

# Riparian vegetation mitigates river warming: exploring its large scale effects on past and future thermal regimes

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➤ Stream (water) temperature ( $T_w$ ) is a key factor for water quality, aquatic communities and socio-economic activities



**Dissolved oxygen**

**Eutrophication**

**Metabolism**

**Growth and survival of species**


**Distribution of aquatic communities**

**PLOS ONE**

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RESEARCH ARTICLE

**Direct habitat descriptors improve the understanding of the organization of fish and macroinvertebrate communities across a large catchment**

Coline Picard , Mathieu Floury, Hanieh Seyedhashemi, Maxime Morel, Hervé Pella, Nicolas Lamouroux, Laëtitia Buisson, Florentina Moatar, Anthony Maire

# Tw warming due to climate change over the past decades

Country	Sites	Period	Rate of change (°C decade <sup>-1</sup> )	Reference
France	52 278 reaches in the Loire basin	1963–2019	+0.17 to +0.72 (mean = +0.38) +0.01 to +0.65 (+0.35) in winter +0.11 to +0.76 (+0.38) in spring +0.08 to +1.02 (+0.44) in summer +0.05 to +0.81 (+0.33) in autumn	Present study
Austria	18 rivers	2010–2017	+1.9 to +3.2 in summer	Niedrist and Füreder (2021)
England	6148 sites	2000–2018	–0.4	Wilby and Johnson (2020)
Switzerland	31 rivers	1979–2018	+0.33 (±0.03) +0.6 to +1.1 in summer	Michel et al. (2020)
Poland	5 Carpathian rivers	1984–2018	+0.33 to +0.92 +0.82 to +0.95 in spring +0.75 to +1.17 in summer +0.51 to +1.08 in autumn +0.25 to +0.29 in winter	Kędra (2020)
France	11 stations on the Loire, Vienne, Rhône, Seine, and Meuse	1980–2015	+0.79 in spring	Maire et al. (2019)
Poland	6 stations on the Warta River	1960–2009	+0.096 to +0.28	Ptak et al. (2019a)
Croatia	6 stations on the Kupa River	1990–2017	+0.23 to +0.796	Zhu et al. (2019)
Switzerland	Rhine, Rhône, Aar, and Thur rivers	1983–2013	+0.27 (±0.03)	Zobrist et al. (2018)
Northern Germany	132 sites	1985–2010 1985–1995	+0.3 (±0.03) +0.69 (+0.10) in spring +0.78 (±0.06) in summer +0.75 (±0.09) in autumn +0.39 (±0.23) in winter +0.81 (±0.2) +0.9 (±0.07)	Arora et al. (2016)
England and Wales	2773 sites	1990–2006	+0.3 (±0.02)	Orr et al. (2015)
Poland	Coastal rivers (Rega, Parsęta, Śłupia, Łupawa, Łeba)	1971–2015	+0.26 to +0.31 +0.46 in April (the month with the highest trend)	Ptak et al. (2016)
France	4 stations on the Loire River	1976–2003	+0.61 to +0.71 +0.86 to +1.07 in spring and summer	Moatar and Gailhard (2006)

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Hydrology and Earth System Sciences  
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## Regional, multi-decadal analysis on the Loire River basin reveals that stream temperature increases faster than air temperature

Hanieh Seyedhashemi<sup>1,2</sup>, Jean-Philippe Vidal<sup>1</sup>, Jacob S. Diamond<sup>1</sup>, Dominique Thiéry<sup>3</sup>, Céline Monteil<sup>4</sup>, Frédéric Hendrickx<sup>4</sup>, Anthony Maire<sup>4</sup>, and Florentina Moatar<sup>1</sup>

- ✓ up to ~1°C increase in summer Tw over the past 30 years in Europe
- ✓ +0.72; +2.31 °C increase in summer Tw under RCP 4.5 in the middle of the century respect to the present

## ➤ Riparian shading:

- can reduce maximum  $T_w$  by up to  $\sim 4^\circ\text{C}$  from unshaded to fully shaded conditions in small lowland streams (Kail et al., 2020, Loicq et al., 2018)
- may mitigate the heating effect of small dams and ponds (Seyedhashemi et al., 2021; Maxted et al., 2005)
- effectiveness depends on many factors (Garner et al., 2017, Imholt et al., 2010, 2013; Dugdale et al., 2018) :
  - channel orientation
  - bank height canopy density
  - within-reach residence times
  - distance from the source
  - vegetation species

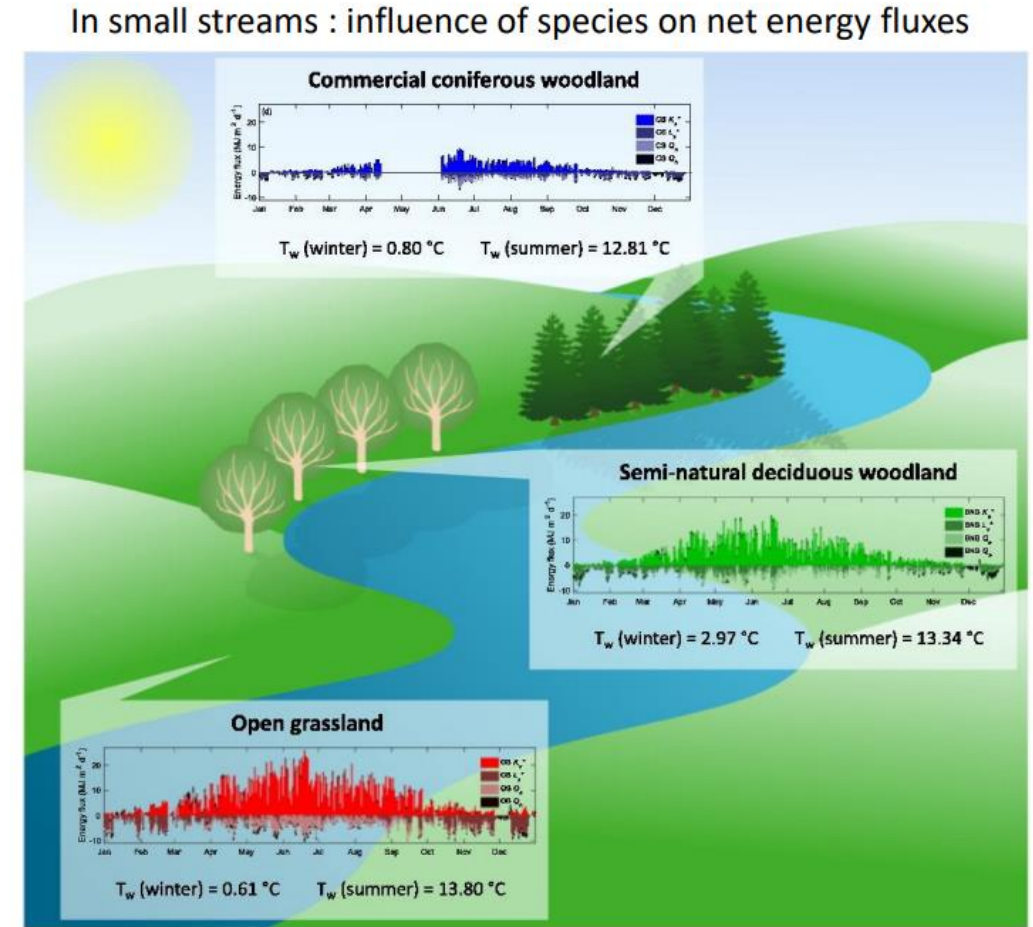


Figure adapted from Dugdale et al. (2018)

## ➤ Objectives:

- ❑ **Modelling thermal regimes under hydroclimatic factors and dynamics of riparian shading at a regional scale and a high spatial resolution over the past and future**

*Syedhashemi, H., Moatar, F., Vidal, J.-P., and Thiéry, D.: Past and future discharge and stream temperature at high spatial resolution in a large European basin (Loire basin, France), Earth Syst. Sci. Data Discuss. [preprint], <https://doi.org/10.5194/essd-2022-451>, in prep, 2023.*

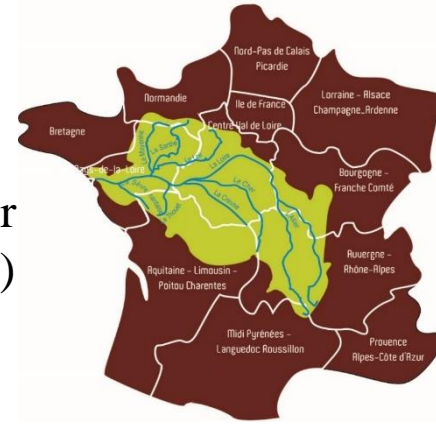
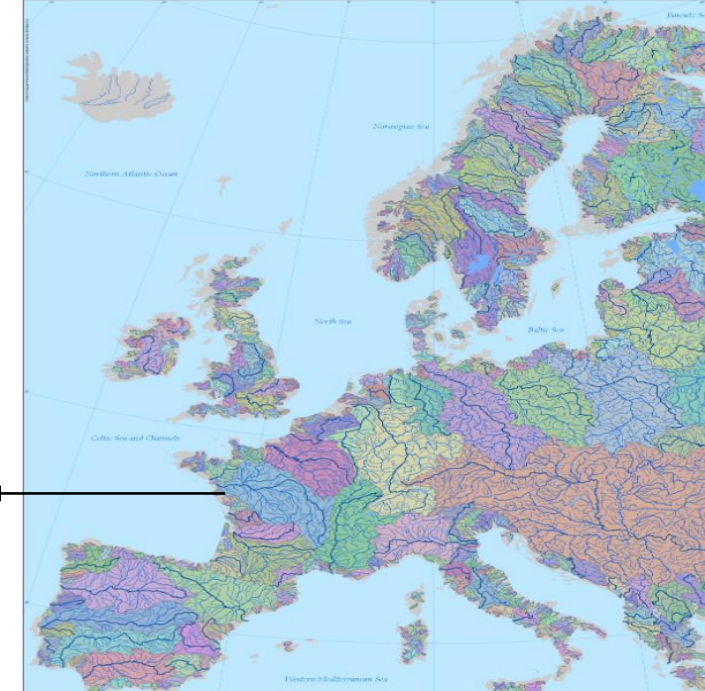
- ❑ **Investigating and quantifying the extent to which riparian shading can help mitigate river warming at a large scale**

For past: *Syedhashemi, H., Vidal, J.-P., Diamond, J. S., Thiéry, D., Monteil, C., Hendrickx, F., Maire, A. & Moatar, F. (2021) Regional, multi-decadal analysis reveals that stream temperature increases faster than air temperature Hydrology and Earth System Sciences. In press. doi: 10.5194/hess-2021-450.*

- ❑ **Exploring the consequences of theoretical scenarios of large-scale riparian restoration or loss on stream temperature**

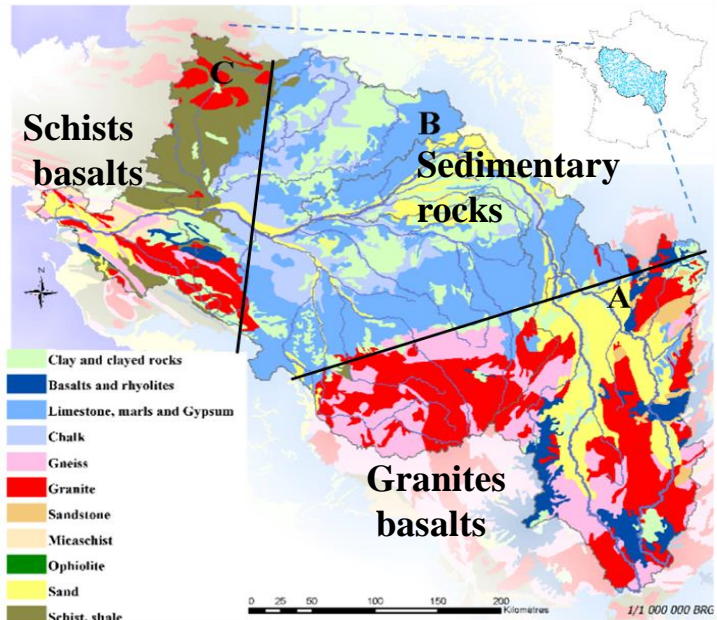
*Syedhashemi et al., in progress*

➤ Study area: a large European basin with contrasting lithology, climate and land use/land cover

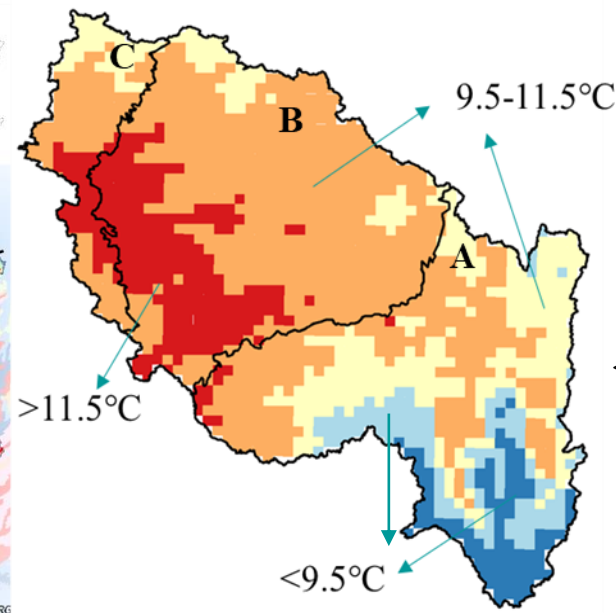


The Loire River basin (10<sup>5</sup> km<sup>2</sup>)

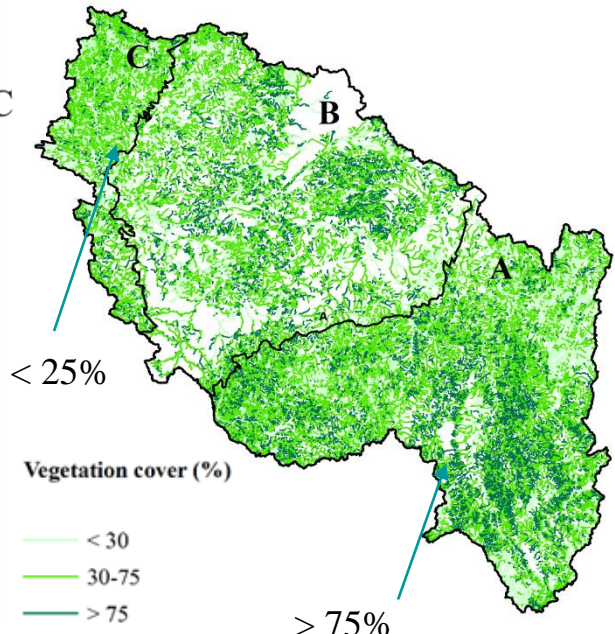
Lithology



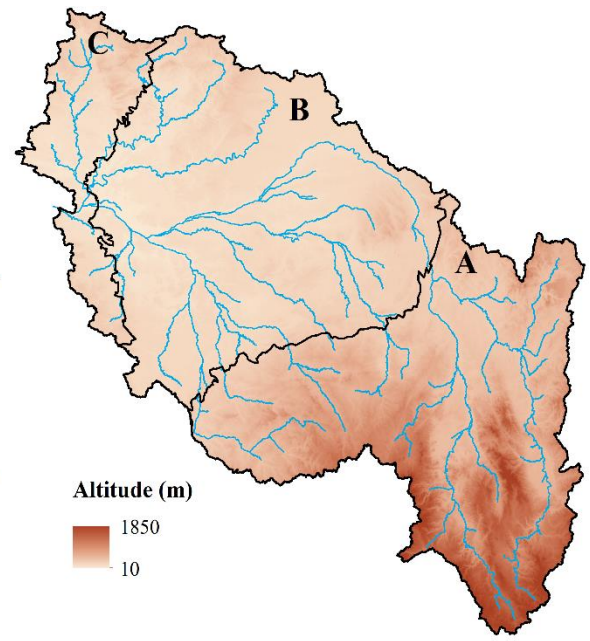
Air temperature



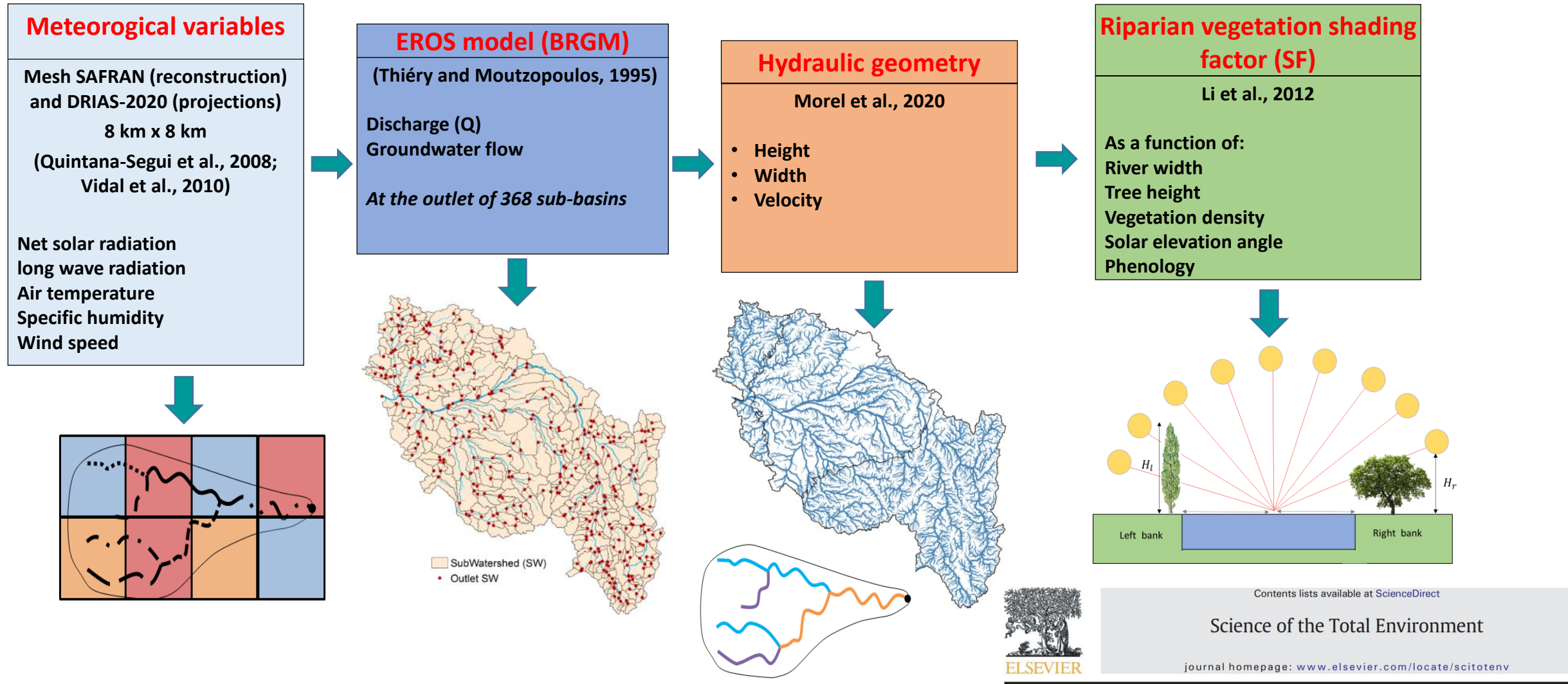
Riparian vegetation



Altitude



# ➤ T-NET thermal model : reconstruction and projection



Improving representation of riparian vegetation shading in a regional stream temperature model using LiDAR data

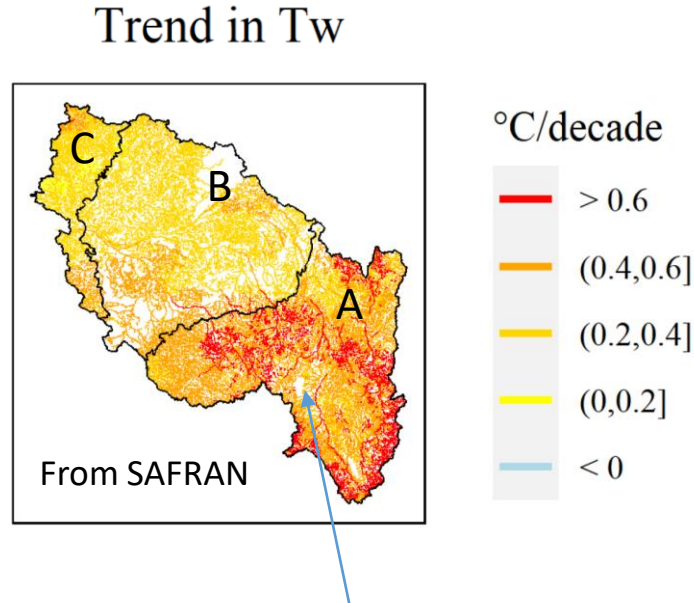
Pierre Loicq <sup>a,\*</sup>, Florentina Moatar <sup>a</sup>, Yann Jullian <sup>b</sup>, Stephen J. Dugdale <sup>c</sup>, David M. Hannah <sup>c</sup>

# ➤ Riparian shading can attenuate increasing trends in summer Tw

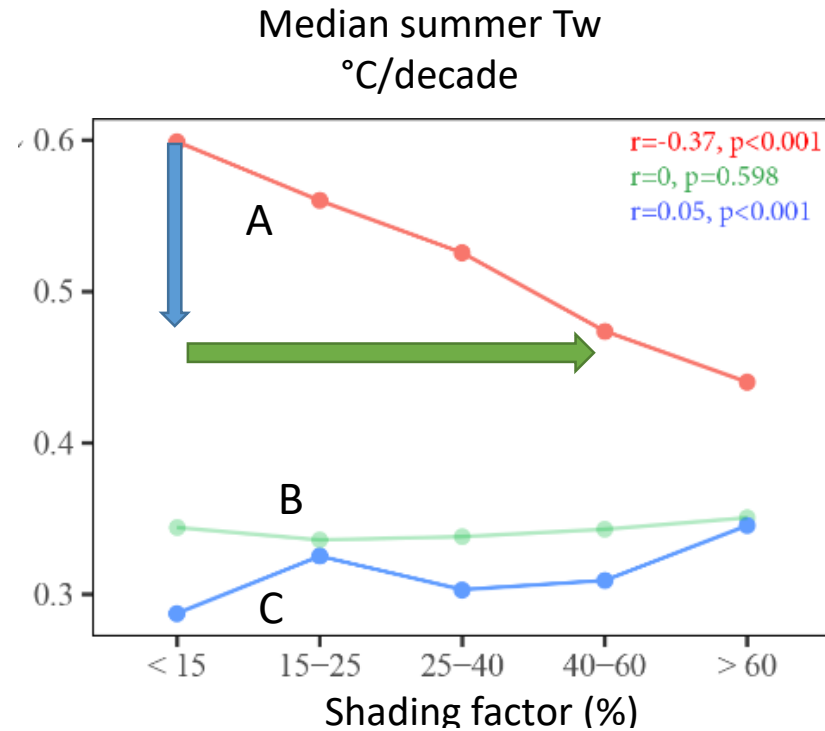
Small streams: distance from the source < 30km



Coise (small)



Increase in Tw by up to +5°C over the past 57 years



- ✓ Riparian shading can attenuate increasing trends in summer Tw in the south of the basin by 0.16°C/decade

**Regional, multi-decadal analysis on the Loire River basin reveals that stream temperature increases faster than air temperature**

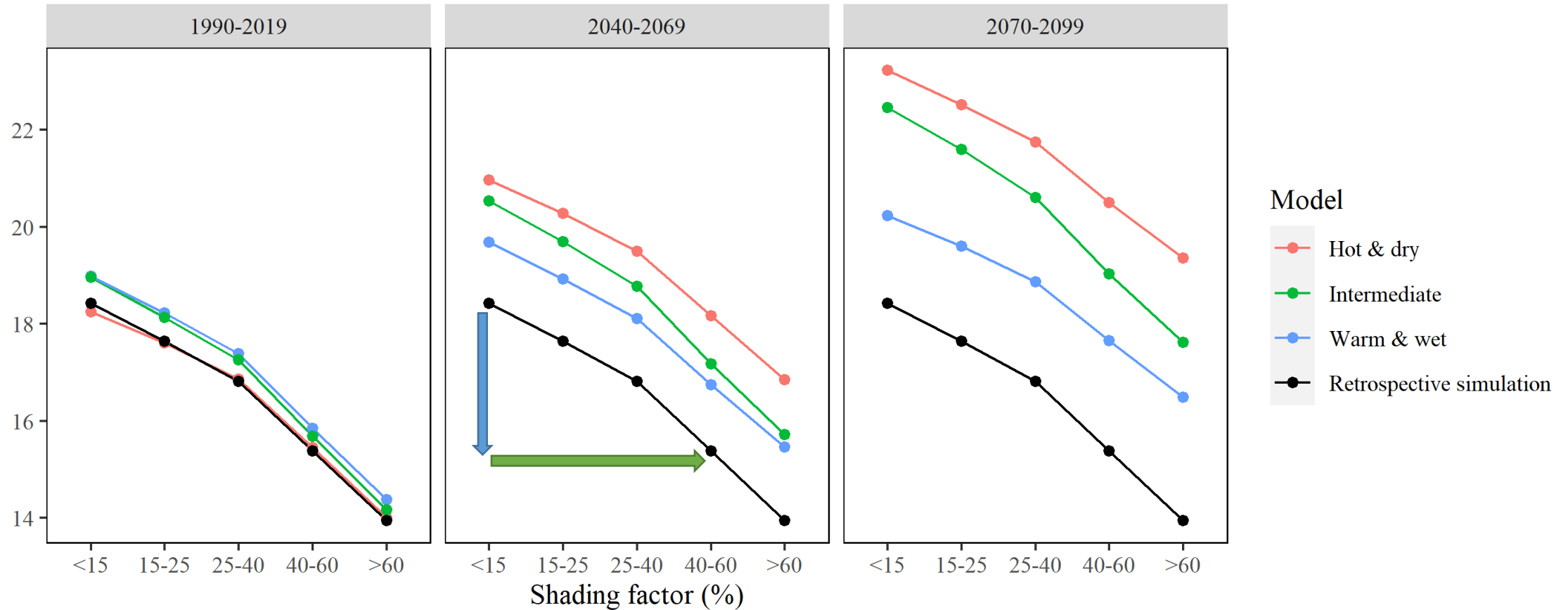
Hanieh Seyedhashemi<sup>1,2</sup>, Jean-Philippe Vidal<sup>1</sup>, Jacob S. Diamond<sup>1</sup>, Dominique Thiéry<sup>3</sup>, Céline Montell<sup>4</sup>, Frédéric Hendrickx<sup>4</sup>, Anthony Maire<sup>4</sup>, and Florentina Moatar<sup>1</sup>



# Riparian shading can attenuate increase in future summer Tw

Small streams: distance from the source < 30km

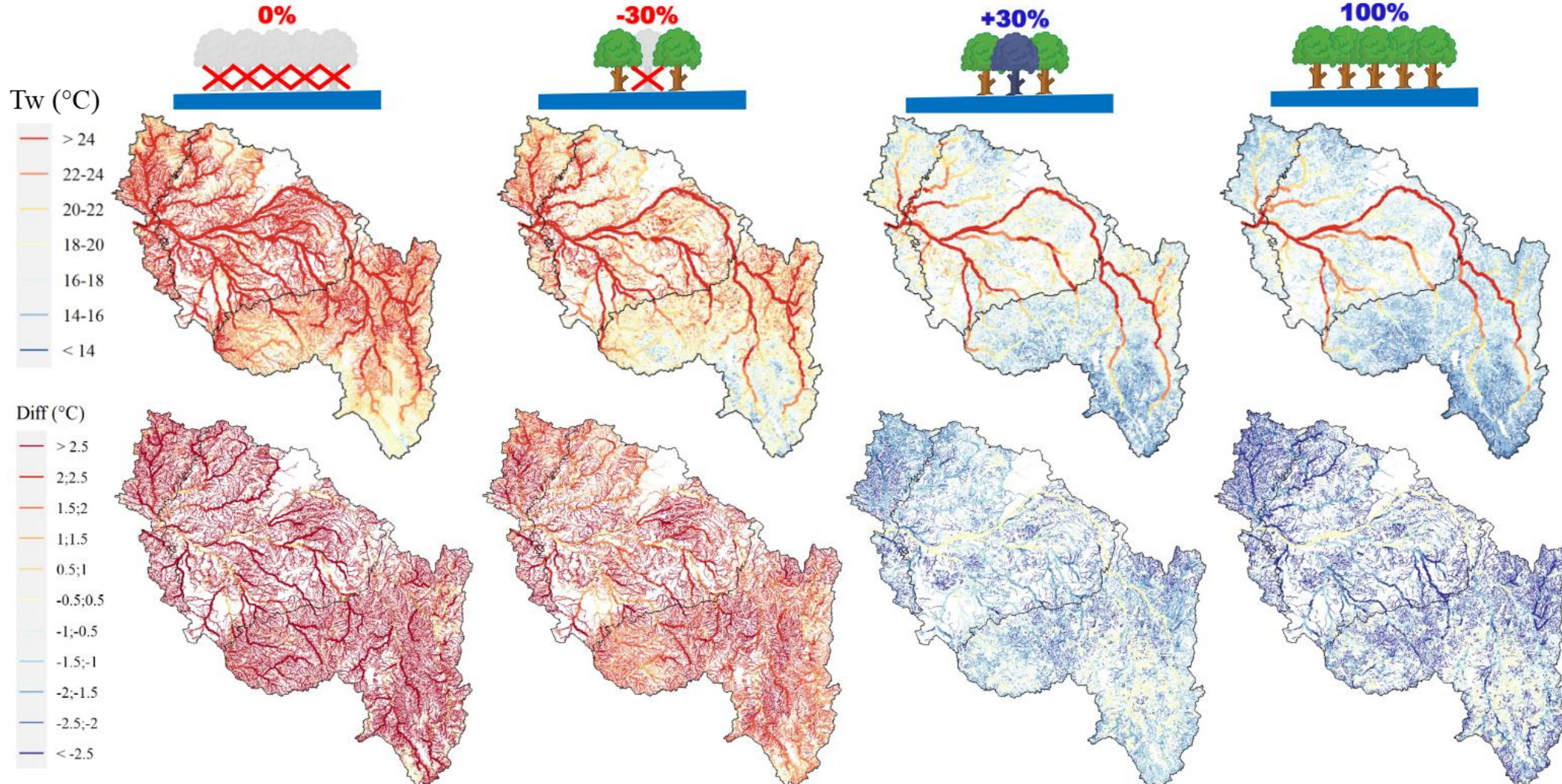
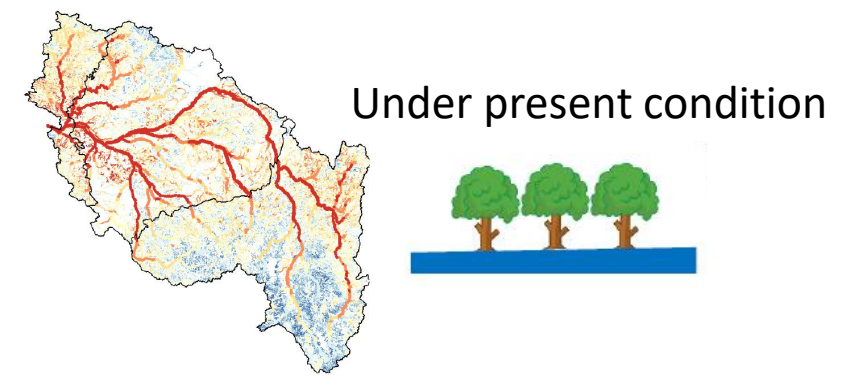
Median summer Tw under RCP 8.5 across reaches



✓ Riparian shading can mitigate the increase in future summer Tw by at least 3.5°C

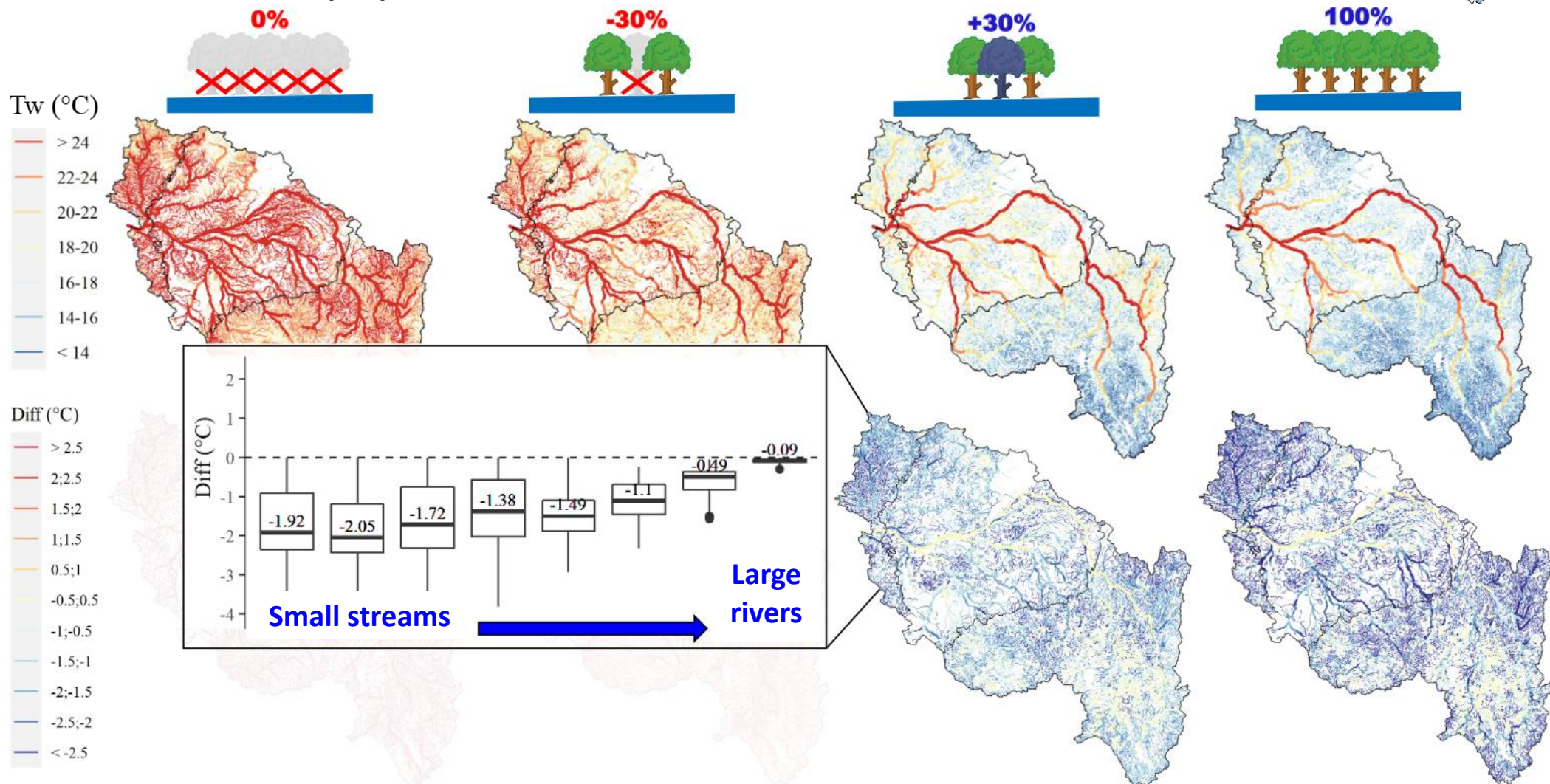
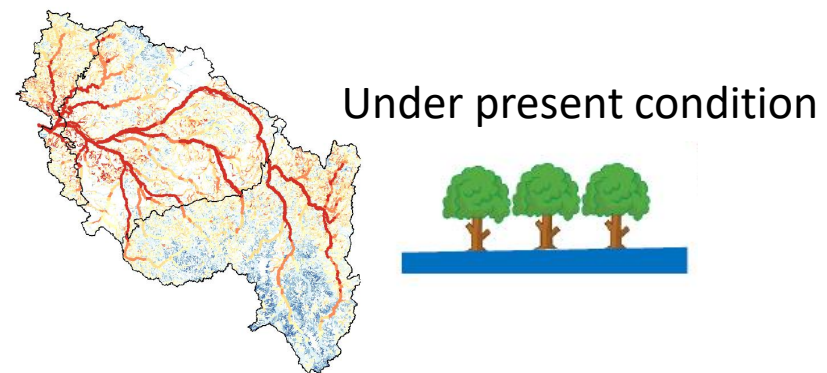
# Theoretical scenarios of riparian restoration or loss and their impacts on Tw

Analysis of riparian vegetation restoration scenarios by thermal modeling  
Reconstitution for **1/08/2003**



# ➤ Theoretical scenarios of riparian restoration or loss and their impacts on Tw

Analysis of riparian vegetation restoration scenarios by thermal modeling  
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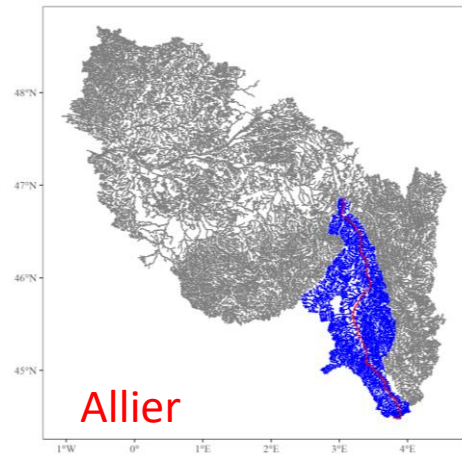
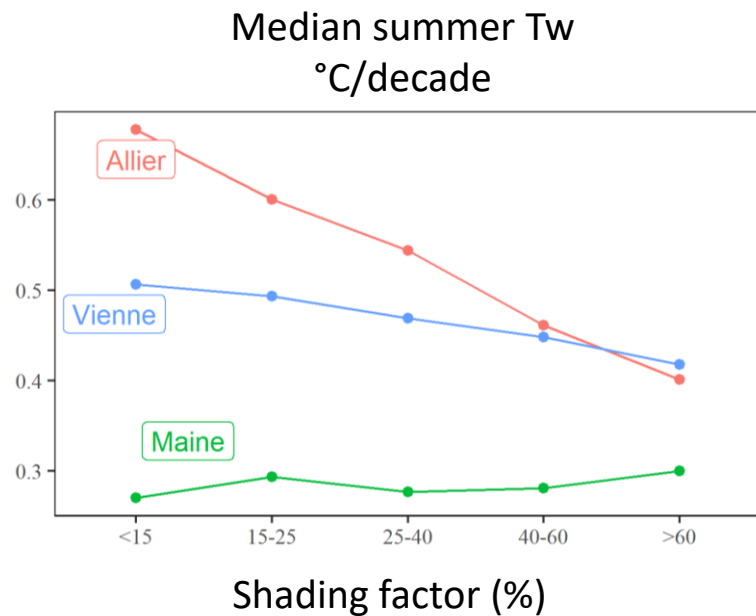


## ➤ Take-home messages

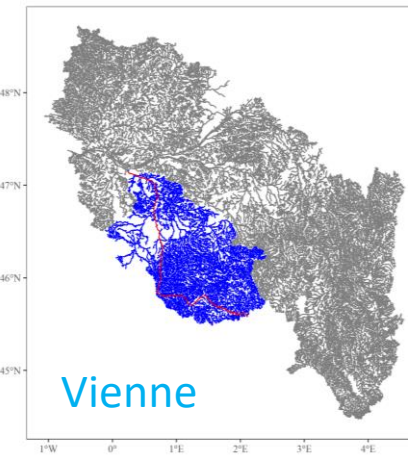
- ✓ From low shaded reaches (<15%) to high shaded ones (>40%) riparian shading mitigate :
  - Increasing past trends in summer Tw by 0.16 °C/decade
  - the increase future summer Tw by at least 3.5°C
  
- ✓ Theoretical scenarios of large-scale riparian restoration showed:
  - No mitigation of increase in Tw for large rivers
  - 30% increase in riparian vegetation in upstream of a reach mitigate the increase in summer Tw by up to ~2°C

## > Perspectives

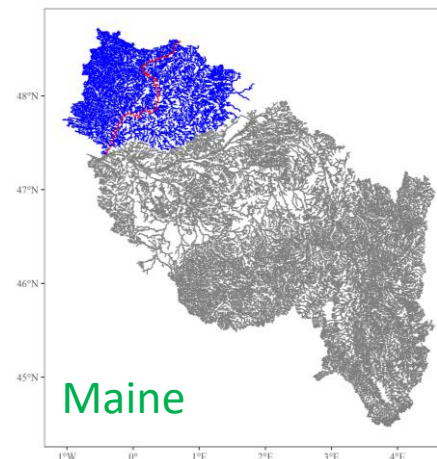
- ❑ Quantifying the downstream diffusion of the thermal gains associated with the restoration of the riparian vegetation depending on the context
- ❑ Characterizing better the potential for thermal gain depending on the river/tributary



High altitudes  
High vegetation



Medium altitudes  
Moderate vegetation



Lowlands  
low vegetation  
Groundwater inputs

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Preprint. Discussion started: 12 January 2023  
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Discussions

## Past and future discharge and stream temperature at high spatial resolution in a large European basin (Loire basin, France)

Hanieh Seyedhashemi<sup>1,2</sup>, Florentina Moatar<sup>1</sup>, Jean-Philippe Vidal<sup>1</sup>, and Dominique Thiéry<sup>3</sup>

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# Thank you!

# PLOS ONE

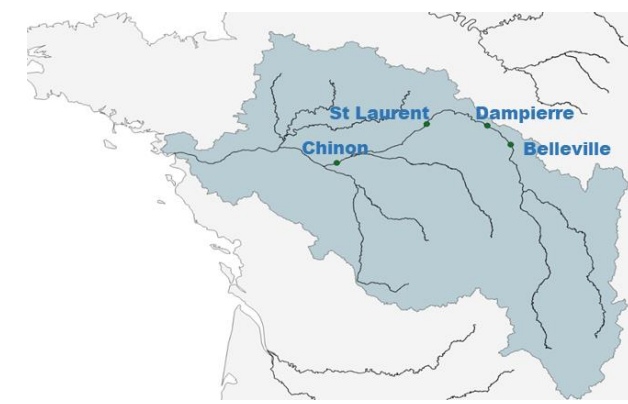
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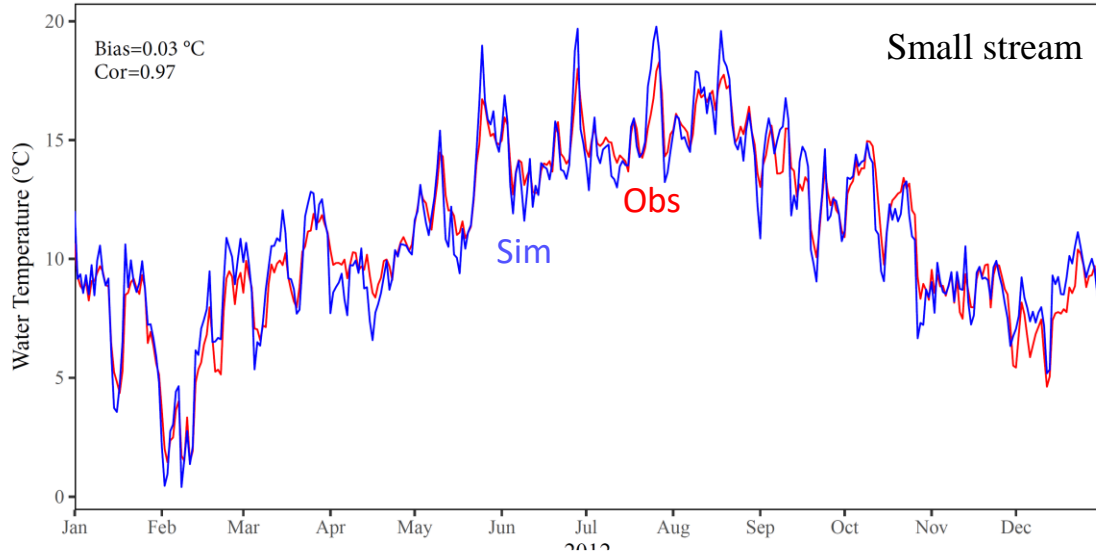
## Direct habitat descriptors improve the understanding of the organization of fish and macroinvertebrate communities across a large catchment

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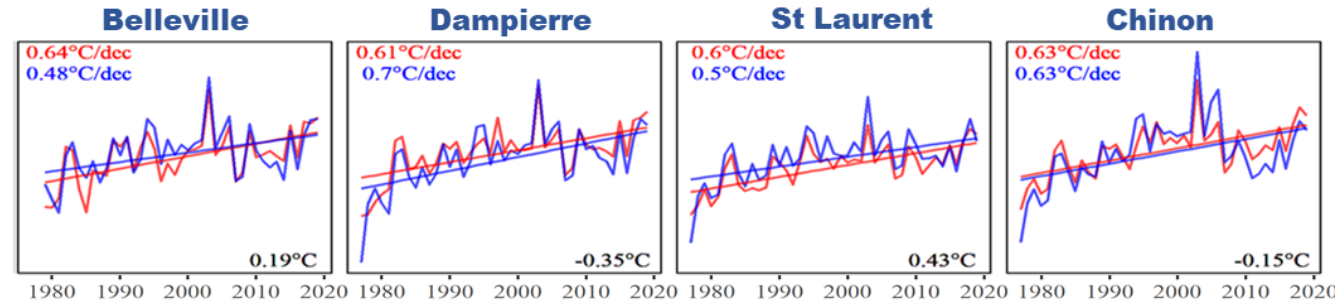
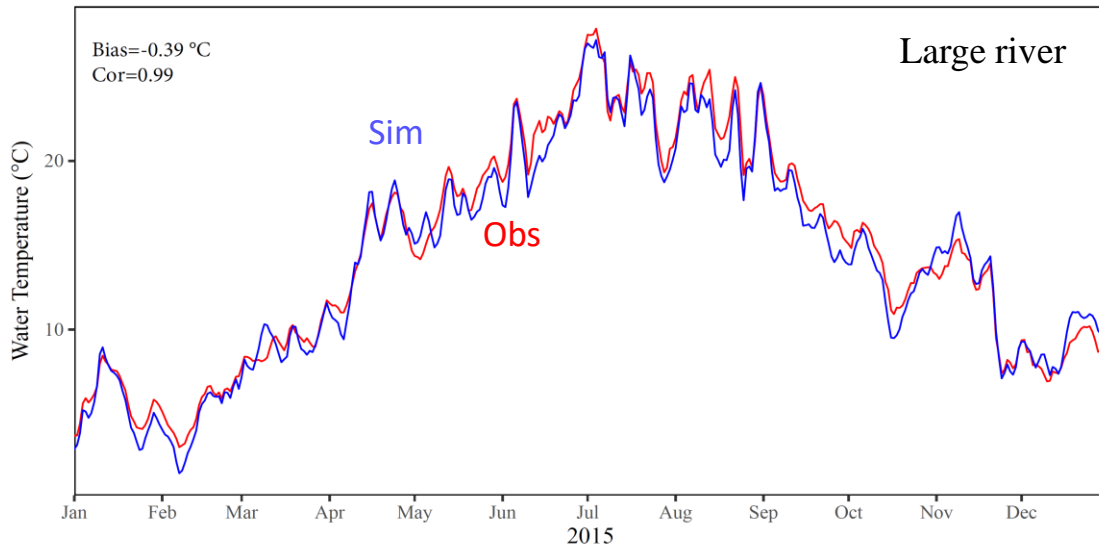
# ➤ Agreement between obs and sim



ERNEE à Larchamp (15 km from the source)



LOIRE à Cinq-Mars-la-Pile (799 km from the source)



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