

# How to present Structural Equation Models?

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Swiss SEM team

05.11.2021

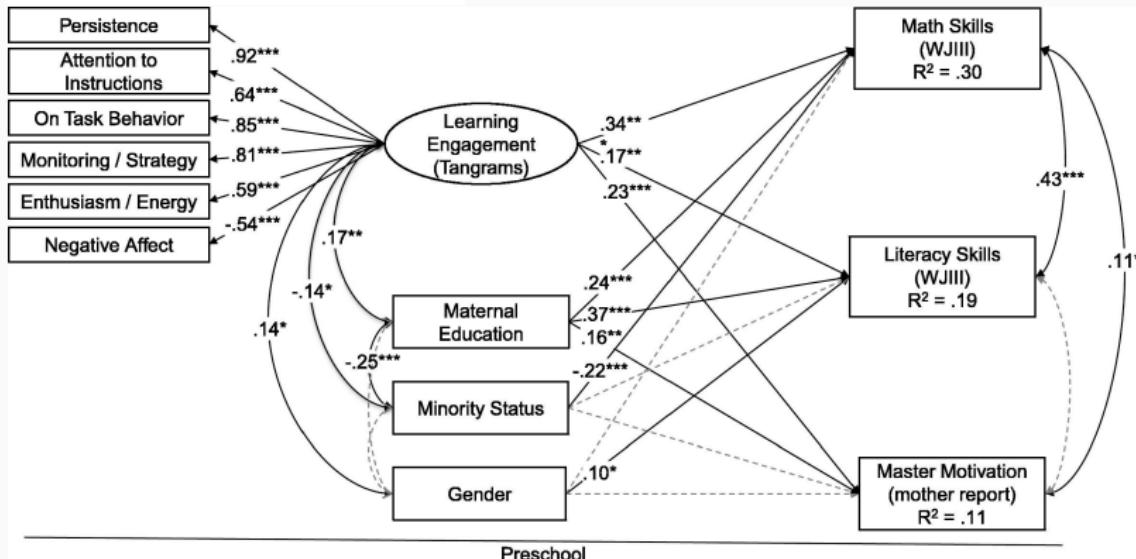
Department of Evolutionary Biology and Environmental Sciences

University of Zurich

## Exercise: Draw your idea

How would you draw your model output for others to reproduce and evaluate this model?

# What can you expect to see out in nature?



# What can you expect to see out in nature?

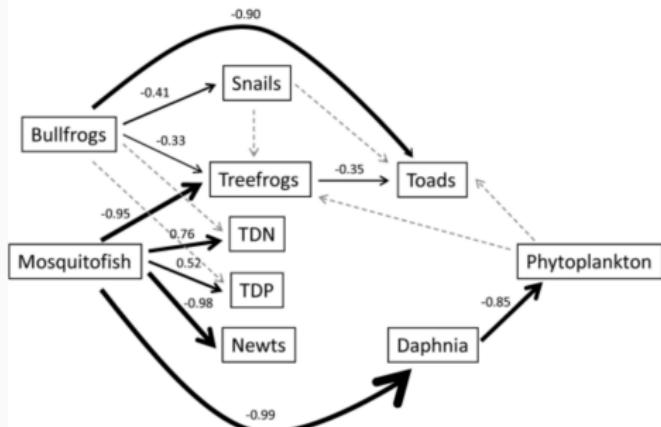
*Ecology*, 93(6), 2012, pp. 1254–1261  
© 2012 by the Ecological Society of America

## Community ecology of invasions: direct and indirect effects of multiple invasive species on aquatic communities

DANIEL L. PRESTON,<sup>1,3</sup> JEREMY S. HENDERSON,<sup>2</sup> AND PIETER T. J. JOHNSON<sup>1</sup>

<sup>1</sup>Department of Ecology and Evolutionary Biology, University of Colorado, Ramaley N122, Campus Box 334, Boulder, Colorado 80309 USA

<sup>2</sup>Department of Zoology, Oregon State University, 3029 Cordley Hall, Corvallis, Oregon 97331 USA



What can you expect to see out in nature?

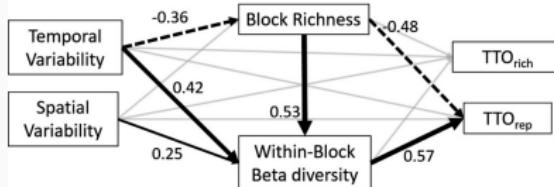
# ECOLOGY LETTERS

Letter | Full Access |

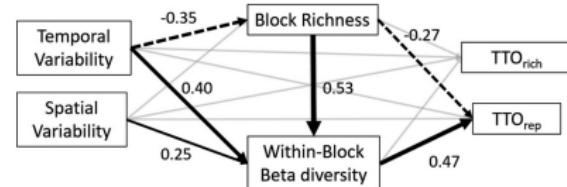
## Spatial heterogeneity in species composition constrains plant community responses to herbivory and fertilisation

Dorothee Hodapp , Elizabeth T. Borer, W. Stanley Harpole, Eric M. Lind, Eric W. Seabloom, Peter B. Adler, Juan Alberti, Carlos A. Arnillas, Jonathan D. Bakker, Lori Biederman ... [See all authors](#)

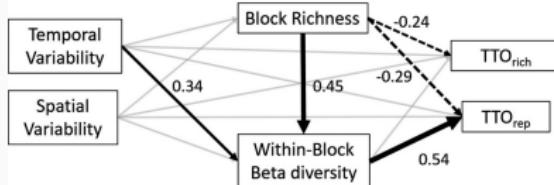
(a) Control (96)



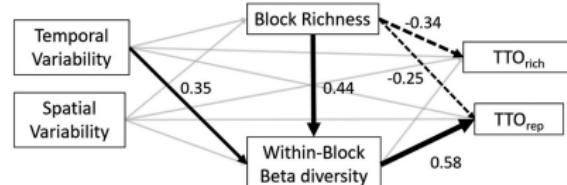
(b) NPK (95)



(c) Fence (79)



(d) NPK+Fence (80)



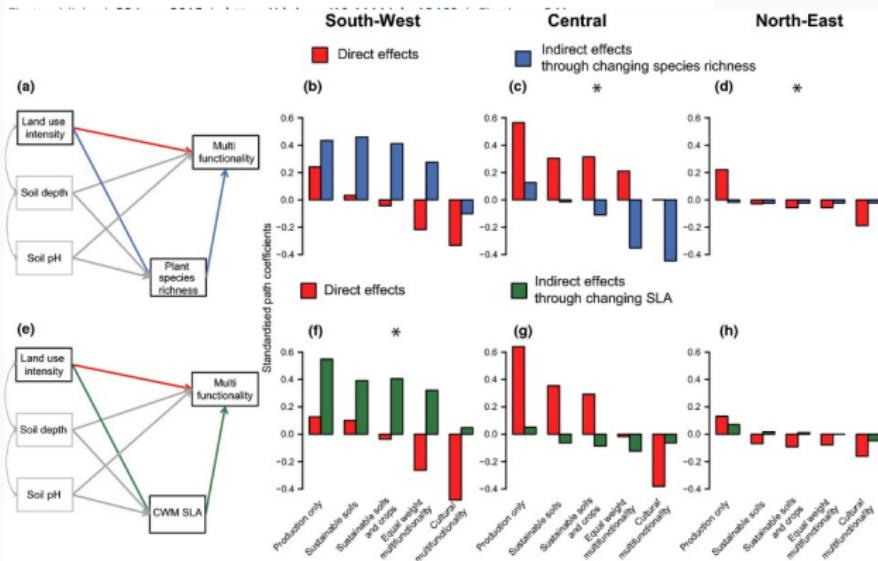
What can you expect to see out in nature?

# ECOLOGY LETTERS

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## Land use intensification alters ecosystem multifunctionality via loss of biodiversity and changes to functional composition

Eric Allan , Pete Manning, Fabian Alt, Julia Binkenstein, Stefan Blaser, Nico Blüthgen, Stefan Böhm, Fabrice Grassein, Norbert Hölzel, Valentin H. Klaus, Till Kleinebecker ... See all authors



What can you expect to see out in nature?

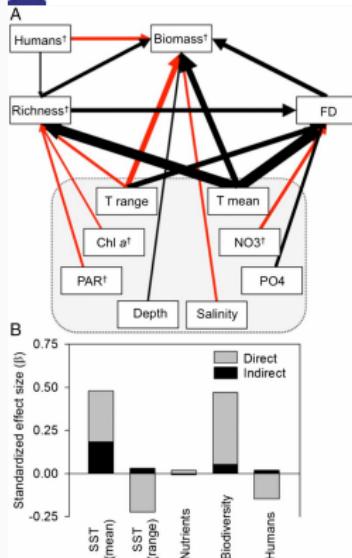
PNAS

# Biodiversity enhances reef fish biomass and resistance to climate change

J. Emmett Duffy<sup>a,1</sup>, Jonathan S. Lefcheck<sup>b</sup>, Rick D. Stuart-Smith<sup>c</sup>, Sergio A. Navarrete<sup>d</sup>, and Graham J. Edgar<sup>c</sup>

<sup>a</sup>Tennenbaum Marine Observatories Network, Smithsonian Institution, Washington, DC 20013-7012; <sup>b</sup>Department of Biological Sciences, Virginia Institute of Marine Science, The College of William & Mary, Gloucester Point, VA 23062; <sup>c</sup>Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, TAS 7001 Australia; and <sup>d</sup>Estación Costera de Investigaciones Marinas and Center for Marine Conservation, LINC-Global, Pontificia Universidad Católica de Chile, Casilla 114-D, Santiago, Chile

Edited by James A. Estes, University of California, Santa Cruz, CA, and approved April 13, 2016 (received for review December 11, 2015)



# What can you expect to see out in nature?



ARTICLE

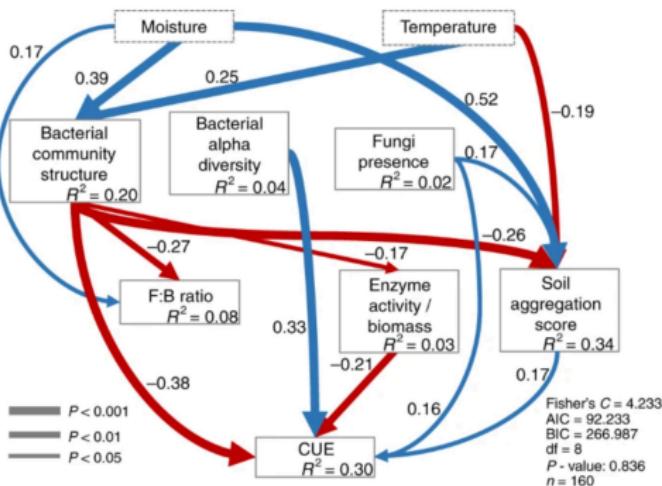
Check for updates

OPEN

## Microbial diversity drives carbon use efficiency in a model soil

Luz A. Domeignoz-Horta<sup>1</sup><sup>✉</sup>, Grace Pold<sup>2</sup>, Xiao-Jun Allen Liu<sup>1</sup>, Serita D. Frey<sup>3</sup>, Jerry M. Melillo<sup>4</sup> & Kristen M. DeAngelis<sup>1</sup><sup>✉</sup>

**Fig. 4: Structural equation model showing the relative influence of soil abiotic and biotic factors on CUE.**



# What can you expect to see out in nature?

The ISME Journal (2018) 12:1817–1825  
https://doi.org/10.1038/s41396-018-0096-y



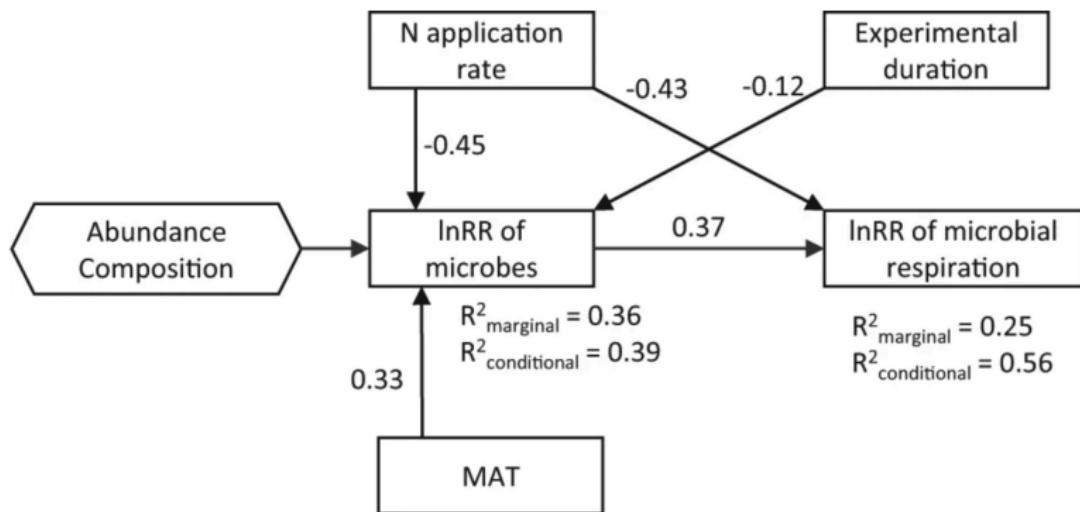
ARTICLE



## Global negative effects of nitrogen deposition on soil microbes

Tian'an Zhang<sup>1</sup> · Han Y. H. Chen<sup>2</sup> · Honghua Ruan<sup>1</sup>

Received: 24 October 2017 / Revised: 13 February 2018 / Accepted: 20 February 2018 / Published online: 27 March 2018  
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PNAS

## Long-term nutrient reductions lead to the unprecedented recovery of a temperate coastal region

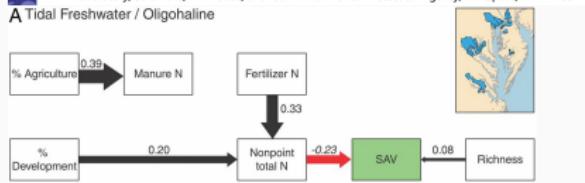
Jonathan S. Lefcheck<sup>a,b,1</sup>, Robert J. Orth<sup>b</sup>, William C. Dennison<sup>c</sup>, David J. Wilcox<sup>b</sup>, Rebecca R. Murphy<sup>d</sup>, Jennifer Keisman<sup>e</sup>, Cassie Gurbisz<sup>f,g</sup>, Michael Hannam<sup>h</sup>, J. Brooke Landry<sup>i</sup>, Kenneth A. Moore<sup>j</sup>, Christopher J. Patrick<sup>k</sup>, Jeremy Testa<sup>k</sup>, Donald E. Weller<sup>h</sup>, and Richard A. Batiuk<sup>k</sup>

<sup>a</sup>Center for Ocean Health, Bigelow Laboratory for Ocean Science, East Boothbay, ME 04544; <sup>b</sup>Department of Biological Sciences, Virginia Institute of Marine Science, The College of William & Mary, Gloucester Point, VA 23062; <sup>c</sup>University of Maryland Center for Environmental Science, Cambridge, MD 21613;

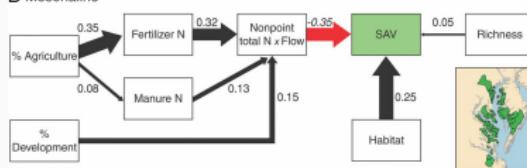
<sup>d</sup>University of Maryland Center for Environmental Science, Chesapeake Bay Program Office, Annapolis, MD 21403; <sup>e</sup>US Geological Survey, Baltimore, MD 21228; <sup>f</sup>National Socio-Environmental Synthesis Center, Annapolis, MD 21401; <sup>g</sup>Environmental Studies Program, St. Mary's College of Maryland, St. Mary's City, MD 20686; <sup>h</sup>Smithsonian Environmental Research Center, Edgewater, MD 21037; <sup>i</sup>Maryland Department of Natural Resources, Annapolis, MD 21401;

<sup>j</sup>Texas A&M University Corpus Christi, Corpus Christi, TX 78412; <sup>k</sup>University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory, Solomons, MD 20688; and <sup>l</sup>US Environmental Protection Agency, Annapolis, MD 21403

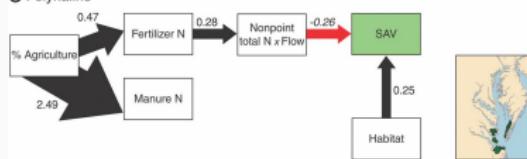
### A Tidal Freshwater / Oligohaline



### B Mesohaline



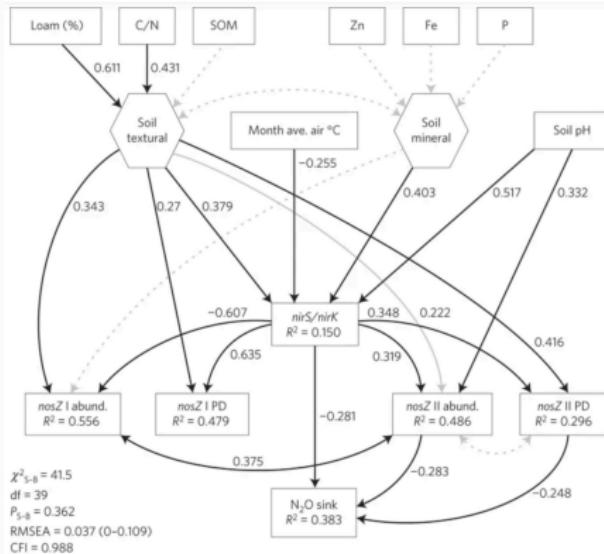
### C Polyhaline



# What can you expect to see out in nature?

## Recently identified microbial guild mediates soil N<sub>2</sub>O sink capacity

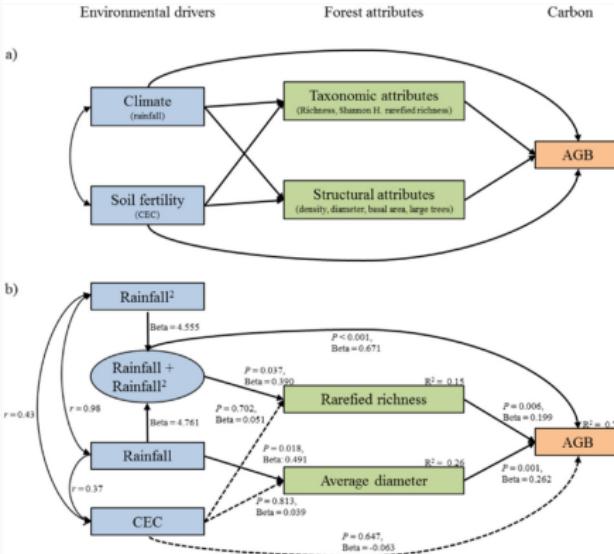
Christopher M. Jones<sup>1,2†</sup>, Aymé Spor<sup>1†</sup>, Fiona P. Brennan<sup>1,3,4</sup>, Marie-Christine Breuil<sup>1</sup>, David Bru<sup>1</sup>, Philippe Lemanceau<sup>1</sup>, Bryan Griffiths<sup>3,5</sup>, Sara Hallin<sup>2\*</sup> and Laurent Philippot<sup>1</sup>



# What can you expect to see out in nature?

## Diversity enhances carbon storage in tropical forests

L. Poorter , M. T. van der Sande, J. Thompson, E. J. M. M. Arets, A. Alarcón, J. Álvarez-Sánchez, N. Ascarrunz, P. Balvanera, G. Barajas-Guzmán, A. Boit, F. Bongers, F. A. Carvalho ... See all authors 



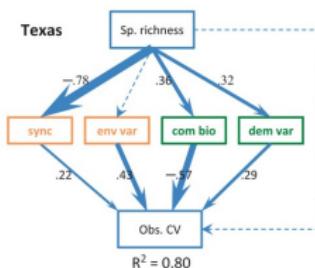
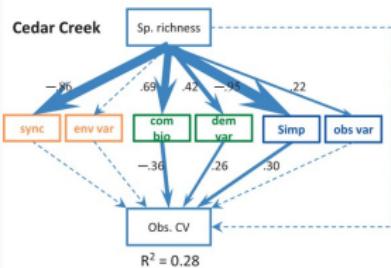
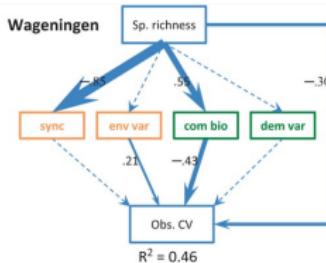
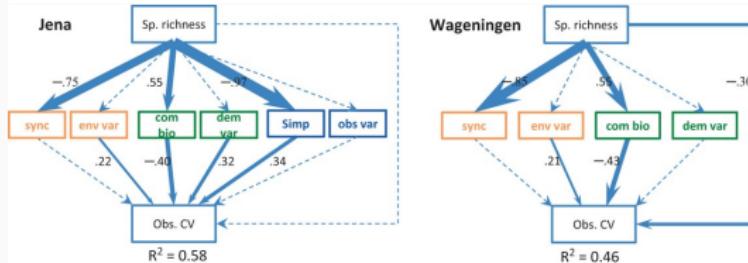
What can you expect to see out in nature?

# ECOLOGY LETTERS

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## Predicting ecosystem stability from community composition and biodiversity

Claire de Mazancourt , Forest Isbell, Allen Larocque, Frank Berendse, Enrica De Luca, James B. Grace, Bart Haegeman, H. Wayne Polley, Christiane Roscher, Bernhard Schmid ... See all authors



# What can you expect to see out in nature?

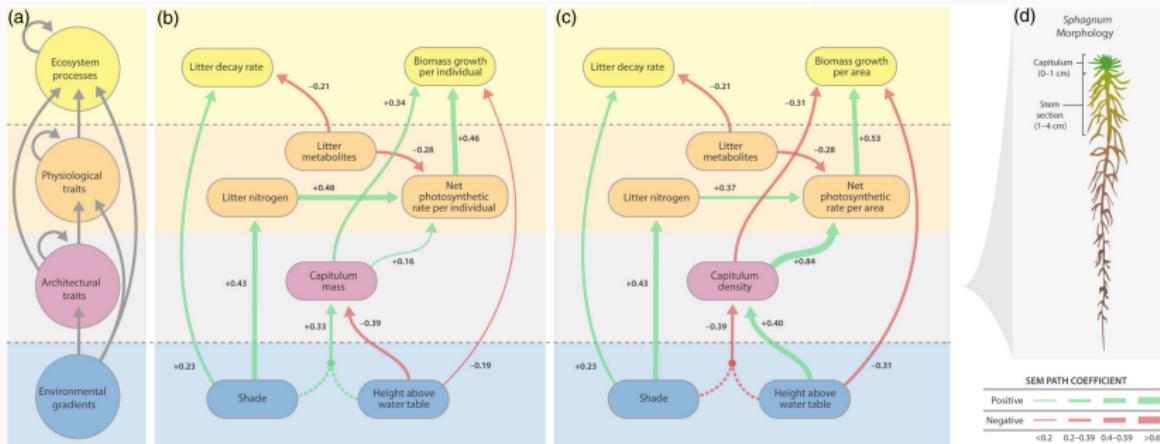
Journal of Ecology



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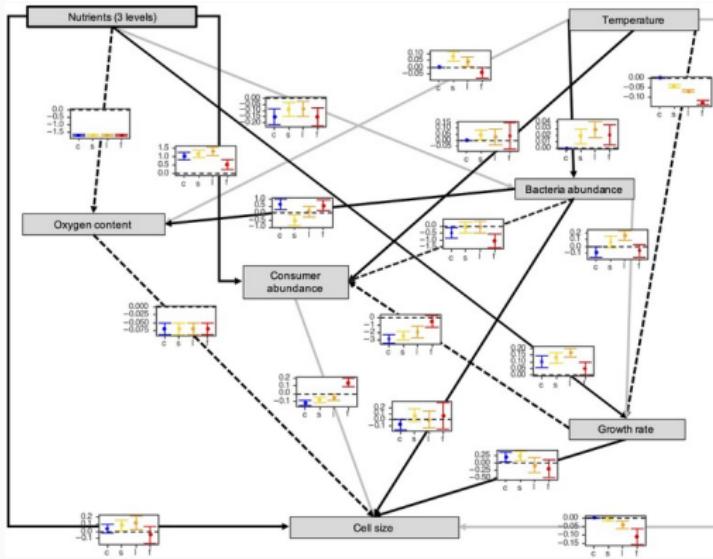
## Scaling functional traits to ecosystem processes: Towards a mechanistic understanding in peat mosses

Adriano Mazzotti, Gustaf Granath, Håkan Rydin, Fia Bengtsson, Jon Norberg



## Testing multiple drivers of the temperature-size rule with nonlinear temperature increase

Andrea Tabi<sup>1,2</sup>  | Aurélie Garnier<sup>1,3</sup> | Frank Pennekamp<sup>1</sup> 



## Discussion

What makes a good data visualization?

## Theory

- What is the important information to convey?

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- Breaking up models into several panels or figures

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  - Top to bottom, or left to right
  - Moving information to a supplement
- Use colours that work for colour-blind people

## What is a good SEM drawing?

- Starting from what you draw and what you just saw, what is the minimum necessary information to include in an SEM?

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- What is missing in your drawing?

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There are no rules. Here are our guidelines to help drawing an informative, interpretable and reproducible SEM diagram.

- 1) Show the relevant variables

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- 4) Report goodness of fit of the model
- 5) Report explanatory power for endogenous variables

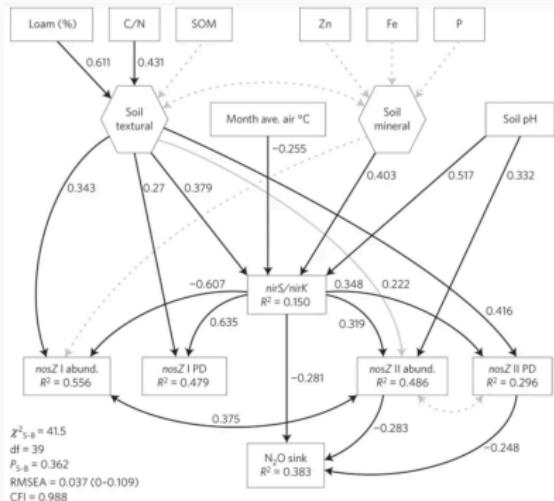
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- 3) Represent all relevant paths (regardless of significance)
- 4) Report goodness of fit of the model
- 5) Report explanatory power for endogenous variables
- 6) Include tables with additional coefficients and derived quantities

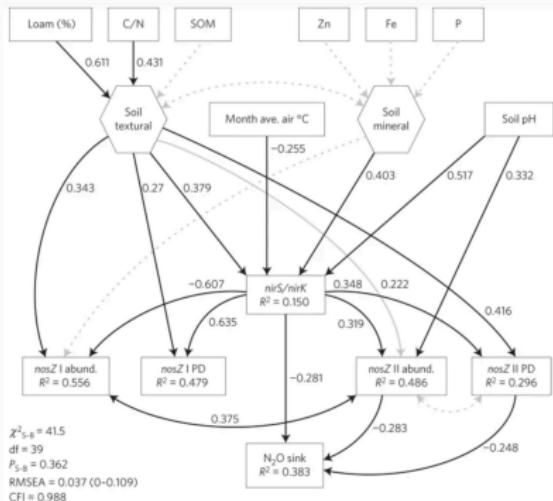
# Show the relevant variables

- Squares are manifest (measured) variables



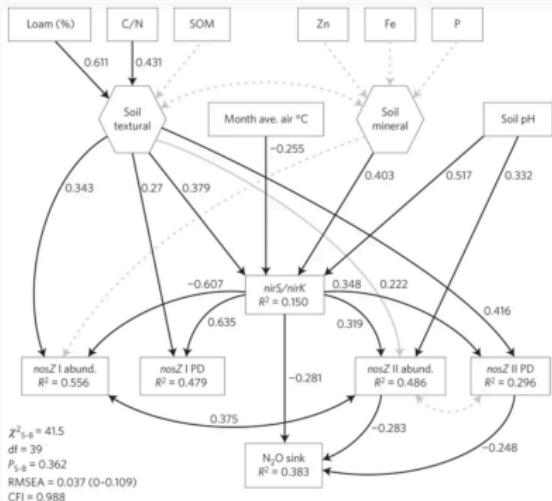
# Show the relevant variables

- Squares are manifest (measured) variables
- Ellipses are latent variables



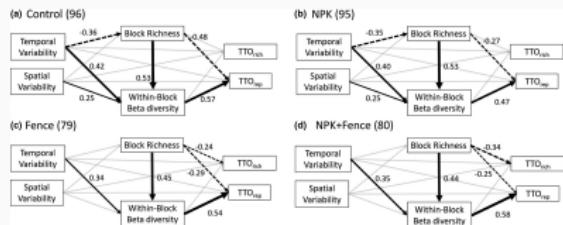
# Show the relevant variables

- Squares are manifest (measured) variables
- Ellipses are latent variables
- Hexagons for composite variables



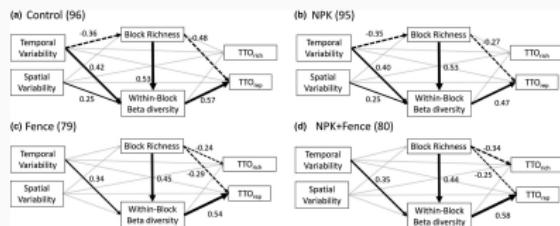
# Represent causal relationships by the path coefficients

- Indicate the magnitude, direction, and significance by:



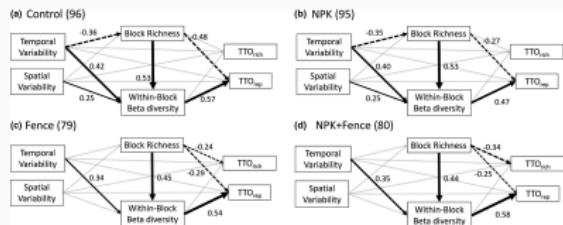
# Represent causal relationships by the path coefficients

- Indicate the magnitude, direction, and significance by:
  - Linetype or color for direction



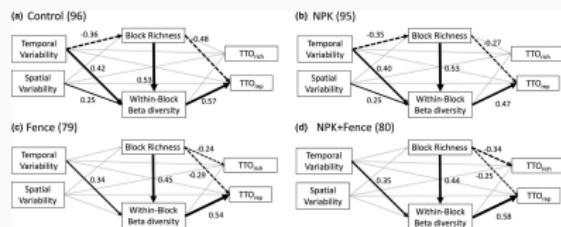
# Represent causal relationships by the path coefficients

- Indicate the magnitude, direction, and significance by:
  - Linetype or color for direction
  - Dashed vs solid for significance



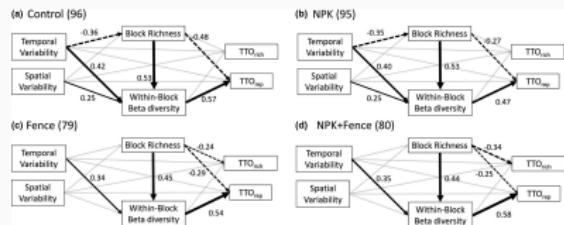
# Represent causal relationships by the path coefficients

- Indicate the magnitude, direction, and significance by:
  - Linetype or color for direction
  - Dashed vs solid for significance
  - Arrow width for magnitude



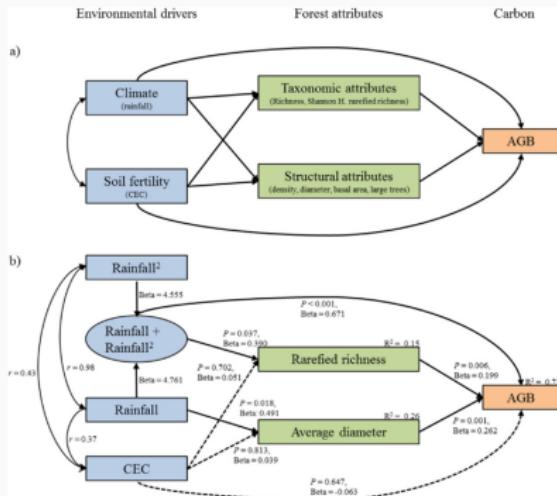
# Represent causal relationships by the path coefficients

- Indicate the magnitude, direction, and significance by:
  - Linetype or color for direction
  - Dashed vs solid for significance
  - Arrow width for magnitude
  - Labelling with coefficient



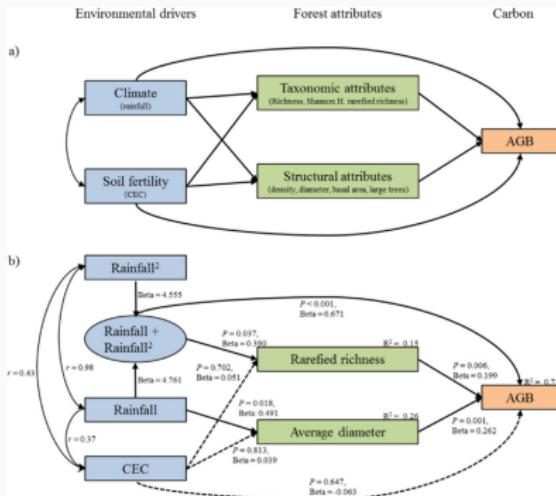
# Represent all relevant paths (regardless of significance)

- Represent all causal paths included in your model regardless of significance.



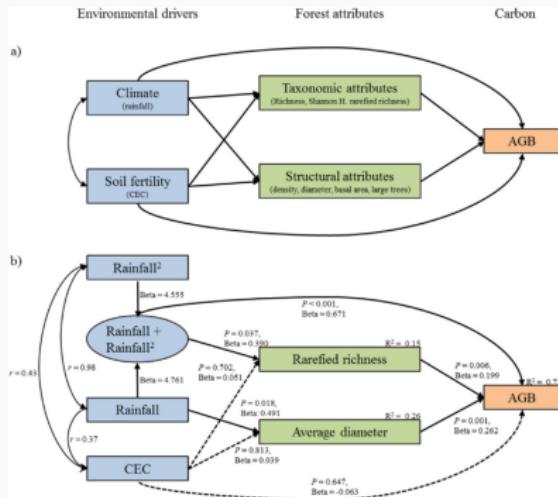
# Represent all relevant paths (regardless of significance)

- Represent all causal paths included in your model regardless of significance.
- Not necessarily in the same figure.



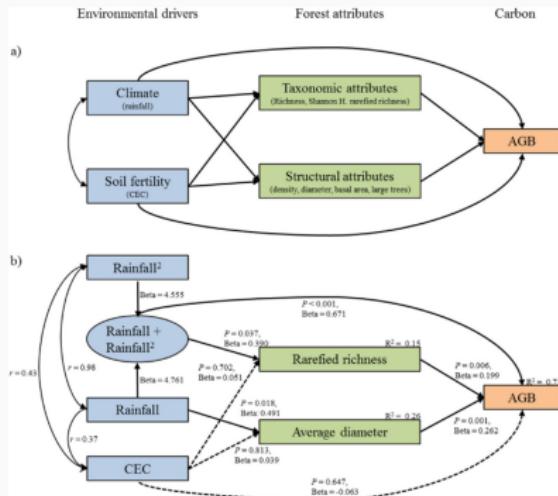
# Represent all relevant paths (regardless of significance)

- Represent all causal paths included in your model regardless of significance.
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- Represent important correlations.



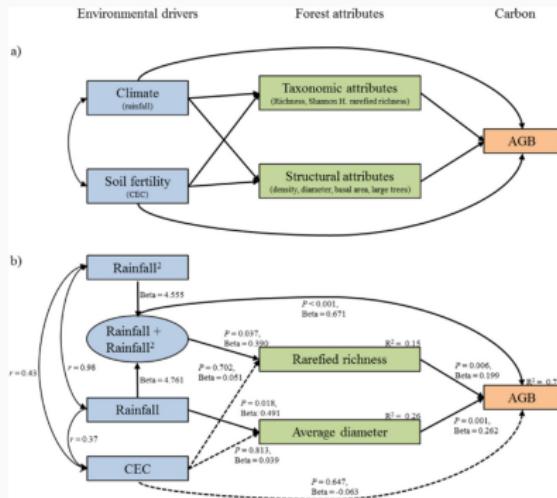
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- Represent important correlations.
- Exogenous variables can be included.



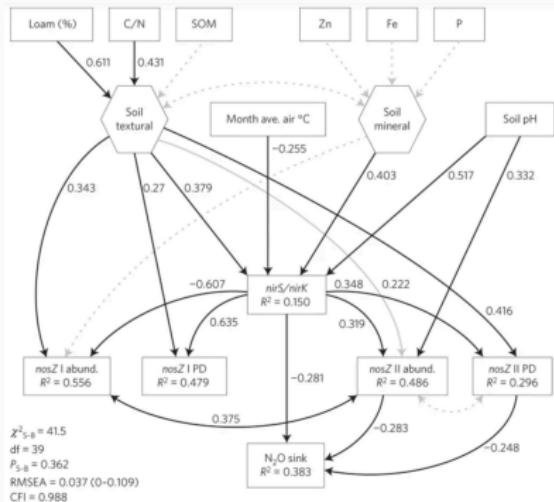
# Represent all relevant paths (regardless of significance)

- Represent all causal paths included in your model regardless of significance.
- Not necessarily in the same figure.
- Represent important correlations.
- Exogenous variables can be included.
- Always include correlations among the errors of endogenous variables.



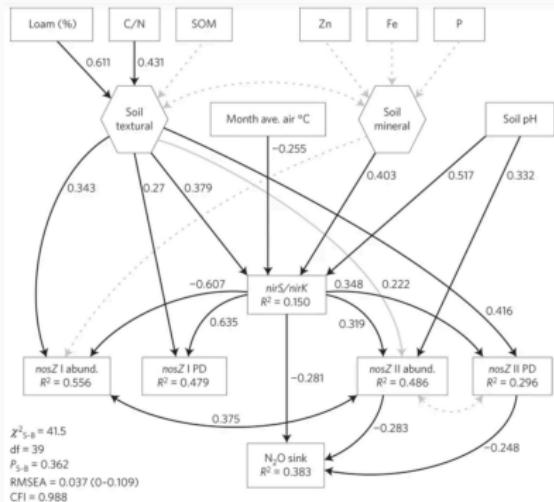
# Report model goodness of fit

- Covariance-based approaches:



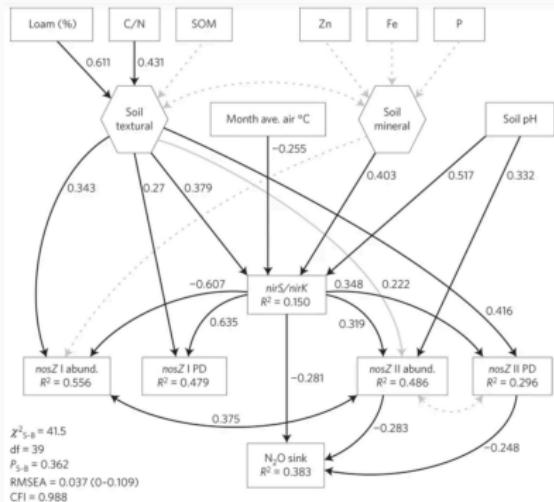
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- Covariance-based approaches:
  - $\chi^2$



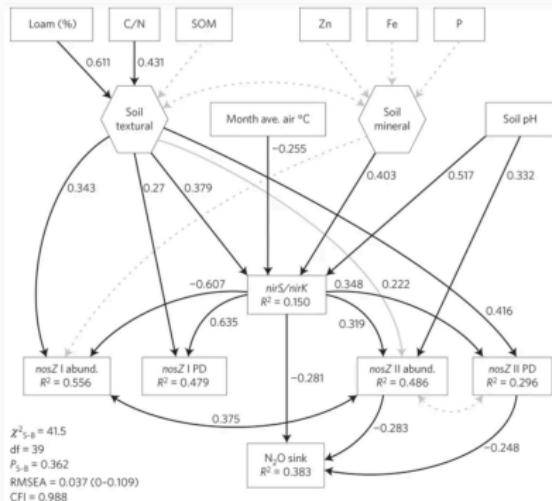
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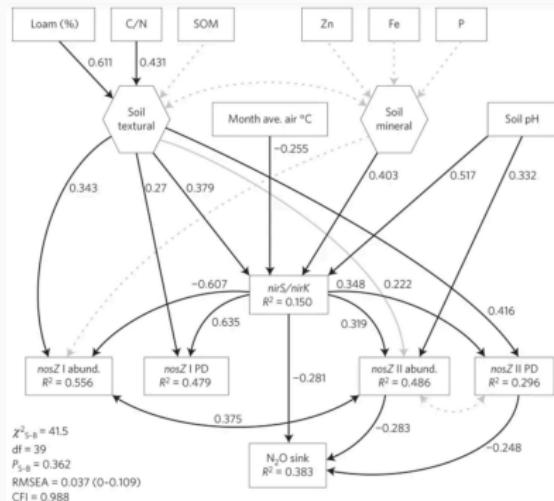
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# Report model goodness of fit

- Covariance-based approaches:
  - $\chi^2$
  - CFI
  - SRMR
  - RMSEA



## Report explanatory power for endogenous variables

- Residual error or  $R^2$

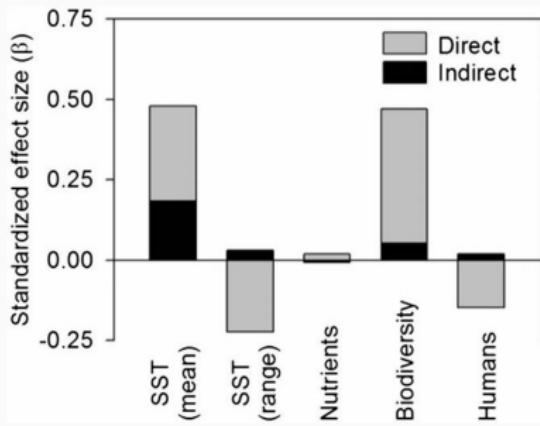
TABLE 1 Coefficients of determination ( $R^2$ ) for the five endogenous variables in the structural equation model

Variable	Fast	Linear	Slow	Constant
Cell size	0.30	0.31	0.43	0.44
Dissolved oxygen content of medium	0.63	0.61	0.60	0.56
Consumer abundance	0.22	0.44	0.50	0.43
Bacteria abundance	0.11	0.11	0.08	0.08
Growth rate	0.77	0.66	0.37	0.11

# Include tables with additional coefficients and derived quantities

- Table of path coefficients

term	Constant	
	estimate	SE
Cell size ~Bacteria abundance	-0.075	0.044
Consumer abundance ~Bacteria abundance	-0.486	0.177
Oxygen content ~Bacteria abundance	0.615	0.193
Growth rate ~Bacteria abundance	-0.087	0.043
Consumer abundance ~Growth rate	-2.811	0.27
Cell size ~Growth rate	0.211	0.078
Oxygen content~temperature	0	0
Growth rate ~temperature	0	0
Consumer abundance ~temperaturep	0	0
Cell size ~temperature	0	0
Bacteria abundance~temperature	0	0
Cell size ~Consumer abundance	-0.122	0.016
Bacteria abundance~nutrients	-0.152	0.035
Cell size ~nutrients	0.041	0.033
Oxygen content ~nutrients	-1.683	0.049
Consumer abundance ~nutrients	1.014	0.101
Growth rate ~nutrients	0.101	0.024
Cell size ~Oxygen content	-0.068	0.01

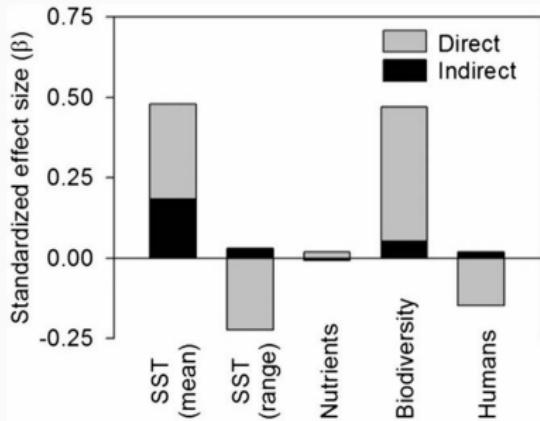


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- Direct, indirect and total effects



## Data presentation

- Showing the underlying data

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  - Plots of raw correlations

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  - Correlation tables

## Data presentation

- Showing the underlying data
  - Plots of raw correlations
  - Correlation tables
  - Shows distribution of data

## Data presentation

- Showing the underlying data
  - Plots of raw correlations
  - Correlation tables
  - Shows distribution of data
  - Partial plots

## Room for artistry

- This will depend on the audience and support:

## Room for artistry

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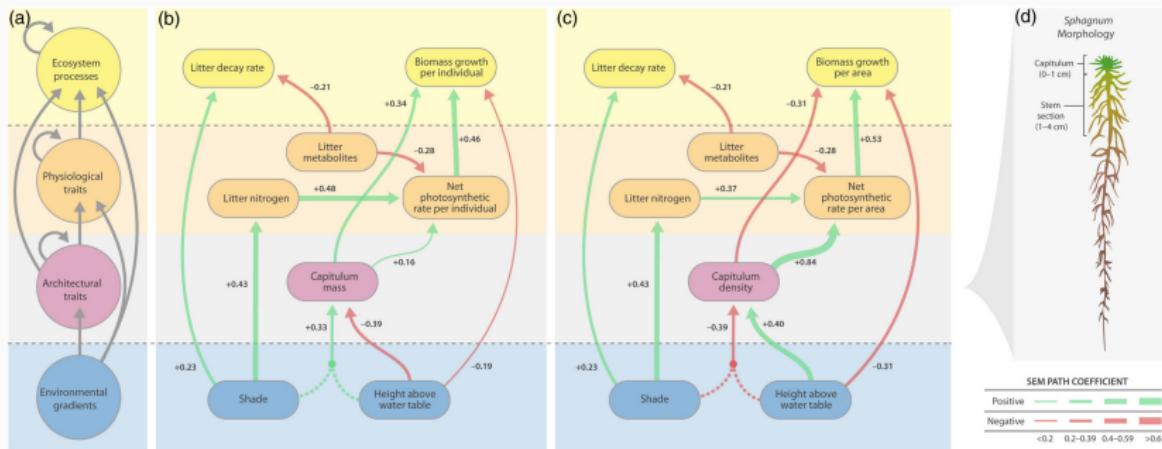
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  - Is this a paper?
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- Key thing here is that one structure might not work in every case.
- Not advocating for anything in particular, but note that the same model for a paper might not be the right presentation for an SEM.

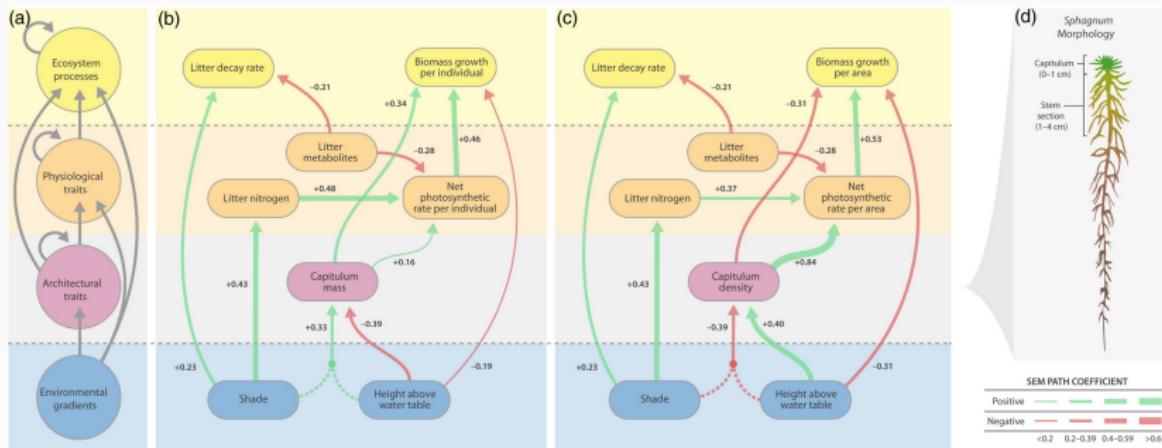
# Room for artistry

- Meta models:



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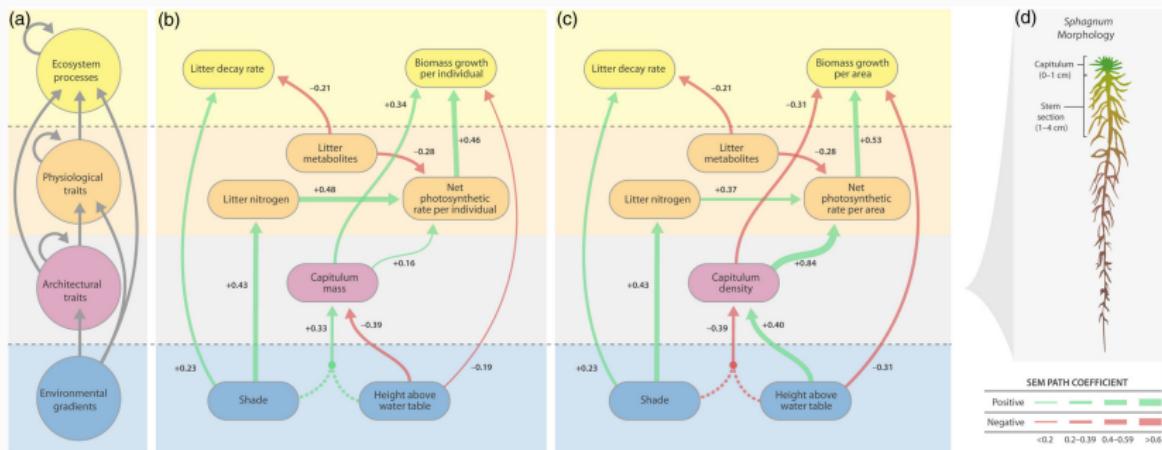
- Meta models:
  - Shows the core concepts and their relationships, ignoring the data.



# Room for artistry

- Meta models:

- Shows the core concepts and their relationships, ignoring the data.
- The most abstracted vision of the causal process you are trying to capture



## Building the plot

- Dedicated packages available in R (e.g., semPlot, lavaanPlot)

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- Dedicated packages available in R (e.g., semPlot, lavaanPlot)
- Fine-tuning in external software like powerpoint, illustrator, or Inkscape.

Questions?

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