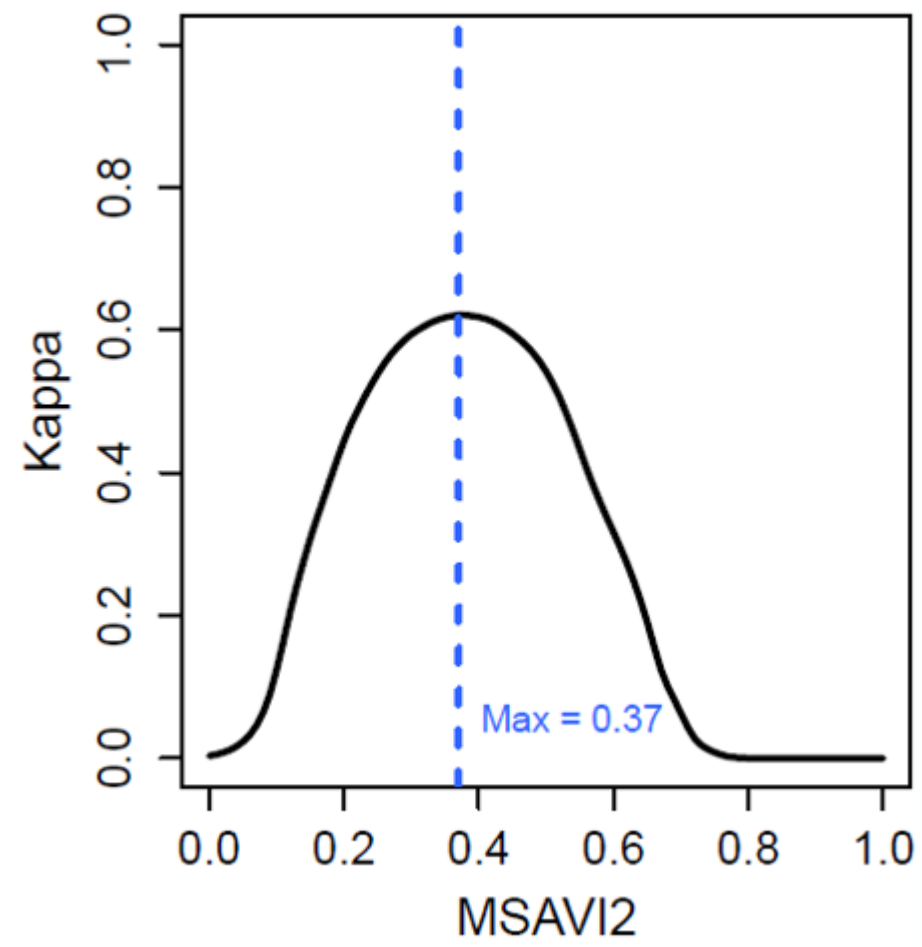
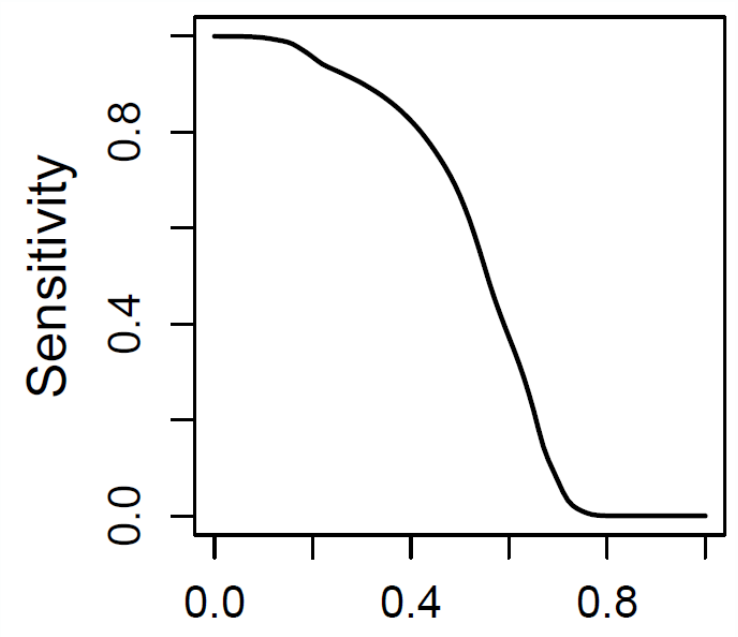
ANNEXE



kappa(k) = (Pr(a) - Pr(e)) / 1 - Pr(e)
exprime la précision de la classification d'une image

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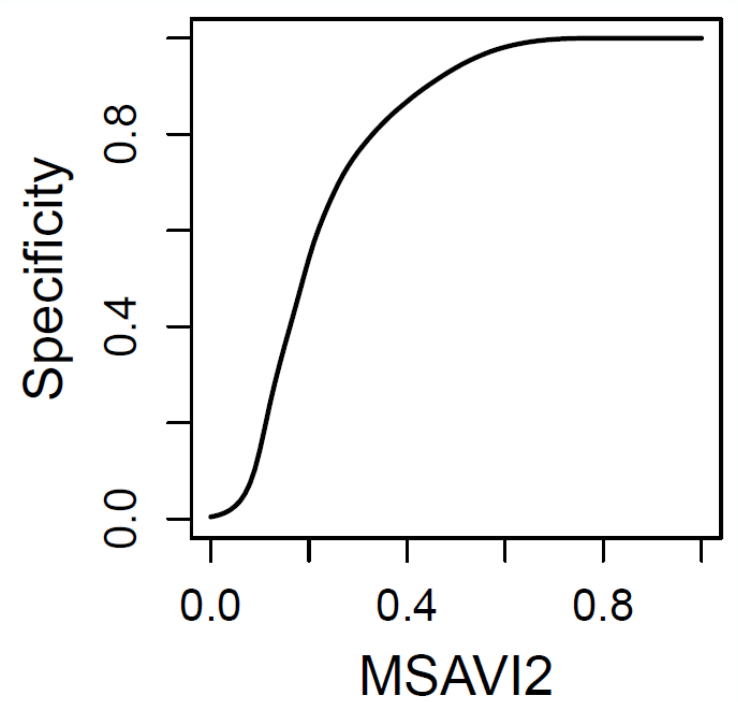
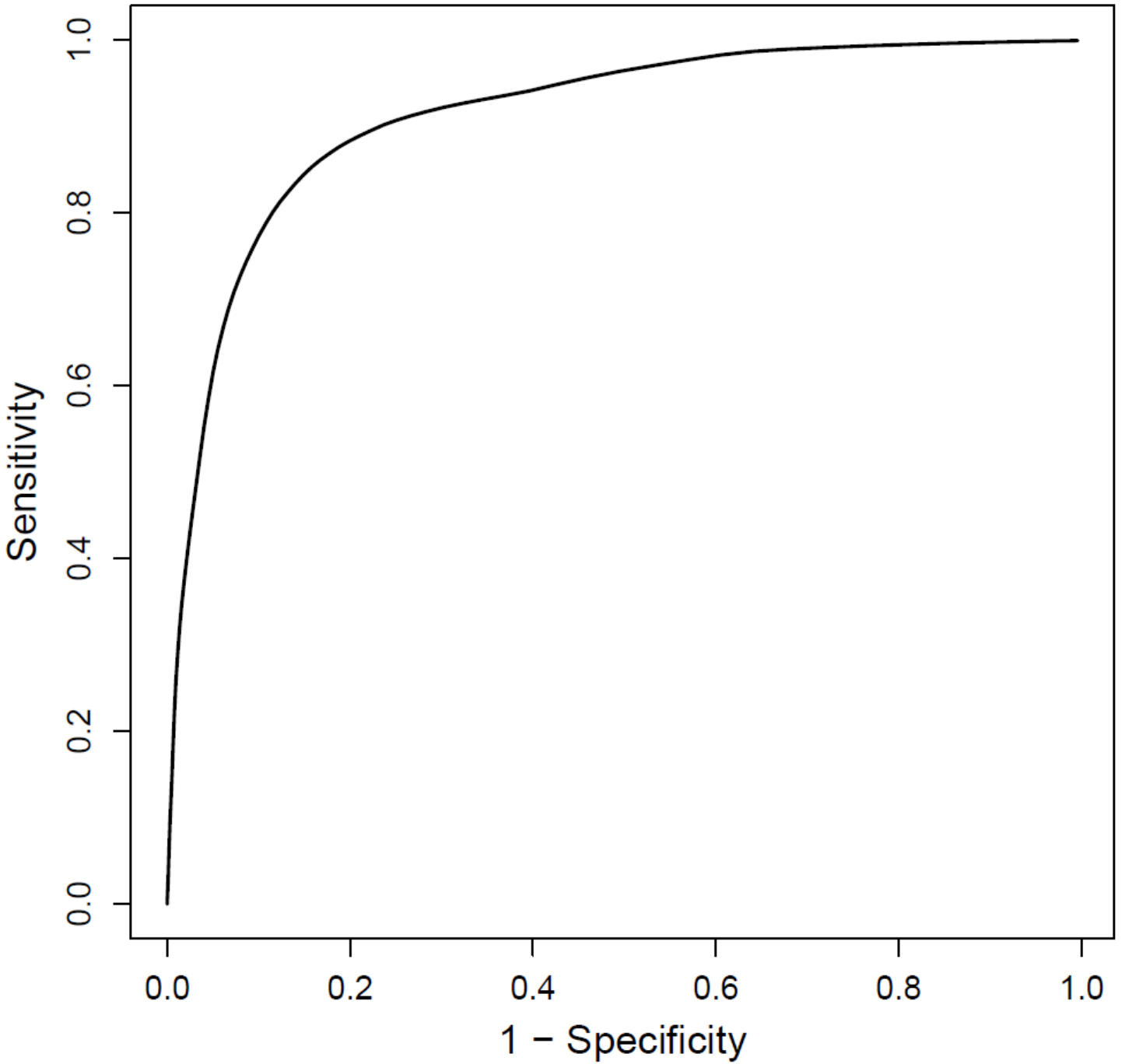
0.4
0.8
0.0
0.4
0.8


Specificity
0.0
0.4
0.8
0.0
0.4
0.8
MSAVI2


Sensitivity
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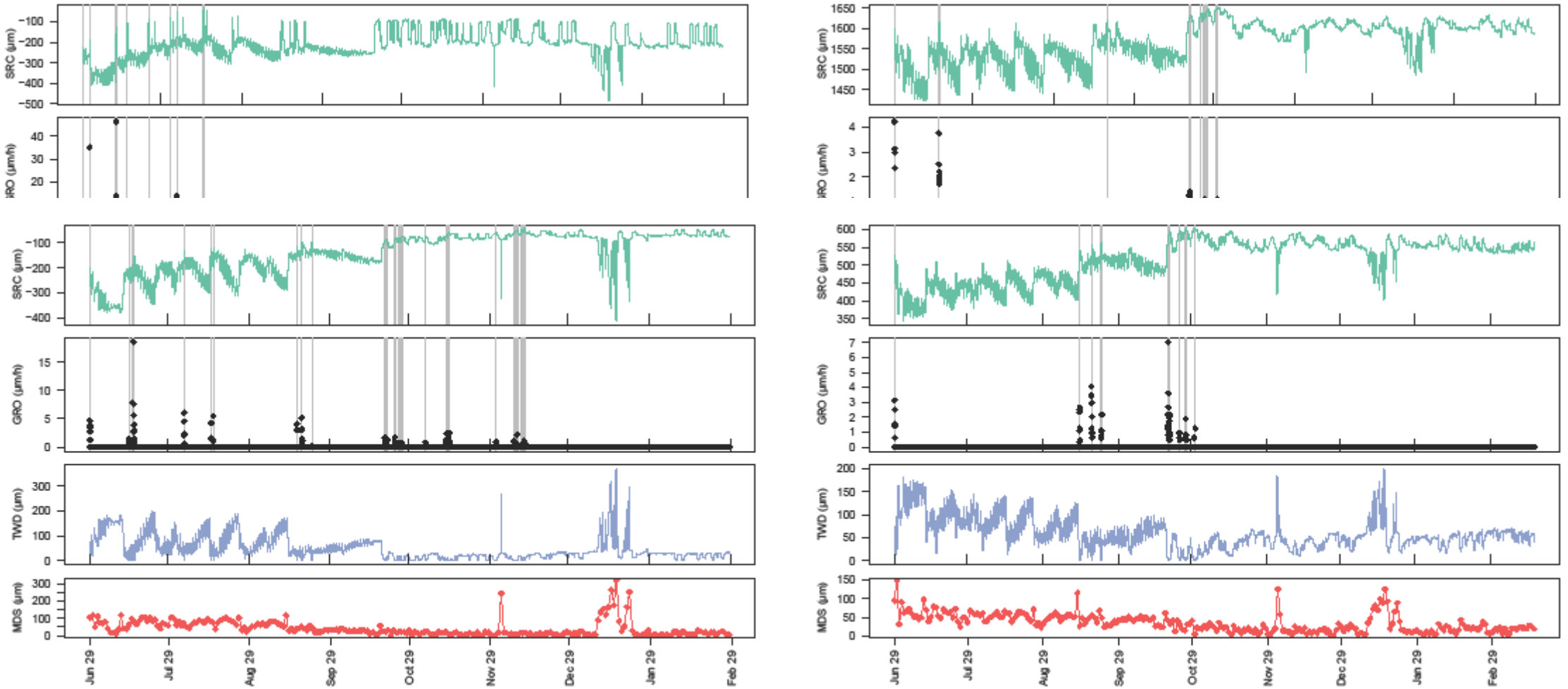
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0
1 − Specificity


12

ANNEXE

- NETTOYAGE DES DONNEES MICRODENDROMETRIQUES



ANNEXE

Table 3

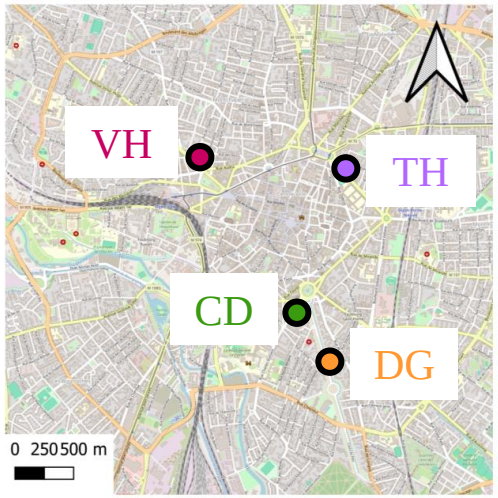
Traits and plant responses relevant for drought resistance in the five studied species according to the results of this study and some published literature results. *Fagus sylvatica* as a relatively drought sensitive species is listed for comparison, based on the studies of Backes and Leuschner (2000), Zimmermann et al. (2015), Knutzen et al. (2017), Leuschner et al. (2019) and Weigel et al. (2023). The traits/responses are assessed in relative terms in their assumed positive effect on the fitness during drought (from clearly positive '+ +' to indifferent (±) and clearly negative '— —'; '?' no data or unclear). We judged more negative P_{TLP} and P_{50}, larger HSM, deeper rooting, P_{50} acclimation, osmotic adjustment, fine root biomass adjustment (increase upon reduced precipitation), higher growth resistance and resilience, higher stem water storage, and sensitive stomatal regulation (which prevents Ψ drops to P_{12} or P_{50}) as leading to higher drought resistance, while higher tree water consumption, negative growth trends, increasing growth synchrony and pointer year frequency, and higher crown damage are assessed as indicators of reduced resistance. While most data for the first five species are from this study, some morphological, physiological and dendrochronological data are taken from Pigott (1991), Bréda et al. (1992), Tissier et al. (2004), Leuzinger et al. (2005), Hemery et al. (2009), Dietrich et al. (2018), Lobo et al. (2018), Kunz et al. (2018), and Latte et al. (2020). The information for *Fagus sylvatica* is mostly derived from Leuschner (2020).

	Acer	Carpinus	Fraxinus	Quercus	Tilia		Fagus
Sensitive stomatal regulation	+	+	— —	± ?	+ +		—
Turgor loss point P_{TLP}	—	+ +	+ +	+	±		+ +
Embolism resistance (P_{50}/P_{88})	+ +	+ +	— ?	+ + ?	±		±
Hydraulic safety margin	+ +	+	+ ?	+ + ?	±		—
P_{50} acclimation to drought	—	—	?	?	+		±
Osmotic adjustment	—?	+ +	+ +	+ +	+ +		+ +
Tree water consumption	±	+	+ +	±	—		±
Stem water storage	+	+	—	—	+ +		+
Maximum rooting depth	+	+	+	+ +	+		+
Fine root drought sensitivity	+	±	+	+ +	—		—
Fine root biomass adjustment	+ +	+	—	—	+		+ +
Growth synchrony increase	+	?	+	+	+		—
Growth resistance to drought	—	?	+	+ +	—		—
Growth resilience to drought	+	?	+ +	+ +	+		±
Neg. pointer year increase	+	?	+	+	+		— —
Long-term growth trend	+	?	+ +	+ +	+ +		— —
Crown damage 2018/19	+	—	+	+ +	±		— —
Drought resistance ranking	**2**	**4**	**2**	**1**	**3**		**5**

METEOROLOGICAL STATIONS

| MEASUREMENTS

Canovas, 2023



4 MétéoDataPIAF stations

RT (°C) – Radiant Temperature

T (°C) – Temperature

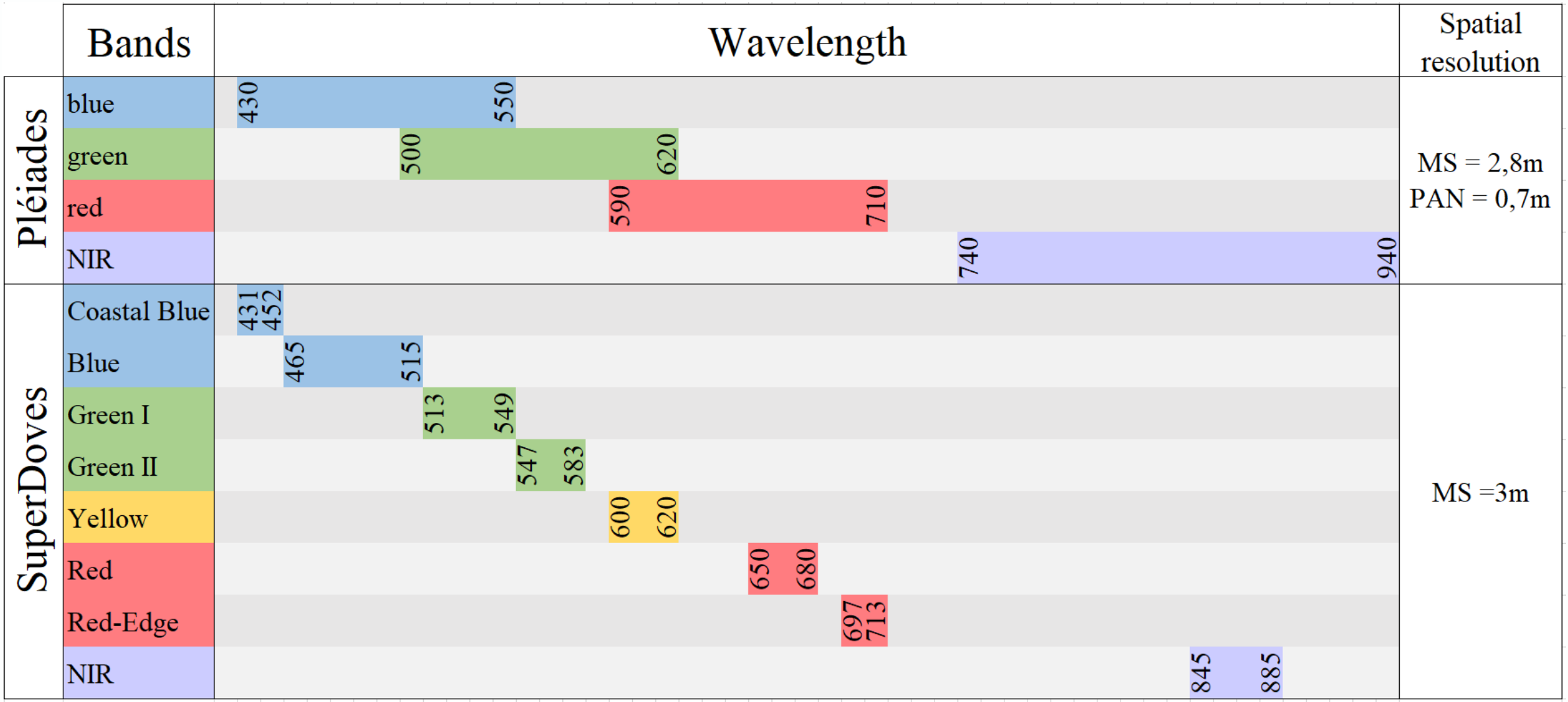
HR (%) – Relative Humidity

VPD (kPa) – Vapor Pressure Deficit (Allen *et al.*, 1998)

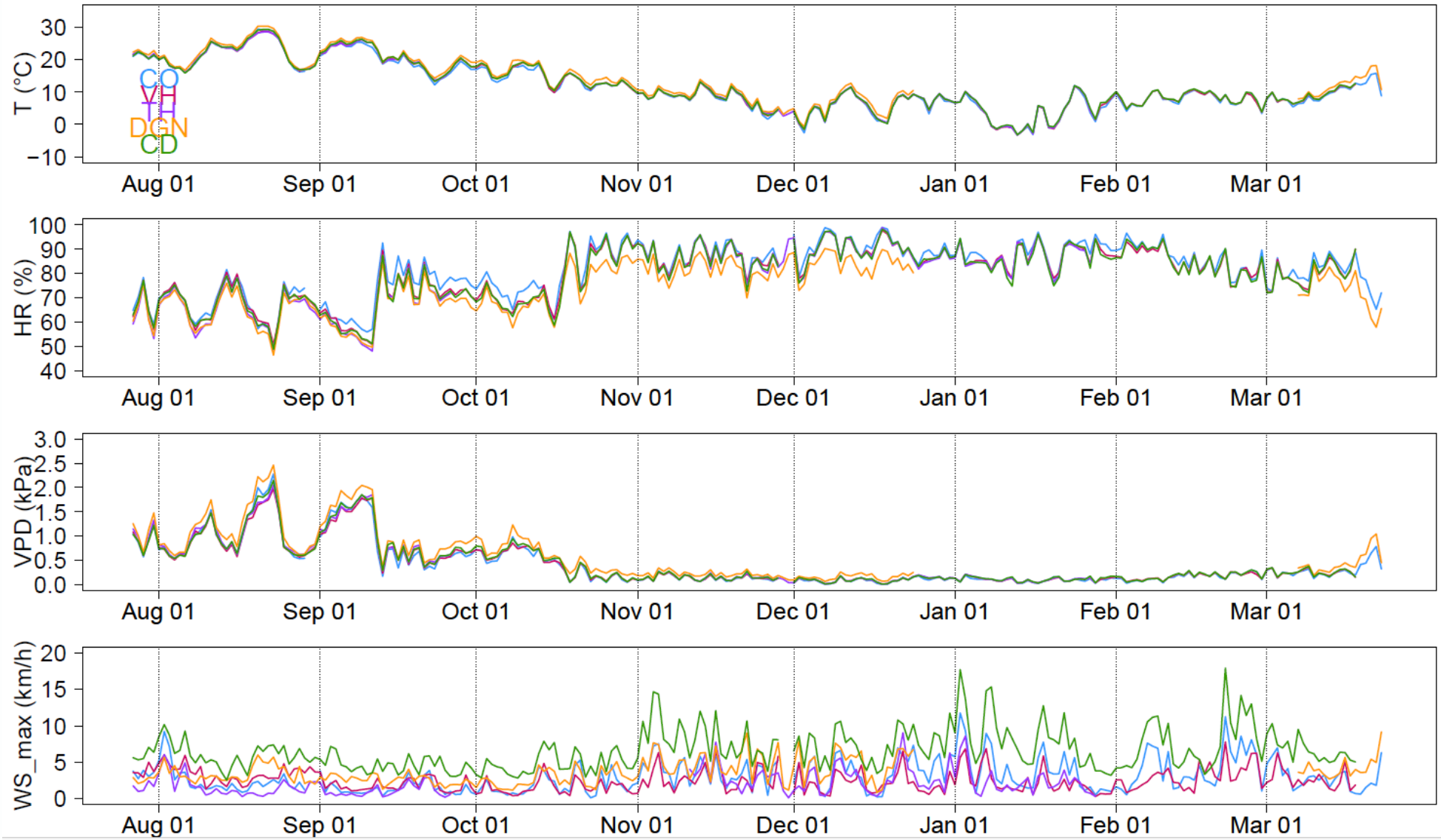
WS (km/h) – Wind speed

(+ RR (mm) – Precipitation (Meteo France, Longvic))

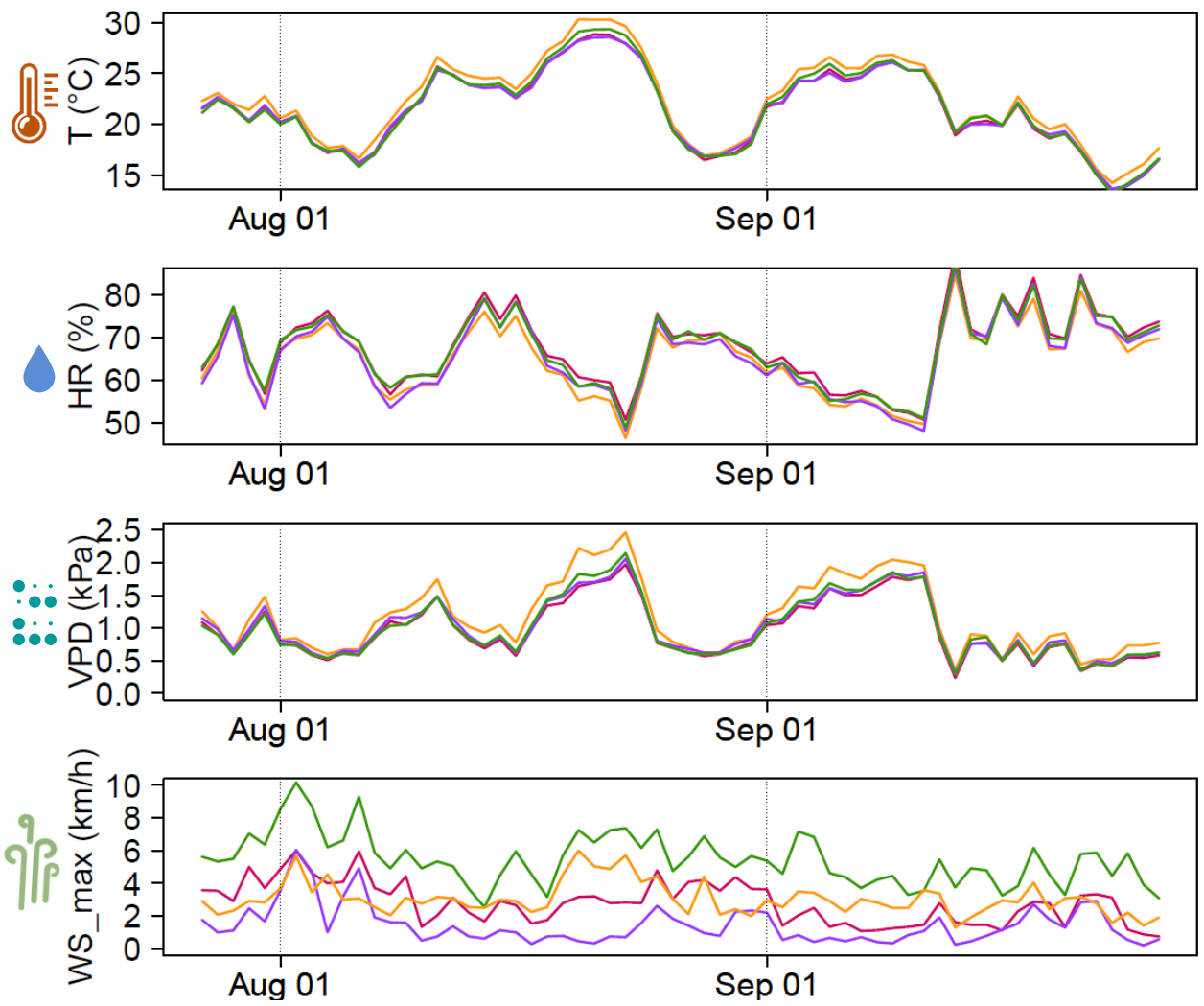
ANNEXE

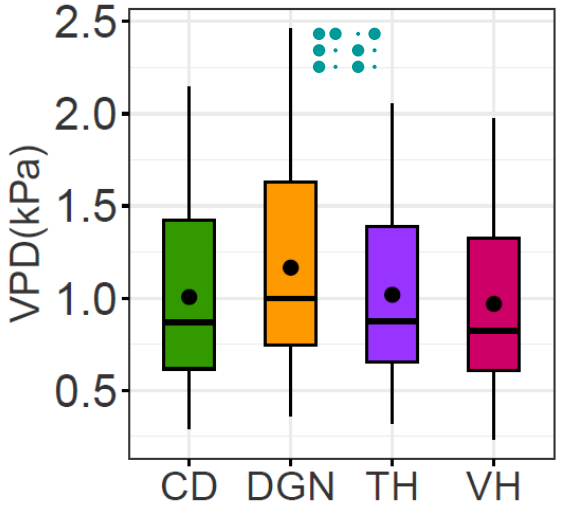

Bands
Wavelength
Spatial resolution
Pléiades
blue
green
red
NIR
430
550
500
620
590
710
740
940
MS = 2,8m
PAN = 0,7m
SuperDoves
Coastal Blue
Blue
Green I
Green II
Yellow
Red
Red-Edge
NIR
431
452
465
515
513
549
547
583
600
620
650
680
697
713
845
885
MS =3m

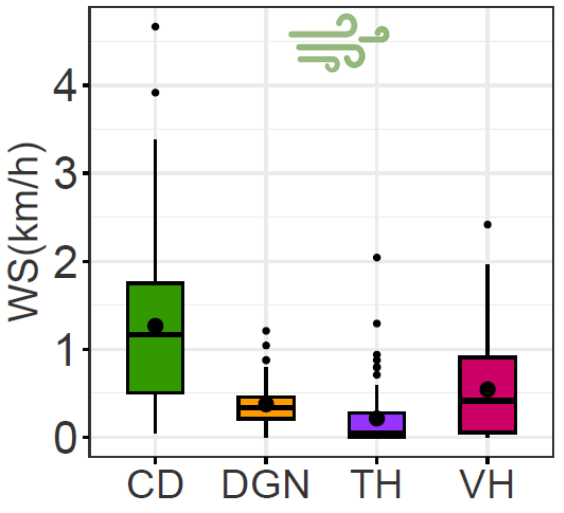
ANNEXE

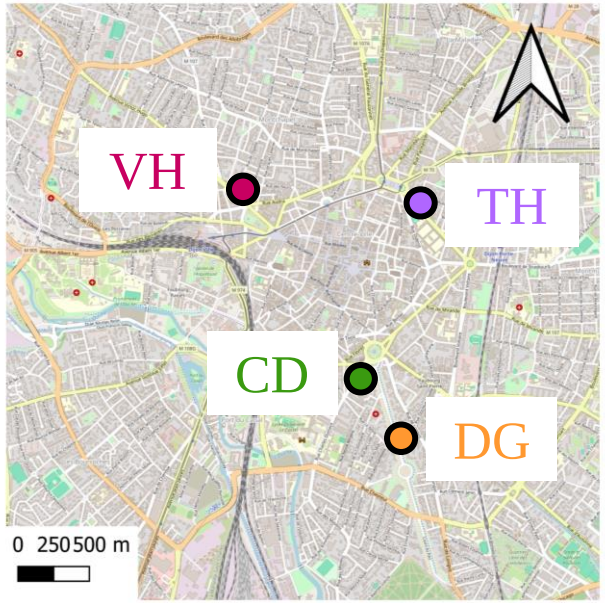

T (°C)
30
20
10
0
−10
CO
VH
DGN
CD
Aug 01
Sep 01
Oct 01
Nov 01
Dec 01
Jan 01
Feb 01
Mar 01
HR (%)
100
90
80
70
60
50
40
VPD (kPa)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
WS_max (km/h)
20
15
10
5
0

METEO. SITES DIFFERENCES









VH, CD, TH < **DG**

DG, TH < VH, CD

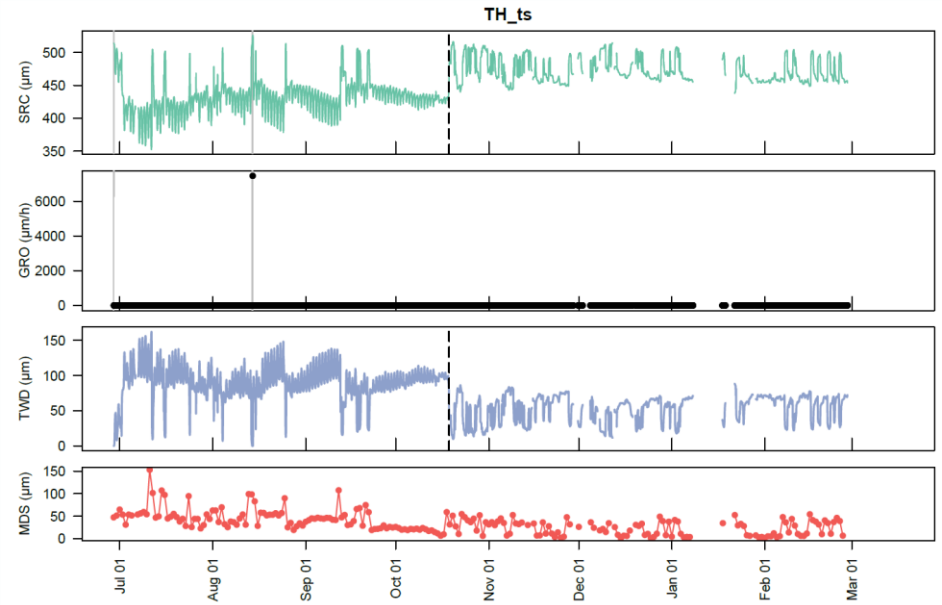
VH, CD, TH, < **DG**

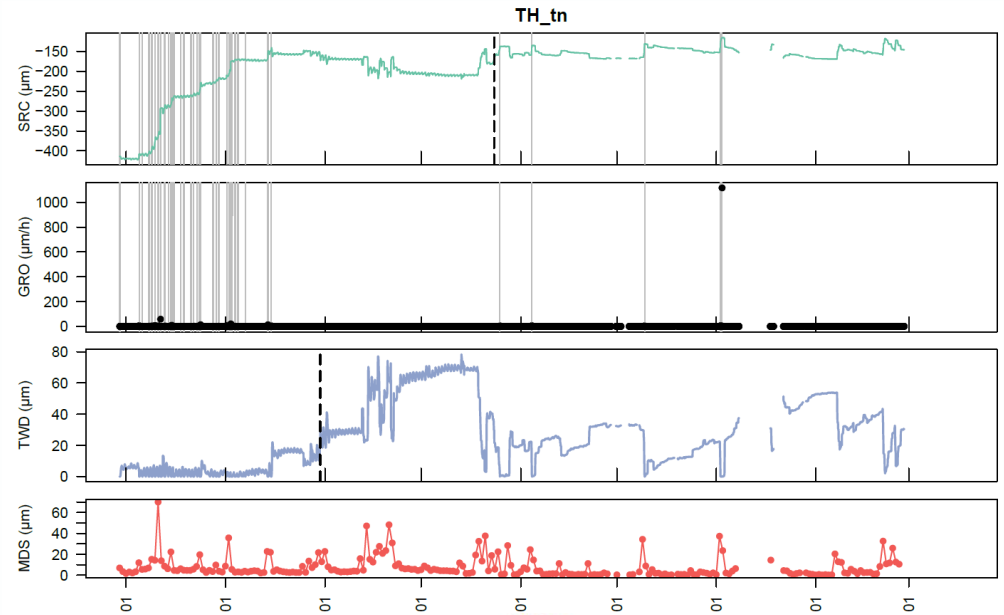
TH, DG, VH < **CD**

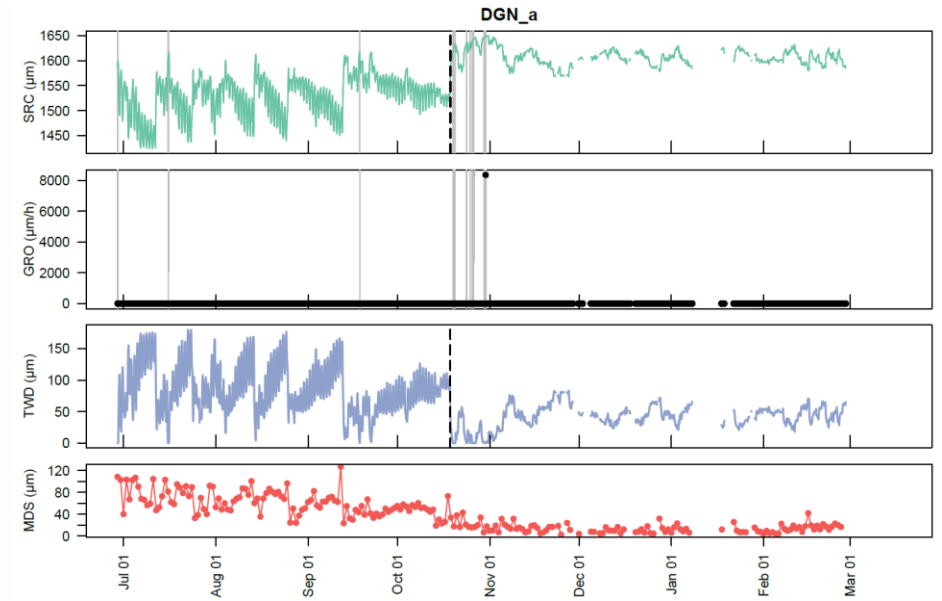
VPD ← Open/narrow street

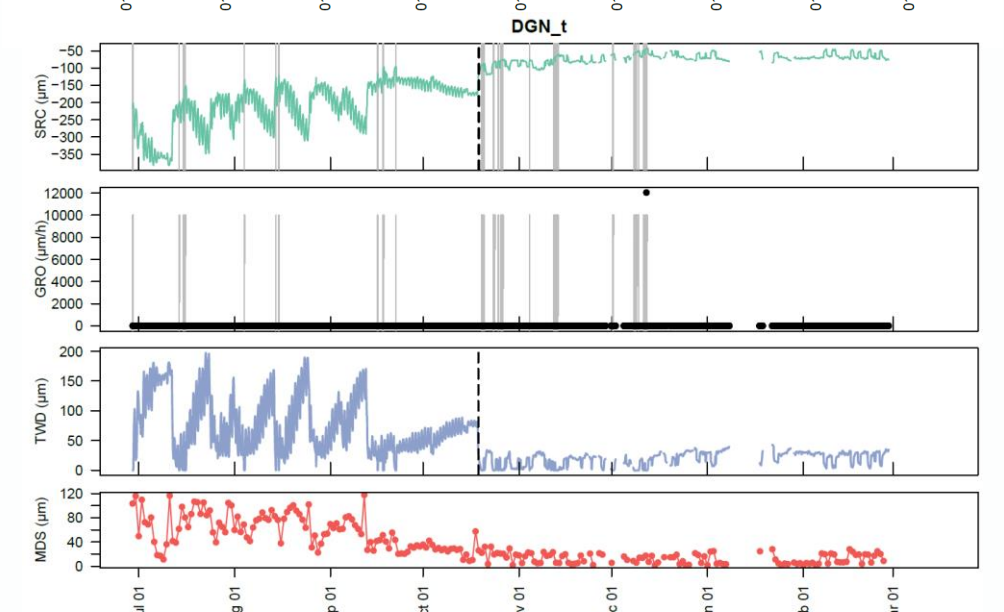
WS ← Street orientation

ANNEXE

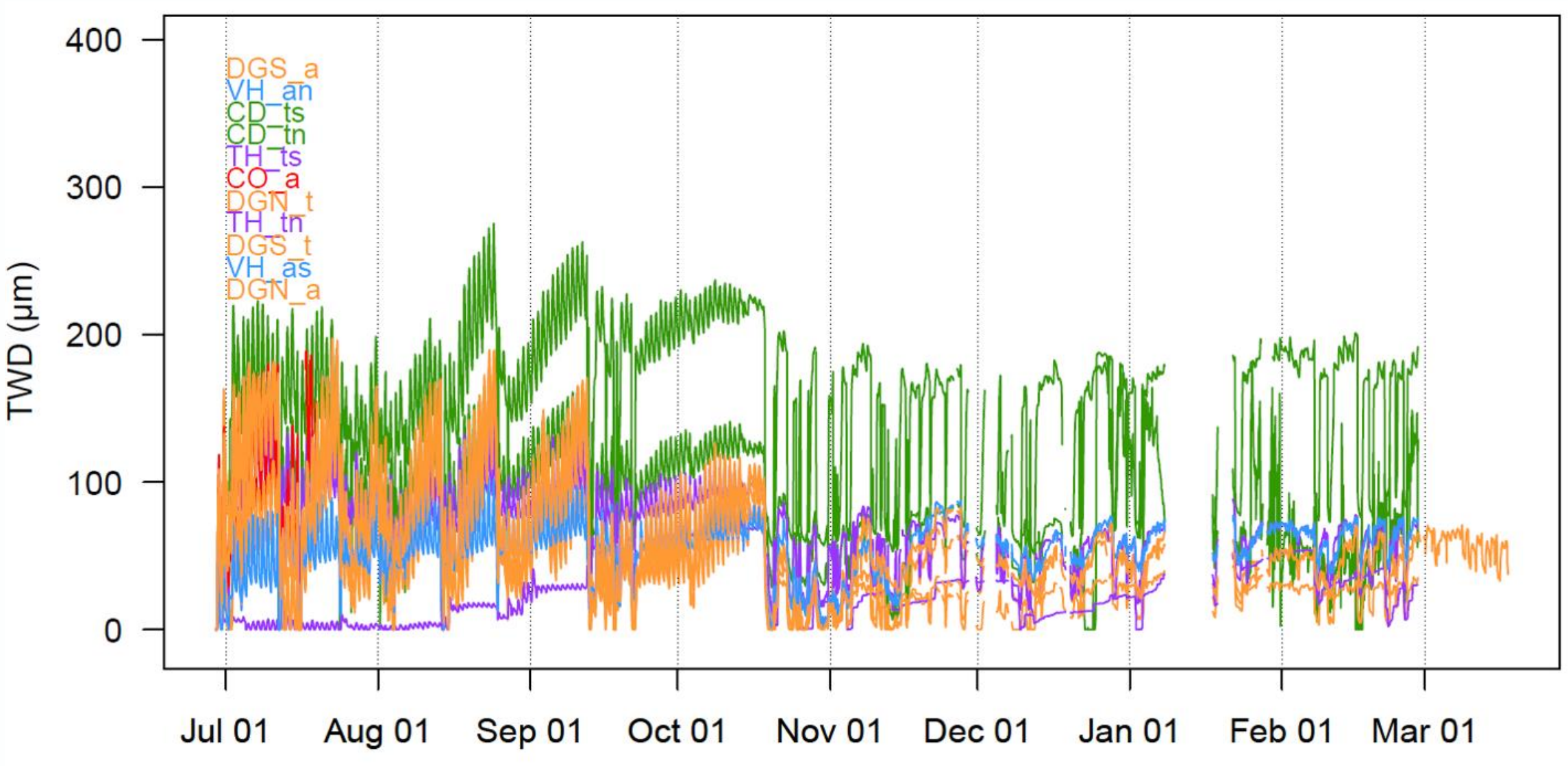

TH_ts
SRC (µm)
GRO (µm/h)
TWD (µm)
MDS (µm)
Jul 01
Aug 01
Sep 01
Oct 01
Nov 01
Dec 01
Jan 01
Feb 01
Mar 01


TH_tn
SRC (µm)
GRO (µm/h)
TWD (µm)
MDS (µm)
01

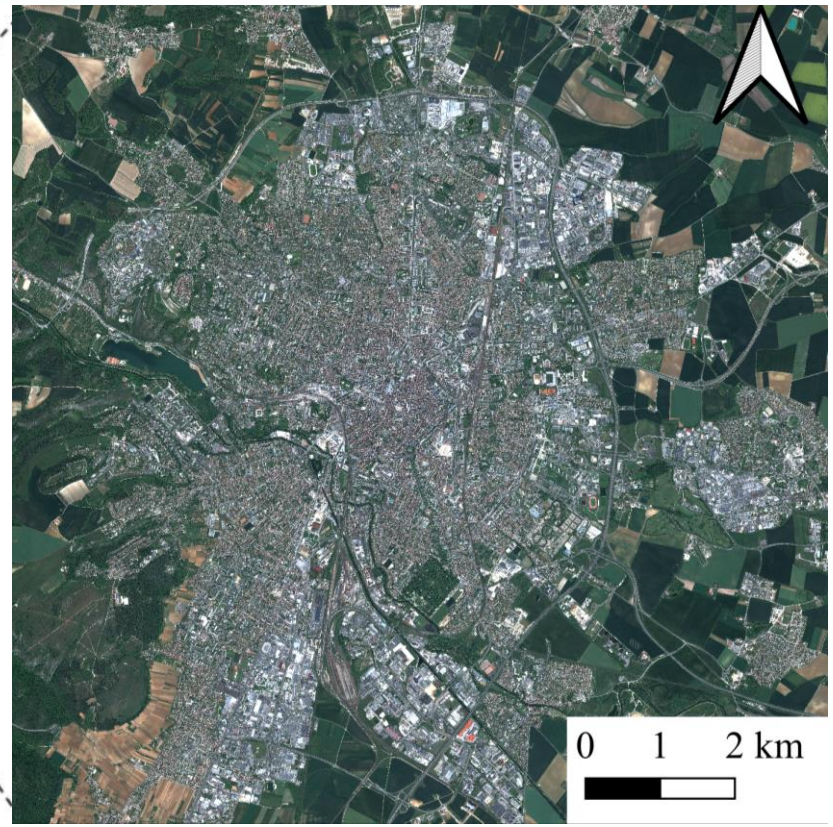

DGN_a
SRC (µm)
GRO (µm/h)
TWD (µm)
MDS (µm)
Jul 01
Aug 01
Sep 01
Oct 01
Nov 01
Dec 01
Jan 01
Feb 01
Mar 01


DGN_t
SRC (µm)
GRO (µm/h)
TWD (µm)
MDS (µm)
Jul 01
Aug 01
Sep 01
Oct 01
Nov 01
Dec 01
Jan 01
Feb 01
Mar 01

ANNEXE


400
300
200
100
0
TWD (µm)
DGS_a
VH_an
CD_ts
CD_tn
TH_ts
CO_a
DGN_t
TH_tn
DGS_t
VH_as
DGN_a
Jul 01
Aug 01
Sep 01
Oct 01
Nov 01
Dec 01
Jan 01
Feb 01
Mar 01

STUDY ENVIRONMENT



Dijon City

Mid-size european city

250,000 inhabitants (Insee, 2020)

12x13km

Majority of *Acer sp.* (27%) and *Tilia sp.* (14%)