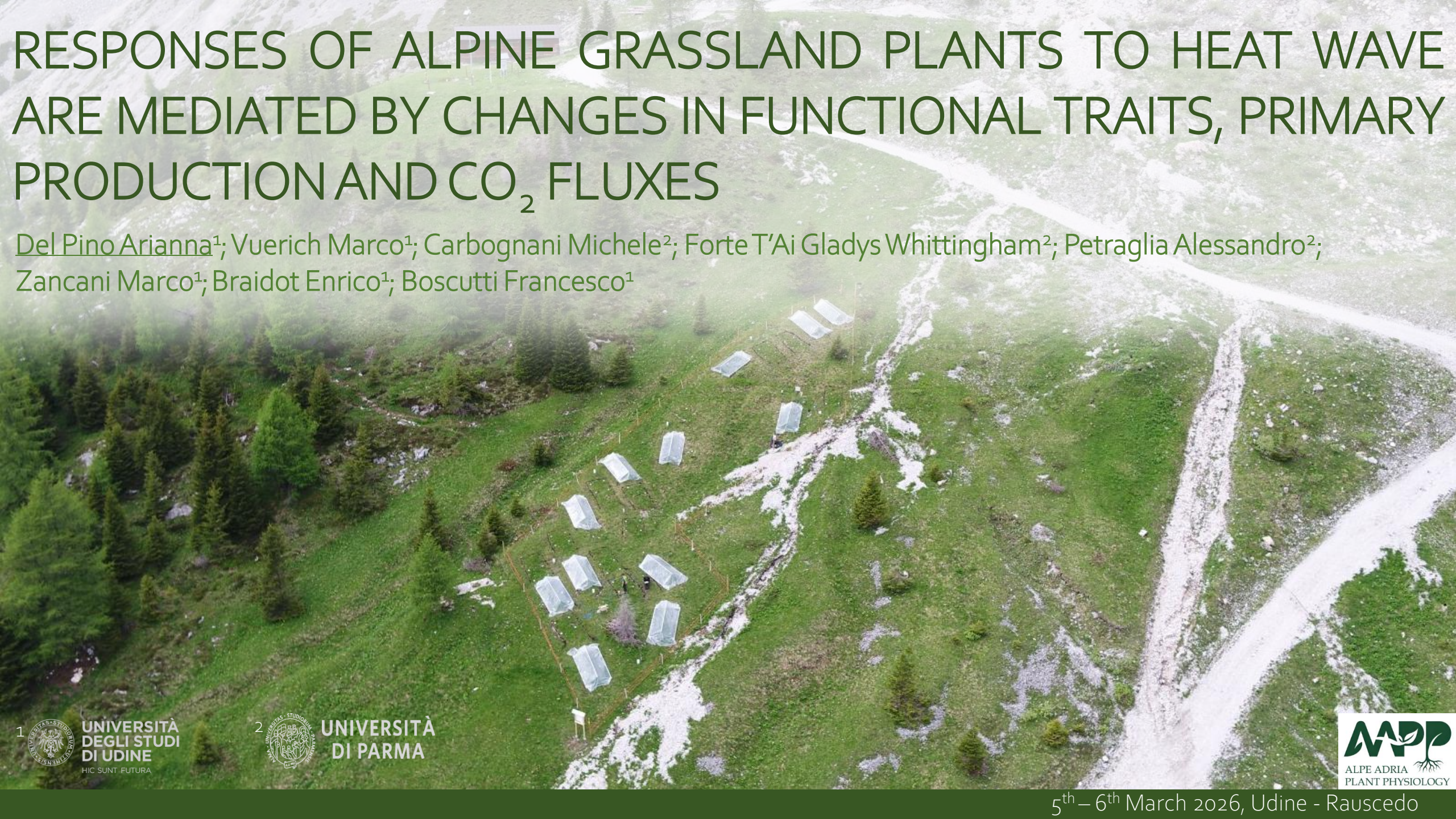
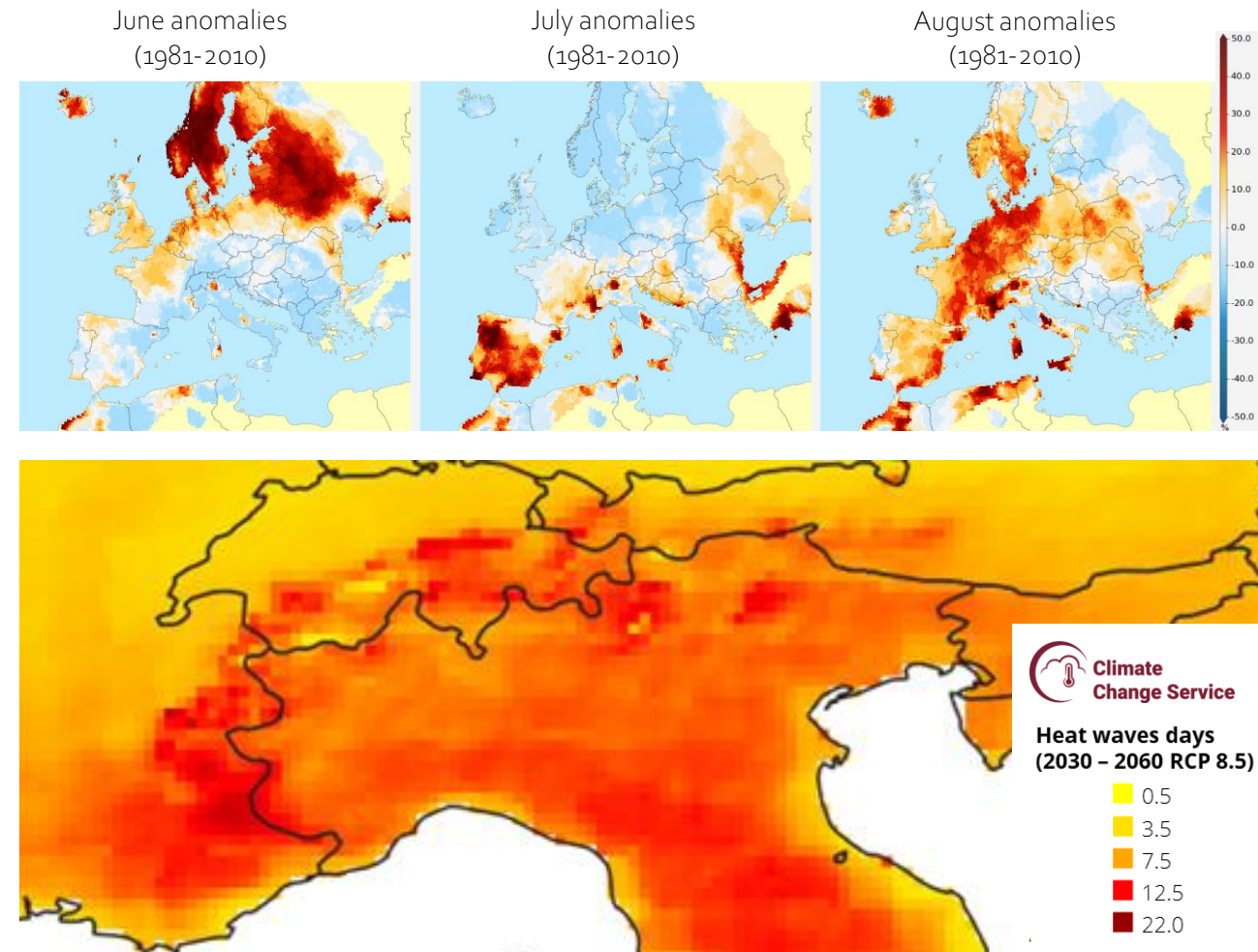
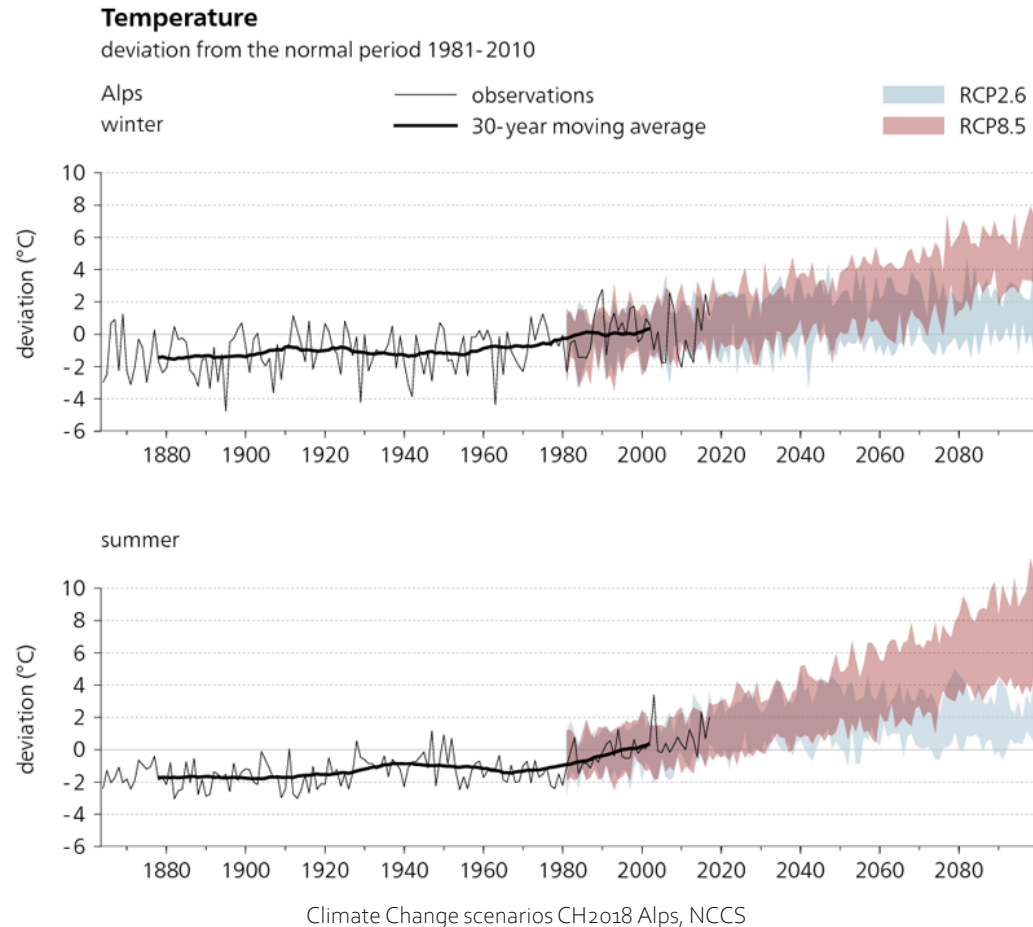


# RESPONSES OF ALPINE GRASSLAND PLANTS TO HEAT WAVE ARE MEDIATED BY CHANGES IN FUNCTIONAL TRAITS, PRIMARY PRODUCTION AND CO<sub>2</sub> FLUXES

Del Pino Arianna<sup>1</sup>; Vuerich Marco<sup>1</sup>; Carbognani Michele<sup>2</sup>; Forte T'Ai Gladys Whittingham<sup>2</sup>; Petraglia Alessandro<sup>2</sup>;  
Zancani Marco<sup>1</sup>; Braidot Enrico<sup>1</sup>; Boscutti Francesco<sup>1</sup>



## Not just a matter of temperature increase



# AIM OF THE PROJECT



A “not fully understood” threat to alpine ecosystems

short growing season +  
strong climatic constraints =

---

sensitivity to thermal extremes

duration



timing



substrate type



# AIM OF THE PROJECT



A “not fully understood” threat to alpine ecosystems

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---

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timing



substrate type



## Experimental questions

How does the duration of the extreme heat event influence grasslands?

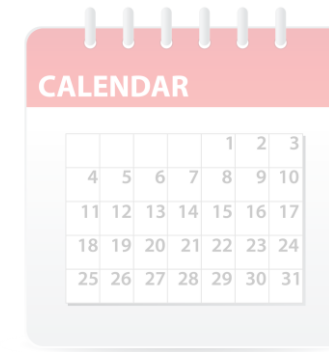
Are different responses between siliceous and calcareous substrate?

Are differences between species-level and community-level?

duration

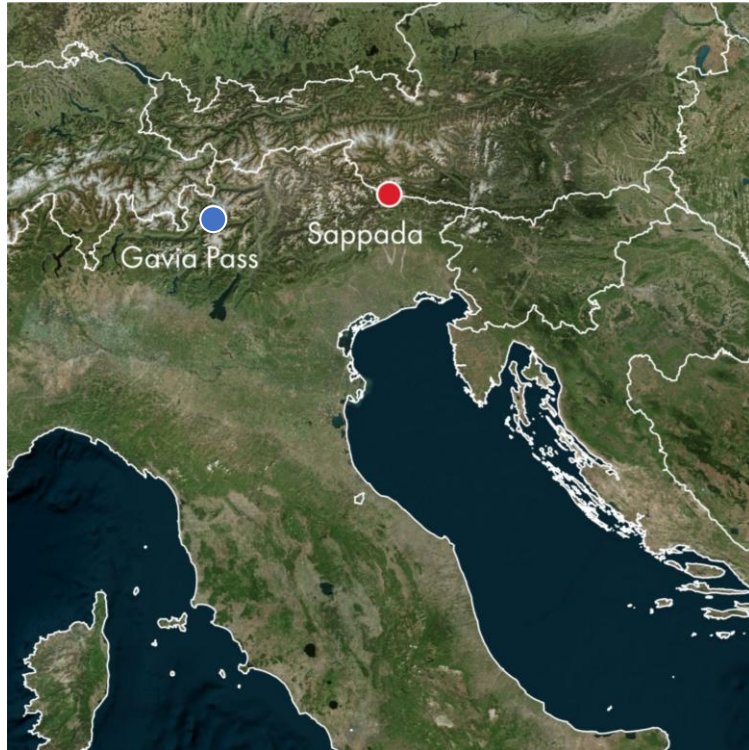


timing



substrate type





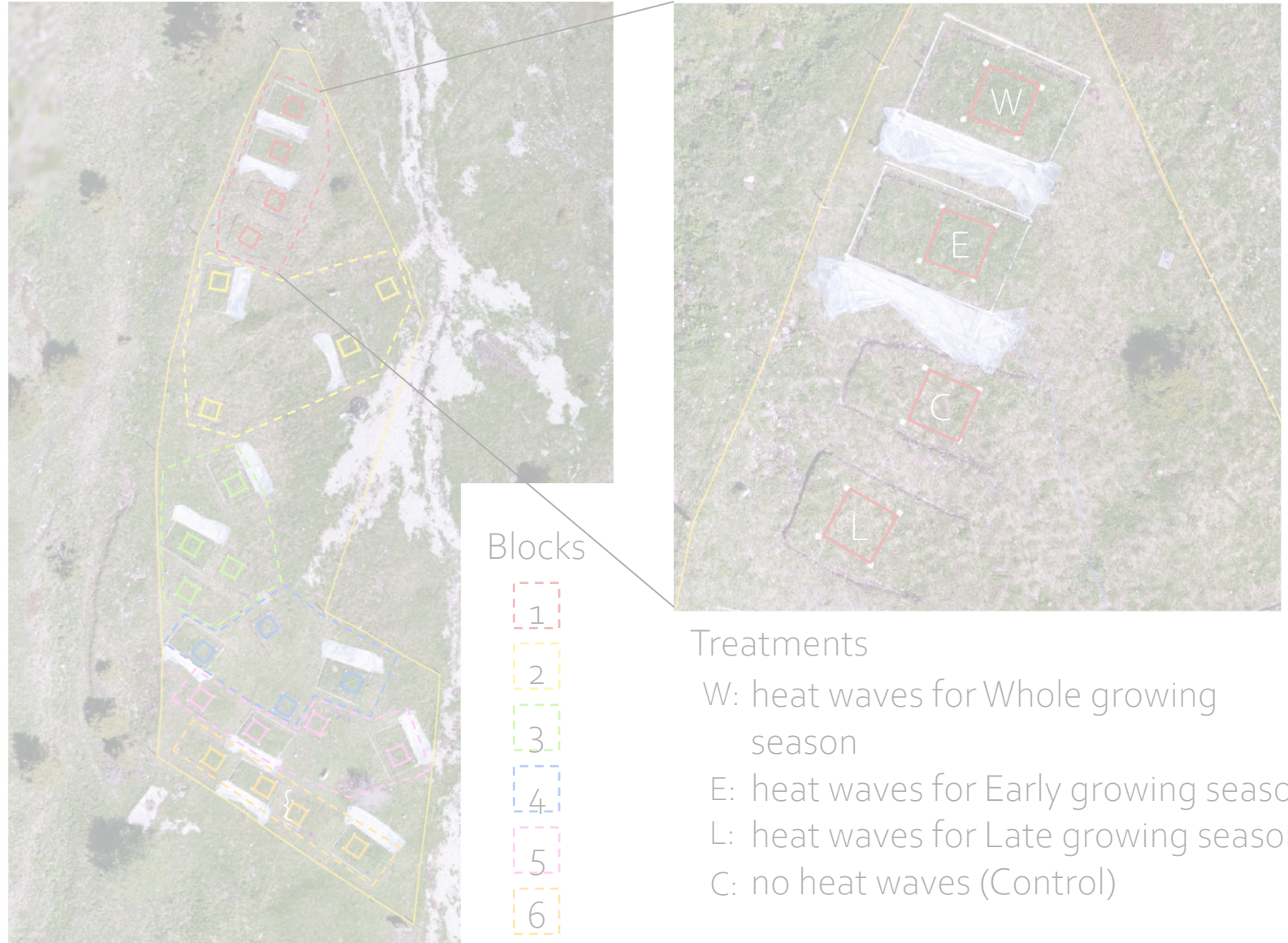
## Study sites

### Gavia Pass:

- 2600 m a.s.l.
- Siliceous substrate
- Habitat 6150

### Sappada:

- 2000 m a.s.l.
- Calcareous substrate
- Habitat 6170



### Blocks

- 1
- 2
- 3
- 4
- 5
- 6

### Treatments

- W: heat waves for Whole growing season
- E: heat waves for Early growing season
- L: heat waves for Late growing season
- C: no heat waves (Control)

# MATERIAL AND METHODS



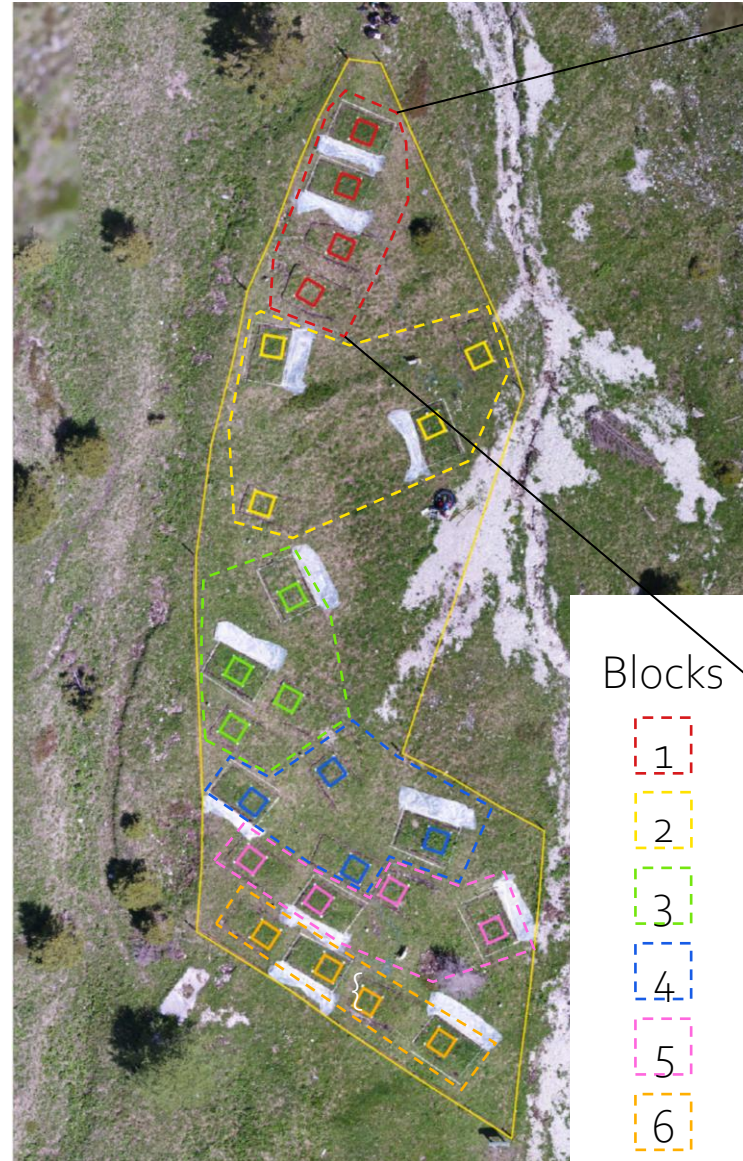
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### Sappada:

- 2000 m a.s.l.
- Calcareous substrate
- Habitat 6170



## Blocks

- 1
- 2
- 3
- 4
- 5
- 6



## Treatments

W: heat waves for Whole growing season

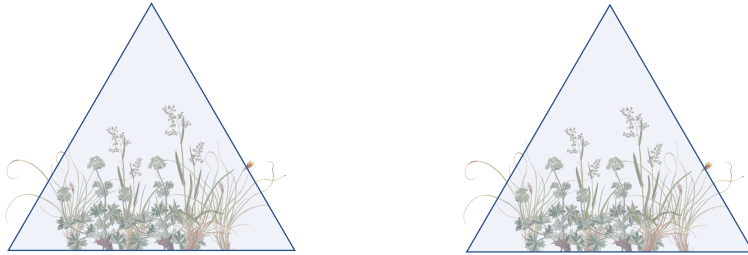
E: heat waves for Early growing season

L: heat waves for Late growing season

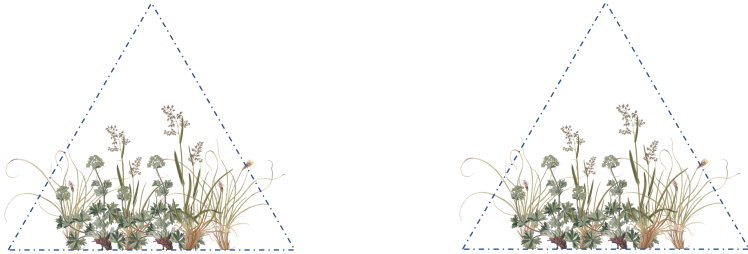
C: no heat waves (Control)

## Experimental design

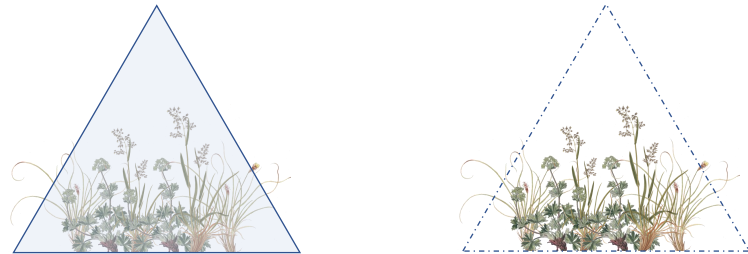
Whole



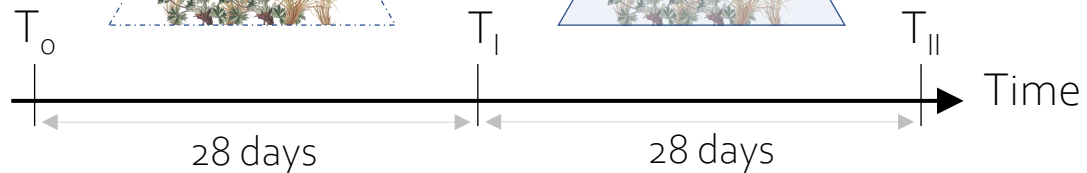
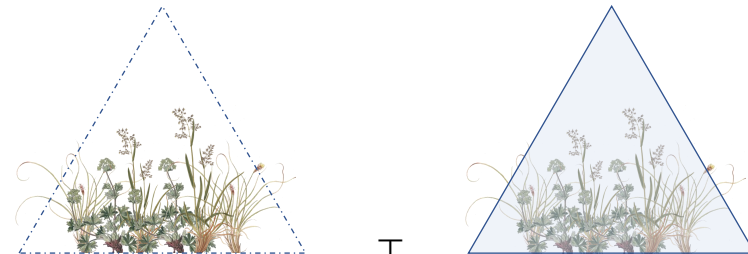
Control



Early



Late



**SAPPADA  
STUDY SITE**

## A multilevel investigation



sedge

*Carex curvula*  
*Carex ornithopoda*



forb

*Alchemilla pentaphyllea*  
*Homogyne alpina*



grass

*Poa alpina*  
*Sesleria caerulea*



whole plant community

- pigment concentration (chlorophyll, carotenoid)
- flavonoid concentration

- multispectral survey (UAV + close range)
- CO<sub>2</sub> fluxes

$T_0$

$T_I$

$T_{II}$

Time

## A multilevel investigation



sedge

*Carex curvula*  
*Carex ornithopoda*



forb

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## A multilevel investigation



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$T_0$

$T_I$

$T_{II}$

Time

## A multilevel investigation



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forb

*Alchemilla pentaphyllea*  
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grass

*Poa alpina*  
*Sesleria caerulea*



whole plant community

- pigment concentration (chlorophyll, carotenoid)
- flavonoid concentration
- morphological traits (SLA, DMC, stomata density)
- root non structural carbohydrate concentration

- multispectral survey (UAV + close range)
- CO<sub>2</sub> fluxes
- biomass (necromass, biomass)
- intercept point vegetation survey

$T_o$

$T_i$

$T_{II}$

Time

## A multilevel investigation



sedge

*Carex curvula*  
*Carex ornithopoda*



forb

*Alchemilla pentaphyllea*  
*Homogyne alpina*



grass

*Poa alpina*  
*Sesleria caerulea*



whole plant community

- pigment concentration (chlorophyll, carotenoid)
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$T_0$

$T_1$

$T_{II}$

Time →

## A multilevel investigation



sedge

*Carex curvula*  
*Carex ornithopoda*



forb

*Alchemilla pentaphylla*  
*Homogyne alpina*



grass

*Poa alpina*  
*Sesleria caerulea*



whole plant community

- pigment concentration (chlorophyll, carotenoid)
- flavonoid concentration
- morphological traits (SLA, DMC, stomata density)
- root non structural carbohydrate concentration

- multispectral survey (UAV + close range)
- CO<sub>2</sub> fluxes
- biomass (necromass, biomass)
- intercept point vegetation survey

$T_0$

$T_1$

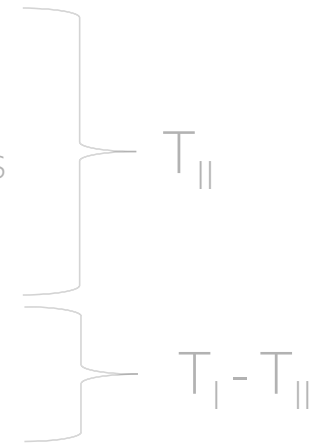
$T_{II}$

Time →

## Statistical analysis

Two datasets (*Gavia pass* and *Sappada*) - Linear mixed models

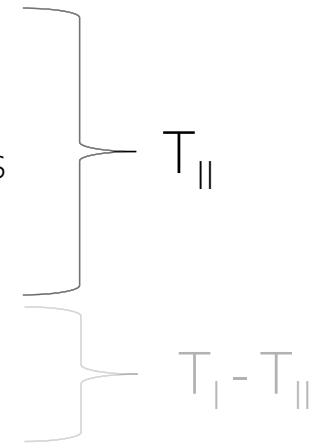
- Morphological traits ~ Treatment \* Functional groups
- Pigments and biochemical analysis ~ Treatment \* Functional groups
- Biomass production ~ Treatment
- Fluxes ~ Treatment \* Time



## Statistical analysis

Two datasets (*Gavia pass* and *Sappada*) - Linear mixed models

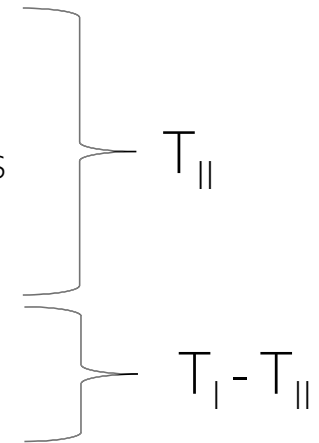
- Morphological traits ~ Treatment \* Functional groups
- Pigments and biochemical analysis ~ Treatment \* Functional groups
- Biomass production ~ Treatment
- Fluxes ~ Treatment \* Time



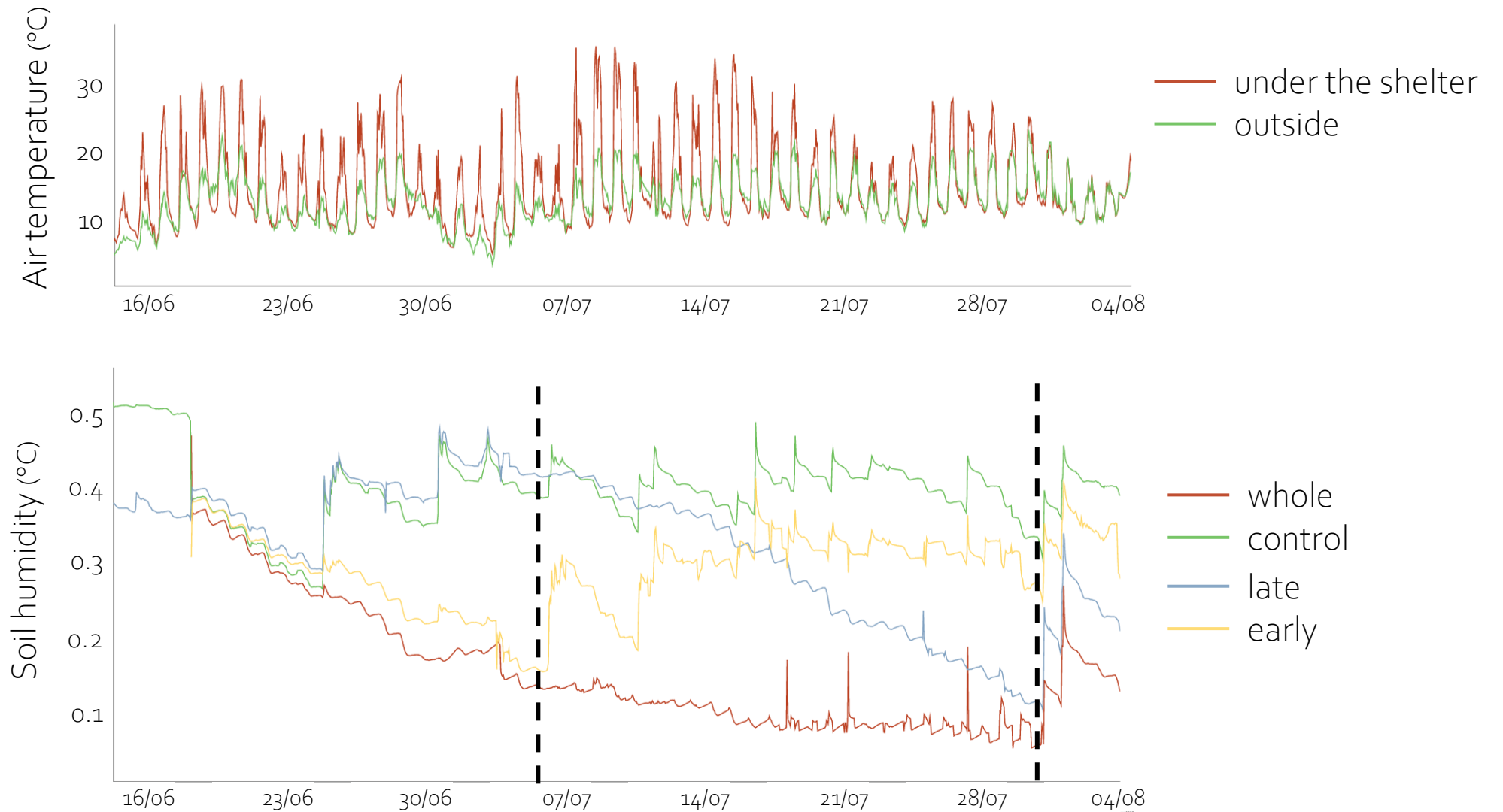
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Two datasets (*Gavia pass* and *Sappada*) - Linear mixed models

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- Pigments and biochemical analysis ~ Treatment \* Functional groups
- Biomass production ~ Treatment
- Fluxes ~ Treatment \* Time



## Climate data

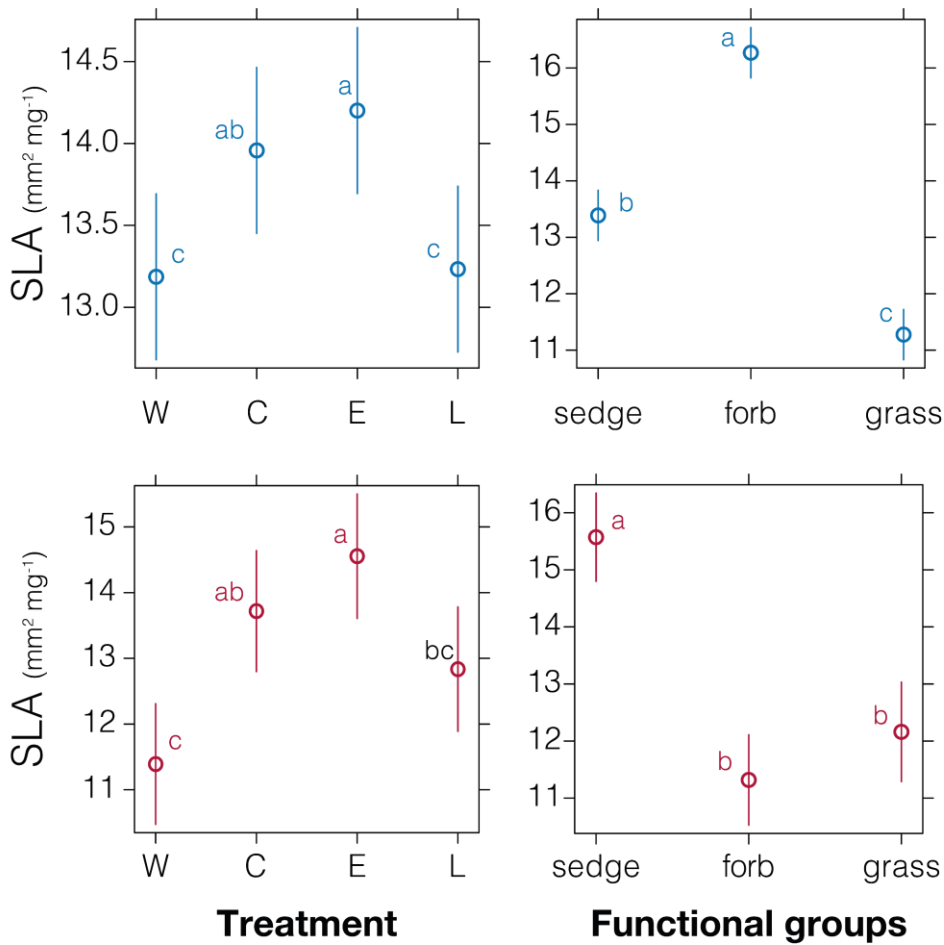


Species scale – morphological traits

| Dependent variable | Site    | Factor                 | P-value     |
|--------------------|---------|------------------------|-------------|
| Specific Leaf Area | Gavia   | Treatment              | < 0.001 *** |
|                    |         | Functional groups      | < 0.001 *** |
|                    | Sappada | Treatment              | 0.004 ***   |
|                    |         | Functional groups      | < 0.001 *** |
| Dry matter content | Gavia   | Treatment              | < 0.001 *** |
|                    |         | Functional groups      | < 0.001 *** |
|                    | Sappada | Treatment              | 0.756       |
|                    |         | Functional groups      | < 0.001 *** |
| Stomata density    | Gavia   | Treat. * Funct. groups | 0.041 *     |
|                    |         | Functional groups      | 0.043 *     |
|                    | Sappada | Treatment              | < 0.001 *** |
|                    |         | Functional groups      | < 0.001 *** |



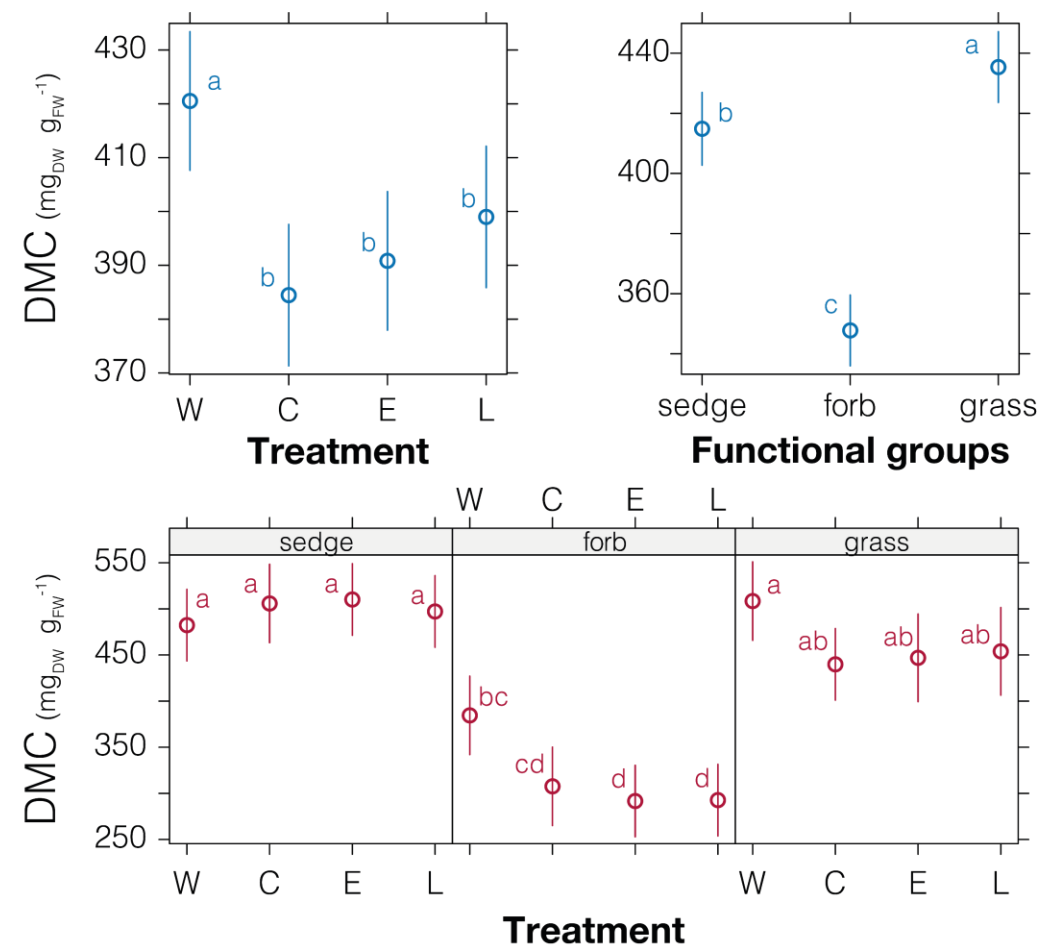
Species scale – morphological traits



| Dependent variable | Site    | Factor                 | P-value     |
|--------------------|---------|------------------------|-------------|
| Specific Leaf Area | Gavia   | Treatment              | < 0.001 *** |
|                    |         | Functional groups      | < 0.001 *** |
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|                    |         | Functional groups      | < 0.001 *** |
|                    | Sappada | Treat. * Funct. groups | 0.041 *     |
|                    |         |                        |             |
| Stomata density    | Gavia   | Treatment              | 0.043 *     |
|                    |         | Functional groups      | < 0.001 *** |
|                    | Sappada | Treatment              | 0.527       |
|                    |         | Functional groups      | < 0.001 *** |



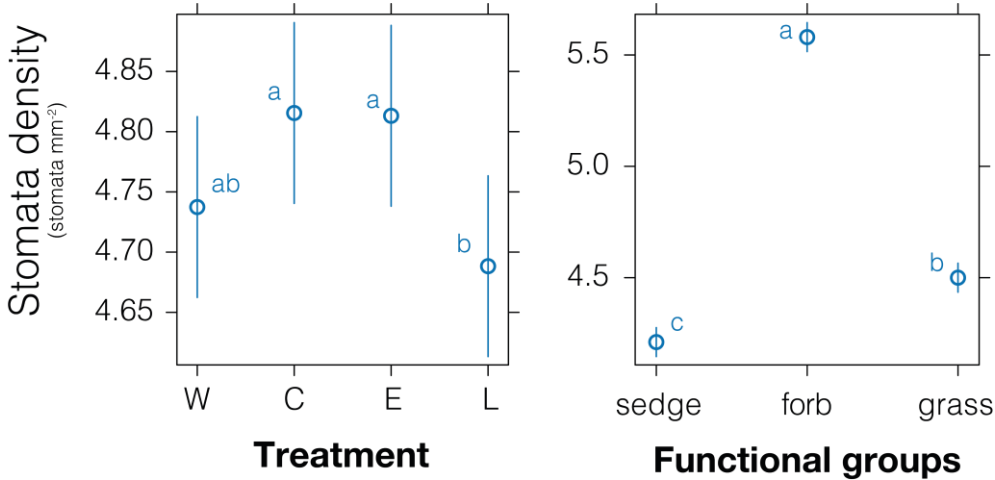
Species scale – morphological traits



| Dependent variable | Site    | Factor                 | P-value     |
|--------------------|---------|------------------------|-------------|
| Specific Leaf Area | Gavia   | Treatment              | < 0.001 *** |
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|                    | Sappada | Treatment              | 0.004 ***   |
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|                    | Sappada | Treatment              | 0.756       |
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|                    |         | Treat. * Funct. groups | 0.041 *     |
| Stomata density    | Gavia   | Treatment              | 0.043 *     |
|                    |         | Functional groups      | < 0.001 *** |
|                    | Sappada | Functional groups      | < 0.001 *** |



Species scale – morphological traits



| Dependent variable | Site    | Factor            | P-value     |
|--------------------|---------|-------------------|-------------|
| Specific Leaf Area | Gavia   | Treatment         | < 0.001 *** |
|                    |         | Functional groups | < 0.001 *** |
|                    | Sappada | Treatment         | 0.004 ***   |
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| Dry matter content | Gavia   | Treatment         | < 0.001 *** |
|                    |         | Functional groups | < 0.001 *** |
|                    | Sappada | Treatment         | 0.756       |
|                    |         | Functional groups | < 0.001 *** |
| Stomata density    | Gavia   | Treatment         | 0.041 *     |
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|                    | Sappada | Treatment         | 0.527       |
|                    |         | Functional groups | < 0.001 *** |



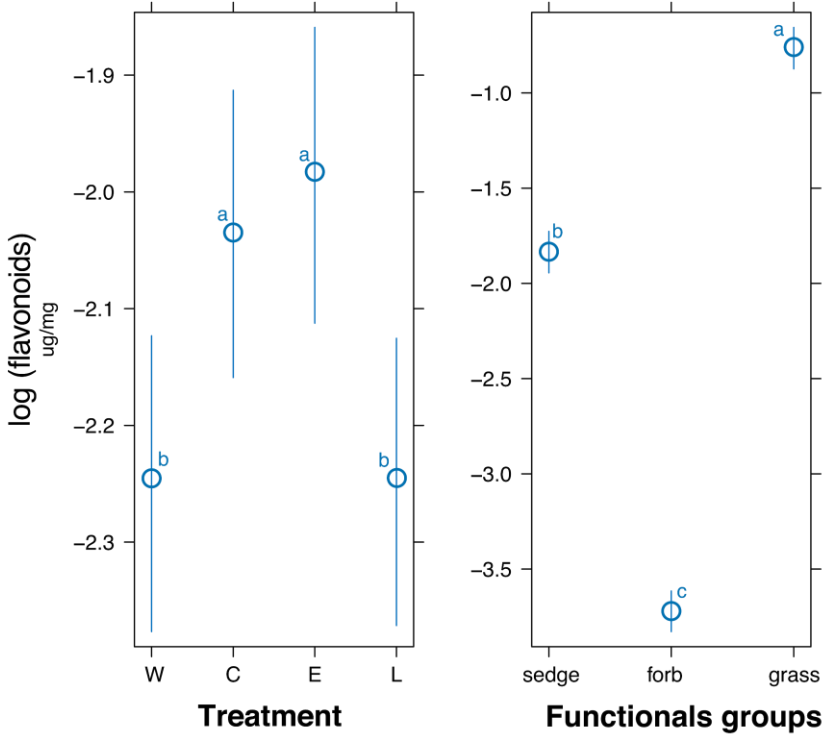
## Species scale – pigments and biochemical analysis

| Dependent variable                | Site    | Factor            | P-value     |
|-----------------------------------|---------|-------------------|-------------|
| Flavonoids                        | Gavia   | Treatment         | 0.002 **    |
|                                   |         | Functional groups | < 0.001 *** |
|                                   | Sappada | Treatment         | 0.660       |
|                                   |         | Functional groups | < 0.001 *** |
| Carotenoids                       | Gavia   | Treatment         | 0.639       |
|                                   |         | Functional groups | < 0.001 *** |
|                                   | Sappada | Treatment         | 0.190       |
|                                   |         | Functional groups | < 0.001 *** |
| Chlorophylls                      | Gavia   | Treatment         | 0.481       |
|                                   |         | Functional groups | < 0.001 *** |
|                                   | Sappada | Treatment         | 0.571       |
|                                   |         | Functional groups | < 0.001 *** |
| Chlorophylls A/<br>Chlorophylls B | Gavia   | Treatment         | Not normal  |
|                                   |         | Functional groups | Not normal  |
|                                   | Sappada | Treatment         | < 0.001 *** |
|                                   |         | Functional groups | < 0.001 *** |



Species scale – pigments and biochemical analysis

| Dependent variable                | Site    | Factor            | P-value     |
|-----------------------------------|---------|-------------------|-------------|
| Flavonoids                        | Gavia   | Treatment         | 0.002 **    |
|                                   |         | Functional groups | < 0.001 *** |
|                                   | Sappada | Treatment         | 0.660       |
|                                   |         | Functional groups | < 0.001 *** |
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|                                   |         | Functional groups | < 0.001 *** |
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|                                   |         | Functional groups | < 0.001 *** |
|                                   | Sappada | Treatment         | 0.571       |
|                                   |         | Functional groups | < 0.001 *** |
| Chlorophylls A/<br>Chlorophylls B | Gavia   | Treatment         | Not normal  |
|                                   |         | Functional groups |             |
|                                   | Sappada | Treatment         | < 0.001 *** |
|                                   |         | Functional groups | < 0.001 *** |



Species scale – pigments and biochemical analysis

| Dependent variable                | Site    | Factor            | P-value     |
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| Flavonoids                        | Gavia   | Treatment         | 0.002 **    |
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|                                   |         | Functional groups | < 0.001 *** |
| Chlorophylls A/<br>Chlorophylls B | Gavia   | Treatment         | Not normal  |
|                                   |         | Functional groups |             |
|                                   | Sappada | Treatment         | < 0.001 *** |
|                                   |         | Functional groups | < 0.001 *** |



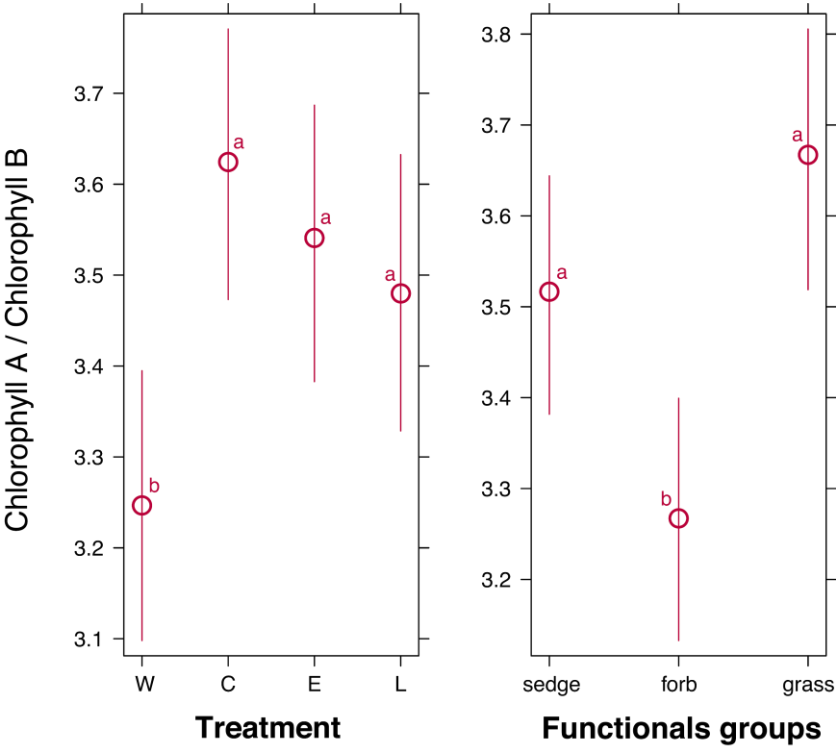
Species scale – pigments and biochemical analysis

| Dependent variable                | Site    | Factor            | P-value     |
|-----------------------------------|---------|-------------------|-------------|
| Flavonoids                        | Gavia   | Treatment         | 0.002 **    |
|                                   |         | Functional groups | < 0.001 *** |
|                                   | Sappada | Treatment         | 0.660       |
|                                   |         | Functional groups | < 0.001 *** |
| Carotenoids                       | Gavia   | Treatment         | 0.639       |
|                                   |         | Functional groups | < 0.001 *** |
|                                   | Sappada | Treatment         | 0.190       |
|                                   |         | Functional groups | < 0.001 *** |
| Chlorophylls                      | Gavia   | Treatment         | 0.481       |
|                                   |         | Functional groups | < 0.001 *** |
|                                   | Sappada | Treatment         | 0.571       |
|                                   |         | Functional groups | < 0.001 *** |
| Chlorophylls A/<br>Chlorophylls B | Gavia   | Treatment         | Not normal  |
|                                   |         | Functional groups |             |
|                                   | Sappada | Treatment         | < 0.001 *** |
|                                   |         | Functional groups | < 0.001 *** |



Species scale – pigments and biochemical analysis

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|                                   |         | Functional groups | < 0.001 *** |
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|                                   |         | Functional groups | < 0.001 *** |
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|                                   |         | Functional groups | < 0.001 *** |
|                                   | Sappada | Treatment         | 0.571       |
|                                   |         | Functional groups | < 0.001 *** |
| Chlorophylls A/<br>Chlorophylls B | Gavia   | Treatment         | Not normal  |
|                                   |         | Functional groups |             |
|                                   | Sappada | Treatment         | < 0.001 *** |
|                                   |         | Functional groups | < 0.001 *** |

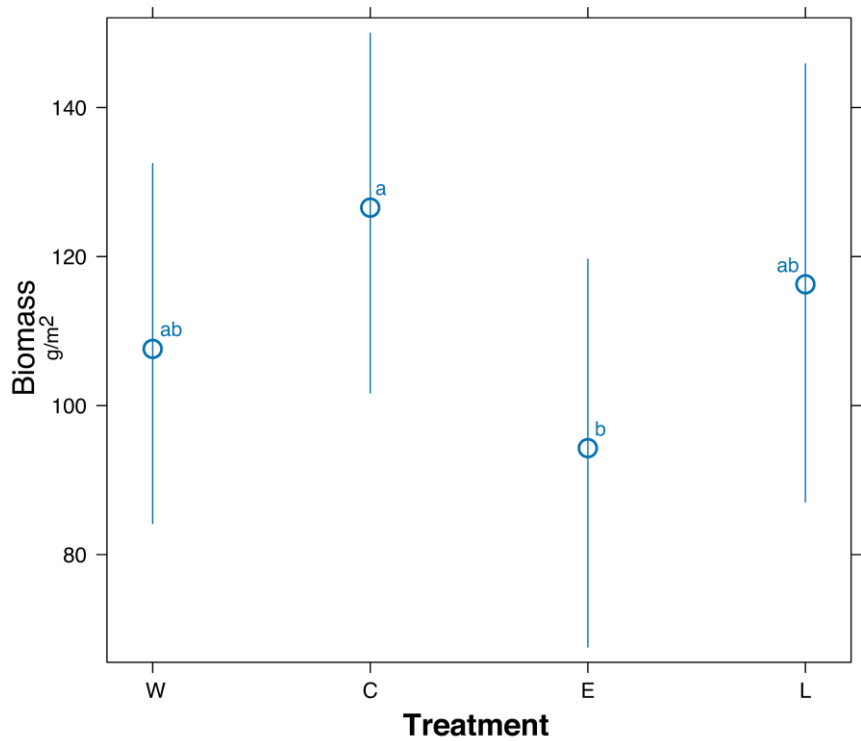


Community scale – biomass production

| Dependent variable | Site    | Factor    | P-value |
|--------------------|---------|-----------|---------|
| Necromass          | Gavia   | Treatment | 0.637   |
|                    | Sappada | Treatment | 0.084   |
| Biomass            | Gavia   | Treatment | 0.014 * |
|                    | Sappada | Treatment | 0.332   |



Community scale – production



| Dependent variable | Site    | Factor    | P-value |
|--------------------|---------|-----------|---------|
| Necromass          | Gavia   | Treatment | 0.637   |
|                    | Sappada | Treatment | 0.084   |
| Biomass            | Gavia   | Treatment | 0.014 * |
|                    | Sappada | Treatment | 0.332   |



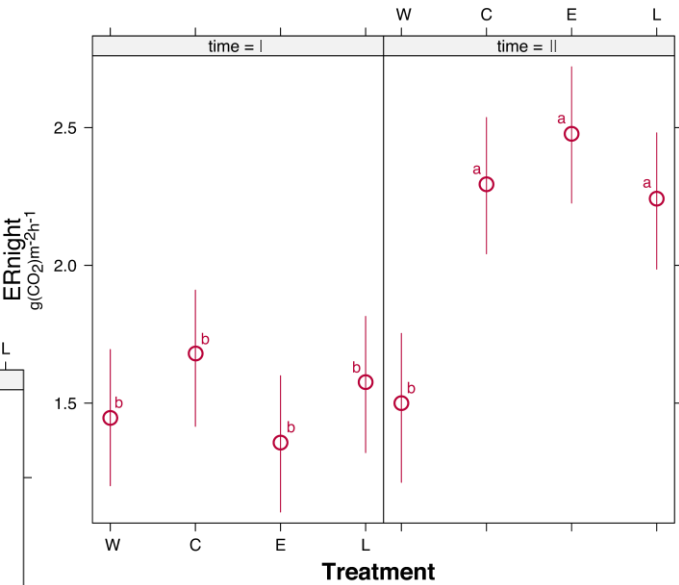
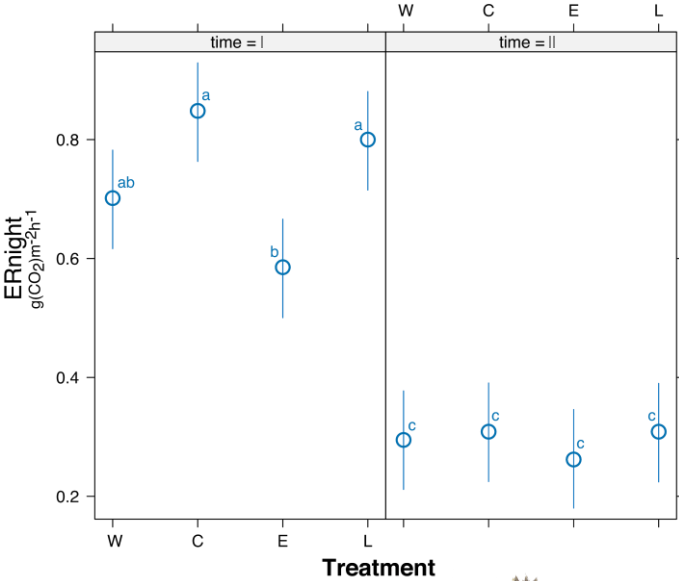
## Community scale – fluxes

| Dependent variable                      | Site    | Factor        | P-value     |
|-----------------------------------------|---------|---------------|-------------|
| Nighttime Ecosystem Respiration         | Gavia   | Treatment     | < 0.001 *** |
|                                         |         | Time          | < 0.001 *** |
|                                         |         | Treat. * Time | 0.019 *     |
|                                         | Sappada | Treatment     | 0.264       |
|                                         |         | Time          | 0.840       |
|                                         |         | Treat. * Time | < 0.001 *** |
| Daytime Net Ecosystem Productivity      | Gavia   | Treatment     | < 0.001 *** |
|                                         |         | Time          | < 0.001 *** |
|                                         |         | Treatment     | 0.961       |
|                                         | Sappada | Time          | < 0.001 *** |
|                                         |         | Treat. * Time | < 0.001 *** |
|                                         |         | Treatment     | < 0.001 *** |
| Gross Primary Productivity with daytime | Gavia   | Time          | < 0.001 *** |
|                                         |         | Treatment     | 0.575       |
|                                         |         | Time          | < 0.001 *** |
|                                         | Sappada | Treatment     | < 0.001 *** |
|                                         |         | Time          | < 0.001 *** |
|                                         |         | Treat. * Time | < 0.001 *** |



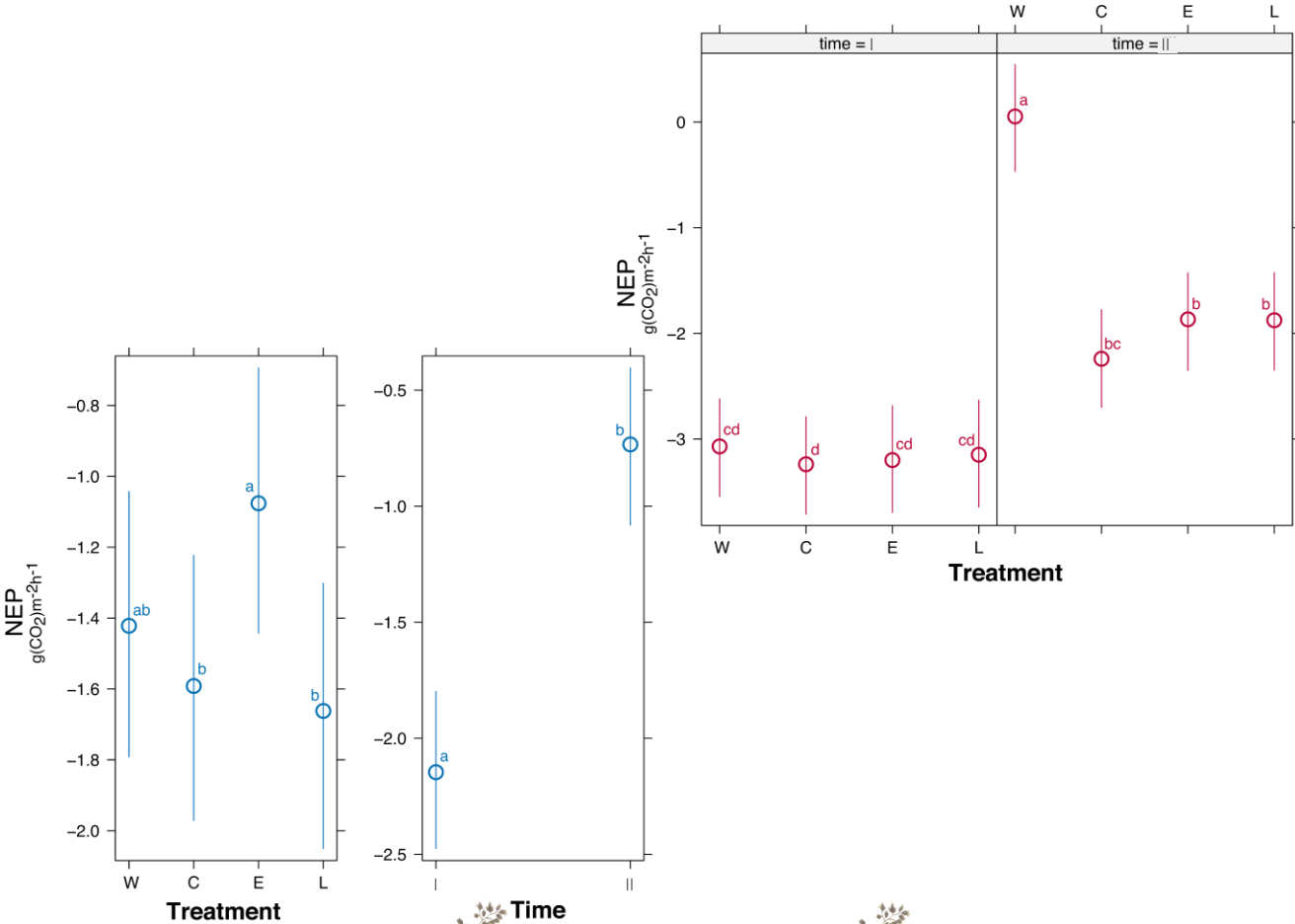
Community scale – fluxes

| Dependent variable                 | Site          | Factor                                  | P-value     |
|------------------------------------|---------------|-----------------------------------------|-------------|
| Nighttime Ecosystem Respiration    | Gavia         | Treatment                               | < 0.001 *** |
|                                    |               | Time                                    | < 0.001 *** |
|                                    |               | Treat. * Time                           | 0.019 *     |
|                                    | Sappada       | Treatment                               | 0.264       |
|                                    |               | Time                                    | 0.840       |
|                                    |               | Treat. * Time                           | < 0.001 *** |
| Daytime Net Ecosystem Productivity | Gavia         | Treatment                               | < 0.001 *** |
|                                    |               | Time                                    | < 0.001 *** |
|                                    |               | Treatment                               | 0.961       |
|                                    | Sappada       | Time                                    | < 0.001 *** |
|                                    |               | Treat. * Time                           | < 0.001 *** |
|                                    |               | Gross Primary Productivity with daytime | Gavia       |
| Time                               | < 0.001 ***   |                                         |             |
| Treatment                          | 0.575         |                                         |             |
| Sappada                            | Time          |                                         | < 0.001 *** |
|                                    | Treat. * Time |                                         | < 0.001 *** |



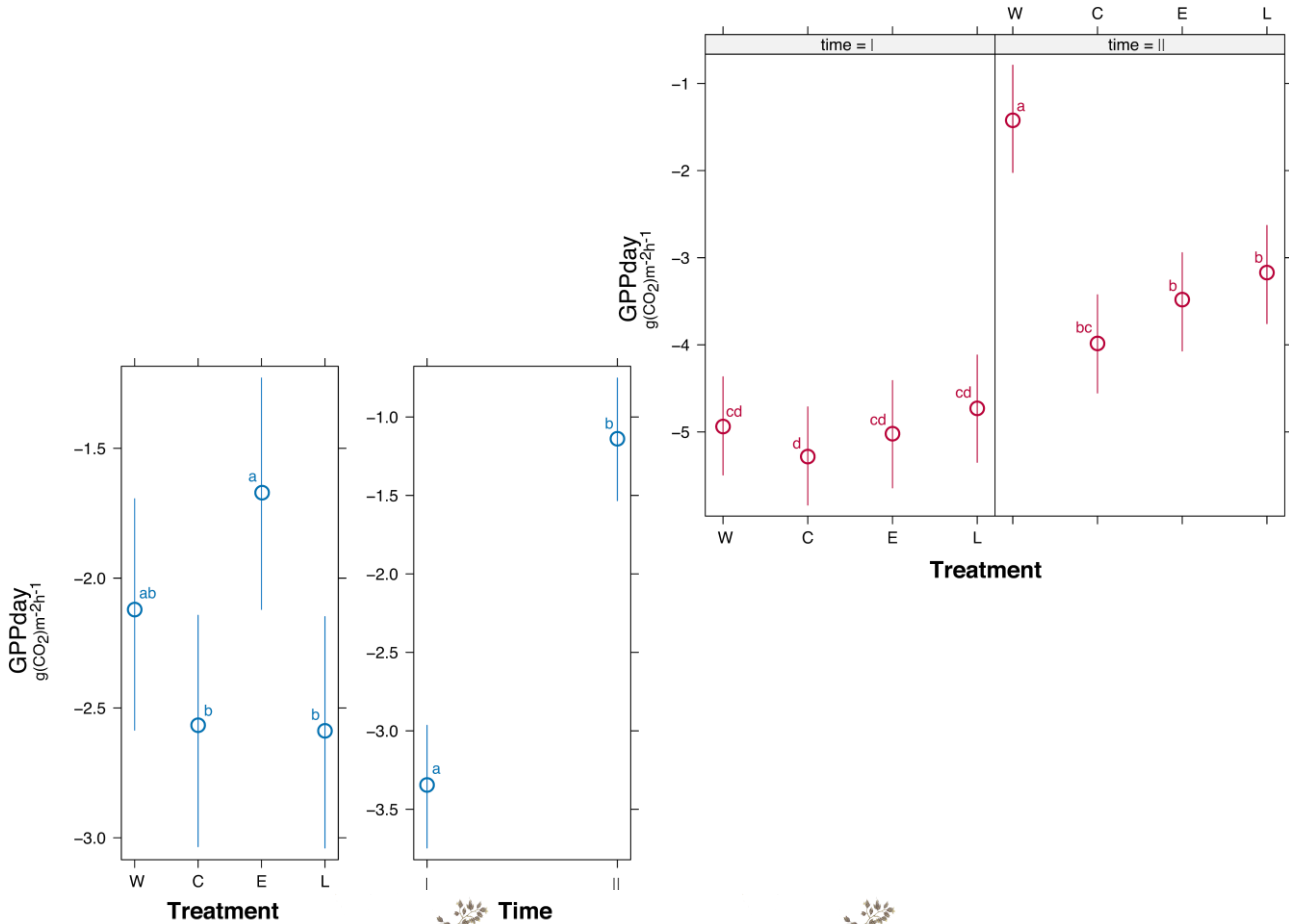
Community scale – fluxes

| Dependent variable                      | Site    | Factor        | P-value     |
|-----------------------------------------|---------|---------------|-------------|
| Nighttime Ecosystem Respiration         | Gavia   | Treatment     | < 0.001 *** |
|                                         |         | Time          | < 0.001 *** |
|                                         |         | Treat. * Time | 0.019 *     |
|                                         | Sappada | Treatment     | 0.264       |
|                                         |         | Time          | 0.840       |
| Daytime Net Ecosystem Productivity      | Gavia   | Treat. * Time | < 0.001 *** |
|                                         |         | Treatment     | < 0.001 *** |
|                                         |         | Time          | < 0.001 *** |
|                                         | Sappada | Treatment     | 0.961       |
|                                         |         | Time          | < 0.001 *** |
| Gross Primary Productivity with daytime | Gavia   | Treat. * Time | < 0.001 *** |
|                                         |         | Treatment     | < 0.001 *** |
|                                         |         | Time          | < 0.001 *** |
|                                         | Sappada | Treatment     | 0.575       |
|                                         |         | Time          | < 0.001 *** |
|                                         | Sappada | Treat. * Time | < 0.001 *** |



Community scale – fluxes

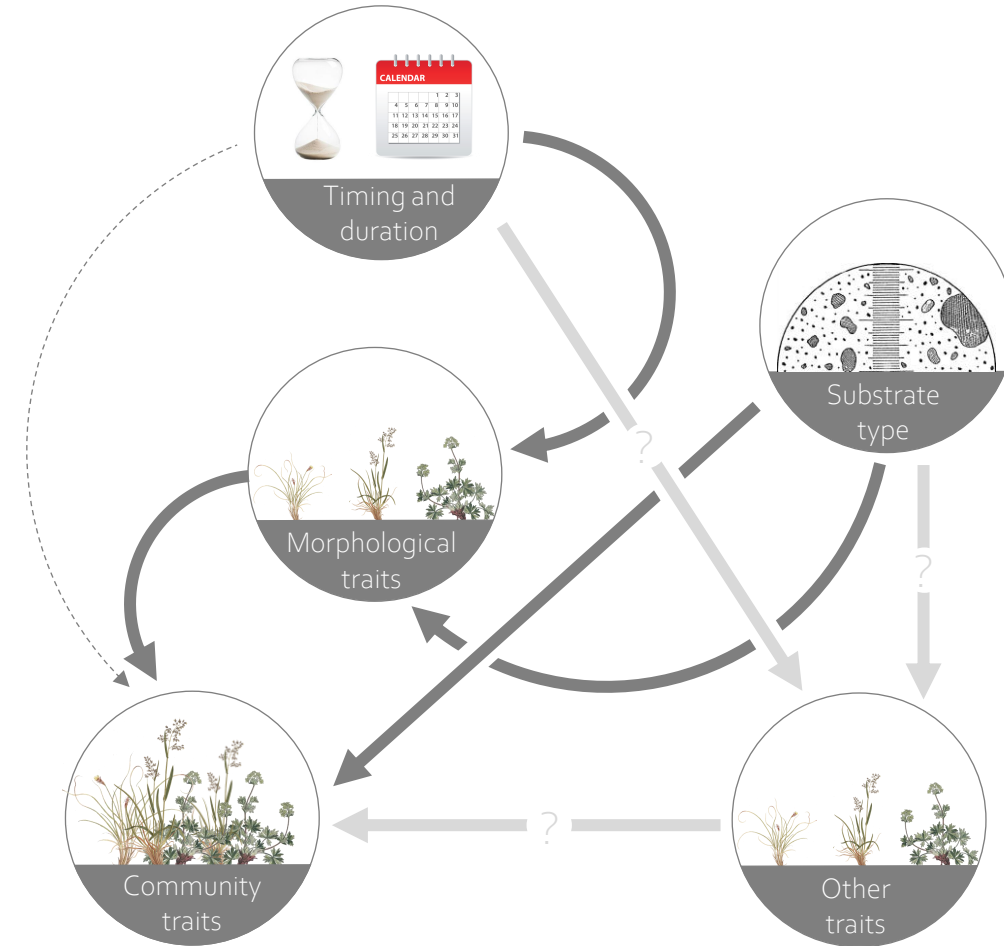
| Dependent variable                      | Site    | Factor        | P-value     |
|-----------------------------------------|---------|---------------|-------------|
| Nighttime Ecosystem Respiration         | Gavia   | Treatment     | < 0.001 *** |
|                                         |         | Time          | < 0.001 *** |
|                                         |         | Treat. * Time | 0.019 *     |
|                                         | Sappada | Treatment     | 0.264       |
|                                         |         | Time          | 0.840       |
|                                         |         | Treat. * Time | < 0.001 *** |
| Daytime Net Ecosystem Productivity      | Gavia   | Treatment     | < 0.001 *** |
|                                         |         | Time          | < 0.001 *** |
|                                         |         | Treat. * Time | 0.961       |
|                                         | Sappada | Treatment     | < 0.001 *** |
|                                         |         | Time          | < 0.001 *** |
|                                         |         | Treat. * Time | < 0.001 *** |
| Gross Primary Productivity with daytime | Gavia   | Treatment     | < 0.001 *** |
|                                         |         | Time          | < 0.001 *** |
|                                         | Sappada | Treatment     | 0.575       |
|                                         |         | Treat. * Time | < 0.001 *** |



# CONCLUSIONS

## An attempt to disentangle a complex answer

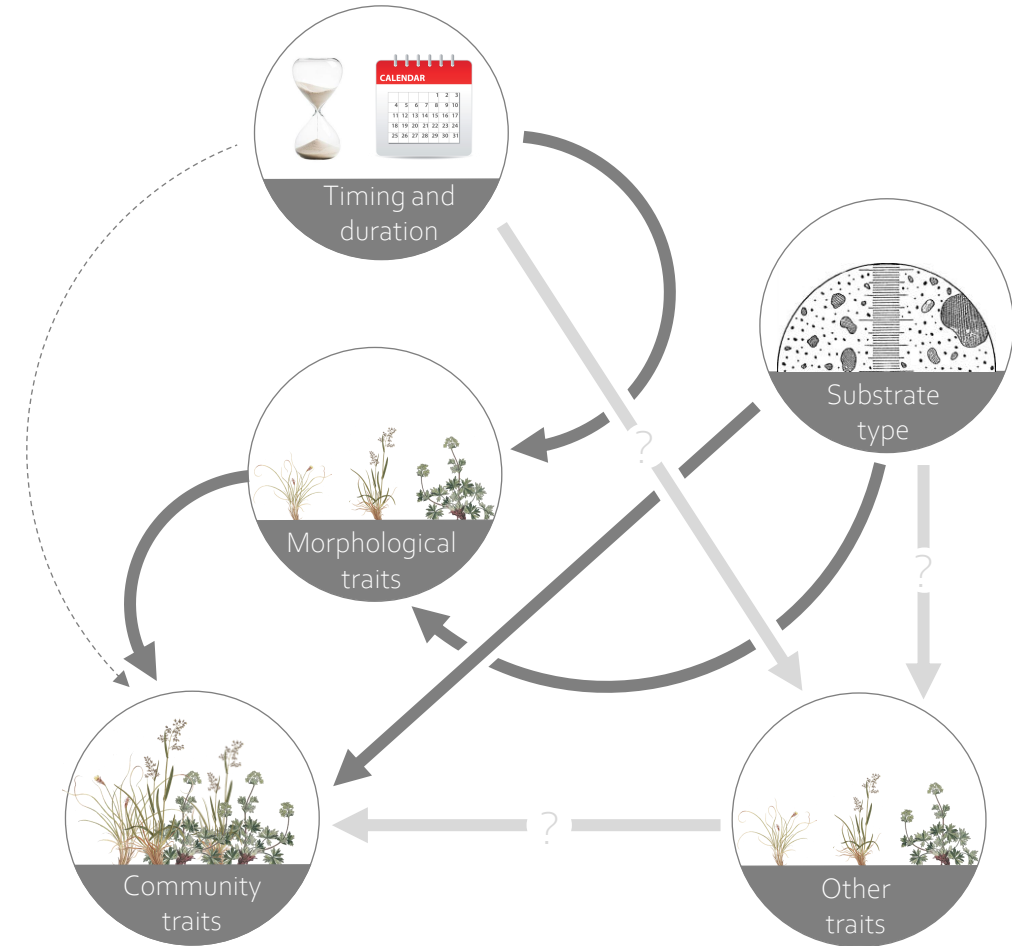
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- Community level response: less straightforward (compensatory dynamics among species)
- The sites show both shared and opposing responses, which may suggest a different involvement of other parameters (hopefully among those we have measured)



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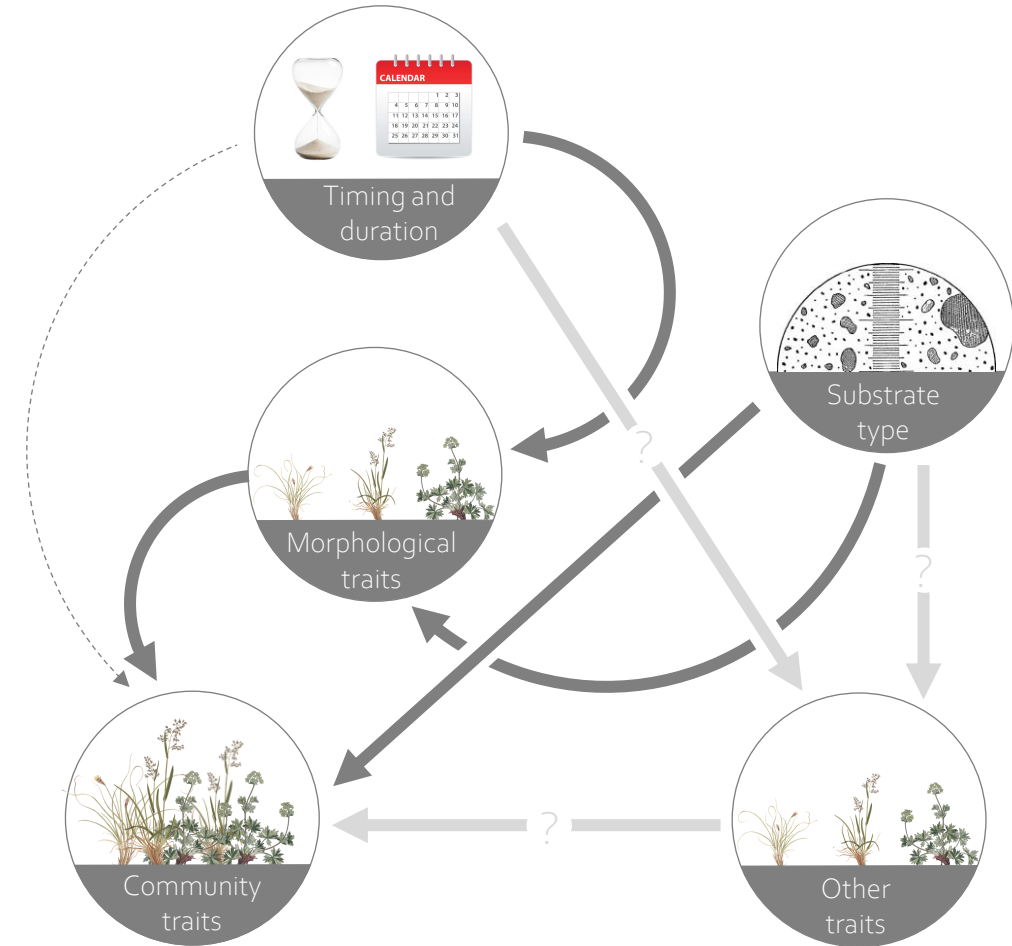
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# THANKS FOR YOUR ATTENTION

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First AAPP Alpine Adria Plant Physiology Meeting



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