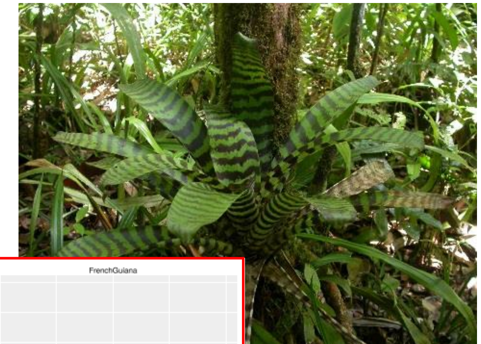
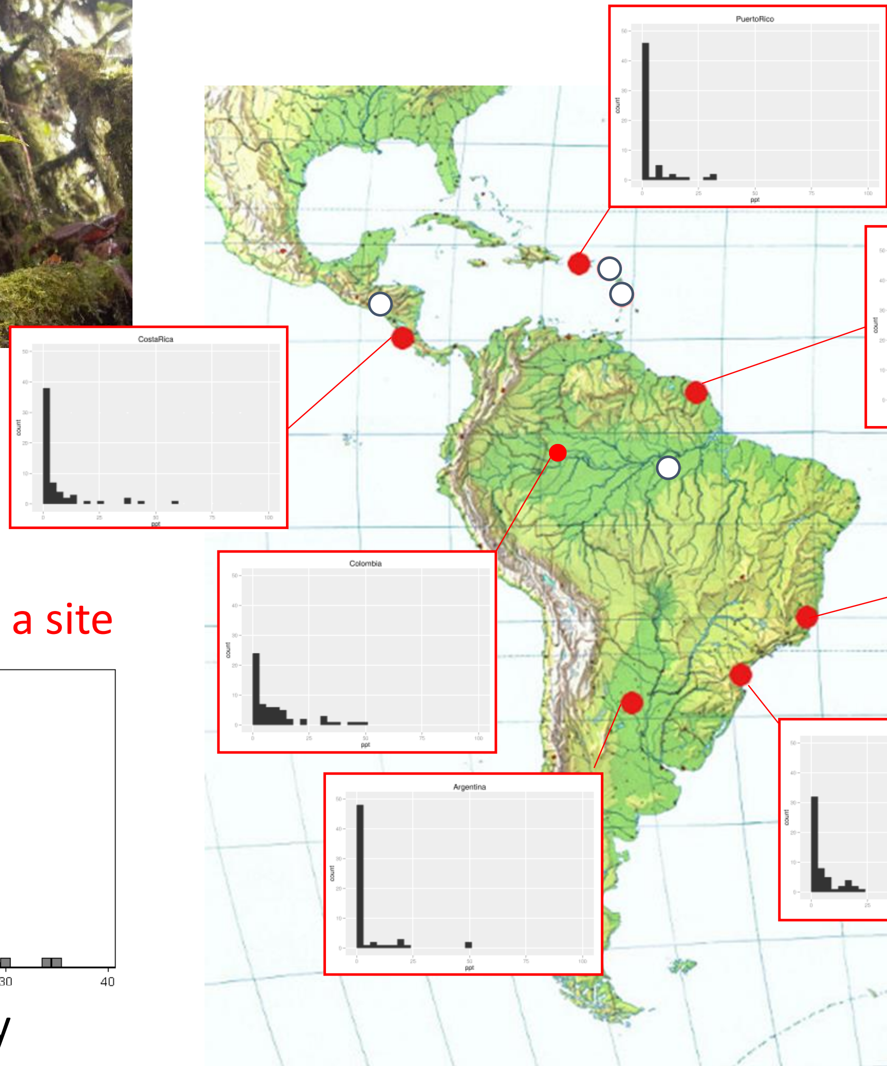
Day and Time	Full group
Day 1: 9:00-12:00	Lead author reports on results: Diane, Ignacio, Regis, Vinicius, Gustavo, Dimaris, Olivier each to present a 10 min talk + 10 min discussion= 140 min (3 hours with a 30 minute coffee break)
Day 1: 12-1:30	Lunch break
Day 1: 1:30-2:30	Proposed Paper 8 (Group Discussion): Gustavo Romero would like to propose a new paper 8, using matrices of predator-prey interaction strengths to calculate effects of drought on connectance and other network metrics.
Day 1: 2:30-3:30	Metrics of hydrology and rainfall (Nicholas, with input from Diane, Andrew, Olivier) – how metrics are calculated, how they are correlated within sites, how they differ between sites.
Day 1: 3:30-5:00	Using BWG tools (Workshop: Andrew) Please bring laptops. We will make sure here that everyone can use bwgtools to access and manipulate the data. Assistants: Diane, Nicholas, Olivier, others?
Day 1: 5:00-5:30	Data managers only: quality control exercise Diane, Regis, Kurt, Rodrigo, Fabiola, Nicholas, Pablo (please bring laptops or photocopies of field notes with the original raw data for your site)

The “drought” experiment

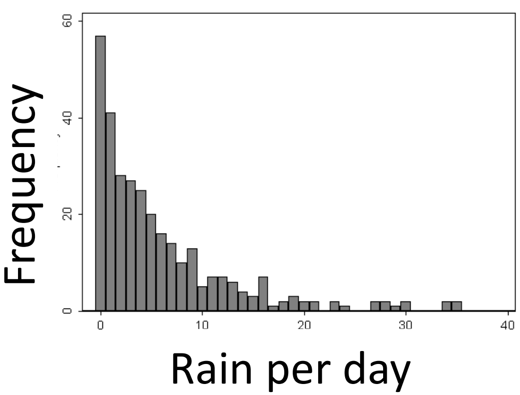
Bromeliads grow in different climates.

Bromeliads grow in different climates.

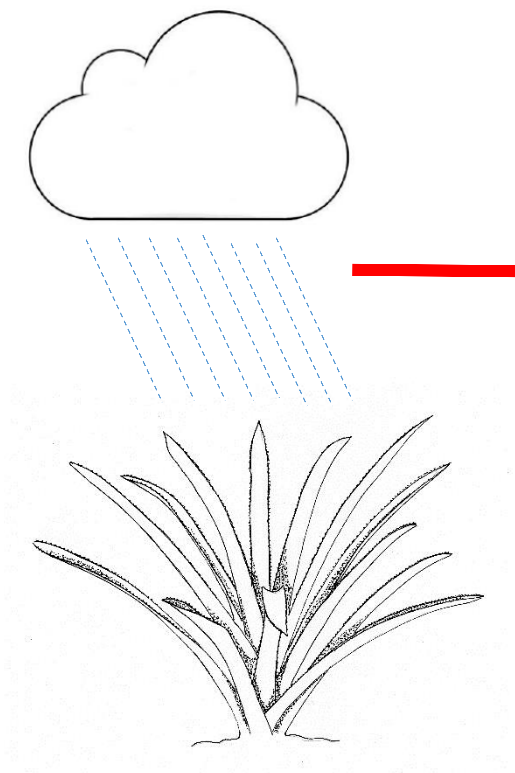




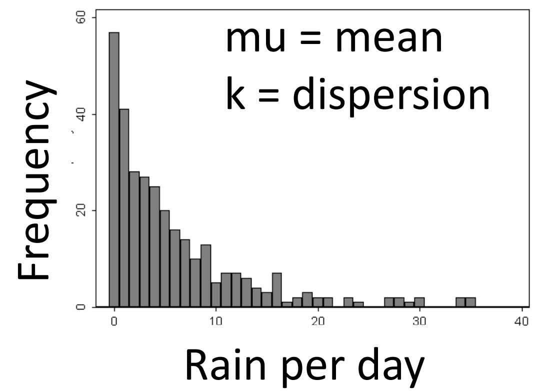
Daily rainfall at a site

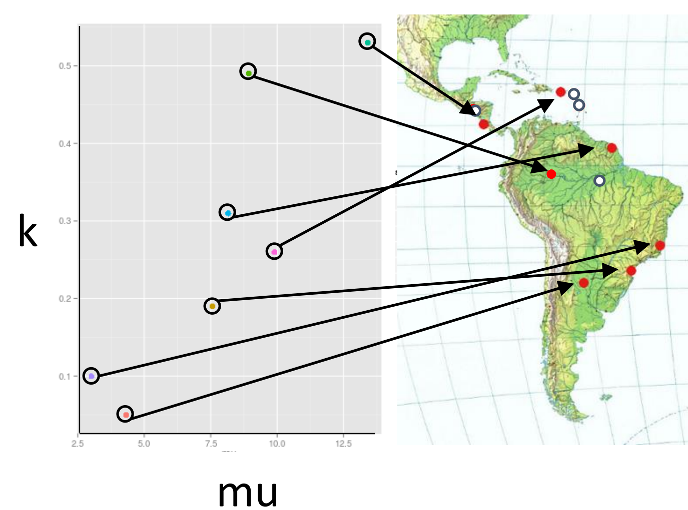


A geographically replicated experiment: effects of precipitation on bromeliad food webs



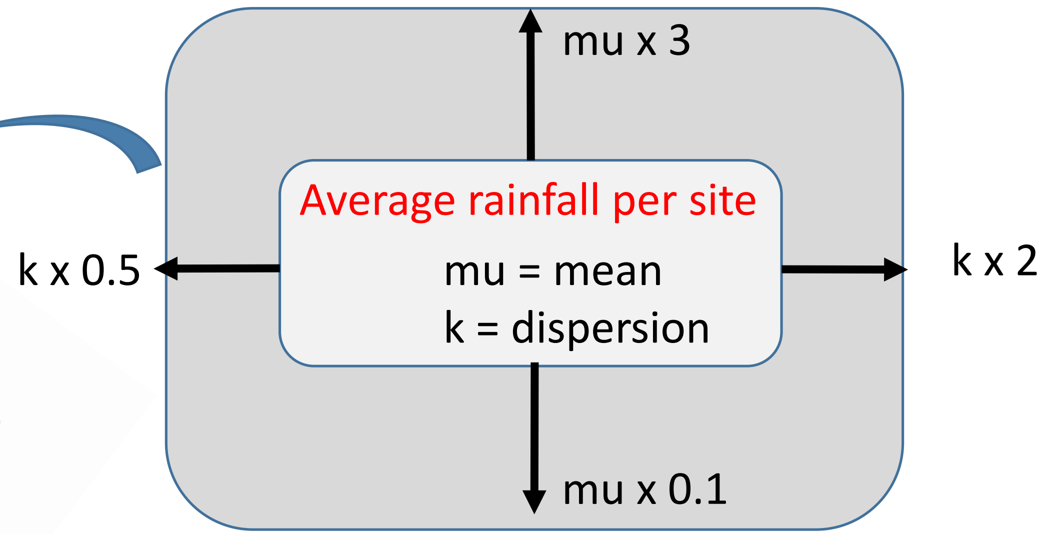
Daily rainfall at a site

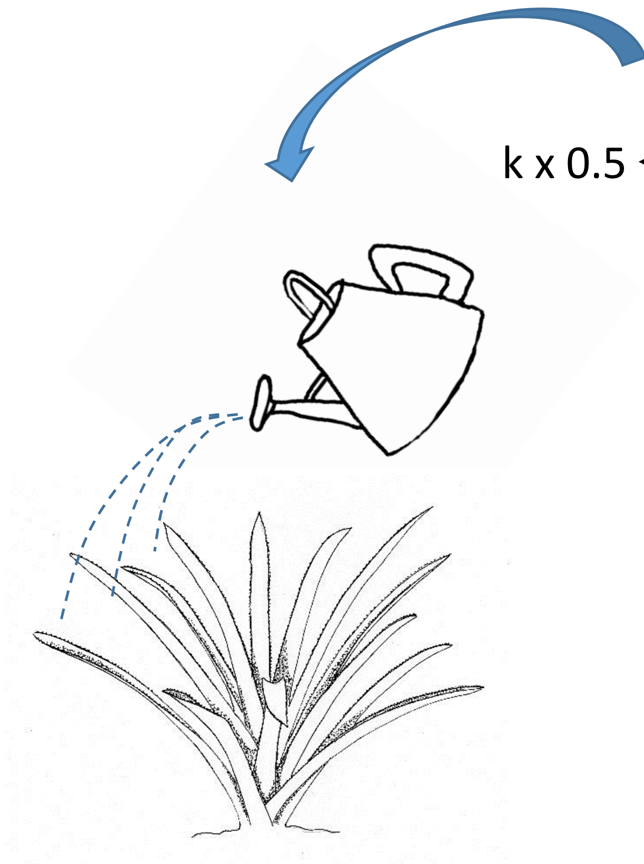




High k: more equitable rainfall, less of a hollow curve

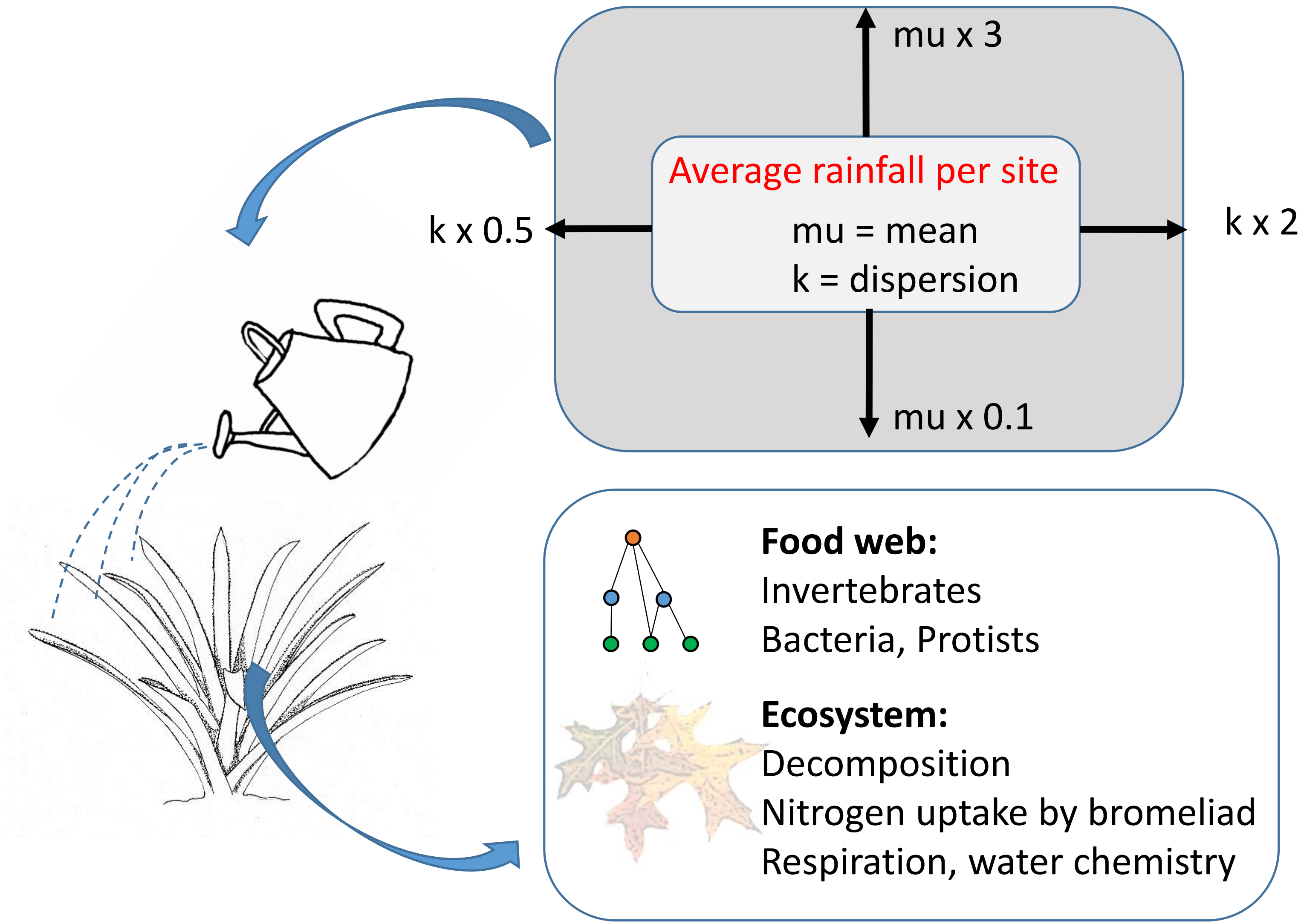
A geographically replicated experiment: effects of precipitation on bromeliad food webs





30 combinations of mu and k simulated by hand watering for 60 days

A geographically replicated experiment: effects of precipitation on bromeliad food webs



A geographically replicated experiment: effects of precipitation on bromeliad food webs

mu x 3

Average rainfall per site

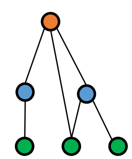
k x 0.5

mu = mean

k = dispersion

k x 2

mu x 0.1

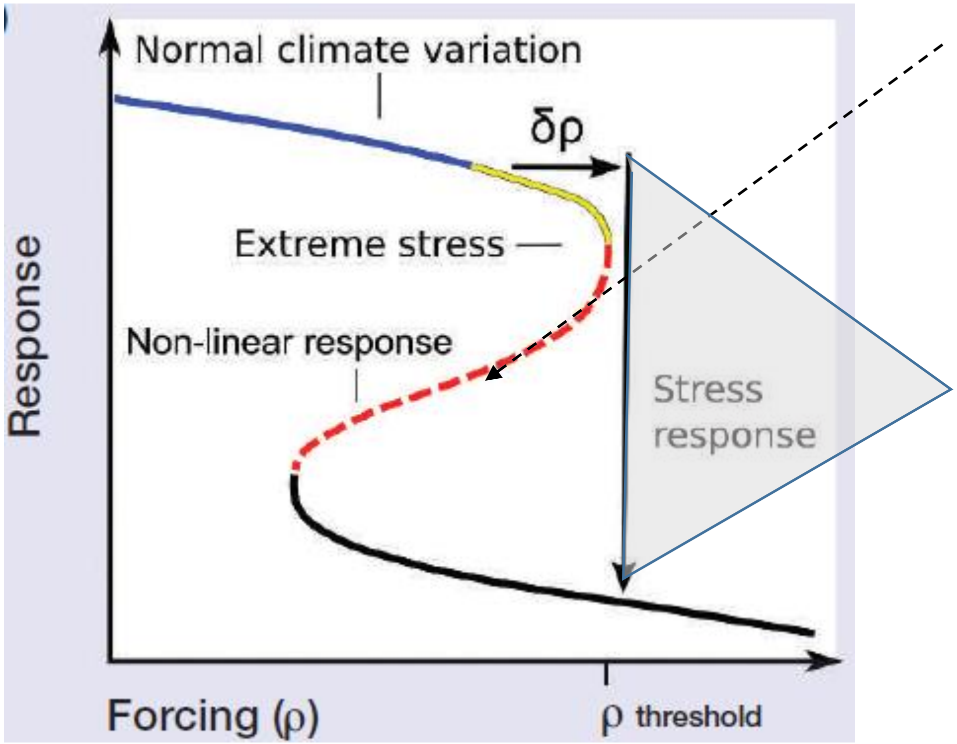


Food web:
Invertebrates
Bacteria, Protists

Ecosystem:
Decomposition
Nitrogen uptake by bromeliad
Respiration, water chemistry

Paper 1:
~~Thresholds~~
Contingency & sensitivity

Focus on sensitivity, not thresholds



Thresholds: requires dynamical analysis to determine if the system can recover when stress is stopped.

Sensitivity: Resistance of the system to a continuing stressor

Figure from Kayler et al. 2015. “Experiments to confront the extremes of climate change” Front. Ecol. Environ.

Are bromeliads everywhere equally sensitive to changes in relative rainfall?

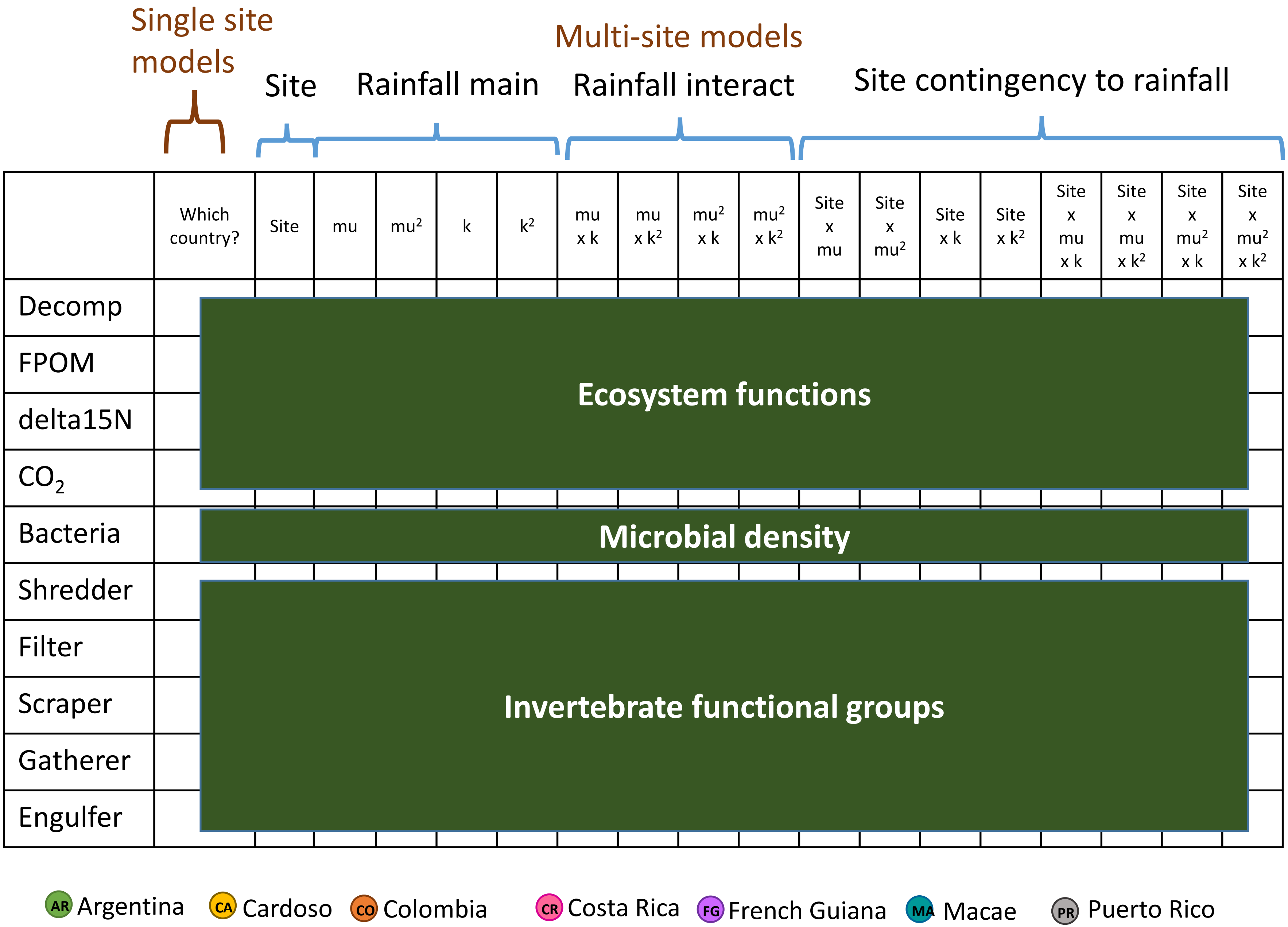
(1) Is there evidence of site contingency? If so, which types of climatic shifts and what types of responses?

(2) How do climatic shifts affect this ecosystem? Is the pattern similar between sites?

(3) Do differences between sites in ambient conditions explain contingency?

(4) Does contingency disappear when we consider hydrological dynamics directly?

Q1. Is there evidence of site contingency? If so, which types of climatic shifts and what types of responses?



Single site models
Multi-site models
Site
Rainfall main
Rainfall interact
Site contingency to rainfall
Which country?
Site
mu
mu^2
k
k^2
mu x k
mu x k^2
mu^2 x k
mu^2 x k^2
Site x mu
Site x mu^2
Site x k
Site x k^2
Site x mu x k
Site x mu x k^2
Site x mu^2 x k
Site x mu^2 x k^2
Decomp
FPOM
delta15N
CO_2
Bacteria
Shredder
Filter
Scraper
Gatherer
Engulfer
Ecosystem functions
Microbial density
Invertebrate functional groups
AR Argentina
CA Cardoso
CO Colombia
CR Costa Rica
FG French Guiana
MA Macae
PR Puerto Rico

		Site	Rainfall main				Rainfall interact				Site contingency to rainfall							
	Which country?	Site	mu	mu^2	k	k^2	mu x k	mu x k^2	mu^2 x k	mu^2 x k^2	Site x mu	Site x mu^2	Site x k	Site x k^2	Site x mu x k	Site x mu x k^2	Site x mu^2 x k	Site x mu^2 x k^2
Decomp	CO PR AR	■		■														
FPOM	CA MA FG																	
delta15N	CO CA PR FG AR																	
CO_2	AR CR	■	■	■														
Bacteria	CO FG PR	■	■															
Shredder	AR FG CA	■			■	■												
Filter	PR		■	■														
Scraper	CO CR PR	■											■					
Gatherer	AR CO	■																
Engulfer	MA FG																	

AR Argentina CA Cardoso CO Colombia CR Costa Rica FG French Guiana MA Macae PR Puerto Rico

		Site	Rainfall main				Rainfall interact				Site contingency to rainfall							
	Which country?	Site	mu	mu^2	k	k^2	mu x k	mu x k^2	mu^2 x k	mu^2 x k^2	Site x mu	Site x mu^2	Site x k	Site x k^2	Site x mu x k	Site x mu x k^2	Site x mu^2 x k	Site x mu^2 x k^2
Decomp	CO PR AR	■		■														
FPOM	CA MA FG																	
delta15N	CO CA PR FG AR																	
CO_2	AR CR	■	■	■														
Bacteria	CO FG PR	■	■															
Shredder	AR FG CA	■			■	■												
Filter	PR		■	■														
Scraper	CO CR PR	■											■					
Gatherer	AR CO	■																
Engulfer	MA FG																	

1. Site and rainfall mean (mu, mu^2) frequently important as main effects, but they don't interact.

		Site	Rainfall main				Rainfall interact				Site contingency to rainfall							
	Which country?	Site	mu	mu^2	k	k^2	mu x k	mu x k^2	mu^2 x k	mu^2 x k^2	Site x mu	Site x mu^2	Site x k	Site x k^2	Site x mu x k	Site x mu x k^2	Site x mu^2 x k	Site x mu^2 x k^2
Decomp	CO PR AR	■		■														
FPOM	CA MA FG																	
delta15N	CO CA PR FG AR																	
CO_2	AR CR	■	■	■														
Bacteria	CO FG PR	■	■															
Shredder	AR FG CA	■			■	■												
Filter	PR		■	■														
Scraper	CO CR PR	■											■					
Gatherer	AR CO	■																
Engulfer	MA FG																	

2. Rainfall dispersion (k, k^2) not often important, appears as only example of site contingency….

		Site	Rainfall main				Rainfall interact				Site contingency to rainfall							
	Which country?	Site	mu	mu²	k	k²	mu x k	mu x k²	mu² x k	mu² x k²	Site x mu	Site x mu²	Site x k	Site x k²	Site x mu x k	Site x mu x k²	Site x mu² x k	Site x mu² x k²
Decomp	CO PR AR	■		■														
FPOM	CA MA FG																	
delta15N	CO CA PR FG AR										Contingent							
CO_2	AR CR	■	■	■														
Bacteria	CO FG PR	■	■															
Shredder	AR FG CA	■			■	■												
Filter	PR		■	■							Contingent							
Scraper	CO CR PR	■									Contingent		■					
Gatherer	AR CO	■																
Engulfer	MA FG										Contingent							

AR Argentina CA Cardoso CO Colombia CR Costa Rica FG French Guiana MA Macae PR Puerto Rico

3. Almost half of responses show evidence of contingency, especially those directly measuring invertebrates or bromeliads.

Which model explains more (adj.) deviance?

Unadjusted D2

	Site x Relative mu, k	Site		Site x Relative mu, k	Site	rainfall P
Decomp	0.89	0.85		0.93	0.85	0.13*
FPOM	0.65	0.64		0.76	0.66	0.29
delta15N	0.67	0.64		0.78	0.66	**--- C---**
CO_2	0.92					
Bacteria	0.71	0.65		0.80	0.67	**0.00001**
Shredder	0.33	0.34		0.53	0.37	0.10*
Filter	0.68	0.50		0.78	0.52	**---- C----**
Scraper	0.68	0.63		0.78	0.65	**---- C --**
Gatherer	0.50	0.46		0.65	0.48	0.47
Engulfer	0.77	0.70		0.84	0.72	**----C-----**
P:D mass ratio				0.53	0.34	**0.003**

*if test rain interactions first, then test main effects of rain, then **p<0.05**

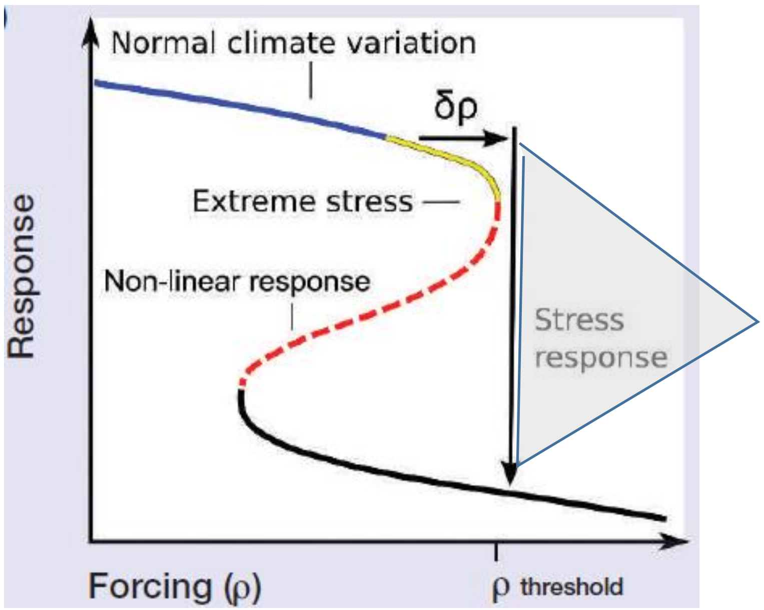
		Site	Rainfall main				Rainfall interact				Site contingency to rainfall							
	Which country?	Site	mu	mu^2	k	k^2	mu x k	mu x k^2	mu^2 x k	mu^2 x k^2	Site x mu	Site x mu^2	Site x k	Site x k^2	Site x mu x k	Site x mu x k^2	Site x mu^2 x k	Site x mu^2 x k^2
Decomp	CO PR AR	■		■														
FPOM	CA MA FG																	
delta15N	CO CA PR FG AR										Contingent							
CO_2	AR CR	■	■	■														
Bacteria	CO FG PR	■	■															
Shredder	AR FG CA	■			■	■												
Filter	PR		■	■							Contingent							
Scraper	CO CR PR	■									Contingent							
Gatherer	AR CO	■																
Engulfer	MA FG										Contingent							

AR Argentina CA Cardoso CO Colombia CR Costa Rica FG French Guiana MA Macae PR Puerto Rico

4. Sensitive sites differ with response, but CO,FG, AR, PR frequently sensitive and MA, CR, CA less often sensitive

Q2. How do climatic shifts affect this ecosystem? Is the pattern similar between sites?

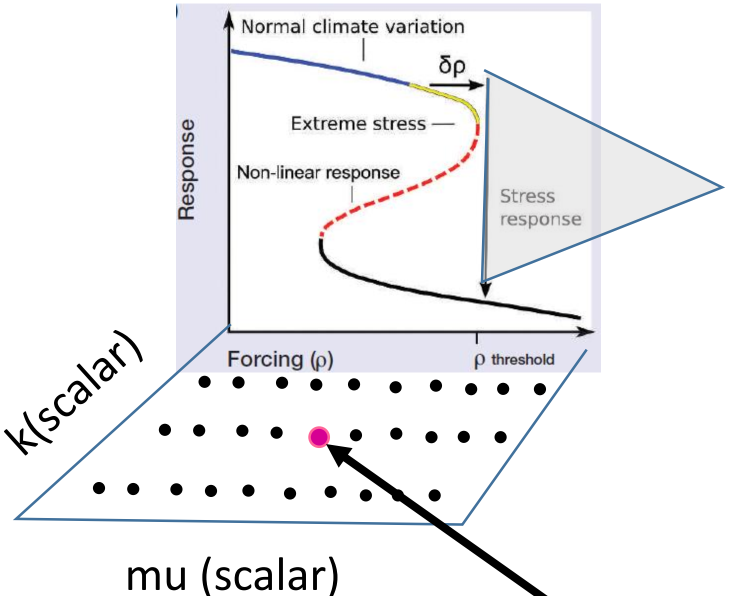
We have not one but two climatic shifts (mu and k)…



Ecosystem Sensitivity = change from ambient conditions with a small shift in climate

Figure from Kayler et al. 2015. “Experiments to confront the extremes of climate change” Front. Ecol. Environ.

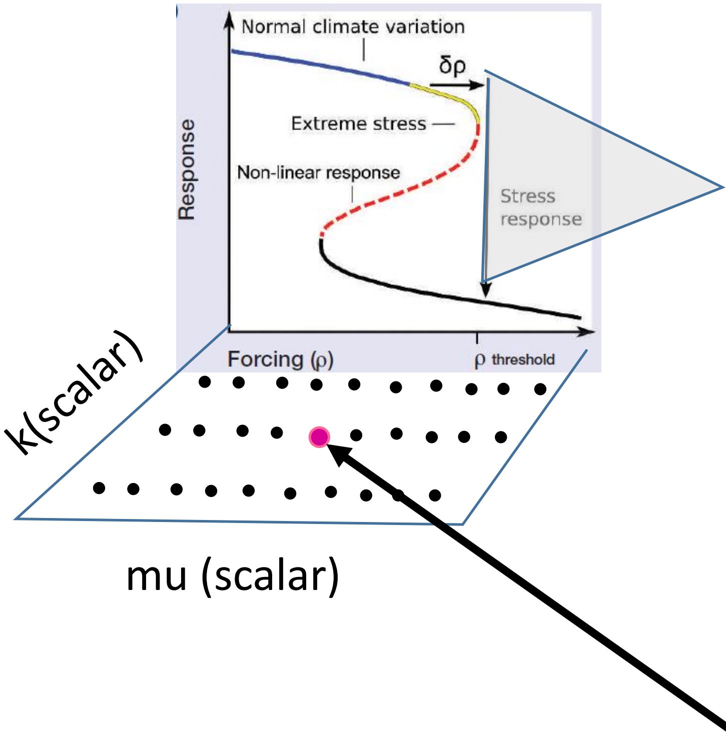
Comparing sensitivity between sites



Ecosystem Sensitivity = change from ambient conditions with a small shift in climate

Ambient:
mu = 1, k = 1

Comparing sensitivity between sites



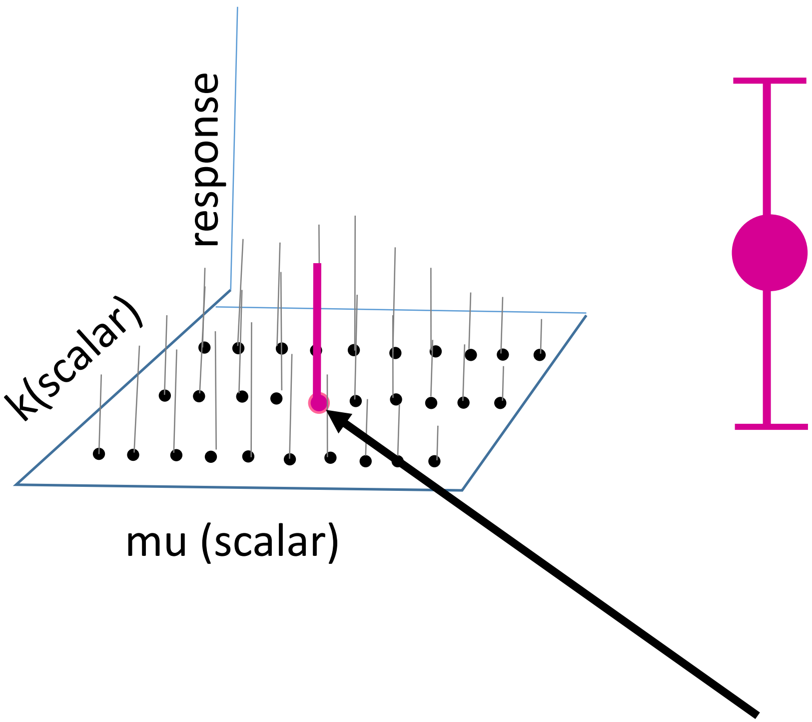
Ecosystem Sensitivity = change from ambient conditions with a small shift in climate

Ambient:
mu = 1, k = 1

The challenge:

1. Estimate ambient conditions with 1 replicate of mu=1 k=1 treatment.
2. Express response relative to site's ambient conditions
3. Plot in a way that allows site comparisons

Comparing sensitivity between sites



mu1k1 estimate, with 95% CI

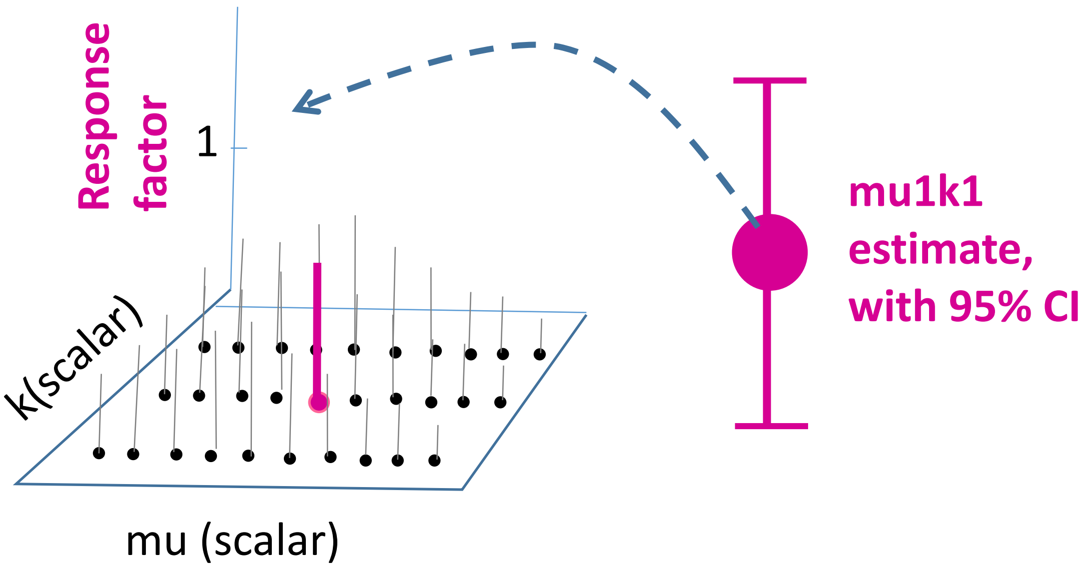
Ambient:
mu = 1, k = 1

The challenge:

1. Estimate ambient conditions with 1 replicate of mu=1 k=1 treatment.

Solution: Build a model with all 30 bromeliads, use model to get best estimate of mu=1, k=1 for median-sized bromeliad

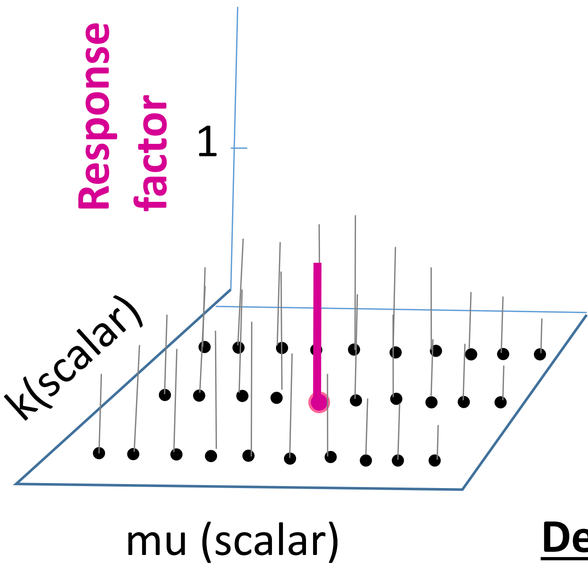
Comparing sensitivity between sites

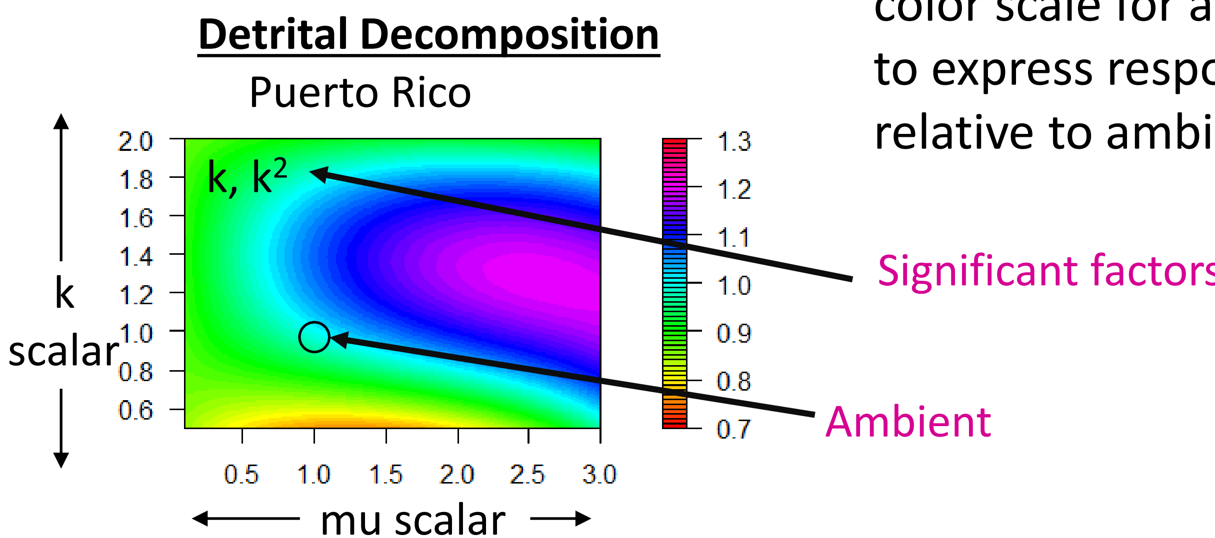


The challenge:
2. Express response relative to site's ambient conditions.

Solution: Divide responses by ambient <u>estimate</u> to obtain the factor by which it decreases (<1) or increases (>1).

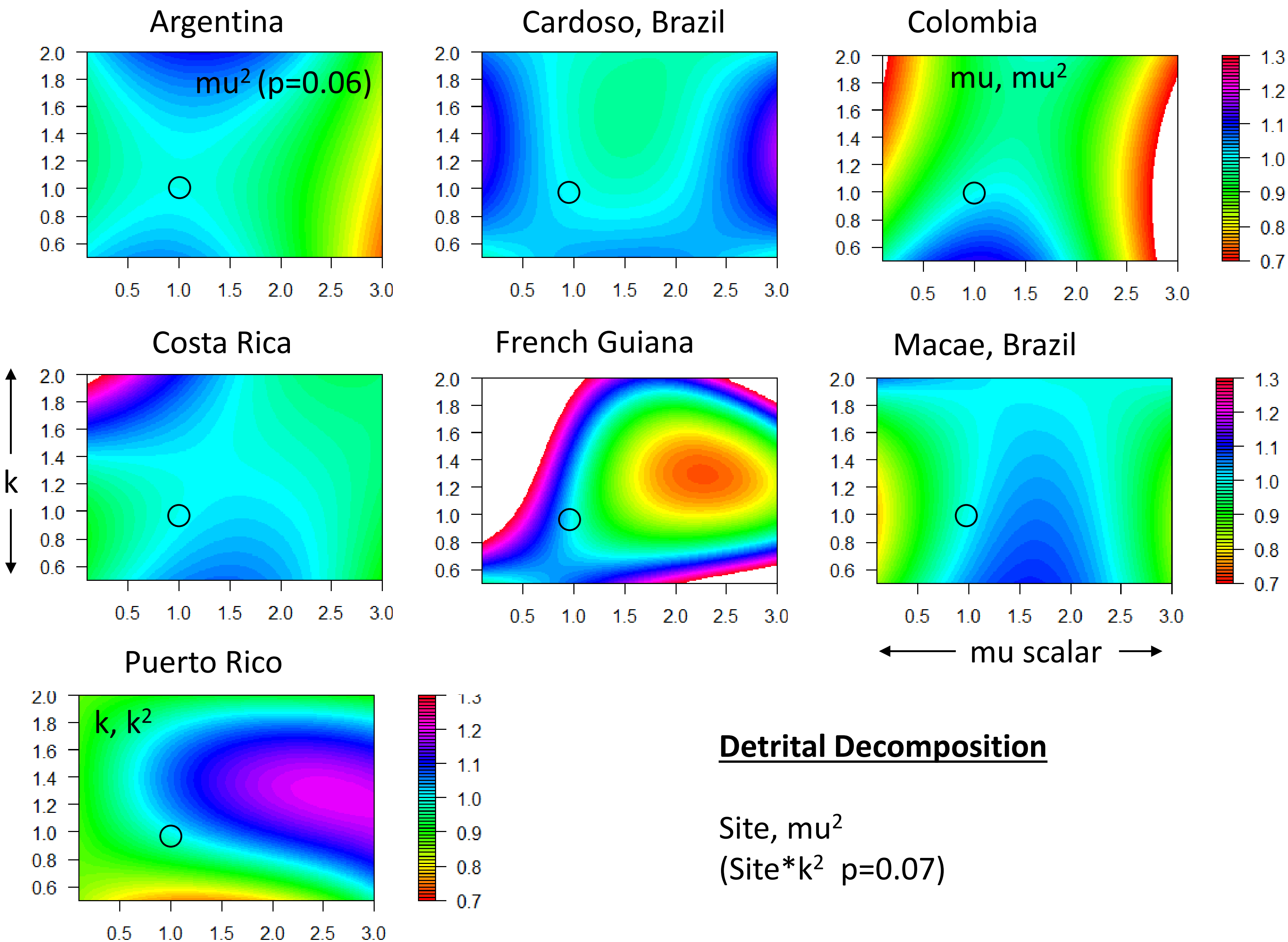
Comparing sensitivity between sites





The challenge:
3. Plot in a way that allows site comparisons

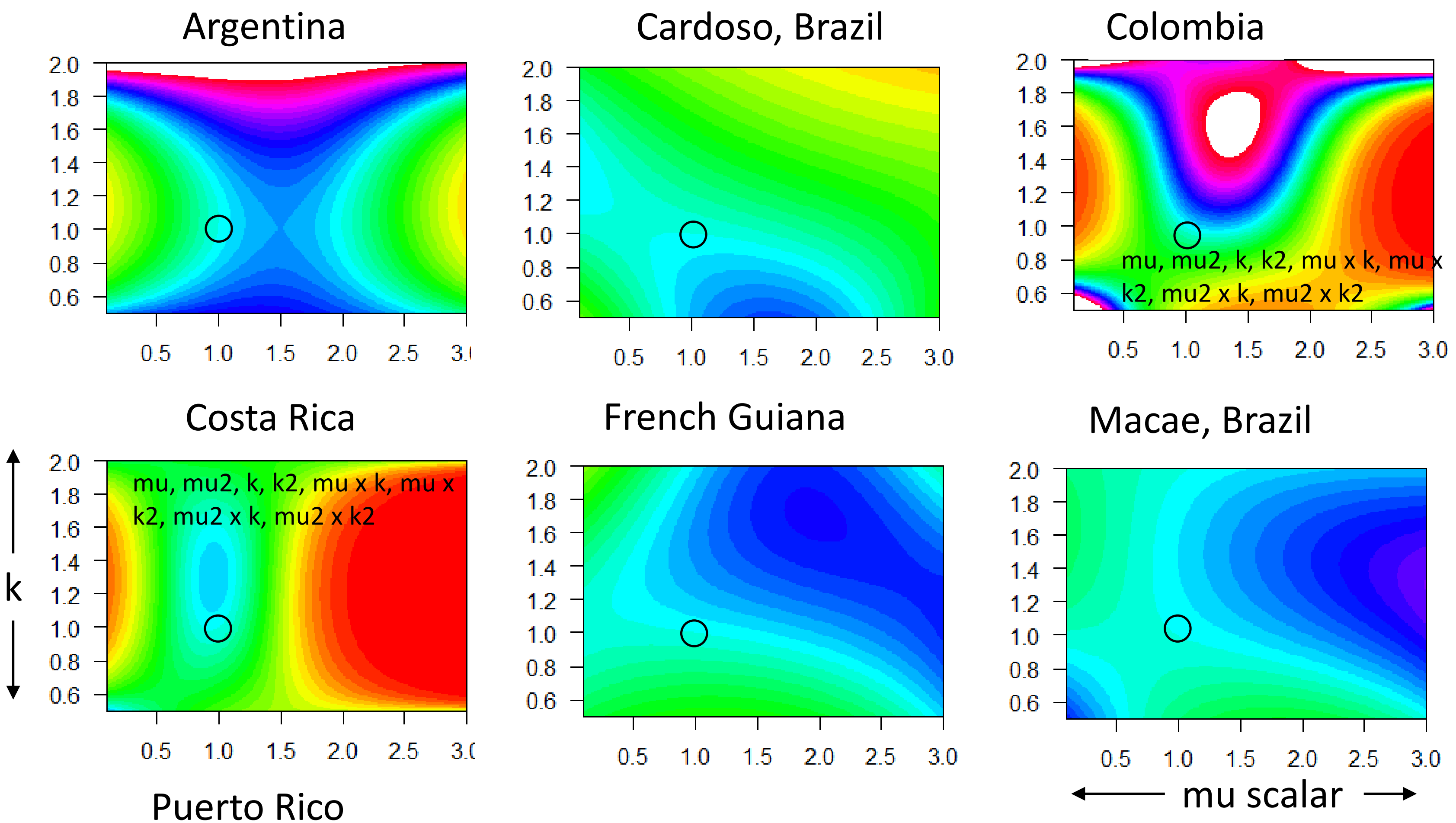
Solution: Use the same color scale for all sites to express responses relative to ambient.

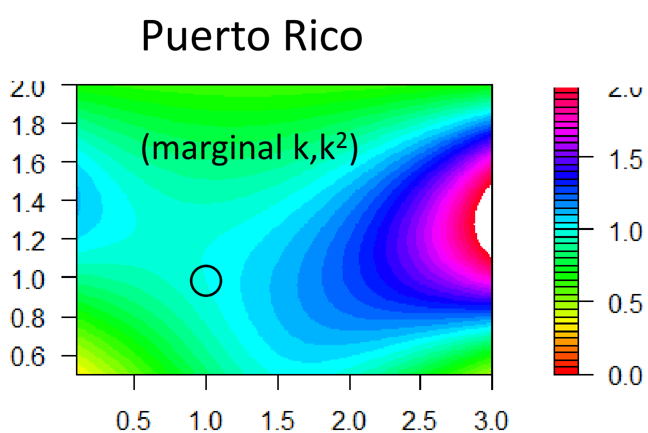


Detrital Decomposition

Site, mu^2

(Site*k^2 $p=0.07$)

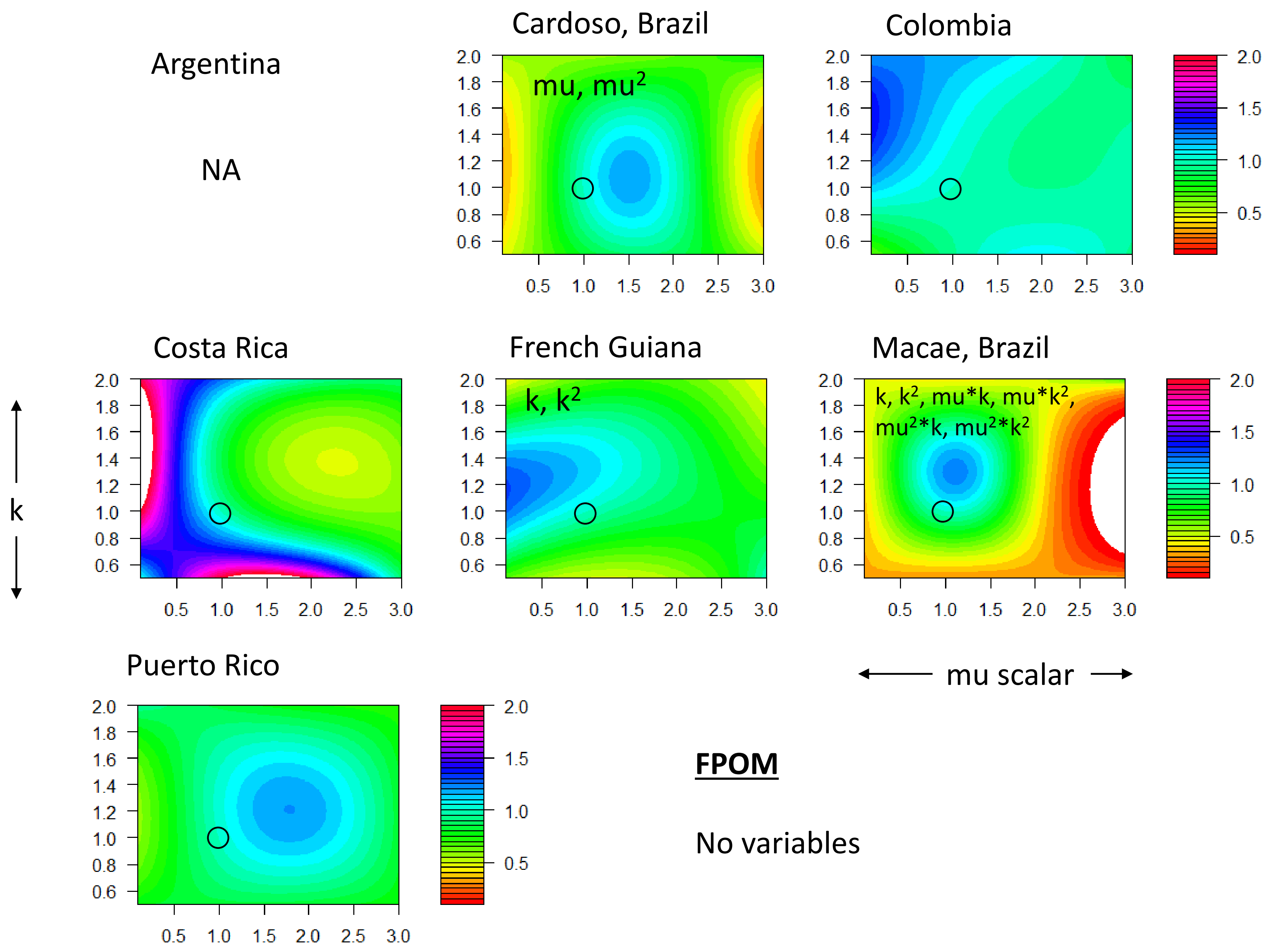




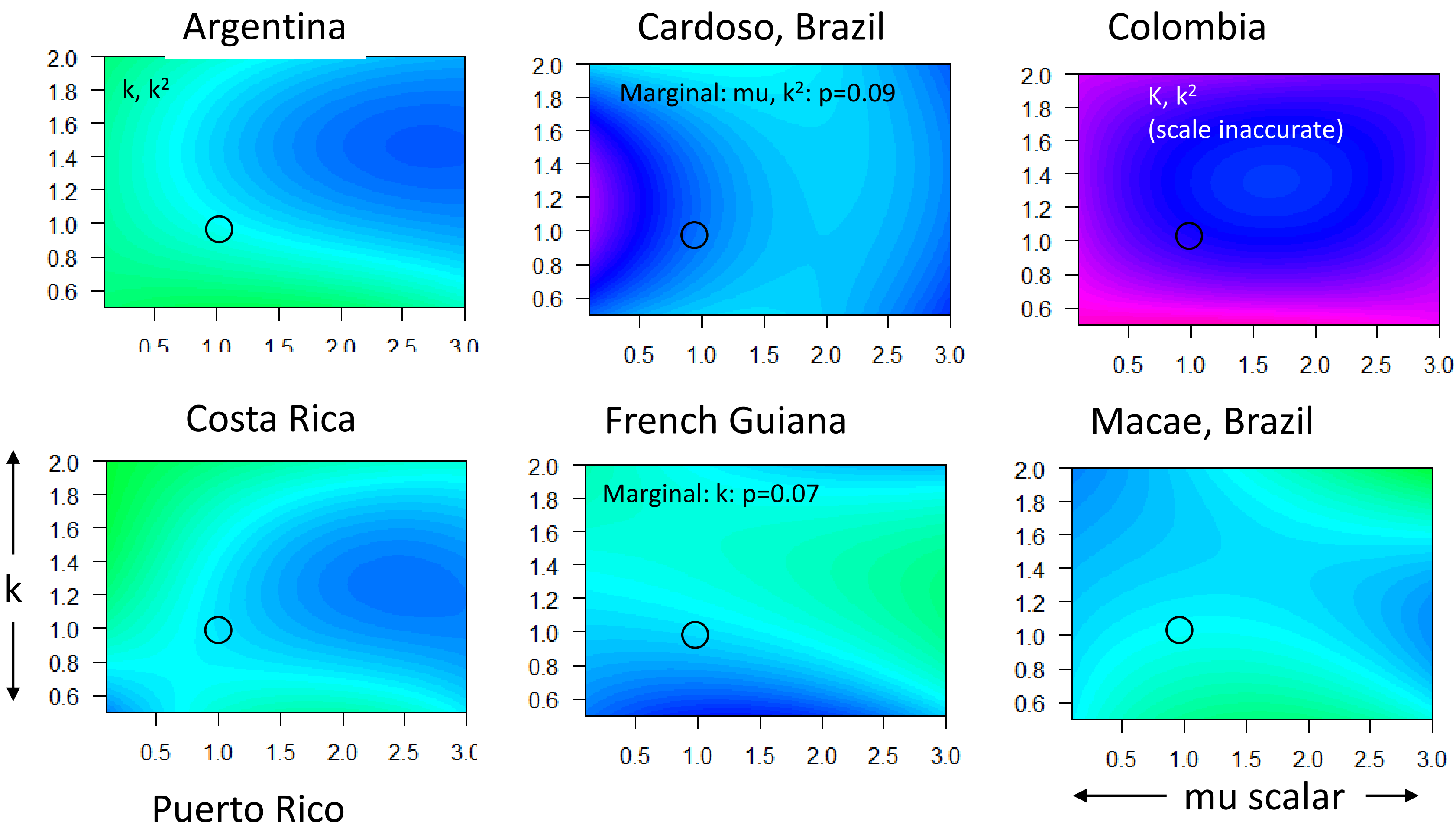
Scraper biomass

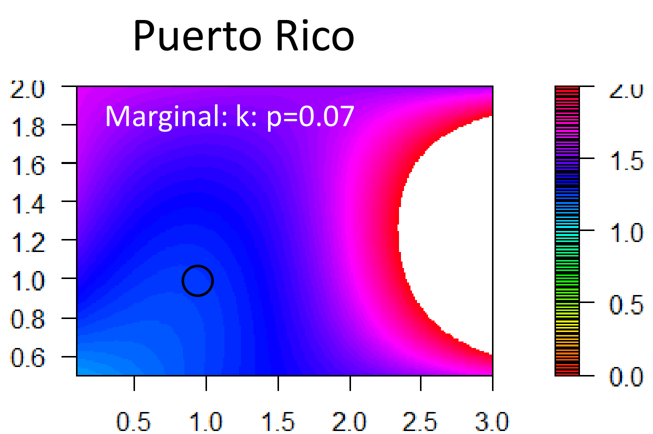
site, site x k (marginally site x k^2 p=0.06)

Contingent



Argentina
NA
Cardoso, Brazil
mu, mu²
Colombia
Costa Rica
French Guiana
k, k²
Macae, Brazil
k, k², mu*k, mu*k²,
mu²*k, mu²*k²
Puerto Rico
k
mu scalar
FPOM
No variables

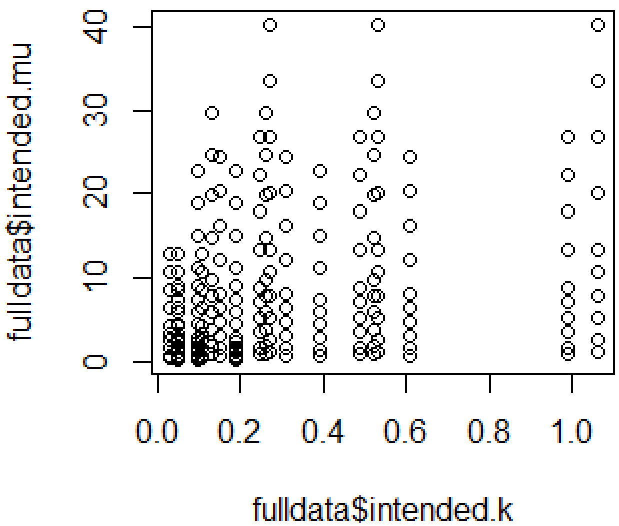




<u>$delta^{15}$ N of bromeliad</u>

No variables

Q3. Is site contingency largely due to differences in the absolute magnitude of mu and k?



Compare this model:
Y ~ site x relative mu &k

With this model:
Y ~ absolute mu &k

If the site effect is primarily due to site differences in ambient rainfall, both models should be equally good.

Which model explains more (adj.) deviance?

	Site x Relative mu, k	Absolute mu, k
Decomp	0.89	0.22
FPOM	0.65	0.05
delta15N	0.67	0.29
CO_2	0.92	0.50
Bacteria	0.71	0.10
Shredder	0.33	0.05
Filter	0.68	0.45
Scraper	0.68	0.21
Gatherer	0.50	0.07
Engulfer	0.77	0.35

Is site contingency largely due to differences in the absolute magnitude of mu and k?

Compare this model:
Y ~ site x relative mu &k

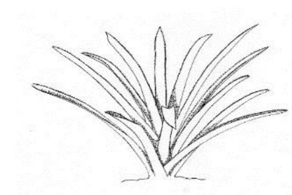
With this model:
Y ~ absolute mu &k

If the site effects is primarily due to site differences in ambient rainfall, both models should be equally good.

Is hydrology the better predictor as it is more direct?

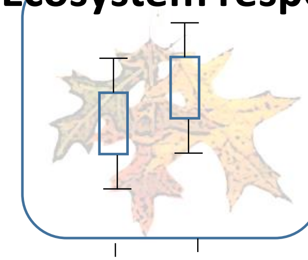
Rainfall:
mu and k

Hydrology:
Frequency of drying
Fluctuations in water depth
Average water depth
Overflow



Buffered by:
- Water retention between days
- Overflow
- Leaf geometry

Ecosystem response

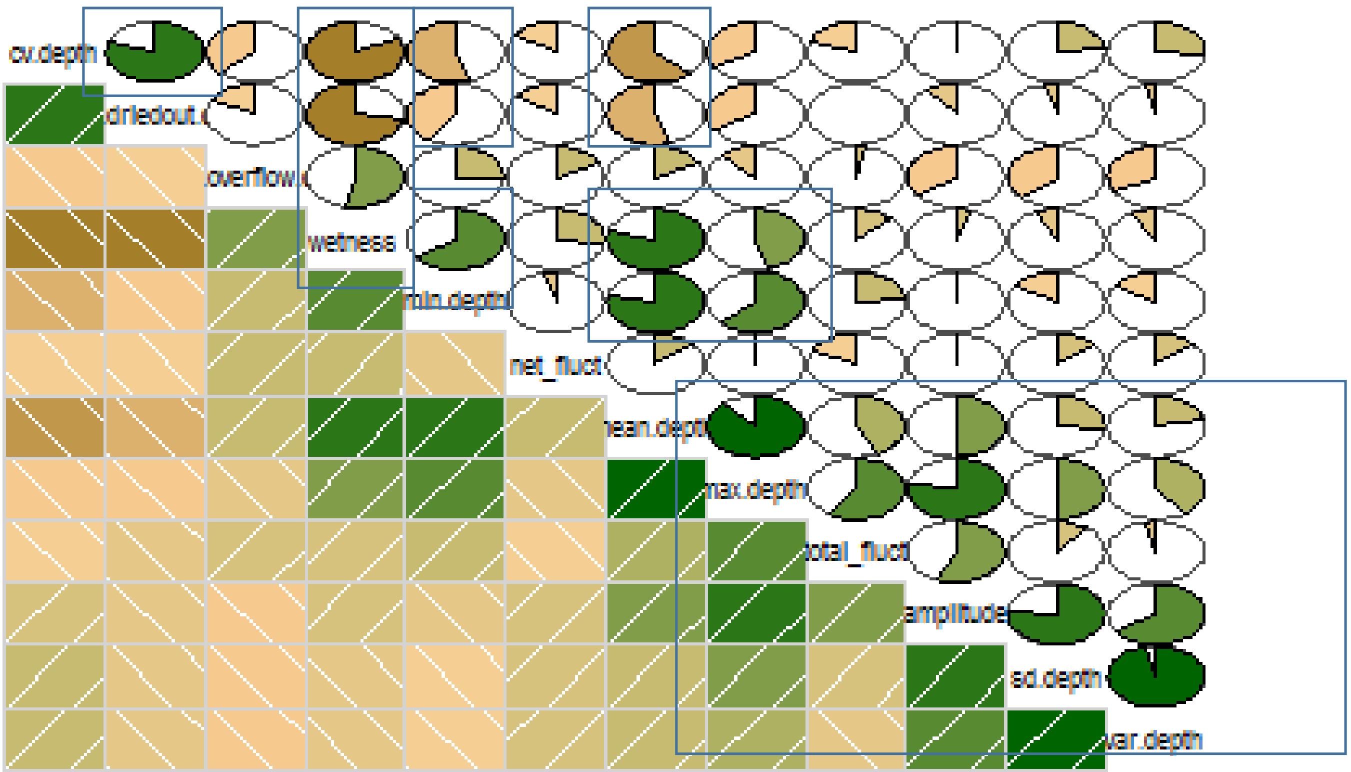


Hydrology variables

Amplitude
Dried out
Overflow
cvdepth

uncorrelated

Correlogram of key responses



Which model explains more (adj.) deviance?

	Site x Relative mu, k	Absolute mu, k	Site x Hydrology
Decomp	0.89	0.22	0.90
FPOM	0.65	0.05	0.73
delta15N	0.67	0.29	0.67
CO_2	0.92	0.50	0.94
Bacteria	0.71	0.10	0.66
Shredder	0.33	0.05	0.40
Filter	0.68	0.45	0.66
Scraper	0.68	0.21	0.69
Gatherer	0.50	0.07	0.52
Engulfer	0.77	0.35	0.29

Surprisingly, hydrology is very similar in predictive power to relative mu, k models.

[1]*Cardoso not in hydrology models*

Which model explains more (adj.) deviance? What hydrology variables are important?

	Site x Relative mu, k	Absolute mu, k	Site x Hydrology	Site	Dried out days	Dried out^2	Over flow days	Over flow^2	Amplitude	Amplitude^2	CV depth	CV depth^2
Decomp	0.89	0.22	0.90	▣	▣	▣	■	■				
FPOM	0.65	0.05	0.73	▣								
delta15N	0.68	0.29	0.67	▣					■	■		
CO_2	0.92	0.50	0.94	▣	▣							▣
Bacteria	0.71	0.10	0.66	□								
Shredder	0.33	0.05	0.40	▣								
Filter	0.68	0.45	0.66	▣					■	■		
Scraper	0.68	0.21	0.69								■	■
Gatherer	0.50	0.07	0.52	▣		■			▣	▣		■
Engulfer	0.77	0.35	0.29									

□ Depends on glm type ▣ Main effect only ■ Site interaction

[1]Cardoso not in hydrology models

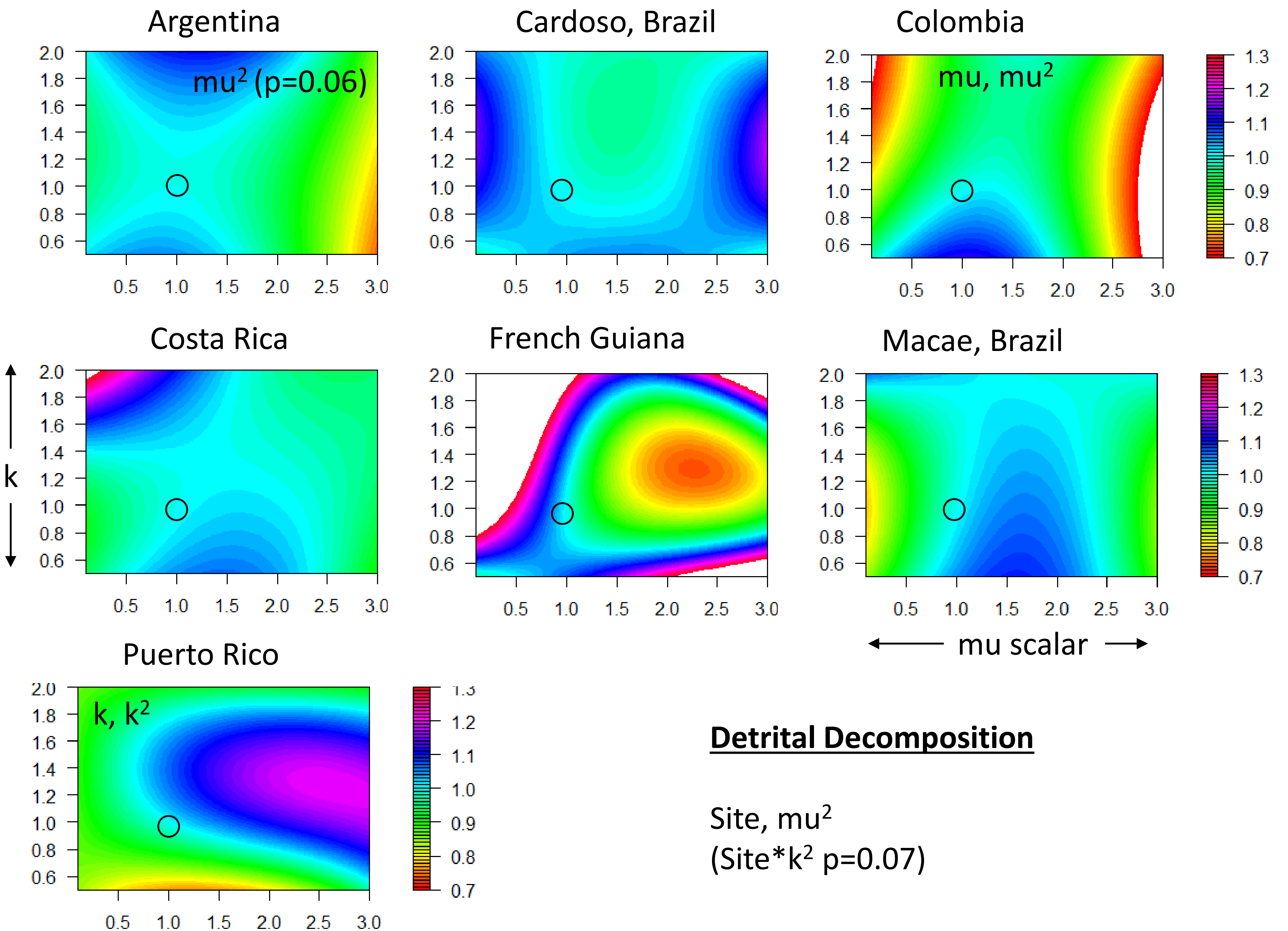
summary

Some aspects of the ecosystem respond similarly to relative changes in rainfall, regardless of geographic site.

Others don’t.

There is more to site contingency than just differences in current conditions.

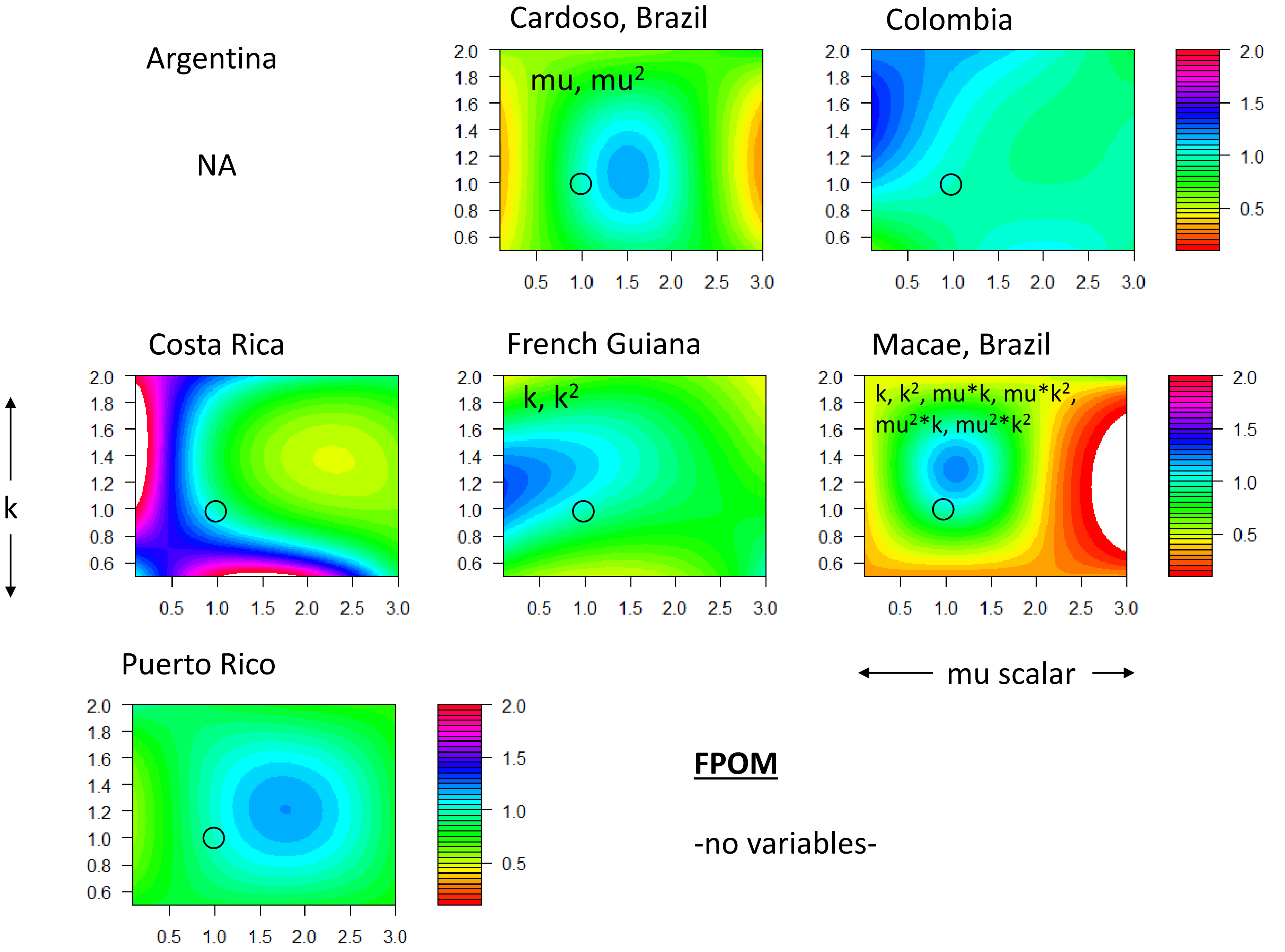
Models of relative rainfall and site are surprisingly good at explaining variance in ecosystem properties.



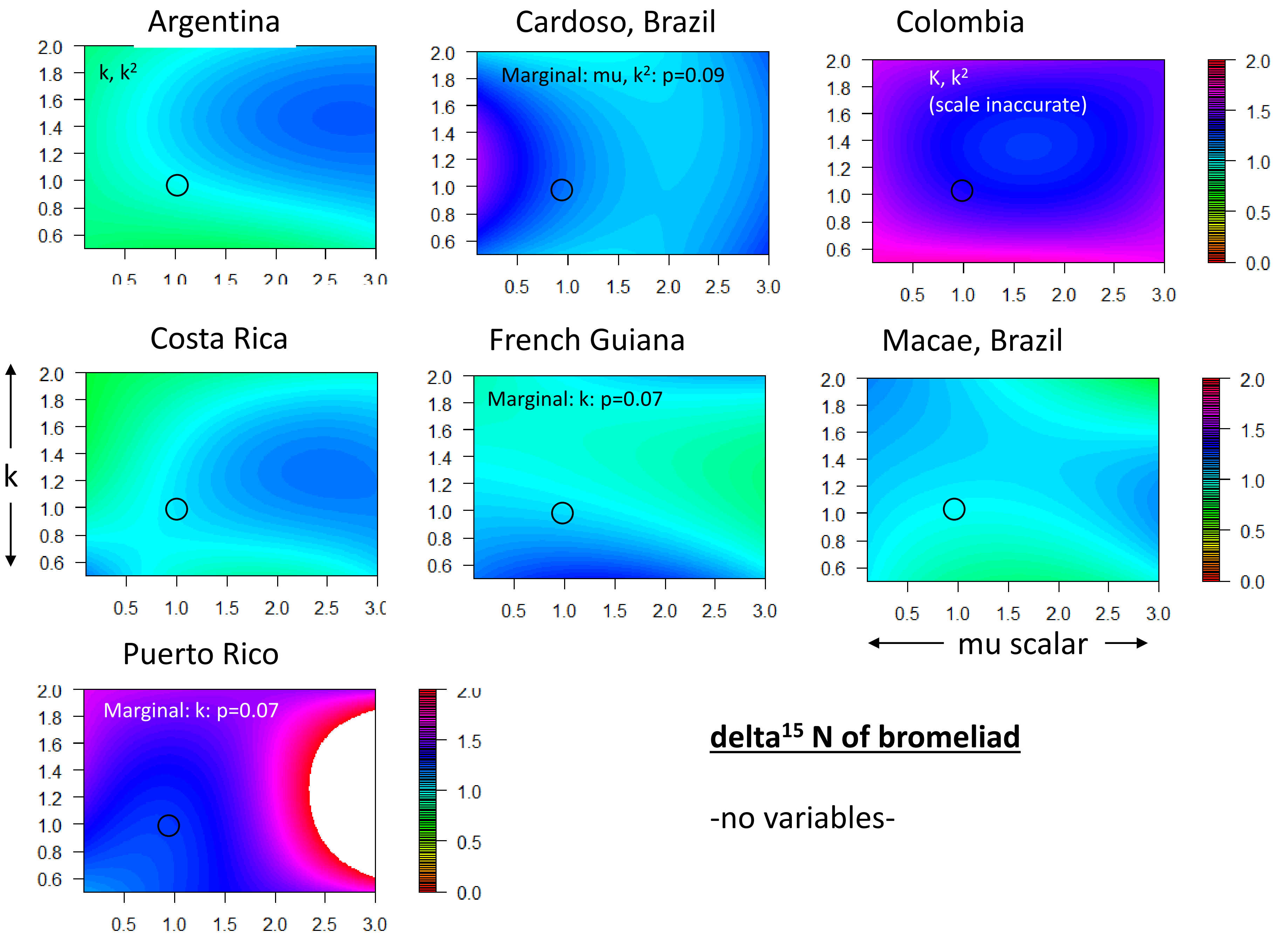
Detrital Decomposition

Site, mu^2

(Site*k^2 $p=0.07$)

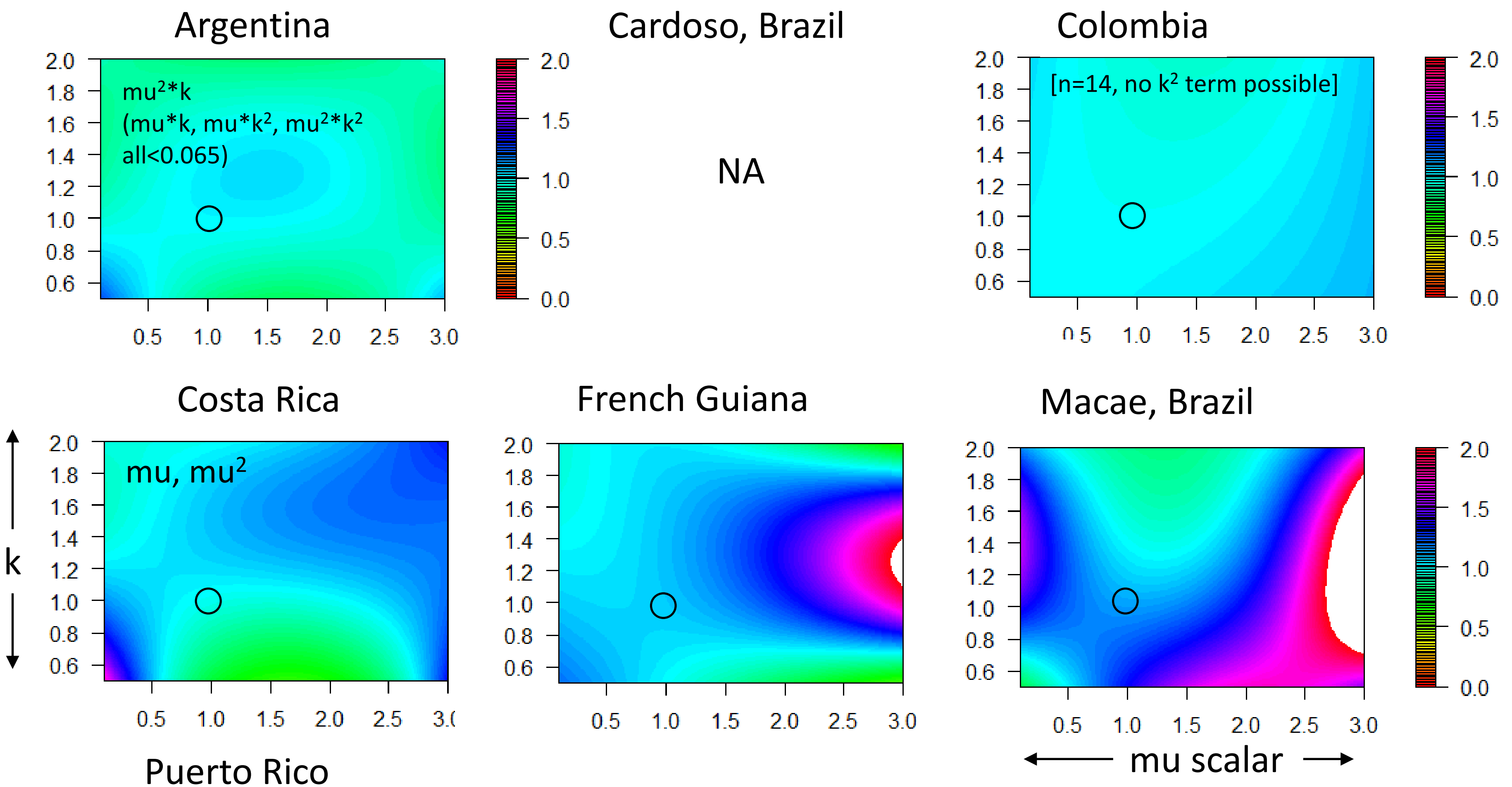


Argentina
NA
Cardoso, Brazil
mu, mu²
Colombia
Costa Rica
French Guiana
k, k²
Macae, Brazil
k, k², mu*k, mu*k², mu²*k, mu²*k²
Puerto Rico
k
mu scalar
FPOM
-no variables-



delta^{15} N of bromeliad

-no variables-



NA

CO_2 (mg/L)

Site, mu. mu^2

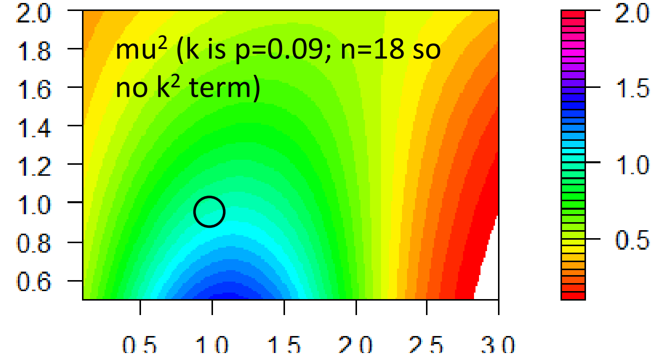
Argentina

NA

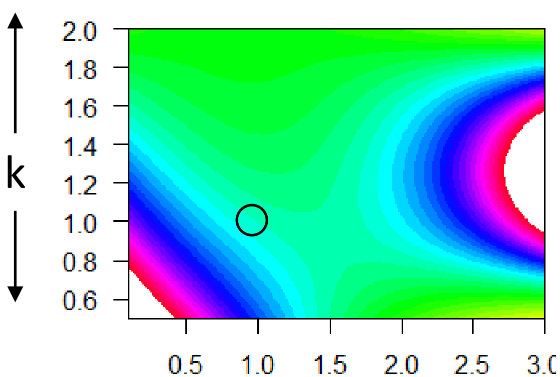
Cardoso, Brazil

NA

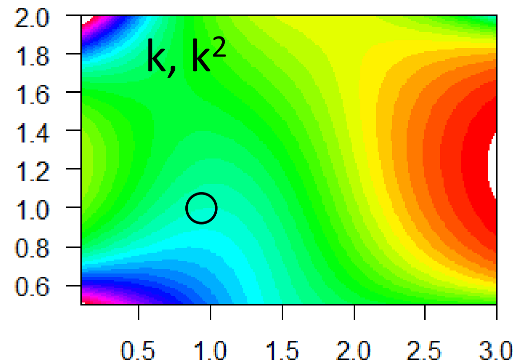
Colombia



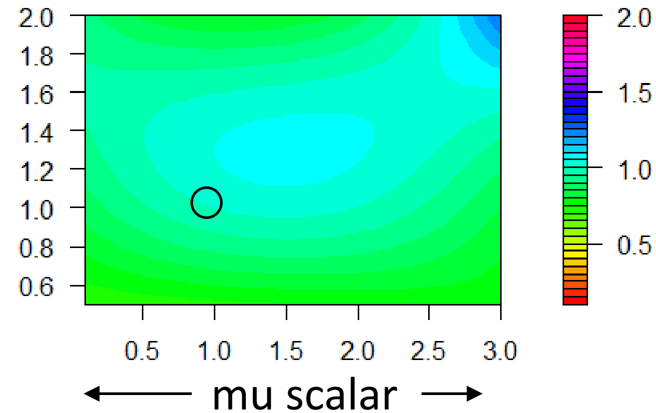
Costa Rica



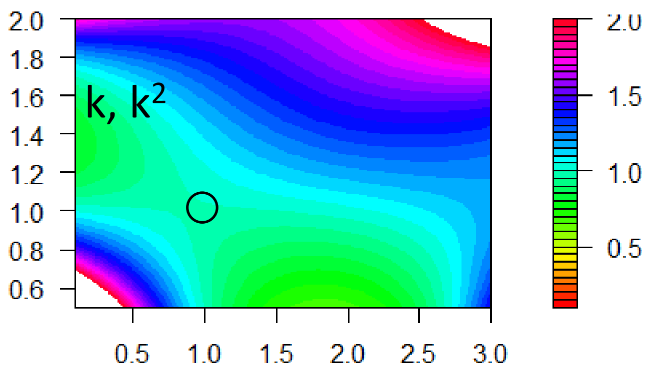
French Guiana



Macae, Brazil

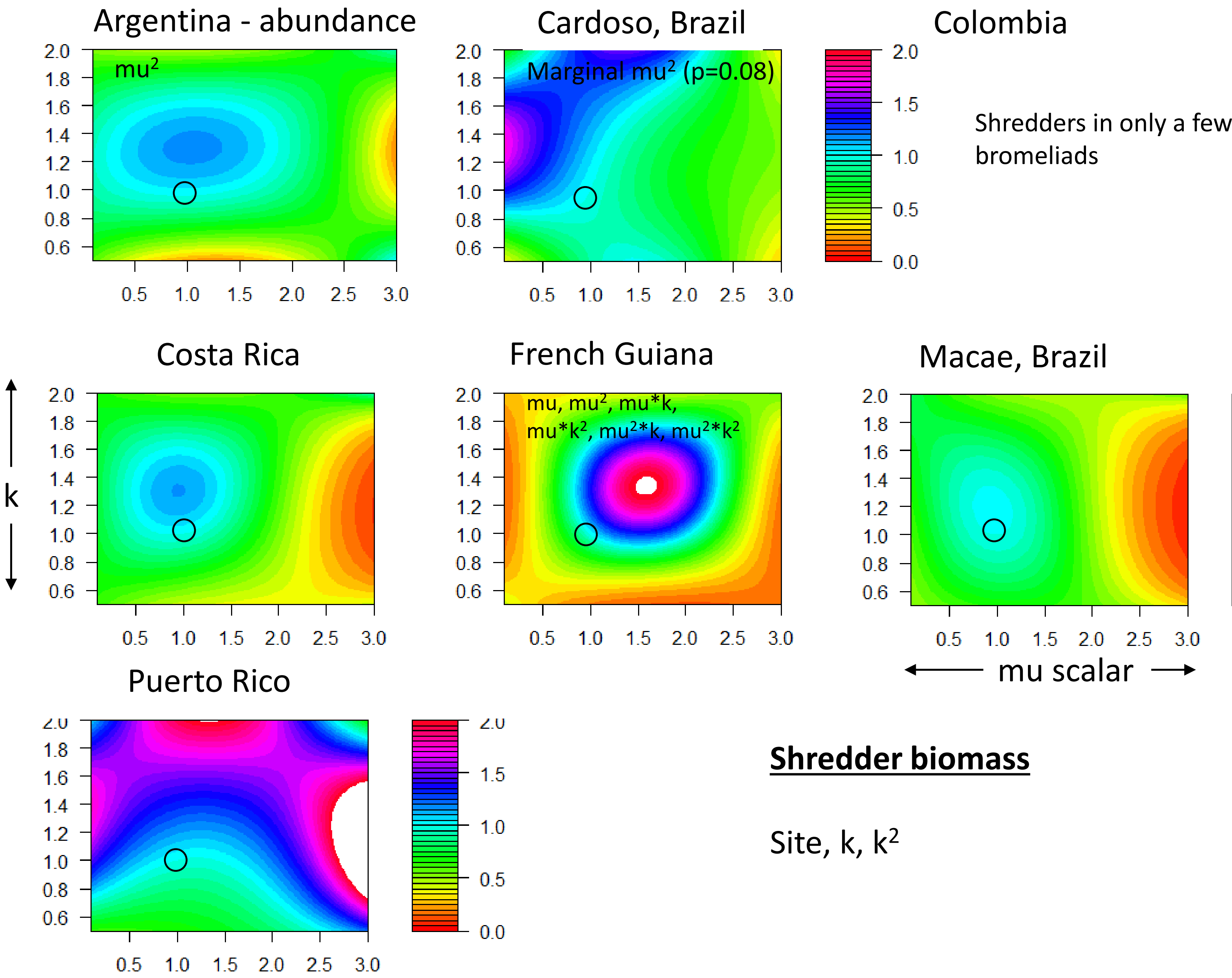


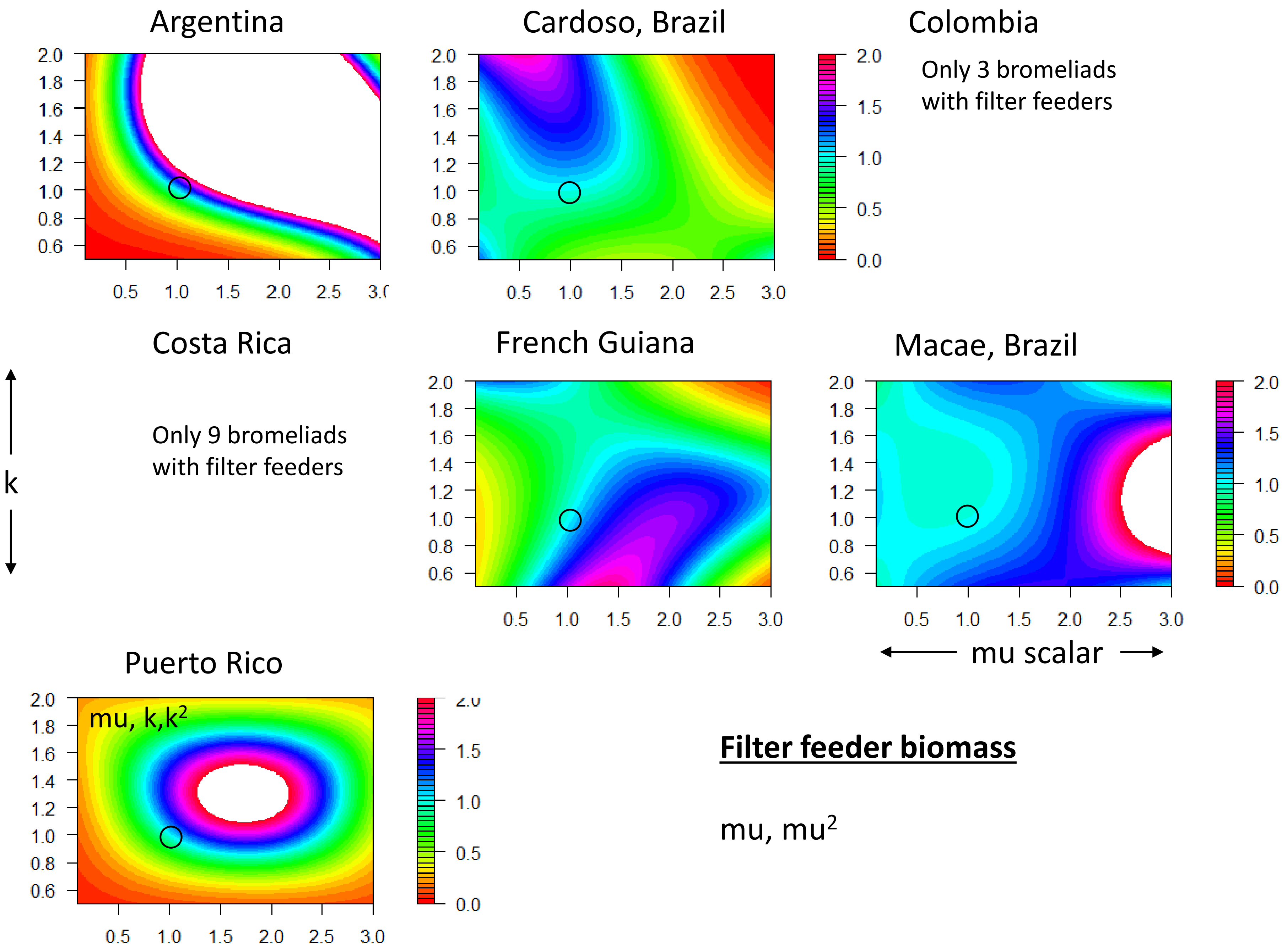
Puerto Rico

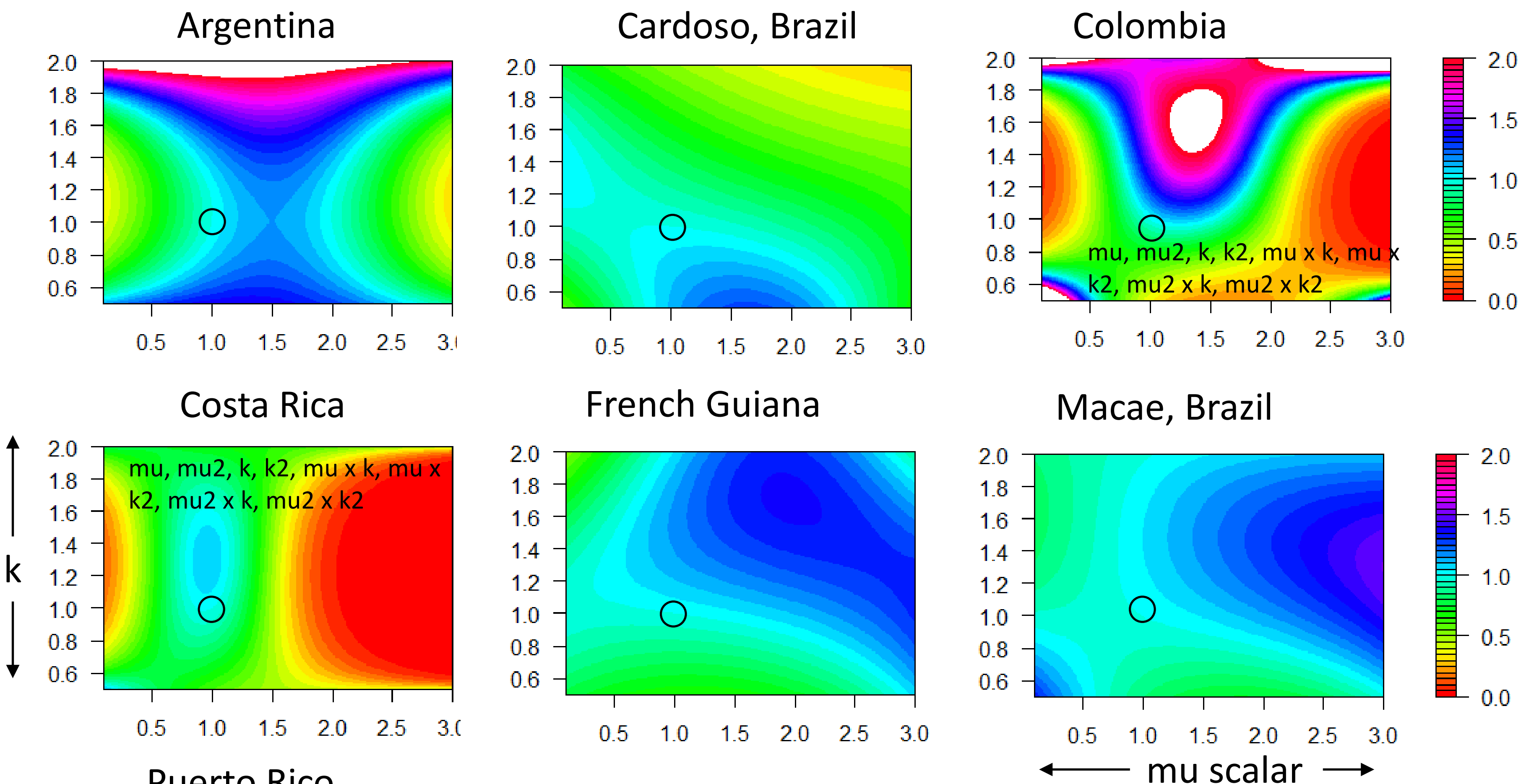


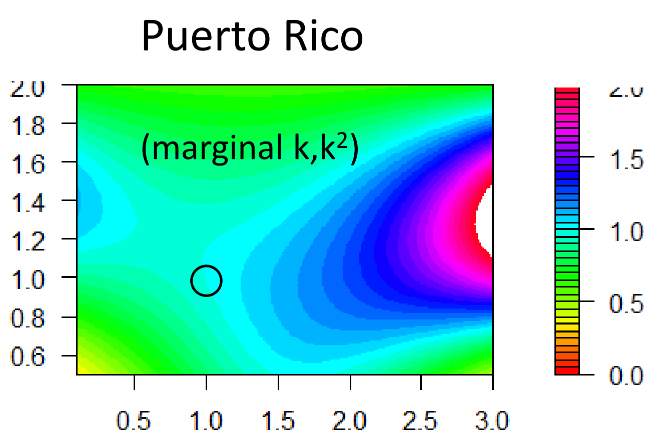
Bacterial density

site, mu


Argentina - abundance
mu^2
Cardoso, Brazil
Marginal mu^2 (p=0.08)
Colombia
Shredders in only a few bromeliads
Costa Rica
French Guiana
mu, mu^2, mu*k, mu*k^2, mu^2*k, mu^2*k^2
Macae, Brazil
Puerto Rico
k
mu scalar
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.5
1.0
1.5
2.0
2.5
3.0
0.0
Shredder biomass
Site, k, k^2

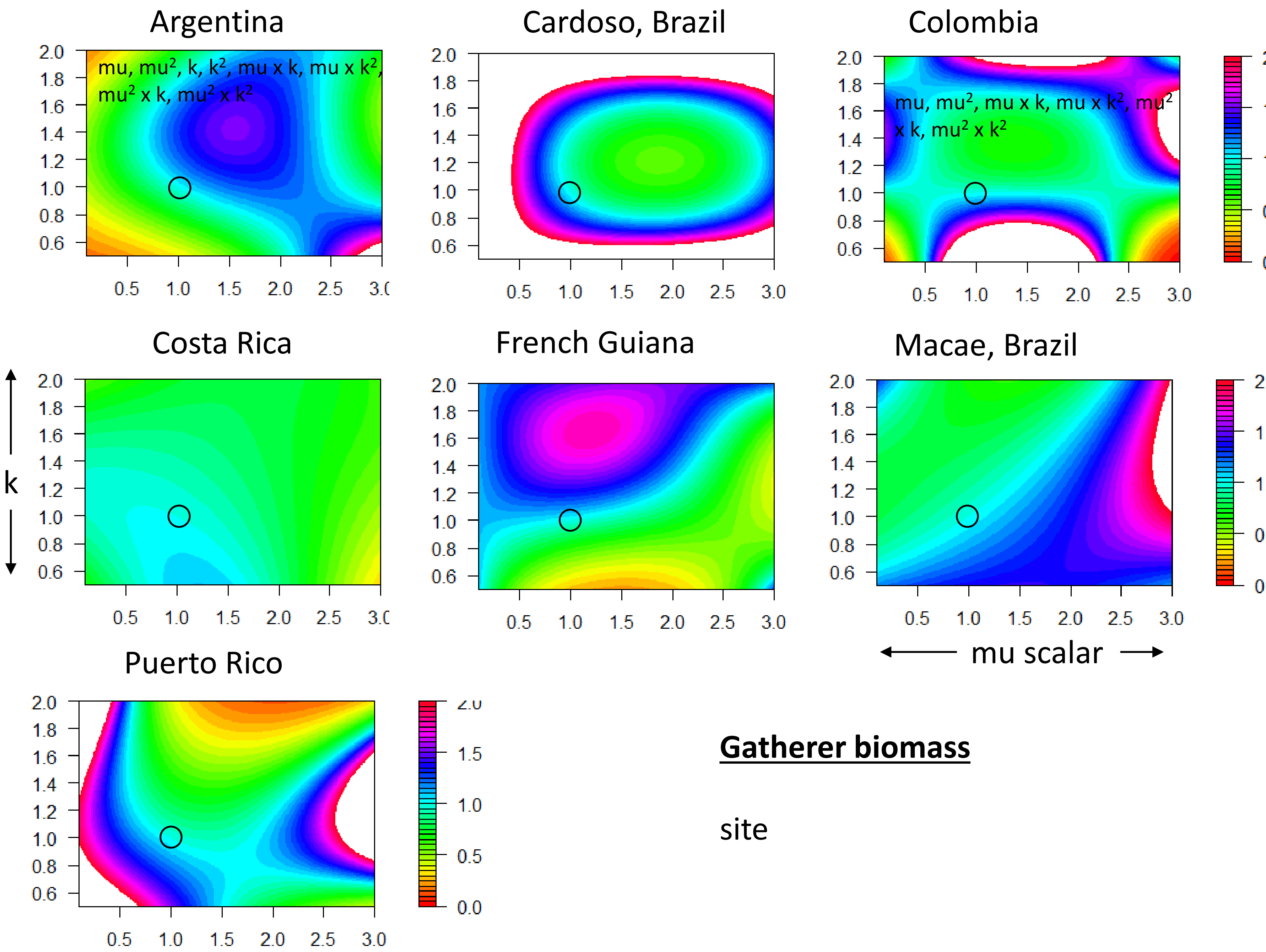

Argentina
Cardoso, Brazil
Colombia
Only 3 bromeliads with filter feeders
Costa Rica
Only 9 bromeliads with filter feeders
French Guiana
Macae, Brazil
k
mu scalar
Puerto Rico
mu, k,k²
Filter feeder biomass
mu, mu²





Scraper biomass

site, site x k (marginally site x k^2 p=0.06)



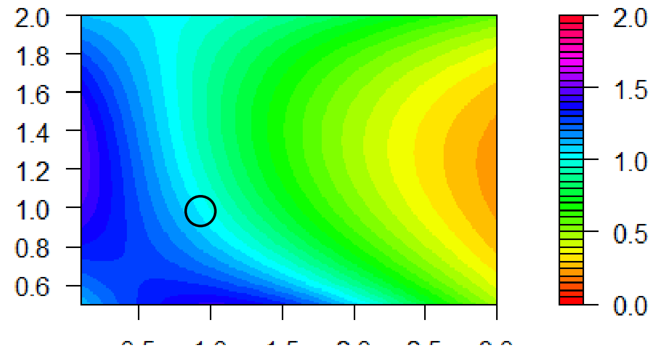
Gatherer biomass

site

Argentina

Only 5 bromeliads with engulfers

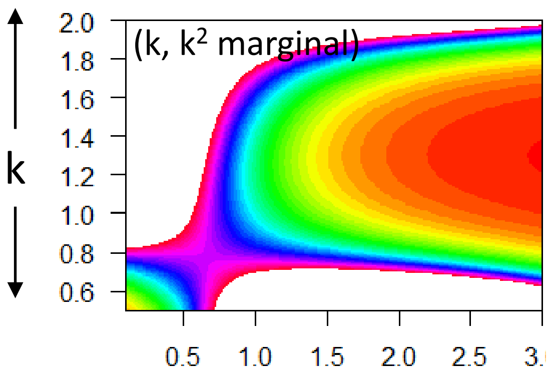
Cardoso, Brazil



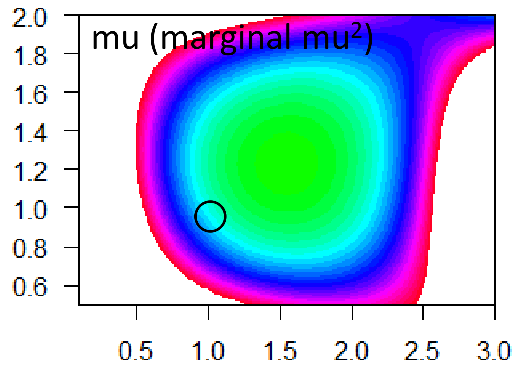
Colombia

No engulfers

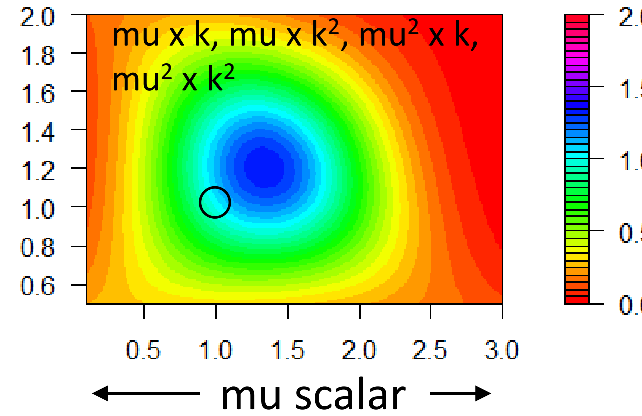
Costa Rica



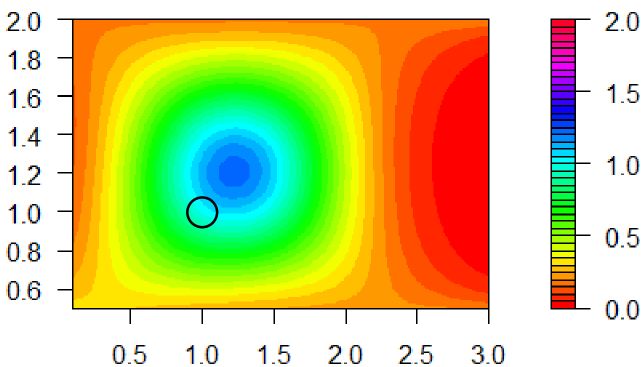
French Guiana



Macae, Brazil



Puerto Rico



<u>Engulfing predator biomass</u>

No variables sig

Cardoso and Macae have high tanypodinae abundances

Which model explains more (adj.) deviance?

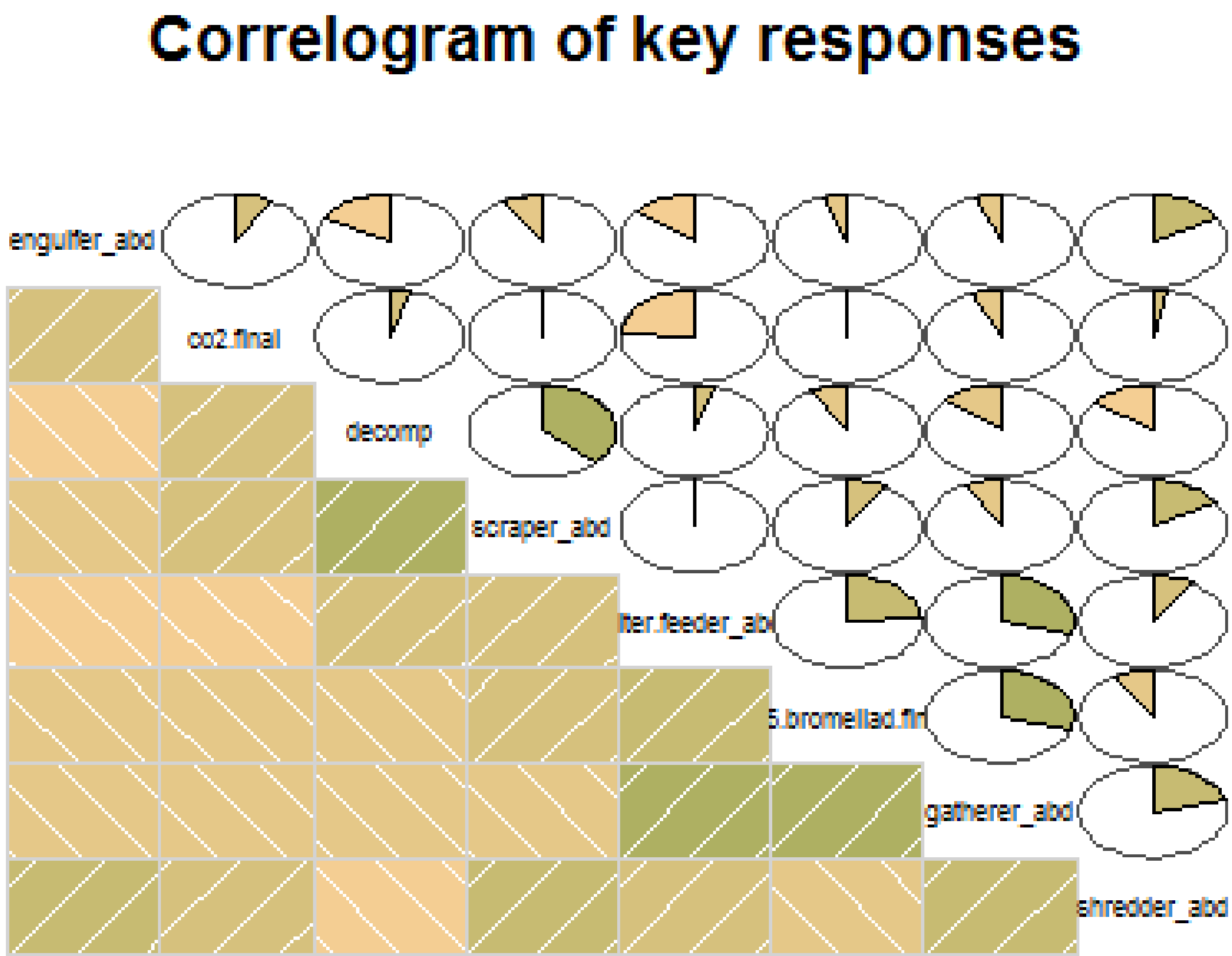
What hydrology variables are important?

	Site x Relative mu, k	Absolute mu, k	Site x Hydrology	Site	Dried out days	Dried out^2	Over flow days	Over flow^2	Amplit ude	Amplit ude^2	CV depth	CV depth^2
Decomp	0.89	0.22	0.90	▒	▒	▒	■	■				
FPOM	0.65	0.05	0.73	▒								
delta15N	0.67	0.29	0.67	▒	▒	▒			■	■		
CO_2	0.92	0.50	0.94	▒	▒							▒
Bacteria	0.71	0.10	0.66	░								
Shredder	0.33	0.05	0.40	▒								
Filter	0.68	0.45	0.66	▒					■	■		
Scraper	0.68	0.21	0.69								■	■
Gatherer	0.50	0.07	0.52	▒		■			▒	▒		■
Engulfer	0.77	0.35	0.29									

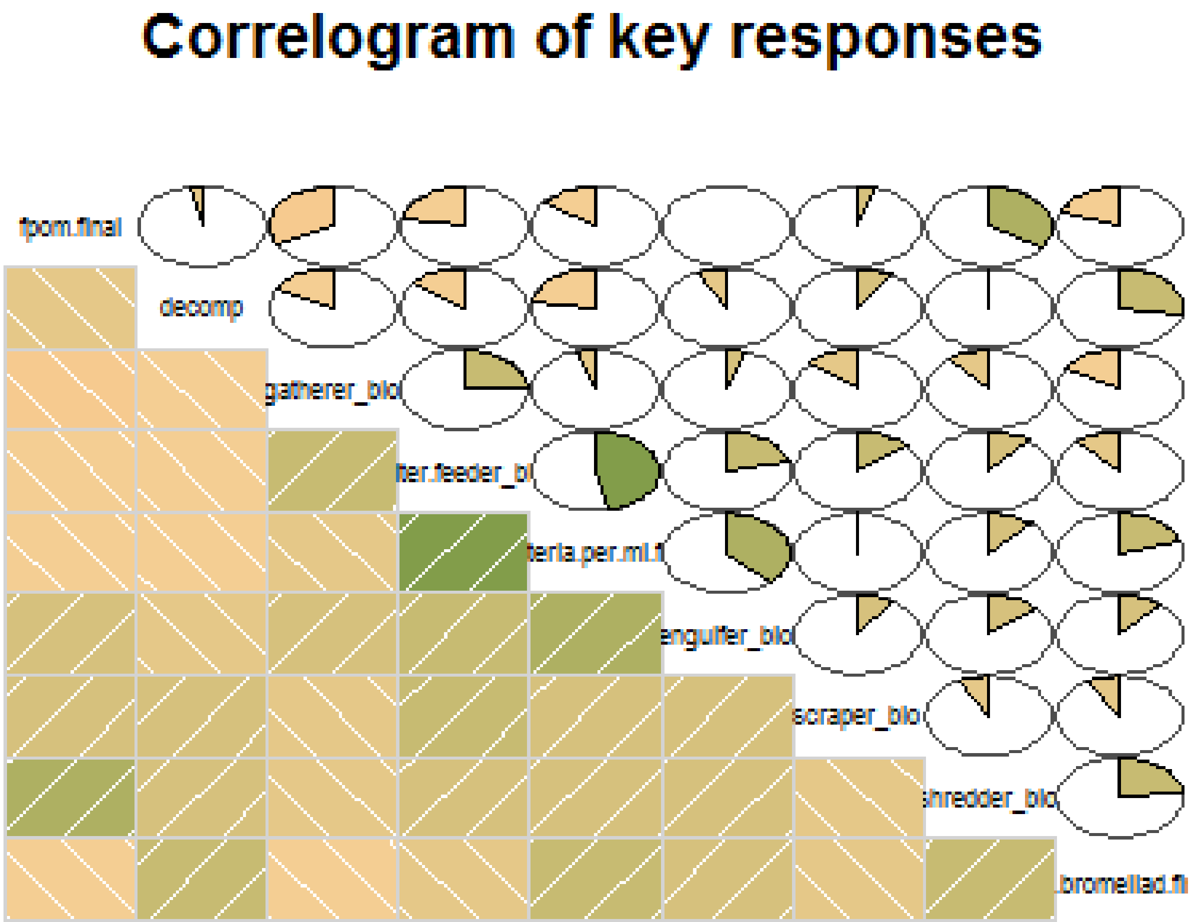
░ Depends on glm type ▒ Main effect only ■ Site interaction

[1]Cardoso not in hydrology models

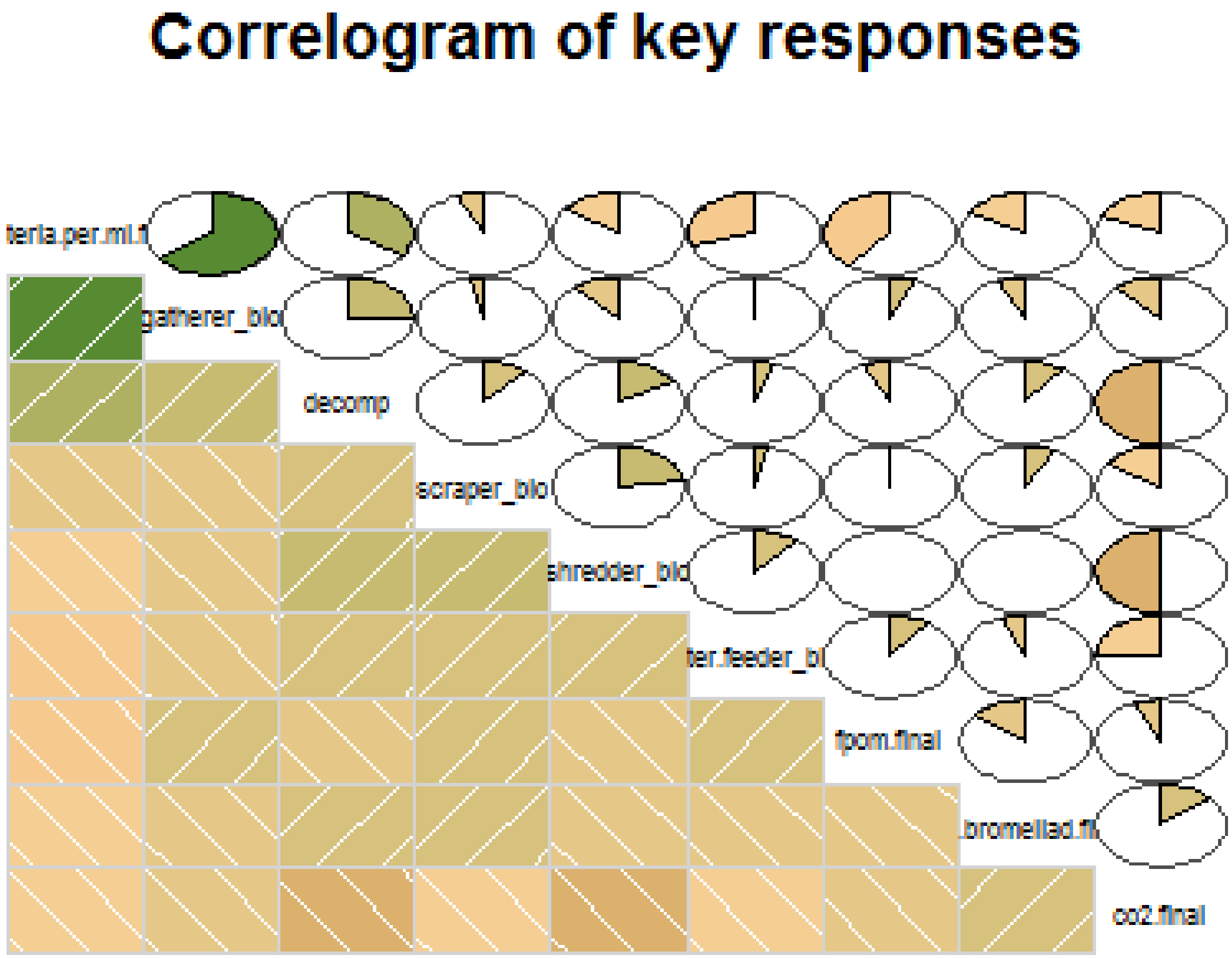
Argentina


Correlogram of key responses
engulfer_abd
co2.final
decomp
scraper_abd
lter.feeder_ab
5.bromeliad.fin
gatherer_abd
shredder_abd

Cardoso

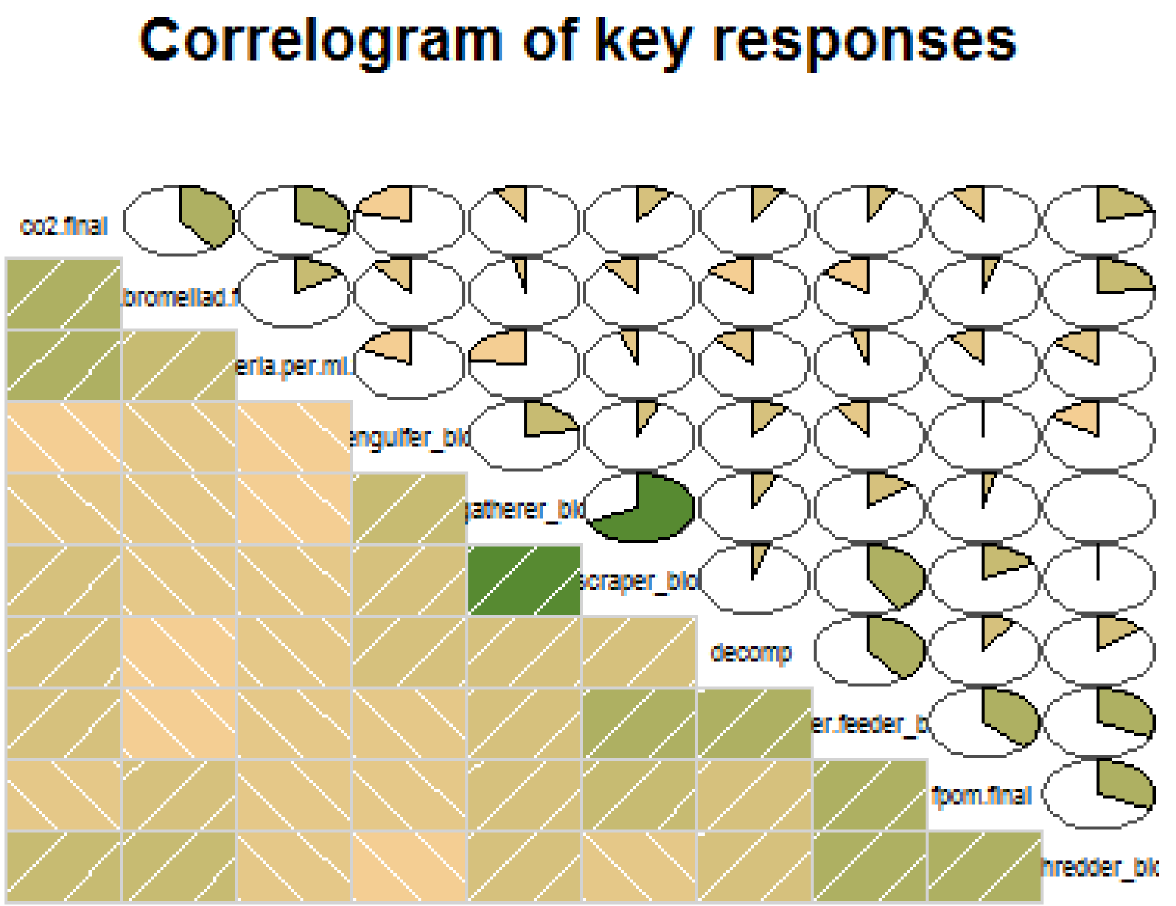

Correlogram of key responses
fpom.final
decomp
gatherer_blo
lter.feeder_bl
teria.per.ml.f
engulfer_blo
scraper_blo
shredder_blo
bromeliad.fi

Colombia

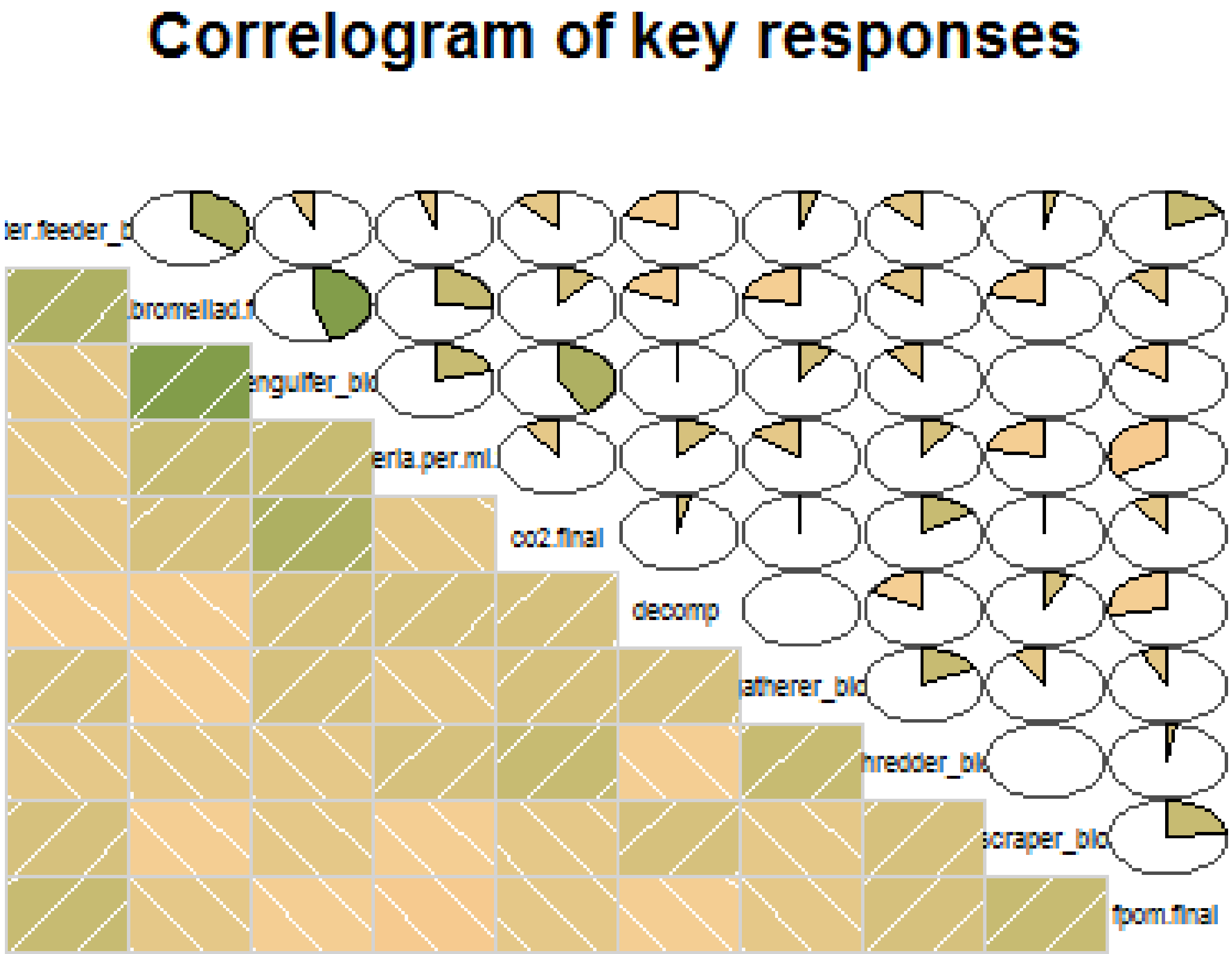


Correlogram of key responses
terla.per.ml.f
gatherer_bio
decomp
scraper_bio
shredder_bio
ter.feeder_bi
fpom.final
bromeliad.fi
co2.final

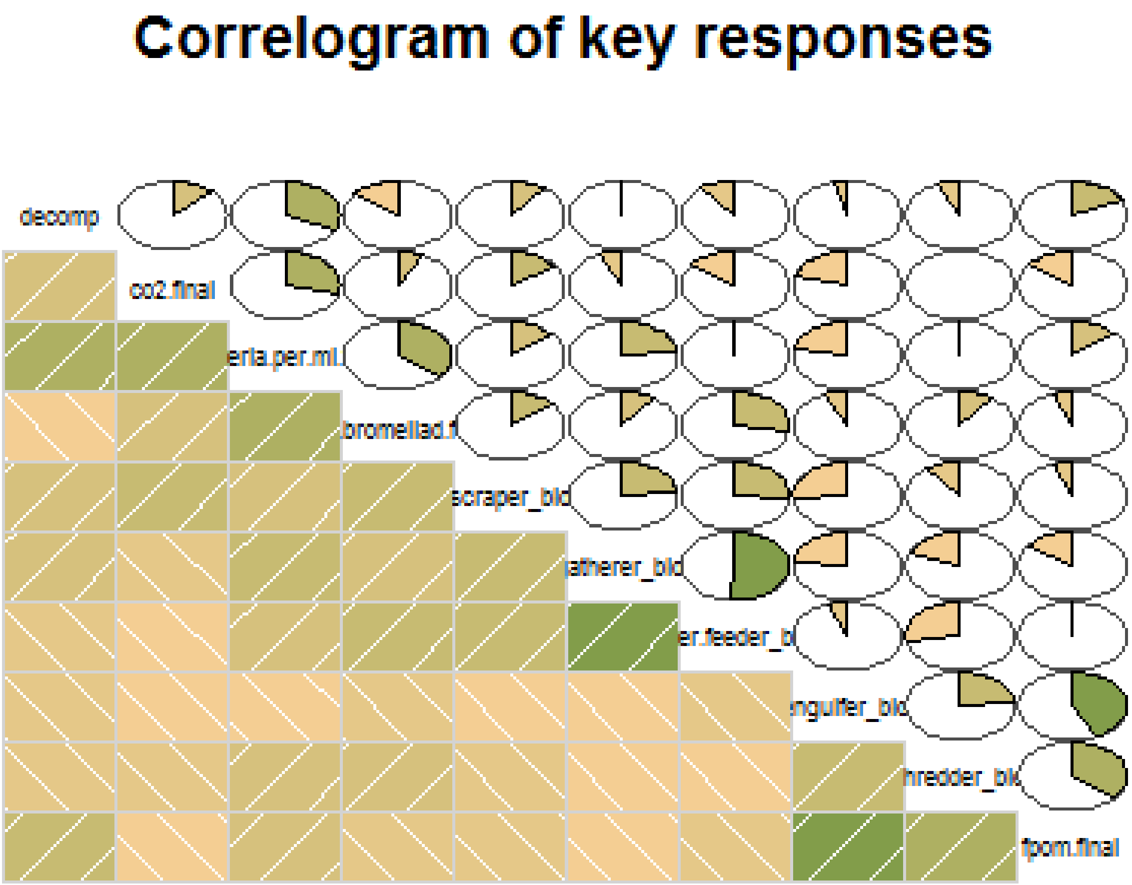
Costa Rica


Correlogram of key responses
co2.final
bromeliad.f
eria.per.ml.
engulfer_bk
jatherer_bk
scraper_bio
decomp
er.feeder_b
fpom.final
hredder_bk

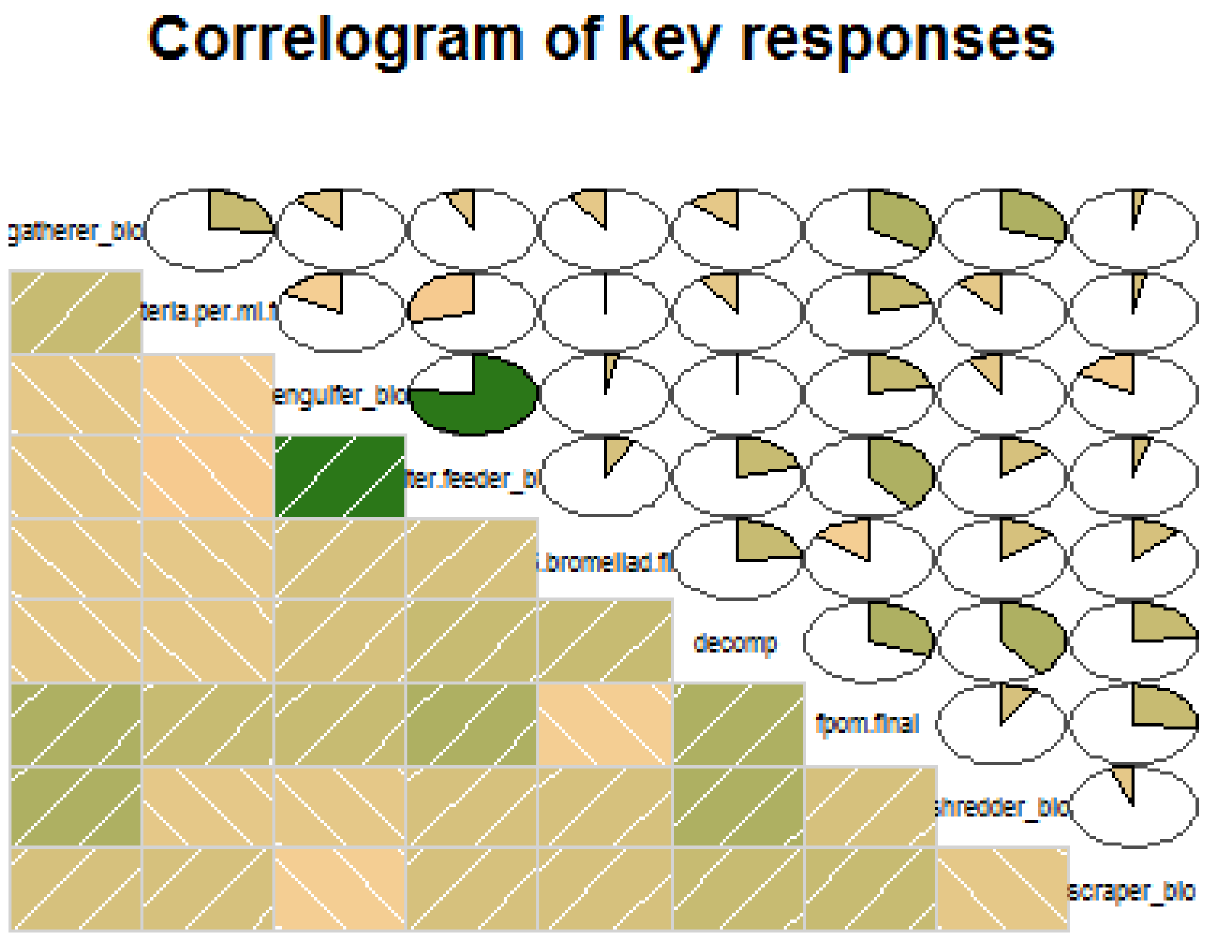
French Guiana



Macae


Correlogram of key responses
decomp
co2.final
erla.per.ml.
bromeliad.f
scraper_bld
atherer_bld
er.feeder_b
ngulfer_blc
hredder_bk
fpom.final

Puerto Rico



Correlogram of key responses
gatherer_blo
teria.per.ml.f
engulfer_blo
lter.feeder_bl
.bromeliad.fl
decomp
fpom.final
shredder_blo
scraper_blo